Ministry for Primary Industries
Manatū Ahu Matua

Report from the Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates

Part 2: John Dory to Red Crab

Compiled by

Ministry for Primary Industries
Fisheries Science Group

May 2012

newzealand.govt.nz

Report from the Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates

Part 2: John Dory to Red Crab

Compiled by

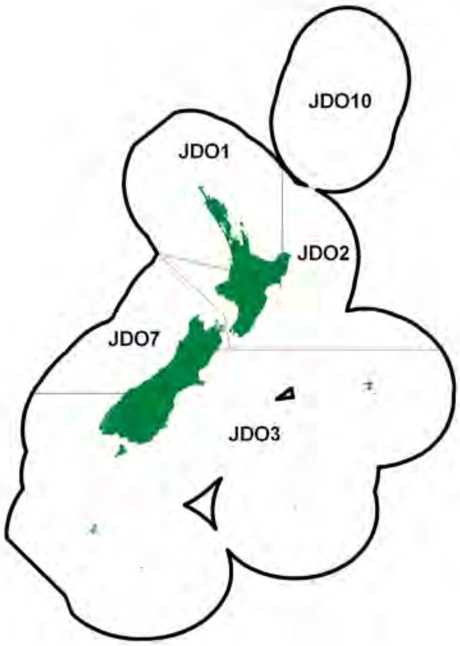
Ministry for Primary Industries
Fisheries Science Group

Citation
Ministry for Primary Industries (2012). Report from the Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1194 p.

Ministry for Primary Industries
May 2012

JOHN DORY (JDO)

(*Zeus faber*)
Kuparu



1. FISHERY SUMMARY

1.1 Commercial fisheries

John dory are taken mainly as a bycatch of the trawl and Danish seine fisheries. In recent years, around 50-65% of the total reported catch has been taken in JDO 1, and around 20% taken in JDO 2. Recent reported landings by Fishstock are shown in Table 1, while the historical landings and TACC values for the three main JDO stocks are depicted in Figure 1.

The increase in JDO 1 landings since 1986-87 is largely attributed to increased targeting of John dory by trawl and Danish seine. The TACC in JDO 1 was exceeded (slightly) in 1994-95, but in the following years landings steadily decreased, reaching a low of 440 t in 2002-03. Landings have increased in recent years, with 482 t being caught in 2007-08. It is estimated that during the 1990s about 10-20% of the annual JDO 1 landings were taken in QMA 9, mainly as bycatch in fisheries targeting snapper and trevally. Landings from the eastern part of JDO 1 (QMA 1) are taken primarily in target fisheries for John dory and snapper. However, since 1990 there has been a steady trend of increased target fishing directed at John dory and decreased landings of this species from the snapper fishery.

Annual landings in JDO 2 have never exceeded the TACC and in the mid 90s, were around 50% of the TACC in each year (Figure 1). From 1999-00 to 2002-03 landings were above 200 t, but in recent years landings have decreased. Landings from JDO 2 are considered to be approximately equally split between QMAs 2 and 8. Substantial proportions of John dory landings are taken as bycatch in target trawl fisheries for jack mackerels in QMA 8, and as tarakihi and red gurnard bycatch in QMA 2.

The JDO 7 catch has exceeded the TACC during eight of the last ten fishing years. Substantial increases in landings from this Fishstock since 1999 are attributed to increased abundance in response to environmental influences on recruitment and stock displacement. JDO 7 is taken largely as a bycatch by FMA 7 trawl fisheries. The JDO 7 TACC was increased to 114 t under the Low Knowledge Bycatch Framework in October 2004. The overall TAC of 120 t includes 1 t for customary interests, 2 t for recreational interests and 3 t for other sources of fishing-related mortality. For the 2009-10 fishing season, the TACC was increased from 114 t to 125 t.

Table 1: Reported landings (t) of John dory by Fishstock from 1983-84 to 2010-11 and actual TACCs (t) for 1986-87 to 2010-11. QMS data from 1986-present.

Fishstock	JDO 1		JDO 2		JDO 3		JDO 7	
QMA (s)	1 & 9		2 & 8		3, 4, 5 & 6		7	
	Landings	TACC	Landings	TAC	Landings	TACC	Landings	TACC
1983-84*	659	-	131	-	1	-	35	-
1984-85*	620	-	110	-	0	-	36	-
1985-86*	531	-	158	-	1	-	45	-
1986-87	409	510	168	240	3	30	57	70
1987-88	476	633	192	246	1	30	89	75
1988-89	480	662	151	253	6	30	47	82
1989-90	494	704	152	262	1	30	54	88
1990-91	505	704	171	269	1	31	53	88
1991-92	562	704	214	269	1	31	60	88
1992-93	578	704	217	269	8	31	50	91
1993-94	640	704	186	269	2	32	37	91
1994-95	721	704	140	270	3	32	30	91
1995-96	696	704	139	270	< 1	32	42	91
1996-97	689	704	140	270	< 1	32	35	91
1997-98	651	704	134	270	< 1	32	26	91
1998-99	672	704	182	270	< 1	32	34	91
1999-00	519	704	235	270	< 1	32	71	91
2000-01	497	704	217	270	1	32	104	91
2001-02	453	704	240	270	4	32	124	91
2002-03	440	704	239	270	2	32	114	91
2003-04	492	704	184	270	< 1	32	155	91
2004-05	561	704	182	270	1	32	133	114
2005-06	549	704	159	270	1	32	124	114
2006-07	544	704	143	270	1	32	127	114
2007-08	482	704	133	270	< 1	32	110	114
2008-09	411	704	136	270	< 1	32	116	114
2009-10	359	704	152	270	< 1	32	109	125
2010-11	386	704	138	270	< 1	32	112	125

Fishstock	JDO 10			
QMA (s)	10		Total	
	Landings	TACC	Landings	TACC
1983-84*	0	-	826	-
1984-85*	0	-	766	-
1985-86*	0	-	735	-
1986-87	< 1	10	638	860
1987-88	0	10	758	994
1988-89	0	10	684	1 037
1989-90	0	10	701	1 094
1990-91	0	10	730	1 102
1991-92	0	10	837	1 102
1992-93	0	10	853	1 105
1993-94	0	10	865	1 106
1994-95	0	10	894	1 107
1995-96	0	10	877	1 107
1996-97	0	10	864	1 107
1997-98	0	10	811	1 107
1998-99	0	10	889	1 107
1999-00	0	10	826	1 107
2000-01	0	10	819	1 107
2001-02	0	10	819	1 107
2002-03	0	10	795	1 107
2003-04	0	10	832	1 107
2004-05	0	10	877	1 129
2005-06	0	10	833	1 129
2006-07	0	10	815	1 129
2007-08	0	10	725	1 129
2008-09	0	10	663	1 129
2009-10	0	10	620	1 140
2010-11	0	10	637	1 140

* FSU data.

1.2 Recreational fisheries

John dory is an important recreational species in the north of New Zealand. Annual recreational take estimated from diary surveys conducted during the 1990s are given in Table 2. The most recent nationwide recreational survey was undertaken in 2001, but the results are still under review and are not currently available. 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.

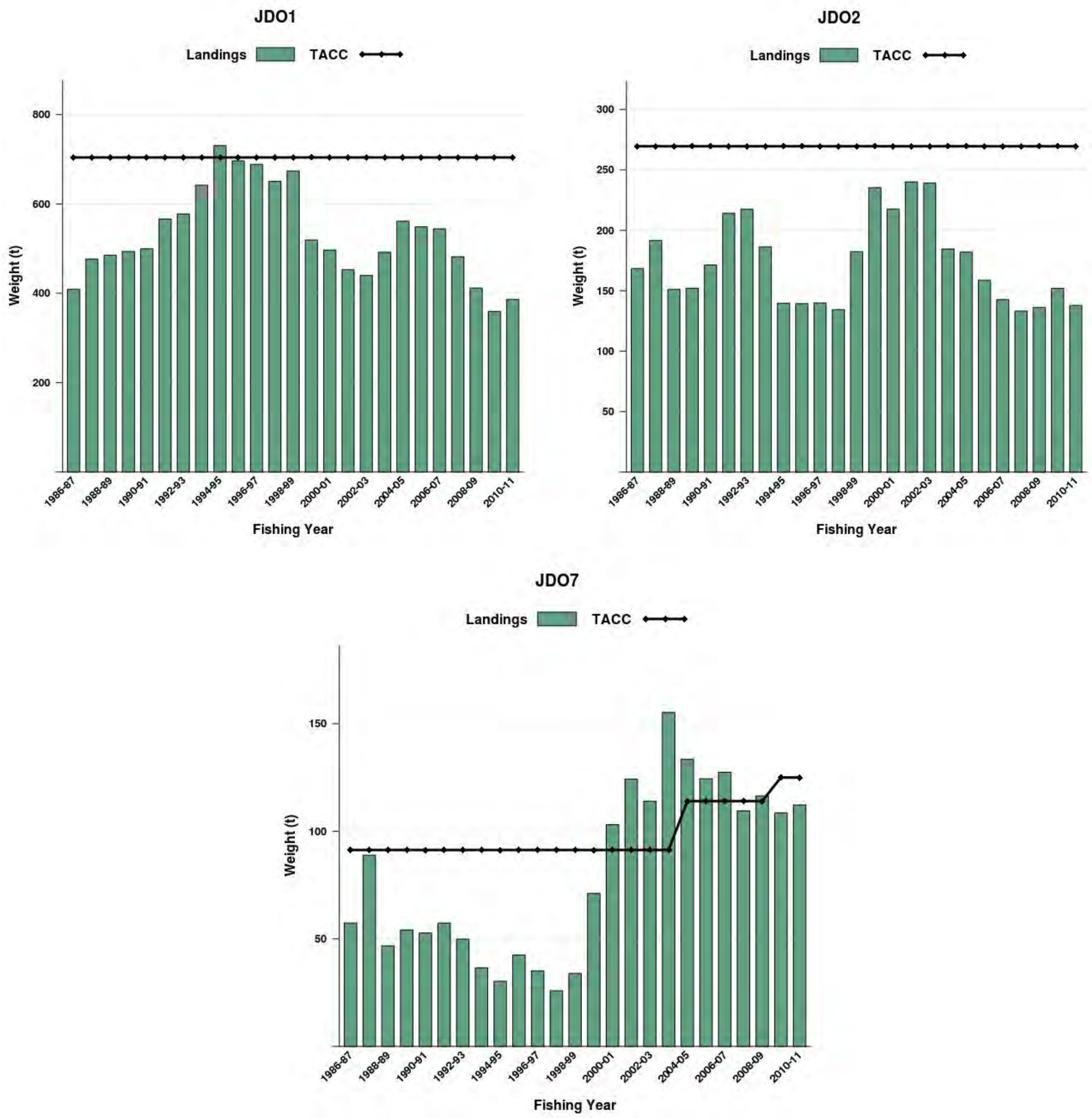


Figure 1: Historical landings and TACC for the three main JDO stocks. From top left: JDO1 (Auckland East), JDO2 (Central East), and JDO7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

1.3 Customary non-commercial fisheries
No quantitative information is available on the current level of Maori customary non-commercial catch.

1.4 Illegal catch
No quantitative information is available.

1.5 Other sources of mortality
No quantitative information is available.

Table 2: Estimated number and weight of John dory harvested by recreational fishers by Fishstock and survey. Surveys were carried out in different years in the Ministry of Fisheries regions: South in 1991-92, Central in 1992-93, North in 1993-94 (Teirney *et al.* 1997) and National in 1996 (Bradford 1998) and Dec 1999-Nov 2000 (Boyd & Reilly 2002).

		Total			
Fishstock	Survey	Number	CV (%)	Estimated harvest range (t)	Point estimate (t)
1992-94					
JDO 1	North	49 000	12	75-95	-
JDO 1	Central	2000	-	0-5	-
1996					
JDO 1	National	46 000	9	80-100	87
1999/2000	National				
JDO 1		129 000	23	174-280	227
JDO 2		9000	41	10-23	16

2. BIOLOGY

John dory are widespread, being found in the eastern Atlantic Ocean, the Mediterranean Sea and around New Zealand, Australia and Japan. They are common in the inshore coastal waters of northern New Zealand, and to a lesser extent in Tasman Bay, to depths of 50 m. In the Hauraki Gulf, adults move to deeper waters during summer, and occasional feeding aggregations occur during winter.

John dory are serial spawners (spawning more than once in a season). There appears to be substantial variation in the time of spawning throughout New Zealand, with spawning occurring between December and April on the northeast coast. The eggs are large and pelagic, taking 12-14 days to hatch. Initially John dory grow rapidly with both males and females reaching 12 to 18 cm standard length (SL) after the first year. From the second year onwards females grow faster than males and reach a greater maximum length. Females mature at a size of 29 to 35 cm SL and in general, larger females mature earlier in the season and are more fecund. Males mature at 23 to 29 cm SL.

M was estimated using the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using a maximum observed age of 12 years, M was estimated to equal 0.38.

Biological parameters relevant to the stock assessment are shown in Table 3.

Table 3: Estimates of biological parameters of John dory.

Fishstock						Estimate	Source
1.Weight = a (length)^b (Weight in g, length in cm total length)							
Combined sexes					a	b	
JDO 1					0.048	2.7	from *Ikatere* 2003
2. von Bertalanffy growth parameters							
		Females				Males	
	K	t_0	L_∞	K	t_0	L_∞	
JDO 1	0.425	-0.223	41.13	0.48	-0.251	36.4	Hore (1982)

3. STOCKS AND AREAS

No information is available to assess the separation of stocks of John dory within New Zealand waters. Current fishstocks are based on an administrative division by FMA. There are no new data which would alter the stock boundaries given in previous assessment documents.

4. STOCK ASSESSMENT

The yield estimates are based on commercial landings data only and have not changed since the 1992 Plenary Report.

4.1 Estimates of fishery parameters and abundance

JDO 1

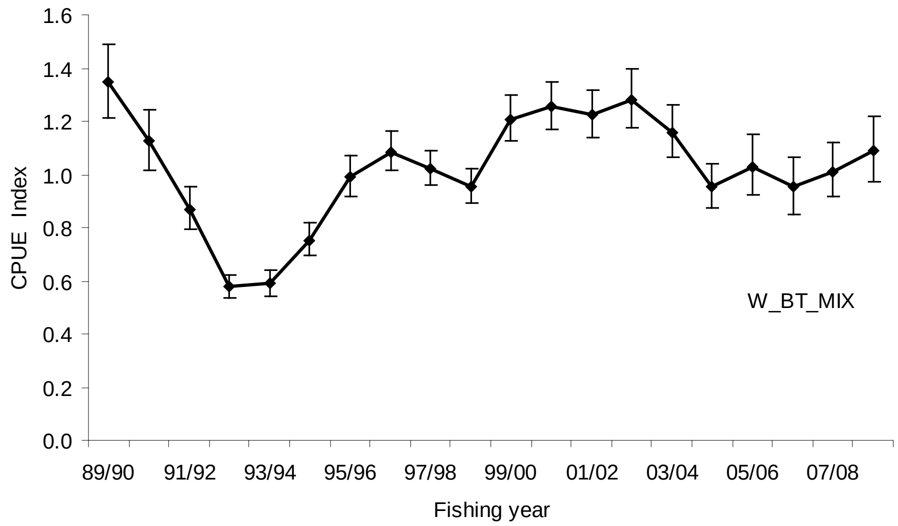


Figure 2: CPUE indices of abundance for JDO 1 West from a lognormal model of positive catches in mixed species bottom trawl tows (Kendrick & Bentley 2010 in prep).

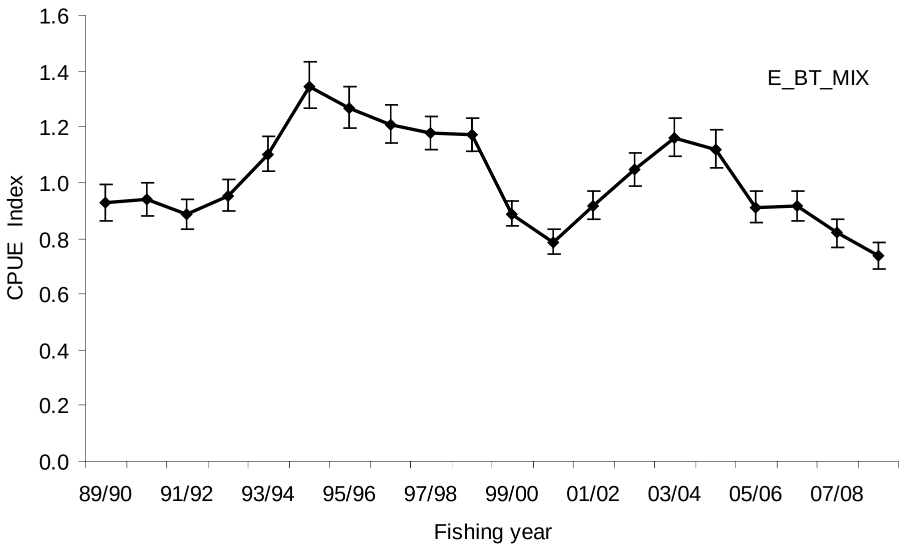


Figure 3: CPUE indices of abundance for JDO 1 East from a lognormal model of positive catches in mixed species bottom trawl tows (Kendrick & Bentley 2010 In prep).

Relative abundance indices have been obtained from trawl surveys of the Bay of Plenty, west coast North Island and Hauraki Gulf within the JDO 1 Fishstock (Table 4). However, there was a change in the configuration of the trawl gear following the 1988 trawl survey. Modifications to the trawl gear may have resulted in a change in the catchability of John dory part way through the time series. Therefore, surveys conducted between 1982 and 1988 and from 1989 onwards should be considered separately for comparisons of biomass indices to be valid. For the west coast North Island (QMA 9),

Bay of Plenty and Hauraki Gulf (both JDO 1), there appears to be no trend in the abundance indices since 1988.
CPUE indices were investigated in 2010 (Kendrick & Bentley in prep). Series based on lognormal models of catch in the mixed species bottom trawl fisheries for each of the three sub regions were accepted by the WG (Figure 2, 3, and 4). The analyses were based on landed catch allocated to trip-stratum and combined data from the main form types. Danish seine and single species JDO target bottom trawl series were also examined but rejected.

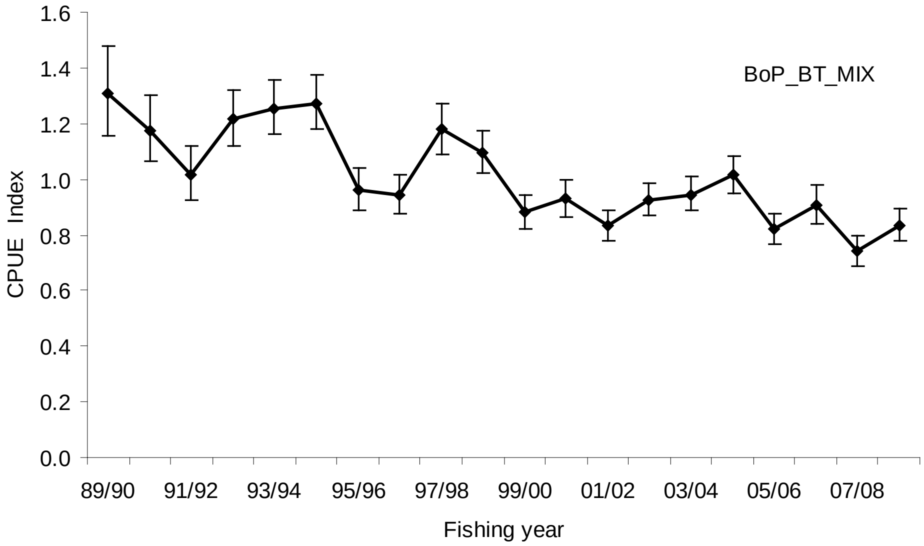


Figure 4: CPUE indices of abundance for JDO 1 Bay of Plenty from a lognormal model of positive catches in mixed species bottom trawl tows (Kendrick & Bentley 2010 In prep).

In JDO 1 W, the lowest point for the series was reached in 1992-93. This was followed by a recovery to almost original levels over the following seven years, followed by a three year plateau. The series subsequently dropped to the mean by 2004-05 and has been relatively stable since then. JDO 1 E shows a more pronounced cyclical pattern with lows in the early 1990s and early 2000s and peaks in the middle of each decade. The index is currently at a low point. The series for JDO 1 in the Bay of Plenty shows more stability and an overall decrease to just below the mean.

JDO 2
Relative abundance indices have also been derived for JDO 2 from trawl surveys of the North Island east coast (QMA 2) and North Island west coast (QMA 8) (Table 4, Figure 5). Similarly, the indices from both of these time series show no trend.

The Southern Inshore Working Group noted that the West Coast South Island trawl survey series appears to be monitoring trends in abundance for the recruits of this population. Length frequency trends for the West Coast South Island John dory catch are presented in Figure 6. These data show that in the early 1990s low numbers were caught by the survey series and there was no evidence of significant numbers of recruits. In 2000 a large number of recruits appeared and these fish seemed to remain in the population through to 2007. There is evidence that a new cohort of recruits has appeared in 2009.

4.2 Biomass estimates
Estimates of absolute reference and current biomass are not available.

4.3 Estimation of Maximum Constant Yield (*MCY*)
MCY was estimated using the equation, $MCY = cY_{AV}$ (method 4). Y_{AV} is the average annual catch for the period 1983-84 to 1985-86. The value of c was set equal to 0.6 based on the estimate of $M = 0.38$.

Estimates of *MCY* are shown in Table 5. The estimates of *MCY* are probably conservative because John dory has probably not been fully exploited in the past, as they are predominantly a bycatch species that is not specifically targeted.

Table 4: Estimates of John dory biomass (t) from *Kaharoa* trawl surveys.

Year	Trip Code	Biomass	CV (%)
Bay of Plenty			
1983	KAH8303	113	24
1985	KAH8506	128	12
1987	KAH8711	155	38
1990	KAH9004	157	16
1992	KAH9202	236	12
1996	KAH9601	193	44
1999	KAH9902	176	14
North Island west coast (QMA 8)			
1989	KAH8918	68	25
1991	KAH9111	142	62
1994	KAH9410	33	47
1996	KAH9615	19	38
North Island west coast (QMA 9)			
1986	KAH8612	155	35
1987	KAH8715	160	16
1989	KAH8918	148	16
1991	KAH9111	216	37
1994	KAH9410	102	47
1996	KAH9615	147	15
1999	KAH9915 (QMAs 8 & 9 combined)	374	9

Year	Trip Code	Biomass	CV (%)
Hauraki Gulf			
1984	KAH8421	292	22
1985	KAH8517	245	20
1986	KAH8613	211	25
1987	KAH8716	181	12
1988	KAH8810	477	32
1989	KAH8917	250	22
1990	KAH9016	322	13
1992	KAH9212	227	35
1993	KAH9311	374	24
1994	KAH9411	288	17
1997	KAH9720	387	18
2000	KAH0012	260	26
North Island east coast			
1993	KAH9304	265	17
1994	KAH9402	268	31
1995	KAH9502	170	18
1996	KAH9605	172	48
West Coast South Island			
1992	KAH9204	102	29
1994	KAH9404	59	26
1995	KAH9504	27	36
1997	KAH9701	17	31
2000	KAH0004	141	16
2003	KAH0304	288	19
2005	KAH0503	222	14
2007	KAH0704	174	26
2009	KAH0904	269	23
2010	KAH1004	378	16

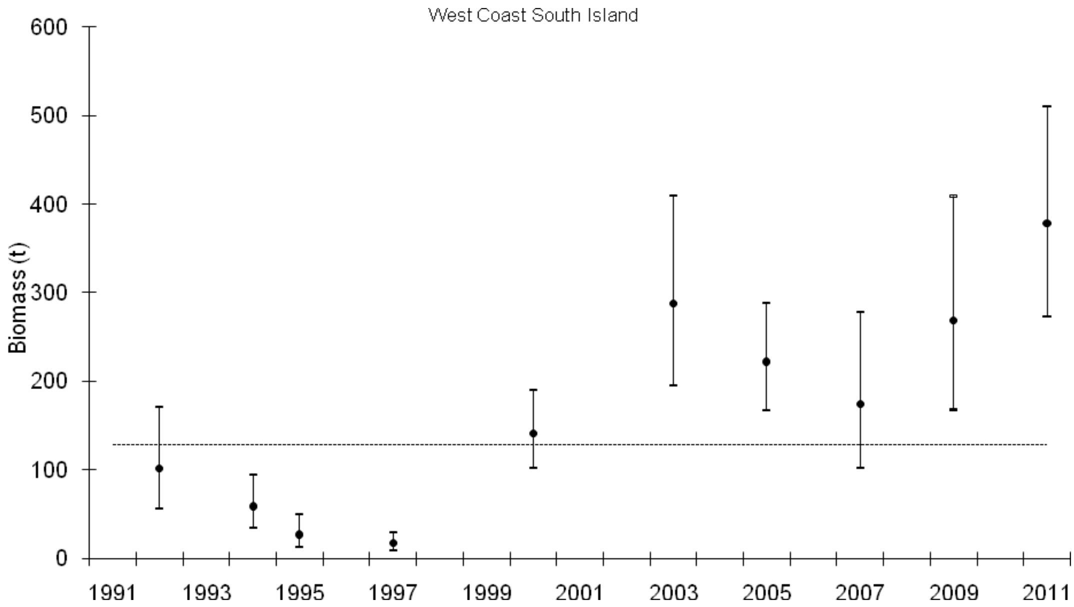


Figure 5: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) and the time series mean (dotted line) from the West Coast South Island trawl surveys.

Table 5: Estimates of *MCY* (t) rounded to the nearest 5 t.

Fishstock	QMA		Y_{AV}	*MCY*
JDO 1	Auckland (East) (West)	1 & 9	600	360
JDO 2	Central (East) (West)	2 & 8	130	80
JDO 3	South-East (Coast) (Chatham),	3, 4,		
	Southland, Sub-Antarctic	5 & 6	1	5
JDO 7	Challenger	7	40	25
JDO 10	Kermadec	10	-	-
Total			771	470

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 estimates of current biomass are available which would permit the estimation of *CAY*

4.5 Other yield estimates and stock assessment results

Current estimates of yield are based upon commercial landings only and are assumed to be independent of the non-commercial catch. There was no indication that John dory were overfished at the time of the introduction of the QMS. There has been no apparent change in the fishing patterns for JDO over the last decade.

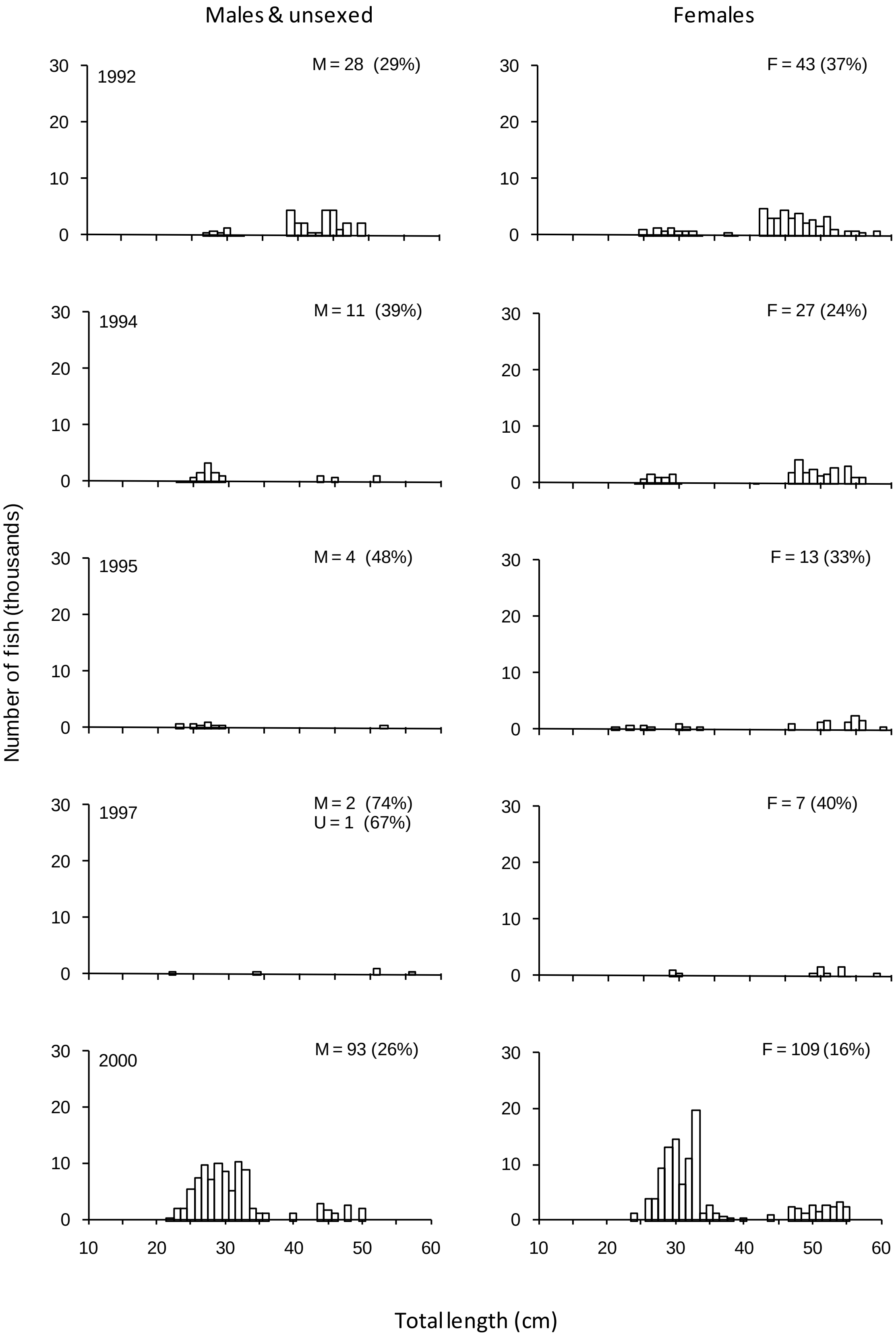


Figure 6: Scaled length frequency distributions for John dory in 30-400 m, for WCSI surveys. M, males; F, females; (CV%) (Stevenson in press).

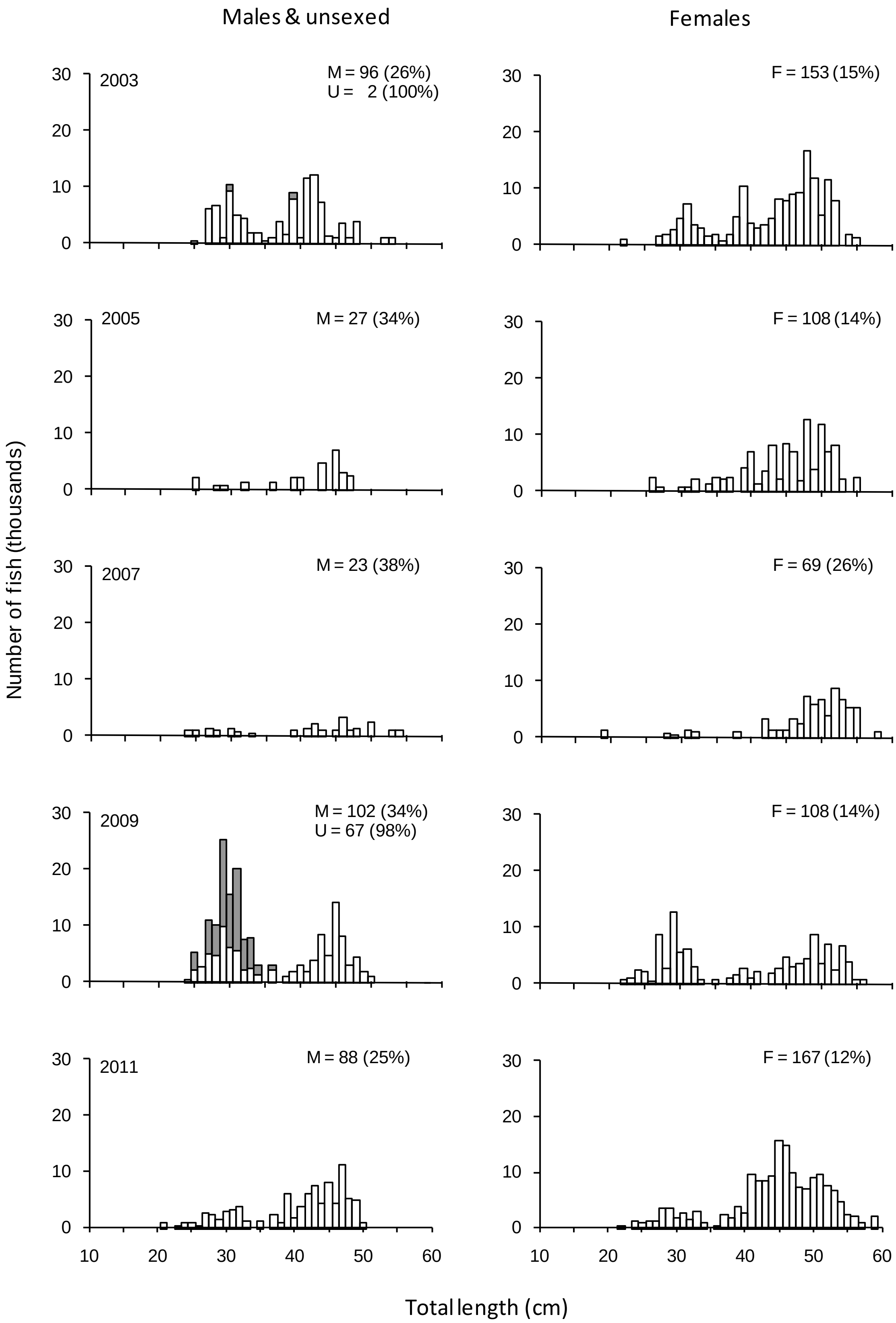


Figure 6 [Continued].

5. STATUS OF THE STOCKS

Estimates of absolute current and reference biomass are not available.

John dory is principally a bycatch species and, as such, estimates of *MCY* based on catch statistics are uncertain. Under such conditions it is difficult to determine whether changes in the reported catches indicate actual changes in the stocks or simply changes in the catches of the target species.

In 1994-95, the TACC for JDO 1 was slightly overcaught for the first time since the start of the QMS. The 1994-95 landings followed a consistent trend of increasing catches, probably due to increased targeting for John dory. However, other factors, such as increased abundance or changing fishing practices, may also have contributed to JDO 1 catch increases but trawl surveys in sub-areas of JDO 1 reveal no apparent trend in John dory biomass. Since 1994-95, the TACC for JDO 1 has been undercaught.

For JDO 1 recent catch levels and the current TACC are likely to be sustainable at least in the short-term. It is not known if recent catch levels and the current TACC are sustainable in the long-term. For all other JDO stocks it is not known if the recent catch levels and current TACCs are sustainable. For all Fishstocks it is unknown if recent catches or the current TACCs are at levels that will allow the stocks to move towards a size that will support the *MSY*.

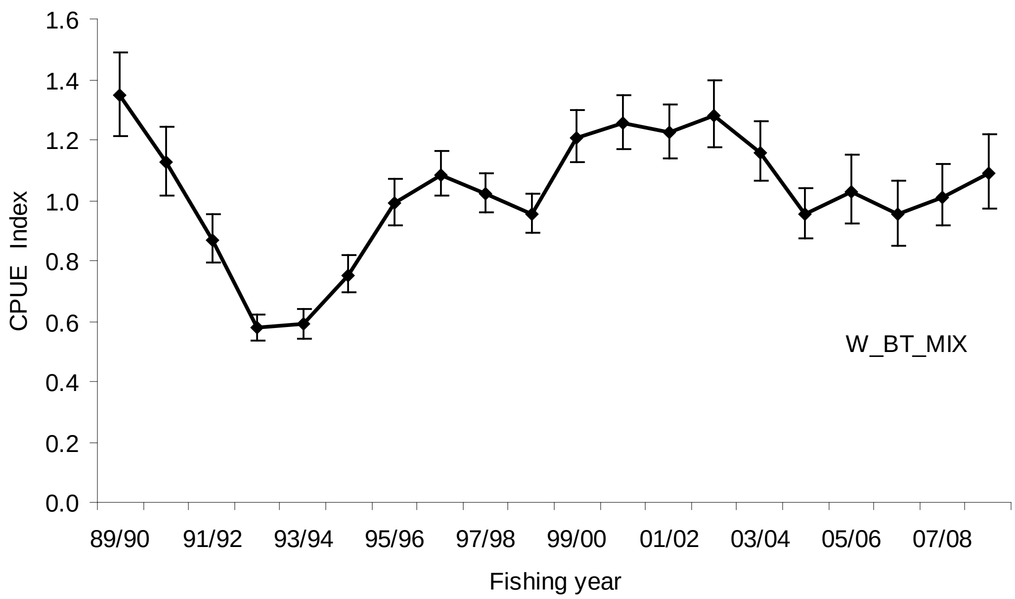
JDO 1

Stock Structure Assumptions
For the purpose of this summary JDO 1 is considered to be a single stock with three sub-stocks.

JDO 1W

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	
Reference Points	Target: *MSY*-compatible proxy based on CPUE (to be determined) 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



Standardised CPUE indices for John dory in JDO 1W from lognormal models of catch rate in successful bottom trawl trips in a mixed target fishery (Kendrick & Bentley In prep).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The lognormal CPUE series has fluctuated at or above the long term mean since 1995-96. The 2008-09 data point is slightly above the long-term mean.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

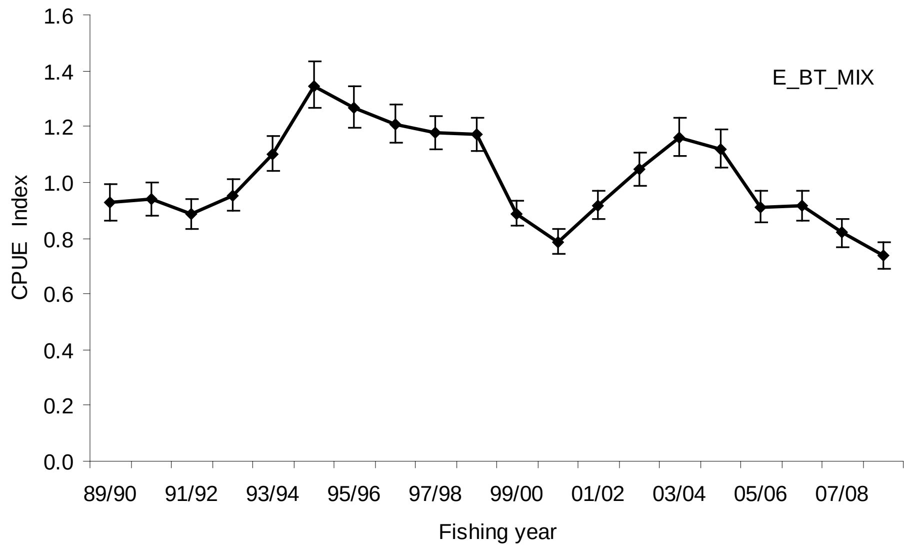
Projections and Prognosis	
Stock Projections or Prognosis	Without corroborating information on recruitment from a trawl survey, it is not possible to predict how the stock will respond in the next few years.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%) (for the current catch)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on lognormal error distribution and positive catches.	
Assessment Dates	Latest assessment: 2010	Next assessment: 2014
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the W_BT_MIXED CPUE index was a credible measure of abundance.	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Inclusion of a wider range of target species appears to have improved the utility of the bottom trawl indices.	
Major Sources of Uncertainty	Uncertainty in the stock structure Relationship between CPUE and biomass.	

Qualifying Comments
As the John dory fishery in FMAs 1 and 9 has a long history, it is not possible to infer stock status from abundance trends from only the last 20 years. This sub-stock appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information.
Fishery Interactions
John dory is taken on the west coast by bottom trawl targeted at snapper trevally, gurnard and tarakihi

JDO 1E

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	
Reference Points	Target: *MSY*-compatible proxy based on CPUE (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown

Historical Stock Status Trajectory and Current Status

Standardised CPUE indices for John dory in JDO 1E from lognormal models of catch rate in successful bottom trawl trips in a mixed target fishery (Kendrick & Bentley In prep).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The lognormal CPUE series is cyclical with an overall downward trend since 1994-95. The 2008-09 data point is the lowest point in the series at about 25% below the long-term mean.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis		
Stock Projections or Prognosis	Without corroborating information on recruitment from a trawl survey, it is not possible to predict how the stock will respond in the next few years.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative stock assessment	
Assessment Method	Standardised CPUE based on lognormal error distribution and positive catches.	
Assessment Dates	Latest assessment: 2010	Next assessment: 2014
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the E_BT_MIX CPUE index was a credible measure of abundance.	
Main data inputs (rank)	Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Inclusion of a wider range of target species appears to have improved the utility of the bottom trawl indices.	
Major Sources of Uncertainty	Uncertainty in the stock structure Relationship between CPUE and biomass.	

Qualifying Comments
As the John dory fishery in FMAs 1 and 9 has a long history, it is not possible to infer stock status

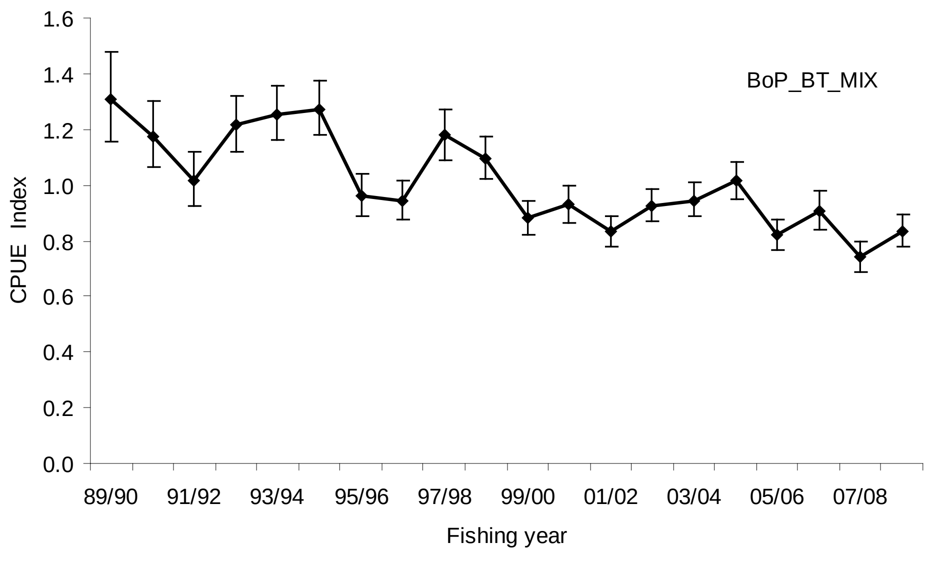
from abundance trends from only the last 20 years. This sub-stock appears to be cyclical, probably in response to recruitment variation, and the current trend is downward. This makes it difficult to predict future trends without recruitment information. Almost 2/3 of the John dory bottom trawl catch in JDO 1E is target JDO. The declining catch JDO 1 is mainly driven by declining catch in JDO 1E. Declining CPUE and catch in recent years suggests that biomass is presently (2010) declining in this sub-area.

Fishery Interactions
John dory is taken on the east coast by bottom trawl and Danish seine targeted at John dory and snapper.

JDO 1BoP

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	
Reference Points	Target: *MSY*-compatible proxy based on CPUE (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices for John dory in JDO 1BP from lognormal models of catch rate in successful bottom trawl trips in a mixed target fishery (Kendrick & Bentley In prep).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The lognormal CPUE series has declined steadily by 30% between 1989-90 to 2008-09.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-
Projections and Prognosis	
Stock Projections or Prognosis	The stock is Likely (> 60%) to continue to decline.

Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative stock assessment	
Assessment Method	Standardised CPUE based on lognormal error distribution and positive catches.	
Assessment Dates	Latest assessment: 2010	Next assessment: 2014
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the BoP_BT_MIX CPUE index was a credible measure of abundance.	
Main data inputs (rank)	Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Inclusion of a wider range of target species appears to have improved the utility of the bottom trawl indices.	
Major Sources of Uncertainty	Uncertainty in the stock structure Relationship between CPUE and biomass.	

Qualifying Comments
-

Fishery Interactions
John dory is taken in the Bay of Plenty by bottom trawl targeted at John dory, snapper, trevally, tarakihi and gurnard; and by Danish seine targeted at snapper and gurnard.

JDO 1 summary

The declining catch in JDO 1 is being driven by declines in JDO 1 E. Declining CPUE trends are seen in JDO 1E (25% below the mean) and BoP (30% below the start). If the CPUE trends in sub-stocks continue to differ, it may be inappropriate to manage JDO 1 as a single stock.

JDO 7

Stock Structure Assumptions

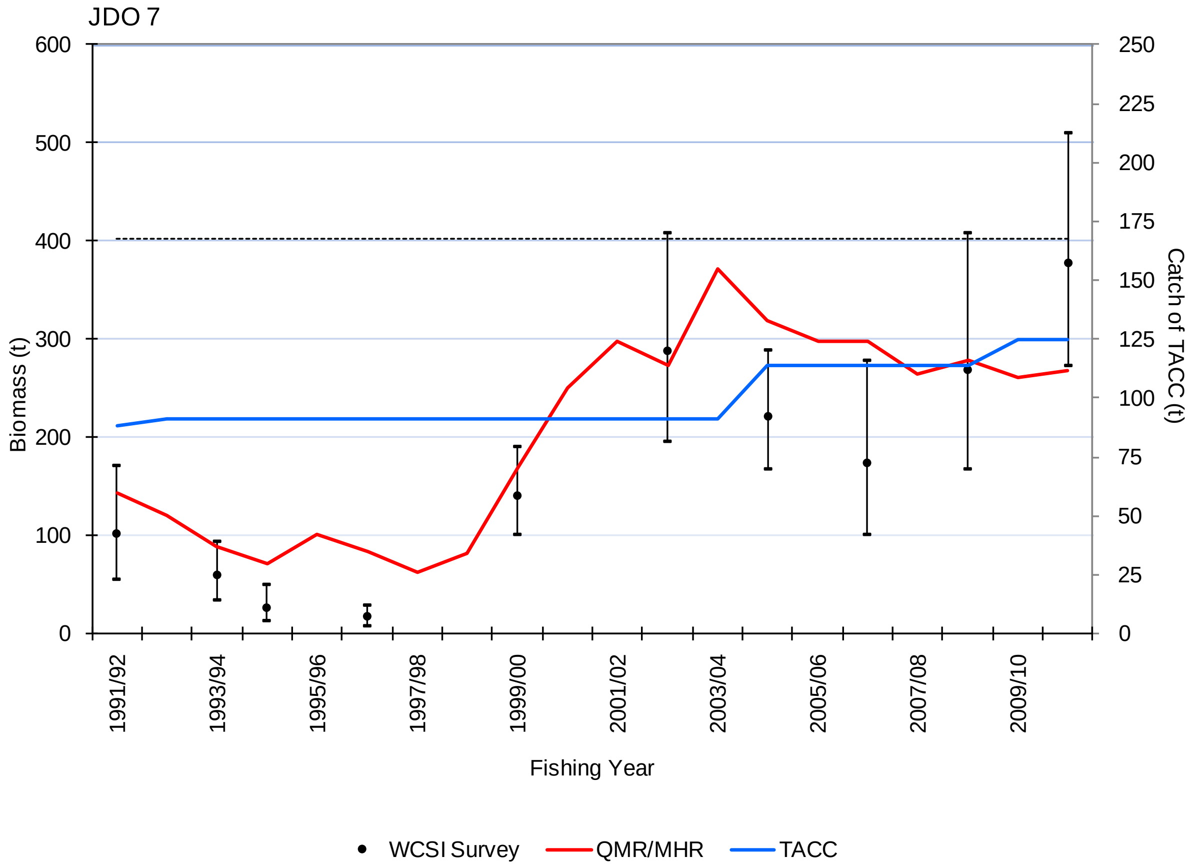
Stock boundaries are unknown, but for the purpose of this summary, JDO 7 is treated as a single management unit.

Stock Status	
Year of Most Recent Assessment	2011 (West Coast South Island Trawl survey)
Reference Points	Target: *MSY*-compatible proxy based on the West Coast South Island trawl survey (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target
Status in relation to Target	About as Likely as Not (40-60%) to be at or above the target
Status in relation to Limits	Unlikely (< 40%) to be below the Soft and Hard Limits

Fishery and Stock Trends	
Trend in Biomass or Proxy	Abundance of John dory fluctuates widely with year class strength. Biomass has been high since 2003 and there was good recruitment in 2009, however that was not apparent in 2011.
Trend in Fishing Mortality or Proxy	The commercial catch trends have largely mirrored those of the trawl survey biomass estimates, declining through the 1990s then increasing from a low of 26 t in 1997-98 to a high of 155 t in 2003-

	04. The average catch from 2002-03 to 2008-09 was 126 t. It is Unlikely (< 40%) that overfishing is occurring.

Historical survey biomass, Catch and TACC Trajectories



West Coast South Island survey biomass (points) commercial catch (red line) and TACC (blue line) for the period 1990 to 2011. Horizontal dashed line is the mean biomass index, 1992-2011.

Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Length frequency analysis from the West Coast South Island trawl survey showed very good recruitment in 2009.

Projections and Prognosis	
Stock Projections or Prognosis	No quantitative stock assessment has been undertaken for this Stock. The 2009 size data as well as the biomass trends suggest that the stock biomass was Likely (> 60%) to increase at recent catch levels. If no new recruitment pulse enters the population biomass is likely to decrease.
Probability of Current Catch / TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Semi-quantitative Stock Assessment - Agreed abundance index	
Assessment Method	Evaluation of survey biomass trends and length frequencies.	
Assessment Dates	Latest assessment: 2011	Next assessment: 2013
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the West Coast South Island trawl survey index was a credible measure of John dory biomass	
Main data inputs (rank)	- West Coast South Island trawl survey - Survey length frequency	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	N/A	
Major Sources of Uncertainty	This stock is assessed using trends in trawl survey relative biomass. No current formal quantitative stock assessment is available for this stock. Therefore, the stock status of JDO 7 is unknown and quantitative projections are not available.	

Qualifying Comments
-

Fishery Interactions
John Dory are primarily taken in conjunction with the following QMS species: barracouta, red cod, stargazer, red gurnard and tarakihi in the West Coast South Island bottom trawl fishery.

Yield estimates, TACCs and reported landings are summarised in Table 6.

Table 6: Summary of yields (t), TACCs (t) and reported landings (t) of John dory for the most recent fishing year.

Fishstock	QMA		*MCY*	2010-11 Actual TACC	2010-11 Reported landings
JDO 1	Auckland (East) (West)	1 & 9	360	704	386
JDO 2	Central (East) (West)	2 & 8	80	270	138
JDO 3	South-East (Coast) (Chatham),	3 & 4			
	Southland, Sub-Antarctic	5 & 6	5	32	< 1
JDO 7	Challenger	7	25	125	112
JDO 10	Kermadec	10	-	10	0
Total			470	1140	637

6. FOR FURTHER INFORMATION

Boyd R.O., Reilly J.L. 2005. 1999/2000 national marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report 2005/XX xxp.

Bradford E. 1998. Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27p.

Fu D., Gilbert D.J., Baird S.J., Manning M.J. 2008. CPUE analysis of John dory (Zeus faber) in New Zealand's main fishery (JDO1). New Zealand Fisheries Assessment Report 2008/14. 42p.

Hanchet S.M., Francies M.P., Horn P.L. 2001. Age and growth of John dory (*Zeus faber*).New Zealand Fisheries Assessment Research Document 2001/10. 26p.

Horn P.L., Hanchet S.M., Stevenson M.J., Kendrick T.H., Paul L.J. 1999. Catch history, CPUE analysis, and stock assessment of John dory (Zeus faber) around the North Island (Fishstocks JDO1 and JDO2). NZ Fisheries Assessment Research Document 99/33. 58 p.

Hore A.J. 1982. The age growth and reproduction of the John dory, *Zeus faber*. (Unpublished MSc thesis, University of Auckland.)

Hore A.J. 1985. John dory *In*: Colman, J.A.; McKoy, J.L.; Baird, G.G. (1985). Background papers for the 1985 Total Allowable Catch recommendations, pp. 117-122. (Unpublished report, held in NIWA library, Wellington.)

Hore A.J. 1988. John dory. New Zealand Fisheries Assessment Research Document 1988/39. 8p.

Morrison M.A., Francis M.P., Parkinson D.M. 2002. Trawl survey of the Hauraki Gulf, 2000 (KAH0012). Fisheries Assessment Research Document 2002/46. 49p.

Stevenson M.L. 2007. Inshore trawl surveys of the west coast of the South Island and Tasman and Golden Bays, March-April 2007 (KAH0704). New Zealand Fisheries Assessment Research Document 2007/41: 64p

Stevenson M.L. 2009. Inshore trawl surveys of the west coast of the South Island and Tasman and Golden Bays, March-April 2007 (KAH0704). New Zealand Fisheries Assessment Research Document 2010/xx

Stevenson M.L. in press. Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March-April 2011. New Zealand Fisheries Assessment Report 2012/xx.

Teirney L.D., Kilner A.R., Millar R.E., Bradford E., Bell J.D. 1997. Estimation of recreational catch from 1991/92 to 1993/94 N.Z. Fisheries Assessment Research Document 1997/15. 43p.

KAHAWAI (KAH)

(Arripis trutta and Arripis xylabion)
Kahawai

1. FISHERY SUMMARY

Kahawai (*Arripis trutta*) and Kermadec kahawai (*Arripis xylabion*) were introduced into the QMS on 1 October 2004 under a single species code, KAH. Within the QMS, kahawai management is based on six QMAs (KAH 1, KAH 2, KAH 3, KAH 4, KAH 8 and KAH 10).

These QMAs differ from the Management Areas used before kahawai were introduced into the QMS. The definitions of KAH 1, KAH 2 and KAH 10 remain unchanged, but KAH 4 was formerly part of KAH 3, as was that part of KAH 8 which is south of Tirua Point. The area of KAH 8 which is north of Tirua point was formerly called KAH 9.

TACs totalling 7612 t were set on introduction into the QMS. These TACs were based on a 15% reduction from both the level of commercial catch and assumed recreational use prior to introducing kahawai into the QMS. The Minister reviewed the TACs for kahawai for the 2005-06 fishing year. Subsequently, he decided to reduce TACs, TACCs and allowances by a further 10% as follows:

Table 1: KAH allowances, TACCs, and TACs, 1 October 2005.

Fishstock	Recreational Allowance	Customary Non-Commercial Allowance	Other mortality	TACC	TAC
KAH 1	1680	495	65	1 075	3 315
KAH 2	610	185	30	705	1 530
KAH 3	390	115	20	410	935
KAH 4	4	1	0	9	14
KAH 8	385	115	20	520	1 040
KAH 10	4	1	0	9	14

1.1 Commercial fisheries

Commercial fishers take kahawai by a variety of methods. Purse seine vessels take most of the catch; however, substantial quantities are also taken seasonally in set net fisheries and as a bycatch in longline and trawl fisheries.

The kahawai purse seine fishery cannot be understood without taking into account the other species that the vessels target. The fleet, which is based in Tauranga, preferentially targets skipjack tuna (*Katsuwonus pelamis*) between December and May, with very little bycatch. When skipjack are not available, usually June through November, the fleet fishes for a mix of species including kahawai, jack mackerels (*Trachurus* spp.), trevally (*Pseudocaranx dentex*) and blue mackerel (*Scomber australasicus*). These are caught ‘on demand’ as export orders are received (to reduce product storage costs). However, since the mackerels and kahawai school together there is often a bycatch of kahawai resulting from targeting of mackerels. Reported landings, predominantly of *A. trutta,* are shown for 1962 up to and including 1982 in Table 2 by calendar year for all areas combined, and from 1983-84 onwards by fishing year and by historic management areas in Table 3 and by QMAs in Table 4. The historical landings and TACC for the main KAH stocks are depicted in Figure 1.

Table 2: Reported total landings (t) of kahawai from 1970 to 1982. Note that these data include estimates of kahawai from data where kahawai were reported within a general category of ‘mixed fish’ rather than separately as kahawai.

Year	Landings	Year	Landings	Year	Landings
1962	76	1969	234	1976	729
1963	81	1970	294	1977	1 461
1964	86	1971	572	1978	2 228
1965	102	1972	394	1979	3 782
1966	254	1973	586	1980	5 101
1967	457	1974	812	1981	3 794
1968	305	1975	345	1982	5 398

Source: 1962 to 1969 - Watkinson & Smith, 1972; 1970 to 1982 - Sylvester, 1989.

Before 1988 there were no restrictions in place for the purse seine fishery.

Table 3: Reported landings (t) of kahawai by management areas as defined prior to 2004 from 1983-84 to 2003-04. Estimates of fish landed as bait or as ‘mixed fish’ are not included. Data for the distribution of catches among management areas and total catch are from the FSU database through 1987-88 and from the CELR database after that date. Total LFRR or MHR values are the landings reported by Licensed Fish Receivers (to 2000-01) or Monthly Harvest returns (to 2003-04).

Fishstock	KAH 1	KAH 2	KAH 3	KAH 9	KAH 10	Unknown Area	Total Catch	Total LFRR/MHR
FMA(s)	1	2	3-8	9	10			
1983-84	1 941	919	813	547	0	46	4 266	-
1984-85	1 517	697	1 669	299	0	441	4 623	-
1985-86	1 597	280	1 589	329	0	621	4 416	-
1986-87	1 890	212	3 969	253	0	1 301	7 525	6 481
1987-88	4 292	1 655	2 947	135	0	581	9 610	9 218
1988-89	2 170	779	4 301	179	0	-	7431	7 377
1989-90	2 049	534	5 711	156	0	16	8 466	8 696
1990-91	1 617	872	2 950	242	0	4	5 687	5 780
1991-92	2 190	807	1 900	199	< 1	7	5 104	5 071
1992-93	2 738	1 132	1 930	832	2	0	6 639	6 966
1993-94	2 054	1 136	1 861	98	15	0	5 164	4 964
1994-95	1 918	1 079	1 290	168	0	24	4479	4 532
1995-96	1 904	760	1 548	237	7	46	4 502	4 648
1996-97	2 214	808	938	194	1	3	4 158	3 763
1997-98	1 601	291	525	264	0	19	2 700	2 823
1998-99	1 833	922	1 209	468	0	3	4 435	4 298
1999-00	1 616	1 138	718	440	0	< 1	3 912	3 941
2000-01	1 746	886	925	272	0	1	3 829	3 668
2001-02	1 354	816	377	271	0	< 1	2 819	2 796
2002-03	933	915	933	221	0	< 1	3 001	2 964
2003-04	1 624	807	109	205	0	0	2 745	2 754

A total commercial catch limit for kahawai was set at 6500 t for the 1990-91 fishing year, with 4856 t set aside for those harvesting kahawai by purse seine (Table 5). Commercial landings for kahawai have decreased in almost every year since 1998-99 (from 4444 to 2013 t in 2005-06), but increased again in 2006-07 (2 500 t). In 2006-07 commercial catches were within 5% of the TACC in KAH 1, 2, and 3 and 23% under in KAH 8. Before the 2002-03 fishing year a high proportion of the purse seine catch was targeted, but in recent years approximately half of the landed catch has been reported as a bycatch in the other purse seine fisheries described above.

Table 4: Prorated landings (t) of kahawai by the Fishstocks defined in 2004 for the fishing years between 1998-99 and 2010-11. Distribution of data were derived by linking through the trip code, catch landing data (CLD), statistical areas and landing points and prorating to CLD totals. Landings since 2004-05 are from QMS MHR data. The TACC is provided for those years since the introduction to the QMS.

	KAH 1		KAH 2		KAH 3		KAH 4		KAH8&9		KAH 10			
	1		2		3, 5, 7		4		8, 9		10		Total	
	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1998-99	1 652	-	975	-	697	-	0	-	1 120	-	0	-	4 444	-
1999-00	1 677	-	973	-	499	-	0	-	768	-	0	-	3 917	-
2000-01	1 678	-	922	-	425	-	0	-	581	-	0	-	3 606	-
2001-02	1 326	-	857	-	156	-	0	-	489	-	0	-	2 831	-
2002-03	869	-	855	-	650	-	0	-	542	-	0	-	2 916	-
2003-04	1 641	-	806	-	33	-	0	-	342	-	0	-	2 822	-
2004f05	1 147	1 195	708	785	129	455	< 1	10	544	580	0	10	2 529	3 025
2005-06	903	1 075	530	705	233	410	0	9	346	520	0	9	2 013	2 728
2006-07	1 046	1 075	672	705	382	410	< 1	9	407	520	0	9	2 507	2 728
2007-08	1 002	1 075	564	705	152	410	0	9	570	520	0	9	2 288	2 728
2008-09	945	1 075	823	705	157	410	0	9	381	520	0	9	2 306	2 728
2009-10	988	1 075	518	705	38	410	< 1	9	451	520	0	9	1 995	2 728
2010-11	1 002	1 075	719	705	46	410	0	9	454	520	0	9	2 221	2 728

In KAH 1, a voluntary moratorium was placed on targeting kahawai by purse seine in the Bay of Plenty from 1 December 1990 to 31 March 1991, which was extended from 1 December to the Tuesday after Easter in subsequent years. While total landings decreased in 1991-92, landings in KAH 1 increased, and in 1993-94 the competitive catch limit for purse seining in KAH 1 were reduced from 1666 t to 1200 t. Purse seine catches reported for KAH 9 were also included in this reduced catch limit, although seining for kahawai on the west coast of the North Island ceased after the reduction in the KAH 1 purse seine limit. Purse seine catch limits were reached in KAH 1 between 1998-99 and 2000-01 and in 2003-04.

Prior to the introduction to the QMS, no change was made to the purse seine limit of 851 t for KAH 2. The KAH 2 purse seine fishery was closed early due to the catch limit being reached before the end of the season in each year between 1991-92 and 1995-96 and between 2000-01 and 2001-02.

Within KAH 3, the kahawai purse seine fleet has voluntarily agreed since 1991-92 not to fish in a number of near-shore areas around Tasman and Golden Bays, the Marlborough Sounds, Cloudy Bay, and Kaikoura. The main purpose of this agreement is to minimise local depletion of schools of kahawai found inshore, and the catches of juveniles. The purse seine catch limit for KAH 3 was reduced from 2339 to 1500 tonnes from 1995-96. Purse seine catch limits have never been reached in KAH 3.

Table 5: Reported catches (t) by purse seine method and competitive purse seine catch limit (t) from 1990-91 to 2003-04. All data are from weekly reports furnished by permit holders to the Ministry of Fisheries except those for 1993-94 which are from the CELR database. Fishstocks are as defined prior to 2004.

	KAH 1		KAH 2		KAH 3		KAH 9		KAH 10		Total	
Year	catch	catch limit	catch	catch limit	catch	catch limit	catch	catch limit	catch	catch limit	catch	catch limit
1990-91	1 422	1 666	493	851	n/a#	2 839*	0	none	0	none	n/a	5 356
1991-92	1 613	1 666	735*	851	1 714	2 339	0	none	0	none	4 080	4 856
1992-93	1 547	1 666	795*	851	1 808	2 339	140	none	0	none	4 290	4 856
1993-94	1 262	1 200	1 101*	851	1 714	2 339	15	§	0	none	4 092	4 390
1994-95	1 225	1 200	821*	851	1 644	2 339	0	§	0	none	3 690	4 390
1995-96	1 077	1 200	805*	851	1 146	1 500	0	§	0	none	3 028	3 551
1996-97	1 017	1 200	620	851	578	1 500	0	§	0	none	2 784	3 551
1997-98	969	1 200	175	851	153	1 500	0	§	0	none	1 297	3 551
1998-99	1 416*	1 200	134	851	463	1 500	2	§	0	none	2 015	3 551
1999-00	1 371*	1 200	553	851	520	1 500	0	§	0	none	2 444	3 551
2000-01	1 322*	1 200	954*	851	430	1 500	0	§	0	none	2 706	3 551
2002-02	838	1 200	747*	851	221	1 500	0	§	0	none	1 806	3 551
2002-03	514	1 200	819	851	816	1 500	0	§	0	none	2 149	3 551
2003-04	1 203*	1 200	714	851	1	1 500	0	§	0	none	1 918	3 551

By March 1991 when the catch limit was imposed, the purse seine catch had already exceeded 2339 t and the fishery was immediately closed. As the catch already exceeded 2339 t before the Minister's decision was announced, an extra 500 t was allocated to cover kahawai bycatch only.
§ Combined landings from KAH 9 and KAH 1 were limited to 1200 t.
* Purse seine fishery for kahawai closed.

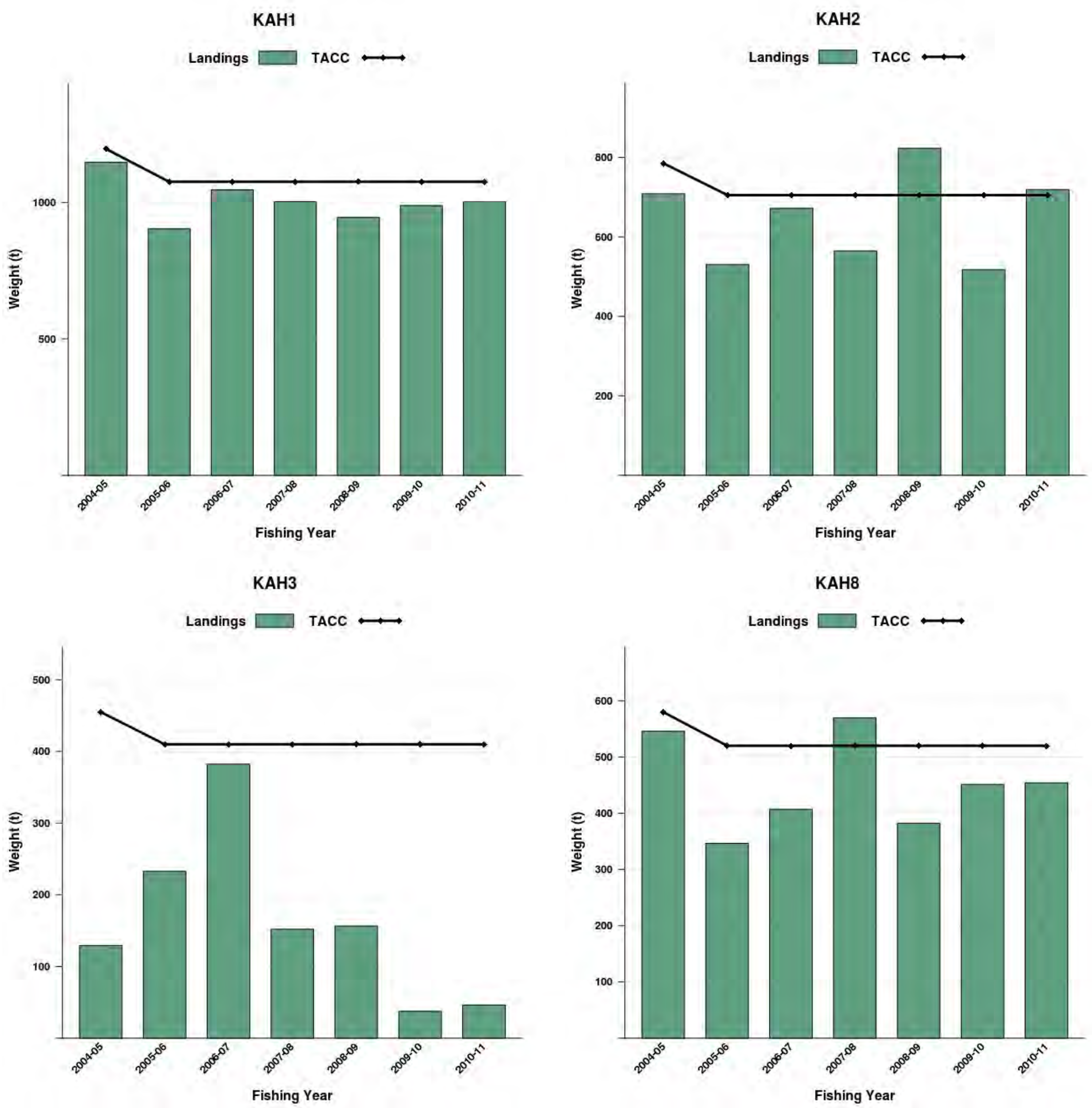


Figure 1: Historical landings and TACC for the four main KAH stocks. From top left to bottom right: KAH1 (Auckland East), KAH2 (Central East), KAH3 (South East Coast, South East Chatham Rise, sub Antarctic, Southland, Challenger), and KAH8 (Central Egmont, Auckland West). Note that these figures do not show data prior to entry into the QMS.

Since kahawai entered the Quota Management System on 1 October 2004, the purse seine catch limits no longer apply and landings, regardless of fishing method, are now restricted by quota availability and fishing company policies.

1.2 Recreational fisheries

Kahawai is the second most important recreational species in FMA 1 (after snapper). Kahawai are highly prized by some recreational fishers, who employ a range of shore and boat based fishing methods to target and/or catch the species. The only regulatory restrictions on recreational fishing for kahawai are a multi-species bag limit of 20 fish and a minimum set net mesh size of 90 mm. Kahawai is one of the fish species more frequently caught by recreational fishers, and recreational groups continue to express concern about the state of kahawai stocks. Historical kahawai recreational catches are poorly known.

1.2.1 Harvest estimates

The first recreational harvest estimates were obtained from regional telephone diary surveys undertaken in 1991-92 in the South Region, 1992-93 in the Central Region and in 1993-94 in the North Region. National telephone diary surveys were undertaken in 1996 and 2000, with a follow up survey in 2001 (i.e., the 2000 and 2001 estimates are not independent). Combined aerial overflight/boat ramp surveys, focusing on snapper, have provided kahawai harvest estimates in 2004 (Hauraki Gulf only) and 2005 (FMA 1 only).

Detailed descriptions for the telephone diary approaches used can be found in Teirney *et al*. (1997), Bradford *et al*. (1998) and Reilly (2002). The aerial overflight methodology is described in Hartill *et al*. (2006b). The key difference between the two approaches is that the telephone diary methodology combines unobserved estimates of the number of fishers in an area obtained via a survey of randomly selected individuals from telephone listings, with volunteer diarist data (which is used to estimate the average catch per fisher), whereas the aerial overflight approach combines aerial counts of boats fishing at mid day with dawn to dusk boat ramp interviews describing fishing effort and catch. The aerial overflight survey is, therefore, based on a direct assessment of the fishery while the telephone diary method is indirect, particularly with respect to the estimate of active participants. It is not, however, possible to reliably quantify shore based fishing from the air, and for this reason it was necessary to derive scalars from 2001 diarist data to account for the shore based kahawai catch (28% of the 2001 estimate).

Recreational harvest estimates are given in Tables 6 (telephone diary surveys) and 7 (Aerial overflight surveys).

Table 6: Estimated kahawai harvest by recreational fishers (in numbers and weight) by Fishstock as defined prior to 2004. (Source: Tierney *et al*. 1997, Bradford 1997, Bradford 1998, Boyd & Reilly 2002, Boyd *et al*. 2004).

	Survey			KAH 1				KAH 2
Year	Number	CV (%)	Range (t)	Estimate (t)	Number	CV (%)	Range (t)	Estimate (t)
1992-93	-	-	-	-	195 000	-	245-350	298
1993-94	727 000	-	920-1 035	978	-	-	-	-
1996	666 000	6	900-1 020	960	142 000	9	190-240	217
2000	1 860 000	13	916-2 475	2 195	1 808 000	74	769-5 105	2 937
2001	1 905 000	13	-	2 248	492 000	20	-	799

	Survey			KAH 3				KAH 9
Year	Number	CV (%)	Range (t)	Estimate (t)	Number	CV (%)	Range (t)	Estimate (t)
1991-92	231 000	-	160-260	210				
1993-94	6000	-	-	8.4#	254 000	-	285-395	340
1996	226 000	7	125-145	137	199 000	9	195-225	204
2000	413 000	16	564-771	667	337 000	20	354-527	441
2001	353 000	18	-	570	466 000	24	-	609

#No harvest estimate available in the survey report, estimate presented is calculated as average fish weight for all years and areas by the number of fish estimated caught.

Table 7: Summary of kahawai harvest estimates (t) derived from an aerial overflight survey of the Hauraki Gulf in 2003-04 (1 December 2003 to 30 November 2004; Hartill *et al*. 2006a) and a similar KAH 1 wide survey conducted in 2004-05 (1 December 2004 to 30 November 2005; Hartill *et al*. 2006b). Values in brackets denote CVs associated with each estimate.

Year	East Northland	Hauraki Gulf	Bay of Plenty	KAH 1
2003-04	-	56 (0.15)	-	-
2004-05	129 (0.14)	98 (0.18)	303 (0.14)	530 (0.09)

The Recreational Technical Working Group (RTWG) concluded that the framework used for the telephone interviews for the 1996 and previous surveys contained a methodological error, resulting in biased eligibility figures. Consequently the harvest estimates derived from these surveys are unreliable.

This group also indicated concerns with some of the harvest estimates from the 2000-01 survey. The following summarises that group's views on the telephone /diary estimates:

"*The RTWG recommends 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 harvest estimates are implausibly high for many important fisheries*."

In 2007, the Pelagic Working Group made the following conclusions in relation to the recreational harvest estimates for KAH 1 based on their current understanding:

- recreational catches are likely to be variable between years;
- the 2000 and 2001 harvest estimates (2195 and 2248 t) are:
  - possibly overestimated for those years and some PELWG members felt that the estimates were implausibly high;
  - are implausibly high if considered as a long term (back to the early 1990s) average; and
  - likely represent the upper limit of the harvest that may have occurred in any year since the 1990s (after the period of increased commercial landings);
- the aerial overflight estimate for kahawai harvest in 2004-05 of 530 t is:
  - possibly underestimated for that year, and
  - some PELWG members felt that it was implausibly low if considered as a long term average back to the early 1990s;
- the earlier diary survey estimates, although biased, are likely to be at plausible levels for those years, but are still uncertain; and
- the aerial overflight estimates for kahawai be treated with caution due to the limited overlap between the method's sampling technique and the fisheries for kahawai, e.g., the significant proportion of harvest taken by shore-based methods that require auxiliary data to account for.

In 2008, the Northern Inshore Finfish Working Group (NINSWG) made the following conclusions in relation to the recreational harvest estimates for other KAH QMAs based on their conclusions for KAH 1:

- the current KAH QMAs do not match up with the strata used for the historical harvest estimates (KAH 3 and 8);
- recreational catches are likely to be variable between years;
- the 2000 harvest estimate for KAH 2 is implausibly high;
- the 2000 and 2001 harvest estimates for the remaining KAH areas are possibly overestimated.

1.3 Customary non-commercial fisheries

Kahawai is an important traditional and customary food fish for Maori. The level of customary catch has not been quantified and an estimate of the current customary non-commercial catch is not available. Some Maori have expressed concern over the state of their traditional fisheries for kahawai, especially around the river mouths in the eastern Bay of Plenty.

1.4 Illegal catch

Estimates of illegal catch are not available, but are probably insignificant.

1.5 Other **sources of mortality**

There is no information on other sources of mortality. Juvenile kahawai may suffer from habitat degradation in estuarine areas.

2. BIOLOGY

Kahawai (*Arripis trutta*) are a schooling pelagic species belonging to the family Arripididae. Kahawai are found around the North Island, the South Island, the Kermadec and Chatham Islands. They occur mainly in coastal seas, harbours and estuaries and will enter the brackish water sections of rivers. A second species, *A. xylabion*, has been described (Paulin 1993). It is known to occur in the northern EEZ, at the Kermadec Islands and seasonally around Northland.

Kahawai feed mainly on fishes but also on pelagic crustaceans, especially krill (*Nyctiphanes australis*). Kahawai smaller than 100 mm mainly eat copepods. Although kahawai are principally pelagic feeders, they will take food from the seabed.

The spawning habitat of kahawai is unknown but is thought to be associated with the seabed in open water. Schools of females with running ripe ovaries have been caught by bottom trawl in 60-100 m in Hawke Bay (Jones *et al*. 1992). Other females with running ripe ovaries have been observed in east coast purse seine landings sampled in March and April 1992, and between January and April in 1993 (McKenzie NIWA, unpublished data). Length-maturation data collected from thousands of samples in early 1990s suggest the onset of sexual maturity in males occurs at around 39 cm and in females at 40 cm (McKenzie NIWA, unpublished data). This closely matches an estimate of 39 cm used for Australian *A. trutta* (Morton *et al*. 2005). This length roughly corresponds to fish of four years of age in both countries. Eggs have been found in February in the outer Hauraki Gulf. Juvenile fish (0+ year class) can be found in shallow water over eelgrass meadows (*Zostera* spp.) and in estuaries.

Kahawai are usually aged using otoliths, following an aging technique that has been validated (Stevens and Kalish 1998). Kahawai grow rapidly, attaining a length of around 15 cm at the end of their first year, and maturing after 3-5 years at about 35-40 cm, after which their growth rate slows. The longest recorded *A. trutta* had a fork length of 79 cm and was caught by a recreational fisher in the Waitangi Estuary, in Hawke Bay in August 1997 (Duffy & Petherick 1999). Northern kahawai, *Arripis xylabion*, grow considerably bigger than kahawai and attain a maximum length of at least 94 cm, but beyond this, little is known about the biology of *A. xylabion*. Male and female von Bertalanffy growth curves appear to be broadly similar, with females attaining a slightly higher value for L_{∞}, although statistical comparison of sex specific curves using a likelihood ratio test (Kimura 1980) suggests that they are statistically different (Hartill & Walsh 2005). Combined-sex growth curves are probably adequate for modelling purposes and are provided for some areas in Table 8. Sex specific growth parameters given for KAH 1 in previous plenary documents have higher estimates for L_{∞} (56.93 for males and 55.61 for females).

The maximum recorded age of kahawai is 26 years. The instantaneous rate of natural mortality (*M*) was estimated from the equation M=$\log_e$ 100/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Based on a maximum age of 26 years, *M* was estimated to equal 0.18. A range of 0.15–0.25 has previously been assumed to reflect the lack of precision in the estimate.

Table 8: Estimates of biological parameters.

Fishstock			Estimate		Source
1. Natural mortality (*M*)					
All			0.18		Jones *et al*. (1992)
2. Weight = a(length)^b (weight in g, length in cm fork length)					
			a	b	
	KAH 1 (resting)		0.0306	2.82	Hartill & Walsh (2005)
	KAH 1 (mature)		0.0103	3.14	Hartill & Walsh (2005)
3. von Bertalanffy growth parameters					
		K	t_0	*L¥*	
KAH 1		0.33	-0.1	54.3	Hartill *et al*. (2007a)
KAH 2		0.34	0.6	53.5	Drummond (1995)
KAH 3		0.3	0.25	54.2	Drummond & Wilson (1993)
KAH 9		0.23	-0.26	55.9	McKenzie, NIWA, unpubl. data

3. STOCKS AND AREAS

Kahawai are presently defined as separate units for the purpose of fisheries management: KAH 1 (FMA 1); KAH 2 (FMA 2); KAH 3 (FMAs 3, 5, 6 & 7); KAH 4 (QMA 4); KAH 8 (FMAs 8 & 9) and KAH 10 (FMA 10).

Returns from tagging programmes do not provide definitive information on the level of potential mixing between KAH QMAs, but tagging returns suggest that most kahawai (*A. trutta*) remain in the same area for several years, but some move throughout the kahawai habitat. The pattern of kahawai movement around New Zealand is poorly understood and there are regional differences in age structure and abundance that are consistent with limited mixing between regions;

Smith *et al*. (2007) compared otolith micro-chemistry (multi-element chemistry and stable isotopes) and meristics (e.g., fin counts) from 0-group kahawai from two regions (Okahu Bay, Waitemata Harbour and Hakahaka Bay, Port Underwood). Two distant sites were chosen in order to provide the best chance of successful discrimination. Neither meristics nor stable isotopes provided any discrimination and magnesium and barium concentrations provided only weak discriminatory power.

On balance it seems possible that there are least two stocks of kahawai (*A. trutta*) within New Zealand waters with centres of concentration around the Bay of Plenty and northern tip of the South Island. These two areas could be assumed to be separate for management purposes. Tagging data show that there is some limited mixing between these areas. Due to the shared QMA boundaries in the lower North Island and South Island, there is likely to be more mixing between the southern KAH QMAs than with the northern QMA (KAH 1).

There is no information about stock structure of *A. xylabion*.

4. STOCK ASSESSMENT

In 2007 an age-structured stock assessment was undertaken for KAH 1 using CASAL (Bull *et al*. 2004). This assessment is reported below. This replaces the 1997 nation-wide assessment which is no longer considered valid by the PELWG due to the simplistic methods used and its historical nature. Therefore, aside from some catch curve estimates of Z from the early 1990s, there is no longer an accepted stock assessment for areas outside KAH 1.

4.1 KAH 1

4.1.1 Estimates of catch, selectivity and abundance indices

(i) Commercial catch
The commercial catch history assumed in the assessment is provided in Table 9. It is noted that catches in the early years are less certain due to reporting (e.g., see Table 3 legend).

(ii) Recreational catch
The recreational catch history in KAH 1 is poorly known. Estimates are available for the Hauraki Gulf in 2003-04 (Hartill *et al*. 2006a) and for three subregions of KAH 1 in 2004-05 (Hartill *et al*. 2006b) which were derived from aerial overflight surveys. These estimates are used in the model for those years.

Two recreational catch scenarios were ultimately considered in the stock assessment model: a constant harvest of either 800 t or 1865 t, except in 2005 when 530 t was used. The 530 t estimate was considered implausibly low as a long term average from 1975 so an arbitrary value of 800 t was used instead. The arbitrary upper bound of 1865 t is equal to the recreational allowance made when kahawai was introduced to the QMS 1 October 2004. This was based on the 2000 harvest estimate reduced by 15%.

Constant harvest tonnages were used as there was concern that if a catch history with an assumed trend was used this trend could influence the model results, despite being essentially unknown. It was felt that these two scenarios would span the likely impacts of intermediate catch scenarios, even those with a trend.

Data from three recent surveys of recreational fishers were used to apportion the annual harvests across the three subregions (Northland, Hauraki Gulf, and Bay of Plenty). These surveys were the two linked telephone diary surveys conducted in 1999-00 (Boyd & Reilly 2002) and 2000-01 (Boyd *et al*. 2004) and the aerial overflight survey conducted in 2004-05 (Hartill *et al*. 2006b). All three surveys suggest very similar catch split proportions: Northland 22%, the Hauraki Gulf 18%, and the Bay of Plenty 60%.

The time series of catches used was assumed to cover both recreational and non-commercial customary catch.

Table 9: Commercial catch time series used in the stock assessment. PS - purse seine, SN - set net, ST - single trawl, OT - other gears.

	East Northland				Hauraki Gulf				Bay of Plenty				KAH 1
Fishing Year	PS	SN	ST	OT	PS	SN	ST	OT	PS	SN	ST	OT	All
1974-75	-	8	1	6	-	27	1	5	12	2	5	2	69
1975-76	-	17	3	13	-	58	2	10	25	4	11	4	146
1976-77	-	33	6	25	-	116	4	21	50	8	21	8	292
1977-78	-	51	9	39	-	176	6	32	77	12	33	12	446
1978-79	-	70	12	53	-	243	9	44	106	16	45	16	614
1979-80	-	74	13	57	-	258	9	47	112	17	48	17	653
1980-81	-	70	12	53	-	244	9	44	106	16	45	16	617
1981-82	-	74	13	56	-	256	9	46	111	17	48	17	647
1982-83	-	112	19	85	-	389	14	70	169	26	72	26	982
1983-84	-	68	12	52	-	237	9	43	1 445	16	44	16	1 941
1984-85	-	87	15	66	-	303	11	55	882	20	56	20	1 517
1985-86	-	56	10	43	-	194	7	35	1 191	13	36	13	1 597
1986-87	-	48	8	36	-	165	6	30	1 544	11	31	11	1 890
1987-88	-	45	8	34	-	157	6	28	3 964	10	29	10	4 292
1988-89	-	72	13	55	-	251	9	45	1 644	17	47	17	2 169
1989-90	1	75	13	57	-	259	9	47	1 698	17	48	17	2 241
1990-91	0	54	10	39	-	189	6	10	1 563	69	65	29	2 035
1991-92	-	68	14	53	3	157	2	21	1 723	65	29	19	2 154
1992-93	199	74	147	93	-	402	14	63	2 326	83	15	53	3 469
1993-94	118	51	19	165	-	278	6	105	1 451	93	55	35	2 377
1994-95	4	103	30	95	-	207	7	73	1 287	67	23	38	1 934
1995-96	1	74	41	71	-	185	4	35	1 368	90	80	39	1 987
1996-97	53	99	63	60	-	120	3	17	989	81	47	34	1 567
1997-98	30	138	40	46	-	144	9	18	682	65	67	22	1 260
1998-99	44	78	28	49	-	110	3	41	1 329	28	115	18	1 843
1999-00	4	74	29	18	-	132	1	25	1 214	31	76	14	1 618
2000-01	34	84	4	27	-	110	-	29	1 359	12	72	15	1 747
2001-02	43	81	5	9	-	195	-	11	949	16	54	37	1 399
2002-03	57	64	12	7	-	173	-	8	551	17	35	29	952
2003-04	52	51	16	11	-	146	-	2	1 311	14	34	24	1 661
2004-05	36	35	11	7	-	101	-	1	905	10	24	16	1 147
2005-06	28	28	9	6	-	80	-	1	713	8	19	13	903

(iii) Catch composition data and selectivity estimates

The earliest catch-at-age data that are available were collected from commercial fisheries in 1991, 1992 and 1993. Landings were sampled from the East Northland purse seine fishery and from the Bay of Plenty single trawl and purse seine fisheries. These age distributions were included in the model with the exception of the 1993 Bay of Plenty purse seine data, which were dropped because they were shown to be unrepresentative of the landings. Age compositions for purse seine landings from east Northland and the Bay of Plenty were available for 2005 and included in the model. Age and length samples from the recreational fisheries in three regions of KAH 1 were available since 2001, and were also included in the model (Armiger *et al*. 2006, Hartill *et al*. 2007a, 2007b).

Selectivity ogives are estimated for each of the six fisheries (i.e., the three regional recreational fisheries, two regional purse seine fisheries, and a single trawl fishery), accounting for a high proportion of the KAH 1 landings in each year. A double normal selectivity ogive was used to describe the set net fishery, which, although it has relatively low landings (200-300 t in most years) compared to the purse seine fishery, has been included so that the associated indices of abundance can be used in the model. No landings have been sampled from this fishery, so the selectivities were not informed by any data.

(iv) Catch-curve analysis results

Annual estimates of total mortality (Z) have been derived from recreation catch data sampled in East Northland and the Bay of Plenty. They were calculated using a Chapman Robson estimator independently from the stock assessment model (Table 10). These estimates were calculated using a range of assumed ages for full recruitment to demonstrate the sensitivity of the results to this assumption.

Table 10: Estimates of *Z* derived from recreational catch sampling in KAH 1, by survey year by assumed age at recruitment.

East Northland Age at recruitment	2001	2002	2003	2004	2005	2006	2007	2008
3	0.33	0.33	0.32	0.28	0.24	0.28	0.28	0.24
4	0.34	0.38	0.35	0.31	0.28	0.32	0.23	0.28
5	0.30	0.37	0.39	0.33	0.33	0.35	0.35	0.33
6	0.30	0.40	0.41	0.38	0.36	0.41	0.41	0.34
Bay of Plenty								
	2001	2002	2003	2004	2005	2006	2007	2008
3	0.23	0.25	0.28	0.20	0.27	0.24	0.24	0.24
4	0.26	0.30	0.32	0.23	0.29	0.27	0.27	0.27
5	0.28	0.33	0.34	0.26	0.30	0.24	0.24	0.29
6	0.30	0.36	0.38	0.32	0.30	0.26	0.26	0.29

(v) Indices of abundance

For the 2007 assessment, regional indices of abundance were available from two sources: recreational fisheries and set net fisheries (Figure 2). Two other indices of abundance were also initially considered from the Bay of Plenty, but dropped: an aerial sightings index, and one based on commercial trawl catch rate data. The former was considered underdeveloped and the latter was based on poor measures of catch and effort. In 2012, an aerial sightings index for the Bay of Plenty was developed and accepted by the working group (see below).

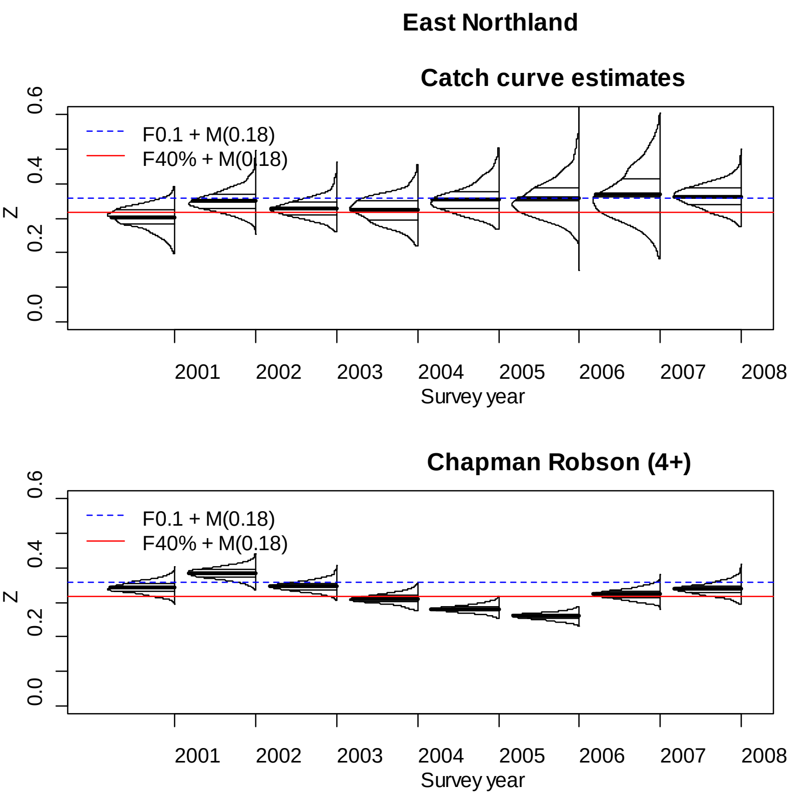


Figure 2: The distribution of bootstrap estimates of total mortality (*Z*) by survey year for East Northland (top two panels) and the Bay of Plenty (lower two panels). Theoretical optimal levels of *Z* derived from the YPR and SPR curves calculated in Hartill *et al*. (2008a) are denoted as horizontal lines for reference purposes (from Armiger *et al*. 2009)

Boat ramp surveys have been conducted in KAH 1 since 1991, and these data have been used to generate standardised CPUE indices for three regional fisheries: East Northland, Hauraki Gulf and Bay of Plenty (Hartill & Walsh 2005). These indices were derived from Poisson-based generalised linear models of the number of kahawai caught in a trip (including those released) given the time spent fishing and other explanatory variables. Poisson-based modelling accommodates a high proportion of zero catches in the data, and posterior statistical tests suggested that the level of dispersion was close to one. Boat ramp data suggest that approximately 80% of the recreational catch is landed (Hartill & Walsh 2005).

Standardised indices of abundance were also derived from commercial set net data reported on CELR forms since 1990 (Figure 2). Generalised log-linear models were used to derive indices for each of the three sub-regions of KAH 1 (McKenzie *et al*. 2007). There were insufficient data available from the Bay of Plenty to provide reliable indices for 2003-04 and 2004-05 so these years were not included in the model. Some PELWG members expressed their concerns at the utility of the set net indices, given the low catches taken by this method, the lack of an appropriate selectivity ogive, the potential for non-reporting of catch; and given that kahawai were not in the QMS for most of the series; and that it is only mandatory to report the top five species in a fishing event.

There is no consistent pattern in catch rates when comparisons are made across and within regions. Recreational catch rates in East Northland increased in the early 1990s, and then declined in recent years, whereas the reverse trend is evident in the set net index. Both indices exhibit interannual variability in the Hauraki Gulf and little trend is apparent. In the Bay of Plenty there is no trend in the recreational index, but a clear decline is evident in the set net index.

Aerial Sightings Index

In 2012, an index of abundance [sightings per unit effort (SPUE)] based on commercial aerial sightings data was accepted by the Northern Inshore Working Group. This index was calculated using data from the Ministry for Primary Industries database *aer_sight* and applying a a generalised additive model (GAM) to produce standardised annual relative abundance indices (Taylor 2011).

Flights were restricted to those that were exclusive to the Bay of Plenty (BoP) (i.e., those having flight paths that remained within an area defined as the BoP), only flown by pilot #2 and were the first flight of the day (apart from some defined exceptions, e.g., short refuelling flights at the start of the day).

Estimates of relative year effects were obtained using a forward stepwise GAM, where the data were fitted using two models: 1) the probability of a flight having a positive sighting modelled using a binomial regression; and 2) the tonnage sighted on positive flights modelled using a lognormal regression. These two models were combined into a single index. The data used for the SPUE analyses consisted of aerial sightings of kahawai, trevally, jack mackerel, blue mackerel, and skipjack tuna collected over the period 1986–87 to 2010–11, with missing years in 1988–89, from 1994–95 to 1996–97 and in 2006–07. Most of these missing years were the result of no available data. By contrast, 2006–07 was dropped because the working group identified a bias in the annual index for that year because of the low number of available flights. The first year of the original series (1985–86) was dropped by the working group for the same reason.

Daily purse-seine catch for the vessels with which the pilot was working in the BoP was used as a proxy for target species . Catch data before 1989 were from the *fsu-new* database and data from 1989 to 2011 were from the *warehou* data base.

The Working Group concluded that the combined model of SPUE for kahawai is probably a reasonable index of abundance in the BoP. The index should be used in a stock assessment, using diagnostics to gauge the quality of the abundance index.

The BoP combined SPUE index for kahawai shows substantial inter-annual variation with an overall gradual declining trend from 1986-87 to , 2002–03; thereafter increasing sharply to a peak in 2007–08, and then declining to points above the long-term mean (Table 10b, Figure 2b).

Table 10b: Standardised SPUE indices for KAH 1 from the binomial-lognormal model fitted to the series 1986–87 to 2010–11 with years of missing data shown.

Fishing year	Lognormal	Binomial	Combined
198687	1.01	0.81	1.22
198788	0.9	1.13	0.89
1988–89	No data	No data	No data
198990	0.6	0.9	0.61
199091	0.62	0.9	0.82
199192	0.8	0.84	0.68
199293	1.12	1.12	1.25
199394	1.57	1.01	1.2
1994–95	No data	No data	No data
1995–96	No data	No data	No data
1996–97	No data	No data	No data
199798	0.84	0.94	0.92
199899	0.45	1.16	0.48
199900	0.54	0.71	0.51
200001	0.75	1.08	0.73
200102	0.6	1.1	0.68
200203	0.54	0.85	0.38
200304	1.41	1.12	1.36
200405	1.83	1.1	1.78
200506	1.9	1.15	2.06
200607	Insufficient data	Insufficient data	Insufficient data
200708	2.06	1.12	2.59
200809	1.92	0.93	1.28
200910	1.6	1.07	1.57
201011	1.38	1.16	1.65

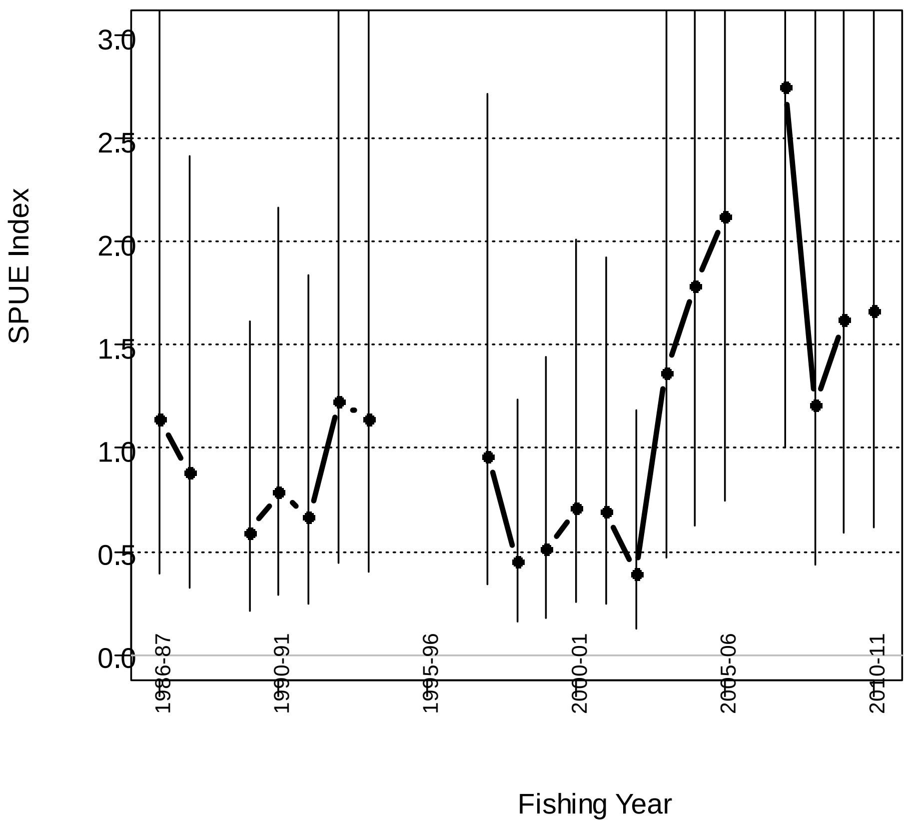


Figure 2b: Standardised sightings per unit effort indices for the Bay of Plenty KAH 1 stock, derived as a combination of year effect estimates from a lognormal and a binomial regression. Vertical lines are the 95% confidence interval.

4.1.2 Model structure

The stock assessment was restricted to KAH 1, because this is the QMA where most of the observational data have been collected. Future assessments may consider a broader stock definition, but improved understanding of the movement dynamics of this species and further development of this model are required before this can be attempted. Even within KAH 1 there is little information on connectivity between the three main areas of the fishery: East Northland, Hauraki Gulf and the Bay of Plenty. Annual sampling of recreational catches, which has taken place in all three areas since 2001 (and intermittently since 1991), suggests that there are consistent regional differences in the length and age compositions of kahawai among these regions. For example, in the Hauraki Gulf, recreational landings of kahawai are regularly dominated by three year olds, with low proportions of fish older than five years. It is improbable that these regional differences in age structure can be attributed to relative fishing pressure alone, which suggests that some form of movement between areas is highly likely. There are few tag data available that can be used to estimate these migration processes, because almost all of the kahawai that have been tagged have been released in the Bay of Plenty. This provides little information about emigration from the Hauraki Gulf and from East Northland. For this reason it was not possible to partition the model into three interconnected sub-stocks, as their connectivity is inestimable. Area specific observational data were combined into a single stock model which includes most of the currently available data.

In the stock assessment model it is assumed that KAH 1 is a single biological stock, exploited by several fisheries. Deviations from the spawner recruitment curve were estimated for those years when there were three or more years of observational catch-at-age data, and were constrained to a mean of 1.0 across all fishing years from 1974-75 to 2005-06.

A single annual time step was used, in which ageing was followed by recruitment, maturation, growth, and then mortality (natural and fishing). The relationships between length and age, and length and weight, were both assumed to be constant through time and were based on the parameter values given in Table 8. Annual abundances of the age classes 1 to 20 were estimated in the model, with 20 year olds representing all fish older than 19 years. The model was not sex specific. Maturation was knife edged at four years of age. There is no information on the relationship between stock size and recruitment, and the rate of natural mortality is uncertain. Sensitivity to these parameters is discussed in the next section.

It was assumed that the population was at an unfished equilibrium state (B_0) in 1975. Key model outputs are probably robust to this assumption as commercial landings were only of the order of a few hundred tonnes and recreational landings were assumed to be low relative to stock size prior to this time. Total fishing mortality was apportioned between fisheries (combinations of method and region) according to observed catches and estimated selectivities. Method specific annual landings from five fishing methods were considered: recreational, purse seine, single trawl, set net, and other minor commercial fisheries. Landings by method are further divided into regional catch histories, as the catch-at-age data were collected at this spatial scale. Purse seine fisheries only occur in East Northland and the Bay of Plenty and share a common estimated selectivity. Separate selectivities were fitted to each of the three regional recreational fisheries.

4.1.3 Evaluation of uncertainty

A common approach in the assessment of fish stocks is to select a ‘base’ or ‘reference’ model which represents the most likely situation and then to evaluate uncertainty by selecting a number of analyses which vary key assumptions relative to the base case model. Frequently the more important sets of runs are evaluated using Bayesian methods to characterise the uncertainty in the estimated and derived parameters.

In the assessment for KAH 1 there was uncertainty in some important model inputs (e.g., recreational catch history and abundance indices) and some influential biological parameters could not be estimated within the model (e.g., natural mortality and steepness).

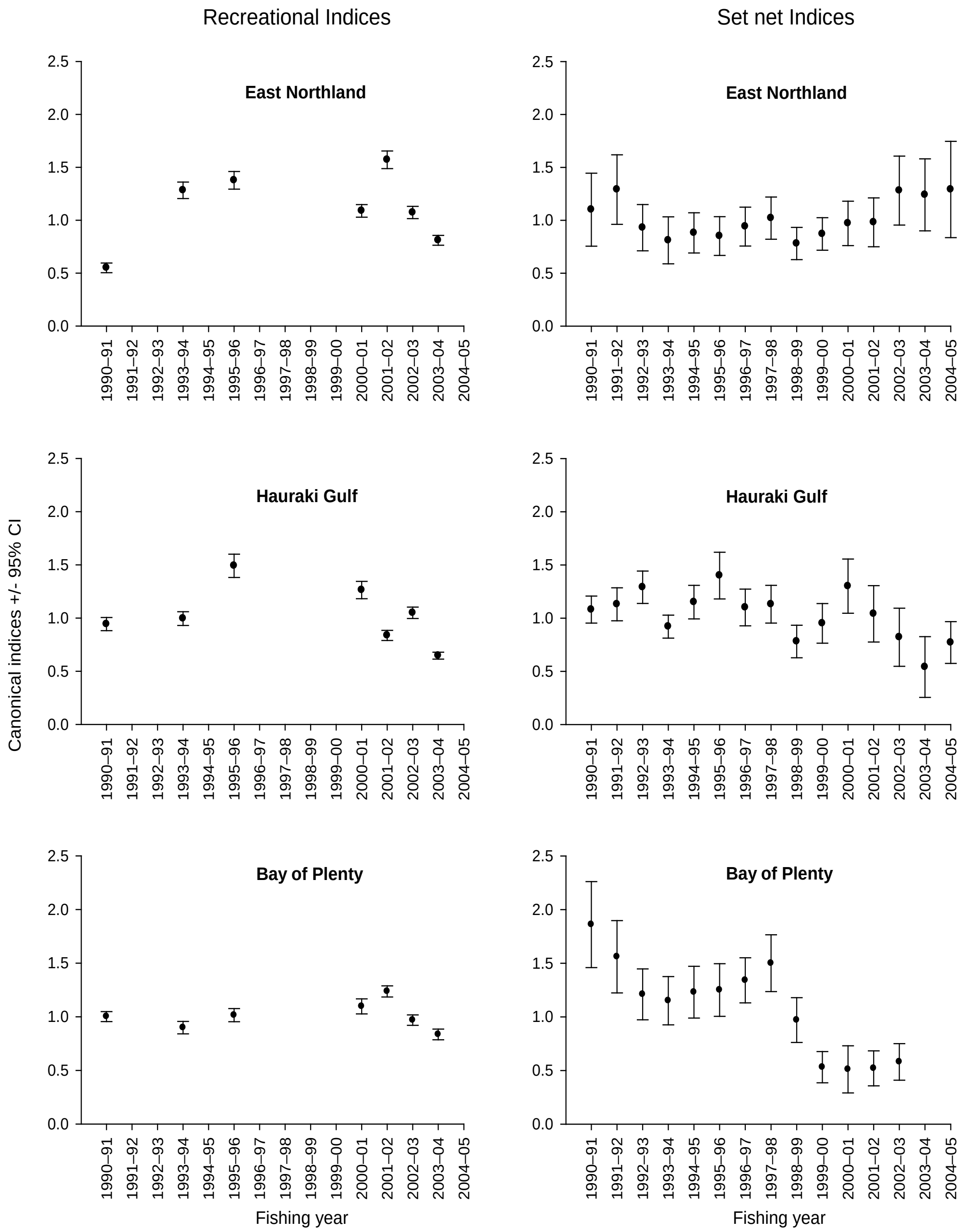


Figure 3: Standardised regional catch rate indices considered in the KAH 1 stock assessment model. Indices derived from recreational fishers using baited hooks and/or jigs since 1991 are given in the left hand panels, and those derived from commercial set net CELR data are given in the right hand panels.

The approach taken to represent uncertainty was to determine the four main factors for which uncertainty was likely to have an impact on key model outputs (referred to as the ‘axes of uncertainty’) and then to select a limited number of plausible options across each axis. Model runs were then undertaken for all possible combinations of options across each axis - this set of options was referred to as the ‘grid’. The selected grid axes are provided in Table 11. Overall, the grid comprised 36 model runs which in totality were thought to be a realistic reflection of the extent of uncertainty in the KAH 1 assessment.

Table 11: Axes of uncertainty and options chosen on grid. *N* is the number of levels on the axis.

Axis	N	Range
M	3	0.12, 0.18, 0.24
H	2	0.75, 1
Non-commercial catch	2	Constant 800, 1865t
Abundance indices	3	All, no set net, no recreational

In relation to the selected grid chosen, it was noted that:

- with additional time and resources the number of axes and/or levels in the grid could be increased;
- model diagnostics were not examined for all grid runs;
- the lower and higher values of *M* used in the grid (0.12 and 0.24) were probably at the limit of what would be considered plausible values;
- if this approach were to be developed further, it would be useful to weight each grid cell based on the plausibility of the cell components. This was not done for this exercise; and
- the range of values selected for recreational catch may not span the plausible range - a lower plausible value was not included in the grid because it was not likely to lead to qualitatively different conclusions.

4.1.4 Results

A grid search of the four axes of uncertainty suggested that there were differences in the magnitude and manner of their influence on the model. The model was largely insensitive to the indices of abundance offered, which is to be expected given the contradictory nature of these indices. The assumed steepness of the stock recruitment relationship also had only small influence on estimates of fishing mortality and yield.

Natural mortality had the most influence on the results. As mentioned in the previous section, both the lower value of 0.12 and the upper value of 0.24 were regarded as being at the limit of plausible values. Lower values of natural mortality resulted in higher levels of estimated fishing mortality, lower yields, and lower current biomass, although there was little contrast in estimates of virgin biomass (Figures 4 and 5, Table 12). Increased levels of natural mortality were offset by estimated selectivity ogives which were shifted to the right, resulting in reduced fishing mortality. The model essentially operated as an integrated catch curve, in which the slope of the right hand limb of the age distributions was approximated by the model parameters and dynamics.

The second most influential axis of uncertainty was the axis relating to the assumed recreational catch history (Figures 4 and 5, Table 12). The assumed recreational catch history had little influence on the predicted stock status (B_{06}/B_{MSY}), but did affect the estimate of total available yield.

Table 12: Model outputs for different values of *M* and assumed non-commercial catches. Values represent the median of the six model runs in each stratum (abundance index and steepness choice). All biomass estimates are in terms of spawning biomass.

		B_0 (t)	B_{06} (t)	B_{06}/B_0	B_{06}/B_{MSY}	*MSY* (t)
	0.12	41 690	11 260	0.27	1.22	2 130
800 t	0.18	38 762	17 582	0.45	1.84	2 822
	0.24	43 216	27 228	0.62	2.12	4 007
	0.12	59 453	14 518	0.24	1.11	3 042
1865 t	0.18	54 614	22 562	0.43	1.78	4 004
	0.24	60 082	35 882	0.59	2.06	5 564

Estimates of B_{MSY} as a proportion of B_0 varied across model runs (18.3-31% B_0). Lower percentages were associated with higher values of steepness.

Based on the scenarios examined, it is likely that current spawning biomass is greater than B_{MSY}, but it is uncertain how far above.

4.1.5 Yields

A modified yield per recruit analysis (incorporating the impact of the stock recruitment relationship) was carried out for each scenario to calculate the equilibrium yield estimates within each grid cell. It was assumed that the maximum sustainable yield (*MSY*) occurs at the maximum yield per recruit ($F = F_{max}$). B_{MSY} was defined as the start of the year biomass producing the maximum yield with fixed selectivities for each method and fixed proportions of the catch for each method based on the catch distribution in 2005-06. Results are expressed relative to virgin start of year biomass (B_0; which is sensitive to the assumed recreational catch history). The yield per recruit and its maximum will vary depending on the allocation of total catch amongst the fishing methods, because yield is mediated through the selectivity curves and these differ among the fisheries.

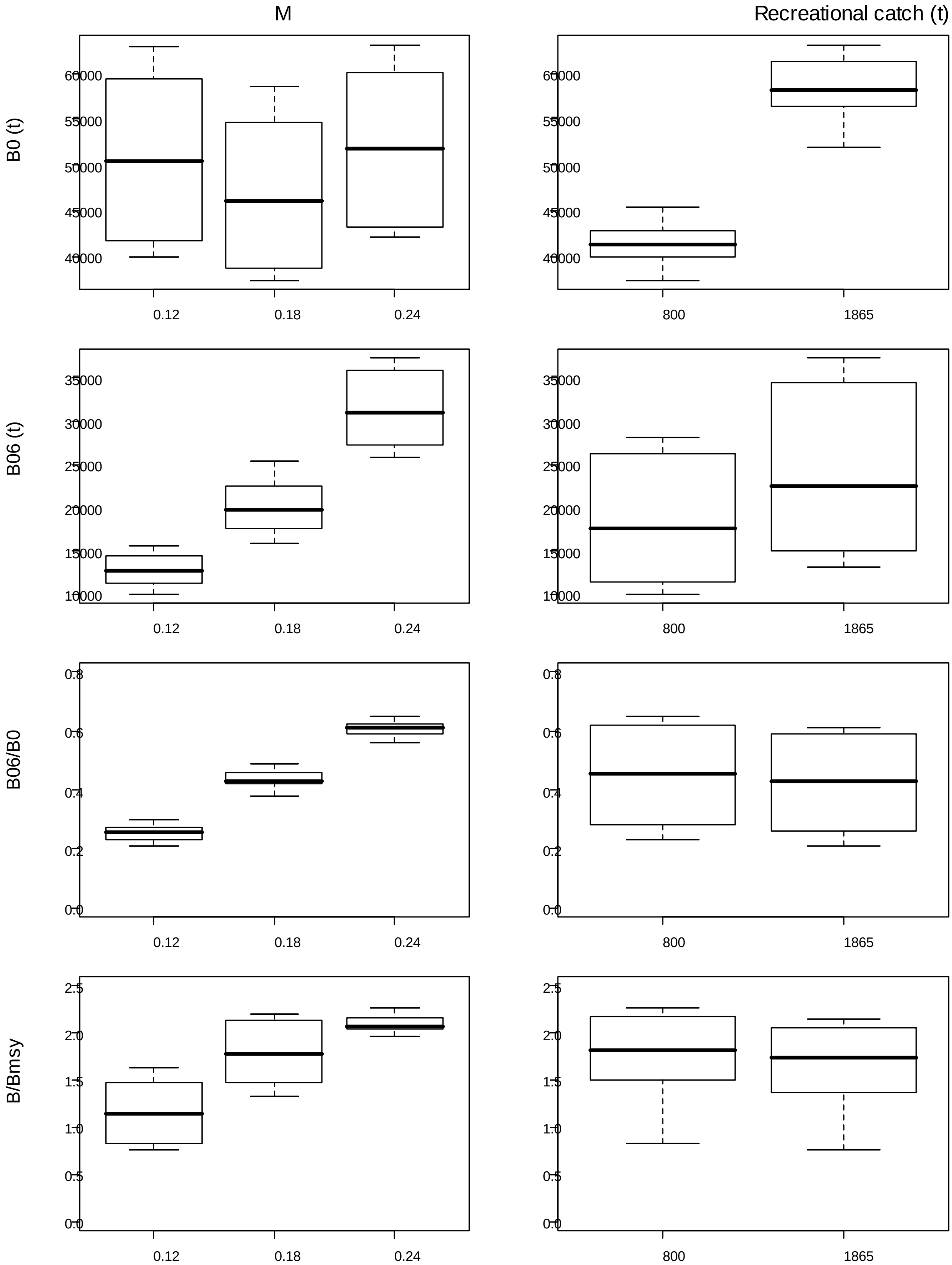


Figure 4: Boxplot showing the distribution of model results for the two key axes in the grid: natural mortality (left) and non-commercial catches (right). Each boxplot summarises 12 and 18 model runs for natural mortality and non-commercial catches respectively.

Estimates of *MSY* (t) derived from differing combinations of *M* and assumed recreational catch history are given in Table 12 and Figure 6. Differences in the range of *MSY* tonnages associated with the two recreational catch history scenarios (Figure 6) are almost solely due to the size of the associated estimates of B_0. That is, the ratio between *MSY* and B_0 is approximately constant across the range of recreational harvest estimates. For this reason, the yield estimates are only valid for each matched recreational harvest estimate. The assumed natural mortality rate also influences the yield estimate, both in an absolute sense, and relative to B_0.

Current assumed removals are lower than almost all estimates of deterministic *MSY*. Combining this with the result that most estimates of B_{06} are well above B_{MSY} it is unlikely that the stock will decline below B_{MSY} at current assumed catch levels, given the model recruitment assumptions.

The current TAC for KAH 1 is 3315 t with a TACC and allowances outlined in Table 1. The estimates of deterministic *MSY* depend on model assumptions, in particular the assumed natural mortality and time series of non-commercial catches. When non-commercial harvests are assumed to have been 800 t per year, median *MSY* estimates from grid strata range from 2130 to 4007 t. When non-commercial harvests are assumed to have been 1865 t per year, median *MSY* estimates from grid strata range from 3042 to 5564 t.

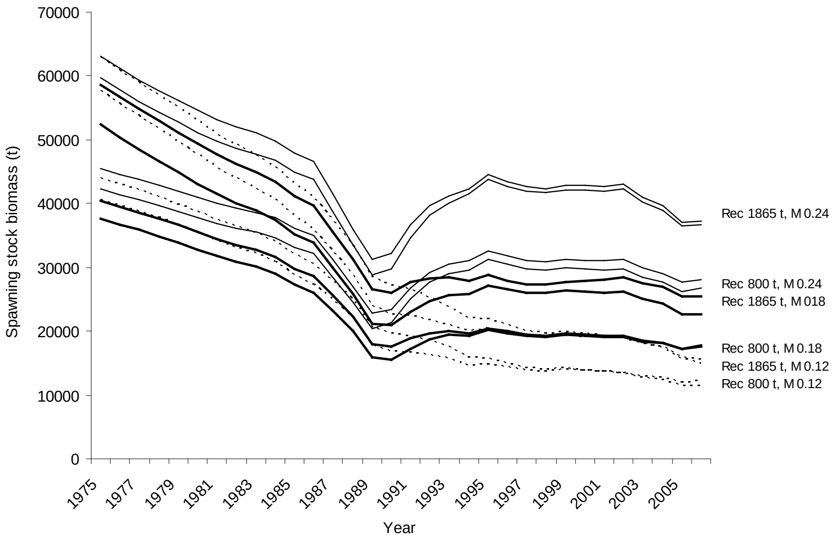


Figure 5: Biomass trajectories for differing assumed values for natural mortality (*M*), stock recruitment steepness (h) and assumed recreational catch history. For a given *M*, the upper pair of trajectories relate to a recreational catch of 1865 tonnes per annum, and the lower pair 800 tonnes. For each pair of trajectories, the upper is based on a steepness of 0.75 and the lower an assumed value of 1.0. The model did not appear to be sensitive the indices of abundance used, and both the set net and recreational indices of abundance are included in these runs.

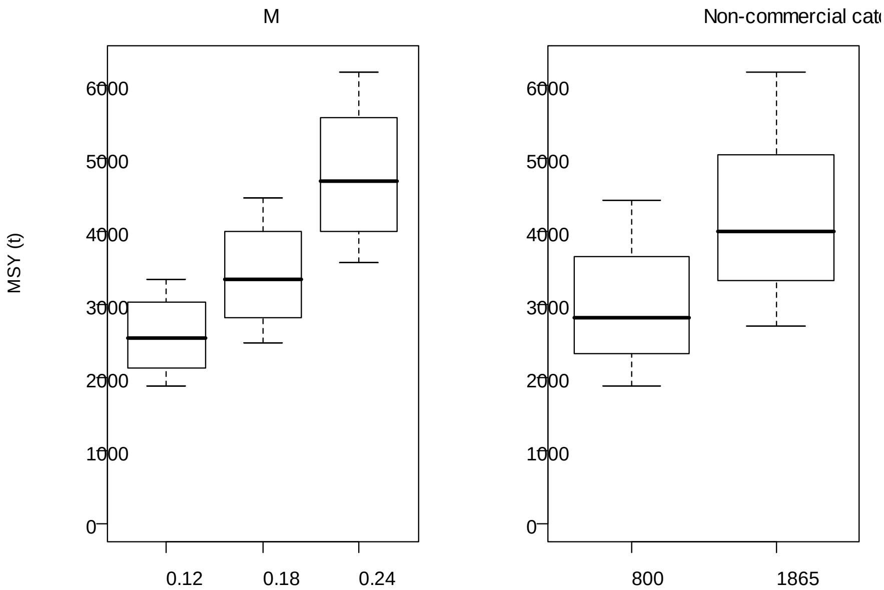


Figure 6: Boxplot showing the distribution of *MSY* estimates for the two key axes in the grid: natural mortality (left) and non-commercial catches (right). Each boxplot summarises 12 and 18 model runs for natural mortality and non-commercial catches respectively.

4.2 Assessment for other KAH areas

Historic estimates of total mortality (*Z*) derived from the age composition of commercial catch data collected in the early 1990s for areas outside KAH 1 are given in Table 13.

Table 13: Estimates of *Z* derived from commercial fisheries catch sampling data.

Fishstock	Estimate	Time sampled	Source
KAH 2	0.24	Nov 92	Drummond (1995)
KAH 3 (Marlborough Sounds)	0.22-0.35	Nov 90-Mar 91	Drummond & Wilson (1993)
KAH 3 (Cloudy/Clifford Bays)	0.19-0.27	Nov 90-Jun 91	Drummond & Wilson (1993)
KAH 3 (Kaikoura)	0.23-0.30	Nov 90-May 91	Drummond & Wilson (1993)
KAH 9	0.11	Feb 91- Mar 91	Jones *et al*. (1992)

The interpretation of catch curve analyses is difficult for schooling pelagic species for several reasons which include: (a) difficulties in obtaining a representative sample of sufficient size to describe the age distribution of the population because of the schooling behaviour of kahawai; (b) uncertainty in the value of *M*; and (c) lack of contrast in the data if exploitation rates are not changing.

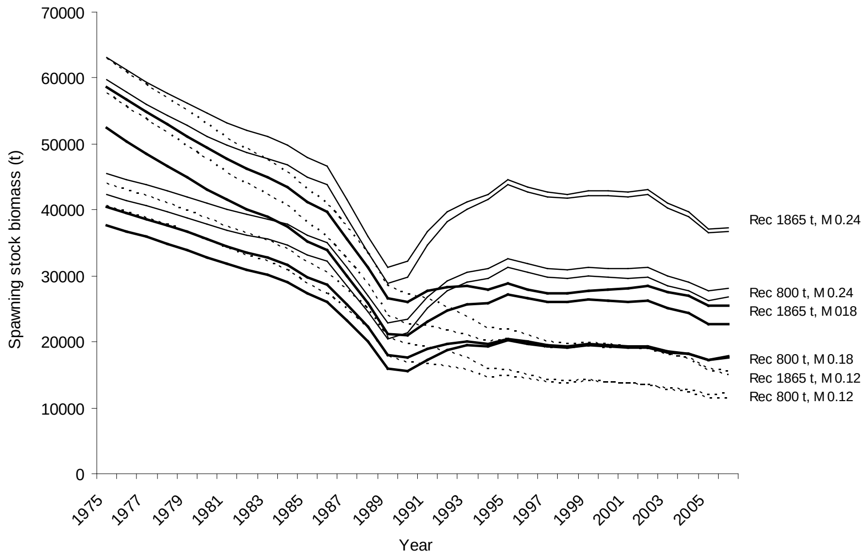
5. STATUS OF THE STOCKS

KAH 1

Stock Structure Assumptions

Two stocks of kahawai (*A. trutta*) are assumed to exist within New Zealand waters with centres of concentration around the Bay of Plenty and northern tip of the South Island. Tagging data show that there is limited mixing between these areas.

Stock Status	
Year of Most Recent Assessment	2007: Stock Assessment 2009: Catch curve analysis
Assessment Runs Presented	Thirty six models were run which encompassed plausible values for several poorly understood model inputs (e.g., recreational catch history, abundance indices, natural mortality and the spawner recruitment relationship).
Reference Points	Target: Not established but B_{MSY} assumed. Estimates of B_{MSY} as a proportion of B_0 varied across the 36 model runs (18.3-31% B_0). Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Based on the scenarios examined, it is Likely (> 60%) that the 2006 spawning biomass was at or above B_{MSY}, but it is uncertain how far above.
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below

Historical Stock Status Trajectory and Current Status

Biomass trajectories for differing assumed values for natural mortality (*M*), stock recruitment steepness (h) and assumed recreational catch history. For a given *M*, the upper pair of trajectories relate to a recreational catch of 1865 tonnes per annum, and the lower pair 800 tonnes. For each pair of trajectories, the upper is based on a steepness of 0.75 and the lower an assumed value of 1.0. The model did not appear to be sensitive to the indices of abundance used, and both the setnet and recreational indices of abundance are included in these runs.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	For *M* greater than 0.12 spawning biomass is estimated to have declined gradually from 1975 to 1990, to have increased somewhat from 1991 to 1995 and to have remained relatively stable until the end of the assessment period in 2007. For *M* = 0.12 spawning biomass declines continuously through the assessment period.
Recent Trend in Fishing Mortality or Proxy	A time series of total mortality estimates for East Northland and the Bay of Plenty from 2001 to 2008, based on recreational catch-at-age data, suggests that there has been little change in fishing mortality over this period. Estimates of total mortality were at or below that associated with $F_{SB40\%}$, suggesting that fishing mortality was at or below $F_{MSY.}$
Other Abundance Indices	There is no consistent pattern in catch rates when comparisons are made across and within regions.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Deterministic projections assuming *M* = 0.18 and including all abundance indices were undertaken in 2008 based on the 2007 assessment. These indicated that biomass was predicted to increase for all scenarios over the next five years.
Probability of Current Catch or TACC causing decline below Limits	Current assumed removals are lower than almost all estimates of deterministic *MSY*. Combining this with the result that most estimates of B_{06} are well above $B_{MSY,}$ it is Unlikely that the stock will decline below B_{MSY} at current assumed catch levels. Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

Assessment Methodology	
Assessment Type	Level 1 - Quantitative stock assessment Level 2 - Total mortality analysis
Assessment Method	Statistical catch at age model implemented under CASAL. For the

	mortality analysis regression methods and the Chapman-Robson estimator were used.	
Main data inputs	- Proportions-at-age data from recreational fishery and commercial purse-seine fishery data. - Estimates of biological parameters (e.g. growth, age-at-maturity and length/weight). - Standardized CPUE indices of abundance from recreational line and commercial set-net fishery - Estimates of *M* - Estimates of steepness for the stock-recruit relationship - Estimates of recreational harvest - Commercial catch	
Period of Assessment	Latest assessment: Level 1: 2007 Level 2: 2009	Next assessment: 2014
Changes to Model Structure and Assumptions	This was a new model.	
Major Sources of Uncertainty	Estimates of *M*, steepness, recreational harvest and degree of mixing between Bay of Plenty, Hauraki Gulf and East Northland.	

Qualifying Comments
The Northern Inshore Working Group reviewed estimates of KAH 1 recreational harvest in 2010 and concluded that, of the two estimates used in the stock assessment, the 800 t estimate was more plausible.

Fishery Interactions
Commercial catches of KAH1 are primarily taken by purse-seine in association with jack mackerel. blue mackerel and trevally.

All other KAH regions

No accepted assessment is available that covers these regions. It is not known if the current catches, allowances or TACCs are sustainable. The status of KAH 2, 3 and 8 relative to B_{MSY} is unknown.

Table 14: Summary of reported landings (t) and TACCs by QMA for the most recent fishing year.

Fishstock	FMA	2010-11 TACC	2010-11 Reported landings
KAH 1	1	1 075	1 002
KAH 2	2	705	719
KAH 3	3, 5, & 7	410	46
KAH 4	4	9	0
KAH 8	8 & 9	520	454
KAH 10	10	9	0
TOTAL		2 728	2 221

6. FOR FURTHER INFORMATION

Armiger H., Hartill B., Tasker R., Smith M. 2006. Length and age compositions of recreational landings of kahawai in KAH 1 in January to April 2003-04 and 2004-05. Final Research Report for Ministry of Fisheries Research Project KAH2003/01 Objectives 1 & 2. 33 p.

Armiger H., Hartill B., Rush N., Vaughan M., Smith M., Buckthought D. 2009. Length and age compositions of recreational landings of kahawai in KAH 1 in January to April 2008 and KAH 8 in January to April 2007. New Zealand Fisheries Assessment Report 2009/36. 40p

Bradford E. 1997. Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993-94. New Zealand Fisheries Assessment Research Document 1997/7. 16p.

Bradford E. 1998. Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27 p.

Bradford E., Fisher D., Bell J. 1998. National recreational fishing survey 1996: overview of catch and effort results. NIWA Technical Report 18. 55 p.

Boyd R.O., Reilly J.L. 2002. 1999/2000 National marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report 2002/xx.

Boyd R.O., Gowing L., Reilly J.L. 2004. 2000-2001 National marine recreational fishing survey: diary results and harvest estimates. Draft New Zealand Fisheries Assessment Report 2004/xx.

Bull B., Francis R.I.C.C. Dunn A., McKenzie A., Gilbert D.J., Smith M.H. 2004. CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manualv2.01.2003/08/01. NIWA Technical Report 124. 223 p.

Drummond K.L. 1995. Report on investigations into the Central New Zealand kahawai purse seine fishery over the 1992/93 summer. Central Fisheries Region Internal Report 25. 33 p.

Drummond K.L., Wilson A.L. 1993. The biology and purse-seine fishery of kahawai (*Arripis trutta* Bloch and Schneider) from central New Zealand, during 1990/91-1991/92. Central Fisheries Region Internal Report 22. 42 p.

Duffy C.A.J., Petherick C. 1999. A new size record for kahawai (*Arripis trutta*) from New Zealand. New Zealand Journal of Marine and Freshwater Research 33: p 565-569.

Hartill B., Armiger H., Tasker R., Middleton C., Fisher D. 2007a. Monitoring the length and age composition of recreational landings of kahawai in KAH 1 in 2000-01, 2001-02 and 2002-03. New Zealand Fisheries Assessment Report 2007/6. 38 p.

Hartill B., Bian R., Armiger H., Vaughan M., Rush N. 2007. Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004-05. New Zealand Fisheries Assessment Report 2007/26. 44p

Hartill B., Smith M., Rush N., Vaughan M., Armiger H. 2007b. Length and age composition of recreational landings of kahawai in KAH 1 from January to April 2005-06. New Zealand Fisheries Assessment Report 2007/28. 30p.

Hartill B., Walsh C. 2005. Characterisation of kahawai fisheries of New Zealand and a review of biological knowledge. Final Research Report for Ministry of Fisheries Research Project KAH200401. 160 p.

Hartill B., Watson T., Cryer M., Armiger H. 2007. Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf in 2003-04. New Zealand Fisheries Assessment Report 2007/25. 55.p

Jones J.B., Cresswell P., Drummond K., McKenzie J. 1992. Kahawai. New Zealand Fisheries Assessment Research Document 1992/2. 27 p.

Kimura D.K.1980. Likelihood methods for the von Bertalanffy growth curve. Fishery Bulletin 77: 765-776.

McKenzie J.R., Walker J., Hartill B. 2007. CPUE from kahawai (*Arripis trutta*) setnet and trawl fisheries in Fishstocks KAH 1, 2, 3, and 8 between 1989 and 2005. New Zealand Fisheries Assessment Report 2007/30 44 p.

Morton A., Lyle J., Welsford D. 2005. Biology and status of key recreational finfish species in Tasmania. Tasmanian Aquaculture and Fisheries Institute Technical Report Series 25. 52 p.

Paulin C. 1993. Review of Australasian fish family Arripididae (Percomorpha), with the description of a new species. Australian journal of marine and freshwater research 44: 459-471.

Reilly J.L. 2002. 1999/2000 National marine recreational fishing survey: weighting methodology for harvest estimates. Draft report by Statistical Insights Ltd. 25 p.

Smith P.J., Hartill B., Hamer P., McKenzie A. 2008. Stock structure of kahawai, *Arripis trutta*. New Zealand Fisheries Assessment Report 2008/20. 42p.

Stevens D.W., Kalish J. 1998. Validated age and growth of kahawai (*Arripis trutta*) in the Bay of Plenty and Tasman Bay. NIWA Technical Report 11. Wellington, National Institute of Water and Atmospheric Research. 33 p.

Sylvester C.T.A. 1989. Kahawai fishery assessment 1989. New Zealand Fisheries Assessment Research Document 1989/10. 17 p.

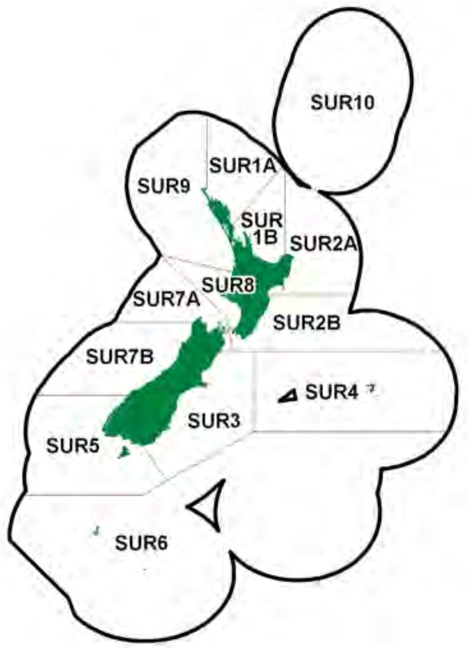
Taylor P.R. In press. Developing indices of relative abundance from observational aerial sightings of inshore pelagic finfish; step 1, exploring the data. Draft New Zealand Fisheries Assessment Report. 66 p.

Teirney L.D., Kilner A.R., Millar R.E., Bradford E., Bell J.D. 1997. Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p.

Watkinson J.G., Smith R. 1972. New Zealand Fisheries. New Zealand Government Print. 91 p.

KINA (SUR)

(*Evechinus chloroticus*)
Kina



1. FISHERY SUMMARY

South Island kina was introduced into the Quota Management System in October 2002. North Island kina was introduced into the Quota Management System from October 2003. Five Quota Management Areas based on the FMAs 3, 4, 5, 7A (Marlborough Sounds) and 7B (west coast) were created in the south island, and current allowances, TACCs, and TACs are summarised in Table 1. Seven Quota Management Areas based on the FMAs 1A (Auckland-North), 1B (Auckland-South), 2A (Central (East-North)), 2B (Central (East-South)), 8, 9 and 10 were created in the north island, and the current allowances, TACCs and TACs are summarised in Table 2. The historical landings and TACC values for the main SUR stocks are depicted in Figure 1.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs (t) for kina Fishstocks 3, 4, 5, and 7 for the latest fishing year.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality Allowance	TACC	TAC
SUR 3	10	10	1	21	42
SUR 4	7	20	3	225	255
SUR 5	10	10	5	455	480
SUR 7A	20	80	3	135	238
SUR 7B	5	10	1	10	26

Table 2: Recreational and customary non-commercial allowances, TACCs and TACs (t) for kina Fishstocks 1,2,8,9 and 10 for the latest fishing year.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality Allowance	TACC	TAC
SUR 1A	65	65	2	40	172
SUR 1B	90	90	4	140	324
SUR 2A	60	60	4	80	204
SUR 2B	35	35	2	30	102
SUR 8	12	12	1	1	26
SUR 9	11	11	1	10	33
SUR 10	0	0	0	0	0

1.1 Commercial fisheries

Most kina are found in waters less than 10 m deep and are harvested by breath-hold diving, although about 10% of the total catch in 1998-99 was by taken by dredge in SUR 7. Some target dredging also occurs in SUR 7. There is no minimum legal size for kina. Almost all of the roe harvested in this fishery is consumed on the domestic market. In 1988-89, competitive TACCs were established in the more important FMAs but not in east Northland (SUR 1) or at the Chatham Islands (SUR 4), both of which developed into productive fisheries in the 1990s (Table 3). On 1 October 1992 the Ministry of Fisheries placed a moratorium on the issue of permits to commercially harvest kina. The kina fishery has evolved considerably since the imposition of the moratorium. Where present, the competitive TACCs were either not caught or were exceeded, both by wide margins. Much of the increase in catch observed in SUR 5 in the early 1990s can be attributed to an experimental fishery developed in SUR 5, between Puysegur Point and Breaksea Island. The short-lived Kina Development Program harvested kina from Dusky Sound in 1993 under special permit.

Table 3: Total reported catch (t greenweight) of kina (SUR) by FMA and fishing year by all methods and target species.

Year	SUR 1	SUR 1A	SUR 1B	SUR 2	SUR 2A	SUR 2B	SUR 3	SUR 4	SUR 5	SUR 6, 8, & 9	SUR 7	SUR 7A	SUR 7B	Total
1983	66.2	-	-	33.0	-	-	4.8	11.3	0.5	3.6	26.3	-	-	157
1984	81.4	-	-	180.3	-	-	14.4	4.0	0.9	0.3	55.1	-	-	342
1985	64.5	-	-	83.8	-	-	4.0	7.4	4.6	0.9	99.6	-	-	275
1986	72.0	-	-	139.1	-	-	6.2	52.7	0.2	2	86.6	-	-	360
1987	52.1	-	-	142.6	-	-	2.4	28.4	4.3	0.1	52.6	-	-	283
1988	22.1	-	-	154.1	-	-	1.7	76.5	2.3	-	175.6	-	-	432
1989	35.5	-	-	92.8	-	-	0.8	216.6	19	1.5	6.2	-	-	372
1990	10.0	-	-	282.4	-	-	4.1	190.0	13.4	6.5	41.5	-	-	548
1991	71.5	-	-	87.2	-	-	21.3	35.3	166.9	4.4	56.3	-	-	443
1992	78.7	-	-	37.3	-	-	15.8	192.9	272.2	5	114.4	-	-	717
1993	89.7	-	-	170.4	-	-	9.9	21.8	*530.3	-	210.2	-	-	1 032
1994	150.7	-	-	176.7	-	-	8.8	55.3	327.2	2.3	98.2	-	-	820
1995	155.9	-	-	129.7	-	-	7.1	100.7	342.9	89.5	149	-	-	975
1996	174.5	-	-	41.2	-	-	6.0	99.5	446.4	0.1	142.2	-	-	910
1997	161.6	-	-	49.9	-	-	5.4	225.7	171.6	0.2	121.7	-	-	736
1998	134.8	-	-	36.5	-	-	3.8	303.1	91.2	1.4	144.7	-	-	716
1999	201.4	-	-	20.2	-	-	38.4	168.2	120.6	0.5	113.9	-	-	663
2000	297.4	-	-	14.5	-	-	50.4	396.5	106.3	0.1	87.9	-	-	956
2001	184.5	-	-	11.4	-	-	11.2	472.6	69.8	3.1	80.1	-	-	832
2001-02	237.0	-	-	3.0	-	-	5.2	368.0	184.9	-	31.7	-	-	829.7
2002-03	211.2	-	-	30.4	-	-	0.3	167.3	132.5	0.9	1.3	63.2	0	607.4
2003-04	1.7	26.9	111.0	0	14.5	4.6	0.3	114.8	199.1	3.8	0	85.4	0	562.3
2004-05	-	20.9	131.1	-	6.5	1.4	0.5	91.7	350.4	0.9	-	101.3	-	704.7
2005-06	-	41.0	138.6	-	22.1	0.2	< 0.1	70.2	473	4.0	-	72.1	5.3	826.5
2006-07	-	37.1	147.3	-	13.8	< 0.1	3.2	108.3	423	8.6	-	117.3	9.2	868
2007-08	-	31.7	140.4	-	18.0	0.2	2.1	147.4	276.2	5.8	-	134.6	6.5	762.9
2008-09	-	30.5	130.6	-	19.8	< 0.1	4.2	135.6	294.9	3.4	-	128.7	6.1	753.8
2009-10	-	40.8	129.9	-	0.1	0.3	5.1	89.7	320.4	2.3	-	119.7	3.5	711.9
2010-11	-	31.7	122.1	-	4.1	< 0.1	5.2	134.9	339.2	0	-	97.4	7.2	741.9

Data from 1989 and 1990 are combined from the FSU and CELR databases. – indicates no recorded catch. Data for the period 1983 to 1999 are from Andrew (2001), and have been groomed. Catch estimates for 2000 and 2001 are taken directly from MFish. * includes 133 t caught in Dusky Sound experimental fishery. Catches from SUR 6, 8, and 9 have been pooled because too few permit holders recorded catches in these FMAs to report them singly.

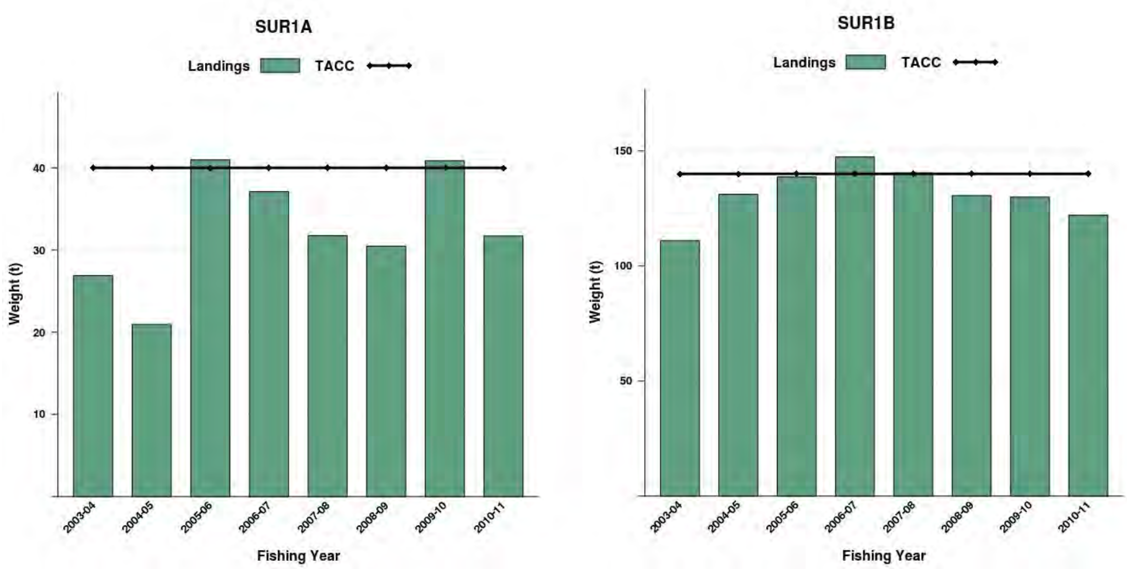


Figure 1: Historical landings and TACC for the nine main SUR stocks. From left to right: SUR1A (Northland) and SUR1B (Hauraki Gulf, Bay of Plenty. [Continued on next page].

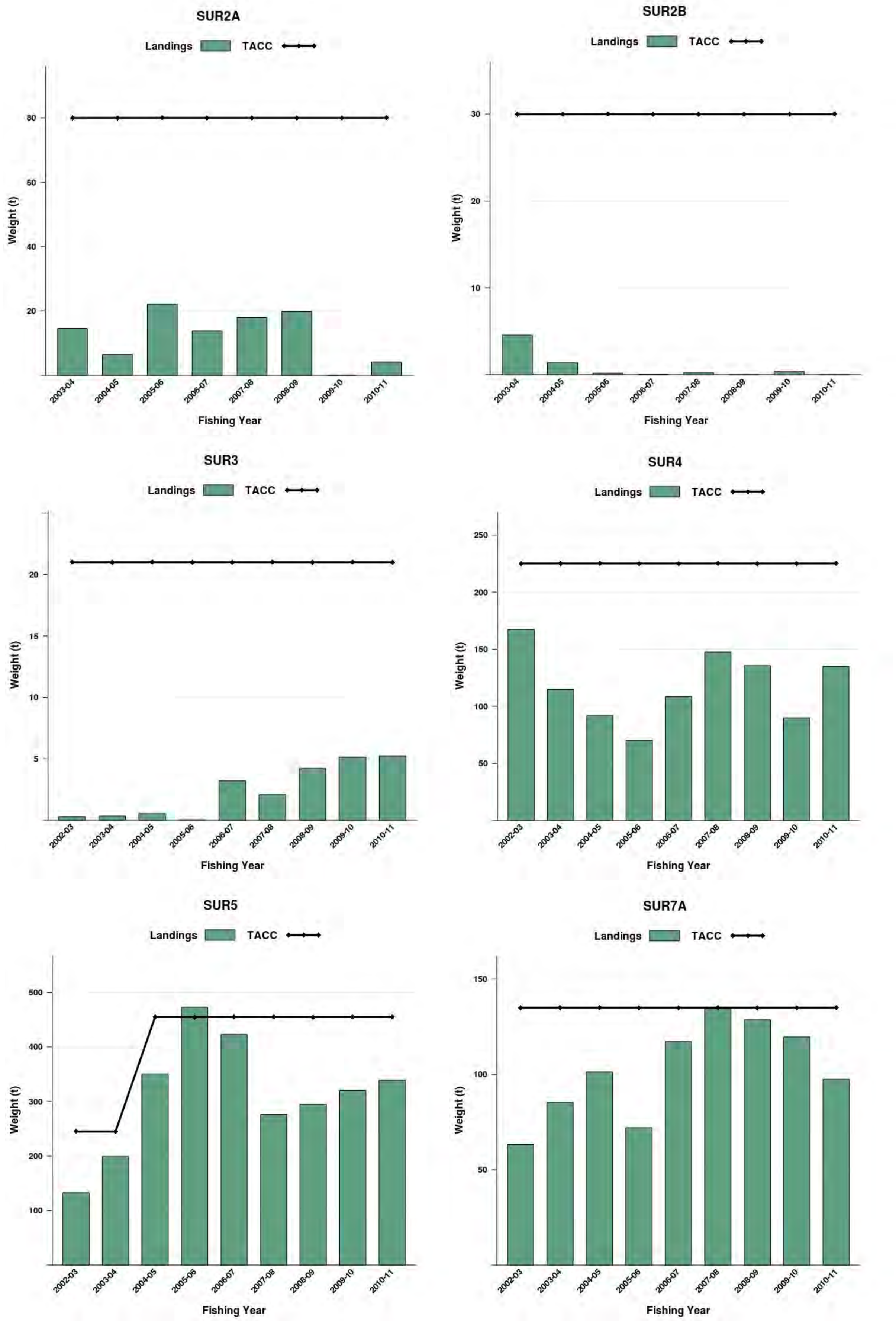


Figure 1: Historical landings and TACC for the nine main SUR stocks. From top left: SUR2A (East Coast), SUR2B (Wairarapa, Wellington), SUR3 (South East Coast), SUR4 (South East Chatham Rise), SUR5 (Southland), and SUR7A (Challenger Nelson Marlborough) [Continued on next page].

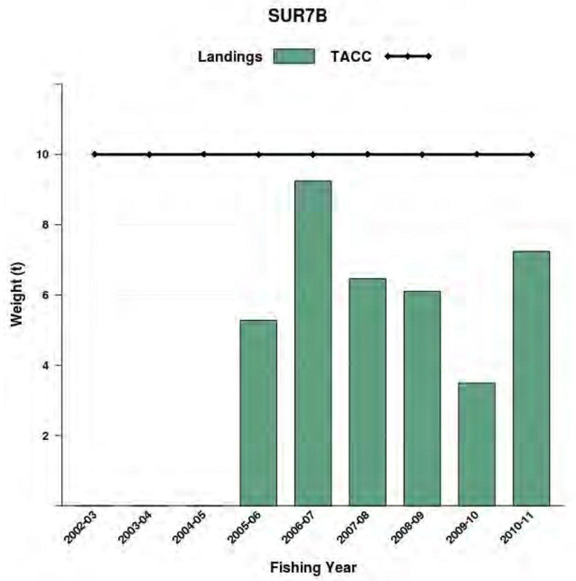


Figure 1 [Continued]: Historical landings and TACC for the nine main SUR stocks. Here: SUR7B (Challenger Westland). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

Recreational catch was estimated in a national survey in 1996 (Fisher & Bradford 1998, Bradford 1998) and 2000 (Boyd & Reilly 2004) (Table 4). There are no estimates of recreational catch from the Chatham Islands. In many instances, insufficient kina were caught to provide reliable estimates of the error associated with the estimates of total harvest. The recreational harvest estimates for 1996 are not considered reliable as estimates of total harvest but provide relative estimates between areas. The harvest estimates for 2000 are considered to be more reliable as absolute estimates with the exception of SUR 2.

1.3 Customary non-commercial fisheries

There is an important customary non-commercial harvest of kina by Maori for food. Where data are available, only small catches of kina have been reported under the customary non-commercial harvest provisions of the Fisheries Act 1996. In SUR 3, 5, and 7, all catches were less than 1 t per year (Table 5). These catch estimates are probably under-estimates as an unknown proportion of the kina harvested by Maori is caught outside of Taiapure or Mataitai and not recorded as customary non-commercial harvest (P. Grimshaw, Ngai Tahu Development Corporation, pers. comm.). No data are available for other regions of New Zealand (S. Kerins, Te Ohu Kai Moana, pers. comm.).

Table 4: Recreational harvest of kina for 1993-94 and 1996.

Area	Number of kina (x 1,000)	CV (%)	Catch (t)*
1993-94			
East Northland	109	60	27.1
Hauraki Gulf	14	-	3.5
Bay of Plenty	648	49	160.9
SUR 1	801	41	198.9
SUR 9	30	72	7.4
1996			
SUR 1	316	24	78.5
SUR 2	61	-	15.1
SUR 3	12	-	3.0
SUR 5	20	-	5.0
SUR 7	2	-	0.5
Area	Number of kina (x 1,000)	CV (%)	Catch (t)*
SUR 8	43	-	10.7
SUR 9	30	-	7.4
2000			
SUR 1	1 793	35	445.2
SUR 2	1 026	57	254.7
SUR 3	8	58	2.0
SUR 5	70	101	17.4
SUR 7	2	101	0.5
SUR 8	85	85	21.1
SUR 9	82	67	20.4

CVs are indicated only for those samples with adequate sample sizes. Data compiled from Bradford (1996, 1998) and Fisher & Bradford (1998).

Catches in numbers have been converted to catch in tonnes by assuming an average whole weight of 248.3 g per kina. In the absence of size-specific catch statistics, a parsimonious conversion assumes kina are caught in equal proportion across a size range of 60 to 110 mm TD. The lower size in this range is approximately the size-at-maturity (see Barker 2001) and the upper size is close to maximum harvested size. Weight-at-size was calculated using a test diameter-weight relationship ($W = (6.27x10^{-4})TD^{2.88}$) derived for kina of 60-110 mm TD from Dusky Sound (n = 1063, unpublished data). The estimates of total catch in tonnes should be considered as indicative only.

Table 5: Reported customary catch by FMA for SUR 3, 5, and 7.

Year	SUR	Count	Weight (kg)
1998-99	3	100	25
	5	1 522	433
	7	0	0
1999-2000	3	0	0
	5	1 631	405
	7	0	0

Data as numbers caught supplied by Ngai Tahu Development Corporation. Catch in kg was estimated using the same conversion rules as described in Table 2.

1.4 Illegal catch
Current levels of illegal harvest are not known.

1.5 Other sources of mortality
Although there is no minimum legal size for kina, some incidental mortality is likely because roe quality (recovery rate and colour) is commonly assessed by opening 'test' kina underwater. These animals are not subsequently landed. There are no estimates of the magnitude to this incidental mortality.

2. BIOLOGY

The biology and ecology of kina has been extensively studied; this literature has most recently been reviewed by Barker (2001). *Evechinus chloroticus* is found throughout New Zealand the sub-Antarctic Islands. Kina has an annual reproductive cycle which culminates in spawning between November and March (Dix 1970, Walker 1982, McShane *et al.* 1994 & 1996, Lamare & Stewart 1997, Lamare 1998). Size at maturity appears to vary considerably and may be as small as 30 mm and as large as 75 mm TD (Dix 1970, Barker *et al.* 1998). In Dusky Sound, kina are reproductively mature at 50-60 mm T.D. (McShane *et al.* 1996). Within these seemingly consistent patterns in the seasonality of the reproductive cycle there are many differences in the gonad size at small spatial scales.

Settlement is likely to be sporadic among years and appears to differ among locations and habitats (Dix 1972, Walker 1995). Laboratory work has shown that kina larval mortality increased with increasing concentrations of suspended sediment at realistic concentrations (Phillips & Shima 2006). In the field, but not in the laboratory, development abnormalities were found associated with suspended sediment concentrations, this suggests the importance of other environmental factors associated with terrestrial runoff (Schwarz *et al.* 2006). Juvenile settlement and mortality has also been increased by sediment at realistic concentrations in a size-specific manner in the laboratory; this agrees with juvenile patterns of distribution observed in the field (Walker 2007). Few small kina were observed in any of the surveys in Dusky Sound (McShane *et al.* 1993). These results suggest that the productivity of stocks in Fiordland may be low and that recruitment over-fishing is a real possibility.

There is relatively little information available on the interactions between kina and its predators and competitors. Although a wide range of fish and invertebrates eat kina, there is limited evidence that these species control or limit populations of kina in Fiordland. Work in a marine reserve, where large predators such as reef fishes and crayfish are abundant, indicates that predators can control numbers of kina surviving the transition from crevice-bound to open substratum grazing (Cole & Keuskamp 1998, Babcock *et al.* 1999). Babcock *et al.* (1999) have drawn a direct link between the increases in snapper and crayfish populations and the long-term decline in kina populations in the Leigh Marine Reserve. There is however, no evidence that high kina densities limit rock lobster populations (Andrew & MacDiarmid 1991). It is likely, however, that changes in the abundance of kina, and the consequent changes in habitat representation, are part of a complex set of interacting processes, including but not exclusively, increased predation.

Kina compete with a range of invertebrate herbivores, including paua. There is no published evidence that high densities of kina limit paua populations in Fiordland. McShane (1997) reported that paua are abundant in Dusky Sound, and in Chalky and Preservation Inlets, but are rare in the fjords.

Lamare & Mladenov (2000) estimate that kina grow 8-10 mm in their first year of life. Growth rates will vary considerably depending on local conditions but kina may take 8-9 years to reach 100 mm TD, and very large individuals may reach ages of 20+ years (McShane & Anderson 1997, Lamare & Mladenov 2000).

3. STOCKS AND AREAS

There appear to be few genetic differences in kina populations from Leigh (North Auckland) and Stewart Island (Mladenov *et al.* 1997) which suggests that there is at least some mixing among populations. There is no direct evidence that populations of kina at the Chatham Islands differ genetically from those on the mainland, nor is there evidence that “populations” of kina at the Chatham Islands are dependent on the dispersal of larvae from the mainland.

4. STOCK ASSESSMENT

Although there is a wealth of information on the biology and ecology of this species (*see* Barker 2001 for reviews), there is relatively little that can be used to assess the status of exploited stocks. There have been no assessments of sustainable yield nor are there estimates of biomass or trends in relative abundance for any Fishstock (Annala 1995).

4.1 Estimates of fishery parameters and abundance

Andrew (2001) reported catch rates from both dive and dredge fisheries but cautioned the interpretation of catch rate information of sedentary invertebrates, like kina, gathered at broad spatial scales.

Indices of relative abundance using timed swims have been reported for Ariel Reef in SUR 2 (Anderson & Stewart 1993), Chatham Islands (Schiel *et al.* 1995, Naylor & Andrew 2002), and D’Urville Island and Arapawa Island in SUR 7 (McShane *et al.* 1994). Numerous surveys of kina have been done over the last 30 years in fished areas, mostly by university-based researchers (e.g. Dix 1970, Choat & Schiel 1982, Schiel *et al.* 1995, Cole & Keuskamp 1998, Babcock *et al.* 1999, Wing *et al*. 2001). Andrew & Naylor (2002) reported a range of densities for kina around Chatham Island at 0.17/m^2 (northwest Chatham Island) to 1.6/m^2 (south east Chatham Island). These were generally lower than estimates made in the mid 1990s by Schiel *et al.* (1995) (0.2/m^2 to 6/m^2). By contrast, lower kina densities of around 0.1/m^2 were reported by McShane *et al.* (1994) for both Arapawa and D'Urville Island. Dix (1970) reported much higher mean relatively high densities of kina ranging from 2.2/m^2 in Queen Charlotte Sound to 6/m^2 at Kaikoura.

4.2 Biomass estimates

McShane & Naylor (1993) reported biomass estimates of 2500 and 500 t respectively for D’Urville and Arapawa Islands (SUR 7), presumably based on an expansion of density estimates reported in McShane *et al.* (1994) by an area estimate, however, the methods are not detailed.

Biomass has been estimated for Dusky Sound and Chalky Inlet (SUR 5) prior to Dusky Sound being opened as an experimental fishery in May 1993 (McShane & Naylor 1991, 1993). Productivity and biomass was to be estimated by depletion methods but this was unsuccessful because only 133 t of the projected 1000 t was caught (McShane *et al.* 1994b) and this catch was insufficient to cause a measurable change in the estimated biomass of kina.

4.3 Estimation of Maximum Constant Yield (*MCY*)

MCY has not been estimated for any SUR fishstock. Within SUR 5, an *MCY* estimate of sustainable yield within Dusky Sound and Chalky Inlet was reported in Annala (1995). This estimate used Method one of Annala (1995) for new fisheries based on surveys done by McShane & Naylor (1991, 1993) and an estimate of a reference fishing mortality derived from McShane *et al.* (1994a). The estimated annual sustainable yield of 275 t for these two areas has never been harvested because they are closed to commercial fishing except under special permit.

4.4 Estimation of Current Annual Yield (*CAY*)

CAY has not been estimated for any SUR fishstock.

5. STATUS OF THE STOCKS

For all Fishstocks it is not known if current catch levels or TACCs are sustainable, or if they are at levels which will allow the stocks to move towards a size that will support sustainable yields.

Table 6: Summary of TACCs (t), and reported landings (t) of kina for the most recent fishing year.

Fishstock	QMA	2010-11 Actual TACC (t)	2010-11 Reported landings (t)
SUR 1A	Auckland (East - North)	40	31.7
SUR 1B	Auckland (East - South)	140	122.1
SUR 2A	Central (East - North)	80	4
SUR 2B	Central (East - South)	30	< 0.1
SUR 3	South-East (Coast)	21	5.2
SUR 4	South-East (Chatham),	225	134.9
SUR 5	Southland	455	339.2
SUR 6	Sub-Antarctic	-	0
SUR 8	Central (Egmont)	1	0
SUR 9	Auckland (West)	10	2.5
SUR 7A	Challenger (North)	135	97.4
SUR 7B	Challenger (South)	10	7.2
Total		1 147	744.4

6. FOR FURTHER INFORMATION

Anderson O., Stewart R. 1993. Gisborne kina survey. (Unpublished report held in the NIWA library, Wellington.) 2p.

Andrew N.L. 1986. The interaction between diet and density in influencing reproductive output in the echinoid *Evechinus chloroticus* (Val.). Journal of Experimental Marine Biology and Ecology 97: 63-79.

Andrew N.L. 2001. Sea urchin fisheries: their status and management with special reference to the New Zealand kina fishery. In*:* Unpublished report to the Ministry of Fisheries and Te Ohu Kai Moana. 124p.

Andrew N.L., Choat J.H. 1985. Habitat related differences in the survivorship and growth of juvenile sea urchins. Marine Ecology Progress Series 27: 155-161.

Andrew N.L., MacDiarmid A.B. 1991. Interrelations among sea urchins (*Evechinus chloroticus*) and spiny lobsters (*Jasus edwardsii*) in northern New Zealand. Marine Ecology Progress Series 70: 211-222.

Annala J.H. 1995. Report from the Fishery Assessment Plenary, May 1995. Stock assessments and yield estimates. 277p.

Babcock R.C., Kelly S., Shears N.T., Walker J.W., Willis T.J. 1999. Changes in community structure in temperate marine reserves. Marine Ecology Progress Series 189: 125-134.

Barker M.F. 2001. The ecology of Evechinus chloroticus. In: Lawrence, J. (ed.). Edible Sea Urchins: Biology and Ecology. Elsevier Science, Amsterdam. 245–260p.

Barker M.F., Keogh J.A., Lawrence J.M., Lawrence A.L. 1998. Feeding rate, absorption efficiencies, growth, and enhancement of gonad production in the New Zealand sea urchin *Evechinus chloroticus* Valenciennes (Echinoidea: Echinometridae) fed prepared and natural diets. Journal of Shellfish Research 17: 1583-1590.

Boyd R.O., Gowing L., Reilly J.L. 2004. 2000-2001 national marine recreational fishing survey: diary results and harvest estimates. Final Research Report for Ministry of Fisheries Project REC2000/03 (Unpublished report held by Ministry of Fisheries, Wellington).

Bradford E. 1998. Harvest estimated from the 1996 national marine recreational surveys. New Zealand Fisheries Assessment Research Document 1998/16: 27p.

Brewin P.E., Lamare M.D., Keogh J.A., Mladenov P.V. 2000. Reproductive variability over a four-year period in the sea urchin *Evechinus chloroticus* (Echinoidea: Echinodermata) from differing habitats in New Zealand. Marine Biology 137: 543-557.

Choat J.H., Schiel D.R. 1982. Patterns of distribution and abundance of large brown algae and invertebrate herbivores in subtidal regions of northern New Zealand. Journal of Experimental Marine Biology and Ecology 60: 129-162.

Cole R.G., Keuskamp D. 1998. Indirect effects of protection from exploitation: patterns from populations of *Evechinus chloroticus* (Echinoidea) in northeastern New Zealand. Marine Ecology Progress Series 173: 215-226.

Dix T.G. 1970. Biology of *Evechinus chloroticus* (Echinodermata: Echinometridae) from different localities. 3. Reproduction. *New Zealand* Journal of Marine and Freshwater Research 4: 385-405.

Fisher D., Bradford E. 1998. National marine recreational fishing survey 1996: catch and effort results by fishing zone. Unpublished Final Research Report for Ministry of Fisheries Research Project REC9701. 38p.

Lamare M.D., Mladenov P.V. 2000. Modelling somatic growth in the sea urchin *Evechinus chloroticus* (Echinoidea: Echinometridae). Journal of Experimental Marine Biology and Ecology 243: 17-43.

MacDiarmid A.B., Breen P.A. 1993. Spiny lobster population changes in a marine reserve. In Battershill, C.N., Schiel, D.R., Jones, G.P., Creese, R.G., & MacDiarmid, A.B. (eds.). Proceedings of the Second International Temperate Reef Symposium. 47-56p. NIWA Marine, Wellington.

McShane P.E. 1992. Sea urchins in Dusky Sound-Prospects for a major kina industry in New Zealand. New Zealand Professional Fisherman December 92: 34-40.

McShane P.E. 1997. A summary of commercial catch data and biological information for kina (Evechinus chloroticus). New Zealand Fisheries Assessment Research Document. 1997/16: 7p.

McShane P.E., Naylor J.R. 1991. A survey of kina populations (*Evechinus chloroticus*) in Dusky Sound and Chalky Inlet, southwest New Zealand. Unpublished report held in the NIWA library, Wellington. 34p.

McShane P.E., Naylor J.R. 1993. SUR 7 - Prospects for development of a kina fishery. Seafood New Zealand 1: 33-34.

McShane P.E., Anderson O.F., Gerring P.K., Stewart R.A., Naylor J.R. 1994a. Fisheries biology of kina (*Evechinus chloroticus*). New Zealand Fisheries Assessment Research Document. 1994/17: 34p.

McShane P.E., Stewart R., Anderson O., Gerring P.K. 1994b. Failure of kina fishery leaves bitter taste. Seafood New Zealand 2: 35-36.

Mead S. 1996. Fertilization success, sustainable management and commercial development of the New Zealand sea urchin, *Evechinus chloroticus*. *Unpublished M.Sc. Thesis,* University of Auckland.

Mladenov P.V., Allibone R.M., Wallis G.P. 1997. Genetic differentiation in the New Zealand sea urchin *Evechinus chloroticus* (Echinodermata: Echinoidea). New Zealand Journal of Marine and Freshwater Research 31: 261-269.

Naylor J.R., Andrew N.L. 2002. Biomass of kina (Evechinus chloroticus) in the Chatham Islands. New Zealand Fisheries Assessment Report xxxx/xx: 9p.

Phillips N.E. Shima J 2006. Differential effects of suspended sediments on larval survival and settlement of New Zealand urchins *Evechinus chloroticus* and abalone *Haliotis iris*. Marine Ecology Progress Series 314: 149-158.

Schiel D.R. 1990. Macroalgal assemblages in New Zealand: structure, interactions and demography. Hydrobiologia 192: 59-76.

Schiel D.R., Andrew N.L., Foster M.S. 1995. The structure of subtidal algal and invertebrate assemblages at the Chatham Islands, New Zealand. Marine Biology 123: 355-367.

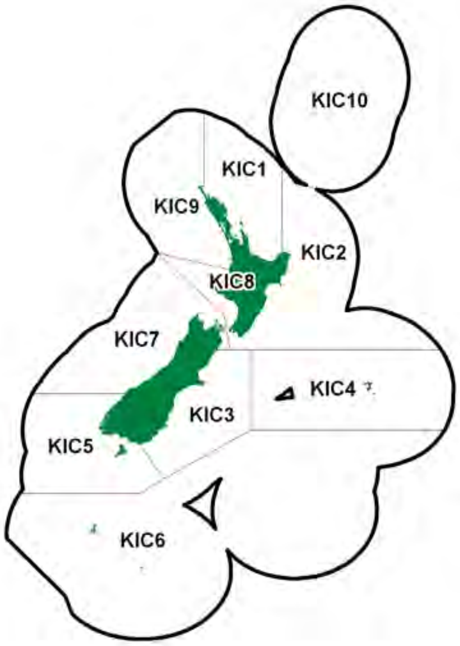
Schwarz A., Cole R., Budd R., Taylor R., Hewitt J., Hunt L., Shima J., Phillips N. 2006. Impacts of terrestrial runoff on the biodiversity of rocky reefs, Aquatic Environment Biodiversity Report 7 109p.

Walker J. 2007.Effects of fine sediments on settlement and survival of the sea urchin *Evechinus chloroticus* in northeastern New Zealand. Marine Ecology Progress Series 331: 109-118.

Wing S.R., Lamare M.D., Vasques J. 2001. Population structure of sea urchins (*Evechinus chloroticus*) along gradients in benthic productivity in the New Zealand fjords. In: Barker, M.F. (ed.). Proceedings of the 10th International Echinoderm Conference. University of Otago, Dunedin. A.A. Balkema, Rotterdam. 569–576p.

KING CRAB (KIC)

(*Lithodes murrayi*, *Neolithodes brodiei*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

King crabs (*Lithodes murrayi* and *Neolithodes brodiei*) were introduced into the Quota Management System on 1 April 2004 with a combined TAC of 9 t and TACC 9 t (Table 1). There are no allowances for customary, recreational or other sources of mortality. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. The two crabs are relatively distinct, and are found at different depths, but may be confused with other species of *Lithodes*.

Landings have been reported from all QMAs except KIC 7 and KIC 9, however these landings are small and are unlikely to reflect the real catch as these crabs are generally discarded at sea and remain unreported. Most of the landed catch has been reported under the aggregated code KIC, although there are a few records by species (i.e., *L. murrayi* [LMU] and *N. brodiei* [NEB]).

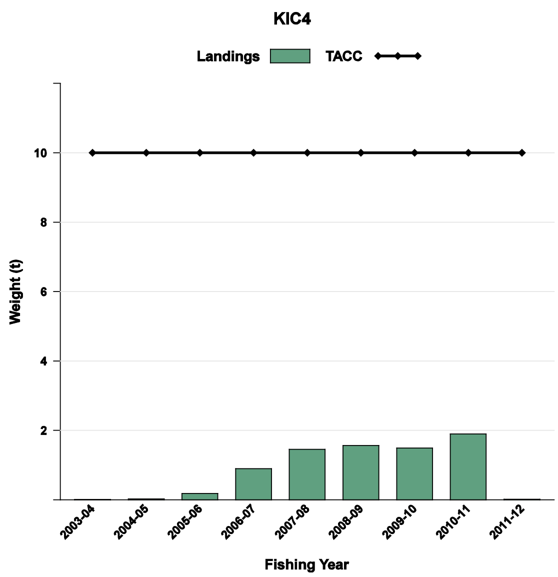


Figure 1: Historical landings and TACC for KIC4 (South East Chatham Rise). Note that this figure does not show data prior to entry into the QMS.

Most of the reported landings since 1992-93 are from KIC 6, and most of this was landed in the 1996-97 fishing year under a special permit. Between 2000 and 2002 landings were also made under a special permit (Table 1). Target fishing is by potting, although the crabs are taken as bycatch in the orange roughy fishery off the Wairarapa coast and in Queen Scallop dredging off the Otago coast. Figure 1 shows the historical landings and TACC for KIC4.

1.2 Recreational fisheries
There are no records of recreational use of these crabs, and because of their depth range recreational catch is unlikely.

1.3 Customary non-commercial fisheries
There are no known records of customary use of these crabs, and because of their depth range customary take is unlikely.

1.4 Illegal catch
There is no known illegal catch of these crabs.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although the crabs are sometimes taken as a bycatch in orange roughy fishing and queen scallop fishing.

Table 1: TACCs and reported landings (t) of king crab by Fishstock from 1992-93 to 2011-12 from CELR and CLR data.

	KIC 1		KIC 2		KIC 3		KIC 4		KIC 5	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1993-94	0	-	0.119	-	0.064	-	0	-	0	-
1994-95	0	-	0	-	0	-	0	-	0	-
1995-96	0	-	0	-	0.055	-	0	-	0	-
1996-97	0	-	0.08	-	0	-	0	-	0	-
1997-98	0	-	0	-	0	-	0	-	0	-
1998-99	0	-	0	-	0	-	0	-	0	-
1999-00	0	-	0	-	0.021	-	0	-	0	-
2000-01	0	-	0	-	0	-	0	-	0	-
2001-02	0.135	-	0.26	-	0	-	0	-	0	-
2002-03	0.01	-	0.005	-	0	-	0	-	0.032	-
2003-04	0	10	0	10	0.009	10	0.012	10	0	10
2004-05	0	10	0.073	10	0.133	10	0.025	10	0.013	10
2005-06	0	10	0.211	10	0.118	10	0.181	10	0.028	10
2006-07	0	10	0.041	10	0.24	10	0.896	10	0.126	10
2007-08	0.078	10	0.408	10	0.206	10	1.455	10	0.068	10
2008-09	0.010	10	0.185	10	0.244	10	1.566	10	0.073	10
2009-10	0	10	.197	10	0.352	10	1.493	10	0.030	10
2010-11	0.018	10	0.183	10	0.253	10	1.898	10	0.143	10
2011-12	0	10	2.476	10	0.066	10	0.016	10	0.037	10

2. BIOLOGY

King crabs belong to the infra order *Anomura*, and differ from true crabs (*Brachyura*) in that the last pair of walking legs is reduced and folded inside the carapace.

*L. murray*i is a large, pear-shaped, dark purplish-red or brick red crab that has been found at depths between 120 m and 700 m. from the east coast of Northland to southern parts of the Campbell Plateau. It is a circumpolar, Southern Ocean species growing so large that the distance between the tips of the second legs can reach 1.25 m. The carapace width in males of this species may exceed 200 mm. Females are smaller.

N. brodiei is also pear-shaped, and typically a uniform brick to bright red colour. It is widely distributed from the Three Kings Islands to the Campbell Plateau, where it occurs on soft and rocky bottoms between about 800 and 1100 m. Carapace width in this species is up to about 180 mm.

Table 1 continued:

	KIC 6		KIC 7		KIC 8		KIC 9		KIC ET	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1993-94	0	-	0	-	0	-	0	-	0	-
1994-95	0	-	0	-	0	-	0	-	0	-
1995-96	0	-	0	-	0	-	0	-	0	-
1996-97	4	-	0	-	0	-	0	-	0	-
1997-98	0	-	0	-	0	-	0	-	0	-
1998-99	0.026	-	0	-	0	-	0	-	0	-
1999-00	0.035	-	0	-	0.072	-	0	-	0	-
2000-01	0.055	-	0	-	0	-	0	-	0	-
2001-02	0.029	-	0	-	0	-	0	-	0	-
2002-03	0.045	-	0	-	0	-	0	-	0	-
2003-04	0.456	10	0	10	0	10	0	10	0	-
2004-05	0.698	10	0	10	0	10	0	10	0	-
2005-06	0.505	10	0	10	0	10	0	10	0.02	-
2006-07	0.308	10	0	10	0	10	0	10	0.004	-
2007-08	0.492	10	0.080	10	0	10	0.019	10	0	-
2008-09	0.424	10	0.063	10	0	10	0	10	0	-
2009-10	0.337	10	0	10	0	10	0.057	10	0	-
2010-11	1.037	10	0	10	0.204	10	0	10	0	-
2011-12	0.343	10	0	10	0	10	0.026	10	0	-

	TOTAL*	
Fishstock	Landings	TACC
1993-94	0.119	-
1994-95	0	-
1995-96	0.102	-
1996-97	4.104	-
1997-98	0	-
1998-99	0.011	-
1999-00	0.119	-
2000-01	0.035	-
2001-02	0.45	-
2002-03	0.063	-
2003-04	0.482	90
2004-05	0.942	90
2005-06	1.063	90
2006-07	1.615	90
2007-08	2.806	90
2008-09	0.487	90
2009-10	2.466	90
2010-11	3.736	90
2011-12	2.964	90

*In 1995-96 and 1998-99, 47 kg and 1 kg of LMU were landed respectively, but no FMA was assigned to the landings. In 1996-97 24 kg of NEB was landed but no FMA was assigned to this landing. These reported landings by species are included in the total landings for KIC in those years.

King crabs are thought to aggregate for protection during breeding and moulting. Migrations between shallow and deep waters also probably occur in response to moulting and mating, at least in near-shore populations. They occur mainly on soft substrates but have also been found on rocky bottoms. They are probably omnivorous, although animal food (sessile, sedentary, and mobile invertebrates, and small fish), including dead material, is their predominant food. Their principal predators are fish and seals.

Sexes are separate in all species of king crabs and they appear to be seasonal spawners, probably spawning in summer or autumn.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on QMAs, however, there is currently no biological or fishery information which could be used to identify stock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any king crab fishstock.

4.2 Biomass estimates

There are no biomass estimates for any king crab fishstock.

4.3 Estimation of Maximum Constant Yield (*MCY*)

There are no estimates of *MCY* for any king crab fishstock.

4.4 Estimation of Current Annual Yield (*CAY*)

There are no estimates of *CAY* for any king crab fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any king crab fishstock.

6. FOR FURTHER INFORMATION

Arnaud P.M., Do-Chi T. 1977. Donnees biologiques et biometriques sur les lithodes *Lithodes murrayi* (Crustacea: Decapoda: Anomura) des Iles Crozet (SW Ocean Indien). Marine Biology 39: 147-159.

Clark M.R., King K.J. 1989. Deepwater fish resources off the North Island, New Zealand: results of a trawl survey, May 1985 to June 1986. New Zealand Fisheries Technical Report No. 11.

Dawson E.W. 1989. King crabs of the world (Crustacea: Lithodidae) and their fisheries. A comprehensive bibliography. New Zealand Oceanographic Institute Miscellaneous Publication 101.

FAO 1985. Southern Ocean CCAMLR Convention area, fishing areas 48, 58 and 88. p. 89-92. FAO species identification sheets for fishery purposes. Vol. 1.

McClay C.L. 1988. Brachyura and crab-like Anomura of New Zealand. Leigh Laboratory Bulletin No. 22.

Macpherson E. (2001). New species and new records of lithodid crabs (Crustacea, Decapoda) from the southwestern and central Pacific Ocean. Zoosystema. Paris 23: 797-805.

Melville-Smith R. 1982. A brief exploitation of the stone crab *Lithodes murrayi* (Henderson) off South West Africa, 1979/80. Fisheries Bulletin of South Africa 16: 45-55.

Naylor J.R., Webber W.R., Booth J.D. 2005. A guide to common offshore crabs in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 2. 47 p.

Miquel J.C., Arnaud P.M. 1987. Aspects de la biologie de *Lithodes murrayi* (Crustacea : Decapoda) aux Iles Crozet, Ocean Indien Subantarctique. CNFRA 57: 81-89.

Miquel J.C., Arnaud P.M., Do-Chi T. 1985. Population structure and migration of the stone crab *Lithodes murrayi* in the Crozet Islands, Subantarctic Indian Ocean. Marine Biology 89: 263-269.

O'Driscoll R.L., Booth J.D., Bagley N.W., Anderson O.F., Griggs L.H., Stevenson M.L., Francis M.P. 2001. Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. Final Research Report for Ministry of Fisheries Research Project ENV2000/04. Objectives 1, 2, & 3.

Webb B.F. 1972. Report on the investigations of the 'Lloret Lopez II' - 8 January to 2 April 1970. Section 3 Crab survey - 18 February to 27 February 1970. Fisheries Technical Report No. 97.

Webber R. 1997. The royal family: king crabs at home and abroad. Seafood New Zealand May: 81-84.

KINGFISH (KIN)

(*Seriola lalandi*)
Haku

1. FISHERY SUMMARY

Kingfish were introduced into the QMS on 1 October 2003, with allowances, TACCs and TACs in Table 1.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs by Fishstock.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of fishing related mortality	TACC	TAC
KIN 1	459	76	47	91	673
KIN 2	65	18	24	63	170
KIN 3	1	1	0	1	3
KIN 4	1	1	0	1	3
KIN 7	10	2	2	7	21
KIN 8	31	9	7	36	83
KIN 10	1	0	0	1	2

An increased minimum legal size (MLS) to 75 cm (from 65 cm) for recreationally caught kingfish was introduced on 15 January 2004. Kingfish were added to the 6th Schedule in October 2005 for all fishing methods except setnet and in all areas. A special reporting code for 6th Schedule releases has also been introduced on 1 October 2006 to allow monitoring of releases. Kingfish released in accordance with 6th Schedule conditions and reported against this code is not counted against ACE.

1.1 Commercial fisheries

Kingfish commercial landings are reported largely as non-target catch of inshore setnet, trawl and longline fisheries. From 1991 to late 2003, targeting of kingfish (as a non-QMS species) was prohibited unless the species was identified on a fishers permit. A few permit holders were authorized to target kingfish and most of their catch was taken using setnets.

Commercially, kingfish is a moderately high value species and is usually sold as fillets or whole chilled. In recent years about one quarter of the commercial catch has been exported, the main markets being the United States and Australia.

The main fishing areas for kingfish are the east (KIN 1 and KIN 2) and west coast (KIN 8) of the North Island of New Zealand (Table 2). The largest commercial catches generally come from KIN 1. Landings were relatively large in 1983-84, especially in KIN 1, and were probably due to the greater number of vessels in the fishery prior to the introduction of the QMS in 1986. In addition, there was increased effort and better reporting as fishers sought to establish a catch history for the main species in anticipation of the introduction of the QMS. By 1988-89, catches of kingfish had reduced to their lowest levels across most areas. This was most likely due to the under-reporting of less common species in the catch (which includes kingfish) and the introduction of non-QMS restrictions. An increase in kingfish landings in FMA 1 between 1988-89 and 1992-93 and in FMA 2 between 1988-89 and 1991-92 may be due to a number of factors. These include: better reporting of catches; changes in fishing patterns with increased catch by setnet; increased numbers of vessels reporting kingfish catch; and, increased targeting of kingfish.

The total reported catch across all FMAs peaked in 1992-93 at 532 t, with 73% of the catch from KIN 1. By 1993-94, the reported catch of kingfish over all QMAs decreased considerably, mainly because of the reduced catch from KIN 1. Possible reasons for this decrease include: the effect of the October 1993 introduction of a MLS of 65 cm on all methods other than trawl; changes in fishing patterns in the snapper and trevally target setnet, trawl, and bottom longline fisheries (that were responsible for most of the non-target catch of kingfish); decreased target fishing for kingfish; and, setnet area closures in FMA 1 from October 1993. The trawl exemption with respect to MLS was removed in December 2000.

Table 2: Reported landings (t) of kingfish by area (QMA) from 1983-84 to 2010-11. From 1986-87 to 2000-01, total landings are from LFRRs and landings by QMA are from CLRs prorated to the LFRR total. Totals include landings not attributed to the listed QMAs. MHR data from 2001-present.

Year	KIN 1	KIN 2	KIN 3	KIN 4	KIN 7	KIN 8	KIN 10	Total
1983-84*	326	58	11	0	3	50	0	448
1984-85*	239	52	8	0	< 1	46	0	345
1985-86*	262	43	4	0	1	70	0	380
1986-87	192	52	9	0	1	49	0	356
1987-88	202	56	9	0	1	49	0	373
1988-89	92	17	4	0	< 1	16	0	460
1989-90	221	62	2	0	3	§26	< 1	428
1990-91	295	85	6	< 1	2	§37	< 1	448
1991-92	362	93	4	< 1	2	§32	9	512
1992-93	378	81	4	0	1	§56	< 1	532
1993-94	184	67	2	< 1	4	29	< 1	288
1994-95	196	73	2	0	6	25	< 1	302
1995-96	214	120	2	< 1	7	45	< 1	380
1996-97	240	114	7	< 1	11	48	6	427
1997-98	155	106	2	< 1	7	42	1	326
1998-99	159	94	3	< 1	16	49	< 1	323
1999-00	111	93	4	< 1	10	51	0	270
2000-01	138	83	4	< 1	11	69	< 1	304
2001-02	95	60	2	< 1	22	52	0	231
2002-03	73	55	1	0	20	143	0	292
2003-04	49	50	1	< 1	3	57	0	160
2004-05	58	63	1	0	19	53	0	194
2005-06	48	73	< 1	0	7	40	< 1	169
2006-07	60	50	1	0	13	39	0	163
2007-08	66	40	< 1	< 1	5	45	0	159
2008-09	61	50	< 1	< 1	5	38	0	155
2009-10	66	56	< 1	< 1	7	43	0	172
2010-11	71	55	< 1	< 1	6	37	0	171

* FSU data (Area unknown data prorated in proportion to recorded catch).
§ Some data included in FMA 1.

The annual catch of kingfish from KIN 1 has fluctuated between 100 and 250 t from 1993-94 through 2000-01 and declined to less than 50 t in 2003-04. The kingfish catch from KIN 2 over the last seven years has steadily decreased from the 1995-96 120 t high to 50 t in 2003-04, but have increased to 73 t in 2005-06 (exceeding the TACC). Landings from KIN 8 have averaged approximately 35 t for the last 19 years, with catches ranging from 19-70 t. In 2002-03 landings nearly triple the 2001-02 level were reported in KIN 8, the highest ever landing in this area. Landings returned to near average in 2003-04 and 2004-05, but still above the TACC. In addition, about 5 t of kingfish has been taken by New Zealand flagged vessels fishing outside NZ fishing waters.

Assuming kingfish targeting effectively ceased during the mid 1990s, early 2000s catches possibly reflect 'true' bycatch levels. This might account for 2004-05 over-catches in KIN 7 and KIN 8 as the TACCs in these QMAs are significantly below the recent pre QMS average.

1.2 Recreational fisheries

Kingfish is highly regarded by recreational fishers in New Zealand for its sporting attributes and large size. Kingfish are most often caught by recreational fishers from private boats and from charter boats, but are also a prized catch for spearfishers and shore based game fishers. Kingfish are recognized internationally as a sport fish, and kingfish caught in New Zealand waters hold 20 of the 22 International Gamefish Association World Records.

Recreational fishers have voiced concerns over a perceived marked decline in the size of kingfish available to them in recent years. Many clubs, competitions and charter boats have implemented a voluntary one kingfish per person per day limit in response. A number of gamefish clubs have also adopted a minimum size limit of 100 cm for kingfish.

Recreational harvest estimates by fish stock have been obtained from national telephone diary surveys undertaken in 1996 and 2000, with a follow up survey in 2001. Regional telephone diary surveys were undertaken in 1991-92 in the South Region, 1992-93 in the Central Region and in 1993-94 in the North Region. There is some uncertainty with all recreational harvest estimates for kingfish as presented in Table 3.

Table 3: Estimated number of kingfish harvested by recreational fishers by Fishstock. (Source: Tierney *et al*. 1997, Bradford 1997, Bradford 1998, Boyd & Reilly 2002, Boyd *et al*. 2004).

	KIN 1				KIN 2			
Survey Year	Number	CV (%)	Range	Estimated Harvest (t)	Number	CV (%)	Range	Estimated Harvest (t)
1992	186 000	-	240-280	260	68 000	-	65-120	92.5
1994	180 000	9	-	228#	62 000	18	-	78.5
1996	194 000	7	215-255	234	67 000	11	60-80	70
2000	127 000	18	590.9-764	800	25 000	38	58.8-102.6	138
2001	449 000	19	-	434.2	107 000	21	-	124.3

	KIN 7				KIN 8			
Survey Year	Number	CV (%)	Range	Estimated Harvest (t)	Number	CV (%)	Range	Estimated Harvest (t)
1992	10 000	-	15-25	20	6 000	-	-	7.6#
1994	-	-	-	-	-	-	-	-
1996	9 000	19	10-15	13	2 000	-	-	2.5#
2000	2 000	55	63.2-256.6	11	1 000	63	5.6-14.8	7
2001	32 000	23	-	33.9	2 000	46	-	1.7

#No harvest estimate available in the survey report, estimate presented is calculated as average fish weight for all years and areas by the number of fish estimated caught.

A telephone diary or personal interview diary survey (2000 and 2001) has three main components: i) the population that fishes recreationally, the group eligible to complete diaries; ii) a diary survey which generates the mean catch in the eligible population; and iii) the mean weight of the catch, usually estimated from boat ramp surveys. The Recreational Technical Working Group (RTWG) concluded that the methodological framework used for telephone interviews produced low eligibility figures for the 1996 and previous surveys. Consequently the harvest estimates derived from these surveys are unreliable.

Comparisons between boat ramp and diary estimates of snapper catch per fisher-trip indicate that there are inconsistencies between the observational and diary information. These inconsistencies,

suggest to the RTWG that the diary methodology used in these surveys produces unreliable estimates of total catch. Relative comparisons may be possible between stocks within these surveys.
Mean weight, the third component of the diary survey, introduces uncertainty in the estimates of total weight of recreational catch. However, it is possible to bypass this problem by using the estimated catch in numbers.

The RTWG recommends 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.

All indications are that the recreational catch is in the range of 500-700 t in KIN 1. Recreational surveys also indicate 85% of the recreational kingfish catch is taken in the northern QMAs (1 & 8).

It was assumed that the introduction of the higher MLS of 75 cm on 15 January 2004 for kingfish would reduce recreational catches.

In 2004-05 a recreational harvest estimate for KIN 1 was requested as part of the combined aerial / boat ramp survey targeted primarily at snapper and kahawai. The PELWG indicated that this estimate should be considered with considerable caution due to the limited overlap between this methods sampling technique and the fisheries for kingfish, e.g., the target fisheries for kingfish are usually in offshore areas from launches which were not sampled by the boat ramp survey. For this reason the results from this survey have not been accepted or included in the working group report at this time.

1.3 Customary non-commercial fisheries
Kingfish is an important traditional food fish for Maori, but no quantitative information on the level of Maori customary non-commercial catch is available. The extent of the traditional fisheries for kingfish in the past is described by the Muriwhenua Fishing Report (Waitangi Tribunal 1988). Because of the coastal distribution of the species and its inclination to strike lures, it is likely that historically Maori caught considerable numbers of kingfish.

1.4 Illegal catch
There is no known illegal catch of kingfish.

1.5 Other sources of mortality
The extent of any other sources of mortality is unknown, however, handling mortality for sub-MLS size fish is likely to occur in both the recreational (sub 75 cm) and commercial (sub 65 cm) fisheries.

2. BIOLOGY

In New Zealand, kingfish are predominantly found in the northern half of the North Island but also occur from 29° to 46° S, Kermadec Islands to Foveaux Strait (Francis 1988) and to depths of 200 m. Kingfish are large predatory fish with adults exceeding one and a half metres in length. They usually occur in schools ranging from a few fish to well over a hundred fish. Kingfish tend to occupy a semi-pelagic existence and occur mainly in open coastal waters, preferring areas of high current and or tidal flow adjacent to rocky outcrops, reefs and pinnacles. However, kingfish are not restricted to these habitats and are sometimes caught or observed in open sandy bottom areas and within shallow enclosed bays.

Estimates of age have recently been derived from opaque-zone counts in sagittal otolith thin sections. Estimates of kingfish von Bertalanffy growth parameters were derived from recreational tagging data and otoliths collected from the eastern Bay of Plenty. Estimates of K and L_{∞} were similar being 0.128 and 130 cm from the otolith age data and 0.130 and 142 cm from the tagging increment data respectively (Table 4). The hard-structure ageing techniques have yet to be validated for New Zealand kingfish and the position of the first annual growth ring is still uncertain.

A Bayesian analysis of length and maturity data suggests that the length of 50% maturity is 97 cm in females and 83 cm in males.

The recent research has provided estimates of *M* ranging from 0.20-0.25, however, these estimates are thought to represent an upper bound as the samples were taken from an exploited population.

Available biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters.

Fishstock		**Estimate**	**Source**
2. Weight = a(length)^b (Weight in g, length in cm fork length).			
	Both Sexes		
	a	b	
KIN 1	0.03651	2.762	Walsh *et al*. (2003)

3. von Bertalanffy growth parameters

Females			Males			Combined			
L_∞	k	t_0	L_∞	k	t_0	L_∞	k	t_0	
135.79	0.119	-0.976	123.81	0.137	-0.911	130.14	0.128	-0.919	McKenzie *et al*. (2005)

3. STOCKS AND AREAS

A study based on meristic characters and parasite loads suggests two stocks of kingfish off the west and east coasts. These stocks are contained within the Tasman current on the west coast and the east Auckland current and east Cape current on the east coast, with little mixing between them. The east coast stock may be further subdivided into northeast and Hawkes Bay stocks based on limited exchange from tagging studies and parasite marker prevalence.

Tagging results suggest that most adult kingfish do not move outside local areas, with many tag returns close to the release site. However, some tagged kingfish have been found to move very long distances; there are validated reports of New Zealand tagged kingfish being caught in Australian waters and Australian tagged kingfish being recaptured in New Zealand waters.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

None are available at present.

4.2 Biomass estimates

Few kingfish are encountered in trawl surveys, suggesting that trawling is not a suitable method for monitoring changes in kingfish abundance. Kingfish are amenable to mark-recapture studies. However, up to now, tagging studies have been conducted solely to describe kingfish movement patterns and to estimate growth. Data from these programmes is inadequate to estimate stock biomass.

4.3 Estimation of Maximum Constant Yield (*MCY*)

MCY estimates were derived using the cY_{AV} method (Method 4, Annala 1993) (Table 5). The natural variability factor, c, is taken to be 0.6, which is based on the estimated natural mortality rate for New South Wales *S. lalandi* (M = 0.38). The working group considers that the Australian estimate of *M* is likely to be higher than *M* for kingfish in New Zealand. The resulting increase to the natural variability factor (c) means that the estimates of *MCY* using this method are likely to be underestimates. Average annual catch (Y_{AV}) was calculated using the fishing years 1983-84 to 1992-93 under the assumption that these years were relatively stable and may best balance out the many factors affecting this non-target fishery (the data can be interpreted in different ways, leading to different estimates of Y_{AV}).

It may be more appropriate to select a new set of more recent years for estimating *MCY*, however, changes to the management of the fishery in recent years create problems with the length of the time series of catch data. Accordingly, the working group has not revised the *MCY* estimate at this time.

Table 5: Summary of the yields (t) from the commercial fishery.

Fishstock	FMA		*MCY*
KIN 1	Auckland (East)	1	195
KIN 2	Central (East)	2	40
KIN 3	South East, Chatham, Southland, Sub-Antarctic and Challenger	3, 4, 5, 6, & 7	5
KIN 8	Central (West)	8	20
KIN 9	Auckland (West)	9	not estimated
KIN 10	Kermadec	10	not estimated

The catch totals do not include the non-commercial catch. In KIN 1, this is assumed to account for over 80% of the current catch. Accordingly, the estimates of *MCY* apply to commercial fisheries only, and are not thought to be a reliable indicator of potential long-term yields from kingfish stocks.

4.4 Estimation of Current Annual Yield (*CAY*)

CAY cannot be estimated because of the lack of current biomass estimates.

4.5 Other yield estimates and stock assessment results

No information is available.

4.6 Other factors

Kingfish in New Zealand can be regarded as a high value species from customary, commercial and recreational perspectives. Although fluctuating, catches of kingfish have shown very little trend over the last 20 years and there is no direct evidence to suggest that the current catch levels are not sustainable. However, recreational fishers are concerned about a perceived decline in the quality of the fishery.

5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available. Although commercial catches are near or below *MCY* levels, it is not known if recent combined commercial and recreational catch levels are sustainable.

Yields, TACCs and reported landings for the 2010-11 fishing year are summarised in Table 6.

Table 6: Summary of yields (t) from the commercial fishery, and reported commercial landings (t) for the most recent fishing year.

Fishstock		QMA	*MCY*	2010-11 Actual TACC	2010-11 Reported landings
KIN 1	Auckland (East)	1	195	91	71
KIN 2	Central	2	40	63	55
KIN 3	South-east (Coast), Southland, Sub-Antarctic	3, 5 & 6	-	1	< 1
KIN 4	South-east (Chatham)	4	-	1	< 1
KIN 7	Challenger	7	-	7	6
KIN 8	Central (West) and Auckland (West)	8 & 9	20	36	37
KIN 10	Kermadec	10	-	1	0
Total			260*****	200	171

*****5 ton *MCY* estimate for FMAs 3,4,5,6 & 7 combined included in total.

6. FOR FURTHER INFORMATION

Bradford E. 1997. Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993-94. New Zealand Fisheries Assessment Research Document 1997/7. 16p.

Bradford E. 1998. Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27p.

Boyd R.O., Reilly J.L. 2002. 1999/2000 National marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report 2002/xx.

Boyd R.O., Gowing L., Reilly J.L. 2004. 2000/2001 National marine recreational fishing survey: diary results and harvest estimates. Draft New Zealand Fisheries Assessment Report 2004/xx.

Hartill B., Bian R., Armiger H., Vaughan M., Rush N. 2007. Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004-05. New Zealand Fisheries Assessment Report. 2007/26. 44p

Hartill B., Davies N.M. 1999. New Zealand billfish and gamefish tagging, 1997-98. NIWA Technical Report No. 57. 39p.Holdsworth J., Saul P. 2003. New Zealand: billfish and game tagging 2001-02. New Zealand Fisheries Assessment Report 2003/15. 39p.

Holdsworth J., Saul P. 2004. New Zealand billfish and gamefish tagging, 2002-2003. New Zealand Fisheries Assessment Report 2004/50. 27p.

Holdsworth J., Saul P. 2005. New Zealand billfish and gamefish tagging, 2003-2004. New Zealand Fisheries Assessment Report 2005/36. 30p

Holdsworth J., Saul P. 2006. New Zealand billfish and gamefish tagging, 2004-05. New Zealand Fisheries Assessment Report 2006/18. 28p.

Holdsworth J., Saul P. 2007. New Zealand billfish and gamefish tagging, 2005-06. New Zealand Fisheries Assessment Report 2007/02. 29p

Francis R.I.C.C. 1988. Maximum likelihood estimation of growth and growth variability from tagging data. New Zealand Journal of Marine and Freshwater Research 22: 42-51.

McKenzie J., Smith M., Watson T., Francis M., O Maolagain C., Poortenaar C., Holdsworth J. in prep. Age, growth, maturity and natural mortality of New Zealand kingfish (*Seriola lalandi lalandi*). Draft New Zealand Fisheries Assessment Report xxxx/xx. 36p.

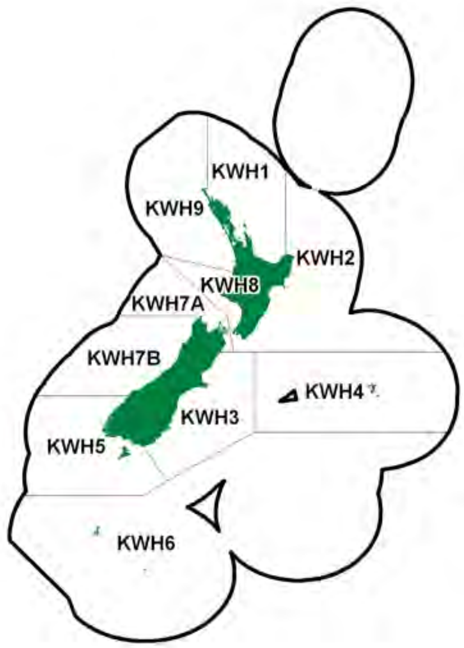
McKenzie J. (in prep.) Review of kingfish (*Seriola lalandi lalandi*) productivity parameters and stock assessment options. Draft New Zealand Fisheries Assessment Report xxxx/xx 17p.

Teirney L.D., Kilner A.R., Millar R.E., Bradford E., Bell J.D. 1997. Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43p.

Walsh C., McKenzie J., McGregor G., Poortenaar C., Hartill B., Smith M. 2003. Information available for the management of New Zealand kingfish (*Seriola lalandi lalandi*) stocks. New Zealand Fisheries Assessment Report 2003/25. 57p.

KNOBBED WHELK (KWH)

(*Austrofusus glans*)



1. FISHERY SUMMARY

Knobbed whelks (*Austrofusus glans*) were introduced into the Quota Management System on 1 October 2006. The fishing year is from 1 October to 30 September and commercial catches are measured in greenweight. TACs have been allocated in 10 QMAs (Table 1). This species is managed under Schedule 6 of the Fisheries Act for all stocks, which allows for them to be returned to where they were taken (as soon as practicable after being taken) providing they are likely to survive.

Table 1: Current TAC, TACC and allowances for customary fishing, recreational fishing and other sources of mortality for *Austrofusus glans.*

QMA	TAC (t)	TACC (t)	Customary fishing	Recreational fishing	Other sources of mortality
1	3	1	1	1	0
2	3	1	1	1	0
3	5	3	1	1	0
4	8	6	1	1	0
5	3	1	1	1	0
6	4	2	1	1	0
7A	53	50	1	1	1
7B	3	1	1	1	0
8	3	1	1	1	0
9	3	1	1	1	0
Total	**88**	**67**	**10**	**10**	**1**

1.1 Commercial fisheries

Target fishing for knobbed whelks is by baited pots. Because economic returns for whelk fishing are poor, most of the historical catch is bycatch from oyster and scallop dredging and from bottom trawling. Due to the low value of this species it is likely that there is a high level of unreported discarded catch.

Landings shown in Table 2 for the period 1990-91 to 2005-06 were recorded under the generic code for whelks (WHE), however the Ministry considers that in FMA 1, 2, 7, and 8, most reported landings were of the knobbed whelk *Austrofusus glans*. In FMA 3, 4, 5, and 6, the Ministry considers that about a third of reported landings were of the knobbed whelk, while the remainder were the large ostrich foot shell *Struthiolaria papulosa*.

Reported landings of knobbed whelk in FMA 1, FMA 2, and FMA 8 have been relatively low and variable since the 1990s and have been (largely or all) accounted for as bycatch. In FMA 7 in the early

1990s higher catches were reported as part of experimental fisheries in Golden and Tasman Bay to provide stock assessment information in these areas (Tables 2 and 3). Landings are split into two tables (before and after the 2006 fishing year) as reporting requirements changed when knobbed whelks entered the QMS.

Table 2: Reported landings (t) of whelks (WHE) by FMA from 1990–91 to 2005–06 from landing returns. See section 1.1 for an explanation of the proportion of WHE that are considered to be knobbed whelks.

Fishstock	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 6	FMA 7	FMA 8	FMA 9	Total
1990–91	0	0	0	0	0	0	44.976	0	0	44.976
1991–92	0	0	0	0	0	0	26.935	0	0	26.935
1992–93	0.021	0	0.018	0	0	0	1.762	0	0	1.801
1993–94	0	0.135	0	0	0	0	49.278	0	0	49.413
1994–95	0	0.707	0.545	0	0	0	21.458	0.593	0	23.303
1995–96	0	0.089	0.178	0	0	0	27.596	0	0	27.863
1996–97	0.002	0.174	0.144	0	0.003	0	8.959	0	0	9.282
1997–98	0	0	0.102	0.150	0	0	0.884	0	0	1.136
1998–99	0	0	0.223	2.205	2.470	0.150	0.570	0	0	5.618
1999–00	0	0	2.286	7.953	3.250	0.790	0.080	0	0	14.359
2000–01	0	0	10.467	17.497	3.538	4.765	0.141	0	0	36.408
2001–02	0	0	1.474	3.995	0.515	1.755	0.002	0	0	7.741
2002–03	0	0	0.212	0.020	0.004	0.780	0.077	0	0	1.093
2003–04	0.035	0	0.491	0	0	0.335	4.217	0	0	5.078
2004–05	0.008	0	0.021	0	0	0.335	0.234	0	0.047	0.639
2005–06	0	0	0.163	0	0	0	0.032	0	0	0.195

Table 3: Landings of Knobbed whelk (KWH) by QMA from 2006-07 to 2010-11 from monthly harvest returns (MHR).

Fishstock	KWH1	KWH2	KWH3	KWH4	KWH5	KWH6	KWH7A	KWH7B	KWH8	KWH9	Total
2006–07	0.080	0	0.010	0	0	0	0.046	0	0	0	0.136
2007–08	0.077	0	0.006	0	0	0	9.174	0.104	0	0	9.361
2008–09	0.103	0	0.121	0	0	0.001	0.226	0.008	0	0	0.459
2009-10	0.088	0	0.053	0	0	0	18.50	0	0	0	18.614
2010-11	0.473	0.036	0	0	0	0	16.033	0	0	0	16.542

1.2 Recreational fisheries
There are no estimates of recreational catch.

1.3 Customary non-commercial fisheries
There are no estimates of current customary catch.

1.4 Illegal catch
There is no known illegal catch of this whelk.

1.5 Other sources of mortality
There is no information on other sources of mortality for this whelk.

2. BIOLOGY

The knobbed whelk *A. glans*, is a widely distributed gastropod found from low tide to about 600 m (Powell 1979). This carnivorous whelk grows up to 5cm long, and occurs throughout New Zealand where it is found on sandy/silt/mud substrate. There is very little published about the biology of this species; most references are identification notes or records of occurrence. It is a scavenger that buries in the substrate when not feeding. A wide variety of invertebrates including polychaetes, gastropods, and bivalves occur within the wide depth range of the knobbed whelk, but no interdependent relationships are documented with *A. glans*.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on QMAs. There is no biological information on stock structure, recruitment patterns, or other biological characteristics which might indicate alternative stock boundaries.

4. ENVIRONMENTAL EFFECTS OF FISHING

This section has yet to be drafted and approved by the Aquatic Environment Working Group.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any knobbed whelk fishstock.

5.2 Biomass estimates

There are no biomass estimates for any knobbed whelk fishstock.

5.3 Estimation of Maximum Constant Yield (*MCY*)

There are no estimates of *MCY* for any knobbed whelk fishstock.

5.4 Estimation of Current Annual Yield (*CAY*)

There are no estimates of *CAY* for any knobbed whelk fishstock.

6. STATUS OF THE STOCKS

- **KWH 7A -** *Austrofusus glans*

Stock Status	
Year of Most Recent Assessment	No formal assessment done of any of the stocks
Assessment Runs Presented	N/A
Reference Points	Target: None Soft Limit: None Hard Limit: None
Status in relation to Target	N/A
Status in relation to Limits	N/A
Historical Stock Status Trajectory and Current Status Unknown	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	In 1990-96 the landings for KWH 7 averaged 28.7 t. However since that time landings have declined in this area to less than 10 t per year. Landings in all other Fishstocks have been variable but total catch across all Fishstocks has been less than 10 t per year since 2001-02.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-
Projections and Prognosis	
Stock Projections or Prognosis	None

Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown It is unknown what effect fishing to date has had on *Austrofusus glans* stocks

Assessment Methodology		
Assessment Type	None	
Assessment Method	N/A	
Main data inputs	N/A	
	Latest assessment: N/A	Next assessment: N/A
Changes to Model Structure and Assumptions	N/A	
Major Sources of Uncertainty	N/A	

Qualifying Comments
-

Fishery Interactions
-

7. FOR FURTHER INFORMATION

Morton J., Miller M. 1968. The New Zealand sea shore. Collins, Auckland. 638p.
Powell AWB. 1979. New Zealand Mollusca. Marine, land and freshwater shells. Collins, Auckland. 500p.

LEATHERJACKET (LEA)

(*Parika scaber*)
Kokiri, Hiriri

1. FISHERY SUMMARY

Leatherjacket was introduced into the QMS on 1 October 2003, with allowances, TACCs and TACs shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs for leatherjacket by Fishstock.

Fishstock	Recreational Allowance	Customary Non-Commercial Allowance	Other sources of mortality	TACC	TAC
LEA 1	5	1	9	188	203
LEA 2	2	1	57	1 136	1 196
LEA 3	2	1	5	100	108
LEA 4	1	1	1	7	10
LEA 10	0	0	0	0	0
Total	10	4		1 431	1 517

1.1 Commercial fisheries

Nationally, very small landings were first reported in 1948. Most of the current leatherjacket catch is taken as a bycatch, and it is very likely that leatherjacket has always been primarily a bycatch species. From only a few tonnes in the early 1960s, reported landings increased to 200-400 tonnes in the 1970s, 1980s and early 1990s (Table 2). Figure 1 shows the historical landings and TACC values for the main leatherjacket stocks. Landings increased further in the late 1990s to around 1000 to 1300 tonnes, but have decreased to less than 500 t in 2005-06. It is possible that actual catches were higher than reported prior to the 1970s, but that some catches were discarded without being reported due to low market demand in this period. On average over the last 4 years total landings have only been 35% of the TACC.

1.2 Recreational fisheries

The National Marine Recreational Fishing surveys in 1994, 1996 and 2000 do not provide an estimate of the non-commercial catches of leatherjacket because very few were caught. It is likely that recreational fishers, especially in the northern region, will have caught some leatherjacket by spear fishing, in rock lobster pots and setnets. Leatherjackets are seldom caught by hook and line.

Table 2: Reported commercial landings (tonnes) of leatherjacket by fishstock for the fishing years from 1989-90 to 2010-11. Landings for LEA 10 have not been shown as these were negligible and were rounded to zero.

Fishstock	LEA 1		LEA 2		LEA 3		LEA 4			
FMA (s)	1&9		2&8		3, 5 & 6		4		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1989-90	114	-	169	-	42	-	-	-	325	-
1990-91	143	-	178	-	61	-	-	-	382	-
1991-92	160	-	85	-	100	-	-	-	345	-
1992-93	154	-	98	-	41	-	-	-	293	-
1993-94	188	-	62	-	37	-	-	-	287	-
1994-95	186	-	148	-	50	-	-	-	384	-
1995-96	152	-	296	-	38	-	-	-	486	-
1996-97	128	-	908	-	70	-	-	-	1 106	-
1997-98	151	-	165	-	66	-	-	-	382	-
1998-99	110	-	413	-	30	-	-	-	553	-
1999-00	115	-	1 136	-	35	-	-	-	1 286	-
2000-01	131	-	880	-	41	-	-	-	1 052	-
2001-02	185	-	953	-	43	-	-	-	1 181	-
2002-03	162	-	568	-	67	-	0	-	797	-
2003-04	189	188	396	1 136	28	100	0	7	613	1 431
2004-05	223	188	221	1 136	56	100	< 1	7	500	1 431
2005-06	173	188	172	1 136	60	100	0	7	405	1 431
2006-07	191	188	215	1 136	49	100	0	7	454	1 431
2007-08	135	188	258	1 136	73	100	0	7	466	1 431
2008-09	178	188	282	1 136	122	100	0	7	582	1 431
2009-10	181	188	455	1 136	117	100	0	7	754	1 431
2010-11	185	188	276	1 136	112	100	< 1	7	573	1 431

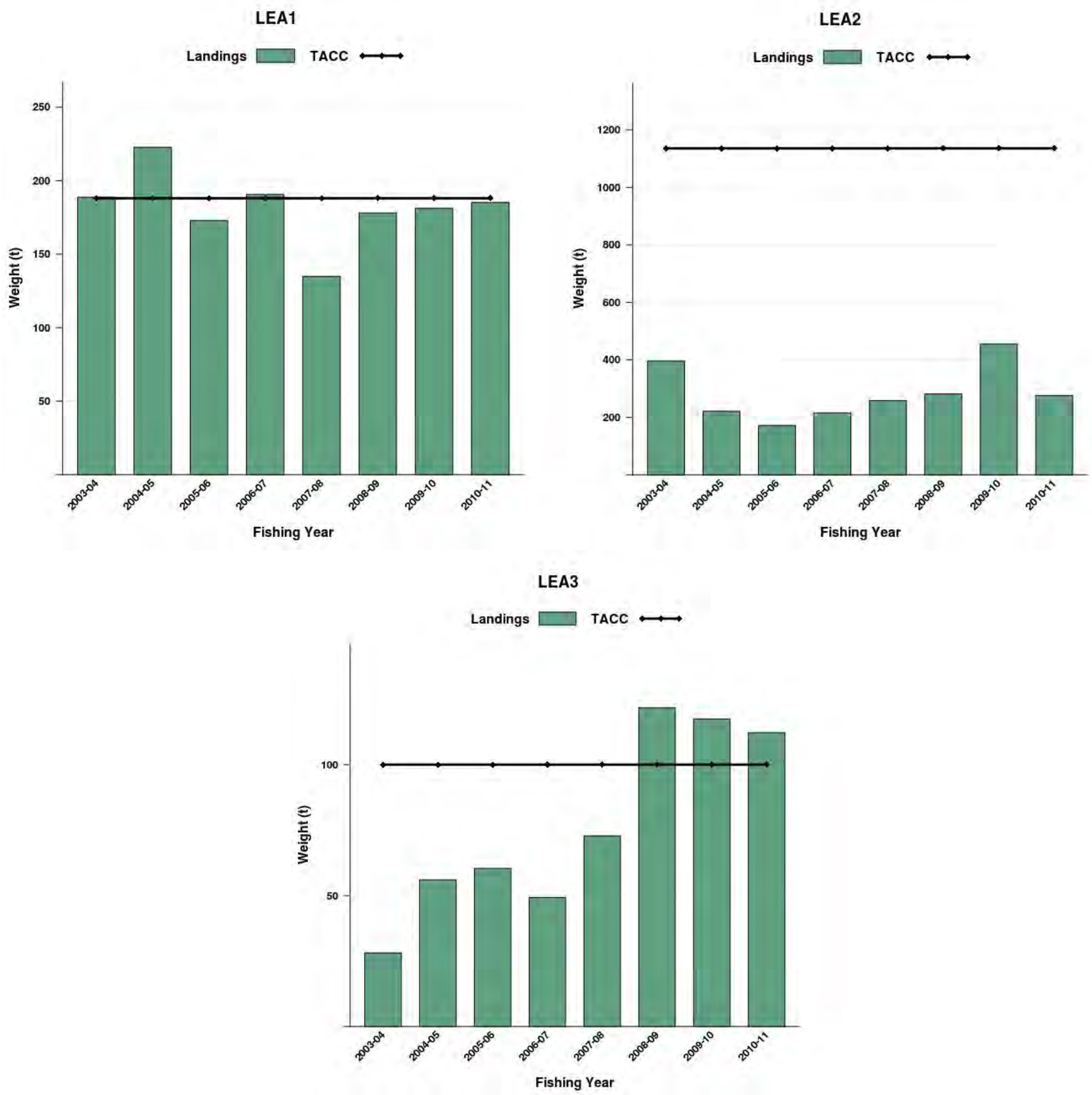


Figure 1: Historical landings and TACC for the main LEA stocks. From top left: LEA1 (Auckland), LEA2 (Central), and LEA3 (South East). Note that these figures do not show data prior to entry into the QMS.

1.3 Customary non-commercial fisheries

There is no quantitative information available to allow the estimation of the amount of leatherjacket taken by customary non-commercial fishers.

2. BIOLOGY

The New Zealand leatherjacket (*Parika scaber*) is present around much of New Zealand, but is most common in the north. Trawl survey records show it to be widespread over the inner shelf north of East Cape and Cape Egmont, in the South Taranaki Bight, in Tasman and Golden Bays, Pegasus Bay and the South Canterbury Bight, extending to depths below 100 m, but with greatest abundance at 40–60 m (Anderson *et al.* 1998). It was less commonly caught along the east coast of the North Island south of East Cape, off the northeast South Island (Cook Strait to Pegasus Bay), northwest South Island (Cape Farewell to Cape Foulwind), and around the South Otago and Southland coast. It has not been taken by trawl on the west coast south of Cape Foulwind.

The New Zealand leatherjack*et al*so occurs in Australia, from New South Wales to the southern coast of West Australia. In the Australian southeast trawl fishery, *Parika scaber* is the main leatherjacket species caught (Yearsley *et al.* 1999). It was once believed that two similar species of leatherjacket occurred in New Zealand – 'rough' and 'smooth' – but these are now considered a single species with variable colouring. Kokiri is the Maori name, but is not in common usage. 'Creamfish' is a New Zealand trade name for the processed (headed/gutted/skinned) product, rather than a name for the fish itself.

Leatherjacket usually occur near reefs and over rough seafloor, but may be found over sand or some distance above the bottom. Although not a schooling species, it does occur in small groups.

There are no published studies on the age and growth *P. scaber*. According to Francis (1996) they live to at least 7 years, maturing at two years and 19-22 cm. The males defend territories and eggs are laid within nests on the seafloor in spring and summer (Ayling & Cox 1982, Milicich 1986).

3. STOCKS AND AREAS

There have been no biological studies directly relevant to the recognition of separate stocks.

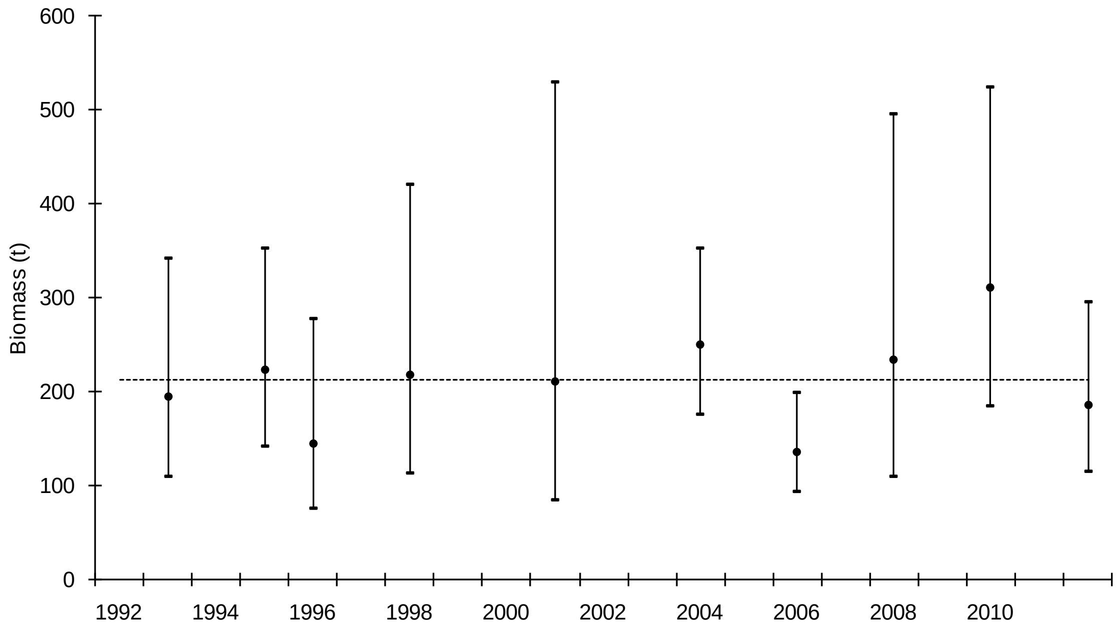


Figure 2: Leatherjacket biomass ±95% CI (estimated from survey CV's) and the time series mean (dotted line) estimated from the West Coast South Island trawl survey.

The West Coast South Island (WCSI) trawl survey probably monitors pre-recruit biomass of leatherjacket. The total biomass trends are shown in Figure 2.

4. STOCK ASSESSMENT

There has been no scientific assessment of the maximum sustainable yield, reference or current biomass of any of the leatherjacket stocks.

5. STATUS OF THE STOCK

There are no estimates of reference or current biomass. It is not known whether the leatherjacket stocks are at, above, or below a level that can produce *MSY*.

Reported landings and TACCs by Fishstock for the 2010-11 fishing year are summarised in Table 3.

Table 3: Summary of TACCs (t) and reported landings (t) of leatherjacket for the most recent fishing year.

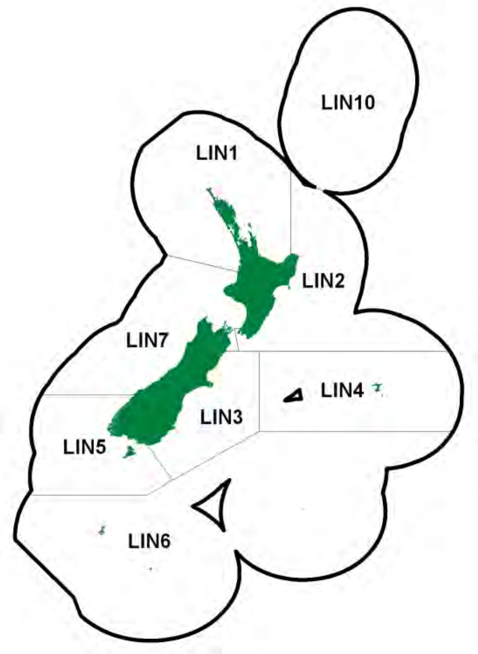
Fishstock		FMA	2010-11 Actual TACC	2010-11 Reported landings
LEA 1	Auckland (East) (West)	1, &9	188	185
LEA 2	Central (East) (West), Challenger	2,7&8	1 136	276
LEA 3	South east (coast), Southland, Sub-Antarctic	3, 4, 5 & 6	100	112
LEA 4	South east (Chatham)		7	<1
Total			1 431	573

6. FURTHER INFORMATION

Anderson O.F., Bagley N.W., Hurst R.J., Francis M.P., Clark M.R., McMillan P.J. 1998 Atlas of New Zealand fish and squid distributions from research bottom trawls. NIWA Technical Report 24. 303p.
Ayling A.M., Cox G.J. 1982. Collins guide to the sea fishes of New Zealand. Collins, Auckland. 343p.
Francis M.P. 1996. Coastal fishes of New Zealand. An identification guide. Revised edition. Reed books, Auckland.
Milicich M.J. 1986. Aspects of the early life history of *Paricka scabe*r (Pisces: Monacanthidae). M.Sc. thesis, University of Auckland.
Yearsley G.K., Last P.R., Ward R.D. (Eds) 1999. Australian seafood handbook. An identification guide to domestic species. CSIRO Marine Research, Australia. 461p.

LING

(*Genypterus blacodes*)
Hoka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Ling was introduced into the Quota Management System (QMS) on 1 October 1986. Ling are widely distributed through the middle depths (200–800 m) of the New Zealand EEZ, particularly to the south of latitude 40° S. From 1975 to 1980 there was a substantial longline fishery on the Chatham Rise (and to a lesser extent in other areas), carried out by Japanese and Korean longliners. Since 1980 ling have been caught by large trawlers, both domestic and foreign owned, and by small domestic longliners and trawlers. In the early 1990s the domestic fleet was increased by the addition of several larger longliners fitted with autoline equipment. This caused a large increase in the catches of ling off the east and south of the South Island (LIN 3, 4, 5 and 6). However, since about 2000 there has been a declining trend in catches taken by line vessels in most areas, offset, to some extent, by increased trawl landings.

The principal grounds for smaller domestic vessels are the west coast of the South Island (WCSI) and the east coast of both main islands south of East Cape. For the large trawlers the main sources of ling are Puysegur Bank and the slope of the Stewart-Snares shelf and waters in the Auckland Islands area. Longliners fish mainly in LIN 3, 4, 5 and 6. In 2010–11, landings from Fishstocks LIN 2, LIN 3, LIN 4 and LIN 6 were under-caught relative to their TACCs by 32%, 19%, 63% and 84%, respectively. The LIN 1, LIN 5, and LIN 7 TACCs were slightly over-caught (10%, 7%, and 13%, respectively. Reported landings by nation from 1975 to 1987–88 are shown in Table 1, and reported landings by Fishstock from 1983–84 to 2010–11 are shown in Table 2. Figure 1 shows the historical landings and TACC values for the main LIN stocks.

Under the Adaptive Management Programme (AMP), the TACC for LIN 1 was increased to 400 t from 1 October 2002, within an overall TAC of 463 t. All stocks including LIN 1 were removed from the AMP on 30th September 2009. In an earlier proposal for the 1994–95 fishing year, TACCs for LIN 3 and 4 had been increased to 2810 and 5720 t, respectively. These stocks were removed from the AMP from 1 October 1998, with TACCs maintained at the increased level. However, from 1 October 2000, the TACCs for LIN 3 and 4 were reduced to 2060 and 4200 t, respectively. From 1 October 2004, the TACCs for LIN 5 and LIN 6 were increased by about 20% to 3595 t and 8505 t, respectively. From 1 October 2009, the TACC for LIN 7 was increased from 2225 t to 2474 t. All other TACC increases since 1986–87 in all stocks are the result of quota appeals.

Table 1: Reported landings (t) from 1975 to 1987–88. Data from 1975 to 1983 from MAF; data from 1983–84 to 1985–86 from FSU; data from 1986–87 to 1987–88 from QMS. –, no data available.

Fishing year	New Zealand			Foreign Licensed					Grand total
				Longline	Trawl			Total	
	Domestic	Chartered	Total	(Japan + Korea)	Japan	Korea	USSR	Total	
1975*	486	0	486	9 269	2 180	0	0	11 499	11 935
1976*	447	0	447	19 381	5 108	0	1 300	25 789	26 236
1977*	549	0	549	28 633	5 014	200	700	34 547	35 096
1978–79#	*657	24	681	8 904	3 151	133	452	12 640	13 321
1979–80#	*915	2 598	3 513	3 501	3 856	226	245	7 828	11 341
1980–81#	*1 028	–	–	–	–	–	–	–	–
1981–82#	*1 581	2 423	4 004	0	2 087	56	247	2 391	6 395
1982–83#	*2 135	2 501	4 636	0	1 256	27	40	1 322	5 958
1983†	*2 695	1 523	4 218	0	982	33	48	1 063	5 281
1983–84§	2 705	2 500	5 205	0	2 145	173	174	2 491	7 696
1984–85§	2 646	2 166	4 812	0	1 934	77	130	2 141	6 953
1985–86§	2 126	2 948	5 074	0	2 050	48	33	2 131	7 205
1986–87§	2 469	3 177	5 646	0	1 261	13	21	1 294	6 940
1987–88§	2 212	5 030	7 242	0	624	27	8	659	7 901

* Calendar years (1978 to 1983 for domestic vessels only).
\# April 1 to March 31.
† April 1 to Sept 30.
§ Oct 1 to Sept 30.

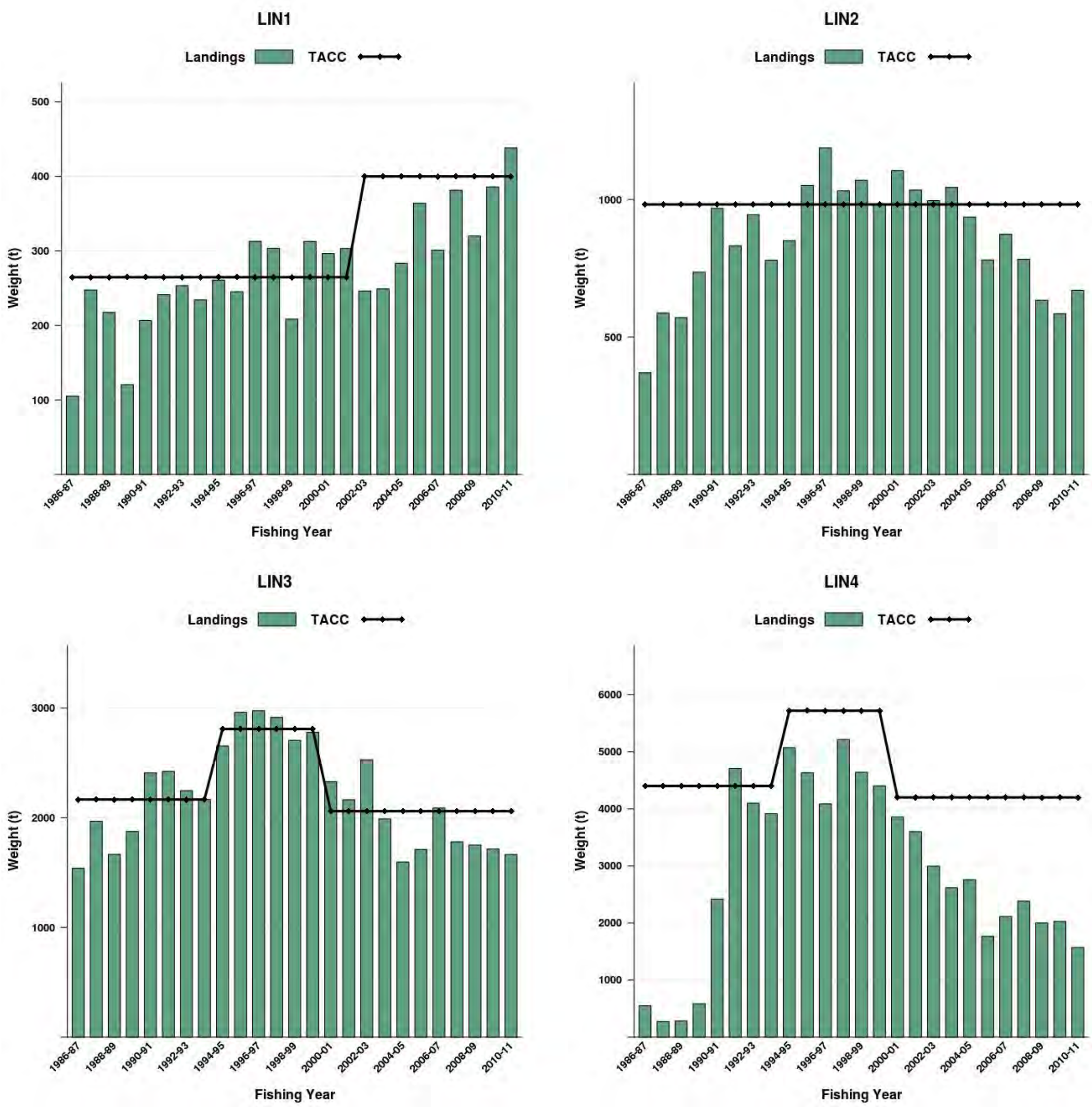


Figure 1: Historical landings and TACC for the seven main LIN stocks. From top left: LIN1 (Auckland East), LIN2 (Central East), LIN3 (South East Coast), LIN4 (South East Chatham Rise). [Continued on next page]…

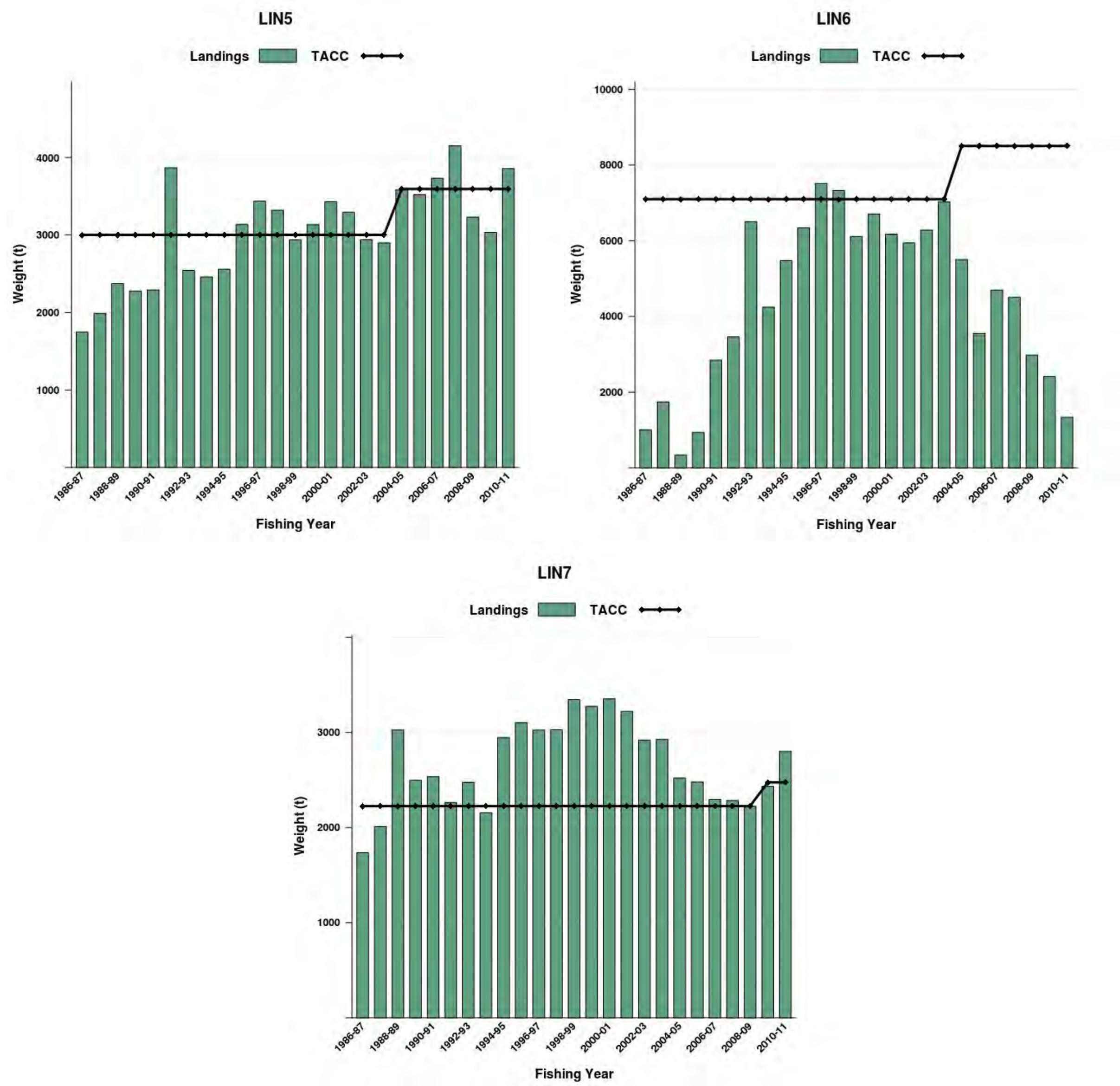


Figure 1 [Continued]: Historical landings and TACC for the seven main LIN stocks. LIN5 (Southland), LIN6 (Sub-Antarctic), and LIN7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

The 1993–94 North region recreational fishing survey (Bradford 1996) estimated the annual recreational catch from LIN 1 as 10 000 fish (CV 0.23). With a mean weight likely to be in the range of 1.5 to 4 kg, this equates to a harvest of 15–40 t.

Recreational catch was recorded from LIN 1, 5, and 7 in the 1996 national diary survey. The estimated harvests (LIN 1, 3000 fish; LIN 5, < 500; LIN 7, < 500) were too low to provide reliable estimates.

1.3 Customary non-commercial fisheries

Quantitative information on the level of Maori customary non-commercial take is not available. Ling bones have been recovered from archaic middens throughout the South Island and southern North Island, and on Chatham Island (Leach & Boocock 1993). In South and Chatham Islands, ling comprised about 4% (by number) of recovered fish remains.

1.4 Illegal catch

It is believed that up to the mid 1990s some ling bycatch from the west coast hoki fishery was not reported. Estimates of total catch including non-reported catch are given in Table 2 for LIN 7.

It is believed that in recent years, some catch from LIN 7 has been reported against other ling stocks (probably LIN 3, 5, and 6). The likely levels of misreporting are moderate, being about 250–400 t in each year from 1989–90 to 1991–92 (Dunn 2003).

1.5 Other sources of mortality

The extent of any other sources of mortality is unknown.

Table 2: Reported landings (t) of ling by Fishstock from 1983–84 to 2010–11 and actual TACCs (t) from 1986–87 to 2010–11. Estimated landings for LIN 7 from 1987–88 to 1992–93 include an adjustment for ling bycatch of hoki trawlers, based on records from vessels carrying observers. QMS data from 1986-present.

Fishstock		**LIN 1**		**LIN 2**		**LIN 3**		**LIN 4**		**LIN 5**
QMA (s)		1 & 9		2		3		4		5
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	141	–	594	–	1 306	–	352	–	2 605	–
1984–85*	94	–	391	–	1 067	–	356	–	1 824	–
1985–86*	88	–	316	–	1 243	–	280	–	2 089	–
1986–87	77	200	254	910	1 311	1 850	465	4 300	1 859	2 500
1987–88	68	237	124	918	1 562	1 909	280	4 400	2 213	2 506
1988–89	216	237	570	955	1 665	1 917	232	4 400	2 375	2 506
1989–90	121	265	736	977	1 876	2 137	587	4 401	2 277	2 706
1990–91	210	265	951	977	2 419	2 160	2 372	4 401	2 285	2 706
1991–92	241	265	818	977	2 430	2 160	4 716	4 401	3 863	2 706
1992–93	253	265	944	980	2 246	2 162	4 100	4 401	2 546	2 706
1993–94	241	265	779	980	2 171	2 167	3 920	4 401	2 460	2 706
1994–95	261	265	848	980	2 679	2 810	5 072	5 720	2 557	3 001
1995–96	245	265	1 042	980	2 956	2 810	4 632	5 720	3 137	3 001
1996–97	313	265	1 187	982	2 963	2 810	4 087	5 720	3 438	3 001
1997–98	303	265	1 032	982	2 916	2 810	5 215	5 720	3 321	3 001
1998–99	208	265	1 070	982	2 706	2 810	4 642	5 720	2 937	3 001
1999–00	313	265	983	982	2 799	2 810	4 402	5 720	3 136	3 001
2000–01	296	265	1 105	982	2 330	2 060	3 861	4 200	3 430	3 001
2001–02	303	265	1 034	982	2 164	2 060	3 602	4 200	3 295	3 001
2002–03	246	400	996	982	2 529	2 060	2 997	4 200	2 939	3 001
2003–04	249	400	1 044	982	1 990	2 060	2 618	4 200	2 899	3 001
2004–05	283	400	936	982	1 597	2 060	2 758	4 200	3 584	3 595
2005–06	364	400	780	982	1 711	2 060	1 769	4 200	3 522	3 595
2006–07	301	400	874	982	2 089	2 060	2 113	4 200	3 731	3 595
2007–08	381	400	792	982	1 778	2 060	2 383	4 200	4 145	3 595
2008–09	320	400	634	982	1 751	2 060	2 000	4 200	3 232	3 595
2009–10	386	400	584	982	1 718	2 060	2 026	4 200	3 034	3 595
2010–11	438	400	670	982	1 665	2 060	1 572	4 200	3 856	3 595

Fishstock		**LIN 6**			**LIN 7**		**LIN 10**		
QMA (s)		6			7 & 8		10		Total
	Landings	TACC	Reported Landings	Estimated Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	869	–	1 552	–	–	0	–	7 696	–
1984–85*	1 283	–	1 705	–	–	0	–	6 953	–
1985–86*	1 489	–	1 458	–	–	0	–	7 205	–
1986–87	956	7 000	1 851	–	1 960	0	10	6 940	18 730
1987–88	1 710	7 000	1 853	1 777	2 008	0	10	7 901	18 988
1988–89	340	7 000	2 956	2 844	2 150	0	10	8 404	19 175
1989–90	935	7 000	2 452	3 171	2 176	0	10	9 028	19 672
1990–91	2 738	7 000	2 531	3 149	2 192	< 1	10	13 506	19 711
1991–92	3 459	7 000	2 251	2 728	2 192	0	10	17 778	19 711
1992–93	6 501	7 000	2 475	2 817	2 212	< 1	10	19 065	19 737
1993–94	4 249	7 000	2 142	–	2 213	0	10	15 961	19 741
1994–95	5 477	7 100	2 946	–	2 225	0	10	19 841	22 111
1995–96	6 314	7 100	3 102	–	2 225	0	10	21 428	22 111
1996–97	7 510	7 100	3 024	–	2 225	0	10	22 522	22 113
1997–98	7 331	7 100	3 027	–	2 225	0	10	23 145	22 113
1998–99	6 112	7 100	3 345	–	2 225	0	10	21 034	22 113
1999–00	6 707	7 100	3 274	–	2 225	0	10	21 615	22 113
2000–01	6 177	7 100	3 352	–	2 225	0	10	20 552	19 843
2001–02	5 945	7 100	3 219	–	2 225	0	10	19 561	19 843
2002–03	6 283	7 100	2 918	–	2 225	0	10	18 903	19 978
2003–04	7 032	7 100	2 926	–	2 225	0	10	18 760	19 978
2004–05	5 506	8 505	2 522	–	2 225	0	10	17 189	21 977
2005–06	3 553	8 505	2 479	–	2 225	0	10	14 184	21 977
2006–07	4 696	8 505	2 295	–	2 225	0	10	16 102	21 977
2007–08	4 502	8 505	2 282	–	2 225	0	10	16 264	21 977
2008–09	2 977	8 505	2 223	–	2 225	0	10	13 137	21 977
2009–10	2 414	8 505	2 446	–	2 474	0	10	12 609	22 226
2010–11	1 335	8 505	2 800	–	2 474	0	10	12 337	22 226

* FSU data.

§ Includes landings from unknown areas before 1986–87, and areas outside the EEZ since 1995–96.

2. BIOLOGY

Ling live to a maximum age of about 30 years; fewer than 0.2% of successfully aged ling have been older than 30 years. A growth study of ling from five areas (west coast South Island, Chatham Rise, Bounty Plateau, Campbell Plateau, Cook Strait) showed that females grew significantly faster and reached a greater size than males in all areas, and that growth rates were significantly different between areas. Ling grow fastest in Cook Strait and slowest on the Campbell Plateau (Horn 2005).

M was initially estimated from the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. The mean M calculated from 5 samples of age data was 0.18 (range = 0.17–0.20). However, a recent review of M, and results of modelling conducted in 2007, suggests that this parameter may vary between stocks (Horn 2008b). The M for Chatham Rise ling appears to be lower than 0.18, while for Cook Strait and west coast South Island the value is probably higher than 0.18.

Ling in spawning condition have been reported in a number of localities throughout the EEZ (Horn 2005). Time of spawning appears to vary between areas: July to November on the Chatham Rise; September to December on Campbell Plateau and Puysegur Bank; September to February on the Bounty Plateau; July to September off west coast South Island and in Cook Strait. Little is known about the distribution of juveniles until they are about 40 cm total length, when they begin to appear in trawl samples over most of the adult range.

Ling appear to be mainly bottom dwellers, feeding on crustaceans such as *Munida* and scampi and also on fish, with commercial fishing discards being a significant dietary component. However, they may at times be caught well above the bottom, for example when feeding on hoki during the hoki spawning season.

Biological parameters relevant to the stock assessment are shown in Table 3.

Table 3: Estimates of biological parameters from Horn (2005). See Section 3 for definitions of Fishstocks.

Fishstock	**Estimate**
1. Natural mortality (M)	
All stocks average (both sexes)	M = 0.18

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

	Female		Male		Area
	a	b	A	b	
LIN 3&4	0.00114	3.318	0.00100	3.354	Chatham Rise
LIN 5&6	0.00128	3.303	0.00208	3.190	Southern Plateau
LIN 6B	0.00114	3.318	0.00100	3.354	Bounty Plateau
LIN 7WC	0.00094	3.366	0.00125	3.297	West Coast S.I.
LIN7CK	0.00094	3.366	0.00125	3.297	Cook Strait

3. von Bertalanffy growth parameters

	Female			Male			Area
	K	t_0	$L_($	K	T_0	$L_($	
LIN 3&4	0.083	–0.74	156.4	0.127	–0.70	113.9	Chatham Rise
LIN 5&6	0.124	–1.26	115.1	0.188	–0.67	93.2	Southern Plateau
LIN 6B	0.101	–0.53	146.2	0.141	0.02	120.5	Bounty Plateau
LIN 7WC	0.078	–0.87	169.3	0.067	–2.37	159.9	West Coast S.I.
LIN7CK	0.097	–0.54	163.6	0.080	–1.94	158.9	Cook Strait

3. STOCKS AND AREAS

A review of ling stock structure (Horn 2005) examined diverse information from studies of morphometrics, genetics, growth, population age structures, and reproductive biology and behavior, and indicated that there are at least five ling stocks, i.e., west coast South Island, Chatham Rise, Cook Strait, Bounty Plateau, and the Southern Plateau (including the Stewart-Snares shelf and Puysegur Bank). Stock affinities of ling north of Cook Strait are unknown, but spawning is known to occur off Northland, Cape Kidnappers, and in the Bay of Plenty.

4. STOCK ASSESSMENT

The stock assessments for two ling stocks (LIN 3&4, Chatham Rise; LIN 5&6, Sub-Antarctic) were updated in 2011. Assessments for other stocks were updated in 2006 (LIN 6B, Bounty Plateau), 2008 (LIN 7WC, west coast South Island), or 2010 (LIN 7CK, Cook Strait). All assessments were updated using a Bayesian stock model implemented using the general-purpose stock assessment program CASAL (Bull *et al*. 2008).

4.1 Estimates of fishery parameters and abundance

Catch histories by stock and fishery are presented in Table 4, and other model input parameters are shown in Table 5. Estimates of relative abundance from standardised CPUE analyses (Table 6) and trawl surveys (Table 7) are also presented below.

Table 4: Estimated catch histories (t) for LIN 3&4 (Chatham Rise), LIN 5&6 (Campbell Plateau), LIN 6B (Bounty Platform), LIN 7WC (WCSI section of LIN 7), and LIN7CK (Cook Strait). Landings have been separated by fishing method (trawl or line), and, for the LIN 5&6 line fishery, by pre-spawning (Pre) and spawning (Spn) season.

Year	LIN 3&4		LIN 5&6			LIN 6B	LIN 7WC		LIN 7CK	
	trawl	line	trawl	Line Pre	Line Spn	line	Trawl	line	trawl	Line
1972	0	0	0	0	0	0	0	0	0	0
1973	250	0	500	0	0	0	85	20	45	45
1974	382	0	1 120	0	0	0	144	40	45	45
1975	953	8 439	900	118	192	0	401	800	48	48
1976	2 100	17 436	3 402	190	309	0	565	2 100	58	58
1977	2 055	23 994	3 100	301	490	0	715	4 300	68	68
1978	1 400	7 577	1 945	494	806	10	300	323	78	78
1979	2 380	821	3 707	1 022	1 668	0	539	360	83	83
1980	1 340	360	5 200	0	0	0	540	305	88	88
1981	673	160	4 427	0	0	10	492	300	98	98
1982	1 183	339	2 402	0	0	0	675	400	103	103
1983	1 210	326	2 778	5	1	10	1 040	710	97	97
1984	1 366	406	3 203	2	0	6	924	595	119	119
1985	1 351	401	4 480	25	3	2	1 156	302	116	116
1986	1 494	375	3 182	2	0	0	1 082	362	126	126
1987	1 313	306	3 962	0	0	0	1 105	370	97	97
1988	1 636	290	2 065	6	0	0	1 428	291	107	107
1989	1 397	488	2 923	10	2	9	1 959	370	255	85
1990	1 934	529	3 199	9	4	11	2 205	399	362	121
1991	2 563	2 228	4 534	392	97	172	2 163	364	488	163
1992	3 451	3 695	6 237	566	518	1 430	1 631	661	498	85
1993	2 375	3 971	7 335	1 238	474	1 575	1 609	716	307	114
1994	1 933	4 159	5 456	770	486	875	1 136	860	269	84
1995	2 222	5 530	5 348	2 355	338	387	1 750	1 032	344	70
1996	2 725	4 863	6 769	2 153	531	588	1 838	1 121	392	35
1997	3 003	4 047	6 923	3 412	614	333	1 749	1 077	417	89
1998	4 707	3 227	6 032	4 032	581	569	1 887	1 021	366	88
1999	3 282	3 818	5 593	2 721	489	771	2 146	1 069	316	216
2000	3 739	2 779	7 089	1 421	1 161	1 319	2 247	923	317	131
2001	3 467	2 724	6 629	818	1 007	1 153	2 304	977	258	80
2002	2 979	2 787	6 970	426	1 220	623	2 250	810	230	171
2003	3 375	2 150	7 205	183	892	932	1 980	807	280	180
2004	2 525	2 082	7 826	774	471	860	2 013	814	241	227
2005	1 913	2 440	7 870	276	894	50	1 558	871	200	282
2006	1 639	1 840	6 161	178	692	43	1 753	666	129	220
2007	2 322	1 880	7 504	34	651	237	1 306	933	107	189
2008	2 350	1 810	6 990	329	821	507	1 067	1 170	115	110
2009	1 534	2 217	5 225	276	432	275	1 089	1 009	108	39
2010	1 484	2 257	4 270	864	313	2	1 346	1 063	74	14
2011	1 500	2 200	4 500	450	450	–	–	–	–	–

Table 5: Input parameters for the assessed stocks.

Parameter	**LIN 3&4**	**LIN 5&6**	**LIN 6B**	**LIN 7WC**	**LIN 7CK**
Stock-recruitment steepness	0.9	0.9	0.9	0.9	0.9
Recruitment variability c.v.	0.6	0.6	1.0	0.6	0.7
Ageing error c.v.	0.05	0.06	0.05	0.05	0.07
Proportion male at birth	0.5	0.5	0.5	0.5	0.5
Proportion of mature that spawn	1.0	1.0	1.0	1.0	1.0
Maximum exploitation rate (U_{max})	0.6	0.6	0.6	0.6	0.6

Maturity ogives*

Age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
LIN 3&4 (and assumed for LIN 6B)													
Male	0.0	0.027	0.063	0.14	0.28	0.48	0.69	0.85	0.93	0.97	0.99	1.00	1.0
Female	0.0	0.001	0.003	0.006	0.014	0.033	0.08	0.16	0.31	0.54	0.76	0.93	1.0
LIN 5&6													
Male	0.0	0.022	0.084	0.27	0.61	0.86	0.96	0.99	1.00	1.0			
Female	0.0	0.001	0.004	0.015	0.06	0.22	0.55	0.84	0.96	1.0			
LIN 7WC (and assumed for LIN7CK)													
Male	0.0	0.015	0.095	0.39	0.77	0.94	1.00	1.00	1.00	1.0			
Female	0.0	0.004	0.017	0.06	0.18	0.39	0.65	0.85	0.94	1.0			

*Proportion mature at age

Table 6: Standardised CPUE indices (with c.v.s) for the ling line and trawl fisheries. Year refers to calendar year.

	LIN 3&4 line		LIN 5&6 line (spawn)		LIN 5&6 line (non-spawn)		LIN 7WC line		LIN 7CK line	
Year	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.
1990	–	–	–	–	–	–	0.92	0.06	0.73	0.16
1991	1.66	0.06	1.28	0.17	0.66	0.12	1.18	0.05	1.10	0.13
1992	2.15	0.05	1.75	0.14	1.01	0.09	1.16	0.04	1.10	0.11
1993	1.54	0.05	1.54	0.11	0.84	0.10	0.92	0.05	0.80	0.11
1994	1.54	0.05	1.33	0.11	0.74	0.09	0.93	0.04	0.71	0.11
1995	1.48	0.05	1.40	0.17	1.02	0.08	0.95	0.04	0.66	0.12
1996	1.19	0.04	1.28	0.11	0.85	0.08	0.78	0.04	0.79	0.13
1997	0.82	0.04	1.16	0.10	0.91	0.06	0.85	0.04	1.05	0.19
1998	0.89	0.04	0.99	0.11	0.79	0.06	0.93	0.04	0.73	0.15
1999	0.78	0.04	1.28	0.10	0.64	0.05	1.02	0.04	1.28	0.19
2000	0.92	0.04	1.32	0.10	0.76	0.07	0.98	0.04	1.45	0.19
2001	0.91	0.04	1.34	0.10	0.91	0.09	1.12	0.04	1.30	0.20
2002	0.74	0.04	1.55	0.10	0.79	0.10	1.06	0.05	1.91	0.11
2003	0.90	0.04	1.12	0.12	0.62	0.12	1.12	0.04	1.68	0.11
2004	0.74	0.04	1.03	0.09	0.57	0.09	1.10	0.05	1.42	0.10
2005	0.84	0.04	1.42	0.12	0.50	0.13	0.85	0.04	1.17	0.11
2006	0.71	0.04	1.29	0.12	0.61	0.14	0.86	0.05	0.94	0.16
2007	0.78	0.04	1.35	0.11	0.98	0.36	1.15	0.04	0.72	0.13
2008	0.99	0.05	1.02	0.14	1.05	0.12	1.14	0.05	0.90	0.22
2009	0.71	0.04	2.05	0.19	0.85	0.13	1.15	0.05	0.65	0.30
2010	0.88	0.04	0.69	0.18	0.85	0.09	–	–	–	–

	LIN 7CK trawl		LIN 7WC trawl		LIN 6B line	
Year	**CPUE**	**c.v.**	**CPUE**	**c.v.**	**CPUE**	**c.v.**
1990	–	–	0.84	0.08	–	–
1991	–	–	0.92	0.08	–	–
1992	–	–	1.59	0.09	1.80	0.13
1993	–	–	1.21	0.08	1.58	0.11
1994	1.03	0.05	1.22	0.08	1.07	0.13
1995	0.84	0.04	0.98	0.06	1.13	0.13
1996	0.80	0.04	0.96	0.08	1.05	0.12
1997	0.78	0.03	1.26	0.09	0.85	0.13
1998	0.77	0.03	0.76	0.06	1.03	0.12
1999	0.81	0.03	1.18	0.04	1.04	0.11
2000	0.93	0.03	0.96	0.03	0.95	0.10
2001	1.06	0.03	0.96	0.03	0.81	0.10
2002	0.98	0.04	0.81	0.03	0.72	0.10
2003	1.00	0.04	0.76	0.03	0.78	0.09
2004	0.81	0.04	0.89	0.03	0.71	0.14
2005	0.88	0.04	0.86	0.03	–	–
2006	0.85	0.04	0.83	0.03	0.97	0.36
2007	0.53	0.05	0.93	0.05	*1.12*	*0.12*
2008	0.55	0.06	0.86	0.05	*1.12*	*0.10*
2009	0.30	0.06	1.24	0.06	*0.80*	*0.11*
2010	–	–	–	–	–	–

Table 7: Biomass indices (t) and estimated coefficients of variation (c.v.).

Fishstock	Area	Vessel	Trip code	Date	Biomass	c.v. (%)
LIN 3 & 4	Chatham Rise	*Tangaroa*	TAN9106	Jan-Feb 1992	8 930	5.8
			TAN9212	Jan-Feb 1993	9 360	7.9
			TAN9401	Jan 1994	10 130	6.5
			TAN9501	Jan 1995	7 360	7.9
			TAN9601	Jan 1996	8 420	8.2
			TAN9701	Jan 1997	8 540	9.8
			TAN9801	Jan 1998	7 310	8.0
			TAN9901	Jan 1999	10 310	16.1
			TAN0001	Jan 2000	8 350	7.8
			TAN0101	Jan 2001	9 350	7.5
			TAN0201	Jan 2002	9 440	7.8
			TAN0301	Jan 2003	7 260	9.9
			TAN0401	Jan 2004	8 250	6.0
			TAN0501	Jan 2005	8 930	9.4
			TAN0601	Jan 2006	9 300	7.4
			TAN0701	Jan 2007	7 800	7.2
			TAN0801	Jan 2008	7 500	6.8
			TAN0901	Jan 2009	10 620	11.5
			TAN1001	Jan 2010	8 850	10.0
			TAN1101	Jan 2011	7 030	13.8
			TAN1201	Jan 2012	8 098	7.4
LIN 5 & 6	Southern Plateau	*Amaltal Explorer*	AEX8902	Oct–Nov 1989	17 490	14.2
			AEX9002	Nov–Dec 1990	15 850	7.5
LIN 5 & 6	Southern Plateau (summer)	*Tangaroa*	TAN9105	Nov-Dec 1991	24 090	6.8
			TAN9211	Nov-Dec 1992	21 370	6.2
			TAN9310	Nov-Dec 1993	29 750	11.5
			TAN0012	Dec 2000	33 020	6.9
			TAN0118	Dec 2001	25 060	6.5
			TAN0219	Dec 2002	25 630	10.0
			TAN0317	Nov-Dec 2003	22 170	9.7
			TAN0414	Nov-Dec 2004	23 770	12.2
			TAN0515	Nov-Dec 2005	19 700	9.0
			TAN0617	Nov-Dec 2006	19 640	12.0
			TAN0714	Nov-Dec 2007	26 492	8.0
			TAN0813	Nov-Dec 2008	22 840	9.5
			TAN0911	Nov-Dec 2009	22 710	9.6
			TAN1117	Nov-Dec 2011	23 178	11.8
LIN 5 & 6	Southern Plateau (autumn)	*Tangaroa*	TAN9204	Mar-Apr 1992	42 330	5.8
			TAN9304	Apr-May 1993	37 550	5.4
			TAN9605	Mar-Apr 1996	32 130	7.8
			TAN9805	Apr-May 1998	30 780	8.8
LIN 7WC	WCSI	*Kaharoa*	KAH9204	Mar-Apr 1992	286	19
			KAH9404	Mar-Apr 1994	261	20
			KAH9504	Mar-Apr 1995	367	16
			KAH9701	Mar-Apr 1997	151	30
			KAH0004	Mar-Apr 2000	95	46
			KAH0304	Mar-Apr 2003	150	33
			KAH0503	Mar-Apr 2005	274	37
			KAH0704	Mar-Apr 2007	180	27
			KAH0904	Mar-Apr 2009	291	37
			KAH1104	Mar-Apr 2011	235	43

4.2 Chatham Rise, LIN 3 & LIN 4

4.2.1 Model structure and inputs

The stock assessment for LIN 3&4 (Chatham Rise) was updated in 2011. For final model runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2011}) biomass were obtained. Year class strengths and fishing selectivity ogives were estimated in the model. Trawl fishery and research survey selectivity ogives were fitted as double normal curves; line fishery ogives were fitted as logistic curves. MCMC chains were constructed using a burn-in length of 5×10^5 iterations, with every 1000th sample taken from the next 10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 3&4, model input data included catch histories, biomass and sexed catch-at-age data from a summer trawl survey series, sexed catch-at-age from the trawl fishery, line fishery CPUE, unsexed catch-at-age and catch-at-length from the line fishery, and estimates of biological parameters. The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 4–7. The stock assessment model partitioned the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 8.

Table 8: LIN 3&4 — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	M^1	Age[2]	Description	$\%Z^3$
1	Dec–Aug	Recruitment fisheries (line & trawl)	0.9	0.5	Trawl survey (summer)	0.2
					Line CPUE	0.5
					Line catch-at-age/length	
					Trawl catch-at-age	
2	Sep–Nov	Spawning and increment ages	0.1	0	–	

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occurred by the start of that time step.
3. %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Most priors were intended to be uninformed, and were specified with wide bounds. The exception was an informative prior for the trawl survey *q*. The prior on *q* for all the *Tangaroa* trawl surveys was estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30. Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

Investigative model runs identified a conflict between the line fishery CPUE and the trawl survey biomass index, where the line fishery biomass index declined between 1991 and 1997, but the trawl survey index remained relatively flat throughout. This difference could not be resolved in a single model run by assuming different selectivity ogives for each biomass index. Therefore, to remove this conflict, a base case model run (Base) used all the observational data except those from the line fishery; the trawl survey biomass index being preferred in the base case because these data were fishery independent. A sensitivity run (NoTrawl) then included the line fishery data, and excluded the trawl survey data.

The error distributions assumed were multinomial for the at-age and at-length data, and lognormal for all other data. The weight assigned to each data set was controlled by the error coefficient of variation (CV). The observation-error CVs were calculated using standard formulae. An additional process error CV of 0.2 was added to the trawl survey biomass index following Francis *et al*. (2001), and a process error CV for the line fishery CPUE was estimated at 0.15 following Francis (2011). The multinomial observation error CVs for the at-age and at-length data were then adjusted using the reweighting procedure of Francis (2011). Reweighting of the at-age and at-length data was completed for the base and sensitivity runs separately.

4.2.2 Model estimates

The fits to the biomass indices, catch-at-age and catch-at-length data, were reasonable to good in all model runs, with generally balanced residuals. Posterior distributions of year class strength estimates from the base case model run are shown in Figure 2; the distribution from the NoTrawl run differed little from the base case. Since 1980, year class strengths were below average except for a period between 1994 and 1999, and in 2007. Estimated year class strengths were not widely variable, with all medians being between 0.5 and 2. Ling were first caught by the trawl survey (mean selectivity A_{50} of

5.2 years), then the trawl fishery (mean A_{50} of 8.0 years), and then the line fishery (A_{50} of 11.0 years). Males were estimated to be less vulnerable than females to the trawl and line fisheries. The estimated median *M* was 0.15.

The assessment is driven by the catch history, and by catch-at-age data, which contain information indicative of a stock decline during the 1990s. This is supported by a declining trend in the line fishery CPUE index during that time. .

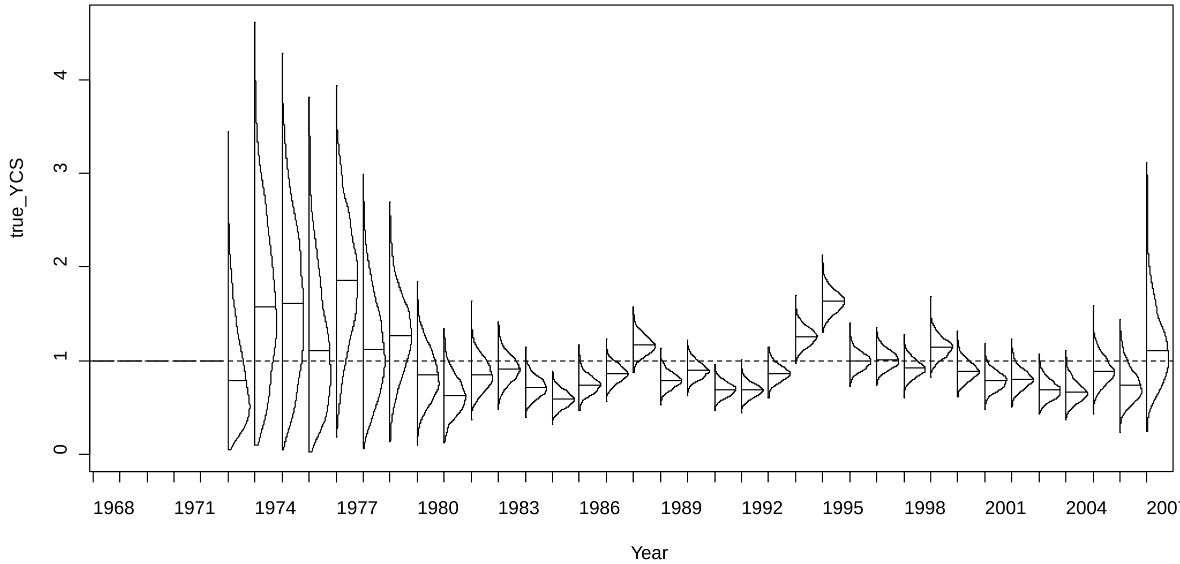


Figure 2: LIN 3&4 — Estimated posterior distributions of year class strength for the base model. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Although estimates of current and virgin stock size were imprecise, it was unlikely that B_0 was lower than 110 000 t for this stock, and very likely that biomass in 2011 was greater than 44% of B_0 (Table 9).

Table 9: LIN 3&4 — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2011} (in tonnes), and B_{2011} as a percentage of B_0 for both model runs.

Model run	B_0		B_{2011}		B_{2011} (% B_0)	
Base	127 400	(110 400–170 300)	70 800	(48 600–121 900)	55	(44–71)

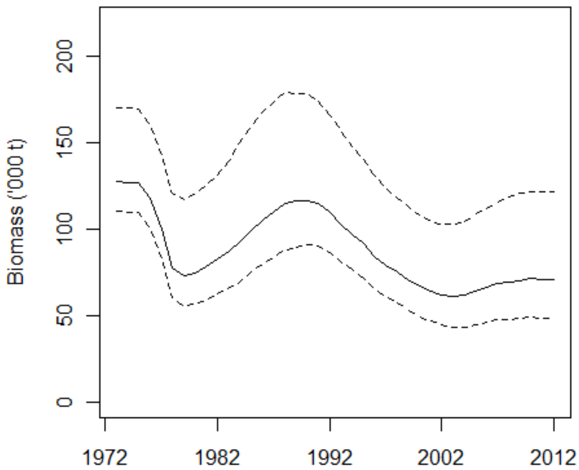


Figure 3: LIN 3&4 — Estimated posterior distributions of the biomass trajectory (in tonnes) from the Base run. Broken lines show the 95% credible intervals and the solid line the median.

The model indicated an increasing biomass since 2004 (driven by a reduction in catch). Annual landings from the LIN 3&4 stock have been less than 4600 t since 2004, markedly lower than the 6000–8000 t taken annually between 1992 and 2003. Biomass projections derived from this assessment are shown below (Section 4.9).

4.3 Sub-Antarctic, LIN 5 & LIN 6 (excluding Bounty Plateau)

4.3.1 Model structure and inputs

The stock assessment for LIN 5&6 (Sub-Antarctic) was updated in 2011. For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2011}) biomass were obtained. Year class strengths and fishing selectivity ogives were also estimated in the model. Trawl fishery selectivity ogives were fitted as double normal curves; line fishery and research survey ogives were fitted as logistic curves. Selectivities were assumed constant over all years in each fishery/survey.

MCMC chains were constructed using a burn-in length of 5×10^5 iterations, with every 2500th sample taken from the next 2.5×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 5&6, model input data include catch histories, biomass and catch-at-age data from summer and autumn trawl survey series, two line fishery CPUE series (from the spawning and home ground fisheries), catch-at-age from the spawning ground and home ground line fisheries, catch-at-age data from the trawl fishery, and estimates of biological parameters. A base case model run incorporated all the data except the CPUE series is presented, with a sensitivity run including the CPUE series. The stock assessment model partitions the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 12.

Table 10: LIN 5&6 — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	**Period**	**Processes**	***M*[1]**	**Age[2]**	**Description**	**%*Z*[3]**
1	Dec–Aug	Recruitment Non-spawning fisheries (trawl & line)	0.75	0.4	Trawl survey (summer) Trawl survey (autumn) Line CPUE (non-spawn) Line (non-spawn) catch-at-age Trawl catch-at-age	0.1 0.5 0.7
2	Sep–Nov	Increment ages Spawning fishery (line)	0.25	0.0	Line CPUE (spawning) Line (spawning) catch-at-age	0.5

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. $\%Z$ is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Lognormal errors, with known CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. The CVs available for those observations of relative abundance and catch data allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in MPD runs of the model (Table 13) and fixed in all subsequent runs.

The assumed prior distributions used in the assessment are given in Table 14. Most priors were intended to be relatively uninformed, and were specified with wide bounds. The exceptions were the choice of informative priors for the trawl survey q. The priors on q for all the *Tangaroa* trawl surveys were estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30.

Table 11: LIN 5&6 — Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
Trawl survey proportion at age (*Amaltal Explorer*, Nov)	1990	0.15
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–10	0.01
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–10	0.15
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.01
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.01
CPUE (longline, spawning fishery)	1991–2010	0.18
CPUE (longline, non-spawning fishery)	1991–2010	0.18
Commercial longline proportion-at-age (spawning, Oct–Dec)	2000–08, 2010	0.3
Commercial longline proportion-at-age (non-spawn, Feb–Jul)	1999, 2001, 2003, 2005, 2009, 2010	0.3
Commercial trawl proportion-at-age (Sep–Apr)	1992–94, 1996, 1998, 2001–10	0.3

Table 12: LIN 5&6 — Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters for lognormal priors are mean (in log space) and c.v.

Parameter description	Distribution	Parameters		Bounds	
B_0	Uniform-log	–	–	50 000	800 000
Year class strengths	Lognormal	1.0	0.70	0.01	100
Trawl survey q	Lognormal	0.13	0.70	0.02	0.3
CPUE q	Uniform-log	–	–	1e-8	1e-3
Selectivities	Uniform	–	–	0	20–200*
Process error c.v.	Uniform-log	–	–	0.001	2
M (x_0, y_0, y_1, y_2)	Uniform	–	–	3, 0.01, 0.01, 0.01	15, 0.6, 1.0, 1.0

* A range of maximum values were used for the upper bound

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 4–7.

4.3.2 Model estimates

Descriptions of two model runs reported are as follows.

- Base case — catch history, all relative abundance series listed in Tables 4, 6, and 7, *M* estimated as an ogive independent of sex, double-normal selectivity ogives for the trawl fishery, logistic ogives for the line fisheries and the resource survey series.
- CPUE — the base case model, but incorporating the two line fishery CPUE series.

Three other sensitivities were investigated: (1) splitting the summer survey series into early (1992–2006) and recent (2007–09) series with independent *q*s, (2) excluding the 2001 survey biomass point, and (3) fitting the survey ogives as double-normal. These models all produced estimates of stock status that were little different to those from the reported models.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 4; the distribution from the CPUE model run differed little from the base case. Year classes were generally weak from 1982 to 1992, strong from 1993 to 1996, and average since then (although 2005 may be strong). Overall, estimated year class strengths were not widely variable, with all medians being between 0.5 and 2. Consequently, biomass estimates for the stock declined through the 1990s, but have exhibited an upturn during the last 12 years (Figure 5). The biomass trajectory from the CPUE model was little different to that derived from the base case.

Biomass estimates for the stock appear very healthy, with estimated current biomass from the two reported models at about 89% of B_0 (Figure 5, Table 15). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.06) in all years as a consequence of the high estimated stock size in relationship to the level of relative catches.

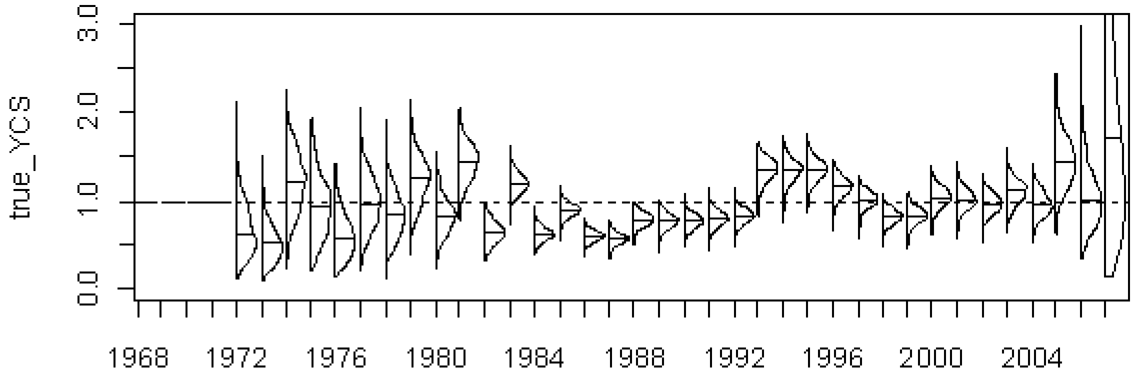


Figure 4: LIN 5&6 — Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

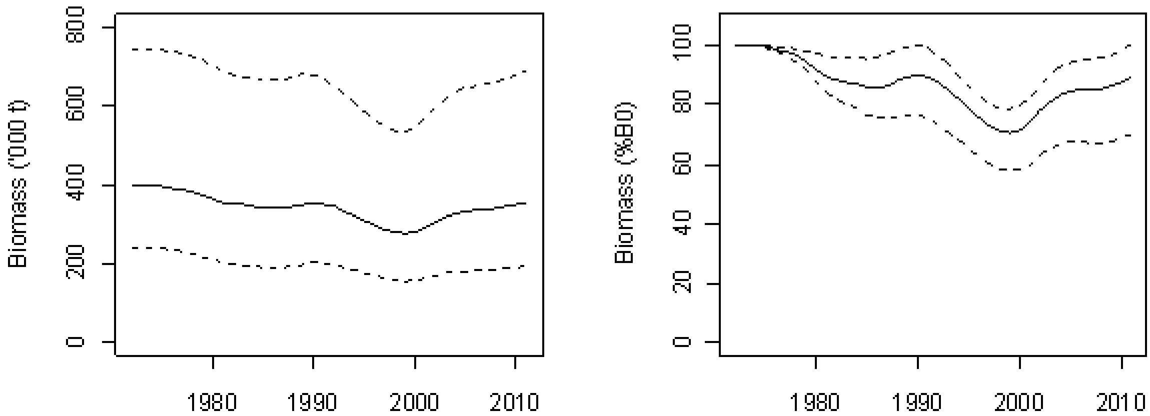


Figure 5: LIN 5&6 — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0 from the base case model run.

Table 13: LIN 5&6 — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2011} (in tonnes), and B_{2011} as a percentage of B_0 for both model runs.

Model run	B_0		B_{2011}		B_{2011} (% B_0)	
Base case	395 660	(240 210–740 790)	355 190	(195 430–689 960)	89.2	(69.8–100.6)
CPUE	442 400	(258 010–763 190)	399 260	(214 270–703 600)	89.8	(74.1–100.3)

Resource survey and fishery selectivity ogives were relatively tightly defined. The survey ogive suggested that ling were fully selected by the research gear at about age 7–9. Fishing selectivities indicated that ling were fully selected by the trawl fishery at about age 9 years, and by the line fisheries at about age 12–16.

The assessment relied on biomass data from the Sub-Antarctic trawl survey series. The summer survey series was not particularly well fitted and had clear patterns in the residuals (Figure 6). It was also apparent that there can be marked changes in catchability between adjacent pairs of surveys. Estimated trawl survey catchability constants were moderately low (about 4–15% based on doorspread swept area estimates), but are consistent with the priors.

The assessments indicated a biomass trough about 1999, and some recovery since then. Although estimates of current and virgin stock size are very imprecise, it is most unlikely that B_0 was lower than 200 000 t for this stock, and it is very likely that current biomass is greater than 70% of B_0. Probabilities that current and projected biomass will drop below selected management reference points are shown in Table 16.

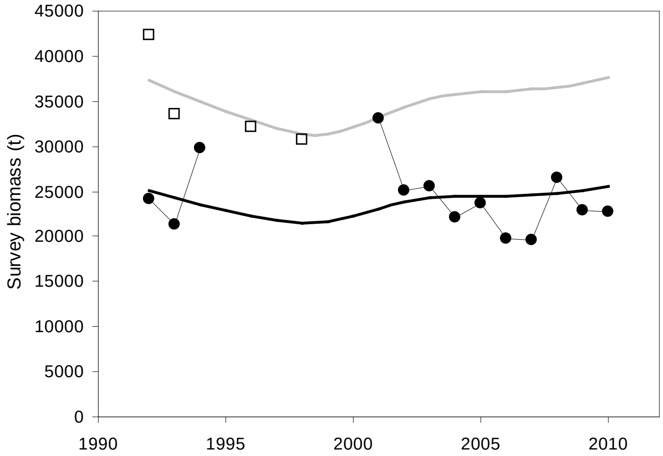


Figure 6: LIN 5&6 — Observed relative biomass from the autumn (open squares) and summer (filled circles) research trawl surveys. Survey biomass trajectories estimated in the base case model are also shown for the autumn (grey line) and summer (black line) surveys.

Table 14: LIN 5&6 — Probabilities that current (B_{2011}) and projected (B_{2016}) biomass will be less than 40%, 20% or 10% of B_0. Projected biomass probabilities are presented for the base case model using two scenarios of future annual catch (i.e., 5900 t, and 12 100 t).

Biomass	**Management reference points**		
	40% B_0	20% B_0	10% B_0
B_{2011}	0.000	0.000	0.000
B_{2016}, 5900 t catch	0.000	0.000	0.000
B_{2016}, 12 100 t catch	0.000	0.000	0.000

Estimates of biomass projections derived from this assessment are shown below (Section 4.9). The relatively high level of uncertainty in the model precluded any updated estimation of *MCY* and *CAY* (although an *MCY* was estimated in the 2007 assessment, as is reported below).

4.4 Bounty Plateau, LIN 6B (Bounty Plateau only)

4.4.1 Model structure and inputs

The stock assessment for the Bounty Plateau stock (part of LIN 6) was updated in 2006. For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2007}) biomass were obtained. Year class strengths and fishing selectivity ogives were also estimated in the model. Line fishery ogives were fitted as logistic curves.

MCMC chains were constructed using a burn-in length of 5×10^5 iterations, with every 1000th sample taken from the next 10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 6B, model input data include catch histories, line fishery CPUE, catch-at-age and catch-at-length from the line fishery, and estimates of biological parameters. In the absence of sufficient stock-specific data, maturity ogives were assumed to be the same as for LIN 3&4, a stock with comparable growth parameters to LIN 6B. Only a base case model run is presented. The stock assessment model partitions the population into two sexes, and age groups 3 to 35 with a plus group. There is one fishery (longline) in the stock. The model's annual cycle is described in Table 16.

Lognormal errors, with known CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. The CVs available for those observations of relative abundance and catch data allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in MPD runs of the model (Table 17) and fixed in all subsequent runs.

Table 15: LIN 6B — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	**Period**	**Processes**	**M^1**	**Age[2]**	**Description**	**$\%Z^3$**
1	Dec–Sep	recruitment	0.9	0.5	Line CPUE	0.5
		fisher y (line)			Line catch-at-age/length	0.5
2	Oct–Nov	increment ages	0.1	0	–	

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. $\%Z$ is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 16: LIN 6B — Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
CPUE (longline, all year)	1992–2004	0.15
Commercial longline length-frequency (Nov–Feb)	1996, 2000–04	0.5
Commercial longline proportion-at-age (Dec–Feb)	2000–01, 2004	0.4

The assumed prior distributions used in the assessment are given in Table 18. All priors were intended to be relatively uninformed, and were estimated with wide bounds.

Table 17: LIN 6B — Assumed prior distributions and bounds for estimated parameters for the assessments. The parameters are mean (in log space) and CV for lognormal.

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	5000	100 000
Year class strengths	lognormal	1.0	0.7	0.01	100
CPUE q	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	20–200
Process error CV	uniform-log	–	–	0.001	2

* A range of maximum values were used for the upper bound

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 4–7.

4.4.2 Model estimates

Only a base case model run was completed.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 7.

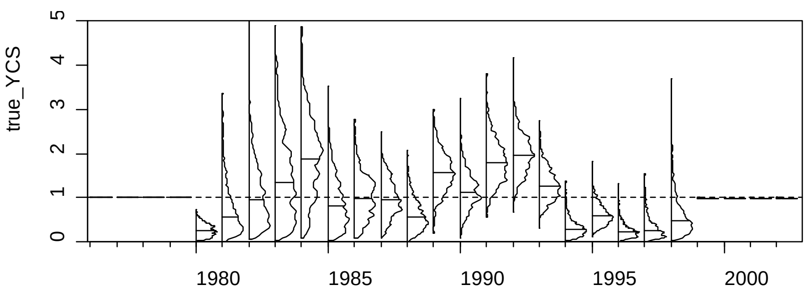


Figure 7: LIN 6B — Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment was driven largely by the catch-at-age and catch-at-length series from the line fishery; the first two years of CPUE data were not well fitted. Biomass estimates are listed in Table 19 and the biomass trajectory is shown in Figure 8. The assessment indicates a declining biomass throughout the history of the fishery. Estimates of current and virgin stock size are not well known, but current biomass is very likely to be above 50% of B_0.

Table 18: LIN 6B — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2006} (in t), and B_{2006} as a percentage of B_0 for the base case model run.

Model run	B_0		B_{2006}		B_{2006} (% B_0)	
Base case	13 570	(10 850–19 030)	8 330	(4 860–14 730)	61	(45–79)

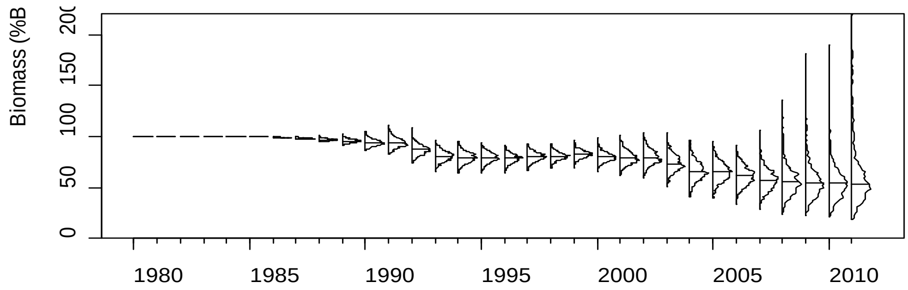


Figure 8: LIN 6B — Estimated posterior distributions of biomass trajectories as a percentage of B_0, from the base case model run (including 5-year projections through to 2011 with assumed constant annual catch of 400 t). Distributions are the marginal posterior distribution, with horizontal lines indicating the median.

Estimates of *MCY*, *CAY*, and biomass projections derived from this assessment are shown below (Sections 4.7–4.9).

4.5 West coast South Island, LIN 7WC

4.5.1 Model structure and inputs

The stock assessment for LIN 7WC (west coast South Island) was updated in 2008. The stock assessment model partitions the population into two sexes, and age groups 3 to 28 with a plus group. The model's annual cycle is described in Table 20.

Year class strengths and fishing selectivity ogives were also estimated in the model. Commercial trawl and research survey selectivities were fitted as double normal curves; line fishery ogives were fitted as logistic curves.

For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2008}) biomass were obtained. MCMC chains were constructed using a burn-in length of 2×10^6 iterations, with every 4000th sample taken from the next 4×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). Single chain convergence tests were applied to resulting chains to determine evidence of non-convergence. No evidence of lack of convergence was found in the estimates of B_0 from the base case model runs, or in the sensitivity runs, but some estimates of selectivity parameters and YCS showed evidence of lack of convergence.

For LIN 7WC, model input data include catch histories, trawl and line fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age and catch-at-length from the line fishery, survey biomass estimates from a multi-survey *Kaharoa* series and a single *Tangaroa* survey, and estimates of biological parameters. The base case used all catch-at-age and catch-at-length data from the fisheries, but no series of relative abundance. Sensitivity runs investigated the signal from the *Tangaroa* trawl survey in 2000 and the effects of using a low value of instantaneous natural mortality (i.e., M = 0.15, replacing the value of 0.22 used in the other runs).

Table 19: LIN 7WC — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

Step	Period	Processes	M[1]	Age[2]	Observations: Description	Observations: %Z[3]
1	Oct–May	Recruitment	0.75	0.5		0.5
		fishery (line)			Line catch-at-age/length	
2	Jul–Sep	increment ages	0.25	0		0.5
		fishery (trawl)			Trawl catch-at-age	

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. %Z is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Lognormal errors, with known CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. The CVs available for those observations of relative abundance and catch data allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in MPD runs of the model (Table 21) and fixed in all subsequent runs.

Table 20: LIN 7WC — Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
CPUE (hoki trawl, Jun–Sep)	1999–2007	0.2
CPUE (longline, all year)	1990–2007	0.2
Commercial trawl proportion-at-age (Jun–Sep)	1991, 1994–2007	0.25
Commercial longline proportion-at-age	2003	0.15
Commercial longline length-frequency	2006	0.25
Trawl survey biomass (*Kaharoa*, Mar–Apr)	1992, 94, 95, 97, 2000, 03, 05, 07	0.3
Trawl survey proportion-at-length (*Kaharoa*, Mar–Apr)	1992, 94, 95, 97, 2000, 03, 05, 07	0.35
Trawl survey biomass (*Tangaroa*, July)	2000	0.2

The assumed prior distributions used in the assessment are given in Table 22. Most priors were intended to be relatively uninformed, and were specified with wide bounds. The exception was the choice of informative priors for the *Tangaroa* trawl survey q. The priors on q for the *Tangaroa* trawl survey were estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30. However, the *Tangaroa* survey off WCSI is estimated to have covered only one-third of the likely ling habitat. Consequently, for this survey, the priors were a lognormal distribution with a mean of 0.043 (i.e., 0.13 × 0.33), CV of 0.7, and bounds of 0.01 to 0.20.

Table 21: LIN 7WC — Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters are mean (in log space) and c.v. for lognormal, and mean and standard deviation for normal.

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	10 000	500 000
Year class strengths	lognormal	1.0	0.7	0.01	100
Tangaroa survey q	lognormal	0.043	0.70	0.01	0.2
Kaharoa survey q	uniform-log	–	–	0.001	10
CPUE q	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	20–200*
Process error c.v.	uniform-log	–	–	0.001	2
M	normal	0.20	0.07	0.1	0.3

* A range of maximum values was used for the upper bound

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 4–7.

4.5.2 Model estimates

Descriptions of the three LIN 7WC model runs presented are as follows.

- Base case — catch history, trawl and line fishery catch-at-age, with double-normal ogives for the trawl fishery and logistic ogives for the line fishery, and M = 0.22.
- *Tangaroa* survey — the base case model, but including the *Tangaroa* biomass estimate.
- M = 0.15 — the base case model, but setting M = 0.15.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 9; distributions from the sensitivity runs differed little from this example.

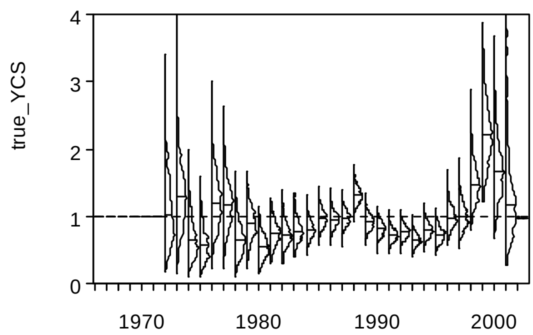


Figure 9: LIN 7WC — Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment is driven by the trawl fishery catch-at-age data, which contains information indicative of a slight but steady stock decline from the mid 1980s to the early 2000s. The *Tangaroa* survey point provides little additional information to the model; median estimates of absolute biomass are slightly higher than in the base case, but the credible intervals are much wider (Table 23, Figure 10). Reductions in M result in more pessimistic assessments; estimates of absolute biomass and current stock status as a percentage of B_0 decline with declining M values. An M of 0.15 is likely to be near the bottom of the logical range of this parameter for ling.

Model runs fitting to the line and trawl CPUE series and to the *Kaharoa* survey series were also completed, but are not reported here. The inshore *Kaharoa* survey sampled a very small fraction of the LIN 7WC population, and so provided little information to the model. The line CPUE series is flat, but very variable, and resulted in unrealistically high estimates of biomass. This series may be indicative of hyper-stable catch rates in the line fishery. The inclusion of the trawl CPUE series had little influence on the base case biomass trajectory, suggesting that the model output is dominated by the catch-at-age proportions.

All model runs indicated a biomass decline from 1985 to 2005, followed by an increase (driven by the recruitment of some average to strong year classes). Estimates of current and virgin stock vary little in the presented assessments, but are still very uncertain owing to the lack of abundance indices in the basecase and the dominance of the catch at age data on model outputs.

Estimates of biomass projections derived from this assessment are shown below (Section 4.9). The relatively high level of uncertainty in the model precluded any updated estimation of *MCY* and *CAY*.

Table 22: LIN 7WC — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2008} (in tonnes), and B_{2008} as a percentage of B_0 for all model runs.

Model run	B_0		B_{2008}		B_{2008} (% B_0)	
Base case	66 110	(55 100–88 500)	45 960	(30 810–72 570)	69	(56–85)
Tangaroa survey	70 630	(56 570–119 160)	51 240	(33 490–102 300)	72	(58–89)
M = 0.15	57 210	(46 060–77 600)	24 800	(13 870–44 690)	43	(29–58)

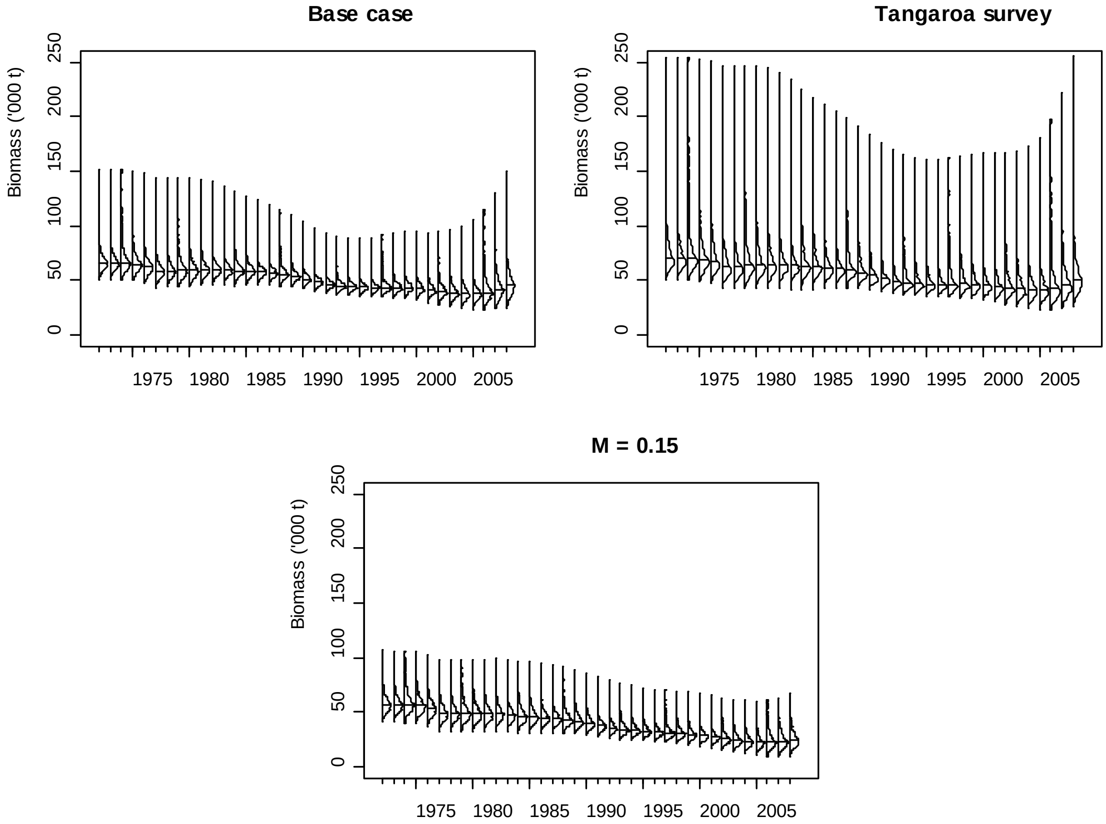


Figure 10: LIN 7WC — Estimated posterior distributions of the biomass trajectory (in tonnes) from the three model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

4.6 Cook Strait, LIN 7CK

4.6.1 Model structure and inputs

The stock assessment for LIN 7CK (Cook Strait) was updated in 2010. The stock assessment model partitions the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 24. Year class strengths and fishing selectivity ogives were also estimated in the model. Commercial trawl selectivity was fitted as double normal curves; line fishery ogives were fitted as logistic curves.

For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2008}) biomass were obtained. MCMC chains were constructed using a burn-in length of 4×10^6 iterations, with every 2000th sample taken from the next 20×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 7CK, model input data include catch histories, trawl and line fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the line fishery, and estimates of biological parameters. Initial modelling investigations found that the line CPUE produced implausible results; this series was rejected as a useful index. The base case used all catch-at-age data from the fisheries, and the trawl CPUE series. Instantaneous natural mortality was estimated in the model.

Lognormal errors, with known CVs, were assumed for all CPUE and proportions-at-age observations. The CVs available for those observations allow for sampling error only. However, additional variance (termed process error), assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance (Table 25).

Table 23: LIN 7CK — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	**Period**	**Processes**	***M*[1]**	**Age[2]**	**Description**	**%*Z*[3]**
1	Oct–May	Recruitment fishery (line)	0.67	0.5	Line CPUE Line catch-at-age	0.5
2	Jun–Sep	increment ages fishery (trawl)	0.33	0	Trawl CPUE Trawl catch-at-age	0.5

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. $\%Z$ is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 24: LIN 7CK — Summary of the available data including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
CPUE (hoki trawl, Jun–Sep)	1994–2009	0.2
Commercial trawl proportion-at-age (Jun–Sep)	1999–2009	1.1
Commercial longline proportion-at-age	2006–7	1.1

The assumed prior distributions used in the assessment are given in Table 26. Most priors were intended to be relatively uninformed, and were specified with wide bounds.

Table 25: LIN 7CK — Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters are mean (in log space) and c.v. for lognormal, and mean and standard deviation for normal.

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	2 000	60 000
Year class strengths	lognormal	1.0	0.9	0.01	100
CPUE q	uniform-log	–	–	1e-8	1e-2
Selectivities	uniform	–	–	0	20–200*
M	lognormal	0.18	0.16	0.1	0.3

* A range of maximum values was used for the upper bound

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 4–7.

4.6.2 Model estimates

A single model was presented incorporating a catch history, trawl and line fishery catch-at-age, trawl CPUE series, with double-normal ogives for the trawl fishery and logistic ogives for the line fishery, and M estimated in the model.

Posterior distributions of LIN 7CK year class strength estimates from the base case model run are shown in Figure 11.

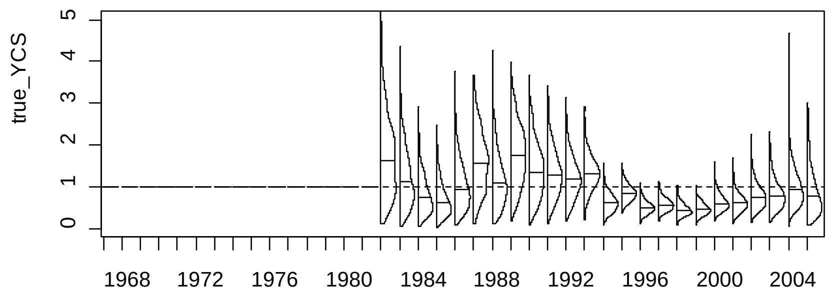


Figure 11: LIN 7CK — Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment is driven by the trawl fishery catch-at-age data and tuned by the trawl CPUE. Both input series contain information indicative of an overall stock decline in the last two decades. The confidence bounds around biomass estimates are wide (Table 27, Figure 12). Probabilities that current and projected biomass will drop below selected management reference points are shown in Table 28. Median *M* was estimated to be 0.24 (95% confidence interval 0.16–0.30). Estimates of biomass are very sensitive to small changes in *M*, but clearly there is information in the model encouraging an *M* higher than the 'default' value of 0.18. The model indicated a slight overall biomass decline to about 2000, followed by a much steeper decline from 2000 to 2010. Exploitation rates (catch over vulnerable biomass) were very low up to the late 1980s, and have been low to moderate (up to about 0.12 yr^{-1}) since then (Figure 13). Since the early 1990s, trawl fishing pressure has generally declined, while line pressure has generally increased.

Table 26: LIN 7CK — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2010} (in tonnes), and B_{2010} as a percentage of B_0 for all model runs.

Model run	B_0		B_{2010}		B_{2010} (%B_0)	
Base case	8 070	(5 290–53 080)	4 370	(1 250–40 490)	54	(23–80)

Table 27: LIN 7CK — Probabilities that current (B_{2010}) and projected (B_{2015}) biomass will be less than 40%, 20% or 10% of B_0. Projected biomass probabilities are presented for two scenarios of future annual catch (i.e., 220 t, and 420 t).

Biomass	**Management reference points**		
	40% B_0	20% B_0	10% B_0
B_{2010}	0.248	0.006	0.000
B_{2015}, 220 t catch	0.179	0.010	0.000
B_{2015}, 420 t catch	0.328	0.094	0.019

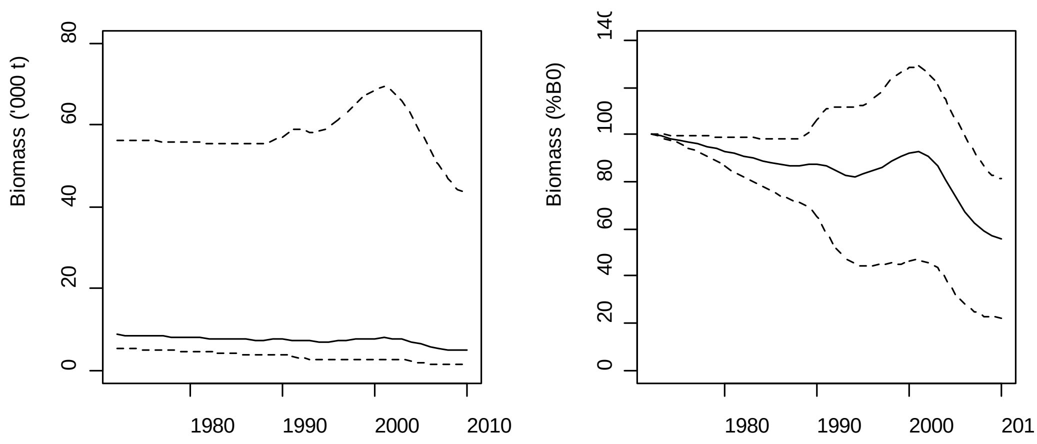


Figure 12: LIN 7CK — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

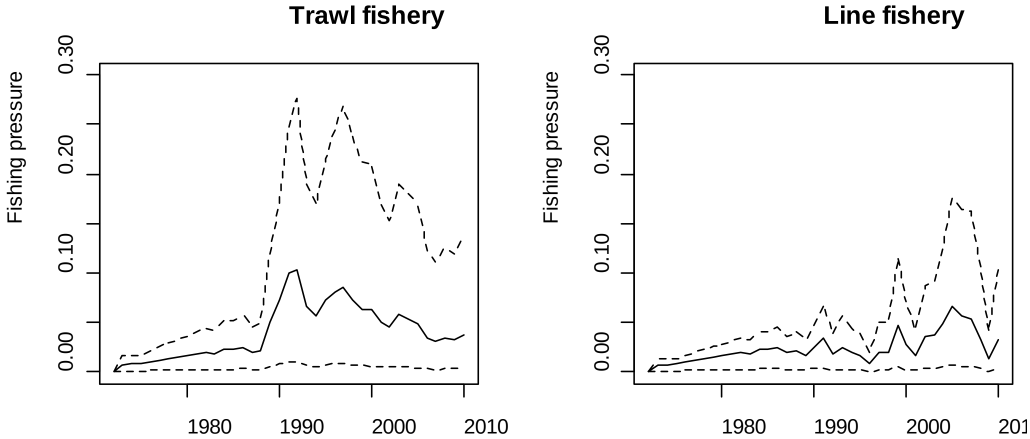


Figure 13: LIN 7CK — Estimated median trajectories (with 95% credible intervals shown as dashed lines) of fishery exploitation rates.

Estimates of biomass projections derived from this assessment are shown below (Section 4.9). The relatively high level of uncertainty in the model precluded any updated estimation of *MCY* and *CAY* (although an *MCY* was estimated in the 2007 assessment, as is reported below).

4.7 Estimation of Maximum Constant Yield (*MCY*)
None.

4.8 Estimation of Current Annual Yield (*CAY*)
None.

4.9 Other yield estimates and stock assessment results
Projections for LIN 6B from the 2006 assessment are shown in Table 31. The LIN 6B stock (Bounty Plateau) is likely to decline out to 2011, but probably will still be higher than 50% of B_0. Projections from 2008 out to 2013 for LIN 7WC, assuming future annual catches equal to the TACC, are shown in Table 32. They indicate that the biomass increase that began about 2005 is likely to continue to 2013, with even the most pessimistic assessment projecting biomass to be higher than 50% of B_0 by then. Projections out to 2015 for LIN 7CK indicate that biomass is likely to increase with future catches equal to recent catch levels, or decline slightly if catches are equal to the mean since 1990 (Table 33). New projections made in 2011 out to 2016 for LIN 3&4 and 5&6, assuming future annual catches equal to recent catch levels, are shown in Table 34. For LIN 3&4, stock size is likely to remain about the same. For LIN 5&6, stock size is likely to increase slightly.

Table 28: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2011}, B_{2011} as a percentage of B_0, and B_{2011}/B_{2006} (%) for the base case LIN 6B.

Stock and model run		Future catch (t)	B_{2011}		B_{2011} (% B_0)		B_{2011}/B_{2006} (%)	
LIN 6B	Base case	600	7 460	(2 950–18 520)	53	(26–116)	86	(51–168)

Table 29: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2013}, B_{2013} as a percentage of B_0, and B_{2013}/B_{2008} (%) for the LIN 7WC base case and sensitivity runs.

Stock and model run		Future catch (t)	B_{2013}		B_{2013} (% B_0)		B_{2013}/B_{2008} (%)	
LIN 7WC	Base case	2 225	58 900	(37 580–97 670)	89	(67–112)	127	(108–150)
	Tangaroa survey	2 225	65 920	(41 830–133 050)	93	(71–118)	127	(111–151)
	M = 0.15	2 225	31 620	(15 200–61 350)	55	(33–80)	127	(104–151)

5. ANALYSIS OF ADAPTIVE MANAGEMENT PROGRAMMES (AMP)

The Ministry of Fisheries revised the AMP framework in December 2000. The AMP framework is intended to apply to all proposals for a TAC or TACC increase, with the exception of fisheries for which there is a robust stock assessment. In March 2002, the first meeting of the new Adaptive Management Programme Working Group was held. Two changes to the AMP were adopted:

- a new checklist was implemented with more attention being made to the environmental impacts of any new proposal
- the annual review process was replaced with an annual review of the monitoring requirements only. Full analysis of information is required a minimum of twice during the 5 year AMP.

Table 30: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2015}, B_{2015} as a percentage of B_0, and B_{2015}/B_{2010} (%) for the base case LIN 7CK run.

Stock and model run		Future catch (t)	B_{2015}		B_{2015} (% B_0)		B_{2015}/B_{2010} (%)	
LIN 7CK	Base case	220	5 030	(1 310–43 340)	59	(24–97)	110	(82–158)
		420	4 320	(590–42 910)	52	(11–92)	95	(45–136)

Table 31: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2016}, B_{2016} as a percentage of B_0, and B_{2016}/B_{2011} (%) for the LIN 3&4 and 5&6 base case and sensitivity runs.

Stock and model run		Future catch (t)	B_{2016}		B_{2016} (% B_0)		B_{2016}/B_{2011} (%)	
LIN 3&4	Base	3 900	69 900	(45 500–122 000)	55	(41–72)	98	(87–111)
LIN 5&6	Base case	5 900	409 400	(210 350–963 680)	103	(84–149)	114	(94–211)
	CPUE	5 900	464 310	(213 840–973 870)	104	(85–141)	114	(94–181)

LIN 1

In October 2002, the TACC for LIN 1 was increased from 265 t to 400 t within the AMP. A full-term review of the LIN 1 AMP was carried out in 2007.

Mid-term Review 2009 (AMP WG/09/09)

Fishery Characterization

- LIN1 entered the QMS in 1986-87 at a TACC of 200 t, which was increased to 238 t in 1988–89 and 265 t in 1989–90, probably due to the quota appeal process. LIN 1 catches remained slightly under the TACC up to 1994–94, but then exceeded the TACC, reaching ~300 t over most of the period 1996–97 to 2001–02. LIN 1 entered the AMP programme in 2002–03, with a TACC increase from 265 t to 400 t.
- After implementation of the AMP, catches dropped back to the previous TACC level for two years, and then increased to 364 t by 2005–06, dipped to 201 t in 2006–07, and increased to 381 t in 2007–08, the highest catch level over the data series.
- 53% of LIN 1 landings come from the bottom trawl fishery and a further 46% by bottom longline since 1989–90. The remaining methods account for < 2% of the total landings.
- Most BT and BLL landings come from the Bay of Plenty. The majority of bottom trawl catches are taken in Statistical Areas 008 to 010, although there have been significant bottom trawl catches of ling on the west coast of the North Island in some years in Areas 046 to 048. There were substantial ling by-catches made by trawl on the North Island west coast from 1996–97 to 2000–01 in the gemfish fishery (which has since ceased), and longline catches have increased from the East Northland area.
- Ling are caught in small quantities across many fisheries. The distribution of BT effort is broader than the distribution of catch, with effort taking some LIN 1 in East Northland and the west coast in most years. Bottom longline landings of LIN 1 have a wider distribution and are more sporadic, with the Bay of Plenty landings coming primarily from Areas 009 and 010. Bottom longline landings increased after about 2000 in East Northland Area 002, but have fallen off considerably in 2007–08.
- There is a small targeted ling trawl fishery, while trawl catches of LIN1 are mainly made in the scampi and gemfish targeted fisheries. The gemfish fishery mainly contributed catches from 1996–97 to 2000–01 and has since considerably diminished with the reduction of the SKI 1 TACC. The Bay of Plenty scampi fishery has also changed considerably during this period, particularly after SCI entered the QMS, moving from a competitive fishery requiring multiple

vessels to a more rationalised fishery requiring only a single vessel. In contrast, ~75% of the ling longline catch is taken in a targeted ling fishery, with only minor by-catches coming from bluenose, ribaldo and hapuku targeted longline fisheries.

- The bottom longline landings of LIN 1 are taken mainly in the final two months of the fishing year, probably due to the economics of the vessels switching from tuna longlining to cleaning up available quota at the end of the fishing year. Bottom trawl catches of ling tend to be more evenly distributed across the year and reflect the fishing patterns of the diverse trawl targets, such as scampi which is also a consistent fishery over the entire year. Both of the major fishing methods which take ling have sporadic seasonal patterns, reflecting the small landings in most years and the by-catch nature of many of the fisheries.

CPUE Analysis

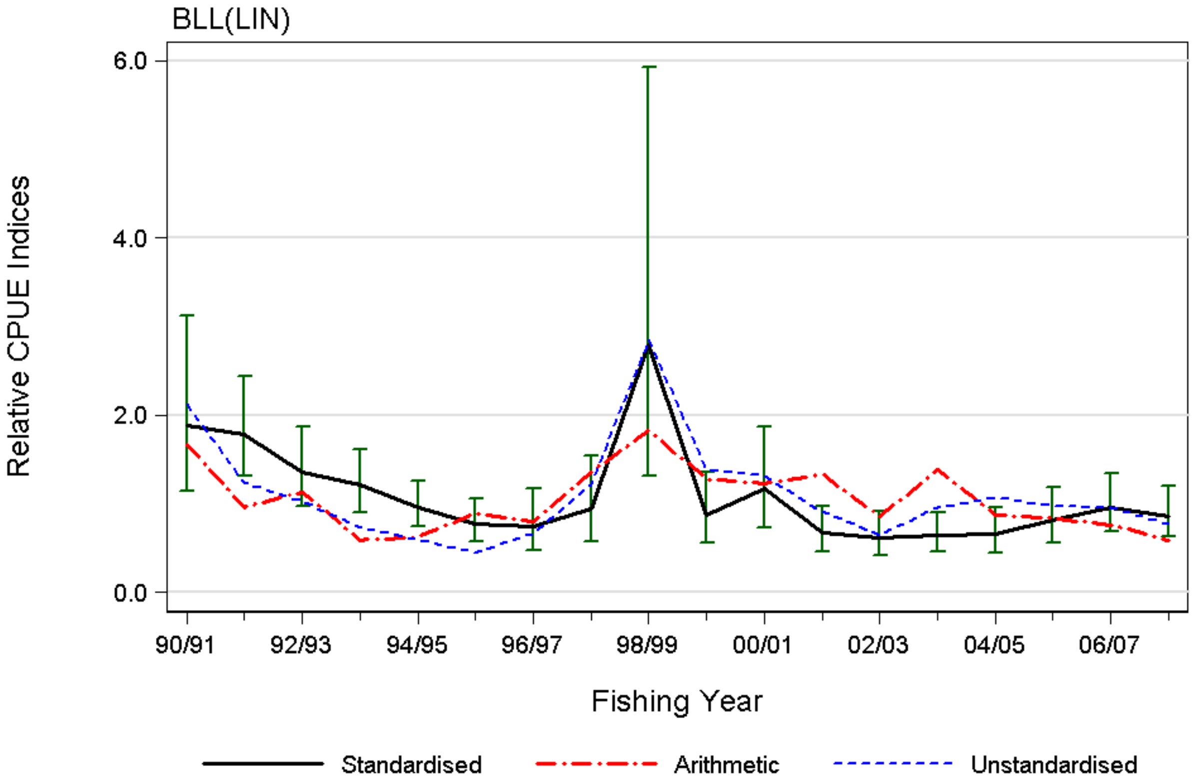


Figure 14: LIN 1 CPUE analysis based on target ling bottom longline data stratified by trip, target species and statistical area for Statistical Areas 002, 003, 004, 008, 009 and 010 standardised with respect to fishing year, number of hooks, vessel, month and number of lines set. Indices from two unstandardised analyses are presented for comparison: a) "arithmetic", the annual sum of landings divided by the total annual number of hooks; and b) "unstandardised", the geometric mean of landings per hook by trip-stratum.

- The depth distribution of ling catches in the trawl fisheries shows two main depths associated with the target species. Most ling are caught in the scampi / hoki / ling fishery at ~400 m depth, but some are taken in the tarakihi / snapper / barracouta / trevally fisheries around 100 m depth. Bottom longline depth records indicate that target ling fishing (as well as target bluenose fishing) takes place at even deeper depths, with most of the records lying between 500 and 600 m.
- The WG has previously noted substantial problems with the quality of LIN 1 data. Estimated catches tend to be less than landed greenweight (the median landed greenweight is about 25% greater than the estimated catch in the same trip), but only 4% of trips by weight neglect to report estimated catches of ling when there are landings. The biggest problem with this data set is the confusion, largely confined to the period prior to about 1995–96, where the FMA has been reported as the statistical area of capture rather than the true statistical area. This is a problem for a LIN 1 analysis because (for instance) FMA 4 (Chatham Rise) will be included in this dataset because statistical area 004 is valid for LIN 1. It is not possible to independently validate such a report because the CELR reporting form used by these vessels does not require a noon position or

some other corroborating evidence of location. This problem is further exacerbated because many trips which apparently are legitimately fishing in FMAs 1 and 9 (the two LIN 1 FMAs) also tend to range widely, circumnavigate the entire North Island and venture into South Island waters. There is a large amount of landings made to the intermediate destination code R (retained on board) which further confounds the analysis because this breaks the continuity of the landings with the effort section of the form, resulting in much of the data being excluded and severely limiting the amount of data available for CPUE analyses.

- The diverse nature and broad geographic range of the LIN 1 fisheries has further complicated the selection of representative CPUE indices. Eight potential fisheries were previously identified as potential CPUE indices, but none of the analyses were considered to be robust due to the diverse nature of the fisheries and relative paucity of data. The AMP WG concluded in 2007, when it last reviewed the LIN 1 fishery, that landed catch data were particularly unreliable, and recommended that estimated catch data should be used instead.
- The 2007 review of the LIN 1 CPUE indices concluded that the LIN bycatch fishery in the target scampi bottom trawl fishery in the Bay of Plenty and the target ling bottom longline fishery in the Bay of Plenty and East Northland had sufficient information to warrant attempting standardised CPUE analyses (Starr *et al*. 2007).
- These two candidate CPUE analyses were updated for this review. However, noting that there is now only one vessel in the scampi fishery, and that the amount of LIN catch data from the scampi bycatch fishery continues to decrease, the WG concluded that the only candidate index of LIN 1 abundance worth considering in this review was the BLL(LIN) index (target ling fishing using bottom longline). The WG recommended that future analyses which included mixed target species bottom trawl effort should be investigated to replace the BT(SCI) index.
- In 2009, the BLL(LIN) index was updated to exclude vessels which only fished in a single year, and calculated alternately using estimated and landed catches. The updated BLL index essentially remains unchanged from the one presented in 2007, consisting of two periods of slowly declining CPUE from 1990–91 to 1996–97 and 1999–00 to 2005–06, separated by a strong, highly uncertain and likely anomalous peak in 1998–99.
- In 2007, the WG noted that BLL reporting rates greatly exceed landed catch weights, reaching 700% in 1998–99. The high CPUE peak in 1998–99 appeared to result from landings which occurred in a single month by two vessels which typically had high catch rates. Many new participants have entered and left this fishery and the vessel effect needs to be investigated further.
- The WG made a number of recommendations for additional data selection procedures and analyses to investigate vessel effects on the BLL(LIN) index (see below).

Status of the Stock

Analysis Recommendations

The following analyses were conducted or recommended during the 2009 review:

- The WG requested that the vessels which only fished in one year be removed from the analysis. This was done and updated analyses were presented to the review.
- At the next review, BLL index standardisations need to further explore the reasons for the peak in 1998–99 (which resulted only from 2 vessels which fished only 2 and 4 trip strata respectively). The linkage of core fleet vessels across this and the effect of inclusion of large autoliners in the BLL index also needs to be investigated.
- Other options should be explored for excluding autoliners or vessels which do not belong in FMA 1 during data extraction, and then modifying grooming procedures to retain a higher proportion of data for the remaining vessels.
- For future analyses, a mixed target BT(HOK,LIN,SKI) index should be calculated to replace the BT(SCI) index.

Abundance Indices

The WG concluded that the BT(SCI) index was not an appropriate index for LIN 1, and had numerous shortcomings related to limited number of vessels, particularly in the most recent 4 years and poor linkage across years. The BLL(LIN) target index appears to have more potential as an index for LIN 1, but shows an apparently anomalous peak in 1998-99 and also has a relatively small amount of data. If this anomalous peak is excluded, the BLL(LIN) index has been stable without trend since 1995/96. However, until the reasons for the peak in BLL CPUE are understood, the WG concluded that the CPUE indices from this series are not reliable indices of LIN 1 abundance.

Sustainability of Current Catches
In the absence of a representative index of abundance, it is not known whether current LIN 1 catches or the TACC are sustainable

Stock Status
The state of the stock in relation to B_{MSY} is unknown.

6. STATUS OF THE STOCKS

Stock Structure Assumptions
Ling are assessed as six independent biological stocks, based on the presence of spawning areas and some differences in biological parameters between areas (Horn 2005).

The Chatham Rise biological stock comprises all of Fishstock LIN 4, and LIN 3 north of the Otago Peninsula. The Sub-Antarctic biological stock comprises all of Fishstock LIN 5, all of LIN 6 excluding the Bounty Plateau, and LIN 3 south of the Otago Peninsula. The Bounty Plateau (part of Fishstock LIN 6) holds another distinct biological stock. The WCSI biological stock occurs in Fishstock LIN 7 west of Cape Farewell. The Cook Strait biological stock includes those parts of Fishstocks LIN 7 and LIN 2 between the northern Marlborough Sounds and Cape Palliser. Ling around the northern North Island (Fishstock LIN 1) are assumed to comprise another biological stock, but there is no information to support this assumption. The stock affinity of ling in LIN 2 between Cape Palliser and East Cape is unknown.

- **LIN 1 Stock**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	None. Fishstock LIN 1 has been managed under an AMP programme since 2003.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	Not available

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	Two CPUE series have been estimated (scampi-targeted bottom trawl, and a ling targeted bottom longline), but neither are considered reliable.
Trends in Other Relevant Indicators or Variables	None available

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing decline below	Soft Limit: Unknown Hard Limit: Unknown

Limits	

Assessment Methodology		
Assessment Type	Level 3 – Qualitative evaluation	
Assessment Method	Evaluation of fishery trends.	
Main data inputs	- CPUE series	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	No modeling completed.	
Major Sources of Uncertainty	Only fishery dependent abundance series were available (CPUE), and these were not considered reliable. The biological stock affinities of ling in LIN 1 are unknown.	

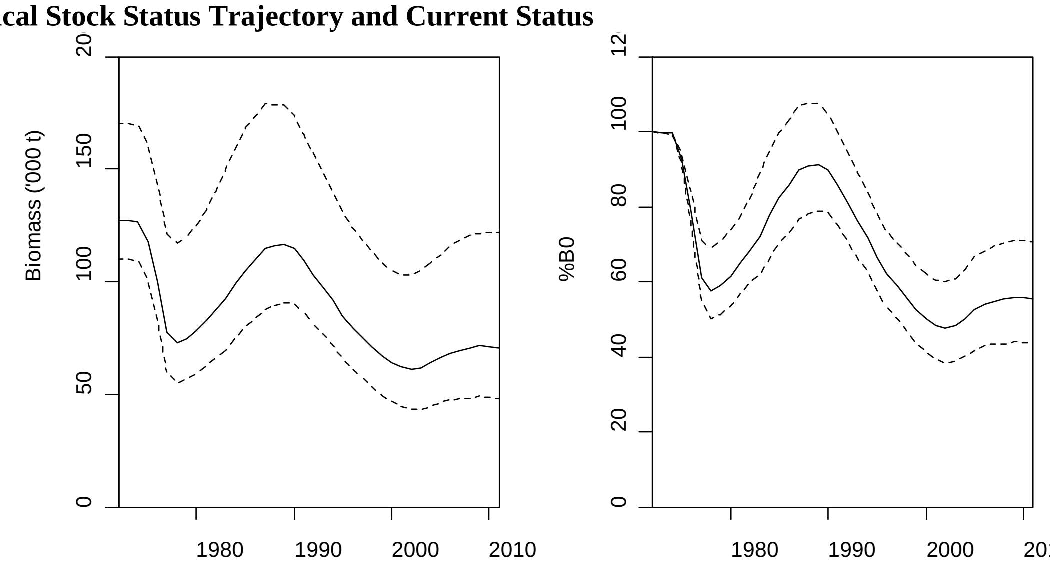
Qualifying Comments
In the absence of a representative and useful index of abundance, it is not known whether current LIN 1 catches or the TACC can be maintained without reducing the stock size. Current stock status is unknown.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries, and scampi target trawl fisheries off northern New Zealand. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

- **Chatham Rise (LIN 3 & 4)**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	A base case and one sensitivity run.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2011} was estimated to be about 55% B_0; Very Likely (> 90%) to be above the target
Status in relation to Limits	B_{2011} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and %B_0, with 95% credible intervals shown as broken lines) for the Chatham Rise ling stock from the start of the assessment period in 1972 to the most recent assessment in 2011. Years on the x-axis are fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is very unlikely to have been below 40% B_0. Biomass is estimated to have been increasing since 2003.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been declining since 1999.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment since the early 1990s is estimated to have been fluctuating slightly around the long-term average for this stock.

Projections and Prognosis (2011)	
Stock Projections or Prognosis	Biomass is uncertain but current catch is unlikely to cause decline. Catches at level of the TACC have unknown prognosis.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch Hard Limit: Exceptionally Unlikely (< 1%) at current catch

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Summer research trawl survey series, annually since 1992. - Proportions-at-age data from the commercial fisheries and trawl survey. - Line fishery CPUE series (annual indices since 1990). - Estimates of biological parameters	
Period of Assessment	Latest assessment: 2011	Next assessment: 2014
Changes to Model Structure and Assumptions	No significant changes since the previous assessment, except that the line fishery CPUE index and composition data were excluded from the base case run.	
Major Sources of Uncertainty	Estimates of current and virgin stock size are very imprecise.	

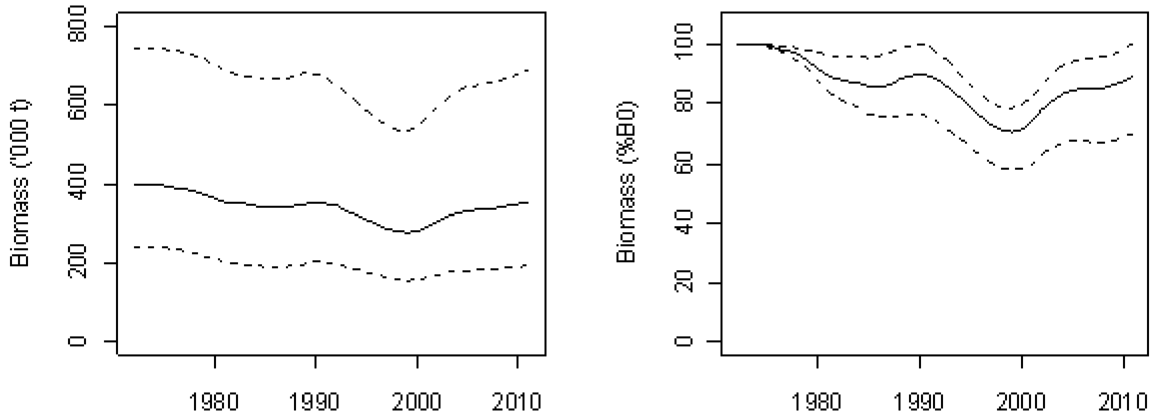
Qualifying Comments
-

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

- **Sub-Antarctic (LIN 5 & 6)**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	A base case and one sensitivity run.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2011} was estimated to be between 70% and 101% B_0; Virtually Certain (> 99%) to be at or above the target
Status in relation to Limits	B_{2011} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and %B_0, with 95% credible intervals shown as broken lines) for the Sub-Antarctic ling stock from the start of the assessment period in 1972 to the most recent assessment in 2007, for the base case model run. Years on the x-axis are fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to have been increasing since 2000.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have always been low, and declining since 1998.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment throughout the 1980s was low relative to the long-term average for this stock, but has been average or better since 1993.

Projections and Prognosis	
Stock Projections or Prognosis	Stock status is predicted to improve over the next 5 years at catch levels equivalent to that from recent years (i.e., 5900 t per year) or equivalent to the TACC (i.e., 12 100 t).
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch Hard Limit: Exceptionally Unlikely (< 1%) at current catch

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Summer and autumn *Tangaroa* trawl survey series. - Proportions-at-age data from the commercial fisheries and trawl surveys. - Line fishery CPUE series (annual indices since 1991). - Estimates of biological parameters (but note that *M* was estimated in the models)	
Period of Assessment	Latest assessment: 2011	Next assessment: 2014
Changes to Model Structure and Assumptions	No significant changes since the previous assessment, except that *M* was estimated as an ogive rather than being fixed at 0.18.	
Major Sources of Uncertainty	The summer trawl survey biomass estimates are variable and catchability clearly varies between surveys. The general lack of contrast in this series (the main relative abundance series) makes it difficult to accurately estimate past and current biomass. The assumption of a single Sub-Antarctic stock (including the Puysegur Bank), independent of ling in all other areas, is the most parsimonious interpretation of available information. However,	

	this assumption may not be correct. Although the catch history used in the assessment has been corrected for some misreported catch (see section 1.4), it is possible that additional misreporting exists.

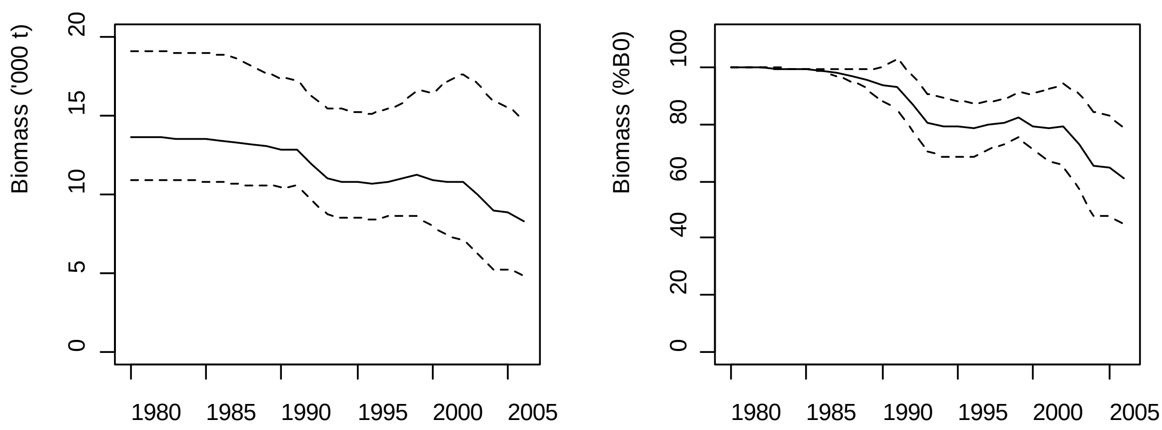
Qualifying Comments
Although estimates of absolute current and reference biomass are unreliable, B_0 was probably over 200 000 t. The stock has probably only been lightly fished.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

- **Bounty Plateau (part of LIN 6)**

Stock Status	
Year of Most Recent Assessment	2006
Assessment Runs Presented	A single model run
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2006} was estimated to be 61% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2006} is Very Unlikely (< 10%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and %B_0, with 95% credible intervals shown as broken lines) for the Bounty Plateau ling stock from the start of the assessment period in 1980 to the most recent assessment in 2006. Years on the x-axis are fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Median estimates of biomass are unlikely to have been below 61% B_0. Biomass is estimated to have been declining since 1999.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been low, but erratic, since 1980.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment was above average in the early 1990s, but below average in the late 1990s. No estimates of recruitment since 1999 are available.

Projections and Prognosis (2006)	
Stock Projections or Prognosis	Stock status is predicted to continue declining slightly over the next 5 years at a catch level equivalent to the average since 1991 (i.e., 600 t per year).
Probability of Current Catch or TACC causing decline below Limits	Note that there is no specific TACC for the Bounty Plateau stock. Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)

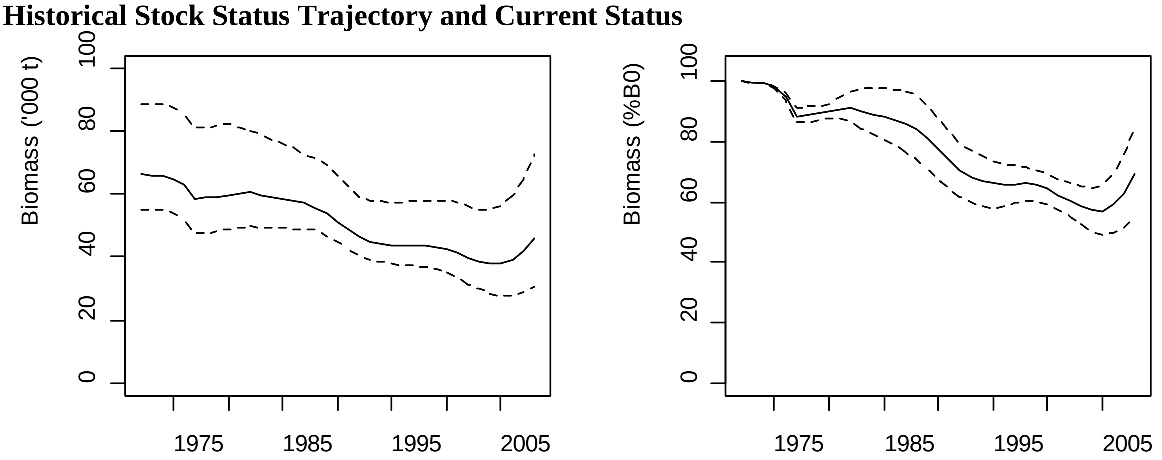
Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Proportions-at-age data from the commercial line fishery. - Line fishery CPUE series (annual indices since 1992). - Estimates of biological parameters.	
Period of Assessment	Latest assessment: 2006	Next assessment: Unknown
Changes to Model Structure and Assumptions	No significant changes since the previous assessment.	
Major Sources of Uncertainty	There are no fishery-independent indices of relative abundance, so the assessment is driven largely by the line fishery CPUE series. Stock projections are based on a constant future catch of 600 t per year. However, historic catches from this fishery have fluctuated widely, so future catches could be markedly different from 600 t per year.	

Qualifying Comments
There is no separate TACC for this stock; it is part of the LIN 6 Fishstock that has a TACC of 8505 t.
Fishery Interactions
Target line fisheries for ling have the main bycatch species of spiny dogfish, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates and seabirds.

- **West coast South Island (LIN 7)**

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	A base case and four sensitivity model runs.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2008} was estimated to be about 69% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2008} is Very Unlikely (< 10%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and %B_0, with 95% credible intervals shown as broken lines) for the WCSI ling stock from the start of the assessment period in 1972 to the most recent assessment in 2008. Years on the x-axis are fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Median estimates of biomass are unlikely to have been below 56% B_0 (in the year 2005). Biomass is estimated to have been increasing since 2005.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been relatively constant, but quite low, since the mid 1990s.
Other Abundance Indices	Series of CPUE indices are available from the line (target) and trawl (bycatch) fisheries, but neither is considered reliable.
Trends in Other Relevant Indicators or Variables	Recruitment throughout the 1990s is estimated to be lower than the long-term average for this stock, but recent recruitment is higher than average (2000–2003).

Projections and Prognosis (2008)	
Stock Projections or Prognosis	No projections were reported in the Plenary document, but all tested models predicted an improvement in stock status over the next 5 years at a catch level equivalent to the TACC.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Proportions-at-age data from the commercial fisheries. - Estimates of biological parameters.	
Period of Assessment	Latest assessment: 2008	Next assessment: Unknown
Changes to Model Structure and Assumptions	No significant changes since the previous assessment.	
Major Sources of Uncertainty	There are no reliable relative abundance series for this stock. Consequently, the model relies on changes in the catch-at-age data to determine the fishing mortality rates for the stock, and estimate past and current biomass. Although the catch history used in the assessment has been corrected for some misreported catch (see section 1.4), it is possible that additional misreporting exists. It is assumed in the assessment models that natural mortality is constant over all ages.	

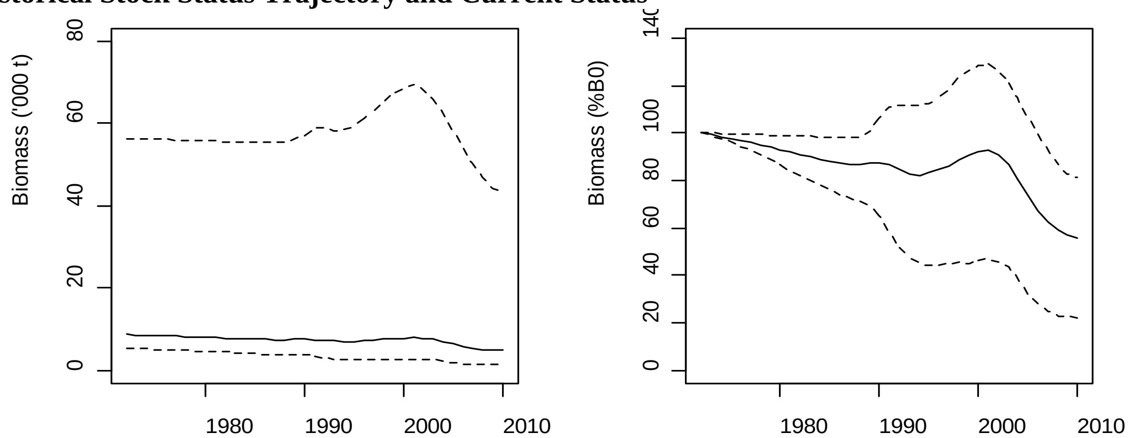
Qualifying Comments
All model runs produced quite similar estimates of stock status (i.e., B_{2008} = 43–69% B_0). However, owing to the lack of a reliable abundance series this assessment is very uncertain, but it is probable that B_{2008} is greater than 40% B_0, and it could be much higher. The relatively constant catch history since 1989 and the relative constancy of the trawl catch-at-age distributions since 1991 suggest that future catches at the current level can be maintained without causing the stock size to decline. The assessment did not include ling from the Cook Strait section of Fishstock LIN 7, which produces about 5% of the LIN 7 landings.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

- **Cook Strait (LIN 2 & 7)**

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	A base case.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2010} was estimated to be 54% B_0; Likely (> 60%) to be at or above the target
Status in relation to Limits	B_{2010} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and %B_0, with 95% credible intervals shown as broken lines) for the Cook Strait ling stock from the start of the assessment period in 1972 to the most recent assessment in 2010. Years on the x-axis are fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been declining since 1999, but is unlikely to have dropped below 30% B_0.
Recent Trend in Fishing Mortality or Proxy	Overall fishing pressure is estimated to have been relatively constant since the mid 1990s, but has trended down for trawl and up for line.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment from 1995 to 2006 was low relative to the long-term average for this stock. There are no estimates for the more recent year classes.
Stock Projections or Prognosis	Stock status is predicted to improve slightly over the next 5 years

	at a catch level equivalent to that since 2006 (i.e., 220 t per year), or remain relatively constant at a catch equivalent to the mean since 1990 (I.e., 420 t per year).
Probability of Current Catch or TACC causing decline below Limits	Note that there is no specific TACC for the Cook Strait stock. Soft Limit: Catch 220 t, Very Unlikely (< 10%); Catch 420 t, Very Unlikely (< 10%) Hard Limit: Catch 220 t, Exceptionally Unlikely (< 1%); Catch 420 t, Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Proportions-at-age data from the commercial fisheries. - Trawl fishery CPUE series (annual indices since 1994). - Estimates of biological parameters.	
Period of Assessment	Latest assessment: 2010	Next assessment: 2013
Changes to Model Structure and Assumptions	No significant changes since the previous assessment.	
Major Sources of Uncertainty	There are no fishery-independent indices of relative abundance. It is not known if the trawl CPUE series is a reliable abundance index. The stock structure of Cook Strait ling is uncertain. While ling in this area are almost certainly biologically distinct from the WCSI and Chatham Rise stocks, their association with ling off the lower east coast of the North Island is unknown. It is possible that trawl selectivity has varied over time, resulting in poor fits to some age classes in some years. Line fishery selectivity is based on only two years of catch-at-age data from the autoline fishery. No information is available from the ‘hand-baiting’ line fishery. The model is moderately sensitive to small changes in *M*, and *M* is poorly estimated.	

Qualifying Comments
There is no separate TACC for this stock; it comprises parts of Fishstocks LIN 7 and LIN 2.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks, and skates. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

Table 32: Summary of TACCs (t), and reported landings (t) for the most recent fishing year.

Fishstock	QMA		TACC	Landings
LIN 1	Auckland	1 & 9	400	438
LIN 2	Central (East)	2	982	670
LIN 3	South-East (Coast)	3	2 060	1 665
LIN 4	South-East (Chatham Rise)	4	4 200	1 572
LIN 5	Southland	5	3 595	3 856
LIN 6	Sub-Antarctic	6	8 505	1 335
LIN 7	Challenger, Central (West)	7 & 8	2 474	2 800
LIN 10	Kernadec	10	10	0
Total			22 226	12 337

7. FOR FURTHER INFORMATION

Bull B., Francis R.I.C.C., Dunn A., McKenzie A., Gilbert D.J., Smith M.H., Bian R. 2008. CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v2.20-2008/02/14. *NIWA Technical Report 130*. 275 p.

Bradford E. 1996. Marine recreational fishery survey in the Ministry of Fisheries North region, 1993–94. *NZ Fisheries Data Report No. 80*. 83 p.

Dunn A. 2003. Investigation of evidence of area misreporting of landings of ling in LIN 3, 4, 5, 6, and 7 from TCEPR records in the fishing years 1989–90 to 2000–01. Final Research Report. (Unpublished document held by Ministry of Fisheries, Wellington.)

Dunn M.R., Connell A., Forman J., Stevens D.W., Horn P.L. 2010. Diet of two large sympatric teleosts, the ling (*Genypterus blacodes*) and hake (*Merluccius australis*). *PLoS ONE 5(10)*: e13647. doi:10.1371/journal.pone.0013647

Horn P.L. 1993. Growth, age structure, and productivity of ling, *Genypterus blacodes* (Ophidiidae), in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 27*: 385–397.

Horn P.L. 2004. A review of the auto-longline fishery for ling (*Genypterus blacodes*) based on data collected by observers from 1993 to 2003. *New Zealand Fisheries Assessment Report 2004/47*. 28 p.

Horn P.L. 2005. A review of the stock structure of ling (*Genypterus blacodes*) in New Zealand waters. *New Zealand Fisheries Assessment Report 2005/59*. 41 p.

Horn P.L. 2006. Stock assessment of ling (*Genypterus blacodes*) off the west coast of the South Island (LIN 7) for the 2005–06 fishing year. *New Zealand Fisheries Assessment Report 2006/24*. 47 p.

Horn P.L. 2007a. A descriptive analysis of commercial catch and effort data for ling from New Zealand waters in Fishstocks LIN 2, 3, 4, 5, 6, and 7. *New Zealand Fisheries Assessment Report 2007/22*. 71 p.

Horn P.L. 2007b. Stock assessment of ling (*Genypterus blacodes*) on the Bounty Plateau and in Cook Strait for the 2006–07 fishing year. Final Research Report for Ministry of Fisheries Research Project LIN2005-01, Objective 3. 51 p. (Unpublished document held by Ministry of Fisheries, Wellington.)

Horn P.L. 2008a. CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 3, 4, 5, 6, and 7 from 1990 to 2006, and a descriptive analysis update. *New Zealand Fisheries Assessment Report 2008/2*. 43 p.

Horn P.L. 2008b. Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise, Campbell Plateau, and in Cook Strait for the 2007–08 fishing year. *New Zealand Fisheries Assessment Report 2008/24*. 76 p.

Horn P.L. 2009a. CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 3, 4, 5, 6, and 7 from 1990 to 2007, and a descriptive analysis update. *New Zealand Fisheries Assessment Report 2009/1*. 52 p

Horn P.L. 2009b. Stock assessment of ling (*Genypterus blacodes*) off the west coast of South Island for the 2008–09 fishing year. *New Zealand Fisheries Assessment Report 2009/16*. 42 p.

Horn P.L. 2010. CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 3, 4, 5, 6, and 7 from 1990 to 2008, and a descriptive analysis update. *New Zealand Fisheries Assessment Report 2010/25*. 54 p.

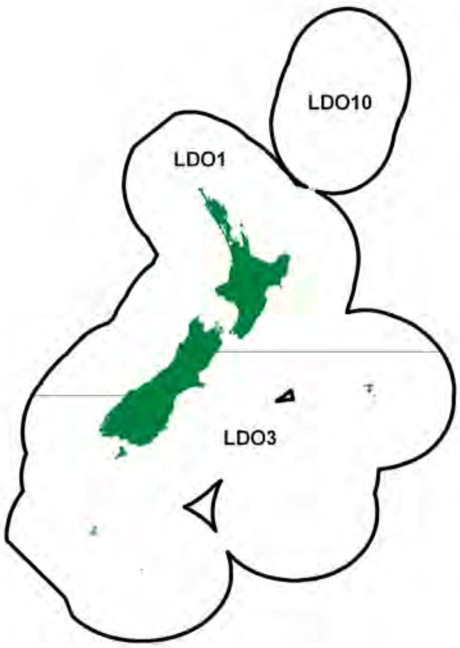
Horn P.L., Dunn A. 2003. Stock assessment of ling (*Genypterus blacodes*) around the South Island (Fishstocks LIN 3, 4, 5, 6, and 7) for the 2002–03 fishing year. *New Zealand Fisheries Assessment Report 2003/47*. 59 p.

Horn P.L., Francis R.I.C.C. in prep. Stock assessment of ling (*Genypterus blacodes*) in Cook Strait for the 2010–11 fishing year. *Draft New Zealand Fisheries Assessment Report*.

Leach B.F., Boocock A.S. 1993. Prehistoric fish catches in New Zealand. British Archaeological Reports International Series 584. 38 p.

LOOKDOWN DORY (LDO)

(Cyttus traversi)



1. FISHERY SUMMARY

Lookdown dory was introduced into the Quota Management System (QMS) on 1 October 2004 with the allowances, TACs and TACCs in Table 1. It is currently managed as three stocks: LDO 1 that comprises FMAs 1-2 and 7-9; LDO 3 that comprises FMAs 3-6; and LDO 10 (Kermadec region).

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs, by Fishstock, for lookdown dory.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	TACC	TAC
LDO 1	0	0	168	168
LDO 3	0	0	614	614
LDO 10	0	0	1	1
Total	0	0	783	783

1.1 Commercial fisheries

Reliable landings data are available from 1989-90 onwards, after the introduction of Catch Landing Returns (CLRs) in the previous year (Table 2). Annual landings are also available from Licensed Fish Receiver Returns (LFRRs), and these agree well with CLR figures in most years (within 10%), but differ by 20-27% in 4 of the 12 years with comparable data (Table 3). Total landings (CLR) have increased steadily from 127 t in 1989-90 to 760 t in 2001-02. Estimated catch as a percentage of recorded landings were moderate in the early 1990s at 60-70%, but subsequently declined to around 30%. Lookdown dory will often not be included within the top five species in a trawl haul, but the reason for the declining percentage of landings recorded as catch is unknown.

Since entering the QMS, catches in LDO 1 have exceeded the TACC slightly in the 2005-06 and 2007-08 fishing years (Table 2). The TACC in LDO 3 has never been caught. This probably reflects the reduction in the size of the trawl fishery on the Chatham Rise where the greatest proportion of lookdown dory has been taken as bycatch. No catch has been reported from LDO 10. Figure 1 shows the historical landings and TACC values for LDO 1 and LDO 3.

There is a seasonal pattern of catch of lookdown dory on the west coast South Island in relation to target fishing for spawning hoki and hake in winter. Catches elsewhere are also dependent on fishing activity in target fisheries but, other than a slight decline in winter months in relation to the shift in area of operation of hoki fleet, they tend to be less seasonal.

Table 2: Reported domestic landings (t) of lookdown dory by Fishstock and TACC from 2004-05 to 2010-11.

Fishstock	LDO1		LDO3		LDO10			
FMA	1,2,7,8&9		3,4,5&6		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004-05	110	168	272	614	0	1	382	783
2005-06	180	168	290	614	0	1	470	783
2006-07	147	168	284	614	0	1	431	783
2007-08	174	168	256	614	0	1	430	783
2008-09	144	168	315	614	0	1	459	783
2009-10	161	168	274	614	0	1	435	783
2010-11	165	168	216	614	0	1	380	783

Table 3: Reported landings and estimated catch (t) of lookdown dory by fishing year. Also, percentage of landings recorded as catch in the catch effort databases.

Year	Landings (CLR)	Landings (LFRR)	Estimated catch (t)	% of CLR landings recorded as estimated catch
1989-90	127	161	80	63
1990-91	164	182	105	64
1991-92	249	216	177	71
1992-93	275	264	159	58
1993-94	188	226	117	62
1994-95	283	277	125	44
1995-96	260	276	107	41
1996-97	354	426	173	49
1997-98	564	557	265	47
1998-99	625	640	228	36
1999-00	637	605	215	34
2000-01	694	504	157	23
2001-02	760	-	254	33

-, data not available

Lookdown dory is generally caught by bottom trawling in depths of 200 to 800 m mainly as bycatch in the hoki fishery, but also in a variety of other target fisheries such as barracouta, hake, ling, scampi, squid and jack mackerel. A small amount of target fishing is reported from FMA 7. Most of the catch has come from FMA 3 (east coast South Island), FMA 4 (Chatham Rise), and FMA 7 (west coast South Island) (Table 4). Landings from around the North Island have been restricted mostly to a few tonnes each from FMAs 1, 2, 8 and 9. In FMA 5 (Southland) and FMA 6 (Sub-Antarctic) landings have been in the order of 10-30 t over the past six years. No landings have been reported from outside the New Zealand EEZ.

Table 4: Reported historic landings (rounded to nearest tonne) of lookdown dory by FMA and fishing year 1989-90 to 2003-04.

Year	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 6	FMA 7	FMA 8	FMA 9	FMA 10
1989-90	2	1	40	20	12	2	51	-	-	-
1990-91	3	4	46	59	10	11	33	< 1	-	-
1991-92	1	2	96	75	17	3	55	-	-	-
1992-93	1	4	63	112	10	2	83	-	-	-
1993-94	< 1	2	62	50	4	3	67	-	< 1	-
1994-95	1	6	73	108	7	3	85	-	< 1	-
1995-96	2	4	99	78	11	3	62	-	< 1	-
1996-97	7	10	108	110	11	7	100	< 1	< 1	-
1997-98	5	8	159	272	11	25	82	-	< 1	-
1998-99	3	3	161	295	21	17	124	< 1	10	-
1999-00	3	5	161	295	21	17	124	< 1	10	-
2000-01	2	6	203	318	24	25	111	< 1	4	-
2001-02	10	10	181	331	26	28	170	3	2	-
2002-03	8	8	261	365	48	32	167	1	2	-
2003-04	13	8	135	210	22	24	113	3	1	-

1.2 Recreational fisheries

There is no quantitative information on recreational harvest levels of lookdown dory. Due to the offshore location and depth distribution of lookdown dory recreational catch is thought to be negligible.

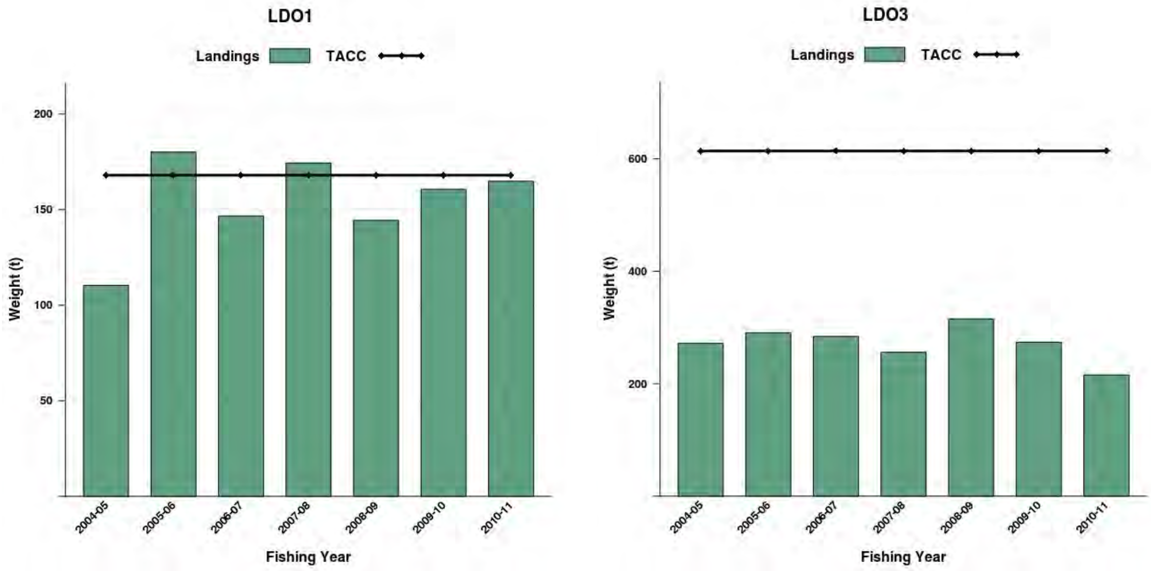


Figure 1: Historical landings and TACC for the two main LDO stocks. Left to right: LDO1 (Challenger, Central, Auckland), and LDO3 (South East Chatham Rise, South East Coast, Sub Antarctic, Southland). Note that this figure does not show data prior to entry into the QMS.

1.3 Customary non-commercial fisheries
An estimate of current catch is not available but given the offshore location and depth distribution of lookdown dory customary non-commercial catch is thought to be negligible.

1.4 Illegal catch
Estimates of illegal catch are not available.

1.5 Other sources of mortality
There is no quantitative information on the level of other sources of mortality.

2. BIOLOGY

Lookdown dory (*Cyttus traversi*) belongs to the family Zeidae. This family includes 13 species in seven genera distributed among the Atlantic and Pacific Oceans and the Mediterranean Sea. Lookdown dory also occurs in Australian waters, mostly east and south of Tasmania (where it is known as king dory), and also in South Africa. It is widely distributed throughout New Zealand waters with most records from the Chatham Rise. The geographical and depth distribution of immature (< 33 cm) fish is similar to that of adults (Hurst *et al*. 2000).

It is one of the less abundant members of a loosely associated group of about 23 common species, which together form the upper slope assemblage of New Zealand's continental shelf (Francis *et al.* 2002). The main species in this group are hoki, javelin fish, ling, pale ghostshark, sea perch, hake, and longnose spookfish (chimaerid). It was identified as a key species characterising the demersal fish community 350-550 m on the Chatham Rise (Bull *et al.* 2001).

Juveniles are found in surface waters up to a length of approximately 12 cm (May & Maxwell 1986), at which stage a metamorphosis occurs associated with the transition from a pelagic to a demersal habitat (James 1976). Adults are most common between 400 to 600 m, but have a wide depth range, from 50 to 1200 m (Anderson *et al.* 1998). Immature fish less than 33 cm have a similar geographical and depth distribution to adults (Hurst *et al*. 2000, O'Driscoll *et al.* 2003). The main prey of lookdown dory are natant decapod crustaceans, followed by euphausid, mysid, galatheid, and nephropsid crustaceans, and fish (Clark & King 1989, Foreman & Dunn, 2010). Lookdown dory is likely to be prey of larger fish and have occasionally been recorded in the stomachs of large ling.

Trawl survey catch distribution across the Chatham Rise is fairly even, with females ranging from 10 to 55 cm total length, and males ranging from 10 to 45 cm. Lookdown dory show early signs of ripening to spawn in the January surveys (Livingston *et al.* 2002). Catch distribution across the Sub-Antarctic is patchier than across the Chatham Rise, particularly during autumn surveys (O'Driscoll & Bagley 2001). Lookdown dory appear to grow larger in the SubAntarctic than on the Chatham Rise with females ranging from 12 to 60 cm total length, and males ranging from 12 to 45 cm.

There are no known aggregations or migrations associated with spawning lookdown dory. Around the North Island, female lookdown dory were reported to mature at about 35 cm (May & Maxwell 1986). Ripe specimens are usually seen in autumn and winter but have also been observed in summer (Clark & King 1989). Livingston *et al.* (2002) reported early signs of ripening in January Chatham Rise trawl surveys. Observer records (MacGibbon *et al.* 2011 submitted) from the east coast South Island and Chatham Rise show that ripe females are more common in summer months and spent females are more common in winter. Females on the west coast South island are mostly resting, immature or spent in winter. Although most spawning takes place in autumn and winter it is likely that it is not a discrete event but occurs over much of the year. Research data from other areas are sparse, but show the presence of fish in spawning condition in most months of the year.

Although there are no published studies of validated age and growth of lookdown dory, preliminary work in Australia suggests this species may live to over 30 years (Stewart & Smith 1992). Tracey *et al.* (2007) attempted to use lead-radium techniques to validate ageing by zone counts of otoliths but were unsuccessful. Based on unvalidated zone counts, they observed maximum ages of 38 and 25 years for males and females respectively for New Zealand lookdown dory from the Chatham Rise. Von Bertalanffy growth parameters are given in Table 5 and length-weight parameters are given in Table 6.

Table 5: Summary of von Bertalanffy growth parameters for Chatham Rise lookdown dory. Source : Tracey *et al.* 2007. NB : Ageing in this study used unvalidated methods.

Sex	*N*	L_∞	SE	95% CI	*K*	SE	95% CI	t_0	SE	95% CI
All	382	50.72	2.53	(45.75, 55.68)	0.058	0.007	(0.044, 0.073)	-3.53	0.67	(-4.84, -2.21)
Males	191	38.78	1.68	(35.49, 42.06)	0.074	0.011	(0.053, 0.095)	-4.28	0.87	(-5.97, -2.57)
Females	191	69.94	5.71	(58.75, 81.13)	0.039	0.006	(0.027, 0.051)	-3.90	0.72	(-5.31, -2.49)

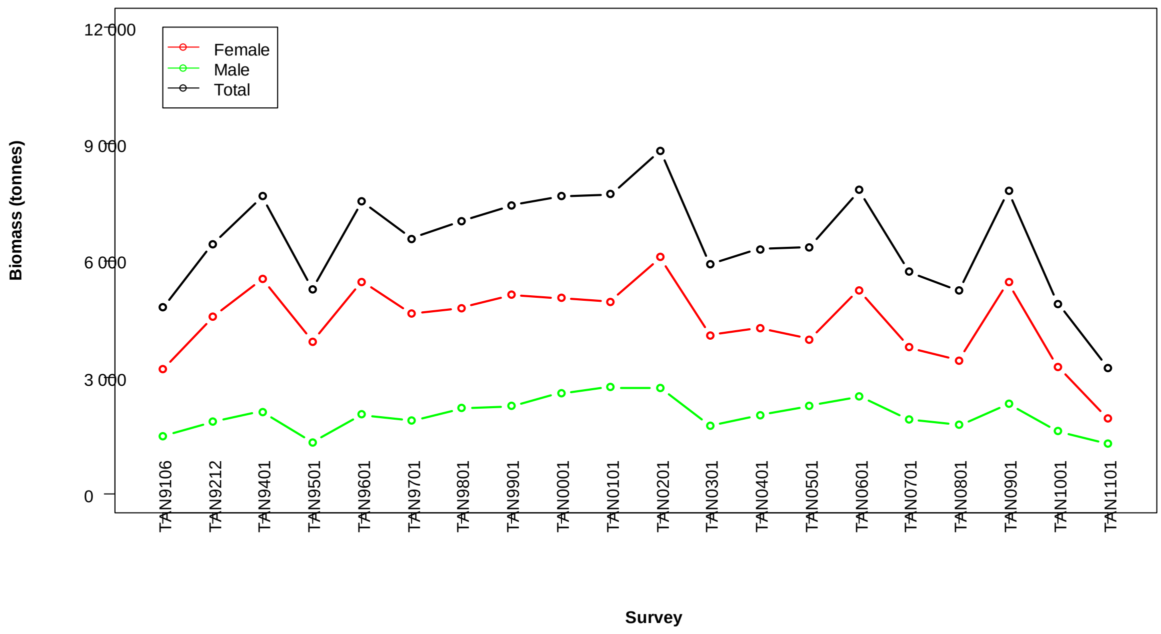
Table 6: Length-weight parameters for Chatham Rise and SubAntarctic lookdown dory.

Fishstock				**Estimate**	**Source**
1.Weight = a(length)b (Weight in g, length in cm total length)					
FMA 3 & 4	Females		Males		Tracey *et al* (2007)
	a	b	a	b	
	0.022	2.98	0.025	2.96	
FMA 5 & 6			Sexes combined		Bagley *et al*, (unpublished data)
			a	b	
			0.022	3.02	

3. STOCKS AND AREAS

A catch-effort characterisation carried out in 2010 identified three main fishing areas where lookdown dory are caught. These are the East Coast South Island (FMA 3), Chatham Rise (FMA 4), and West Coast South Island (FMA 7).

There is little information on stock structure, recruitment patterns, or other biological characteristics on which to base any biological fishstock boundaries. MacGibbon *et al* (2011) found both sexes grow to a larger size in the SubAntarctic compared with the Chatham Rise suggesting the possibility of different stocks. There is also a difference in abundance between males and females in both areas with females nearly always outnumbering males (Figure 2).



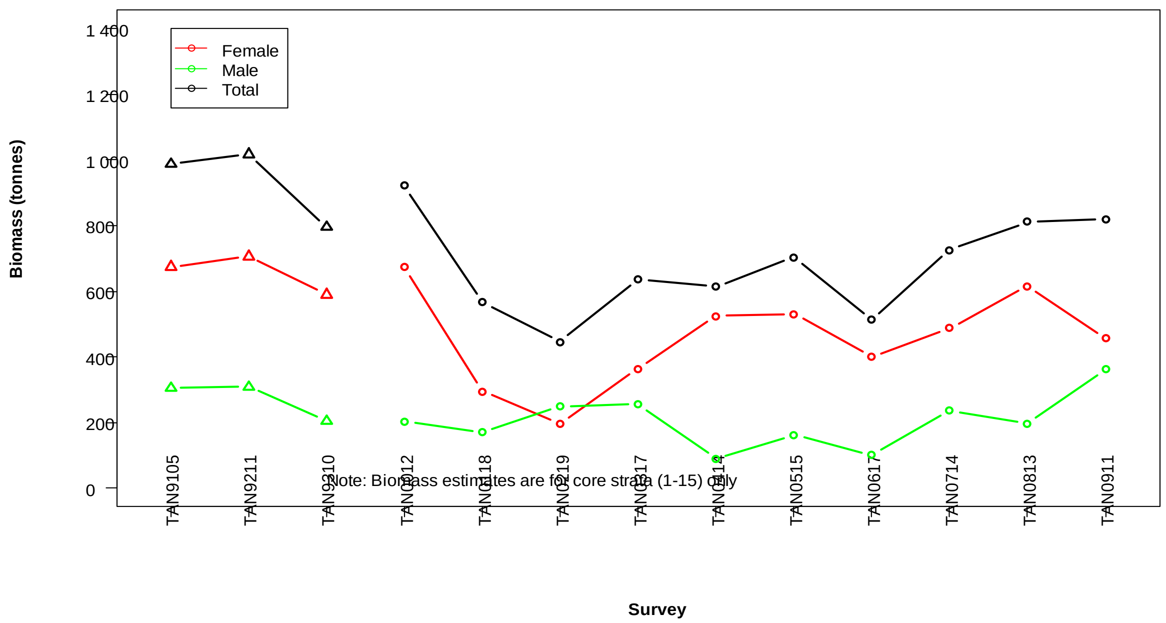


Figure 2: Doorspread biomass estimates of lookdown dory by sex from the Chatham Rise 1991 to 2011 (upper) and SubAntarctic 1991 to 1993 and 2000 to 2009 (lower), from *Tangaroa* surveys.

4. STOCK ASSESSMENT

The Middle Depths Working Group agreed in February 2011 that relative biomass estimates of lookdown dory from middle depth trawl surveys on the Chatham Rise and the Sub-Antarctic were suitable for monitoring major changes in lookdown dory abundance for LDO 3. Standardised CPUE indices from a mixed target species trawl fishery on the ECSI and Chatham Rise area were not accepted by the Working Group. There are no stock monitoring indices for LDO 1.

4.1 Estimates of fishery parameters and abundance

Lookdown dory biomass is usually in the top 10 species on the Chatham Rise and CVs are relatively precise (usually < 15%) (Table 7). Biomass indices on the Chatham Rise have been fairly flat through the time series although they decreased in the last 2 surveys. Females have consistently comprised more of the biomass than males (Figure 2). Biomass indices on the Sub-Antarctic have higher but still acceptable CVs (generally < 30%). Relative biomass declined to a low period from 2002-06 but has since increased.

Table 7: Biomass indices (t) and coefficients of variation (cv) for lookdown dory from *Tangaroa* trawl surveys (Assumptions: areal availability, vertical availability and vulnerability = 1). NB: estimates are for the core strata only for the respective time series.

Area	Vessel	Trip code	Date	Biomass (t)	% cv
Chatham Rise					
	Tangaroa	TAN9106	Dec 91-Feb 92	4797	5.6
		TAN9212	Dec 92-Feb 93	6439	5.2
		TAN9401	Jan 94	7664	7.2
		TAN9501	Jan 95-Feb 95	5270	6.5
		TAN9601	Dec 95-Jan 96	7540	8
		TAN9701	Jan 97-Jan 97	6568	7.6
		TAN9801	Jan 98-Jan 98	7019	6
		TAN9901	Jan 99-Jan 99	7417	8.2
		TAN0001	Dec 99-Jan 00	7655	7
		TAN0101	Dec 00-Jan 01	7713	6.5
		TAN0201	Dec 01-Jan 02	8821	11.1
		TAN0301	Dec 02-Jan 03	5853	7
		TAN0401	Dec 03-Jan 04	6304	8
		TAN0501	Dec 04-Jan 05	6351	9.3
		TAN0601	Dec 05-Jan 06	7818	8.5
		TAN0701	Dec 06-Jan 07	5714	7.7
		TAN0801	Dec 07-Jan 08	5230	9.3
		TAN0901	Dec 08-Jan 09	7789	8.7
		TAN1001	Jan 10	4896	9.7
		TAN1101	Jan 11	3257	21.4
		TAN1201	Jan 12	5 913	13.2
SubAntarctic (summer)					
	Tangaroa	TAN9105	Nov-Dec 91	987	13.3
		TAN9211	Nov-Dec 92	1017	11.3
		TAN9310	Nov-Dec 93	796	13.5
		TAN0012	Nov-Dec 00	921	15.2
		TAN0118	Nov-Dec 01	566	19.7
		TAN0219	Nov-Dec 02	446	22.1
		TAN0317	Nov-Dec 03	636	23.7
		TAN0414	Nov-Dec 04	614	27.9
		TAN0515	Nov-Dec 05	703	19.1
		TAN0617	Nov-Dec 06	513	35.1
		TAN0714	Nov-Dec 07	725	20
		TAN0813	Nov-Dec 08	811	24.7
		TAN0911	Nov-Dec 09	820	25.1
		TAN1117	Nov-Dec 11	349	33
SubAntarctic (autumn)					
	Tangaroa	TAN9204	Apr-May 92	1154	40
		TAN9304	May-Jun 93	1955	44.1
		TAN9605	Mar-Apr 96	1058	17.8
		TAN9805	Apr-May 98	529	32.6

Length frequencies of Chatham Rise lookdown dory suggest that recruitment is variable (MacGibbon *et al*. 2010). Generally, when a strongly recruiting year class is present, the male length frequencies are often bimodal and females show two or three modes. Length frequency plots show that females are usually more numerous than males with a mean ratio for the time series of 1.15 females to every male (range 0.98-1.52). Males don’t grow as large as females, with few males growing larger than 40 cm.

Length frequencies from the summer Sub-Antarctic series are less informative and no tracking of cohorts is possible. Overall, scaled population numbers are much lower for both sexes here than on the Chatham Rise but, again, females are more numerous than males with a mean ratio for the time series of 1.8 females for every male (range 0.55-3.9). Females also grow to a larger size than males and both sexes grow to a larger size on the Sub-Antarctic than on the Chatham Rise, which suggests the possibility that it may be a separate biological stock. This could also potentially be due to real differences in fishing pressure.

4.2 Estimation of Maximum Constant Yield (*MCY*)
MCY cannot be estimated.

4.3 Estimation of Current Annual Yield (*CAY*)
CAY cannot be estimated.

4.4 Other yield estimates and stock assessment results
No information is available.

5. STATUS OF THE STOCK

There are no known sustainability concerns in the lookdown dory fishery. For LDO 3, trawl surveys on the Chatham Rise and Sub-Antarctic indicate abundance has fluctuated in both areas. There are no abundance indices for LDO 1.

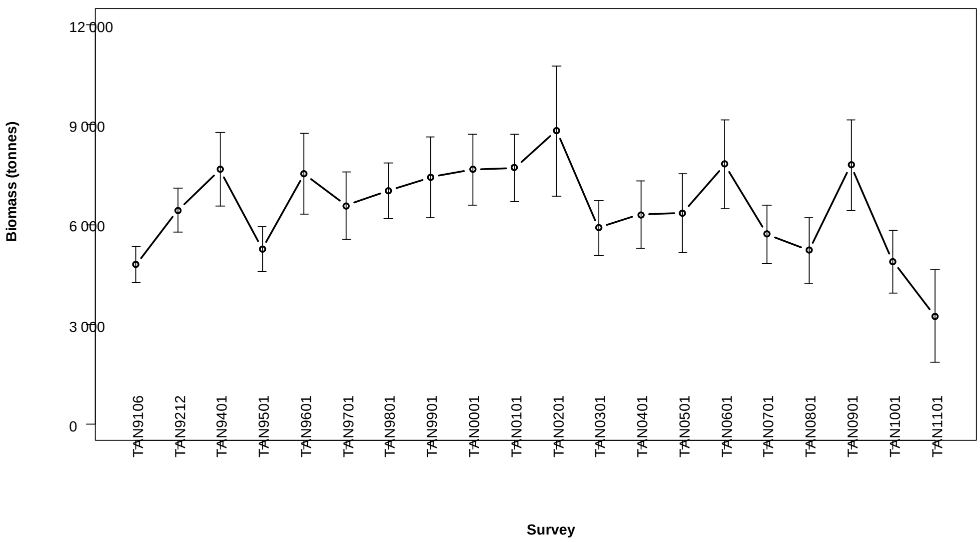
LDO 1

In LDO 1, lookdown dory are taken primarily as bycatch in bottom trawl west coast South Island hoki and hake target fisheries and east coast North Island scampi fisheries. Smaller catches are reported by midwater trawl. A variety of other target fisheries also report catching lookdown dory but in very small amounts.

- **LDO 3 (Chatham Rise & Sub-Antarctic)**

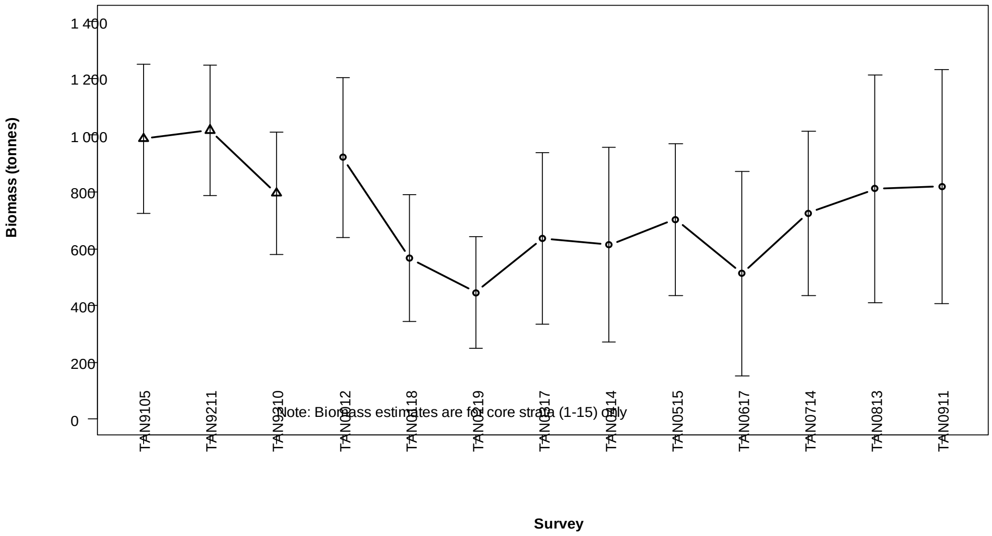
Stock Status	
Year of Most Recent Assessment	2011
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown for Soft limit Unlikely (< 40%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Doorspread biomass estimates of lookdown dory (error bars are ± two standard deviations) from the Chatham Rise, from *Tangaroa* surveys from 1991 to 2011.

Historical Stock Status Trajectory and Current Status (continued)



Doorspread biomass estimates of lookdown dory (error bars are ± two standard deviations) from the SubAntarctic, from *Tangaroa* surveys from 1991 to 1993, and 2000 to 2009.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Within LDO 3, FMAs 3 & 4 biomass indices have been fairly flat throughout the time series of Chatham Rise trawl surveys with the exception of 2010 and 2011 which show a decline. For FMAs 5 & 6 biomass indices from the Sub-Antarctic series declined to 2002 and have been increasing steadily since 2006.
Recent Trend in Fishing Mortality or Proxy	Unknown

Projections and Prognosis	
Stock Projections or Prognosis	Stock size is Unlikely (< 40%) to change much at current catch levels in FMA 5&6.
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	Evaluation of agreed trawl survey indices thought to index FMA 3 & 4, and FMA 5 & 6 abundance.	
Main data inputs	None	
Period of Assessment	Latest assessment: 2011	Next assessment: 2012.
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
There is some indication that lookdown dory on the Chatham Rise may be a different stock to the Sub-Antarctic (i.e., different maximum sizes, evidence of some spawning activity in the Sub-Antarctic, as well as more extensively on the Chatham Rise)

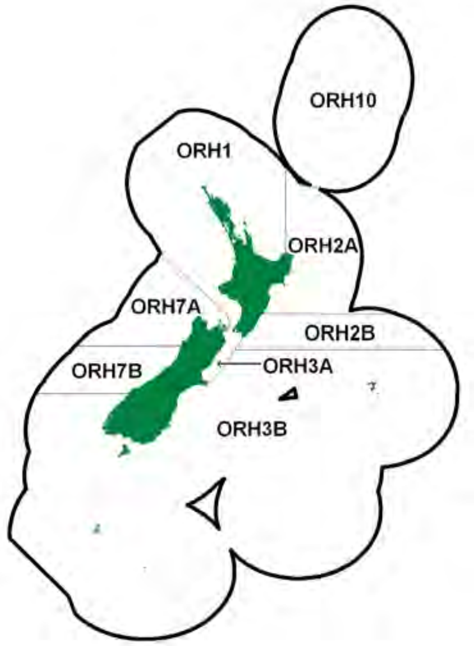
Fishery Interactions
In LDO 3 lookdown dory are mainly caught as bycatch in the hoki target bottom trawl fishery but also in many other middle depth fisheries. Interactions are the same as those for the hoki fishery.

7. FOR FURTHER INFORMATION

Anderson O.F., Bagley N.W., Hurst R.J., Francis M.P., Clark M.R., McMillan P.J. 1998. Atlas of New Zealand fish and squid distribution from research bottom trawls. NIWA Technical Report 42. 303 p.
Anderson O.F., Gilbert D.J., Clark M.R. 2001. Fish discards and non-target catch in the trawl fisheries for orange roughy and hoki in New Zealand waters for the fishing years 1990-91 to 1998-99. New Zealand Fisheries Assessment Report 2001/16. 57 p.
Bagley N.W., O'Driscoll R.L. 2010. Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November-December 2009 (TAN0911). *New Zealand Fisheries Assessment* (in press)
Bull B., Livingston M.E., Hurst R.J., Bagley N. 2001. Upper-slope fish communities on the Chatham Rise, New Zealand, 1992-99. New Zealand Journal of Marine and Freshwater Research 35 (3): 795-815.
Clark M.R., King K.J. 1989. Deepwater fish resources off the North Island, New Zealand: results of a trawl survey, May 1985 to June 1986. New Zealand Fisheries Technical Report 11. 56 p.
Forman J.S., Dunn M.R. (submitted). The influence of ontogeny and environment on the diet of lookdown dory, *Cyttus traversi*. *New Zealand Journal of Marine and Freshwater Research*. 44 p329-42.
Francis M.P., Hurst R.J., McArdle B., Bagley N.W., Anderson O.F. 2002. New Zealand demersal fish assemblages. Environmental Biology of Fishes 62(2): 215-234.
Hurst R J., Bagley N.W., Anderson O.F., Francis M.P., Griggs L.H., Clark M.R., Paul L.J., Taylor P.R. 2000. Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. NIWA Technical Report 84. 162p.
James G.D. 1976. Cyttus traversi Hutton: Juvenile form of *C. ventralis* Barnard and Davies (Pisces: Zeidae). Journal of the Royal Society of New Zealand 6(4): 493-498.
Livingston M.E., Bull B., Stevens D.W., Bagley N.W. 2002. A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992-2001. NIWA Technical Report 113. 146 p.
Livingston M.E., Clark M., Baird S.J. 2003. Trends in incidental catch of major fisheries on the Chatham Rise for fishing years 1989-90 to 1998-99. New Zealand Fisheries Assessment Report 2003/52. 74p.
Livingston M.E., Stevens D.W. 2005. Trawl survey of hoki and middle depth species on the Chatham Rise, January 2004 (TAN0401). New Zealand Fisheries Assessment Report 2005/21. 62 p.
MacGibbon D.J., McGregor V., Hurst R.J. 2011. Fishery characterisation and standardised CPUE analyses for lookdown dory, *Cyttus traversi* (Hutton, 1872) (Zeidae), 1989-90 to 2008-09**.** New Zealand Fisheries Assessment Report 2011 MID2009-01 (In Press)
May J.L., Maxwell J.G.H. 1986. Trawl fish from temperate waters of Australia. CSIRO Division of Fisheries Research, Tasmania. 492 p.
Nelson. 1994. Fishes of the world. Third edition. J. Wiley, New York. 600 p.
O'Driscoll R.L., Bagley N.W. 2001. Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic area 1991-98. NIWA Technical Report 102. 115 p.
O'Driscoll R.L., Booth J.D., Bagley N.W. Anderson O.F., Griggs L.H., Stevenson M.L., Francis M.P. 2003. Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. NIWA Technical Report 119. 377 p.
Stewart B.D.,Smith D. 1992. Development of methods to age commercially important dories and oreos. Newsletter of the Australian Society for Fish Biology 22 (2): 53-54.
Tracey D.M., Horn P.L., Andrews A.H., Marriott P.M., Dunn M.R. 2007. Age and growth, and an investigation of age validation of lookdown dory (*Cyttus traversi*). *Final Research Report for Ministry of Fisheries Project LDO2004-01 Objective 1*. 36 p.

ORANGE ROUGHY (ORH)

(*Hoplostethus atlanticus*)



1. INTRODUCTION

Orange roughy was introduced into the Quota Management System (QMS) on 1 October 1986. The main orange roughy fisheries have been treated separately for assessment and management purposes, and individual reports produced for each of five different areas consisting of one or more stocks as follows:

1. Northern North Island (ORH 1)
    - Mercury-Colville stock
    - Other stocks
2. Cape Runaway to Banks Peninsula (ORH 2A, 2B, & 3A)
    - East Cape stock
    - Mid-East Coast stock
3. Chatham Rise and Puysegur (ORH 3B)
    - Northwest Chatham Rise stock
    - East Chatham Rise stock
    - South Chatham Rise stock
    - Puysegur stock
    - Other minor stocks or subareas
4. Challenger Plateau (ORH 7A)
5. West coast South Island (ORH 7B)
6. Outside the EEZ
    - Lord Howe
    - Northwest Challenger
    - Louisville
    - West Norfolk
    - South Tasman

Note that since 2006, the area that was formerly referred to as the Northeast Chatham Rise is now called the East Chatham Rise to be consistent with the names of management areas used within ORH 3B.

2. BIOLOGY

Orange roughy inhabit depths between 700 m and at least 1500 m within the New Zealand EEZ. Their maximum depth range is unknown.

Orange roughy are very slow-growing, long-lived fish. On the basis of otolith ring counts and radiometric isotope studies, orange roughy may live up to 120-130 years. Age determination from otolith rings has been validated by length-mode analysis for juveniles up to four years of age, and adult ages have been validated from a preliminary study by Andrews & Tracey (2003).

Orange roughy otoliths have a marked transition zone in banding which is believed to be associated with first spawning (Francis & Horn 1997). This has been used to estimate mean age at the onset of maturity, which ranges from 23 to 31.5 years for fish from various New Zealand fishing grounds (Horn *et al*. 1998, Seafood Industry Council/NIWA unpublished data). Orange roughy in New Zealand waters reach a maximum size of about 50 cm standard length (SL), and 3.6 kg in weight. Their average size is around 35 cm SL, although there is some variation between areas.

Spawning occurs once each year between June and early August in several areas within the New Zealand EEZ, from the Bay of Plenty in the north, to the Auckland Islands in the south. Spawning occurs in dense aggregations at depths of 700-1000 m and is often associated with bottom features such as pinnacles and canyons. Spawning fish are also found outside the EEZ on the Challenger Plateau, Lord Howe Rise, and Norfolk Ridge to the west, and the Louisville Ridge to the east. It is likely that individual orange roughy do not spawn every year.

Fecundity is relatively low, with females carrying on average about 40 000-60 000 eggs. The eggs are large (2-3 mm in diameter), are fertilised in the water column, and then drift upwards towards the surface and remain planktonic until they hatch close to the bottom after about 10 days. Details of larval biology are poorly known.

Orange roughy juveniles are first available to bottom trawls at age about 6 months, when they exhibit a mean length of about 2 cm. Juveniles have been found in large numbers in only one area, at a depth of 800-900 m about 150 km east of the main spawning ground on the north Chatham Rise.

Orange roughy also form aggregations outside the spawning period, presumably for feeding. Their main prey species include mesopelagic and benthopelagic prawns, fish and squid, with other organisms such as mysids, amphipods and euphausiids occasionally being important.

Natural mortality (M) is estimated at 0.045 yr^{-1}. This was based on otolith age data from a 1984 research survey of the Chatham Rise that used an estimation technique based on mean age. A similar estimate was obtained in 1998 from a lightly fished population in the Bay of Plenty.

Biological parameters used in the following assessments (Tables 1 and 2) were estimated by Doonan (1994) with modifications of A_r, A_m, S_r, and S_m for the 1998 stock assessment meetings by Francis and Horn (1997), Horn *et al*. (1998), and Doonan *et al.* (1998), and further modifications for the 2006 assessment by Hicks (2006).

Possible biases in reading ages from otoliths were recently identified and it was recommended by the reviewers of orange roughy workshops in October 2005 and February 2006 that no age data should be input into the assessments until the biases can be quantified and corrected for. They suggested, however, that the age data could be used post-estimation to check for severe inconsistencies in a model or run.

It is believed that ages from otoliths collected during the 1984 and 1990 trawl surveys of the East Chatham Rise and aged by NIWA personnel do not contain serious biases, thus these were used to estimate a single-sex growth curve, length-weight parameters, and a maturity ogive based on transition zones. The estimates are shown in Table 1 and were used for both the East Chatham Rise and the Northwest Chatham Rise, although the otoliths used were collected from only the East Chatham Rise (of which most were from the Spawning Box).

The growth and length-weight parameters were estimated in a slightly different way than in the past. The models used for orange roughy assessments bin the lengths by 1cm and use the midpoint of each bin. For example, a length of 32.3 cm is in the length class between 32 and 33 cm, and is treated as 32.5 when calculating age or weight. Therefore, the lengths in the external estimation of the growth and length-weight parameters were treated the same.

The maturity estimates were only used in initial runs. In final runs the maturity ogive was assumed equal to estimated selectivity, where appropriate. See Section 3(c) below for a more in-depth explanation.

Table 1: Biological parameters as used for orange roughy assessments. -, not estimated.

Parameter	Symbol	Male	Female	Both sexes
Natural mortality	M	-	-	0.045 yr^{-1}
Age of recruitment	A_r (a_{50})	-	-	$=A_m$
Gradual recruitment	S_r (a_{to95})	-	-	$=S_m$
Age at maturity	A_m (a_{50})	-	-	Table 2
Gradual maturity	S_m (a_{to95})	-	-	Table 2
von Bertalanffy parameters				
- Chatham Rise (default)	L_∞	36.4 cm	38.0 cm	-
- Northwest Chatham Rise†	L_∞	-	-	37.78 cm
- East Chatham Rise*	L_∞	-	-	37.78 cm
- Ritchie Bank	L_∞	-	-	37.63 cm
- Challenger Plateau	L_∞	33.4 cm	35.0 cm	-
- All areas (default)	k	0.070 yr^{-1}	0.061 yr^{-1}	-
- Northwest Chatham Rise†	k	-	-	0.059 yr^{-1}
- East Chatham Rise*	k	-	-	0.059 yr^{-1}
- Ritchie Bank	k	-	-	0.065 yr^{-1}
- All areas (default)	t_0	-0.4 yr	-0.6 yr	-
- East Chatham Rise*	t_0	-	-	-0.491
- Northwest Chatham Rise†	t_0	-	-	-0.491
- Ritchie Bank	t_0	-	-	-0.5
Length-weight parameters				
- default	a	-	-	0.0921
- East & Northwest Chatham Rise*	a			0.0800
- default	b	-	-	2.71
- East & Northwest Chatham Rise*	b			2.75
Recruitment variability	s_R	-	-	1.1
Recruitment steepness		-	-	0.75

*New estimates used in 2006 assessments, estimated using floored+0.5 lengths

†New estimates used in 2006 assessment estimated from East Chatham Rise data

Table 2: Estimates of A_m and S_m by area for New Zealand orange roughy from transition zone observations.

	A_m			S_m		
Area	M	F	Both sexes	M	F	Both sexes
Chatham Rise (default)	-	-	29	-	-	3
Northwest Chatham Rise*	-	-	28.51	-	-	4.56
East Chatham Rise*	-	-	28.51	-	-	4.56
Ritchie Bank	-	-	31.5	-	-	7.11
Challenger Plateau	-	-	23	-	-	3
Puysegur Bank	-	-	27	-	-	3
Bay of Plenty	26	27	-	4	5	-

*New estimates used in 2006 assessments from East Chatham Rise only data

The differing parameter values in Tables 1 and 2 by area mean that yield estimates also differ by fishing ground (Table 3).

Table 3: Estimates of *MCY*, E_{CAY} and *MAY* for New Zealand orange roughy.

Area	*MCY* (%B_0)	E_{CAY}	*MAY* (%B_0)
Bay of Plenty (ORH 1)	1.47	0.063	1.94
Ritchie Bank (ORH 2A)	1.46	0.062	1.92
Chatham Rise (ORH 3B)	1.51	0.064	1.99
Puysegur Bank (ORH 3B)	1.47	0.062	1.94
Challenger Plateau (ORH 7A)	1.40	0.060	1.84

For all these stocks, the mean biomass when fishing using an *MCY* policy is estimated to be 51% of B_0, and for a *CAY* policy it is 30% of B_0 (these values varied by less than 1% between the various stocks).

3. ENVIRONMENTAL & ECOSYSTEM CONSIDERATIONS

This section was updated with new tables for the May 2012 Fishery Assessment Plenary based on reviews of similar chapters by the Aquatic Environment Working Group. This summary is from the perspective of the deepwater trawl fisheries for orange roughy, oreos, and cardinalfish; a more detailed summary from an issue-by issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review (http://fs.fish.govt.nz/Page.aspx?pk=113&dk=22982).

3.1 Role in the ecosystem

Not yet considered.

3.2 Incidental catch (fish and invertebrates)

Anderson (2011) summarised the bycatch of orange roughy and oreo trawl fisheries from 1990–91 to 2008–09. For orange roughy trawls since 2005–06, orange roughy accounted for about 84% of the total observed catch and the remainder comprised mainly oreos (10%), hoki (0.4%), and cardinalfish (0.3%). About 240 other species or species groups were recorded by observers, including various deepwater dogfishes (1.8%), rattails (1.0%), morid cods (0.8%), and slickheads (0.3%). For oreo trawl since 2002, oreos accounted for about 92% of the observed catch and the remainder was mainly orange roughy (3.5%), hoki (0.6%), and ling (0.3%). About 240 other species or species groups were recorded, including deepwater dogfish (1.2%), rattails (1.0%), morid cods (0.1%), and slickheads (0.1%). No information is available for cardinalfish.

3.3 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 or caught on a hook but not brought onboard the vessel, Middleton & Abraham 2007, Brothers *et al*. 2010).

3.3.1 Marine mammal interactions

Trawlers targeting orange roughy or oreos occasionally catch NZ fur seals (which were classified as “Not Threatened” under the NZ Threat Classification System in 2010, Baker *et al*. 2010). Between 2002–03 and 2009–10, there were 14 observed captures of NZ fur seals in orange roughy, oreo, and cardinalfish trawl fisheries. In the 2009-10 fishing year there were no observed captures (Table 4) but there were 4 (95% c.i.: 0 - 13) estimated captures, with the estimates made using a statistical model (Thompson & Abraham 2012). All observed fur seals captures occurred in the SubAntarctic region. The average rate of capture for these years was 0.10 per 100 tows (range 0 to 0.25). This is a low rate compared with that in the hoki fishery (1.5 to 5.6 per 100 tows).

Table 4: 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 2009-10. 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. Data from Thompson & Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

		Observed				Estimated		
	Tows	No.obs	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	8 871	1 378	15.5	0	0.00	4	0 - 11	99.9
2003–04	8 005	1 261	15.8	2	0.16	7	2 - 16	99.9
2004–05	8 417	1 617	19.2	4	0.25	17	5 - 53	99.8
2005–06	8 305	1 294	15.6	2	0.15	12	3 - 32	99.8
2006–07	7 367	2 323	31.5	2	0.09	3	2 -6	99.9
2007–08	6 730	2 811	41.8	4	0.14	8	4 - 20	100.0
2008–09	6 131	2 373	38.7	0	0.00	4	0 - 14	100.0
2009–10	6 011	2 133	35.5	0	0.00	4	0 - 13	99.9

3.3.2 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,c, 2005a, Abraham & Thompson 2011, Abraham *et al*. 2009). 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 5). In the 2009-10 fishing year there were 19 observed captures of birds in orange roughy, oreo, and cardinalfish trawl fisheries at a rate of 0.9 birds per 100 observed tows (Thompson & Abraham 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 0.4 birds per 100 tows, a low rate relative to trawl fisheries for squid (13.3 birds per 100 tows), scampi (3.53 birds per 100 tows) and hoki (2.2 birds per 100 tows) over the same years.

Table 5: Number of tows by fishing year and observed seabird captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002-03 to 2009-10. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Data from Thompson & Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

	Tows	No. obs	% obs	Captures	Rate
2002–03	8 871	1 378	15.5	0	0.00
2003–04	8 005	1 261	15.8	3	0.24
2004–05	8 417	1 617	19.2	20	1.24
2005–06	8 305	1 294	15.6	7	0.54
2006–07	7 367	2 323	31.5	1	0.04
2007–08	6 730	2 811	41.8	5	0.18
2008–09	6 131	2 373	38.7	8	0.34
2009–10	6 011	2 133	35.5	19	0.89

Salvin’s albatross were the most frequently captured albatross (48% of observed albatross captures) but seven different species have been observed captured since 2002–03. Cape petrels were the most frequently captured other bird (63%, Table 6). 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 (MFish 2006). The 2006 notice mandated that all trawlers >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).

Table 6: Number of observed seabird captures in orange roughy, oreo, and cardinalfish fisheries, 2002-03 to 2009-10, 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 *et al*. 2011 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for orange roughy, oreo, and cardinalfish. Other data from Thompson & Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

Species	Risk ratio	Chatham Rise	East Coast South Island	Sub-Antarctic	Stewart-Snares Shelf	Total
Salvin's albatross	2.49	11	2	3	0	16
Chatham Island albatross	2.71	7	0	0	0	7
White capped albatross	0.83	4	0	0	0	4
Southern Buller's albatross	1.28	3	0	0	0	3
Gibson's albatross	1.25	1	0	0	0	1
Northern royal albatross	2.21	1	0	0	0	1
Shy albatross	–	0	0	1	0	1
Total albatrosses		**27**	**2**	**4**	**0**	**33**
Cape petrels	0.76	9	10	0	0	19
Grey petrel	0.39	2	0	1	0	3
Common diving petrel	0.00	2	0	0	0	2
Sooty shearwater	–	0	1	0	1	2
Northern giant petrel	3.00	1	0	0	0	1
Storm petrels	–	1	0	0	0	1
White chinned petrel	0.79	0	1	0	0	1
White-faced storm petrel	0.00	1	0	0	0	1
Total other birds		**16**	**12**	**1**	**1**	**30**

3.4 Benthic interactions

Orange roughy, oreo, and cardinalfish are taken using bottom trawls and 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 1 200 m depth (Baird *et al*. 2011).

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 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 Aquatic Environment and Biodiversity Annual Review (2012).

3.5 Other considerations

None.

4. STOCK ASSESSMENT ISSUES

In recent assessments of individual stocks and areas, some issues arose which affect all orange roughy stocks. These concern the use of CPUE (catch per unit effort) as an index of abundance, the use of research surveys as indices of abundance, and the relationship between maturity and vulnerability to commercial fishing.

4.1 CPUE and abundance

Some previous orange roughy assessments in both NZ and Australia have shown inconsistencies between CPUE and survey indices, with models based on CPUE biomass indices estimating lower relative stock sizes than models based solely on survey biomass indices (for example, this behaviour has been observed in the ORH 2AS/2B/3A and ORH 3B NW assessments [Annala *et al*. 2002]). One possible way of reconciling the difference between these data sources is achieved by allowing a non-linear relationship between CPUE and vulnerable biomass (*V*) as in Equation 1 (Hilborn & Walters 1992).

$$CPUE = qV^{\beta} \qquad (1)$$

A meta-analysis was undertaken on orange roughy assessments where there were comparable estimates of stock abundance based on CPUE data and fishery independent surveys to determine the relationship between CPUE and abundance. Of the four stocks analysed, three showed significant hyperdepletion, where CPUE declines faster than abundance (Hicks 2004a). The fourth stock, ORH 3B NE, did not show a significant departure from a linear proportional relationship. Using these meta-analysis results, a prior for the parameter β (Eq. 1) was determined to allow this parameter to be estimated within a stock assessment model. The prior for β is log-normal with the mean of $\ln(\beta)$ equal to 0.7075 and the standard deviation of $\ln(\beta)$ equal to 1.0446 (Hicks 2004b).

While working on assessments in 2004 and 2005 there was some debate about the utility of estimating β. For the 2004 assessments, it was agreed that at least two alternative runs would be carried out for each stock: one in which β was estimated using the prior from the meta-analysis (‘EstBeta’), and another in which it was not estimated but was set equal to 1 (‘Beta1’). For stocks with fishery-independent data, a third run was made in which the CPUE data were excluded (NoCPUE). For both stocks where all three runs were made, the results from the EstBeta and NoCPUE runs were similar and quite different from those for Beta1. This emphasis on CPUE reflects differing signals received from fishery-independent vs. fishery-dependent data for orange roughy.

Work examining various aspects of the utility of estimating β was done intersessionally in late 2005 and early 2006, and it was found that the decision to estimate β involved a trade-off between bias and variance. In other words, if in truth, β was not equal to one, not estimating β in an assessment with CPUE data would result in a biased estimate of population size. Estimating β, however, would result in higher variance in the estimate of population size, but less bias. In an effort to reduce possible bias without estimating β in 2006 assessments, the first three values were omitted from CPUE series covering the start of a hill fishery or CPUE series that have historically shown hyperdepletion. CPUE series from the Spawning Box, for example, were left complete, as the pre-closure series showed no significant hyperdepletion in the meta-analysis done by Hicks (2004a) and the post-closure series occurs late in the fishery.

4.2 Survey abundance indices

Three types of survey indices have been used in orange roughy assessments in New Zealand: trawl surveys, acoustic surveys, and egg surveys. Assessments in 2006 viewed trawl surveys and acoustics surveys differently than in past assessments, while egg surveys remained unchanged as absolute surveys. If a trawl survey series was composed of different vessels, a separate catchability was estimated for each vessel with informed priors relating the catchabilities to each other. For example, the Spawning Box trawl survey series is made up of three vessels and thus estimated three separate catchabilities. Acoustic surveys were treated as relative indices of abundance instead of absolute indices, and informed priors were assigned to the estimated catchability. The methods for developing the informed priors are explained in Cordue (2006).

4.3 Maturity and vulnerability

Until recently it was assumed in New Zealand orange roughy stock assessments that all mature fish were vulnerable to commercial fishing but that no immature fish were. This section describes the basis of that assumption, the new data that challenge it, and the decisions that were made in response to these data.

The original assumption was based on the fact that, in the early years, most orange roughy fishing took place on spawning aggregations. There was no evidence that immature fish were present in any numbers in these spawning aggregations, nor that fishers were avoiding smaller (or younger) mature fish. Because there were no data available on the age at which fish entered the fishery it seemed reasonable to assume, as an approximation, that this was the same as the age at which they reached maturity. As fisheries developed, more fishing took place outside the spawning season when, on average, slightly smaller fish were caught. Thus, there were grounds for assuming that the age of vulnerability was slightly less than the age at maturity. However, as vulnerability data were still lacking the original assumption persisted.

Initial model runs for two stocks in 2004 suggested that this assumption was wrong. The age of vulnerability was estimated to be 7 to 20 years greater than the age at maturity and current mature biomass to be substantially larger than the vulnerable biomass (Table 7). In these runs, the age of vulnerability was estimated either from length-frequency samples or from otolith readings. The age of maturity was estimated from the "transition zone" in the otoliths, a zone that has previously been interpreted as representing the onset of maturity.

Table 7: Examples of estimates from initial model runs done in 2004 for the Mid-East Coast and Northwest Chatham Rise stocks in which the maturity and vulnerability were allowed to differ. The vulnerable biomass is that which is available to the commercial fishery. a_{50} (maturity) is the age at which 50% of fish are mature, a_{50} (commercial) is the age at which 50% of fish are available to the commercial fishery. Values are given from a range of runs, using both the NIWA and the UW/SeaFIC model and with a range of alternative assumptions.

	Current biomass		*a*50 (y)	
Stock	Mature	Vulnerable	maturity	Commercial
Northwest Chatham Rise	37 400	6 200	27.9	39.4
	37 200	5 500	27.9	39.0
	40 200	9 900	27.9	43.1
	44 200	8 000	27.9	47.1
Mid-East Coast	38 300	12 600	31.3	40.3
	47 000	23 600	31.3	38.3
	53 800	30 300	31.3	37.8

The Working Group rejected these model runs on the grounds that it did not seem plausible that the current vulnerable biomass was so much less than the mature biomass. It was agreed that, for the 2004 and subsequent assessments, the Working Group would revert to the original assumption that the ages of maturity and vulnerability were the same. Further work on interpretation of transition zones is needed.

This assumption was implemented in different ways for different stocks. Where both maturity and vulnerability data were available the former were rejected. This was because the maturity data were deemed to be indirect because they are based on the assumption that the transition zone in the otolith marks the onset of maturity (Francis & Horn, 1997). In contrast, the age- and length-frequency data used for estimating vulnerability were direct observations on the commercial fishery. Thus, for the MEC and Northwest Chatham Rise stocks the age at maturity was assumed to be the same as the age of vulnerability (technically, the maturity ogive was set equal to the estimated selectivity ogive). For stocks without vulnerability data (ORH 7B and South Chatham Rise) the age at vulnerability was assumed equal to the age at maturity (i.e., the selectivity ogive was set equal to the maturity ogive).

5. FOR FURTHER INFORMATION

Abraham E.R., Thompson F.N., Oliver M.D. 2010. Summary of the capture of seabirds, mammals, and turtles in New Zealand commercial fisheries, 1998-99 to 2007-08. New Zealand Aquatic Environment and Biodiversity Report No.45. 149p.

Abraham E.R., Thompson F.N. 2011. Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09 New Zealand Aquatic Environment and Biodiversity Report No. 80.

Anderson O.F. 2011. Fish and invertebrate bycatch and discards in orange roughy and oreo fisheries from 1990–91 until 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 67.

Anderson O.F., Dunn M.R. 2007. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B and 7B to the end if the 2004-05 fishing year. New Zealand Fisheries Assessment Report 2007/29. 71p.

Andrews A.H. Tracey D.M. 2003. Age validation of orange roughy, oreos, and black cardinalfish. Final Research Report for Ministry of Fisheries Research Project DEE2000/02. NIWA. 25p.

Baird S.J. 2004a. Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999-2000. New Zealand Fisheries Assessment Report 2004141.56 p.

Baird SJ. 2004b. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000-01. New Zealand Fisheries Assessment Report 2004158.63 p.

Baird S.J. 2004c. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001-02. New Zealand Fisheries Assessment Report 2004160.51 p.

Baird S.J. 2005. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002-03. New Zealand Fisheries Assessment Report 200512.50 p.

Baird S.J., Smith M.H. 2007. Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. New Zealand Aquatic Environment and Biodiversity Report No. 14. 98 p.

Baird S.J., B.A. Wood, *et al*. 2011. Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989-90 to 2004-05. New Zealand Aquatic Environment and Biodiversity Report 73. 143 p.

Baird S.J., Wood B.A. 2012. Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with sealoor contact. New Zealand Aquatic Environment and Biodiversity Report 89. 43 p.

Baker C.S., Chilvers B.L., Constantine R., DuFresne S., Mattlin R.H., van Helden A., Hitchmough R. 2010. Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. New Zealand Journal of Marine and Freshwater Research 44: 101-115.Ballara, S.L.; Anderson, O.F. (2009). Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 38. 102 p.

Brothers N., Duckworth A.R., Safina C., Gilman E.L. 2010. Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. PloS One 5: e12491. doi: 10.1371/journal.pone.001249

Clark M.R. 2008. Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, northwest Challenger Plateau, west Norfolk Ridge, south Tasman Rise and Louisville Ridge to the end of the 2005-06 fishing year. New Zealand Fisheries Assessment Report 2008/12. 45p.

Clark M.R. 2006. Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2004-05 fishing year. New Zealand Fisheries Assessment Report 2006/56. 38p.

Clark M.R., Fincham D.J., Tracey D.M. 1994. Fecundity of orange roughy (Hoplostethus atlanticus) in New Zealand waters. N.Z. Journal of Marine and Freshwater Research 28: 193-200.

Cordue P.L. 2006: Prior distributions for trawl and acoustic survey proportionality constants used in the 2006 orange roughy stock assessments. 29p. Draft New Zealand Fisheries Assessment Report.

Doonan I.J. 1994. Life history parameters of orange roughy; estimates for 1994. New Zealand Fisheries Assessment Research Document: 1994/19: 14p.

Doonan I.J., Tracey D.M. 1997. Natural mortality estimates for orange roughy in ORH 1 (Bay of Plenty). New Zealand Fisheries Assessment Research Document 1997/26: 9p.

Doonan I.J., Francis R.I.C.C., Horn P., Tracey D.M. 1998. Update of biological parameters for orange roughy. (Unpublished report to Deepwater Stock Assessment Working Group, 98/16.

Francis R.I.C.C. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8: 27p.

Francis R.I.C.C., Robertson D.A., Clark M.R., Doonan I.J., Coburn R.P., Zeldis JR. 1993. Assessment of the ORH 3B orange roughy ishery for the 1993/94 fishing year. New Zealand Fisheries Assessment Research Document 1993/7: 44p.

Francis R.I.C.C., Horn P.L. 1997. The transitions zone in otoliths of orange roughy (*Hoplostethus atlanticus*) and its relationship to the onset of maturity. Marine Biology 129: 681-687.

Hermsen J.M., Collie J.S., Valentine P.C. 2003. Mobile fishing gear reduces benthic megafaunal production on Georges Bank Mar. Ecol. Prog. Ser. 260: 97-108

Hicks A.C. 2004a. A meta-analysis of CPUE in orange roughy fisheries. WG-Deepwater-04/10. (Unpublished report held by Ministry of Fisheries, Wellington.)

Hicks A.C. 2004b. A meta-analysis of CPUE in orange roughy fisheries: creating a prior. WG-Deepwater-04/20. (Unpublished report held by Ministry of Fisheries, Wellington.)

Hicks A.C. 2006. Growth, length-weight, and maturity estimates for the Northeast Chatham Rise. WG-Deepwater-06/13. (Unpublished .report held by Ministry of Fisheries, Wellington.)

Hiddink J.G., Jennings S., Kaiser M.J., Queiros A.M., Duplisea D.E., Piet G.J. 2006. Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. Can. J. Fish. Aquat. Sci. 63:721–36

Hilborn R.,Walters C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York, 570 pp.

Horn P.L., Tracey D.M., Clark M.R. 1998. Between-area differences in age and length at first maturity of orange roughy (*Hoplostethus atlanticus*). Marine Biology 132 (2): 187-194.

Leathwick J.R., Rowden A., Nodder S., Gorman R., Bardsley S., Pinkerton M., Baird S.J., Hadfield M., Currie K., Goh A. 2009. Benthic-optimised marine environment classification for New Zealand waters. Final Research Report project BEN2006/01. 52 p.

Mace P.M., Fenaughty J.F., Coburn R.P., Doonan I.J. 1990. Growth and productivity of orange roughy (*Hoplostethus atlanticus*) on the north Chatham Rise. New Zealand Journal of Marine and Freshwater Research 24: 105-119.

MacKenzie D., Fletcher D. 2006. Characterisation of seabird captures in commercial trawl and longline fisheries in New Zealand 1997/98 to 2003/04. Final Research Report for ENV2004/04, held by Ministry of Fisheries, New Zealand. 102p.

Pankhurst N.W. 1988. Spawning dynamics of orange roughy, *Hoplostethus atlanticus*, in mid-slope waters of New Zealand. Environmental biology of fishes 21: 101-116.

Paul L.J., Tracey D.M., Francis R.I.C.C. 2002. Age validation of deepwater fish species, with particular reference to New Zealand orange roughy and oreos: a literature review. Final Research Report for Ministry of Fisheries Research Project DEE200002. NIWA. 33p.

Rice J. 2006. Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Rossechi E., Tracey D.M., Weber W.R. 1988. Diet of orange roughy, *Hoplosthethus atlanticus* (Pisces: Trachichthyidae), on the Challenger Plateau, New Zealand. Marine biology 99: 293-306.

Thompson F.N., Abraham E.R., Oliver M.D. in press. Estimation of fur seal bycatch in New Zealand sea lions trawl fisheries, 2002-03 to 2007-08. DRAFT New Zealand Aquatic Environment and Biodiversity Report. 39p.

Tracey D.M., Horn P.L. 1999. Background and review of ageing orange roughy (*Hoplostethus atlanticus*, Trachichthyidae) from New Zealand and elsewhere. New Zealand Journal of Marine & Freshwater Research 33: 67-86.

Zeldis J.R., Grimes P.J., Ingerson J.K.V. 1994. Ascent rates, vertical distribution, and a thermal history model of development of orange roughy (*Hoplostethus atlanticus*) eggs in the water column. Fishery bulletin (United States) 93: 373-385.

ORANGE ROUGHY NORTHERN NORTH ISLAND (ORH 1)

1. FISHERY SUMMARY

1.1 Commercial fisheries

This region extends northwards from west of Wellington around to Cape Runaway. Prior to 1993-94 there was no established fishery, and reported landings were generally small (Table 1). A new fishery developed in winter 1994, when aggregations were fished on two hill complexes in the western Bay of Plenty. In 1996 catches were also taken off the west coast of Northland. Figure 1 shows the historical landings and TACC values for ORH 1.

A TACC of 190 t was set from 1989-90. Prior to that there had been a 10 t TAC and various levels of exploratory quota. From 1995-96, ORH 1 became subject to a five year adaptive management programme, and the TACC was increased to 1190 t. A catch limit of 1000 t was applied to an area in the western Bay of Plenty (Mercury-Colville 'box'), with the former 190 t TACC applicable to the remainder of ORH 1. In 1994 and 1995, research fishing was also carried out under Special Permit (not included in the TACC). For the period June 1996-June 1997, a Special Permit was approved for exploratory fishing. This allowed an additional 800 t (not included in the TACC) to be taken in designated areas, although catches were limited from individual features (hills and seamounts etc).

Table 1: Reported landings (t) and TACCs (t) from 1982-83 to 2010-11. - no TACC. The reported landings do not include catches taken under an exploratory special permit of 699 t in 1998-99 and 704 t in 1999-2000. QMS data from 1986-present.

	Reported landings			
Fishing year	West coast	North-east coast	Total	TACC
1982-83*	< 0.1	0	< 0.1	-
1983-84*	0.1	0	0.1	-
1984-85*	< 0.1	96	96	-
1985-86*	< 1	2	2	-
1986-87*	0	< 0.1	< 0.1	10
1987-88	0	0	0	10
1988-89	0	19	19	10
1989-90	37	49	86	190
1990-91	0	200	200	190
1991-92	+	+	112	190
1992-93	+	+	49	190
1993-94	0	189	189	190
1994-95	0	244	244	190
1995-96	55	910	965	1 190
1996-97	+	+	1 021	1 190
1997-98	+	+	511	1 190
1998-99	+	+	845	1 190
1999-00	+	+	771	1 190
2000-01	+	+	858	800
2001-02	+	+	1 294	1 400
2002-03	+	+	1 123	1 400
2003-04	+	+	986	1 400
2004-05	+	+	1 151	1 400
2005-06	+	+	1 207	1 400
2006-07	+	+	1 036	1 400
2007-08	+	+	1 104	1 400
2008-09	+	+	905	1 400
2009-10	+	+	825	1 400
2010-11	+	+	772	1 400

* FSU data.
\+ Unknown distribution of catch.

Reported catches have varied considerably between years, and the location of the catch in the late 1980s/early 1990s is uncertain, as some may have been taken from outside the EEZ, as well as misreported from other areas. Research fishing carried out under Special Permit in 1994 and 1995 resulted in catches of 45.2 t and 200.7 t, respectively (not included in Table 1).

Based on an evaluation of the results of an Adaptive Management Programme (AMP) for the Mercury-Colville box initiated in 1995, the AMP was concluded and the TACC was reduced to 800 t for the 2000-01 fishing year. Catch limits of 200 t were established in each of four areas in ORH 1, with an individual seamount feature limit of 100 t. From 1 October 2001, ORH 1 was reintroduced into the AMP with different design parameters for five years, and the TACC was increased from 800 to 1400 t and allocated an allowance of 70 t for other mortality caused by fishing.

In recent years the fishery has also developed off the west coast and sizeable catches have been taken off the Tauroa Knoll and West Norfolk Ridge.

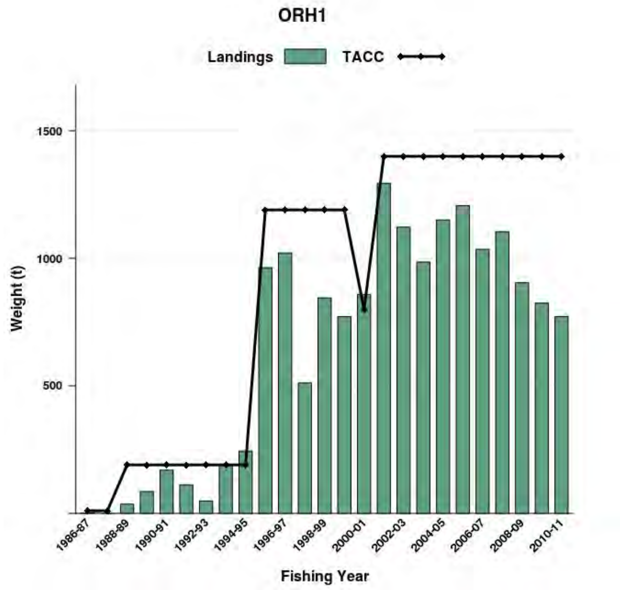


Figure 1: Historical landings and TACC for ORH 1 (Auckland East). Note that this figure does not show data prior to entry into the QMS.

1.2 Recreational fisheries
There is no known non-commercial fishery for orange roughy in this area.

1.3 Customary non-commercial fisheries
No customary non-commercial fishing for orange roughy is known in this area.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch in this area.

1.5 Other sources mortality
There may be some overrun of reported catch because of fish loss with trawl gear damage and ripped nets. In other orange roughy fisheries, a level of 5% has been estimated.

2. STOCKS AND AREAS

Orange roughy are distributed throughout the area. Spawning is known from several hills in the western Bay of Plenty as well as from features in the western regions of ORH 1. Stock status/affinities within the QMA are unknown. The Mercury-Colville grounds in the Bay of Plenty are about 120 n. miles from fishing grounds at East Cape (ORH 2A North), and spawning occurs at a similar time. Hence, it is likely that these are separate stocks. The Mercury and Colville Knolls in the Bay of Plenty are about 25 miles apart and may form a single stock. Stock affinities with other fishing hills in the southern and central Bay of Plenty are unknown. The Tauroa Knoll and outer Colville Ridge seamounts are distant from other commercial grounds, and these fish may also represent separate stocks.

3. STOCK ASSESSMENT

An assessment for the Mercury-Colville box was carried out in 2001 and is repeated here. A deterministic stock reduction technique (*after* Francis 1990) was used to estimate virgin biomass (B_0) and current biomass ($B_{current}$) for the Mercury-Colveille orange roughy stock. The model was fitted to the biomass indices using maximum likelihood and assuming normal errors. In common with other orange roughy assessments, the maximum exploitation rate was set at 0.67. The model treats sexes separately, and assumes a Beverton-Holt stock-recruit relationship. Confidence intervals of the biomasss estimates were derived from bootstrap analysis (Cordue & Francis 1994).

3.1 Estimates of fishery parameters and abundance

A series of trawl surveys of the Mercury-Colville box to estimate relative abundance were agreed under an Adaptive Management Programme. The first survey was carried out in June 1995 with a second survey in winter 1998 (Table 2). The biomass index of the latter survey was much lower than 1995, and it was uncertain whether the 1998 results were directly comparable to the 1995 results because of warmer water temperatures. They were not incorporated in the decision rule for the adaptive management programme. A third survey was carried out in June 2000, with the results suggesting that the abundance of orange roughy in the box had decreased considerably and was at low levels. However, these estimates are uncertain because of the suggestion that environmental factors may have influenced the distribution of orange roughy. The abundance indices from trawl survey and commercial catch-effort data used in the assessment are given in Table 2. The trawl survey indices had *c.v.*'s of 0.27, 0.39 and 0.29 for 1995, 1998, and 2000 respectively.

Table 2: Biomass indices and reported catch used in estimation of B_0. Values in square brackets are included for completeness; they are not used in the assessment.

Year	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
Trawl survey	-	76 200	-	-	[2 500]	-	3 800
CPUE	8.3	9.1	5.4	4.2	[0.5]	1.5	(2.0)
Catch (t)	230	440	915	895	295	140	250

The CPUE series is mean catch per tow (sum of catches divided by number of tows, target ORH) from Mercury Knoll in the month of June. This is the only month when adequate data exist from the fishery to compare over time. A *c.v.* of 0.30 was assigned to the CPUE data.

Catch history information is derived from TCEPR records, scaled to the reported total catch for ORH 1. Figures differ slightly from unscaled data summarised by Clark (1999), but this would make little difference to the assessment. Overrun of reported catch (e.g., burst bags, inappropriate conversion factors) was assumed to be zero, as even if there was some, it is likely that it was similar between years. The catch in 1999-00 was assumed to be 250 t.

Assessments were carried out for three alternative sets of biomass indices (Table 3).

Table 3: Three alternative sets of biomass indices used in the stock assessment.

Alternative	Trawl survey indices	CPUE indices
1	1995, 2000	All except 1998
2	1995, 2000	None
3	1995, 2000	All except 1998 and 2000

Biological parameters used are those for the Chatham Rise stock, except for specific Bay of Plenty values for the maturity and recruitment ogives (Annala *et al.* 2000).

3.2 Biomass estimates

The estimated virgin biomass (B_0) is very similar for all three alternative assessments (Table 4). With alternative 1 the estimated B_0 is 3200 t, with a current biomass of 15% B_0. For both alternatives 2 and

3, the estimated B_0 is 3000 t, which is B_{min}, the minimum stock size which enables the catch history to be taken given a maximum exploitation rate of 0.67.

Table 4: Biomass estimates (with 95% confidence intervals in parentheses) for stock assessments with the three alternatives of Table 3. B_0 is virgin biomass; B_{MSY} is interpreted as B_{MAY}, which is 30%B_0; $B_{current}$ is mid-season 1999-00; and B_{beg} is the biomass at the beginning of the 2000-01 fishing year. Estimates are rounded to the nearest 100 t (for B_0), 10 t (for other biomasses), or 1%.

Biomass	Alternative 1		Alternative 2		Alternative 3	
B_0 (t)	3 200	(3 000, 3 600)	3 000	(3 000, 3 500)	3 000	(3 000, 3 300)
B_{MSY} (t)	960	(900, 1080)	900	(900, 1050)	900	(900, 990)
$B_{current}$ (t)	490	(290, 890)	290	(290, 790)	290	(290, 590)
$B_{current}$ (%B_0)	15	(10, 25)	10	(10, 23)	10	(10, 18)
B_{beg} (t)	480	(270, 900)	270	(270, 800)	270	(270, 590)

The model fits the CPUE data reasonably well but estimates a smaller decline than is implied by the two trawl survey indices.

3.3 Estimates of Yield

Yield estimates were determined using the simulation method described by Francis (1992) and the relative estimates of *MCY*, E_{CAY} and *MAY*, as given by Annala *et al.* (2000).

Yield estimates are all much lower than recent catches (Table 5). Estimates of current yields (MCY_{current} and *CAY*) lie between 16 t and 35 t; long-term yields ($MCY_{\text{long-term}}$ and *MAY*) lie between 44 t and 67 t.

Table 5: Yield estimates (t) for stock assessments with the three alternatives of Table 3.

Yield	Alternative 1		Alternative 2		Alternative 3	
MCY_{curren}	35	(22, 53)	22	(22, 51)	22	(22, 44)
$MCY_{\text{long-term}}$	47	(44,53)	44	(44, 51)	44	(44, 49)
CAY	29	(16, 54)	16	(16, 48)	16	(16, 36)
MAY	67	(58, 70)	58	(58, 68)	58	(58, 64)

CSP for this stock is just under 100 t for any B_0 between 3000 t and 3600 t.

4. ANALYSIS OF ADAPTIVE MANAGEMENT PROGRAMME

The ORH 1 TACC was increased from 800 to 1400 t in October 2001/02 under the Adaptive Management Programme. The objectives of this AMP were to determine stock size, geographical extent, and long-term sustainable yield of the ORH 1 stock. This is a complex AMP, with ORH 1 divided into four sub-areas (see Figure 2), each with total catch and “feature” catch limits (a “feature” was defined as being within a 10 nm radius of the shallowest point).

Table 6: Description of control rules implemented in the ORH 1 AMP.

ORH 1 Subarea	Proposed Catch Limit	Feature Limit (t/fishing year)
Area A	200 t	100 t
Area B	500 t	150 t
Area C	500 t	150 t
Area D	200 t	75 t

Feature limits also serve as limits to the total catch in any area due to the limited number of available productive features. The Mercury-Colville “Box” (located within Area D) has been given a specific limit of 30 t per year to allow for the bycatch of orange roughy when fishing for black cardinalfish. The catch of orange roughy in the Mercury-Colville “Box” is included in the overall limit for Area D.

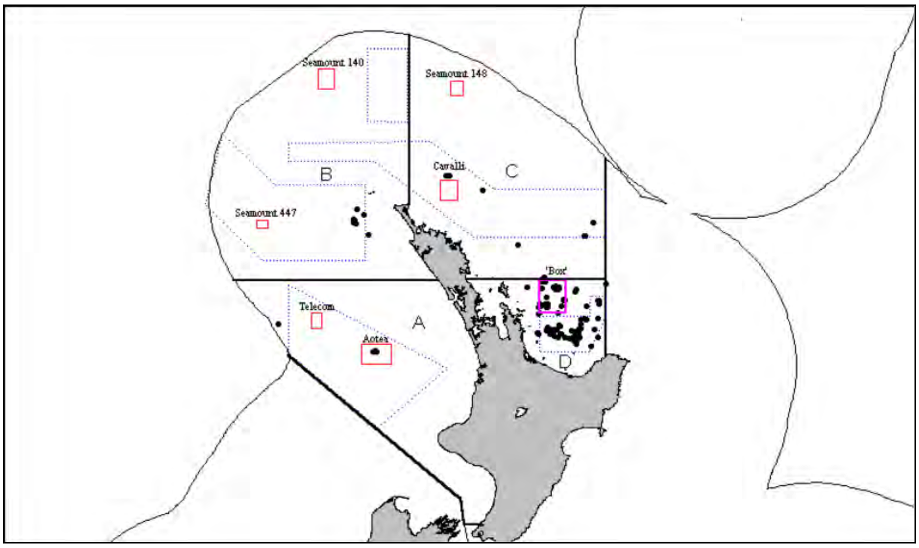


Figure 2: Four sub-management areas for the ORH 1 AMP (labelled A-D). Dotted lines enclose the exploratory fishing areas defined in the special permit issued on 6 July 1998. Solid lines enclose seamount closures and the Mercury-Colville Ohena 'box' (labelled at their top). Trawls (dots) where orange roughy were reported as the target species and caught during 1997-98 and 1998-99 are shown. Note that the lines separating Areas A and D from Areas B and C are incorrectly drawn at 36° S latitude rather than 35°30' S latitude.

From 1 October 2007 the stock is no longer part of the Adaptive Management Programme but stakeholders have agreed to continue with the sub-area and feature limits within the overall ORH 1 TACC.

Review of ORH 1 AMP in 2007

In 2007 the AMP FAWG reviewed the performance of the AMP after the full 5-year term.

Fishery Characterisation

- In most years, the total catch has been less than the TACC.
- The area splits into A, B, C and D only occurred in 2001.
- Main fishery is in area B; the fishery in area A only began in 2002.
- Two main goals of the AMP:
    - Reduce fishing in area D, in particular the Mercury-Colville "box".
    - Look for new fishing areas, distributing effort across the QMA, with feature limits to reduce the possibility of localised overfishing

Table 6: Estimated target catches by sub-area, scaled to landings, reported landings, and TACC for ORH 1. The scaling factor is calculated as reported catch/estimated (all target) catch (source: Anderson 2007b)

	Sub-area target catch (t) A	B	C	D	Total target catch(t)	Reported landings (t)	TACC (t)	Scaling factor
1998	0.5	5.6	0.0	491.0	497	511	1 190	0.99
1999	5.2	575.2	165.0	724.5	1 470	1 543	1 190	0.99
2000	0.8	644.6	164.8	597.5	1 408	1 476	1 190	1.03
2001	8.5	166.3	99.4	164.6	439	858	800	1.11
2002	122.7	440.5	265.8	227.1	1 056	1 294	1 400	1.06
2003	196.7	508.1	237.9	72.2	1 015	1 123	1 400	0.98
2004	223.2	421.7	117.0	110.1	872	986	1 400	1.01
2005	277.0	389.8	173.4	174.1	1 014	1 151	1 400	1.13
2006	151.0	473.2	372.6	186.0	1 183	1 201	1 400	1.13

CPUE Analysis

- Unstandardised CPUE is in kg/tow. The short time series, the nature of the fishery (fishing aggregations spread over a wide area in different seasons) and the impact of catch limits on features and sub-areas prevent any useful relative abundance indices from being developed at this point for ORH 1.

- Where features are less than 10 nm apart, catch is apportioned according to the distance to the feature. Industry in-season reporting is based on the feature closest to the start of the tow.
- Possible problems with the area A observations in 2005-06, as there seem to be more reported tows than expected given the number of vessels operating in the area.

Observer Programme

- 50% observer coverage prior to 1 October 2006 (a high level relative to that for other deepwater stocks, with a large number of samples taken relative to the size of the fishery). From 1 October 2006, 100% coverage was requested by the Minister, but this has not been fully achieved, as some ORH 1 is taken as bycatch on trips that do not predominantly target ORH.
- The size frequency data show high levels of stock variability between fisheries on features or feature groups. Size variation does not seem to be linked to exploitation rate.

Environmental Effects

- Observer data from 2000 to 2003 indicated that incidental captures of seabirds did not occur in the ORH 1 target fishery (Baird 2005). Marine mammal interactions are also not .a problem.
- Only 3 non-fish bycatch records have been reported from observed trips (in 1994 and 1995). All were shearwaters that landed on deck and were released alive. It was verified that observers were briefed in the same way as for other MFish trips including recording non-fish bycatch i.e. seabirds and marine mammals. Note that this does not include benthic organisms.
- The overall impact of bottom trawling on seamounts in ORH1 is not known. A number of seamounts have been closed to fishing and the Norfolk Deep BPA is included in the industry accord relating to benthic protection areas within New Zealand's EEZ.

Sub-area D Directed Adaptive Exploratory Fishing Programme

- The purpose of this exercise was to establish whether fish populations shift between features in different years in sub-area D.
- Based on the results from the exploratory fishing from 2002 to 2005 it is evident that catches from all features contained a high proportion of ripe or ripe running females and that synchronised spawning occurs on a range of hills during winter.
- In 2006 the AMP Working Group recommended some changes to the design of the exploratory survey; however, this was not achieved during the 2006 survey.

The abbreviated checklist questions for full- and mid-term reviews are:

1. Is stock abundance adequately monitored?

   The working group concluded that CPUE does not seem to be a proportional measure of abundance for this stock. However, CPUE is used in ORH 1 as a management tool. When CPUE drops on a feature, fishers are meant to move to another feature.

2. Is logbook coverage sufficient?

   As there are MFish observers on these vessels, fishers are not required to complete detailed logbooks for the AMP. This is the highest level of monitoring of any ORH fishery in New Zealand.

3. Are additional analyses of current data necessary?

   No. The Working Group concluded that no other information can currently be extracted from the existing data that will provide insight into the status of the ORH 1 stocks. However, a potential problem with the 2005-06 catch records from Area A still needs to be checked.

4. Based on the biomass index, is current harvest sustainable?

   Unknown. The purpose of the AMP was to spread effort in an attempt to reduce fishing pressure on any one sub-area or feature (and Area D in particular). ORH 1 is a large area, with orange roughy aggregations spread across a number of areas and features. The amount of fishing in some areas appears to be low, but without any indication of current abundance, there is no way to determine if this level of fishing is in fact sustainable, or if current feature limits will avoid overexploitation of localised areas.

5. Where is stock, based on weight of evidence, in relation to B_{MSY}?
   Unknown. In 2001, when the AMP was initiated, the Working Group stated that the stock was likely above B_{MSY}; while the information collected since that time has not improved the understanding about the status of the stock, the intent of the AMP design for ORH1 was to spread effort to reduce the likelihood of the biomass declining below B_{MSY}.
   ORH 1 is unlikely to be a single biological stock, and probably includes a number of constituent stocks. The Working Group concluded that it is not possible to estimate B_{MSY} for any of the individual stocks, l*et al*one aggregate up to an estimate for ORH 1 as a whole. Moreover, a better understanding is not possible in the near future. B_{MSY} is difficult to estimate in situations involving an unknown number of constituent stocks.
6. Are the effects of fishing adequately monitored?
   Yes, there is good observer coverage. The Working Group noted that one consequence of deliberately spreading effort was to increase the possible benthic impact.
7. Are rates of non-fish bycatch acceptable?
   Yes.
8. Should the AMP be reviewed by the plenary?
   This AMP does not need to be reviewed by the Plenary.

5. STATUS OF THE STOCKS

From 1 October 2001, the TACC for ORH 1 was increased to 1400 t within the AMP, with sub-area and feature limits. From 1 October 2007 the stock is no longer part of the Adaptive Management Programme but stakeholders have agreed to continue with the sub-area and feature limits within the overall ORH 1 TACC.

In most years the total catch has been less than the TACC. However, it is not known if recent catch levels or current TACCs are sustainable in the long term. Except for the small area of the Mercury-Colville box no assessment of stock status is currently available.

An assessment of the Mercury-Colville box in 2001 indicated that biomass had been reduced to 10-15% B_0 (compared to an assumed B_{MSY} of 30% B_0). As the stock was considered to be well below B_{MSY}, a catch limit of 30 t was set for the box. The assessment indicated that a catch level of about 100 t would probably maintain the stock at the 2000 stock size (assuming deterministic recruitment) and catch levels from 16 to 35 t (consistent with *CAY* or *MCY* strategies) might allow the stock to rebuild slowly.

In other areas of ORH 1 the status of the constituent stocks is unknown. The amount of fishing in some areas appears to be low, but without any indication of current abundance, there is no way to determine if this level of fishing is in fact sustainable or if current feature limits will avoid overexploitation of localised areas.

6. FOR FURTHER INFORMATION

Anderson O.F. 2007z. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1 to the end of the 2005-06 fishing year.. Deepwater-WG-07/39. 11p.

Anderson O.F. 2007b. Report to SeaFIC on the orange roughy Adaptive Management Programme in ORH 1. (unpublished document held at NZ Seafood Industry Council Library, Wellington).

Anderson O.F., Dunn M.R. 2006. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2003-04 fishing year. New Zealand Fisheries Assessment Report 2006/20. 59p

Annala J.H., Sullivan K.J., O'Brien C.J. 2000. Report from the Fishery Assessment Plenary, May 2000: stock assessments and yield estimates. (unpublished report held in NIWA library, Wellington.)

Baird S.J. 2005a. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002-03. New Zealand Fisheries Assessment Report 2005/2. 50 p.

Clark M.R. 2001. A description of the orange roughy fishery in northern North Island waters (ORH 1) for 1997-98 to 1999-2000: an update of commercial catch and effort information. New Zealand Fisheries Assessment Report 2001/76. 23 p.

Clark M.R., Tracey D.M. 1988. Assessment of the west coast South Island and northern North Island orange roughy fisheries. New Zealand Fisheries Assessment Research Document 1988/20. 11 p.

Clark M.R., King K.J. 1989. Deepwater fish resources off the North Island, New Zealand: results of a trawl survey, May 1985 to June 1986. N.Z. Fisheries Technical Report No. 11. 56 p.

Clark M.R., Field K.D. 1998. Distribution, abundance and biology of orange roughy in the western Bay of Plenty: results of a trawl survey, June 1995 (SMT9501). NIWA Technical Report 14. 29 p.

Cordue P.L., Francis R.I.C.C. 1994. Accuracy and choice in risk estimation for fisheries assessment. *Canadian journal of Fisheries and Aquatic Sciences 51*: 817-829.

Francis R.I.C.C. 1990. A maximum likelihood stock reduction method. New Zealand Fisheries Assessment Research Document 1990/4. 8p.

Francis R.I.C.C. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p.

SeaFIC 2006. Report to the Adaptive Management Programme Fishery Assessment Working Group:Full Term Review of the ORH1 Adaptive Assessment Programme. AMP-WG-06-

Starr P., Clark M.R., Francis R.I.C.C. 1996. ORH 1: blueprint for controlled development of an orange roughy fishery? *Seafood New Zealand 4(2)*: 29-31.

ORANGE ROUGHY, CAPE RUNAWAY TO BANKS PENINSULA (ORH 2A, 2B, 3A)

1. FISHERY SUMMARY

1.1 Commercial fisheries

The first reported landings of orange roughy between Cape Runaway and Banks Peninsula were in 1981-82 with the development of the Wairarapa fishery. Total reported landings and TACs grouped into orange roughy Fishstocks for 1981-82 to 2010-11 are shown in Table 1. The historical landings and TACC for these stocks are depicted in Figure 1.

Table 1: Reported landings (t) and TACCs (t) from 1981-82 to 2010-11. QMS data from 1986-present.

Fishing	QMA 2A		QMA 2B		QMA 3A		All areas	
Year	(Ritchie + E.Cape)		(Wairarapa)		(Kaikoura)		combined	
(1 Oct-30 Sep)	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1981-82*	-	-	554	-	-	-	554	-
1982-83*	-	-	3 510	-	253	-	3 763	-
1983-84†	162	-	6 685	-	554	-	7 401	-
1984-85†	1 862	-	3 310	3 500	3 266	§	8 438	-
1985-86†	2 819	4 576	867	1 053	4 326	2 689	8 012	8 318
1986-87	5 187	5 500	963	1 053	2 555	2 689	8 705	9 242
1987-88	6 239	5 500	982	1 053	2 510	2 689	9 731	9 242
1988-89	5 853	6 060	1 236	1 367	2 431	2 839	9 520	10 266
1989-90	6 259	6 106	1 400	1 367	2 878	2 879	10 537	10 352
1990-91	6 064	6 106	1 384	1 367	2 553	2 879	10 001	10 352
1991-92	6 347	6 286	1 327	1 367	2 443	2 879	10 117	10 532
1992-93	5 837	6 386	1 080	1 367	2 135	2 879	9 052	10 632
1993-94	6 610	6 666	1 259	1 367	2 131	2 300	10 000	10 333
1994-95	6 202	7 000	754	820	1 686	1 840	8 642	9 660
1995-96	4 268	4 261	245	259	612	580	5 125	5 100
1996-97	3 761	4 261	272	259	580	580	4 613	5 100
1997-98	3 827	4 261	254	259	570	580	4 651	5 100
1998-99	3 335	3 761	257	259	582	580	4 174	4 600
1999-00	3 120	3 761	234	259	617	580	3 971	4 600
2000-01	1 385	1 100	190	185	479	415	2 054	1 700
2001-02	1 087	1 100	180	185	400	415	1 667	1 700
2002-03	782	680	105	99	235	221	1 122	1 000
2003-04	703	680	103	99	250	221	1 056	1 000
2004-05	1 120	1 100	206	185	416	415	1 742	1 700
2005-06	1 076	1 100	172	185	415	415	1 663	1 700
2006-07	1 131	1 100	203	185	401	415	1 736	1 700
2007-08	1 068	1 100	209	185	432	415	1 709	1 700
2008-09	1 114	1 100	173	185	414	415	1 701	1 700
2009-10	1 117	1 100	213	185	390	415	1 720	1 700
2010-11	1 113	1 100	158	185	420	415	1 690	1 700

* MAF data † FSU data. § Included in QMA 3B TAC.

There was a major change in the ORH 2A fishery in 1993-94 with a shift of effort from the main spawning hill on Ritchie Bank to hills off East Cape. Although these hills had apparently only been lightly fished in the past, during 1993-94 52% of the total catch from ORH 2A was taken from the East Cape area (Table 2). This led to an agreement between industry and the Minister of Fisheries that from 1994-95 the traditionally fished areas within ORH 2A (south of 38°23', hereafter referred to as "2A South") would be managed separately from the new East Cape fishery (north of 38°23', "2A North"). ORH 2A South was combined with ORH 2B and ORH 3A to form the Mid-East Coast (MEC) stock for management purposes.

The catch limits for these two areas changed three times in the following four years, including a subdivision of 2A North (Table 3). Catches in the exploratory sub-area of 2A North never approached the catch limit, with only 37 t being caught in 1996-97 and less in subsequent years.

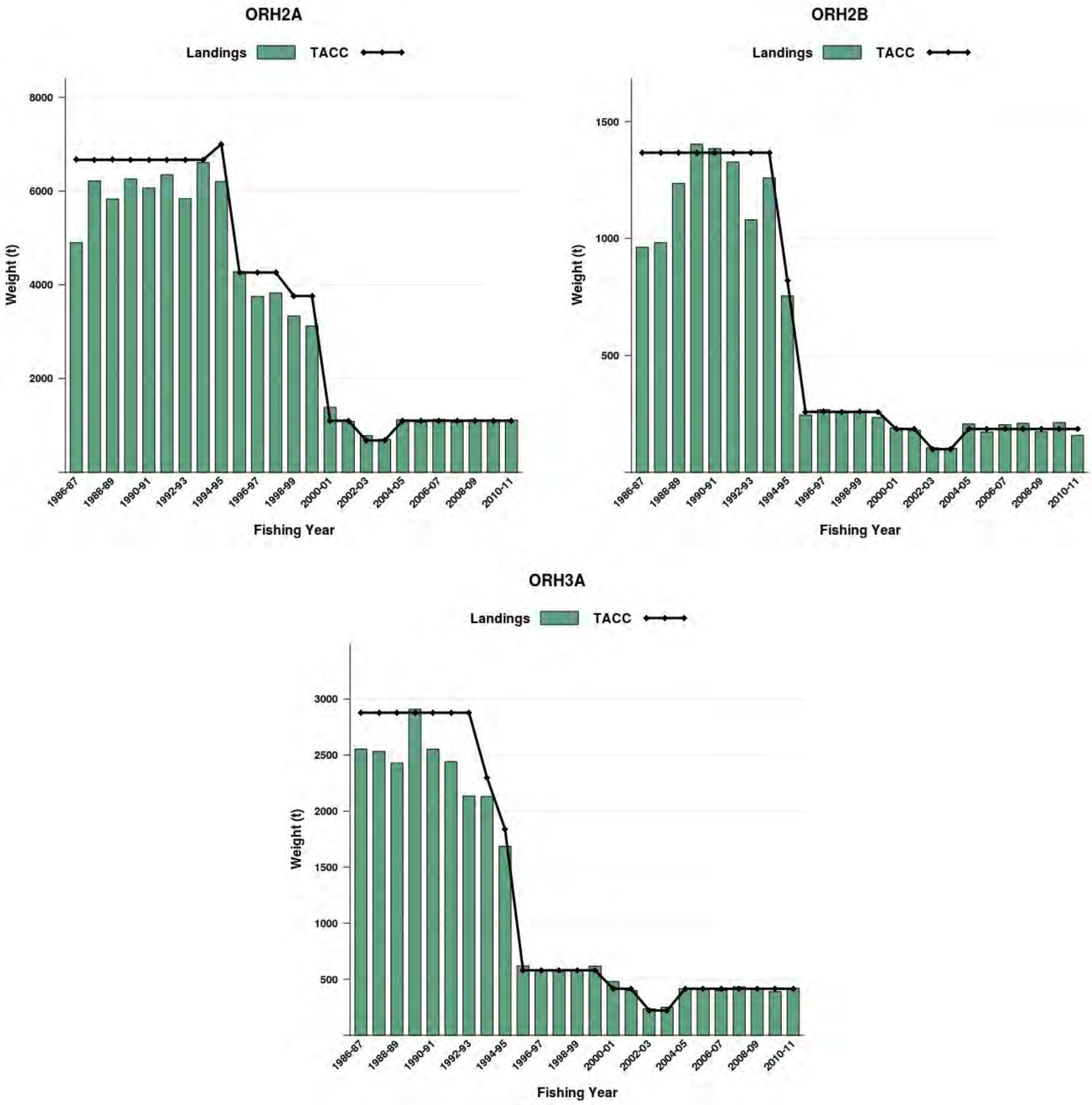


Figure 1: Historical landings and TACC for ORH2A (Central (Gisborne)), ORH2B (Central (Wairarapa)), and ORH3A (Central/Challenger/South-East (Cook Strait/Kaikoura)). Note that these figures do not show data prior to entry into the QMS.

For the 2000-01 fishing year the TACC for ORH 2A was reduced to 1100 t, for ORH 2B to 185 t, and for ORH 3A to 415 t. Within the TACC for ORH 2A, the catch limit for all of 2A North was reduced to 200 t, with no separate catch limits for the East Cape Hills and exploratory area, and the catch limit for 2A South was reduced to 900 t. This gave a catch limit for the MEC stock of 1500 t. The catch limit for MEC was reduced to 800 t (and ORH 2A South to 480 t) for the 2002-03 and 2003-04 fishing years. From 1 October 2004 there was an increase in the TACC to 1 100 t, 185 t, and 415 t in 2A, 2B, and 3A respectively. Furthermore an allowance of 58 t, 9 t, and 21 t, for other mortality was allocated to 2A, 2B, and 3A in 2004 as well.

1.2 Recreational fisheries
Recreational fishing for orange roughy is not known in this area.

1.3 Customary non-commercial fisheries
No information on customary non-commercial fishing for orange roughy is available for this area.

1.4 Illegal catch
No information is available about illegal catch in this area.

Table 2: North Mid-East Coast + East Cape (ORH 2A) catches by area, in tonnes and by percentage of the total ORH 2A catch. (Percentages up to 1993-94 and from 2007-08 calculated from Ministry of Fisheries data; 1994-95 to 1996-97 from NZFIB data, and 1997-98 to 2006-07 from Orange Roughy Management Co.) Mid-East Coast (MEC) stock (ORH 2A South, ORH 2B, and ORH 3A combined) catches in tonnes.

Fishing year	2A North		2A South		MEC (t)
	t	%	t	%	
1983-84	0	0	162	100	7 401
1984-85	4	< 1	1 858	99	8 434
1985-86	41	1	2 778	99	7 971
1986-87	253	5	4 934	95	8 452
1987-88	36	< 1	6 203	99	9 695
1988-89	143	2	5 710	98	9 377
1989-90	20	< 1	6 239	99	10 517
1990-91	13	< 1	6 051	99	9 988
1991-92	18	< 1	6 329	99	10 099
1992-93	30	< 1	5 807	99	9 022
1993-94	3 437	52	3 173	48	6 563
1994-95	2 921	47	3 281	53	5 721
1995-96	3 235	76	1 033	24	1 890
1996-97	2 491	66	1 270	34	2 122
1997-98	2 411	63	1 416	37	2 240
1998-99	1 901	57	1 434	43	2 273
1999-00	1 456	47	1 666	53	2 517
2000-01	302	22	1 083	78	1 752
2001-02	186	17	901	83	1 480
2002-03	173	24	546	76	886
2003-04	170	24	533	76	886
2004-05	271	24	849	76	1 471
2005-06	216	20	859	80	1 445
2006-07	229	20	902	80	1 506
2007-08	200	24	868	76	1 509
2008-09	230	21	884	79	1 471
2009-10	267	24	850	76	1 453

Table 3: Catch limits (t) by sub-area within ORH 2A, as agreed between the industry and the Minister of Fisheries since 1994-95 and the catch limit for the Mid-East Coast (MEC) stock (ORH 2A South, ORH 2B, ORH 3A combined). (Note that 2A North was split, for the years 1996-97 to 1999-2000, into the area round the East Cape Hills and the remaining area, which is called the exploratory area).

Fishing year	2A North		2A South	MEC
1994-95	3 000		4 000	6 660
1995-96	3 000		1 261	2 100
	East Cape Hills	Exploratory		
1996-97	2 500	500	1 261	2 100
1997-98	2 500	500	1 261	2 100
1998-99	2 000	500	1 261	2 100
1999-00	2 000	500	1 261	2 100
	2A North			
2000-01	200		900	1 500
2001-02	200		900	1 500
2002-03	200		480	800
2003-04	200		480	800
2004-05	200		900	1 500
2005-06	200		900	1 500
2006-07	200		900	1 500
2007-08	200		900	1 500
2008-09	200		900	1 500
2009-10	200		900	1 500

1.5 Other sources of mortality

There has been a history of catch overruns in this area because of lost fish and discards. In the assessments presented here total removals were assumed to exceed reported catches by the overrun percentages in Table 4.

All yield estimates and forward projections presented make an allowance for the current estimated level of overrun of 5%.

Table 4: Catch overruns (%) by QMA and year. -, no catches reported.

Year	2A (North and South)	2B	3A
1981-82	-	30	-
1982-83	-	30	30
1983-84	50	30	30
1984-85	50	30	30
1985-86	50	30	30
1986-87	40	30	30
1987-88	30	30	30
1988-89	25	25	25
1989-90	20	20	20
1990-91	15	15	15
1991-92	10	10	10
1992-93	10	10	10
1993-94	10	10	10
1994-95 and subsequent years	5	5	5

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy section.

3. STOCKS AND AREAS

Two major spawning locations have been identified in ORH 2A, one at the East Cape hills in "2A North" and the other on the Ritchie Bank in "2A South". Spawning orange roughy were located in Wairarapa (ORH 2B) in winter 2001, but no large concentrations were found, and the significance of this spawning event is not known. Spawning orange roughy have not been located in Kaikoura (ORH 3A). The major spawning area in ORH 2A South, ORH 2B, and ORH 3A is still believed to be the Ritchie Bank.

Results from allozyme studies show that orange roughy from the three areas, "2A South", Wairarapa, and Kaikoura cannot be separated, but are distinct from fish on the eastern Chatham Rise. Earlier data suggesting a genetic stock boundary between East Cape and Ritchie Bank were not supported by a more recent replicate sample from East Cape. For these reasons, orange roughy in this region are currently treated as two stocks: the mid-East Coast (MEC) stock (2A South, Wairarapa, and Kaikoura) and the East Cape (EC) stock (2A North). The relationship between these areas and the location of the main fishing grounds is shown in Figure 2.

4. STOCK ASSESSMENT

Stock assessments are reported below for East Cape from 2003 and for Mid East Coast (MEC) from 2011.

4.1 East Cape stock (2A North)

The stock assessment for the East Cape was last updated in 2003 and is summarised here (Anderson 2003). An attempt to update the assessment with a new set of CPUE indices was made in 2006, but was rejected by the Working Group because of changes in the fishery which essentially invalidated the utility of the CPUE series as an index of abundance. With no other abundance estimates available, an updated stock assessment was not possible.

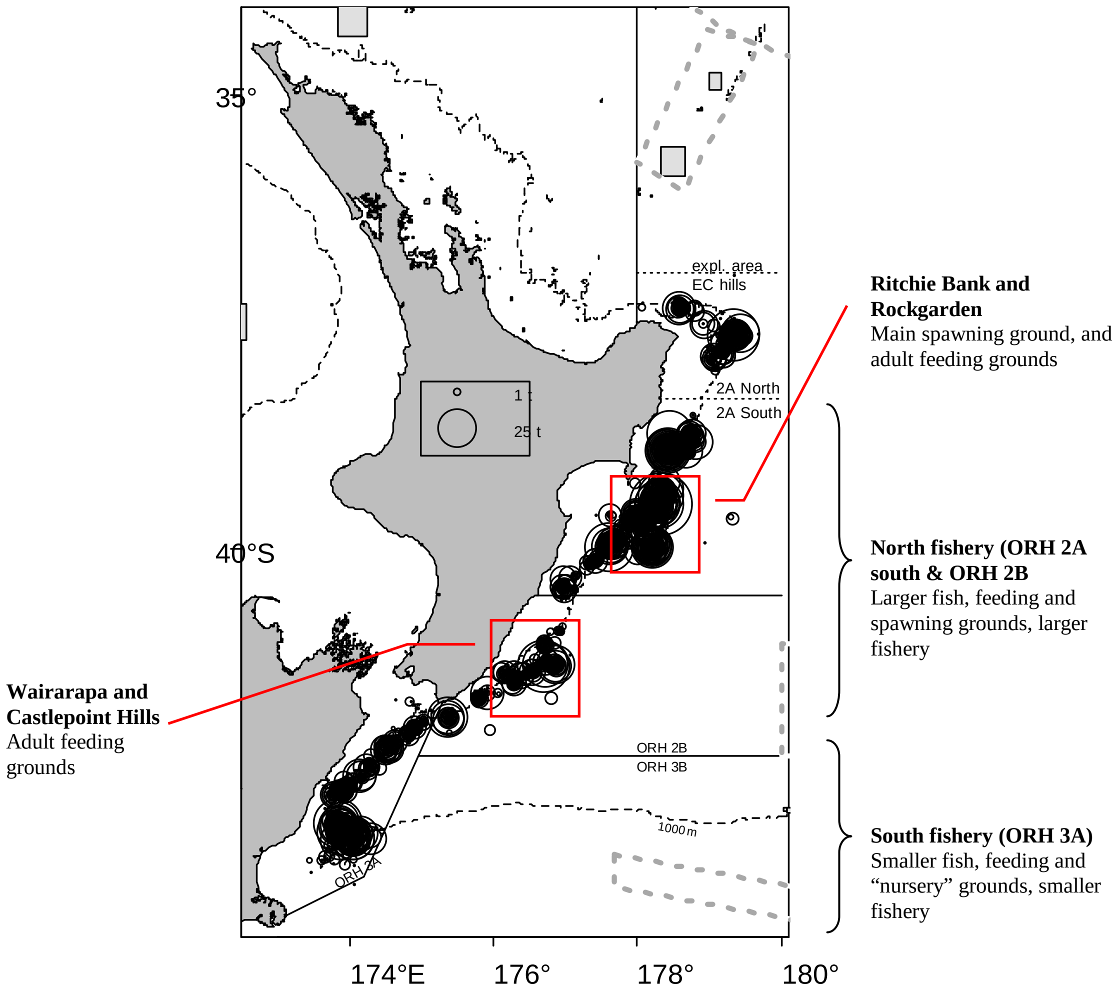


Figure 2: Catch (t) per tow of orange roughy in ORH 2A, ORH 2B, and ORH 3A for the five fishing years from 2006-07 to 2010-11 (circles, with area proportional to catch size), location of the fisheries assumed during stock assessment, and the location of the main spawning, feeding, and nursery grounds. Perimeters of Benthic Protection Areas (BPAs) closed to bottom trawling are marked with dashed grey lines, and seamounts closed to trawling are marked as shaded rectangles.

4.1.1 Assessment Inputs

A CPUE analysis was performed in 2006, but was considered unreliable because of a change in fishing patterns and fleet size corresponding to the reduction of the catch limit to 200 t in 2000-01. The CPUE analysis was updated in 2011 and was considered more reliable by the Working Group due to the increase in the number of trawls per year since 2006. The 2011 analysis showed that standardised CPUE decreased after a peak in 2003-04, and has subsequently remained at a level similar to that in the late 1990s to early 2000s (Table 5).

Previous concerns by the Working Group that the fishery was being dominated by a single vessel were alleviated somewhat by the return or entry of three other vessels to the fishery since 2003-04, but the utility of CPUE analyses in fisheries where substantial catch limit reductions have caused major changes in fishing patterns remains an issue for this stock.

The model inputs for the 2003 stock assessment were catches, an egg survey, and CPUE indices (Table 5). The biological parameters used are presented in the Biology section at the beginning of the Orange Roughy section.

Table 5: Standardised CPUE and egg survey indices, and CVs for the East Cape stock, as used in the 2003 assessment, and an updated standardised CPUE index derived in 2011. -, no data.

	CPUE index 2003	CV(%)	Egg survey	CV(%)	CPUE index 2011	CV(%)
1993-94	1.00	12	-	-	0.95	23
1994-95	0.69	8	29 000	69	0.76	22
1995-96	0.60	8	-	-	0.61	23
1996-97	0.41	8	-	-	0.47	22
1997-98	0.25	7	-	-	0.27	23
1998-99	0.25	7	-	-	0.28	23
1999-00	0.22	9	-	-	0.23	23
2000-01	0.21	15	-	-	0.28	26
2001-02	0.22	16	-	-	0.23	27
2002-03	-	-	-	-	0.51	32
2003-04	-	-	-	-	0.50	30
2004-05	-	-	-	-	0.29	27
2005-06	-	-	-	-	0.37	28
2006-07	-	-	-	-	0.36	29
2007-08	-	-	-	-	0.27	28
2008-09	-	-	-	-	0.24	28
2009-10	-	-	-	-	0.20	27

4.1.2 Stock assessment

A stock assessment analysis for the East Cape stock was performed by NIWA in 2003 using the stock assessment program, CASAL (Bull *et al.* 2002) to estimate virgin and current biomass.

- The model was fitted using Bayesian estimation and partitioned the EC stock population by sex, maturity (the fishery was assumed to act on mature fish only) and age (age-groups used were 1-70, with a plus group).
- The model estimated virgin biomass, B_0, and the process error for the CPUE indices. Catchability, q, was treated as a nuisance parameter by the model.
- The stock was considered to reside in a single area, and to have a single maturation episode modelled by a logistic-producing ogive where 50% of fish of both sexes were mature at age 26 and 95% at age 29.
- 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.
- The size at age model used was the von Bertalanffy.
- No stock recruitment relationship 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 and egg survey indices. Additionally, process error variance was estimated by the model and added to the CVs from the CPUE indices.
- Confidence intervals were calculated from the posterior profile distribution of B_0 estimates, where the process error parameter was fixed at the value previously estimated.

4.1.3 Biomass estimates

Biomass estimates for this stock are given in Table 6 and the biomass trajectories, plotted against the scaled indices, are shown in Figure 3. The base case assessment of the EC stock included only the CPUE indices. An alternative assessment was carried out including the point estimate of biomass from the 1995 egg survey along with the CPUE indices. The CPUE indices agree well with the biomass estimates, with only the 1993-94 and 1997-98 indices departing from the biomass 95% confidence intervals. The egg survey biomass estimate, with the large associated CV, has little effect on the biomass trajectory.

Table 6: Estimates of virgin biomass (B_0), B_{MSY} (calculated as B_{MAY}, the mean biomass under a *CAY* policy), and $B_{current}$, for the EC stock (with 95% confidence intervals in parentheses).

					$B_{CURRENT}$		
Assessment	Index	B_0 (t)		B_{MSY} (t)	(t)	% B_0	
Base case	CPUE	21 100	(19 650-23 350)	6 300	5 100	24	(20-32)
Alternative	CPUE + Egg survey	21 200	(19 700-23 550)	6 380	5 200	25	(20-33)

The base case estimate of $B_{CURRENT}$ (the mid-year biomass in 2002-03) is 5100 t (24% B_0) with a 95% confidence interval of 3800 to 7550 t. This is almost twice the value of $B_{CURRENT}$ estimated for mid-year 1999-2000 in the previous assessment (Anderson 2000). The alternative assessment gives a very similar estimate of $B_{CURRENT}$.

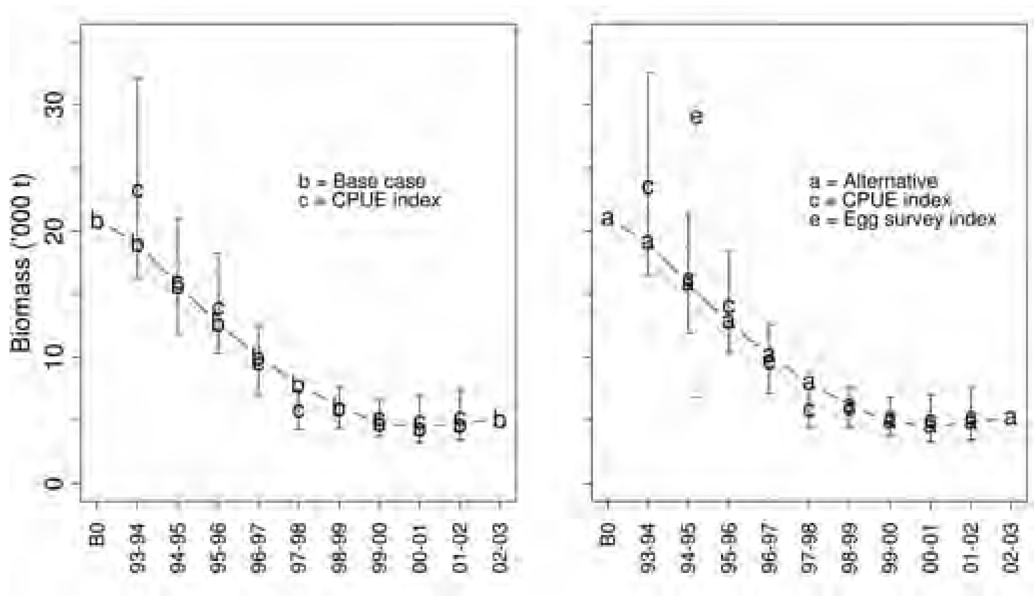


Figure 3: Estimated biomass trajectories for the base case and alternative model runs for the EC stock. Annual biomass estimates are mean posterior density (MPD) values and 95% confidence intervals (grey dashed lines) are calculated from the posterior profile distribution of B_0 estimates. The CPUE index CVs (sampling error plus process error) are shown, as is the CV calculated for the egg survey biomass estimate.

4.1.4 Estimation of Yields

Estimates of *MCY* and *CAY* for the *EC* stock were calculated from large numbers of simulation runs using posterior profile sampling of B_0 and a series of trial harvest levels. These estimates, together with MAY (the mean catch with a *CAY* harvesting strategy) and *CSP* (current surplus production) are given in Table 7. *CSP* is driven by recruitment of fish spawned before the fishery began.

Table 7: Estimates of *MCY*, *CAY*, MAY, and *CSP* for the *EC* stock, with 95% confidence intervals in parentheses (all corrected for an assumed overrun of 5%).

Assessment	*MCY* (t)	*CAY* (t)	*MAY* (t)	*CSP* (t)
Base case	350	370	410	550
Alternative	350	370	410	550

4.2 Mid-East Coast stock (2A South, 2B, 3A)

The stock assessment for the Mid-East Coast was last updated in 2011 and is summarised here.

4.2.1 Assessment inputs

The 2011 assessment inputs were updated catches, revised standardised CPUE indices, acoustic mature biomass estimates for 2001 and 2003, an egg production spawning biomass estimate for 1993, research trawl surveys for 1992-94 and 2010 (Table 8), length frequency samples from the commercial fishery in the north (ORH 2A south and ORH 2B) for 16 years between 1988-89 and 2009-10, and the south

(ORH 3A) for nine years between 1989-90 and 2008-09, and age frequency samples from commercial landings of the spawn fishery in ORH 2A south in 1989, 1990, 1991, and 2002 (Table 9).

Age frequency samples from 1989, 1990, and 1991 were aggregated and treated as a single observation for 1990. The biological parameters used in the assessments are presented in the Biology section at the beginning of the orange roughy section. The catches used were calculated by taking the ORH 2B and ORH 3A catches from Table 1 and the 2A South catches in Table 2, increasing them by the overrun values in Table 4, and then summing by year. The acoustic survey in 2003 did not survey the background strata surveyed in 2001 (Doonan *et al.* 2004). The difference between the areas surveyed in 2001 and 2003 was incorporated, along with other potential biases, into an informed prior of the ratio between the biomass estimates from the 2001 and 2003 surveys (Cordue, unpublished).

Table 8: Standardised CPUE indices, research trawl survey vulnerable biomass estimates, and egg survey and acoustic survey mature biomass estimates, and their calculated CVs, as used in the stock assessment for the MEC stock. - , no data.

Fishing year	CPUE (early)	CV (%)	CPUE (late)	CV (%)	Trawl survey	CV (%)	Egg survey	CV (%)	Acoustic survey	CV (%)
1983-84	3.77	11	-	-	-	-	-	-	-	-
1984-85	2.34	12	-	-	-	-	-	-	-	-
1985-86	2.38	13	-	-	-	-	-	-	-	-
1986-87	2.02	13	-	-	-	-	-	-	-	-
1987-88	2.86	14	-	-	-	-	-	-	-	-
1988-89	-	-	-	-	-	-	-	-	-	-
1989-90	1.35	12	-	-	-	-	-	-	-	-
1990-91	1.89	6	-	-	-	-	-	-	-	-
1991-92	1.21	8	-	-	20 838	29	-	-	-	-
1992-93	1.03	8	-	-	15 102	27	22 000	49	-	-
1993-94	0.78	8	-	-	12 780	14	-	-	-	-
1994-95	0.52	9	-	-	-	-	-	-	-	-
1995-96	0.57	12	-	-	-	-	-	-	-	-
1996-97	0.98	13	-	-	-	-	-	-	-	-
1997-98	-	-	0.39	15	-	-	-	-	-	-
1998-99	-	-	0.40	15	-	-	-	-	-	-
1999-00	-	-	0.37	15	-	-	-	-	-	-
2000-01	-	-	0.33	15	-	-	-	-	25 300	38
2001-02	-	-	0.64	16	-	-	-	-	-	-
2002-03	-	-	0.80	16	-	-	-	-	6 460	38
2003-04	-	-	0.98	16	-	-	-	-	-	-
2004-05	-	-	0.80	15	-	-	-	-	-	-
2005-06	-	-	0.84	16	-	-	-	-	-	-
2006-07	-	-	0.96	16	-	-	-	-	-	-
2007-08	-	-	0.82	17	-	-	-	-	-	-
2008-09	-	-	0.66	16	-	-	-	-	-	-
2009-10	-	-	0.49	17	7 074	19	-	-	-	-

Table 9: Details of age samples from the spawning fishery as used for the stock assessment for the MEC stock, indicating the number of trips sampled, the number of age samples (*N* age) and accompanying length samples (*N* length), and the median, minimum and maximum age range.

Year	Number of trips	N age	N length	Median Age	Age range
1989	3	150	1 538	65	26-164
1990	4	200	2 053	60	24-174
1991	5	249	2 529	53	17-192
2002	7	795	1 437	44	21-145

4.2.2 Stock assessment

Stock assessment was performed by NIWA using the stock assessment program CASAL (Bull *et al.* 2002) to estimate virgin and current biomass.

- The model was fitted using Bayesian estimation and partitioned the MEC stock population by age (age-groups used were 1-120, 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 to have a single maturation episode, with maturation modelled by a logistic ogive fixed to equal the north fishery selectivity ogive.
- Two fisheries were assumed, in the north (ORH 2A south and ORH 2B), and south (ORH 3A), each with separate selectivities.
- Selectivity of the north fishery was modelled by a logistic ogive, and of the south fishery by a double normal ogive, both fitted to length frequency data.
- 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.
- 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.
- Selectivities and the coefficient of variation for mean length at age were estimated in a model run including only length frequencies from the north fishery, south fishery, and trawl survey. The estimated ogives and coefficient of variation of mean length at age were then fixed, and the length frequencies excluded. Subsequent model runs therefore fitted only to biomass indices and estimates.
- Where age frequency data were included (to estimate natural mortality), an ageing error misclassification matrix was applied, derived from an analysis of all orange roughy ageing data available to the working group.
- All length frequencies assumed multinomial error distributions, and age frequencies assumed Coleraine error distributions, with effective sample sizes estimated outside of the model.
- Lognormal errors, with known (sampling error) CVs were assumed for the CPUE, trawl survey, and egg and acoustic surveys. An additional estimated process error variance of 0.2 was added to the CVs from the early CPUE index, and 0.4 was added to the CVs from the late CPUE and trawl survey estimates.
- The CPUE, trawl survey, and acoustic survey series were treated as relative biomass indices, and the egg survey as an absolute biomass estimate.
- Deterministic recruitment was assumed. In the assessments, recruitment was assumed to be constant. Runs estimating recruitment from the age frequency data were explored, but they did not improve fits to the age frequency and trawl survey data, and therefore no results are presented.
- The model estimated virgin biomass, B_0, five catchabilities, five selectivity parameters, and two parameters for the CV of mean length at age (a total of thirteen parameters).

The Working Group agreed on two final model runs that spanned the plausible range of assessments of stock status. The first run (M2.5) provided the best fit (of 26 preliminary runs) to the trawl survey biomass index, but not the CPUE index (Figure 4). It assumed a natural mortality of 2.5%, which is at the lower 95% confidence interval of previous estimates of M (Doonan 1994), and excluded the late CPUE index, the egg survey biomass estimate and the age data. In this run, the mature biomass was estimated to have declined continually during the fishery (Figure 5). However, the Plenary noted that this run underestimated the extent of the decline observed in the trawl survey indices (Figure 4). The second run (EstM) used the same model structure and assumptions, except that the age frequency observations were included and M was estimated in the model. It fitted the CPUE data better, but did not fit the trawl survey data (Figure 4). In this run, M was estimated to be 5.4% and the mature biomass was estimated to have slowly increased after 2001-02 (Figure 5).

4.2.3 Biomass estimates

The two model runs produced different estimates of initial biomass, current biomass and current stock status (%B_0) (Table 11). When assuming a low M, the initial biomass was estimated to be larger but also more depleted.

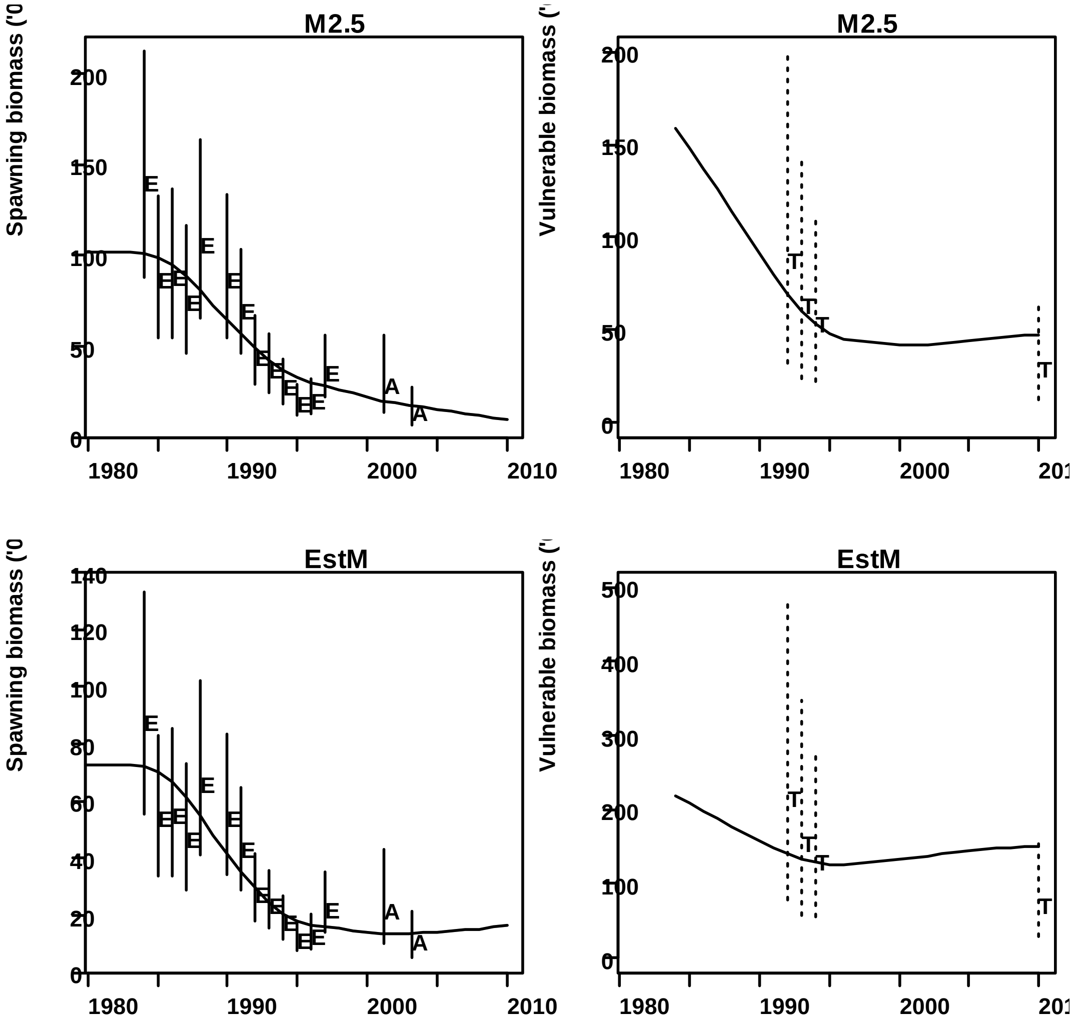


Figure 4: Estimated biomass trajectories (lines) and fitted data (points) from the M2.5 (top) and EstM (bottom) model runs. Data are identified by plotting symbol (‘E’ = CPUE (early series), ‘A’ = acoustic, ‘T’ = trawl survey). CPUE data are scaled up to the biomass. Vertical bars show 95% confidence intervals.

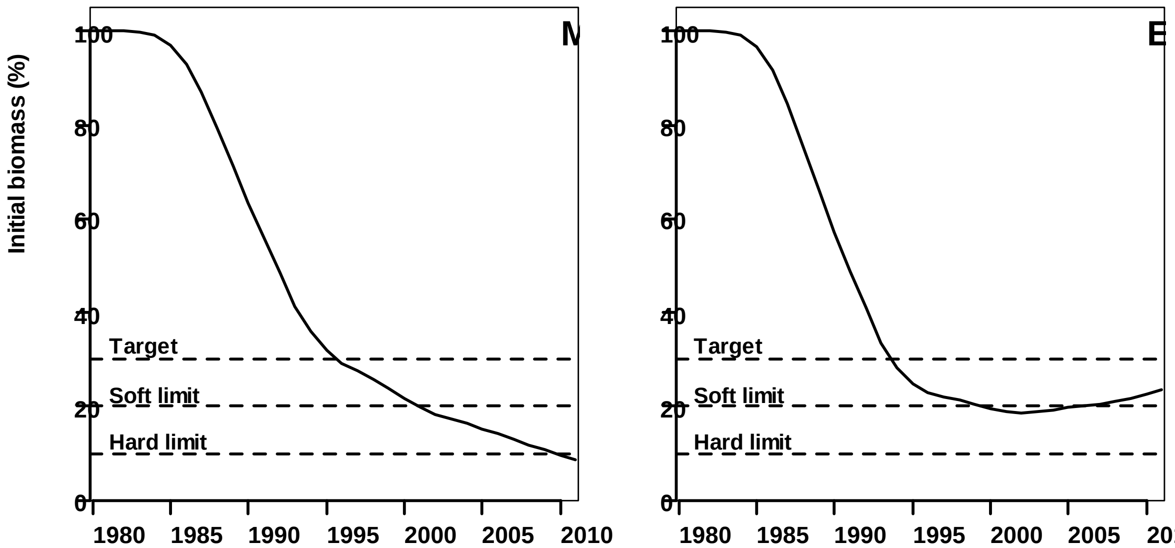


Figure 5: Estimated biomass trajectories (%B_0) from the M2.5 (left) and EstM (right) model MPD runs. Dashed lines show the stock target and limits.

Table 11: Biomass estimates (MPDs) for each model. B_{2011} is the mid-year biomass in 2011 (2010-11 fishing year).

Model run	B_0 (t)	B_{2011} (t)	% B_{2011}/B_0
EstM	72 900	17 100	23.0
M2.5	101 900	8 900	9.0

4.2.4 Sensitivity analyses

Several sensitivity analyses were conducted (reported in more detail in Fishery Assessment Reports). Three of the more consequential sensitivity analyses are briefly summarised here.

There was a conflict between the increasing late CPUE index, and the decreasing trawl survey biomass index. The Working Group agreed that the trawl survey biomass index was more reliable than the CPUE index, and as a result the late CPUE index was excluded from final model runs. However, sensitivity runs showed that the best fit to the late CPUE index, with the trawl survey index excluded, could be given by setting M at 6.2%, the higher 95% confidence interval of the M estimate. The model fit and biomass estimates from this run were similar to that estimated by the EstM run, and as a result only the EstM run was reported here.

Sensitivity runs excluding all CPUE data estimated a very large stock showing little depletion. This was inconsistent with other observations of the fishery, and indicated the model needed information on the initial rate of biomass decline, or a precise absolute biomass estimate. The egg survey was treated as an absolute spawning biomass estimate, but has historically been considered unreliable, and has been excluded from most previous stock assessments. When other biomass series were excluded it was sometimes highly influential. When the early CPUE index was included, the egg survey had little influence. Although the relationship between CPUE and abundance is uncertain for orange roughy, the early CPUE index was thought to be potentially more reliable than the late CPUE index, as it included much more data, and covered a period of higher catches and greater underlying biomass change.

To determine whether the decline in the trawl survey biomass index could be a result of recruitment trends, sensitivities were conducted estimating recruitment deviates, over a range of fixed Ms (3.5-6.2%). In these runs, the age frequencies and trawl survey length frequencies were included. The fits to the trawl survey biomass indices were all worse than estimated by the M2.5 run.

4.2.5 Five year projection results

Forward projections were carried out over a 5-year period using the MPD model fit and a constant catch, set at the 2010-11 catch limit of 1500 t. The projections predict that the biomass will slowly increase for the EstM run, and continue to decrease to levels well below the hard limit for the M2.5 run.

Table 13: Projected mid-year spawning biomass (B_{curr}; labelled as year ending) and B_{curr} as a fraction of the initial biomass (%B_0) in the years 2011 to 2016 for the Mid-East Coast stock for the two model runs, with the annual catch set to the current TACC (1500 t).

		Mid-year spawning biomass (t)					
Model run		2011	2012	2013	2014	2015	2016
EstM	B_{curr}	17 100	17 800	18 600	19 500	20 300	21 200
	%B_0	23	24	26	27	28	29
M2.5	B_{curr}	8 900	8 000	7 200	6 500	5 900	5 500
	%B_0	9	8	7	6	6	5

5. STATUS OF THE STOCKS

Stock Structure Assumptions

Orange roughy in ORH2A, 2B and 3A are treated as two biological stocks based on the location of spawning grounds. These stocks are managed and assessed separately however some mixing has been shown to occur. The 2A North stock spawns around the East Cape hills off of the North Island. The

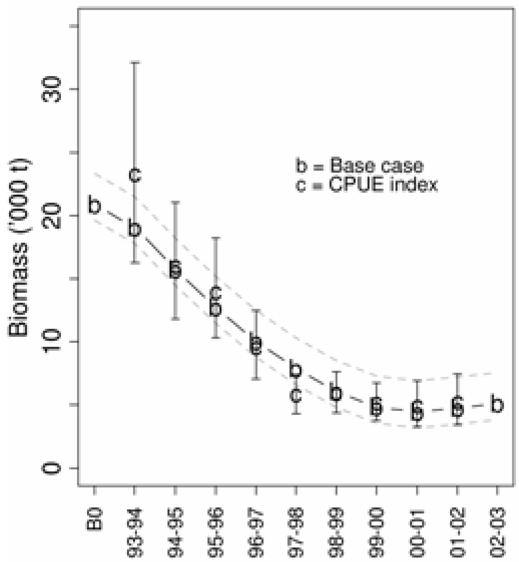
2A South, 2B and 3A stock is assumed to spawn on the Ritchie Bank.

For these stocks, B_{MSY} is assumed to be equal to 30% B_0, which, in previous assessments has been estimated to be the average biomass under a *CAY* management policy.

- **ORH East Cape Stock (2A North)**

Stock Status	
Year of Most Recent Assessment	2003
Assessment Runs Presented	A base case with one alternative
Reference Points	Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2003} was 24% B_0, which was Unlikely (< 40%) to be at or above the target
Status in relation to Limits	B_{2003} was Unlikely (< 40%) to be below the Soft Limit, and Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Estimated biomass trajectory for the base model run for the EC stock. Annual biomass estimates are mean posterior density (MPD) values and 95% confidence intervals (grey dashed lines) are calculated from the posterior profile distribution of B_0 estimates. The CPUE index CVs (sampling error plus process error) are shown.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined in the early 1990s but appeared to stabilise at around 5000 t
Recent Trend in Fishing Mortality or Proxy	*F* has declined along with the agreed catch limit and remains stable at the current catch level of 200 t
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2003)	
Stock Projections or Prognosis	The estimated *CAY* (370 t) and *MAY* (410 t) were both greater than the catch limit of 200 t, and this suggested the stock would start to rebuild.
Probability of Current Catch or TACC causing decline	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

below Limits	

Assessment Methodology		
Assessment Type	Type 1 - Quantitative stock assessment	
Assessment Method	Statistical catch-at-age model implemented in CASAL with Bayesian estimation of posterior distributions.	
Main data inputs	- Catch data - Standardised CPUE data - 1994-95 ORH egg survey	
Period of Assessment	Latest assessment: 2003	Next assessment: Unknown
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	-	

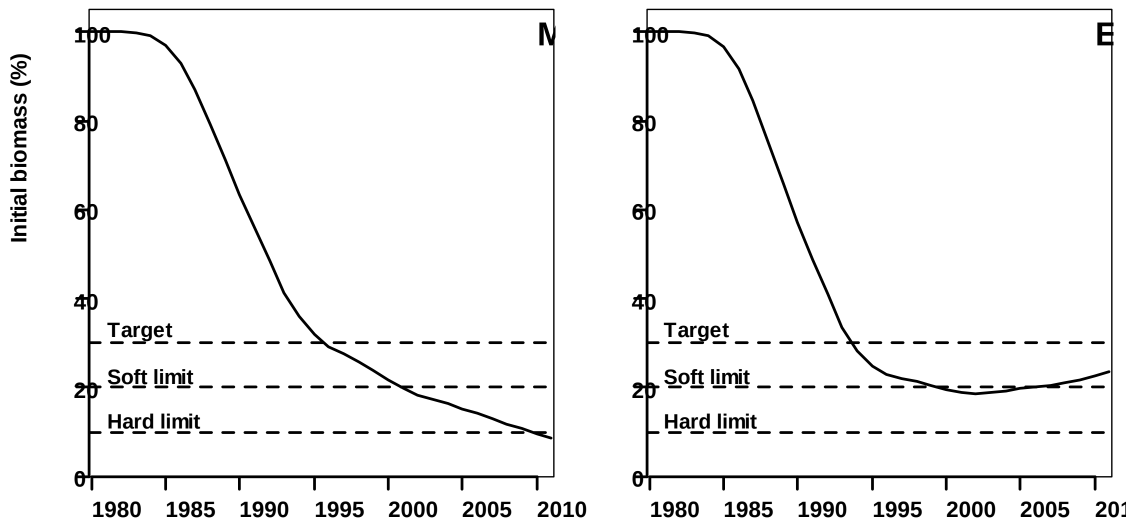
Qualifying Comments
The most recent assessment (2003) is now 8 years out-of-date. In recent years, the ability of stock assessment models that assume deterministic recruitment for orange roughy stocks to reflect current or projected stock status has been called into question.

Fishery Interactions
The main bycatch species are cardinalfish and alfonsino. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Protected species bycatch includes seabirds and corals.

- **ORH Mid-East Coast Stock (2A South, 2B, 3A)**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	Two alternative MPD model runs
Reference Points	Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2011} was 9% or 23% B_0 in the 2 model runs and was Very Unlikely (< 10%) to be above the target.
Status in relation to Limits	B_{2011} was Likely (> 60%) to be below the Soft Limit B_{2011} was Unlikely (< 40%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Estimated biomass trajectories (%B_0) from the M2.5 (left) and EstM (right) model MPD runs. Dashed lines show the stock target and limits.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The M2.5 run indicated that biomass has declined continually since the inception of the fishery, while the EstM run indicated that biomass declined until 2001-02 and has been slowly increasing since.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	At the current TACC (1500 t), under the M2.5 run the biomass was projected to continue to decline over the next 5 years, while under the EstM run the stock was projected to slowly increase over 5 years.
Probability of Current Catch or TACC causing decline below Limit	Soft Limit: Likely (> 60%) Hard Limit: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1 - Full quantitative stock assessment	
Assessment Method	Statistical catch-at-age model implemented in CASAL.	
Main data inputs	- Catch data - Revised CPUE indices (1984-97) - 2001 and 2003 acoustic biomass estimate - 1992-94 and 2010 research trawl surveys - Age-frequency data 1989-91 and 2002 - Length-frequencies data 1989-90 to 2009-10	
Period of Assessment	Latest assessment: 2011	Next assessment: 2015
Changes to Model Structure and Assumptions	-	

Major Sources of Uncertainty	- Model highly sensitive to assumptions about the mean productivity (natural mortality rate) - Recruitment was assumed to be deterministic - Conflict between trawl survey biomass indices and recent commercial CPUE - Accuracy and precision of aging data - Estimates of catch overruns

Qualifying Comments
The model was unable to fit all of the data. In particular, it could not simultaneously fit the trawl survey and CPUE indices well. The two runs reported here were chosen to span the plausible range of assessments of stock status.

Fishery Interactions
The main bycatch species are cardinalfish and alfonsino. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Protected species bycatch includes seabirds and corals.

6. FOR FURTHER INFORMATION

Anderson O.F. 2000. Assessment of the East Cape hills (ORH 2A North) orange roughy fishery for the 2000-01 fishing year. New Zealand Fisheries Assessment Report 2000/19. 29 p.

Anderson O.F. 2003. A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2001-02 fishing year. New Zealand Fisheries Assessment Report 2003/21. 25p.

Anderson O.F. 2003. CPUE analysis and stock assessment of the East Cape hills (ORH 2A North) orange roughy fishery for 2003. New Zealand Fisheries Assessment Report 2003/24. 20 p.

Anderson O.F. 2005. CPUE analysis and stock assessment of the South Chatham Rise orange roughy fishery for 2003-04. New Zealand Fisheries Assessment Report. 2005/07.

Anderson O.F., Dunn M.R. 2007. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2003-04 fishing year. New Zealand Fisheries Assessment Report. 2006/20.

Anderson O.F., Dunn M.R. 2007. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2004-05 fishing year. New Zealand Fisheries Assessment Report. 2007/29.

Anderson O.F., Francis R.I.C.C., Hicks A.C. 2002. CPUE analysis and assessment of Mid-East Coast orange roughy stock (ORH 2A South, 2B, 3A). New Zealand Fisheries Assessment Report 2002/56. 23 p.

Annala J.H., Sullivan K.J., O'Brien C.J., McL. Smith N.W., Grayling S.M. 2003. Report from the Fishery Assessment Plenary, May 2003: stock assessments and yield estimates. Ministry of Fisheries May 2003.

Annala J.H., Sullivan K.J., O'Brien C.J (Comps.) 2000. Report from the Fishery Assessment Plenary, May 2000: stock assessments and yield estimates. 495 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Bull B., Francis R.I.C.C., Dunn A., Gilbert D.J. 2002. CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v1.02.2002/10/21. NIWA Technical Report 117. 199 p.

Clark M.R., Taylor P., Anderson O.F., O'Driscoll R. 2002. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2000-01 fishing year. New Zealand Fisheries Assessment Report. 2002/62.

Clark M., Anderson O., Dunn M. 2003. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2001-02 fishing year. New Zealand Fisheries Assessment Report 2003/60. 51p.

Doonan, I.J. 1994. Life history parameters of orange roughy: estimates for 1994. New Zealand Fisheries Assessment Research Document 94/19. 13 p.

Doonan I.J., Tracey D.M., Grimes P.J. 2004. Relationships between macroscopic staging and microscopic observations of oocyte progression in orange roughy during and after the mid-winter spawning period, Northwest Hills, Chatham Rise, July 2002. New Zealand Fisheries Assessment Report 2004/6. 28p.

Doonan I.J., Coburn R.P., Hart A.C. 2004. Acoustic estimates of the abundance of orange roughy for the Mid-East Coast fishery, June 2003. New Zealand Fisheries Assessment Report 2004/54. 21p.

Doonan I.J., Hicks A.C., Coombs R.F., Hart A.C., Tracey D. 2003. Acoustic estimates of the abundance of orange roughy in the Mid-East Coast fishery, June-July 2001. New Zealand Fisheries Assessment Report 2003/4. 22 p.

Dunn M.R. 2005. CPUE analysis and assessment of the Mid-East Coast orange roughy stock (ORH 2A South, 2B, 3A) to the end of the 2002-03 fishing year. New Zealand Fisheries Assessment Report 2005/18. 35p.

Dunn M., Anderson O.F., McKenzie A. 2005. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2002-03 fishing year. New Zealand Fisheries Assessment Report. 2005/19.

Field K.D., Francis R.I.C.C., Zeldis J.R., Annala J.H. 1994. Assessment of the Cape Runaway to Banks Peninsula (ORH 2A, 2B, and 3A) orange roughy fishery for the 1994-1995 fishing year. New Zealand Fisheries Assessment Research Document 1994/20. 24 p.

Francis R.I.C.C. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p.

Francis R.I.C.C., Clark M.R., Coburn R.P., Field K.D., Grimes P.J. 1995. Assessment of the ORH 3B orange roughy fishery for the 1994-95 fishing year. New Zealand Fisheries Assessment Research Document 1995/4. 43 p.

Francis R.I.C.C., Field K.D. 2000. CPUE analysis and assessment of the Mid-East Coast orange roughy stock (ORH 2A South, 2B, 3A). New Zealand Fisheries Assessment Report 2000/29. 20 p.

Francis R.I.C.C., Hicks A.C. 2004. Comparing NIWA and UW base cases for NW Chatham Rise ORH. WG-Deepwater-04/44. Unpublished report held by Ministry of Fisheries, Wellington.

Francis R.I.C.C., Horn P.L. 1997. Transition zone in otoliths of orange roughy (*Hoplostethus atlanticus*) and its relationship to the onset of maturity. Marine Biology 129: 681-687.

Francis R.I.C.C., Hurst R.J., Renwick J.A. 2001. An evaluation of catchability assumptions in New Zealand stock assessments. New Zealand Fisheries Assessment Report 2001/1. 37 p.

Grimes P. 1994. Trawl survey of orange roughy between Cape Runaway and Banks Peninsula, March-April 1992 (TAN9203). New Zealand Fisheries Data Report 42. 36 p.

Grimes P. 1996a. Trawl survey of orange roughy between Cape Runaway and Banks Peninsula, March-April 1993 (TAN9303). New Zealand Fisheries Data Report 76. 31 p.

Grimes P. 1996b. Trawl survey of orange roughy between Cape Runaway and Banks Peninsula, March-April 1994 (TAN9403). New Zealand Fisheries Data Report 82. 31 p.

Hart A., Doonan I.J., Coombs R.F. 2003. Classification of acoustic fish marks for the 2001 Mid-East Coast orange roughy fishery, June-July 2001. New Zealand Fisheries Assessment Report. 2003/18.

Hicks A.C. 2004. MEC expanded 2003 acoustic biomass. WG-Deepwater-04/37. Unpublished report held by Ministry of Fisheries, Wellington.

Hicks A.C., Francis R.I.C.C. 2005. Differences between Coleraine and CASAL. Based on the 2005 NECR assessment. WG-Deepwater-05/83. Unpublished report held by Ministry of Fisheries, Wellington.

Hilborn R., Maunder M., Parma A., Ernst B., Payne J., Starr P. 2003. Coleraine: A generalized age-structured stock assessment model. (Unpublished report from the School of Aquatic and Fisheries Sciences, University of Washington, available at: http://www.fish.washington.edu/research/coleraine/).

Tracey D., Ayers D. 2005. Biological data from the orange roughy abundance surveys in the Mid-East Coast fishery. New Zealand Fisheries Assessment Report. 2005/10.

Zeldis J.R., Francis R.I.C.C., Field K.D., Clark M.R., Grimes P.J. 1997. Description and analyses of the 1995 orange roughy egg surveys at East Cape and Ritchie Bank (TAN9507), and reanalyses of the 1993 Ritchie Bank egg survey. New Zealand Fisheries Assessment Research Document 1997/28. 34 p.

ORANGE ROUGHY, CHATHAM RISE AND SOUTHERN NEW ZEALAND (ORH 3B)

1. FISHERY SUMMARY

1.1 Commercial fisheries

Orange roughy are found in waters deeper than 750 m throughout Quota Management Area 3B. Historically, the main fishery has been concentrated on the Chatham Rise. Annual reported orange roughy catches in ORH 3B were mostly just over 30 000 t in the 1980s but have progressively decreased since 1989-90 because of a series of TACC reductions (Table 1).

Table 1: Annual reported catches and TACCs of orange roughy from ORH 3B. (Catches from 1978-79 to 1985-86 are from Robertson and Mace 1988) and from 1986-87 to 2010-11 from Fisheries Statistics Unit and Quota Monitoring System data). ‡

Fishing year	Reported catch (t)	TACC (t)
1979-80†	11 800	-
1980-81†	31 100	-
1981-82†	28 200	23 000
1982-83*	32 605	23 000
1983-84*	32 535	30 000
1984-85	29 340	30 000
1985-86	30 075	29 865
1986-87	30 689	38 065
1987-88	24 214	38 065
1988-89	32 785	38 300
1989-90	31 669	32 787
1990-91	21 521	23 787
1991-92	23 269	23 787
1992-93	20 048	21 300
1993-94	16 960	21 300
1994-95	11 891	14 000
1995-96	12 501	12 700
1996–97	9 278	12 700
1997-98	9 638	12 700
1998-99	9 372	12 700
1999-00	8 663	12 700
2000-01	9 274	12 700
2001-02	11 325	12 700
2002-03	12 333	12 700
2003-04	11 254	12 700
2004-05	12 370	12 700
2005-06	12 554	12 700
2006-07	11 271	11 500
2007-08	10 291	10 500
2008-09	8 758	9 420
2009-10	6 662	7 950
2010-11β	3 486	4 610
2011-12β	-	3 600

† Catches for 1979-80 to 1981-82 are for an April-March fishing year.
* Catches for 1982-83 and 1983-84 are 15 month totals to accommodate the change over from an April-March fishing year to an October-September fishing year. The TACC for the interim season, March to September 1983, was 16 125 t.
‡ Catches from 1984-85 onwards are for a 1 October - 30 September fishing year.
β Of the 4 610 t TACC for 2010-11, the quota owners have agreed to avoid fishing the 750 t catch limit for the Northwest Rise to provide for rebuilding of this fishstock, meaning that the 2010-11 total catch should not have exceeded 3 860 t. Of the 3 600 t TACC for 2011-12, quota owners have agreed to avoid fishing the 750 t catch limit for the Northwest Rise, meaning that the 2011-12 total catch should not exceed 2 850 t.

There have been major changes in the distribution of catch and effort over the history of this fishery (Table 2). Initially, it was confined to the Chatham Rise and, until 1982, most of the catch was taken from areas of relatively flat bottom on the northern slopes of the Rise (in the Spawning Box), between mid-June and mid-August, when the fish form large aggregations for spawning (Figure 1).

From 1983 to 1989 about one third of the catch was taken from the south and east Chatham Rise, where new fishing grounds developed on and around knolls and hill features. Much of the catch from these areas was taken outside the spawning season as the fishery extended to most months of the year.

In the early 1990s, effort within the Chatham Rise further shifted from the Spawning Box to eastern and northwestern parts of the Rise. The Spawning Box was closed to fishing from 1992-93 to 1994-95. In recent years, catches from the main fishing grounds on the Chatham Rise have declined due to TACC reductions. However, the TACC was undercaught by 7% in 2008-09, by 16% in 2009-10, and by 24% in 2010-11 (or, in the latter case, by 10% if the voluntary agreement to avoid fishing on the Northwest Rise is taken into account).

Table 2: ORH 3B catches by area, to the nearest 10 t or 100 t, and by percentage (to the nearest percent) of the total ORH 3B reported catch. Catches are equivalent to those shown in Table 1, but allocated to area using the ratio of estimated catches, and revised such that all years are from 1 October-30 September. Note that catches for the East Rise are given by the sum of Spawning Box and Rest of East Rise.

Year	Northwest Rise		South Rise		Spawning box		Rest of East Rise		Non-Chatham	
	t	%	t	%	t	%	t	%	t	%
1978-79	0	0	0	0	11 500	98	300	2	0	0
1979-80	1 200	4	800	3	27 900	90	200	4	0	0
1980-81	8 400	30	3 700	13	16 000	57	100	0	0	0
1981-82	7 000	28	500	2	16 600	67	800	3	0	0
1982-83	5 400	35	4 800	31	4 600	30	600	4	0	0
1983-84	3 300	13	5 100	21	15 000	61	1 500	6	0	0
1984-85	1 800	6	7 900	27	18 400	63	1 100	4	0	0
1985-86	3 700	12	5 300	18	17 000	56	4 100	13	0	0
1986-87	3 200	10	4 900	16	20 200	66	2 400	8	0	0
1987-88	1 600	7	6 800	28	13 500	56	2 300	10	0	0
1988-89	3 800	12	9 200	28	16 700	51	3 100	9	0	0
1989-90	3 300	10	11 000	35	16 200	51	1 100	3	200	1
1990-91	1 500	7	6 900	32	6 100	28	6 100	29	900	4
1991-92	300	1	2 200	9	1 000	4	12 000	51	7 800	34
1992-93	3 800	19	5 400	27	100	0	4 700	23	6 100	30
1993-94	3 500	21	5 100	30	0	0	4 900	29	3 500	20
1994-95	2 400	20	1 600	13	500	5	3 500	30	3 800	32
1995-96	2 400	19	1 300	10	1 600	13	2 200	17	5 000	40
1996–97	2 200	24	1 400	15	1 700	19	1 900	21	1 900	21
1997-98	2 300	23	1 700	17	2 400	24	2 200	22	1 600	16
1998-99	2 700	28	1 200	13	1 100	11	2 500	27	1 900	21
1999-00	2 100	24	1 100	13	1 500	17	3 100	36	800	9
2000-01	2 600	27	1 700	18	1 200	13	2 300	24	1 500	17
2001-02	2 200	19	1 100	10	3 100	28	3 600	31	1 300	12
2002-03	2 200	19	1 500	13	3 200	27	3 900	33	1 500	7
2003-04	2 000	18	1 400	12	4 300	38	2 600	23	1 000	9
2004-05	1 600	13	1 700	14	4 100	33	3 000	24	2 000	16
2005-06	1 400	11	1 300	10	3 900	31	3 900	31	2 100	16
2006-07	700	7	1 200	11	4 200	37	3 700	32	1 500	16
2007-08	800	8	1 300	13	3 800	37	2 700	26	1 600	16
2008-09	750	8	1 170	14	3 400	39	2 150	25	1 290	15
2009-10	720	11	940	14	3 120	47	1 260	19	620	9
2010-11	40	1	460	13	1 860	53	740	21	380	11

The early 1990s also saw the Puysegur fishery develop, followed by other fishing grounds near the Auckland Islands and on the Pukaki Rise, which is now the focus for the fishery south of the Chatham Rise.

Since 1992-93, the distribution of the catch within ORH 3B has been affected by a series of catch-limit agreements between the fishing industry and the Minister of Fisheries. Initially, the agreement was that at least 5000 t be caught south of 46° S. Subsequently, the catch limits, and the designated sub-areas to which they apply, have changed from year to year.

The TACC has been reduced to 3600 t for 2011-12 (Table 3). The agreed catch limit for the Chatham Rise is currently 1950 t. A three-year staged process to reduce F to F_{MSY} was initiated on 1 October 2008. Under this approach the catch limit is to be set at 4.5% ($F_{MSY} = M$) of the estimated current biomass in each year from 1 October 2010.

Within the Chatham Rise, catches have generally been about the same as these agreed catch limits (Tables 2 and 3), except that the catch limit for the sub-Antarctic was substantially undercaught in 2009-10 (a catch of 620 t from a limit of 1850 t). However, the combined east and south Rise sub-area catch limits was exceeded by 450 t in 2005-06 and by 350 t in 2006-07 (100 t was taken against the allowance for industry research surveys). Taking the research allowance into account, catch limits for the combined east and south Rise sub-area have not been exceeded in subsequent years. Since 2004-05, 250 t of the ORH 3B TACC has been set aside for industry research surveys (Table 3), although this has sometimes been used in areas outside the east and south Chatham Rise.

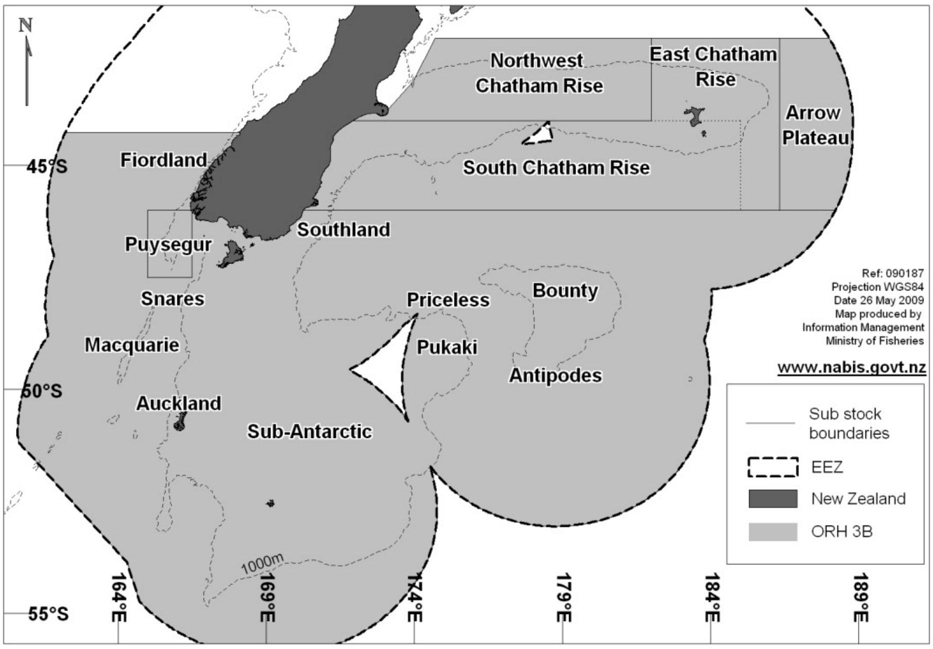


Figure 1: ORH3B sub-areas and the approximate position of other named fisheries outside of the Chatham Rise. The Spawning Box is in the western part of the East Rise (to the west of the vertical broken line at 175°W). The East and South Rise are currently managed as a single unit. The Arrow Plateau has been designated a Benthic Protected Area. The sub-Antarctic is all areas below 46°S on the east coast, and 44°16'S on the west coast, except Puysegur.

Table 3: Catch limits (t) by designated sub-area within ORH 3B, as agreed between the industry and Minister of Fisheries since 1992-93. Note that East Rise includes the Spawning Box, closed between 1992-93 and 1994-95. Sub-area boundaries have varied somewhat between years. * South Rise included in East Rise catch limit. ** Arrow Plateau included in Sub-Antarctic.

Year	Northwest Rise	East Rise	South Rise	Puysegur	Arrow Plateau	Sub-Antarctic
1992-93	3 500	4 500	6 300	5 000	-	2 000
1993-94	3 500	4 500	6 300	5 000	-	2 000
1994-95	2 500	3 500	2 000	2 000	3 000	1 000
1995-96	2 250	4 950	*	1 000	**	4 500
1996-97	2 250	4 950	*	500	**	5 000
1997-98	2 250	4 950	*	0	1 500	4 000
1998-99	2 250	4 950	*	0	1 500	4 000
1999-00	2 250	4 950	*	0	1 500	4 000
2000-01	2 250	4 950	*	0	1 500	4 000
2001-02	2 000	7 000	1 400	0	1 000	1 300
2002-03	2 000	7 000	1 400	0	1 000	1 300
2003-04	2 000	7 000	1 400	0	1 000	1 300
2004-05†	1 500	7 250	1 400	0	1 000	1 300
2005-06†	1 500	7 250	1 400	0	1 000	1 300
2006-07†	750	8 650‡	*	0	0	1 850
2007-08†	750	7 650#	*	0	0	1 850
2008-09†	750	6 570§	*	0	0	1 850
2009-10†	750	5 100§	*	0	0	1 850
2010-11†	750β	2 960§	*	150	0	500
2011-12†	750β	1 950§	*	150	0	500

† 250 t set aside for industry research surveys.
‡ 8650 t allocated to the East and South Chatham Rise combined, with no more than 2000 t from the South Rise, and no more than 7250 t from the East Rise.
# Combined East and South Rise catch not to exceed 7650 t; East Rise not to exceed 6500 t; South Rise catch not to exceed 1750 t.
§ East & South Rise managed as a single sub-area. In 2008-09, the catch from the spawning plume was not to exceed 3285 t.
β From 2010-11, quota owners have agreed to avoid fishing the Northwest Rise.

For Chatham Rise areas outside the spawning box, the overall median catch rate (for target tows) fluctuated around 5 t/tow from 1979-80 to 1986-87, dropped to around 2 t/tow until 1992-93, and has since dropped further to the recent level of 0.5-1 t/tow. However, outside the Spawning Box catches increased in the 1990s and catch rates have been highly variable, sustained largely by the discovery of new fishing areas. Flat areas on the Northwest Rise and several major hills on the South Rise were important in the late 1980s, but do not support their previous levels of catch, now accounting for less than 5% of the estimated catch (Table 4). High catch rates can still occur, but these are sporadic. Catches from the Northwest Rise fell to near zero in 2010-11 as a result of an agreement among quota owners to avoid fishing in this area (Table 2). This agreement has been extended to the 2011-12 fishing year (Table 1).

Between 1991-92 and 2000-01, more than half of the Chatham Rise catch came from four hill complexes: the Andes, Smith City and neighbours, Graveyard, and Big Chief and neighbours (Table 4). All of these have shown a decline in unstandardised catch rate since the early years of the fishery, and in recent years most catch rates have remained relatively low. After 2000-01, the proportion of the catch from these hill complexes decreased, as a greater proportion of the catch came from the Spawning Box (about 39% in 2008-09). In addition, large catches have been made in recent years outside of the spawning season, in recently developed areas of the southeast Rise. Catches from the Spawning Box taken during the spawning season (which peaks in July) have been relatively high since 2001-02, although unstandardised catch rates have been variable.

Since 1990, there has been considerable exploratory fishing throughout ORH 3B, and several fisheries have developed in areas outside the Chatham Rise (Table 5).

The first fishery to be developed south of the Chatham Rise was on Puysegur Bank, where spawning aggregations of orange roughy were found during a joint Industry-MFish exploratory fishing survey in 1990-91. The fishery developed rapidly, but from 1993-94 catch limits were substantially under-caught. Catch limits were subsequently reduced from the initial level of 5000 t, and the industry implemented a catch limit of 0 t beginning in the 1997-98 fishing year (reported catches in 2004-05 and 2005-06 were taken during industry surveys). No fishing in this area occurred in 2010-11 in spite of an increase in the catch limit to 150 t (Tables 3 and 5).

Exploratory fishing on the Macquarie Ridge south of Puysegur in 1993 saw a fishery develop off the Auckland Islands. Total catches rose to around 900 t in 1994-95, but then dropped to less than 200 t by 1999-00, and have been infrequent in recent years (Table 5).

In 1993-94, the first major catches were taken to the east of the Chatham Rise, on the ‘Arrow Plateau’. A catch limit of 3000 t was put in place for 1994-95, with a limit of 500 t for any one hill. Only a few hills in this area have been fished successfully, and the catch never reached the catch limit, which was reduced to 1000 t by the early 2000s (Tables 3 and 5). The Arrow Plateau was closed to orange roughy fishing when it was designated a Benthic Protected Area in 2007.

In 1995-96, large catches were reported on the southeast Pukaki Rise, with a catch total of over 3000 t (Table 5). However, the catches dropped rapidly, and within a few years the fishery had effectively ceased. From 2001-02, a fishery developed on the northeast Pukaki Rise, and included the area known as Priceless, where catches were mostly taken at the start of the fishing year. Catches at Priceless reached the feature limit of 500 t for each of the 5 years up to 2007-08, but catches and catch rates declined substantially in 2009-10, and were less than 40 t and 0.1 t/tow. Areas of the northeast Pukaki Rise outside of Priceless were developed in 2004-05 and also showed a rapid decline in catch rates. By 2007-08, the fishery in the sub-Antarctic was limited to the Auckland Islands and northeast Pukaki Rise areas. In 2008-09 and 2009-10, the fishery extended over a relatively wide area, but catch rates were low (≤ 0.5 t/tow) throughout.

Catches of orange roughy have also been taken off the Bounty Islands (around 100-200 t per year from 1997-98 to 2004-05, but infrequently since then; Table 5), off the Snares Islands (up to around 500 t per year, but infrequently since then), areas of the Macquarie Ridge (100-500 t per year from 2000-01 to 2004-05, and in 2008-09), and off Fiordland (around 500 t in 2000-01, but subsequent catches rapidly decreased).

Table 4: Orange roughy estimated catches (to nearest 10 t) and unstandardised median catch rates (to nearest 0.1 t/tow) for four important hill complexes and the Spawning Box In season (spawning plume area, May-August) and Out season (September-April) on the Chatham Rise (letters indicating subareas, as in Table 3, in parentheses), using catch and effort data held by NIWA. Only tows targeted at orange roughy are included. (Approximate positions are: Big Chief, 44.7 S, 175.2 W; Smiths City and near-neighbours, 43.1 S, 174.2 W; Andes, 44.2 S, 174.6 W; Graveyard, 42.8 S, 180 W). -, catch < 10 t (2009-10 data are provisional, and catch totals are possibly incomplete). - means catch < 10 t. NA means there were fewer than 3 vessels in the fishery.

	Andes (E)			Smith's City Northeast Hills (E)			Spawning Box In (E)			Spawning Box Out (E)			Rest of East (E)		
Year	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow
1979-80	-	-	-	110	36	3.1	9 800	968	10.7	7 450	803	6.0	560	206	2.2
1980-81	-	-	-	-	2	-	11 100	890	11.5	6 300	466	11.5	30	10	3.5
1981-82	-	-	-	40	11	3.6	4 750	470	4.5	4 460	607	4.9	360	77	4.0
1982-83	-	-	-	40	2	17.8	3 980	227	13.4	3 870	390	8.1	1 030	63	8.5
1983-84	-	-	-	60	7	6.3	6 590	378	13.4	8 630	837	7.7	1 190	139	6.4
1984-85	-	-	-	10	3	3.2	9 320	676	10.4	7 460	537	10.0	990	80	9.5
1985-86	-	-	-	670	52	11.4	8 521	659	10.0	7 660	861	6.0	3 030	306	8.1
1986-87	-	-	-	210	34	3.9	8 090	597	8.9	12 040	1 040	6.2	1 950	296	4.6
1987-88	-	-	-	160	33	4.5	7 870	622	8.0	5 840	706	5.0	2 100	324	5.3
1988-89	30	18	0.3	310	48	3.9	7 070	598	9.6	6 540	816	5.0	2 080	299	4.5
1989-90	90	13	1.5	40	9	4.0	6 830	403	12.5	5 020	606	5.2	360	86	3.0
1990-91	80	12	3.2	4 890	633	3.5	2 820	238	8.0	2 810	206	8.0	480	87	1.0
1991-92	7 080	724	5.0	1 270	222	2.0	650	85	6.0	310	56	5.7	3 050	366	5.0
1992-93	2 940	345	5.0	600	84	2.0	50	2	27.0	-	-	-	570	75	2.0
1993-94	3 320	605	1.8	560	109	2.8	-	-	-	-	-	-	510	122	1.9
1994-95	1 650	573	1.0	1 140	345	1.0	490	86	0.3	10	25	-0.1	440	195	1.0
1995-96	1 120	418	0.5	410	145	1.0	1 360	127	5.0	160	28	0.9	450	120	0.5
1996-97	730	260	1.0	720	164	1.0	930	101	3.0	620	133	2.0	370	117	1.0
1997-98	1 140	476	0.5	400	146	0.4	1 580	118	6.0	630	151	1.4	450	259	0.3
1998-99	1 260	448	1.0	810	272	1.0	510	73	2.7	490	139	1.6	350	214	0.3
1999-00	1 990	529	1.0	680	210	0.8	910	34	25.0	510	111	2.0	390	162	0.3
2000-01	980	354	1.1	650	191	1.0	810	59	5.5	430	123	2.0	580	155	1.0
2001-02	2 040	546	1.5	490	167	0.9	2 120	159	4.0	990	224	2.0	900	240	1.1
2002-03	2 230	872	1.0	400	124	0.5	2 150	166	8.0	1 000	216	1.8	1 280	397	0.8
2003-04	1 170	677	0.5	360	160	0.8	1 880	163	6.0	2 080	429	2.8	840	394	0.6
2004-05	1 090	518	0.6	310	127	0.9	1 910	214	4.4	1 890	430	2.7	1 330	405	0.9
2005-06	1 340	727	0.5	370	119	0.7	1 630	117	9.0	1 890	322	3.0	1 810	533	0.8
2006-07	1 160	583	0.5	570	201	0.7	1 980	121	11.2	1 800	399	2.5	1 540	573	0.9
2007-08	N/A	N/A	N/A	N/A	N/A	N/A	2 550	200	5.0	930	247	2.3	N/A	N/A	N/A
2008-09	N/A	N/A	N/A	N/A	N/A	N/A	2 020	121	18.0	1 110	248	2.8	1 170	443	1.0
2009-10	440	243	0.5	160	84	0.5	1 980	136	8.5	910	275	2.4	560	217	1.2
2010-11	460	151	1.2	90	27	0.4	1 230	75	15.0	470	59	3.0	130	43	0.6

	Graveyard (NW)			Rest of Northwest (NW)			Hegerville (S)			Big Chief (S)			Rest of South (S)		
Year	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow
1979-80	-	-	-	840	81	7.7	20	2	8.1	-	-	-	20	12	< 0.1
1980-81	50	7	4.0	7 960	2 074	2.3	980	235	3.3	-	-	-	110	25	3.4
1981-82	90	12	6.4	3 830	616	4.4	40	9	4.3	-	-	-	30	28	1.1
1982-83	90	11	5.0	8 500	1 484	3.6	7 440	856	7.1	-	-	-	180	31	< 0.1
1983-84	-	-	-	2 780	657	2.9	3 370	493	4.5	-	-	-	120	86	0.1
1984-85	-	-	-	1 640	314	3.3	5 660	824	4.5	-	-	-	870	289	0.6
1985-86	30	11	2.5	3 400	564	2.8	3 660	840	1.8	-	-	-	530	198	0.6
1986-87	30	11	2.0	2 920	660	2.3	2 470	601	1.6	-	-	-	1 440	433	1.1
1987-88	130	19	4.7	1 360	386	2.4	2 020	673	0.8	-	-	-	3 180	924	0.7
1988-89	130	25	3.2	2 780	782	1.8	1 170	568	0.6	1 010	199	1.7	4 650	1 768	0.3
1989-90	160	28	5.5	2 100	602	2.0	470	237	0.6	2 830	529	1.5	4 090	1 121	1.0
1990-91	10	2	4.2	1 230	261	2.6	170	75	0.3	3 150	453	2.1	1 620	500	0.3
1991-92	70	25	1.3	180	60	2.0	30	52	< 0.1	820	138	2.5	780	308	0.3
1992-93	3 300	297	5.1	170	69	1.4	290	83	1.5	3 310	703	2.0	1 190	462	< 0.1
1993-94	2 180	363	1.9	1 120	213	1.0	220	129	0.5	2 350	698	0.6	2 060	1 129	0.1
1994-95	1 510	363	1.0	720	268	1.0	100	95	< 0.1	510	242	0.8	880	937	< 0.1
1995-96	1 790	355	1.0	430	212	0.8	80	104	< 0.1	580	151	1.0	460	553	< 0.1
1996-97	870	243	0.5	1 210	400	2.0	170	75	0.2	560	195	0.5	440	304	< 0.1
1997-98	830	305	0.4	1 290	487	1.0	60	52	0.1	950	285	0.4	410	503	0.1
1998-99	930	186	0.8	1 510	550	1.0	50	1	0.5	560	215	0.5	390	258	0.3
1999-00	630	239	0.5	1 280	353	1.0	50	10	0.3	380	123	0.5	430	173	0.5
2000-01	1 010	301	0.5	1 310	613	1.0	100	21	3.0	1 020	213	0.8	400	203	0.5
2001-02	730	206	0.9	1 260	645	0.8	30	18	0.6	660	234	0.9	280	186	0.5
2002-03	1 080	253	0.8	1 050	593	0.8	150	42	1.4	660	276	0.5	480	204	0.5
2003-04	740	126	0.7	1 030	586	1.0	100	48	0.4	570	300	0.5	460	266	0.4
2004-05	920	170	1.1	560	331	0.7	100	23	2.2	790	308	0.5	490	231	0.6
2005-06	960	188	0.6	380	238	0.7	90	53	0.5	500	303	0.4	400	281	0.4
2006-07	590	78	1.8	80	29	0.2	160	38	0.6	510	282	0.4	200	187	0.3
2007-08	390	176	0.6	320	109	0.8	280	107	0.6	690	335	0.5	170	189	0.3
2008-09	390	75	1.3	280	110	0.5	500	182	0.5	330	307	0.2	120	158	0.1
2009-10	290	90	0.8	360	193	1.2	470	120	1.0	180	121	0.3	40	68	0.2
2010-11	N/A	N/A	N/A	30	5	1.0	130	32	2.0	210	60	0.5	30	34	< 0.1

Table 5: Estimated ORH 3B catches (to the nearest 10 t) and unstandardised median catch rates (to nearest 0.1 t/tow) for areas outside the Chatham Rise, using estimated catch and effort data held by NIWA. Only tows targeted at orange roughy are included. For this table the areas were defined by the following rectangles: Arrow - 42.17-46°S, 173.67°W; Auckland - 49-52 °S, 165-167 °E; Bounty - 46-47.5°S, 177.5-180°E; Priceless - 48-48.44°S, 174.7-175.2°E; Other Pukaki - 47-50.4°S, 174-176.4°E (and not in Priceless); Puysegur - 46-47.5 °S, 165-166.5 °E. The area described as Antipodes in previous reports is now included in Other Pukaki. All years are from 1 October-30 September (2009-10 data are provisional and catch totals may be incomplete). - means catch < 10 t. N/A means there were fewer than 3 vessels in the fishery.

	Arrow		Auckland		Bounty		Priceless		Other Pukaki		Puysegur		Other	
Year	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow
1985-86	120	18.5	-	-	-	-	-	-	-	-	-	-	-	-
1986-87	110	10.6	-	-	-	-	-	-	-	-	-	-	-	-
1987-88	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1988-89	-	-	-	-	-	-	-	-	-	-	-	-	30	<0.1
1989-90	-	-	-	-	-	-	-	-	-	-	100	1.4	50	6.0
1990-91	150	4.5	-	-	-	-	-	-	-	-	600	4.6	20	<0.1
1991-92	100	10.0	-	-	-	-	-	-	-	-	6 320	10.6	170	0.6
1992-93	10	6.5	30	< 0.1	-	-	-	-	-	-	4 280	6.7	330	< 0.1
1993-94	470	1.0	180	< 0.1	-	-	-	-	-	-	2 410	1.9	80	< 0.1
1994-95	750	0.3	880	0.2	-	-	-	-	-	-	1 260	7.9	20	< 0.1
1995-96	170	0.1	380	0.1	-	-	-	-	3 060	5.0	730	2.4	520	< 0.1
1996-97	280	0.1	120	< 0.1	20	< 0.1	-	-	670	< 0.1	490	2.6	400	< 0.1
1997-98	210	0.1	370	0.1	240	< 0.1	10	< 0.1	130	< 0.1	-	-	1 050	< 0.1
1998-99	580	0.3	440	0.1	150	0.1	-	-	120	< 0.1	-	-	1 820	0.5
1999-00	240	0.1	150	< 0.1	170	< 0.1	-	-	-	-	-	-	60	< 0.1
2000-01	180	0.1	60	< 0.1	150	0.3	-	-	20	< 0.1	-	-	1 030	0.3
2001-02	55	0.2	130	0.1	40	0.1	550	22.3	-	-	-	-	460	0.4
2002-03	220	0.2	-	-	120	1.5	480	7.0	-	-	-	-	400	0.4
2003-04	130	0.1	-	-	90	0.2	450	0.3	-	-	-	-	440	< 0.1
2004-05	60	0.1	-	-	100	0.4	540	0.3	520	9.8	100	5.6	550	< 0.1
2005-06	60	0.1	-	-	40	0.2	540	0.9	740	4.0	190	2.6	250	< 0.1
2006-07	-	-	-	-	-	-	470	0.5	730	1.0	-	-	-	-
2007-08	-	-	N/A	N/A	-	-	N/A	N/A	700	0.5	-	-	-	-
2008-09	-	-	N/A	N/A	-	-	N/A	N/A	600	0.5	-	-	150	0.5
2009-10	-	-	N/A	N/A	-	-	40	< 0.1	320	0.3	-	-	60	< 0.1
2010-11	-	-	N/A	N/A	N/A	N/A	-	-	N/A	N/A	-	-	20	0.4

1.2 Recreational fisheries

No recreational fishing for orange roughy is known in this quota management area.

1.3 Customary non-commercial fisheries

No customary non-commercial fishing for orange roughy is known in this quota management area.

1.4 Illegal catch

No information is available on illegal catch in this quota management area.

1.5 Other sources of mortality

There has been a history of catch overruns on the Chatham Rise because of lost fish and discards, and discrepancies in tray weights and conversion factors. In assessments, total removals from each part of the Chatham Rise were assumed to exceed reported catches by the overrun percentages in Table 6.

Table 6: Catch overruns (%) by year.

Year	1978–79	1979–80	1980–81	1981–82	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88
Overrun	30	30	30	30	30	30	30	28	26	24

Year	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95 & subsequently
Overrun	22	20	15	10	10	10	5

For Puysegur and other southern fisheries there is no reason to believe that, if there was an overrun in catches, this shows any trend over time. For this reason, it was assumed that there was no overrun for this area.

A 25 t allowance was allocated for “other” mortalities beginning on 1 October 2010.

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy section.

3. STOCKS AND AREAS

For the purposes of this report the term “stock” refers to a biological unit with a single major spawning ground, in contrast to a “Fishstock” which refers to a management unit.

Genetically two main stocks are recognised within ORH 3B (Chatham Rise and Puysegur; Smith & Benson 1997) and these are considered to be distinct from stocks in adjacent areas (Cook Canyon and Ritchie Bank). However, it is likely, because of their geographical separation and discontinuities in the distribution of orange roughy, that concentrations of spawning fish on the Arrow Plateau, near the Auckland Islands, and west of the Antipodes Islands also form separate stocks.

Genetic data has been applied to define stock boundaries, both within ORH 3B, and between it and adjacent areas. Mitochondrial DNA shows that there are considerable differences between Puysegur fish and fish from the geographically adjacent areas Cook Canyon and Chatham Rise. Allozyme frequency studies suggest that Chatham Rise fish are distinct from those on the Ritchie Bank (ORH 2A). These data also suggest multiple stocks within the Chatham Rise, but do not indicate clear stock boundaries. Although there is significant heterogeneity amongst allozyme frequencies from different areas of the Rise, these frequencies varied as much in time (samples from the same location at different times) as in space (samples from different locations at the same time).

Chatham Rise

In 2008 the stock structure of orange roughy on the Chatham Rise was comprehensively reviewed (Dunn & Devine 2010). The approach evaluated all available data as no single dataset seems to provide definitive information about likely stock boundaries. The data analysed included: catch distribution and CPUE patterns; location of spawning and nursery grounds; inferred migrations; size, maturity and condition data; genetic studies, and habitat and natural boundaries.

There is evidence that a separate stock exists on the Northwest Rise. The Northwest Rise contains a substantive spawning ground on the Graveyard Hills, and also nursery grounds around, and primarily to the west of, the Graveyard Hills. There is a gap in the distribution of early juveniles (< 15 cm SL) between the Graveyard area and the Spawning Box at approximately 178°W. A research trawl survey found post-spawning adult fish to the west, but not to the east, of the Graveyard Hills, and a westerly post-spawning migration was inferred. Analyses of median length from commercial and research trawls found orange roughy on the Northwest Chatham Rise and Graveyard Hills were smaller than those on the East Rise. A substantial decline in the size of 50% maturity after 1992 was found for both the Graveyard Hills and the Northwest Rise, but not for other areas. The only information that does not support the Northwest Rise being a separate stock is an indication from patterns in commercial catch rates that some fish arriving to spawn in the Spawning Box may come from the west (Doonan & Coburn 1994, 1997). Catch data and genetic studies do not shed any further light on stock structure. Oceanographic models suggest that a gyre to the east of the Graveyard may provide a mechanism for a separation between the Northwest Chatham Rise and the East Rise. Based on the available data the Northwest Chatham Rise is considered to be a separate stock.

The previous separation of the Northeast Hills and Andes as separate stocks from the Spawning Box and Eastern Flats was based on simultaneous spawning aggregations occurring on these hills, and because stock assessment models indicated a mismatch between the standardised CPUE trends. However, the scale of spawning on these hills is not known. The information that suggests all of these areas are a single stock includes: the occurrence of a continuous nursery ground throughout the area; similar trends in size of 50% maturity in each area; essentially continuous habitat with similar environmental conditions; inferred post-spawning migrations from the Spawning Box towards the east Rise. Analyses of median lengths from commercial catches showed no obvious differences between areas. In addition, the spawning aggregations found on the Northeast Hills and Andes appear to have been minor compared to that in the Spawning Box. The spawning aggregation on the Northeast Hills is also associated with an increase in mean length and catch rates, suggesting fish spawning on these hills are not resident, and thus are not separate from the surrounding area. Based on the available data the Northeast Hills and Andes are therefore considered to be the same stock as the Spawning Box and Eastern Flats.

The only evidence to separate the eastern area of the South Rise (Big Chief and surrounds) from the East Rise is the lack of spawning migrations inferred from an absence of a seasonal effect in standardised CPUE analyses. The evidence that the Big Chief area is the same stock as the East Rise includes: the nursery grounds and habitat are continuous; there were no splits between the areas identified from analyses of median length; and the fisheries are similar. The reports of spawning fish around Big Chief have been infrequent, and so are considered equivocal on stock structure. The Big Chief area is therefore considered part of the East Rise stock.

There is weak evidence that the area of the South Rise west of and including Hegerville is a separate stock. This includes: median length analyses indicated a split in this area; and there is an oceanographic front at 177°W. However, very few catches of spawning orange roughy have been reported in this area, and there appears to be no substantial nursery ground. Both of these factors support the idea that this area does not have a separate stock. In the area to the west of the suggested split the fish are relatively small during spawning, and relatively large during non-spawning. Combined with a standardised CPUE which shows a decline in abundance around July (peak spawning), and a somatic condition factor which declines during September-November (post-spawning). This supports a hypothesis of adult fish leaving the area to spawn elsewhere.

The South Rise could provide feeding habitat for the stock, which is estimated to have had an initial biomass of over 300 000 t, an amount that was probably too large to inhabit only the East Rise. There is more evidence to support orange roughy in this area being part of the East Rise stock than there is to the contrary. The current hypothesis is that the area to the west of the current convergence may be relatively marginal habitat, where larger juvenile, maturing and adult orange roughy were once predominant, and there is little spawning and few juveniles because the water is relatively cold.

Based on these analyses, the Chatham Rise has been divided into two areas: the Northwest, and the East and South Rise combined (Figure 1). The centre of the Northwest stock is the Graveyard Hills. The centre of the East and South Rise stock is the Spawning Box during spawning, and the southeast corner of the Rise during non-spawning.

4. STOCK ASSESSMENT

In 2008, the Plenary reviewed the status of the East and South Rise orange roughy stock using available information sources; of these only the acoustic estimates of orange roughy biomass in the spawning plume, along with associated evaluations of stock status, have been updated in each of the years 2009, 2010, 2011 and 2012. Because the conclusions of the 2008 analyses of stock structure (section 3 above) indicated that the East and South Rise were likely to be a single stock, the earlier stock assessments for these areas are no longer considered to be reliable and are not reported here. The 2006 assessment for the Northwest Chatham Rise, and the 1998 assessment for Puysegur are reported as previously. There are no assessments for any other areas of ORH 3B.

4.1 Northwest Chatham Rise

4.1.1 Assessment inputs

Four sets of observational data are used in the assessment:

(1) A standardised CPUE series;
(2) An absolute mature biomass estimate (egg survey);
(3) Three relative mature biomass estimates (acoustic/trawl wide-area surveys); and
(4) A commercial fishery length-frequency data series.

The standardised CPUE series excluded short duration tows made in the Graveyard Hills complex (McKenzie 2006), and is shown in Table 7. The first three point of this series were excluded from the assessment (see Introduction), and a process error of 20% was added to the CVs for the series.

Table 7: Estimates of standardised catch per unit effort (and CVs) for the Northwest Chatham Rise stock. The first three points were excluded from the assessment (1980-81 though to 1982-83). A 20% process error has been added to each of the CVs.

Fishing year	CPUE (All months)	(CV%)
1980-81	1.34	28
1981-82	1.61	25
1982-83	0.96	24
1983-84	0.60	24
1984-85	0.89	25
1985-86	1.09	25
1986-87	0.80	24
1987-88	0.58	24
1988-89	0.44	25
1989-90	0.68	24
1990-91	0.67	26
1991-92	0.46	33
1992-93	0.38	35
1993-94	0.43	34
1994-95	0.42	27
1995-96	0.22	34
1996-97	0.40	26
1997-98	0.31	26
1998-99	0.18	28
1999-00	0.22	30
2000-01	0.19	27
2001-02	0.17	27
2002-03	0.13	28
2003-04	0.16	28
2004-05	0.15	28

Biomass estimates from four resource-surveys were used in this assessment: a 1996 egg survey, and acoustic surveys in 1999, 2002, and 2005 (Table 8).

Table 8: Estimates of mature biomass (and their CVs) for the Northwest Chatham Rise stock.

Source	Date	Biomass (t)	CV	Reference
Egg survey	June/July 1996	49 000	0.8	Francis *et al*. (1997)
Acoustic survey	June/July 1999	29 000	0.425	Bull *et al*. (2000), Francis & Bull (2000)
Acoustic survey	June/July 2002	42 000	0.63	Doonan & Hart (2003)
Acoustic survey	June/July 2005	9100	0.40	Smith (2006)

The 1996 egg survey estimate was treated as absolute but very uncertain. Although the best estimate (which combines data from all four snapshots) is 49 000 t, estimates from individual snapshots varied widely (from 12 000 t in snapshot 2 to 1 000 000 t in snapshot 1), probably because the assumptions under which they were made (e.g., that daily egg production and mortality was constant throughout each snapshot) were violated. Thus, it was not possible to calculate a CV for this estimate, and an arbitrary high value of 0.8 was assigned.

The acoustic survey estimates were treated as relative estimates with informed priors. There is uncertainty about the expansion of the acoustic biomass estimates to the whole of the Northwest Chatham Rise. Two alternative approaches for 1999 gave a “low” and “high” estimate (Bull *et al*. 2000, Francis & Bull 2000) of which the “high” estimate was used. The 2002 estimate (Doonan & Hart, 2003) expanded the biomass by a spawning ratio of 1.35 to obtain a single value of 42 000 tonnes. Hicks (2004c) gives a brief overview of the 1999 and 2002 surveys. The 2005 estimate was from a wide-area survey that covered almost the entire Northwest Chatham Rise. An informed prior was placed on the 2005 proportionality constant (q_{2005}). Informed priors were also developed for the ratios q_{1999}/q_{2005} and q_{2002}/q_{2005}. All priors on q were lognormal with the best estimate equated to the median of the prior distribution (Cordue 2006). These and other priors are summarised in Table 9.

Table 9: The prior distributions on the free parameters and ratio penalty quantities in the model. The parameters, μ and CV, defining the lognormal priors are in natural space. No explicit bounds were put on the ratios q_{1999}/q_{2005} or q_{2002}/q_{2005}, but are implicit from the bounds on q_{1999}, q_{2002}, q_{2005}.

Free parameters	Prior	[lower bound, upper bound]
B_0 (t)	uniform-log	[5000, 300 000]
relativity constant (q)	uniform-log	[1e-07, 0.01]
catchability 1999 (q_{1999})	Uniform	[0.1, 4.0]
catchability 2002 (q_{2002})	Uniform	[0.1, 4.0]
catchability 2005 (q_{2005})	lognormal (μ=1.113, CV=0.6069)	[0.1, 4.0]
commercial logistic selectivity a_{50}	Uniform	[5, 50]
CV at age 1 for length-at-age	Uniform	[0.001, 1]
CV at age 80^+ for length-at-age	Uniform	[0.001, 1]
Ratio penalty quantities	**Prior**	**[lower bound, upper bound]**
q_{1999}/q_{2005}	lognormal (μ=1.027, CV=0.2330)	-
q_{2002}/q_{2005}	lognormal (μ=0.952, CV=0.03301)	-

Nine years of length-frequency data from the period 1989-97 were collected into a single length-frequency that was centred on the 1993 fishing year. Eight years of length-frequency data from the period 1998-05 were collected into a single length-frequency that was centred on the 2002 fishing year. The effective sample size was set at 1/6 of the number of tows for each period: 19 for the “1993” period and 35 for the “2002” period (A. Hicks pers. comm.).

Age frequency data (used in the 2004 assessment) were excluded from the 2006 assessment as intersessional work indicated that the ages assigned to orange roughy otoliths were both biased and imprecise (see Introduction). The use of age data was restricted to the estimation of basic biological parameters. Unfortunately, it was not possible to use otoliths from the Northwest Chatham Rise stock itself as only 69 suitable otoliths were available. Therefore, otolith data from the adjacent East Chatham rise were used to re-estimate the parameter values for the sexual maturity, length-at-age, and weight-at-length curves. The values for other biological parameters (i.e., natural mortality and maximum exploitation rate) were unchanged from the 2004 assessment (McKenzie 2005)

4.1.2 Stock assessment

The observational data were incorporated in a Bayesian stock assessment with deterministic recruitment to estimate stock size and do forward projections. The stock was considered to reside in a single area, with no partition by sex or maturity. Age groups were 1-80 years, with a plus group of 80+. Exploratory model fits demonstrated an apparent disparity between the age of sexual maturity as found from the otolith data (using counts to the transition zone) and the size of fish caught by the commercial fishery. Therefore, the maturity data were not used and the maturity ogive was set equal to the selectivity ogive, which was estimated within the model using the length-frequency data (see Introduction).

Three alternative model runs are reported: Alldata (in which both the CPUE and biomass survey data were incorporated), Nobiomass (in which the biomass survey data were omitted), and NoCPUE (in which the CPUE data were omitted). For each run, the uncertainty in the estimated parameters was evaluated using Monte Carlo Markov Chain (MCMC) techniques. For the MCMCs, 3000 samples were taken from a chain of length 3 million.

4.1.3 Biomass estimates

For the Alldata run, B_0 was estimated to be 55 000 t (95% confidence interval 51 400-59 500 t; Table 10), the 2006 biomass was 6000 t (4200-9300 t), or 11% (8-16%) B_0. The Nobiomass run produced slightly lower estimates of all biomass metrics. The NoCPUE run produced higher estimates of B_0 (79 800 t; 59 600-128 600 t) and $B_{CURRENT}$ (30 900; 12 400-77 500 t) with the median estimate for the ratio of the two being 39% (21-61%) B_0.

Neither of the runs that included the survey estimates fit all four biomass indices well (Figure 2). For the Alldata run, the estimated biomass trajectories provided a reasonable fit to the acoustic biomass indices, but not the egg survey. The NoCPUE run provided a reasonable fit to the egg survey and the first two acoustic biomass indices, but was above the upper confidence interval of the most recent (2005) biomass index.

Table 10: Biomass estimates (medians, with 95% confidence intervals in parentheses) for three runs. $B_{CURRENT}$ is the mid-year biomass in 2006.

Run	B_0(t)	$B_{CURRENT}$(t)	$B_{CURRENT}$(% B_0)
Alldata	55 000 (51 400-59 500)	6000 (4200-9300)	11 (8-16)
Nobiomass	52 500 (48 300-56 400)	4400 (3200-6900)	9 (6-13)
NoCPUE	79 800 (59 600-128 600)	30 900 (12 400-77 500)	39 (21-61)

The large discrepancy between the NoCPUE run and the other two runs reflects the relative influence of biomass *vs.* CPUE indices. When CPUE data are included, they dominate the result (as in the Alldata and Nobiomass runs) because there are a large number of CPUE observations and they cover a period in the fishery when the biomass changed a lot. In contrast, there are only four fishery-independent indices of biomass and they occur in recent years when the biomass is not likely to have changed much. In addition, two of these indices have extremely high CVs. The egg survey, in particular, is deemed to be unreliable (thus its high CV).

The Plenary noted that the three runs presented should not be given equal weight. The NoCPUE run was not considered to give a reliable assessment of stock status because it relies on survey estimates that are few in number, have high CVs, and are restricted to the end of the time series when there is relatively little contrast in stock size. However, it should also be noted that there is uncertainty in the other two runs that include CPUE because the extent to which the CPUE (which is based only on flat tows) indexes the entire stock is unknown.

For the Alldata and Nobiomass runs, exploitation rates appear to have been higher than the exploitation rate associated with a *CAY* strategy, E_{CAY} (0.064) for most of the history of the fishery (Figure 3). This is to be expected since the fishery was purposely managed to have a fishing down phase. Estimated exploitation rates for 2004-05 were 0.26 and 0.34 for the Alldata and Nobiomass runs respectively, both of which were considerably higher than the estimate for the NoCPUE run (0.053).

4.1.4 Sensitivity analyses

Independently estimating maturity ogives (from otolith transition zone data, outside the stock assessment model) and selectivity ogives (from length-frequency and other information, within the model) gave similar results to previous assessments (selectivity curves estimated to be well to the right of maturity curves; see Introduction), an outcome believed by the Plenary to be untenable.

Halving the natural mortality gave moderately better fits to all the observational data, with a current %B_0 that was slightly less than that from the Alldata model.

4.1.5 Projections

Five-year projections based on deterministic recruitment were carried out using a range of constant catch options. For each catch option, three measures of fishery performance were calculated:

(1) $P_{0.2}$: the probability that the biomass in 2011 is greater than 20% B_0 [P(B_{2011} > 20%B_0)];
(2) P_{MSY}: the probability that the biomass in 2011 is greater than B_{MSY} [P(B_{2011} > B_{MSY})] (where 30% B_0 is used as a proxy for B_{MSY}, as is conventional for New Zealand orange roughy stocks - see Introduction); and
(3) B_{MED}: the median biomass in 2011 (expressed as a percentage of B_0).

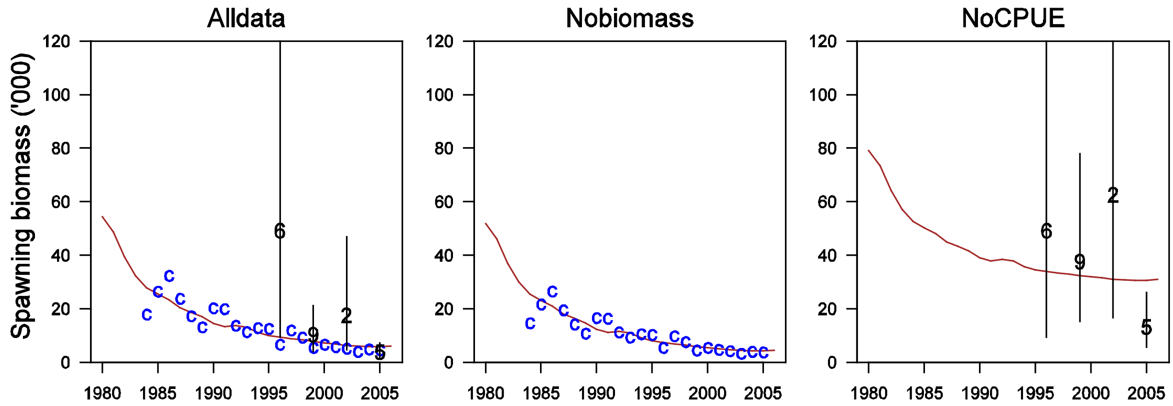


Figure 2: Estimated biomass trajectories (lines) and fitted data (points) from all model runs. The data are identified by the plotting symbol ('c' = CPUE, '6' = 1996, '9' = 1999, '2' = 2002, '5' = 2005). CPUE data are scaled up to the biomass. Vertical bars (for biomass indices only) show 95% confidence intervals. Plots are from the medians of the posterior distribution.

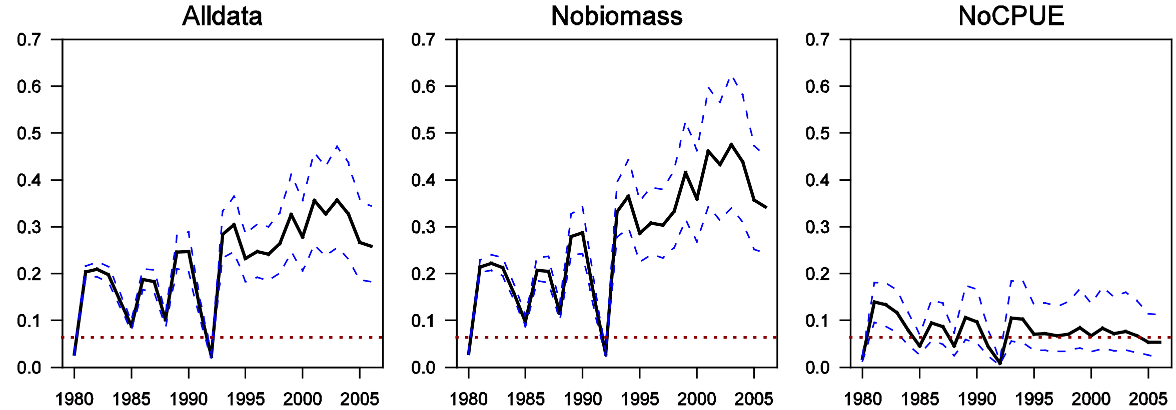


Figure 3: Estimated exploitation rates (solid line) with 95% CI (dashed line) for all model runs. The horizontal dotted line shows the exploitation rate under a *CAY* policy, E_{CAY} (0.064).

For all runs the projections indicate that the biomass should slightly increase with a catch of 1500 t (Table 11). However, for the Alldata and Nobiomass runs, maintaining the catch at 1500 t results in close to zero probability that the stock will have rebuilt to 20% B_0 or to B_{MSY} within 5 years. Zero catch results in a high probability of rebuilding to 20% B_0, but almost zero probability of rebuilding to B_{MSY}.

Table 11: Results from projections to 2011 for three runs from each model. $B_{CURRENT}$ (as %B_0) is given in parentheses next to the run name for B_{MED}. A 5% overrun was assumed for all years (i.e., the actual catches were assumed to be 5% higher than the values shown). $B_{CURRENT}$ is the mid-year biomass in 2006.

		Annual catch (t, over five-year period)				
Performance measure	Run	0	500	1000	1500	2000
$P_{0.20}$	Alldata	0.97	0.50	0.09	0.01	0.00
	Nobiomass	0.71	0.11	0.01	0.00	0.00
	NoCPUE	1.00	1.00	1.00	0.99	0.98
P_{MSY}	Alldata	0.00	0.00	0.00	0.00	0.00
	Nobiomass	0.00	0.00	0.00	0.00	0.00
	NoCPUE	0.99	0.97	0.94	0.88	0.81
B_{MED} (10.6)	Alldata (10.9)	23.4	20.0	16.7	13.6	10.5
	Nobiomass (8.5)	20.9	17.5	14.3	11.2	8.3
	NoCPUE (38.8)	49.0	46.5	44.0	41.4	38.8

4.1.6 Yield estimates

For Chatham Rise orange roughy, the exploitation rate under a *CAY* policy is 0.064 and the associated long-term average yield (*MAY*) is 1.99% B_0 (see Introduction). The Alldata and Nobiomass results suggest that a catch of 1500 t is 3.7-4.8 times the estimated *CAY*, and 1.4-1.5 times the associated long-term average yield (*MAY*) (Table 12).

Table 12: Estimated yields: *CAY* for 2007 and long-term yield under a *CAY* policy (*MAY*). The median is shown with the 95% confidence interval in parentheses. All yields were adjusted to allow for an assumed over-run of 5% in future catches.

Run	CAY_{2007} (t)	*MAY* (t)
Alldata	410 (300-610)	1 040 (970-1 130)
Nobiomass	310 (230-470)	990 (910-1 070)
NoCPUE	1 950 (810-4 790)	1 510 (1 130-2 440)

4.2 East and South Chatham Rise

Based on the conclusions of the 2008 analyses of stock structure (section 3 above) this evaluation of stock status assumes the East and South Rise to be a single stock. Previous stock assessments split the area into 4 sub-areas: the Spawning Box and Eastern Flats, the Northeast Hills, the Andes, and the South Rise.

The Northeast Hills, Andes, and the combined Spawning Box and Eastern Flats were last assessed in 2006. The Northeast Hills and Andes were treated separately from the Spawning Box and Eastern Flats because of a mismatch between declining CPUE trajectories in the hill areas, and a model estimated biomass rebuild for the combined Spawning Box and Eastern Flats. All the model runs for the Spawning Box and Eastern Flats predicted that the stock biomass had been rebuilding since the catches were substantially reduced in the early 1990s. However, this rebuild was insensitive to the recent observational data: when all of the data after 1994 were excluded the model gave an almost identical result to when they were included. From this result, it became clear that the rebuild was largely being driven by model assumptions about incoming recruitment, rather than actual data.

The South Chatham Rise was last assessed in 2004. The stock assessment model did not provide a good fit to the biomass indices (standardised CPUE), and predicted a biomass rebuild which was not seen in the CPUE indices. The rebuild was also driven by model assumptions concerning recruitment.

Analyses of the main observational data are reviewed to draw conclusions on likely stock status. The data considered include (a) research trawl surveys, (b) acoustic surveys of the spawning plume and background areas, (c) catch, and (d) standardised CPUE. In addition the size of the virgin biomass is discussed.

4.2.1 Research trawl surveys

(i) Spawning Box surveys 1984 to 1994

Research trawl surveys of the Spawning Box during July were completed from 1984 to 1994, using three different vessels: *FV Otago Buccaneer*, *FV Cordella*, and *RV Tangaroa* (Figure 4). A consistent area was surveyed using fixed station positions (with some random second phase stations each year).

Whether the survey estimates of biomass are comparable within each series depends on whether the trawl surveys were consistently indexing the full spawning biomass. None of the fixed stations are located in the area where the plume is currently found and few if any of the survey stations fished on a "genuine spawning plume" (i.e., aggregations with a large vertical extent). This is of no consequence if in each year the spawning plume(s) contained a constant proportion of the spawning biomass. However, if there was an increasing (or decreasing) proportion of biomass within the plume(s) then the trawl indices would tend to overestimate (or underestimate) the decline in spawning biomass.

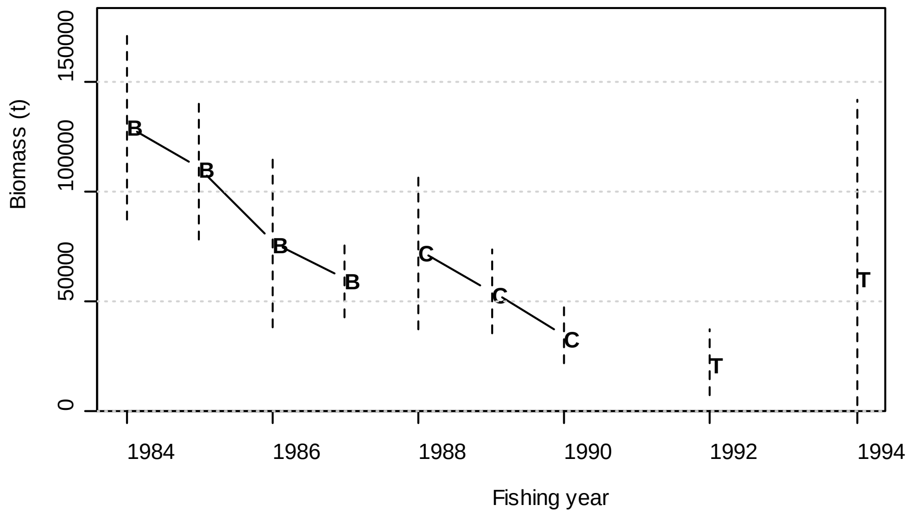


Figure 4: The Spawning Box trawl survey biomass index (assuming a catchability of 1 for each vessel), with 95% confidence intervals shown as vertical bars. Vessels indicated as B, *FV Otago Buccaneer*; C, *FV Cordella*; T, *RV Tangaroa*.

Under the assumption that the proportion of spawning fish in the plume was constant over time, each series gives a relative index of abundance over time. Four alternative abundance series were considered:

(a) *Otago Buccaneer*
Over 4 years the relative biomass estimates declined steadily from 130 000 t in 1984 to 60 000 t in 1987. The biomass in 1987 was 46.1% of the 1984 level.

(b) *Cordella*
Over 3 years the relative biomass estimates from the series declined from 73 000 t to 34 000 t. The biomass in 1990 was 46.6% of the 1988 level. There were some differences in the timing of the three *Cordella* surveys which means that the three estimates in this series may not be as comparable as the earlier *Otago Buccaneer* series.

(c) *Tangaroa*
The biomass estimate increased from 22 000 t to 61 000 t, a roughly 2.8-fold increase; however, the 1994 survey has wide confidence bounds due to the influence of a single large tow (Figure 4).

(d) 1984-90 time series
If the *Otago Buccaneer* and the *Cordella* are both assumed to have had the same catchability then the point estimate of spawning biomass in 1990 would be 26% of the 1984 spawning biomass. However, it is likely that the vessels had different relative catchabilities.
It is highly likely that the biomass was less than 50% B_0 by 1987 as the *Otago Buccaneer* series alone shows a decline of over 50% and the cumulative catch from the stock was about 130 000 t (including estimated catch overruns from Table 6) before the first *Otago Buccaneer* survey in July 1984. The subsequent *Cordella* series then shows a continuing decline in abundance consistent with the continuing high level of catches over the years 1988-90. The exact level of the decline remains uncertain because of the poorly known relative catchabilities of the different vessels and the possible impact of the timing of the surveys, but the 2008 Plenary agreed that by 1990 the stock was likely to have been of the order of 30% B_0.

4.3 Wide-area surveys 2004 and 2007

The 2004 and 2007 surveys by *Tangaroa* covered the area which extends from the western edge of the Spawning Box around to the northern edge of the Andes. The area surveyed did not include the spawning plume, the Northeast Hills, or the Andes. The survey used a random design over sixteen strata grouped into five sub-areas, and was a combined acoustic and trawl survey in 2004, and a trawl survey in 2007. The trawl net used was the full-wing and relatively fine mesh ‘ratcatcher’ net. The surveys covered the same survey area as the Spawning Box trawl surveys from 1984 to 1994 as well as additional strata to the east. The depth range surveyed was 825 m to 1250 m, except in subarea 2, where the limits were 800 m to 1350 m. The total area surveyed was 13 147 km^2. In 2007, the survey ran from 4-27 July and 62 trawl tows were completed. In 2004, the survey ran from 7-29 July and 57 trawl tows were completed.

The relative abundance of orange roughy estimated from the trawl surveys did not change significantly between 2004 and 2007 (Table 13). The size distribution of the fish did change, however, with an increase of about 2 cm in the left hand limb (see Figure 5).

Table 13: Relative estimates of orange roughy mature biomass and number of fish (CV in parentheses) from the 2004 and 2007 trawl surveys, assuming a catchability of 1 between the wingtips (25.4 m).

Year	Biomass (t)		Numbers (‘000,000)
	Total	Mature (> = 33cm)	Total
2004	17 000 (10%)	7 000 (12%)	19.1 (13%)
2007	17 000 (13%)	7 100 (17%)	18.8 (12%)

It is not known whether the difference in the size distribution between the last two wide area surveys reflects a real change in the population size structure. However, the surveyed areas were similar and the data appear to be comparable. The length distribution suggests recruitment has been poor or absent at the bottom end of the length range (Figure 5). Using assumed orange roughy growth rates, this recruitment failure, if real, would reach the spawning stock and the fishery in about 10 years from 2007). Further surveys would be required to determine whether the drop in recruitment is real.

4.3.1 Acoustic surveys

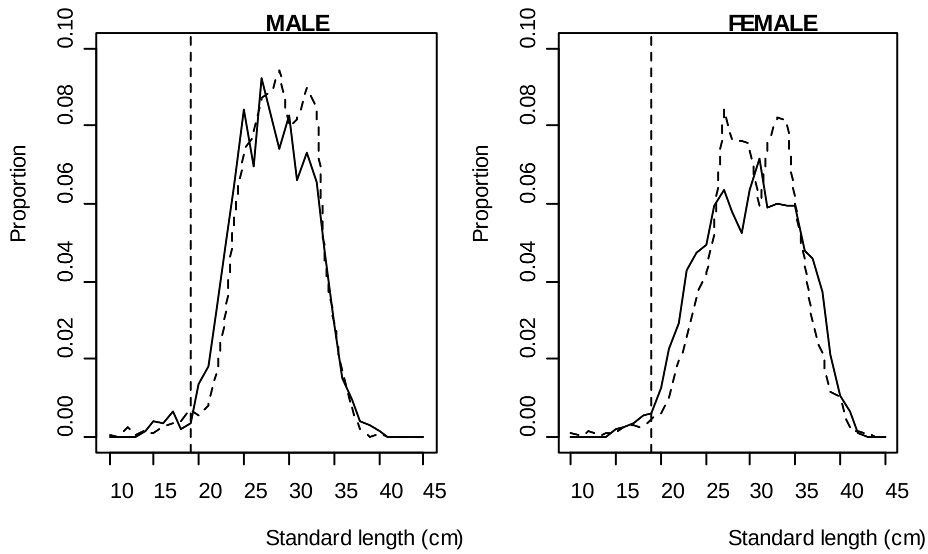


Figure 5: Orange roughy proportion at length estimated from the *RV Tangaroa* wide-area trawl survey of the Spawning Box and Eastern Flats in July 2004 (solid line) and July 2007 (dashed line). The vertical broken lines indicate a length of 19 cm, equivalent to the length of 50% vulnerability to the trawl net.

i) Plume surveys

Acoustic estimates of the biomass in spawning aggregations (plumes) in the Spawning Box during July were thoroughly reviewed and revised in 2008-2010 (Cordue 2008; Doonan 2009; Hampton *et al*. 2008, 2009, 2010). For the 2002-10 time series, the main changes were:

a) identification and removal of snapshots which were possibly biased because of excessive signal loss due to poor weather (mean wind speed > 20 knots), or where the snapshot was interrupted, or where the fish movement alongshelf was too great, as explained in Hampton *et al*. (2009);

b) removal of transects on which no orange roughy were detected, and trimming of zero estimates along the remaining transects to improve CV estimates;

c) replacement of the weather corrections in all years by a correction to each transect obtained from the linear bottom reference model (Base Case Model blm3) presented to the Working Group by Patrick Cordue on 23 April 2010;

d) replacement of the transducer calibrations in years of poor calibration conditions with the geometric mean of the calibrations in good conditions for reasons given in Hampton *et al*. (2009);

e) application of new estimates of target strength based on observations of individual orange roughy (Macaulay *et al*. 2009) applied to a single pooled length distribution for each survey (TS = 16.15 LogL - 76.81);

f) direct correction for errors in absorption coefficient applied to each survey rather than correction through the error model;

g) correction of each survey estimate between 2002 and 2007 for small software errors in the ES60 software, as explained in Hampton *et al*. (2008) and Hampton *et al*. (2009). No corrections to the 2008 and 2009 estimates were necessary since the error was removed in later software upgrades; and

h) estimation of the sampling CV from the variation between the snapshot estimates (CV2).

For the 1996-2000 acoustic surveys of the Spawning Plume, similar refinements were undertaken where appropriate data were available, along with other analyses, in an attempt to ensure they were as consistent as possible with each other and with the 2002-10 time series (Figure 6). However, the Working Group still had reservations about the comparability of the 1996, 1998 and 2000 surveys to the 2002-10 time series because of the different methodologies used and the relatively small number of transects involved in the earlier surveys (as reflected in their wide confidence intervals). For this reason, it is only the 2002-11 estimates that are assumed to represent a consistent time series. This time series indicates a substantial decline in biomass from 2002 to 2011.

The patterns in the biomass estimates in Figure 6 are markedly different from those presented in 2008, which indicated no trend in biomass for the Spawning Plume from 2002 to 2007. The patterns in the Figure 6 estimates are, however, similar to the series presented in the 2009, 2010 and 2011 Plenary documents based on the bottom reference method. The addition of a further survey estimate from 2011 has continued the declining trend.

However, in 2011 a new spawning plume to the west of the main plume area surveyed during 1996-2011 (Figure 7) was discovered and surveyed (Doonan *et al*. 2011). This plume may have been seen by fishers in 2010, but there is no record of its existence in any previous year. The estimate of biomass in the “main” spawning plume in 2011 was 16 422 t (CV 7.5%), while the estimate of biomass in the western plume was 28 114 t (CV 18.4%). It is difficult to reconcile the discovery of this plume with the available information and assumptions about the biomass of orange roughy on the east and south Chatham Rise over the past few years.

In addition, an acoustic survey was undertaken of Mt Muck (to the east of the two spawning plumes, Figure 7) and preliminary results were presented the Deepwater Working Group (Kloser *et al*. 2011). The total biomass was preliminarily estimated to be 10 263 t (CV not calculated), although 43% of this estimate was derived from the shadow zone, leaving 5 833 t actually observed. This preliminary result, while higher than previous estimates, is less unexpected due to the difficulty of sampling this rugged area.

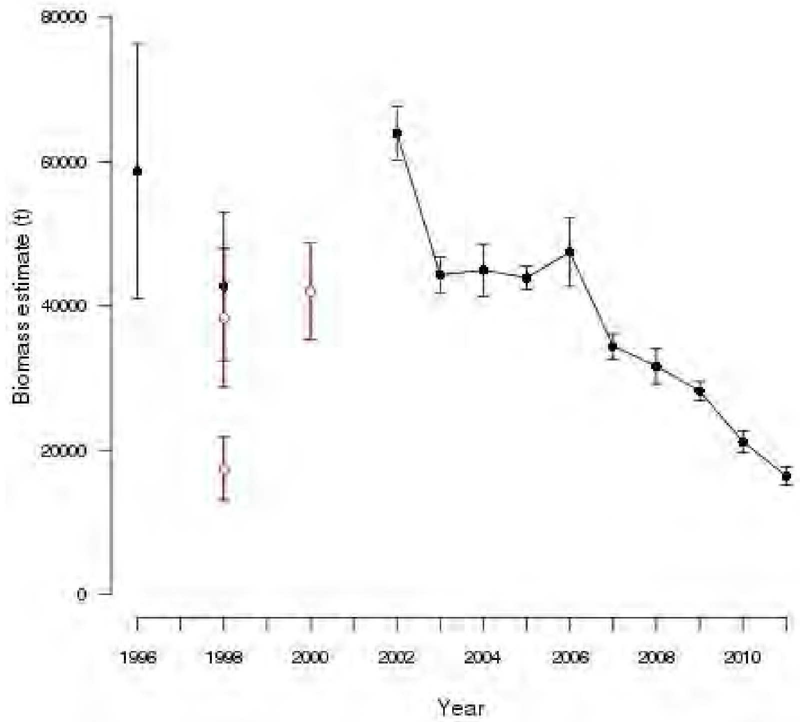


Figure 6: Acoustic biomass estimates for the Spawning Plume in the Spawning Box during July, completed by MFish/NIWA using *RV Tangaroa* (1996, lower 1998, and 2000 points), by ORMC/CSIRO using *FV Amaltal Explorer* (higher 1998 point) or by the Deepwater Group/FRS using *FV San Waitaki* (time series from 2002-10). Open circles are estimates from towed body surveys, closed circles are from surveys with vessel-mounted transducers. The 2002-10 time series is from Table 22 of Soule *et al*. 2010. Error bars are ±2 standard deviations.

ii) Wide area acoustic surveys

In addition to the acoustic biomass series for the Spawning Plume a wide-area survey of the Spawning Plume, Spawning Box background areas, and Northeast Flats combined was completed by *Tangaroa* in 2004. The wide-area survey was designed to survey the entire stock, unlike the Plume surveys, which were assumed to index a constant proportion of mature orange roughy in the Spawning Box and Northeast Flats sub-area. These surveys show that there are mature fish outside the spawning plume and allowance needs to be made for this biomass in determining current stock size.

It is difficult to regard the wide area estimates as estimates of absolute biomass because they include fish from mixed-species marks. The low target strength of orange roughy relative to other species in the mixed-species marks means that there is much greater potential for bias in determining estimates outside the aggregations. Although there is obviously some mature biomass outside the plume, the proportion is difficult to determine.

iii) Acoustic surveys on hills

Acoustic surveys of the Northeast Hills (Smith’s City & Camerons) have been completed by the industry vessel *FV San Waitaki* in 2003, 2004, 2006 and 2008 and by *RV Tangaroa* in 2004 and 2007. Because the species mix is not known it is difficult to determine the biomass of orange roughy in this area. Estimates of biomass from the *Tangaroa* surveys suggested a low abundance of orange roughy, with no change in total acoustic backscatter between 2004 and 2007. Earlier *Tangaroa* surveys and the *San Waitaki* surveys suggested that larger quantities of roughy may have been present.

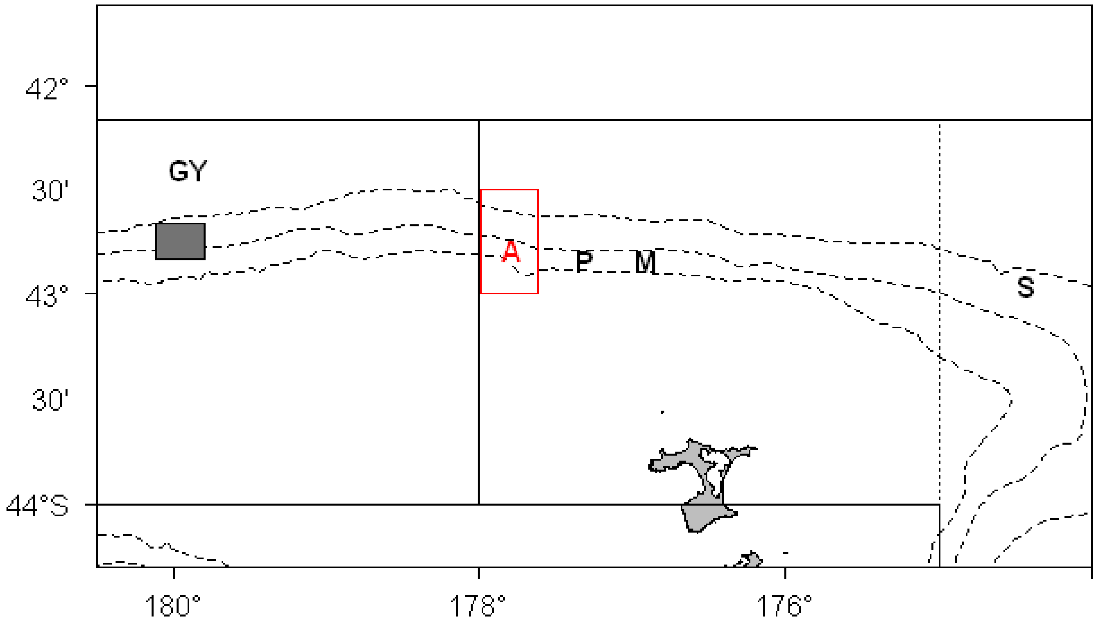


Figure 7. Location of the Graveyards Hills (GY), the western spawning plume (A), the "main" spawning plume (P), Mt Muck (M) and Smith's City (S).

Acoustic surveys of Mt Muck were completed by *RV Tangaroa* in 2000 and 2004 and by *FV San Waitaki* in 2008, 2009 and 2010. During the 2009 and 2010 surveys of Mt Muck, catches of orange roughy in acoustic target identification trawl tows averaged 98.9% and 99.7% by weight. The working group did not accept estimates from these surveys on the basis of concerns about the uncertainty associated with the determination of the species mix in the acoustic marks. Mt Muck was surveyed in 2011 from the *FV San Rakaia* using a towed body equipped with an acoustic optical system (AOS), a technology developed to improve the species identification capacity of schools of mixed species. The Working Group accepted the preliminary estimate of 10 260 t in spite of the large proportion of the estimate (43%) contained in the dead zone, due to the steep aspect of the surveyed seamount.

4.3.2 Catch patterns

The extent and timing of the commercial fishery for orange roughy on the Chatham Rise has changed over time. The fishery started in the Spawning Box during the spawning season (centred on July), and the south Rise west of Hegerville outside of spawning. During the period around the Spawning Box closure (1992-93 to 1994-95) large catches were taken during the spawning season on the Northeast Hills, Andes, and Big Chief and neighbouring hills. Spawning season catches continued on Smith's City in subsequent years, but were negligible from 2001-02, leaving the Spawning Box as the only substantial spawning season fishery. The non-spawning fishery operated in the Spawning Box in 1979-80 and 1981-82, but otherwise was focused on the South and East Rise.

On the South Rise, catches progressed eastwards during the mid to late 1980s, an effect which was described as a serial depletion of orange roughy from the hills (Clark 1997). Since the early 1990s, the focus of the non-spawning fishery has been on the Northeast Hills, the Andes, and Big Chief and neighbouring hills. Little catch has come from the South Rise west of Big Chief and neighbours, and the only notable catches on the North Rise west of the Northeast Hills have been at the western end of the Spawning Box in 2003-04 and 2004-05, and at the eastern end of the Spawning Box pre-spawning (peaking in May) during 2005-06 and 2006-07. The non-spawning fishery has therefore largely contracted to the hill complexes on the southeast corner of the Rise, where in recent years some new fishing locations have been developed between the Andes and Big Chief ('Middleground'), and just north of the Andes ('Harrisville').

Overall, there has been a spatial contraction of the fishery during the spawning period to the Spawning Box, and a spatial contraction of the fishery during the non-spawning phase towards the southeast corner of the Rise. If we assume that the fishery focuses effort on the areas where catch rates are consistently highest, we can infer these areas are the centre of the distribution for this orange roughy stock. It is also unlikely that there are now many areas where high densities of recruited orange roughy can be found that have not already been fished.

4.3.3 Standardised CPUE

Eight standardised CPUE indices were developed for the east and south Rise, five of which have been updated to the end of the 2006-07 fishing year (Figure 8). The catch and effort data used in the analyses included all target species on the south Rise, where there is a substantial and overlapping oreo fishery, but were restricted to tows which caught or targeted orange roughy on the north and east Rise, where orange roughy was the dominant target species. Vessels were only included in the analyses if they had completed 20 or more tows in 3 or more years, and fine-scale sub-areas (2' squares) were only included if they had been fished 3 or more times for 8 or more years. The latter criterion was intended to restrict the analyses to areas which had been consistently fished. Tows which were believed to have come fast, and data for 1988-89, were also excluded. The estimation of indices took no account of potential technology creep.

Standardised CPUE indices for the spawning-box fishery show different trends pre and post closure of the spawning box. Post closure there is little trend, but pre closure there is a reduction by the early 1990s to about 35% of the 1980 level (Figure 8). The fishery on the eastern flats (which targeted orange roughy migrating out of the spawning box) also showed a marked decline in catch rates to about 35% of the initial level, but over the period 1983 to 1988 (Figure 8). The remaining CPUE indices (hill fisheries and the South Rise flat fishery) show initial very steep declines, followed by little trend (Hegerville and Neighbours, and South Rise flats) or a continuing decline (Northeast Hills, Andes Complex, Big Chief and Neighbours). Since 1995, all of the hill indices, except Hegerville and Neighbours, have shown an overall decline of more than 50% (Figure 9).

Due to the targeted nature of fishing, and other factors, CPUE indices may not be proportional to stock abundance, and must be interpreted with care. Also, the orange roughy CPUE indices presented here cannot be considered equally reliable. In particular, the indices from the Spawning Box fishery, which targets predictable spawning aggregations, are unreliable as indices of abundance and are only presented for completeness (Coburn & Doonan 1997, Dunn 2007).

It is likely that the hill CPUE indices reflect trends in "local abundance" (i.e., orange roughy associated with the hills during the non-spawning season). They suggest that total local abundance of the Northeast Hills, Andes Complex, and Big Chief and Neighbours is about 5% of that in the early 1990s. On Hegerville and Neighbours it is perhaps 20% of the early 1980s level. The local abundance on the South Rise Flats has also likely declined to very low levels.

It is less certain that the hill CPUE indices (or the South Rise Flats index) reflect trends in total stock biomass. Certainly, the initial steep declines are too rapid to be indexing total abundance (e.g., if the biomass in the early 1990s was 30-50% B_0 then three of the hill CPUE time series suggest current biomass in the range of 1.5-2.5% B_0 - which is the level of current annual catches). However, although the initial declines are not proportional to total stock abundance, the CPUE indices for the main non-spawning fisheries have all declined at a similar overall rate since the mid-1990s, which suggest that vulnerable biomass may be continuing to decline at current catch levels.

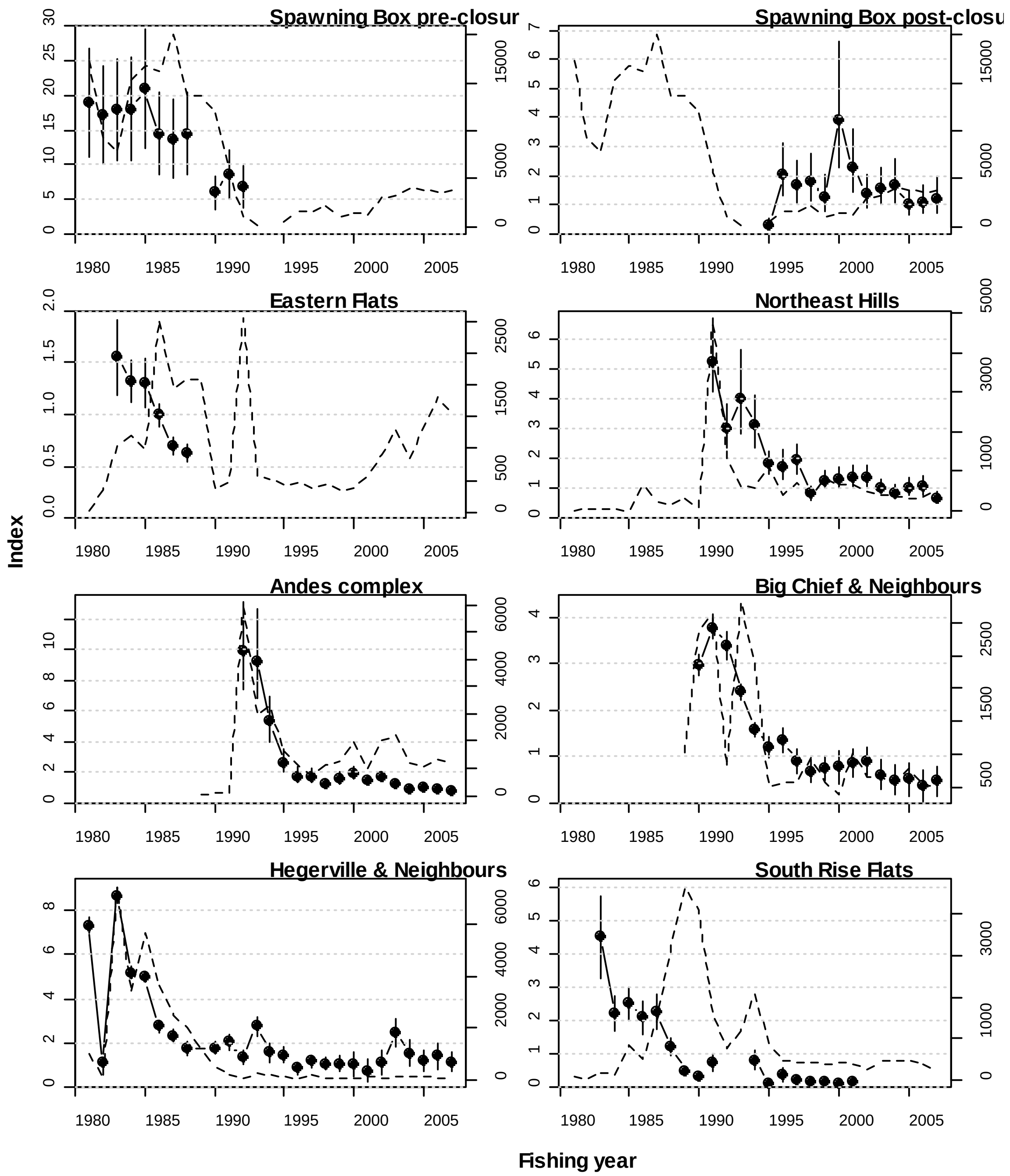


Figure 8: Orange roughy standardised CPUE indices (black circles with bars showing 95% confidence intervals) and annual catches (broken lines) from the commercial fisheries on the East and South Chatham Rise.

4.3.5 Estimates of virgin biomass

By the time the 1990 trawl survey was completed, about 325 000 t had been caught from the East and South Rise stock, 70% of which came from the Spawning Box. The fishery has since been extended to the hills on the East and South Rise and the total cumulative catch (including over-runs) from the stock up to 2006-07 was 499 000 t.

Although recent models used to assess Chatham Rise orange roughy stocks are not thought to be useful in determining recent stock status (see section 4.2 above), earlier models are believed to provide approximate estimates of the initial stock size before fishing began. Model outputs from the assessments in the early 1990s gave B_0 estimates of between 300 000 and 450 000 t. Simple stock reduction models with the catch data give similar ranges. Based on the cumulative catch and the previous stock assessments for Chatham Rise orange roughy, the 2008 Plenary considered that B_0 was likely to fall in the range 300 000 to 450 000 t.

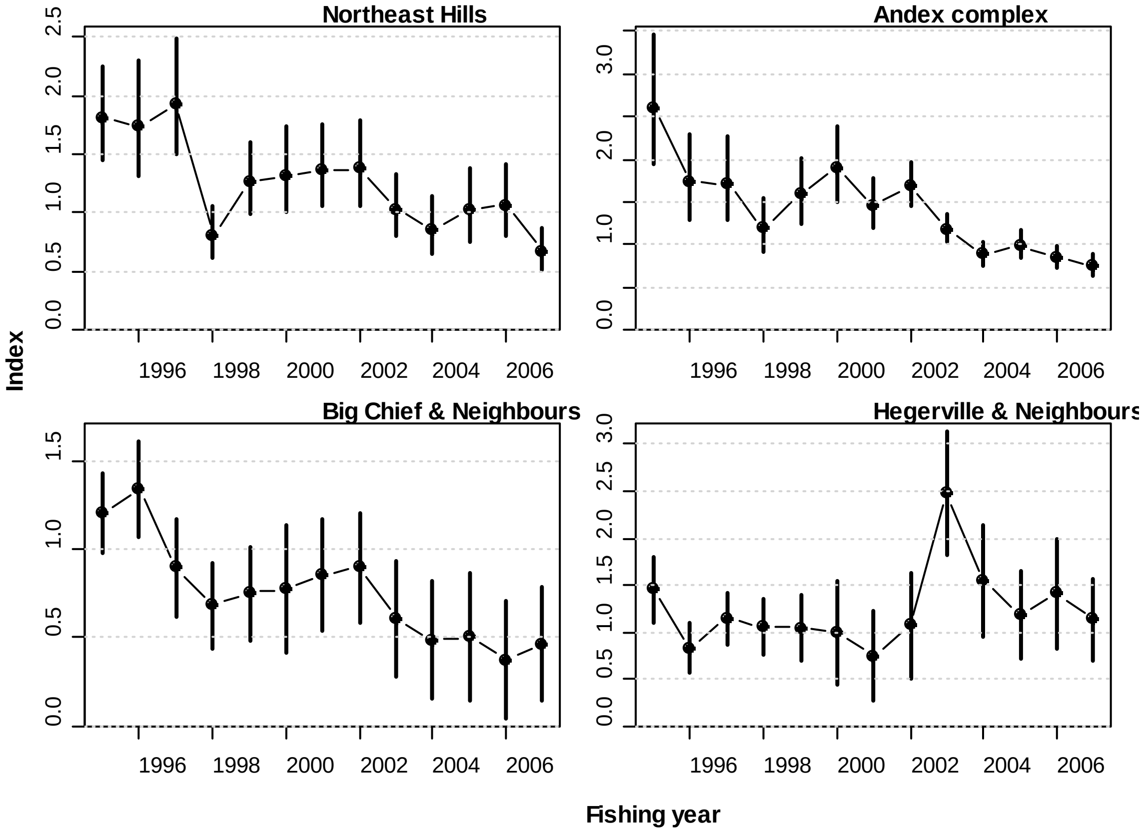


Figure 9: Orange roughy standardised CPUE indices (with 95% confidence intervals) for the main hill complexes in the commercial fishery on the East and South Chatham Rise between 1994-95 and 2006-07.

4.3.6 Estimates of current biomass

The results from acoustic surveys, reported in section 4.3.1, were used in the 2008 Plenary to derive an estimate of the total 2007 spawning biomass including the spawning plume and other areas on the East and South Chatham Rise. Although the acoustic surveys for areas outside the plume were mostly conducted prior to 2007, no adjustment for potential subsequent changes in biomass was made at the time. However, given that the spawning plume point estimate decreased by about 17% between 2007 and 2009, the 2010 Plenary believed that it was likely that the biomass in other areas had also declined. The simplest assumption was that the plume represented the same proportion of the total spawning biomass in 2009 as it did in 2007 (81%; from Table 15 in the 2008 Plenary report). This resulted in a point estimate of total spawning biomass for 2009 of 35 000 t.

Table 14: Acoustic estimates of spawning biomass for East and South Chatham Rise orange roughy. The estimate for both spawning plumes and Mt Muck are the point estimates from the 2011 acoustic surveys (see section 4.3.1). Estimates for all other areas combined are based on area-specific estimates from Table 15 in the 2008 Plenary report (a total of 12 700 t), pro-rated to match the proportional extent of decline in the estimate for the main spawning plume.

Area	Mean (t) with total Mt Muck estimate
Main spawning plume	16 422
Western spawning plume	28 114
Mt Muck	10 263
Other areas	5 357
Total	60 156

Subsequent to the 2008 Plenary, the estimate of the 2007 spawning plume biomass was revised downwards. If the revised number had been used in the 2008 Plenary, it would have resulted in the spawning plume representing 73% of the total spawning biomass. Assuming that the estimate of the 2010 spawning plume biomass also represented 73% of the total spawning biomass in that year resulted in a total spawning biomass of 29 000 t for 2010. A similar method was used for the estimate of total spawning biomass in 2011, except that the resulting estimate for Mt Muck was replaced by the new acoustic survey estimate, and the new estimate for the western plume was added in to reflect the fact that both areas were surveyed at the same time as the main spawning plume and therefore represented a different groups of fish (Table 14).

Estimates of the proportion of the total mature biomass that was likely to be spawning were considered by the 2008 Plenary. A review of available literature found that the multiplier of the spawning biomass to obtain an estimate of mature biomass ranged from 1.01 to 1.91 (Dunn 2008). The 2008 Plenary considered which of these estimates were more reliable and concluded that a maximum credible range was 1.1 to 1.91, with a mean of 1.49.

Applying these multipliers to the estimate of total spawning biomass in Table 14 gives a range of estimates of the 2011 mature biomass of 66 200 to 114 900 t, with a mean of 89 600 t.

The Working Group considered that the mean is the best estimate of current biomass to use for management purposes. It was noted that only about 60% of this biomass was obtained from actual measurements from surveys of the spawning plumes and Mt Muck. The remainder has been derived from earlier biomass estimates or from the assumption that approximately one-third of the mature biomass does not spawn in any year. The Working Group considers that the large proportion of unverified biomass in this estimate reduces its confidence in this assessment.

Similar methods were used in the 2008-2012 assessments to calculate a mean estimate of the total mature biomass and a plausible range (Figure 10). In the 2008 assessment, the range calculated for the 2007 mature biomass included uncertainty due to target strength in addition to the proportion spawning. Had target strength uncertainty not been included, Figure 10 would show a steady decline from 2007 to 2010 for any assumed value of proportion spawning. The reason for the large increase in biomass from 2010 to 2011 was due mainly to the inclusion of the western spawning plume. There are several possible hypotheses to explain the appearance of this plume, including:

- The proportion of the total mature fish that migrated to the spawning grounds in 2011 was higher than usual;
- There has been a surge in recent recruitment;
- The western spawning plume has existed for some time but has not been discovered previously.

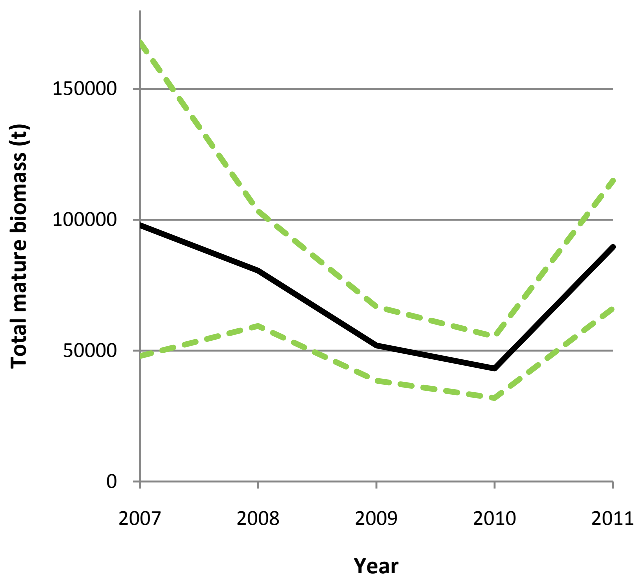


Figure 10. Estimates of mature biomass in 2007-2011 from the 2008-2012 assessments respectively. The range in each year was generated by different assumed values of the proportion spawning (and also by different assumptions about target strength for 2007).

4.4 Recent management strategy

Since 2009-10, the management strategy for East and South Chatham Rise orange roughy has been to step the catch limits down to a level that equates F_{MSY}=M=4.5%, which was achieved for 2011-12, based on the previous biomass estimates. Given the increase in biomass estimated for 2011, the fishing intensity for 2011-12 is likely to be below the 4.5% target.

4.5 Summary

Catch data from the East and South Chatham Rise indicate that the stock was fished down from an initial biomass of about 300 000 to 450 000 t at a reported rate of about 30 000 t per year from 1980-81 to 1989-90. Catches from the stock were then cut back and new fisheries developed in the southern parts of ORH 3B. Initial catches and the trawl surveys of the Spawning Box suggest a reduction in stock size by 1987 to less than 50% B_0, with further declines through to the end of the *Cordella* survey series in 1990. Given the level of catches from 1987 to 1990 (an additional 130 000 t), the 2008 Plenary agreed that the stock was likely to have been of the order of 30% B_0 by 1990.

It is likely that the hill CPUE indices reflect real trends in “local abundance”. It is less certain that the hill CPUE indices (or the South Rise Flats indices) reflect trends in total stock abundance. However, the CPUE indices for the main non-spawning fisheries have all declined at a similar overall rate since the mid-1990s, suggesting that vulnerable biomass may be continuing to decline at current catch levels.

Point estimates of biomass from acoustic surveys of the main spawning plume from 2002 to 2011 have declined substantially, from about 64 000 t in 2002 to 16 400 t in 2011 (Figure 6). However, in 2011 a new spawning plume to the west of the “main” one was discovered and surveyed. This plume may have been seen by fishers in 2010, but there is no record of its existence in any previous year. The estimate of biomass in the western plume was 28 114 t (CV 18.4%), about 70% higher than the estimate for the “main” spawning plume. It is difficult to reconcile the apparent sudden appearance of this plume with the available information and assumptions about the biomass of orange roughy on the east and south Chatham Rise over the past few years. In addition, an acoustic survey was undertaken of spawning orange roughy on Mt Muck in 2011 (Figure 7), with preliminary estimates of total biomass being 10 263 t, although 43% of this estimate was derived from a large shadow zone leaving 5833 t actually observed. This preliminary result, while higher than most previous estimates is less unexpected due to the difficulty of sampling this rugged area.

The 2011 point estimates of biomass from the spawning plumes and Mt Muck derived from the acoustic surveys were used as a basis for estimating the current mature biomass, by first adding on an allowance for spawning fish in other areas and then scaling up the estimated spawning biomass to the total mature biomass using a range of multipliers of 1.1-1.9, with a mean of 1.49. This resulted in a range of mature biomass estimates for the East and South Chatham Rise of 66 200 to 114 900 t, with a mean of 89 600 t.

Combining these B_{2011} and B_0 estimates gives a current stock status range of 14.7% B_0 to 38.3% B_0 (Table 15), with an overall mean of 23.9% B_0. The apparent improvement in stock status in 2011 is due mainly to the discovery of a new and substantial spawning plume. However, the acoustic estimates of the main spawning plume and CPUE indices have continued to decline since 1990 when the 2008 Plenary concluded that the stock was of the order of 30% B_0.

Table 15: Current biomass as a percentage of the initial biomass (B_0) using a range of estimates for B_0 and current

B_0 (t)	Low B_{2011} (66 200 t)	High B_{2011} (114 900 t)	Mean B_{2011} (89 600 t)
300 000	22.1%	38.3%	29.9%
375 000	17.7%	30.6%	23.9%
450 000	14.7%	25.5%	19.9%

5. STATUS OF THE STOCKS

For orange roughy stocks, the management target is 30% B_0.

5.1 Chatham Rise

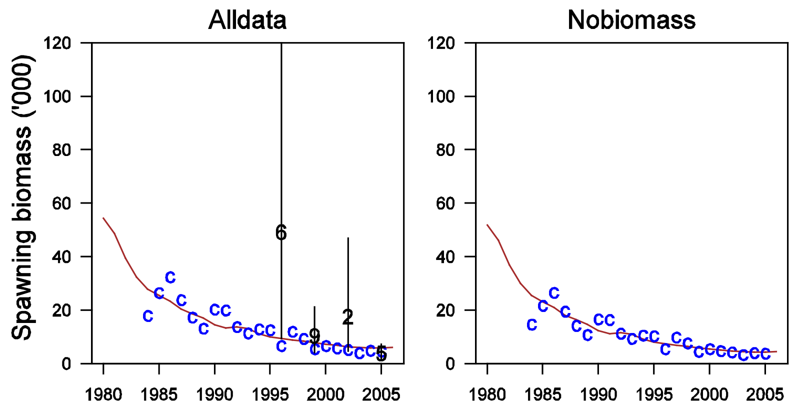
Stock Structure Assumptions

Chatham Rise orange roughy are believed to comprise two biological stocks; these are assessed and managed separately: one on the Northwest of the Chatham Rise and the other ranging throughout the East and South Rise, based on the presence of two main areas where spawning takes place simultaneously, and observed and inferred migration patterns of adults and juveniles. These two biological stocks form the bulk of the ORH 3B Fishstock. They are geographically separated from all other ORH 3B biological stocks.

Northwest Chatham Rise

Stock Status	
Year of Most Recent Assessment	2006
Assessment Runs Presented	2 alternative runs
Reference Points	Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	The Alldata run suggested that B_{2006} was approximately 11% B_0, and the Nobiomass run slightly lower (9% B_0). Both suggest that B_{2006} was Very Unlikely (< 10%) to be at or above the target biomass.
Status in relation to Limits	B_{2006} was Very Likely (> 90%) to be below the Soft Limit, and About As Likely As Not (40-60%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Estimated biomass trajectories (lines) and fitted data (points) from all model runs. The data are identified by the plotting symbol ('c' = CPUE, '6' = 1996, '9' = 1999, '2' = 2002, '5' = 2005). CPUE data are scaled up to the biomass. Vertical bars (for biomass indices only) show 95% confidence intervals. Plots are from the medians of the posterior distribution.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass was projected to have declined from the 1980s to 2006.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2006)	
Stock Projections or Prognosis	Under both models the stock was not projected to recover to the soft limit unless catches were reduced.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Below Soft Limit in 2006. Hard Limit: Likely (> 60%)

Assessment Methodology	
Assessment Type	Type 1 - Quantitative stock assessment
Assessment Method	Statistical catch-at-age model implemented in CASAL with Bayesian estimation of posterior distributions.

Main data inputs	- Standardised CPUE index, excluding short tows made in the Graveyard hills - 1996 egg survey, as an absolute mature biomass estimate - 3 Relative mature biomass estimates (acoustic/trawl surveys) - Commercial length-frequency data	
Period of Assessment	Latest assessment: 2006	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Recruitment assumed to be deterministic - Results are strongly dependent on CPUE data and the extent to which these data index the entire stock is unknown. - Survey biomass indices are few and are restricted to the end of the timeline where there is less contrast in the biomass. - Neither model run provided an entirely satisfactory fit to all survey estimates.	

Qualifying Comments (2012)
The catch limit for the Northwest Chatham Rise orange roughy was reduced to 750 t from 1 October 2006. Based on the 2006 assessment, the stock size was expected to increase over the following 5 years at this catch level. Beginning in 2010-11, the fishing industry has agreed to avoid fishing this stock in order to provide for more rapid rebuilding.

Fishery Interactions
Main bycatch species are smooth oreo, black oreo, rattails, deepwater dogfish and hoki, with lesser bycatches of Johnson's cod and ribaldo. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Overall, bycatch usually comprises less than 5% of the total catch.

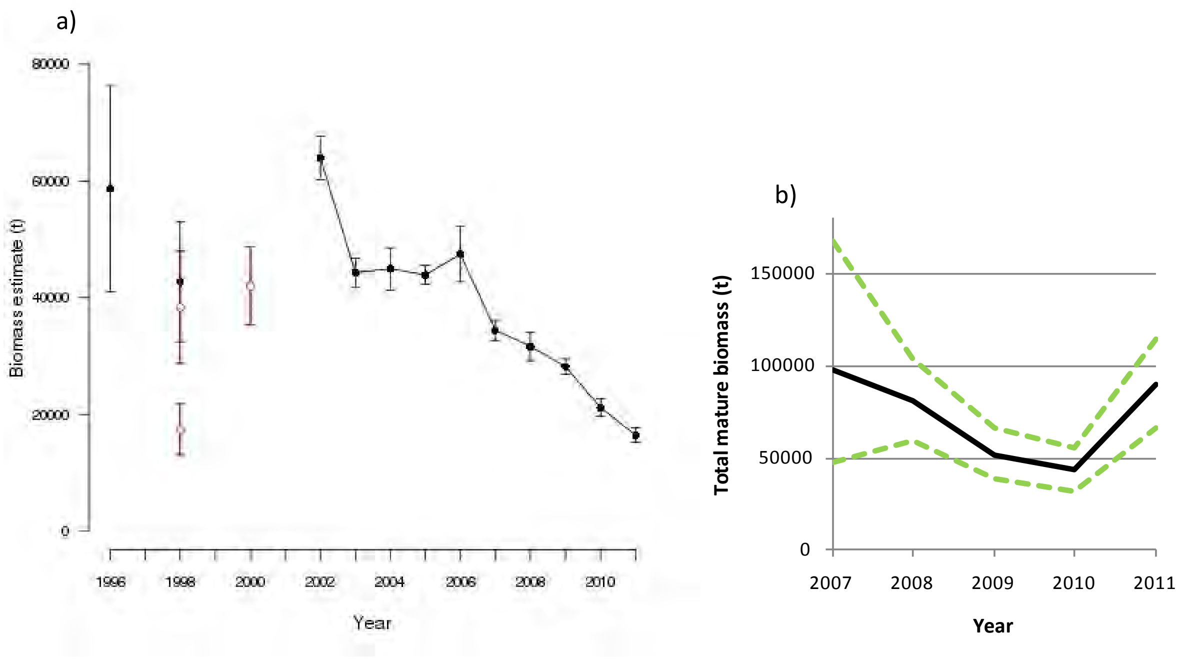
East and South Chatham Rise

- **East and South Chatham Rise Orange Roughy**

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	No quantitative stock assessment model
Reference Points	B_{MSY}: 30% B_0 Management Targets: Biomass 30% B_0 Fishing intensity no greater than 4.5% (F=M) Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2011} was estimated to be 15-38% B_0 depending on assumptions, with an overall mean of 24% B_0

	Unlikely (< 40%) to be at or above the biomass management target Likely (> 60%) to be below the fishing intensity target
Status in relation to Limits	B_{2011} is About as Likely as Not (40-60%) to be below the Soft Limit B_{2011} is Unlikely (< 40%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



a) Acoustic biomass estimates for the spawning aggregations in the Spawning Box during July 1996, 1998, 2000 and 2002-2011. Error bars are ±2 standard deviations. b) Estimates of mature biomass in 2007-2011 from the 2008-2012 assessments respectively. Note that the scales differ.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The increase in total mature biomass in 2011 is due mainly to the discovery of a substantial new spawning plume. However, the acoustic estimates of the main spawning plume have continued to decline.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality has probably been decreasing in recent years
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Formal projections were not conducted
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: About as Likely as Not (40-60%) Hard Limit: Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Non-model integration of separate analyses of research trawl surveys, wide area combined acoustic and trawl surveys, acoustic surveys on the spawning plume and hills, catch patterns and standardised CPUE.	
Assessment Dates	Latest assessment: 2012	Next assessment: 2013
Overall assessment quality	2 –Medium or mixed quality: an empirical analysis that does not	

rank	fully integrate all relevant data and sources of uncertainty	
Main data inputs (rank)	-Research trawl surveys, wide area combined acoustic and trawl surveys, acoustic surveys on the spawning plume and hills, catch patterns and standardised CPUE (to inform the feasible range of B_0). -2011 acoustic estimates of biomass from two spawning plumes and Mt Muck	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	The largest source of uncertainty is the average proportion of the mature stock in the spawning plume each year, and the variability in the proportion spawning from year to year, particularly given the discovery of the even larger western spawning plume. Other major sources of uncertainty include target strength and the range of estimates of B_0.	

Qualifying Comments
Some major sources of uncertainty, particularly in the target strength, have not been incorporated into the analyses.

Fishery Interactions
Main bycatch species are smooth oreo, black oreo, rattails, deepwater dogfish and hoki, with lesser bycatches of Johnson's cod and ribaldo. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Overall, bycatch usually comprises less than 5% of the total catch.

5.2 Southern ORH 3B fisheries

Puysegur

The 1998 assessment for this stock (Annala *et al*. 1998) was uncertain because the three time series of biomass indices on which it was based are all very short. However, all three series (two of trawl surveys and one of CPUE) suggested that the biomass was reduced substantially up to 1998. The point estimate of biomass from this assessment was probably below B_{MSY}, but it was uncertain. Estimates of *MCY* and *CAY* were 420 t or less. The fishery was voluntarily closed in 1997–98 in order to maximise the rate of rebuilding. It was re-opened in 2010-11 with a catch limit of 150 t (Table 3).

Auckland Islands (Pukaki South)

The Deepwater Working Group examined the data on orange roughy catch and effort from the Auckland Islands area in 2006, and found that there had been relatively little fishing activity in this area in the previous few years. There were insufficient data to conduct a standardised CPUE analysis, and it was believed that unstandardised CPUE did not provide a suitable index of relative abundance. Therefore, a stock assessment could not be carried out.

Other fisheries

In 2006 the Deepwater Working Group examined the data on orange roughy catch and effort from other parts of ORH 3B - the Bounty Islands, Pukaki Rise, Snares Island and the Arrow Plateau - and agreed that there were insufficient data to carry out standardised CPUE analyses for any of these areas.

The Working Group noted the substantial declines in commercial catches and nominal catch rates for Bounty, Priceless, Pukaki and other areas in the sub-Antarctic since about 2007-08 (Table 5).

6. FOR FURTHER INFORMATION

Anonymous 2001. Notes of a technical workshop of 22nd February 2001. WG-Deepwater-01/15. (Unpublished report held by Ministry of Fisheries, Wellington.)

Annala J.H., Sullivan K.J., O'Brien C.J., Smith N.W.McL., Grayling S.M. 2003. Report from the fishery assessment plenary, May 2003: stock assessments and yield estimates. 616 p. (Unpublished report held in NIWA library, Wellington.)

Annala J.H., Sullivan K.J., O'Brien C.J., Iball S.D. (Comps) 1998. Report from the Fishery Assessment Plenary, May 1998: stock assessments and yield estimates. 409 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Bull B., Francis R.I.C.C., Dunn A., McKenzie A., Gilbert D.J., Smith M.H. 2003. CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.01-2003/08/01. NIWA Technical Report 124. 223p.

Bull R., Doonan I.J., Tracey D.M., Coombs R.F., 2000. An acoustic estimate of orange roughy abundance on the Northwest Hills, Chatham Rise, June-July 1999. New Zealand. Fisheries Assessment Research Document 2000/20. 36p.

Clark M.R., Anderson O.F., Dunn M. 2003. Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2001-02 fishing year. New Zealand Fisheries Assessment Report 2003/60. 51p.

Clark M.R., Anderson O.A., Francis R.I.C.C.,Tracey D.M. 2000. The effects of commercial exploitation on orange roughy (*Hoplostethus atlanticus*) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. Fisheries Research 45(3): 217-238.

Coburn R.P., Doonan I.J. 1994. Orange roughy fishing on the North East Chatham Rise: a description of the commercial fishery, 1979-1988. New Zealand Fisheries Technical Report 38.

Coombs R.F., Barr R. 2007. *In situ* measurements of orange roughy (*Hoplostethus atlanticus*) target strength. ICES Journal of Marine Science, 64: 1220-1234

Cordue P.L. 2006: Prior distributions for trawl and acoustic survey proportionality constants used in the 2006 orange roughy stock assessments. 29p. Draft New Zealand Fisheries Assessment Report.

Cordue P.L. 2008: Review of estimates of Chatham Rise orange roughy biomass from plume surveys. Report prepared for the New Zealand Ministry of Fisheries. 39 p.Cordue P.L., Francis RICC. 1994. Accuracy and choice in risk estimation for fisheries assessment. Canadian Journal of Fisheries and Aquatic Sciences 51: 817-829.

Doonan I.J. 1991. Orange roughy fishery assessment, CPUE analysis - linear regression, NE Chatham Rise 1991. New Zealand Fisheries Assessment Research Document 1991/9. 48p.

Doonan I.J. 1994. Life history parameters of orange roughy; estimates for 1994. New Zealand Fisheries Assessment Research Document 1994/19. 13p.

Doonan I. 2009. Re-analysis of the spawning plume biomass, towbody acoustics surveys 1998 & 2000. Deepwater Working Group document 2009/16. Unpublished report held by Ministry of Fisheries, Wellington..

Doonan I., Bull B. 2001. Absolute biomass for 1999, NE and East Chatham Rise. WG-Deepwater-01/27. (Unpublished report held by Ministry of Fisheries, Wellington.)

Doonan I., Bull B., Dunford A., Coombs R., Tracey D., Hart A. 2001: Acoustic estimates of the biomass of aggregations of orange roughy in the Spawning Box and on the Northeastern and Eastern Hills, Chatham Rise, JuIy 2000. New Zealand Fisheries Assessment Report 2001/70. 31 p.

Doonan I.J., Dunn M., Dunford A., Hart A.C., Tracey D. 2006. Acoustic estimates of orange roughy abundance on the Northeastern and Eastern Chatham Rise, July 2004: wide-area survey and hill survey. New Zealand Fisheries Assessment Report 2006/58. 45 p.

Doonan I.J., Dunn M., Hart A.C. 2009. Abundance estimates of orange roughy on the Northeastern and Eastern Chatham Rise, July 2007: wide-area trawl survey and hill acoustic survey (TAN0709). New Zealand fisheries assessment report ; 2009/20. 38 p.

Doonan I., Hart A.C. 2003. Notes on the abundance of mature orange roughy on the NW Chatham Rise and Graveyard Hills, ORH 3B, 20 June - 7 July 2002. WG-Deepwater- 03/01. (Unpublished report held by Ministry of Fisheries, Wellington.)

Doonan I., Hart A.C., Bagley N. 2011. Acoustic survey of the spawning plume, north Chatham Rise (project ORH 2010/01). DWWG 2011-51. (Unpublished report held by Ministry of Fisheries, Wellington.)

Dunn M.R. 2007 CPUE analysis and assessment of the Northeast Chatham Rise orange roughy stock (part of ORH 3B) to the end of 2004-05 fishing year. New Zealand Fisheries Assessment Research Document 2007/8. 75p.

Dunn M.R., Devine J.A. 2010 An holistic approach to determining stock structure of orange roughy on the Chatham Rise. New Zealand Fisheries Assessment Research Document 2010/17. 65p.

Dunn M.R., Anderson O.F., Doonan I.J. 2008 Evaluation of stock status for orange roughy on the east and spouth Chatham Rise for 2008. New Zealand Fisheries Assessment Research Document 2008/65. 30p.

Dunn M.R., Rickard G.J., Sutton P.J.H., Doonan I.J. 2009 Nursery grounds of orange roughy around New Zealand. ICES Journal of Marine Science 66: 871-885

Francis R.I.C.C., Hicks A.C. 2004. Comparing NIWA and UW base cases for NW Chatham Rise ORH. WG-Deepwater-04/44. (Unpublished report held by Ministry of Fisheries, Wellington.)

Francis R.I.C.C. 2006 Some recent problems in New Zealand orange roughy assessments. New Zealand Fisheries Assessment Research Document 2006/43. 65p.

Francis R.I.C.C. 2001a. Orange roughy CPUE on the South and east Chatham Rise. New Zealand Fisheries Assessment Report 2001/26 30p.

Francis R.I.C.C. 2001b. Stock Assessment of orange roughy on the South Chatham Rise. New Zealand Fisheries Assessment Report 2001/27 25p.

Francis R.I.C.C. 2001c. Stock assessment for 2001 of orange roughy on the northeast Chatham Rise. New Zealand Fisheries Assessment Report 2001/41. 32p.

Francis R.I.C.C. 1996. Orange roughy sex ratios and catch rate distributions in the Chatham Rise Spawning Box. New Zealand Fisheries Assessment Research Document 1996/13.27p.

Francis R.I.C.C. 1995. The longevity of orange roughy: a reinterpretation of the radiometric data. New Zealand Fisheries Assessment Research Document 1995/2. 13p.

Francis R.I.C.C. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 26p.

Francis R.I.C.C., Bull B. 2000. Assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). New Zealand Fisheries Assessment Report 2000/21. 17p.

Francis R.I.C.C., Horn P.L. 1997. Transition zone in otoliths of orange roughy (*Hoplostethus atlanticus*) and its relationship to the onset of maturity. Marine Biology 129: 681-687.

Francis R.I.C.C., Hurst R.J., Renwick J.A. 2001. An evaluation of catchability assumptions in New Zealand stock assessments. New Zealand Fisheries Assessment Report 2001/1. 37p.

Francis R.I.C.C., Clark M.R., Coburn R.P., Field K.D., Grimes PJ. 1995. Assessment of the ORH 3B orange roughy fishery for the 1994-95 fishing year. New Zealand Fisheries Assessment Research Document 1995/4. 43p.

Francis R.I.C.C., Clark M.R., Grimes P.J. 1997. Calculation of the recruited biomass of orange roughy on the northwest Chatham Rise using the 1996 Graveyard Hill egg survey (TAN9608). New Zealand Fisheries Assessment Research Document 1997/29. 18p.

Hampton I., Soule M., Nelson J. 2008. Standardisation of acoustic estimates of orange roughy biomass in the North Chatham Rise Spawning Plume between 1996 and 2007, made with vessel-mounted transducers. 26 p. (Unpublished report held by the Ministry of Fisheries, Wellington).

Hampton I., Soule M., Nelson J. 2009. Corrections to time series of acoustic estimates of orange roughy spawning biomass in the Spawning Plume in area ORH3B from vessel-mounted transducers, 1996 to 2008. 29 p. WG-Deepwater-09/14. (Unpublished report held by the Ministry of Fisheries, Wellington).

Hampton I., Soule M.A., Nelson J.C. 2010. Standardised acoustic estimates of orange roughy biomass in the Spawning Plume in area ORH 3B from vessel-mounted and towed transducers, 1996-2009. (Unpublished report held by the Ministry of Fisheries, Wellington).

Hicks A.C. 2006. Changes in lengths from the commercial catch in the Spawning Box. WG-Deepwater-06/ (Unpublished report held by the Ministry of Fisheries, Wellington).

Hicks A.C. 2004a. A meta-analysis of CPUE in orange roughy fisheries: creating a prior. WG-Deepwater-04/20. (Unpublished report held by Ministry of Fisheries, Wellington.)

Hicks A.C. 2004b. Comparing the 2003 San Waitaki Graveyard Hill acoustic survey to the previous Northwest Chatham Rise and Graveyard Hills surveys conducted by NIWA. WG-Deepwater-04/19. (Unpublished report held by Ministry of Fisheries, Wellington.)

Hicks A.C. 2004c. Comparability between the three NWCR acoustic surveys and corrected, expanded 2003 acoustic estimates for the northwest Chatham Rise. Notes to the Deepwater Working Group, 5 March 2004. WG-Deepwater-04/33. (Unpublished report held by Ministry of Fisheries, Wellington.)

Hilborn R., Maunder M., Parma A., Ernst B., Payne J., Starr P. 2003. Coleraine: A generalized age-structured stock assessment model. (Unpublished report from the School of Aquatic and Fisheries Sciences, University of Washington, available at: http://www.fish.washington.edu/research/coleraine/).

Hilborn R., Walters C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York, 570p.

Horn P.L., Tracey D.M., Clark M.R. 1998. Between-area differences in age and length at first maturity of the orange roughy *Hoplostethus atlanticus*. Marine Biology 132 (2): 187-194.

Kloser R.J., Horne J.K. 2003. Characterizing uncertainty in target-strength measurements of a deepwater fish: orange roughy (*Hoplostethus atlanticus*). ICES Journal of Marine Science 60: 516-523.

Kloser R.J, Macaulay G., Ryan T., Lewis M. 2011. Improving acoustic species identification and target strength using frequency difference and visual verification: example for a deep-sea fish orange roughy. DWWG 2011-52. (Unpublished report held by Ministry of Fisheries, Wellington.)

Langley A. 2001. Analysis of catch and effort data from the ORH 3B (Spawning Box) fishery, 1982/83 to 1999/00. WG-Deepwater-01/23. (Unpublished report held by Ministry of Fisheries, Wellington.)

Macaulay G., Kloser R.J., Ryan T. 2009: Visually verified in situ target strength measurements of orange roughy from the Chatham Rise, July 2007. Final Research Report for Ministry of Fisheries Research, Project ORH2006-01A, Objective 2. (Unpublished report held by Ministry of Fisheries, Wellington.) 45p.

Mace P.M., Fenaughty J.M., Coburn R.P., Doonan I.J. 1990. Growth and productivity of orange roughy (*Hoplostethus atlanticus*) on the north Chatham Rise. New Zealand Journal of Marine and Freshwater Research 24: 105-119.

McKenzie A. 2006. Standardised CPUE of the northwest Chatham Rise orange roughy stock (part of ORH 3B) up to the 2004-05 fishing year. In preparation.

McKenzie A. 2005. Standardised CPUE analysis and stock assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). Final Research Report. 42p.

McKenzie A. 2003. Standardised CPUE analysis and stock assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). New Zealand Fisheries Assessment Report 2003/61. 24p.

Robertson D.A., Mace P.M. 1988. Assessment of the Chatham Rise orange roughy fishery for 1987/88. New Zealand Fisheries Assessment Research Document 1988/37. 5p.

Smith M.H. 2006. Northwest Chatham rise mature biomass estimate for the stock assessment. WG-Deepwater-06/17. (Unpublished report held by Ministry of Fisheries, Wellington.)

Smith P.J., Benson P.G. 1997. Genetic diversity in orange roughy from the east of New Zealand. Fisheries Research 31(3): 197-213.

Soule M.A., Nelson J.C., Hampton I. 2007. Acoustic survey of orange roughy in the spawning plume on the North Chatham Rise, New Zealand. DWWG-2008/83.

Soule M.A., Hampton I., Nelson J.C., Tilney R.L. 2010. Acoustic survey of orange roughy on the North Chatham Rise (ORH 3B), New Zealand. June/July 2010. Report prepared for New Zealand Deepwater Group Ltd.

Sullivan K.J., Mace P.M., Smith N.W.McL., Griffiths M.H., Todd P.R., Livingston M.E., Harley S.J., Key J.M., Connell A.M. (Comps.) 2005: Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792p. (Unpublished report held in NIWA library, Wellington.)

Taylor P. 2001. Assessment of orange roughy fisheries in southern New Zealand for 2000. New Zealand Fisheries Assessment Report 2001/24. 30p.

ORANGE ROUGHY CHALLENGER PLATEAU (ORH 7A)

1. FISHERY SUMMARY

1.1 Commercial fisheries

Historically, the fishery mainly occurred in the southwestern region of the Challenger Plateau, both inside and outside the EEZ. Fish were caught throughout the year, with most effort in winter when the orange roughy form aggregations for spawning. Domestic vessels caught most of the quota. Total catches peaked in the late 1980s at 10 000–12 000 t annually from 1986-87 to 1988-89 (Table 1). Total catch and ORH 7A catch were less than 2100 t annually from 1990-91 until the closure in 2000-01 (Table 1, Figure 1), when the TACC for this stock was reduced to 1 t.

Recent surveys have shown an increase in biomass in the area. On 1 October 2010 the TACC was increased from 1 t to 500 t, with a 25 t allowance for other mortality, raising the TAC to a total of 525 t.

Table 1: Reported catches (t) and TACs (t) from 1980-81 to 2010-11. QMS data from 1986-present.

Fishing year	Inside EEZ	Outside EEZ	Total catch	TAC
1980-81†	1	32	33	-
1981-82†	3 539	709	4 248	-
1982-83†	4 535	7 304	11 839	-
1983-84†	6 332	3 195	9 527	4 950
1984-85†	5 043	74	5 117	4 950
1985-86†	7 711	42	7 753	6 190
1986-87†	10 555	937	11 492	10 000
1987-88	10 086	2 095	12 181	12 000
1988-89	6 791	3 450	10 241	12 000
1989-90	3 709	600	*4 309	*2 500
1990-91	1 340	17	1 357	1 900
1991-92	1 894	17	1 911	1 900
1992-93	1 412	675	2 087	1 900
1993-94	1 594	138	1 732	1 900
1994-95	1 554	82	1 636	1 900
1995-96	1 206	463	1 669	1 900
1996–97	1 055	253	1 308	1 900
1997–98	+	+	1 502	1 900
1998–99	+	+	1 249	1 425
1999–00	+	+	629	1 425
2000–01	+	+	0.2	1
2001–02	+	+	0.1	1
2002–03	+	+	4	1
2003–04	+	+	< 0.1	1
2004–05	+	+	< 1#	1
2005–06	+	+	< 1#	1
2006-07	+	+	< 0.1	1
2007-08	+	+	< 0.1	1
2008-09	+	+	0.12#	1
2009-10	+	+	< 0.1#	1
2010-11			476	525

†FSU data.
*This is a minimum value, because of unreported catches by foreign vessels fishing outside the EEZ.
+Unknown distribution of catch.
Catches taken during winter trawl and acoustic surveys were approximately 200 t each year.

1.2 Recreational fisheries

There is no known recreational fishing for orange roughy in this area.

1.3 Customary non-commercial fisheries

There is no known customary non-commercial fishing for orange roughy in this area.

1.4 Illegal catch

There is no quantitative information available on illegal catch.

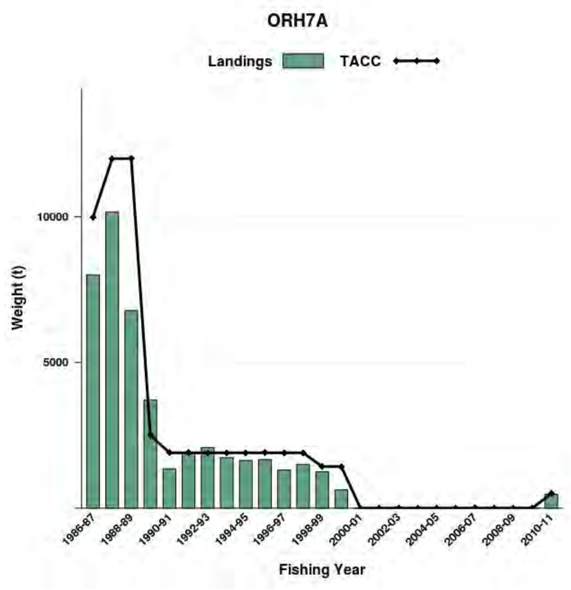


Figure 1: Historical landings and TACC for ORH 7A. Note that this figure does not show data prior to entry into the QMS.

1.5 Other sources of mortality

In previous stock assessments, catch overruns from various sources (including lost and/or discarded fish, use of nominal tray weights and low conversion factors) have been estimated as: 1980-81 to 1987-88, 30%; 1988-89, 25%; 1989-90, 20%; 1990-91, 15%; 1991-92 to 1992-93, 10%; 1993-94 onwards, 5%.

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy section.

3. STOCKS AND AREAS

There are no new data which would alter the stock boundaries given in previous assessment documents.

Orange roughy on the Challenger Plateau are regarded as a single separate stock. Size structure, parasite composition, flesh mercury levels, allozyme frequency and mitochondrial DNA studies show differences to other major fisheries. Spawning occurs at a similar time to fish on the Chatham Rise, Puysegur Bank, Ritchie Banks, Cook Canyon and Lord Howe Rise.

4. STOCK ASSESSMENT

An assessment was carried out for this stock in 2000 (Annala *et al*. 2000, Field & Francis 2001) and is reported here. It was similar to the 1998 assessment (Annala *et al*. 1998, Field 1999) in using standardised CPUE in a stock reduction analysis (Francis 1990), but differs from that assessment in allowing stochastic recruitment (i.e., it uses the enhanced stock reduction method of Francis *et al*. 1992; *see* Appendix of Francis *et al*. 1995 for details).

In 2005 the working group considered a revised assessment, although there was little new data available for the stock since 2000. The primary reason for the re-assessment was to determine whether a Bayesian modelling framework, similar to that used for other orange roughy stock assessments, would give a substantially different result. A new standardised CPUE series was calculated with the additional fishing year 1999-00, shown in Table 2 alongside the CPUE series used in the 2000 assessment. The trawl survey biomass indices and length frequencies from 1987 to 1990 were included in the 2005 analysis, along with observer length frequencies from the 1987-88 and 1988-89 fishing years. Results from the 2005 assessment are summarised qualitatively in section 4.3, but no new quantitative estimates are presented here.

In 2010, the results of the 2009 trawl and acoustic survey of the Challenger Plateau (NIWA & FRS, 2009) were used to estimate mature biomass. Two types of estimates were produced: a “minimum” estimate which only used the acoustic estimates from plumes seen on the flat; and total estimates which used trawl and acoustic data from the whole survey area (Cordue 2010). The “total estimates” used an estimate of orange roughy trawl vulnerability which, as it was based on very limited data, was considered unreliable. Therefore, the 2010 assessment results were based on the minimum acoustic estimate.

For the 2012 assessment, the results of the trawl and acoustic surveys in 2005, 2006, 2009-2011 were used to produce total mature biomass estimates for 2009, 2010, and 2011 (Cordue 2012). An updated estimate of orange roughy trawl vulnerability was used, which was obtained from the 2005 and 2009-2011 survey results. The 2009-2011 total biomass estimates were combined to produce a single estimate for the 2012 assessment (Cordue 2012). The minimum acoustic biomass estimate, from the 2010 assessment, was retained for comparison.

The 2000 stock assessment results have been retained in this report because they give an idea of the initial stock size for ORH 7A (B_0 was estimated at 91 000 t). This allows the current biomass estimates from acoustic surveys to be used to indicate stock status of ORH 7A relative to B_0

.

4.1 Estimates of fishery parameters and abundance

Catch-per-unit-effort

Table 2: CPUE indices from unstandardised data (mean catch [t/trawl] in the June-September period, all N.Z. vessels combined), and from standardised data (all months included) from 1982-83 to 1999-2000. A new standardised CPUE index was added to the table in 2005.

Fishing year	2000 Unstandardised index	2000 Standardised index	2005 Standardised index
1982-83	15.8	1.000	1.00
1983-84	15.3	1.300	1.038
1984-85	13.5	0.370	0.712
1985-86	10.8	0.590	0.652
1986-87	9.4	0.280	0.418
1987-88	5.3	0.084	0.212
1988-89	3.5	0.062	0.110
1989-90	5.8	0.089	0.071
1990-91	3.9	0.038	0.088
1991-92	4.3	0.038	0.139
1992-93	2.7	0.026	0.112
1993-94	3.2	0.025	0.086
1994-95	3.8	0.027	0.066
1995-96	3.7	0.024	0.058
1996–97	1.8	0.012	0.043
1997–98	1.6	0.021	0.032
1998–99	0.9	0.017	0.020
1999-00	-	-	0.033

In the 2000 assessment, commercial catch and effort data were examined from 1983 using both an unstandardised and standardised analysis. CPUE indices from both methods are given in Table 2. Unstandardised mean catch per tow during winter months declined rapidly until the late 1980s, and has continued to decline since then, but at a slower rate. The standardised analysis used catch per nautical mile for tows in all months and all areas in a linear regression model. Indices from this model show a similar trend to unstandardised catch rates except that the initial decline was more extreme. This reflects increasing tow length and shifts to new areas within the fishery, which could not be incorporated in the unstandardised analysis. For this reason, the Working Group decided not to use unstandardised results in the stock assessment.

Research surveys

Trawl surveys of orange roughy on the Challenger Plateau were regularly conducted from 1983 to 1990. However, a variety of vessels and survey strata were used which makes comparisons problematic (Dunn *et al*., 2010). Wingtip biomass estimates in 1983-1986 ranged from 100 000-185 000 t but in 1989 and 1990 the estimates were approximately 10 000 t.

In 2005, a new series of combined trawl and acoustic surveys began using the *FV Thomas Harrison* with a survey area comparable to that used from 1987-1990 (Clark *et al*. 2005). The survey was repeated in 2006 (with an increased survey area) and then conducted annually from 2009-2011 (Clark *et al*. 2006, NIWA & FRS 2009, Doonan *et al.* 2010, Hampton *et al.* 2012). In 2005 and 2006, the trawl survey indices were of the order of 20 000 t, but in 2009 the trawl-survey index was 52 000 t (NIWA & FRS 2009).

The large increase in spawning biomass from 2005 and 2006 to 2009 was confirmed by the acoustic survey results (NIWA & FRS 2009). Few signs of spawning were seen in 2005 or 2006, but in 2009 there were two separate plumes surveyed in the flat strata (Table 3). The plume in stratum 22 contained more biomass on 4-5 July (snapshots 5&6) compared to the earlier period of 27 June-2 July (snapshots 1-4) (Table 3; snapshots 1-4, mean = 6692 t, CV = 27%; and snapshots 5-6, mean = 16,791 t, CV = 26%). Strong acoustic marks were also seen on some hills but the species composition of these marks is not known (NIWA & FRS 2009).

Table 3: Acoustic biomass estimates of orange roughy from the 2009 acoustic survey of the Challenger Plateau (NIWA & FRS, 2009; Hampton, 2010).

Stratum	Snapshot	Date	Biomass (t)	CV (%)
22	1	27-28 June	7 447	67
22	2	28 June	8 968	26
22	3	1 July	4 518	90
22	4	2 July	5 836	36
22	5	4 July	18 024	37
22	6	5 July	15 557	37
24	1	5 July	6 304	61

Table 4: Trawl survey estimates of orange roughy biomass from the 2009 trawl survey of the Challenger Plateau (NIWA & FRS 2009, Cordue 2010). Stratum 24 was post-stratified by Cordue (2010) because of the plume in the north-east corner (original estimate = 17 454 t, CV = 55%).

Stratum	Biomass (t) (length ≥ 27 cm)	CV (%)
9	1 407	53
1	124	31
3	265	86
4	216	73
10	1 735	62
11	3 787	66
21	982	50
22	10 211	49
23	15 336	51
24plume	9 883	34
24	1 650	57
25	378	40
Total	45 974	22

In the 2009 trawl survey, the two strata which contained plumes provided the highest biomass estimates (strata 22 & 24plume - see Table 4), contributing 44% of the post-stratified index (the total in Table 4). However, there was also a large estimated biomass within stratum 23 where no plumes were seen (Table 4). The remaining strata each contained relatively small estimates but collectively made up 23% of the post-stratified index.

In the 2010 and 2011 surveys there was an apparent drop in biomass from the 2009 survey. Orange roughy plumes were seen in both years but the estimated biomass in the plumes was much lower than in 2009 when two plumes had a combined estimate of 23 100 t, CV 25% (compared with 2010: 7100 t, CV 11%; 2011: 10 870 t, CV 26%).

The time series of combined acoustic and trawl surveys from 2005-2011 was analysed by Cordue (2012) to produce comparable estimates of mature biomass given differences in survey area and survey design. Trawl-survey estimates were produced for 2006, 2009, and 2011 (Table 5), with total (acoustic and trawl) estimates for 2009, 2010, and 2011 (see section 4.4). The trawl estimate for 2010 was not considered to be comparable to other years because spawning plumes were explicitly excluded from the trawl survey area in that year. The 2005 estimate was excluded because strata 23 and 24 were not part of the survey area. No 2006 acoustic estimate was possible as no plumes were identified in the survey.

Table 5: Estimates of mature biomass in 2006, 2009, and 2011 based on trawl survey results. The median and mean of the distribution estimates are from Cordue (2012) who used the consistently surveyed strata (1, 3, 4, 21-24) and assumed a trawl vulnerability of 1.66 (which is the mean of the distribution-estimate of trawl vulnerability).

	Median (t)	Mean (t)	CV (%)
2006	9600	10 100	28
2009	27 500	28 600	26
2011	14 800	15 400	28

Results of ageing study

Doonan *et al*. (2012) estimated age distributions from otoliths collected during the 1987 and 2009 trawl surveys. Approximately 130 otoliths were used from each survey. These were taken from trawl stations which occurred in a similar area and over a similar timeframe in each year. The otoliths were read using the agreed protocols from a 2007 orange roughy ageing workshop (Tracey *et al*. 2007).

The age frequencies showed that the spawning population in 2009 was much younger than the population in 1987. The age frequencies had mean ages of 33 years (2009) and 53 years (1987). The age range for the otoliths were 18–90 years (2009) and 26–145 years (1987). The age frequency in 2009 had 97% of its weight to the left of the 1987 mean age. The conclusion of the study was that the 2009 spawning population consisted mainly of relatively young recruits (mean age of maturity is estimated at 23 years for the Challenger), most of which would not have been present prior to 2000.

4.2 Outcome of the 2000 assessment

In the 2000 assessment, stochastic stock reduction analyses were carried out using relative abundance indices from the standardised CPUE analysis (Table 2), which were assumed to be normally distributed with a CV of 0.3. The catches used in the model were the "Total catch" given in Table 1, adjusted by the estimated overrun (*see* Section 1.5). The model treats sexes separately, and has natural mortality occurring prior to fishing mortality (the Challenger fishery occurs largely in June and July, near the end of the fishing year).

Table 6: Estimates of mid-year biomass (t), with upper and lower bounds for 95% confidence intervals. B_{2000} is the mid-year biomass in 1999-00; B_{MSY} is calculated as 30% B_0, which is the mean biomass under a *CAY* policy (evaluated following Francis 1992).

			B_{2000}	
	B_0(t)	B_{MSY}(t)	(t)	(%B_0)
Estimate	91 000	27 000	2 500	3
Lower bound	60 000	18 000	1 300	1
Upper bound	130 000	39 000	5 400	6

In terms of virgin biomass, the 2000 estimate of 91 000 t (Table 6) is similar to the range estimated (95 000-99 000 t) in the 1998 assessment. However, in terms of current biomass the assessments are very different: 3% B_0 in 2000, compared to 15-19% B_0 in 1998. This difference is because the stochastic model fits the CPUE data reasonably well, whereas the deterministic model does not (Figure 2).

4.3 Outcome of the 2005 assessment

The ORH 7A assessment in 2005 with the new CPUE series proved inconclusive. The stochastic stock reduction model fit was not persuasive because fitting nearly 80 parameters to 19 CPUE data points is questionable. Relatively small changes in the CPUE were accommodated through large perturbations in the recruitment residuals, indicating that the model was over fitted. Adding the survey and observer data did not change the model predictions, but the model was not able to fit the data convincingly, even under the assumption of stochastic recruitment. It is not known if this outcome is due to unreliable data or to model mis-specification. The estimation of a hyperdepletion parameter helped to fit the early part of the 2005 CPUE series but not the latter part.

It was concluded that stock status in 2000 when the fishery was closed was likely to have been poor, although the actual stock size is uncertain. Predictions of the amount of rebuilding that had taken place since the closure of the fishery were uncertain.

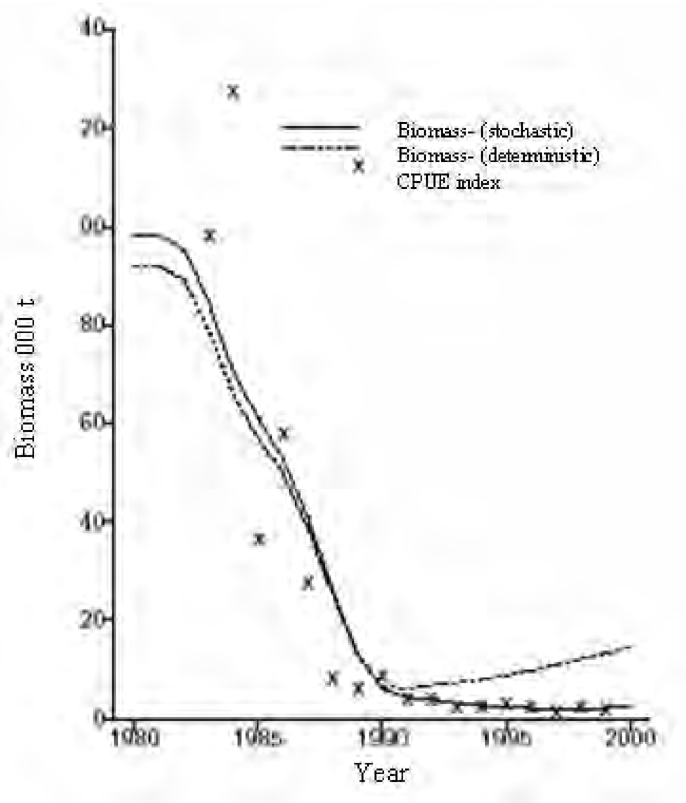


Figure 2: Biomass trajectories estimated in the 2000 assessment (solid line) and also using the deterministic model of the 1998 assessment (broken line).

4.4 2012 stock assessment

The status of the stock was assessed in 2012 by using the virgin biomass estimate from the 2000 assessment (91 000 t) and estimating mature biomass from the 2009-2011 surveys (Cordue 2012). The estimation procedure took account of potential bias in orange roughy target strength and incorporated observation error (Cordue 2010, Cordue 2012). The minimum acoustic estimate from the two plumes seen in the 2009 survey was also used, with the assumed virgin biomass, to provide an alternative estimate of current biomass. The 2010 status of the stock was based on the minimum acoustic estimate.

The estimates are presented as probability distributions with the preferred point estimate taken as the median (Table 7). The WG concluded that the best estimate of current stock status was given by the "average" distribution for 2009-2011. Orange roughy have a low level of productivity and there has been little catch since the 2009 survey so it would be expected that mature biomass was relatively constant from 2009 to 2011. Therefore, combining the estimates from the three years should provide the best estimate of current biomass.

Table 7: Summary statistics for 2009, 2010, and 2011 mature-biomass distribution-estimates. The distribution for the average biomass in 2009-2011 is also shown (Av. 2009-2011) together with the minimum acoustic estimate in 2009 (Aco5-6).

Year (model)	Median (t)	10^{th} percentile (t)	25^{th} percentile (t)	Mean (t)	CV (%)
2009	30 600	19 700	24 100	32 600	36
2010	18 400	12 700	15 100	19 300	31
2011	18 200	13 300	15 300	19 400	31
Av. 2009-2011	22 700	16 100	18 900	23 900	29
2009 (Aco5-6)	22,700	14,600	17,800	25,300	43

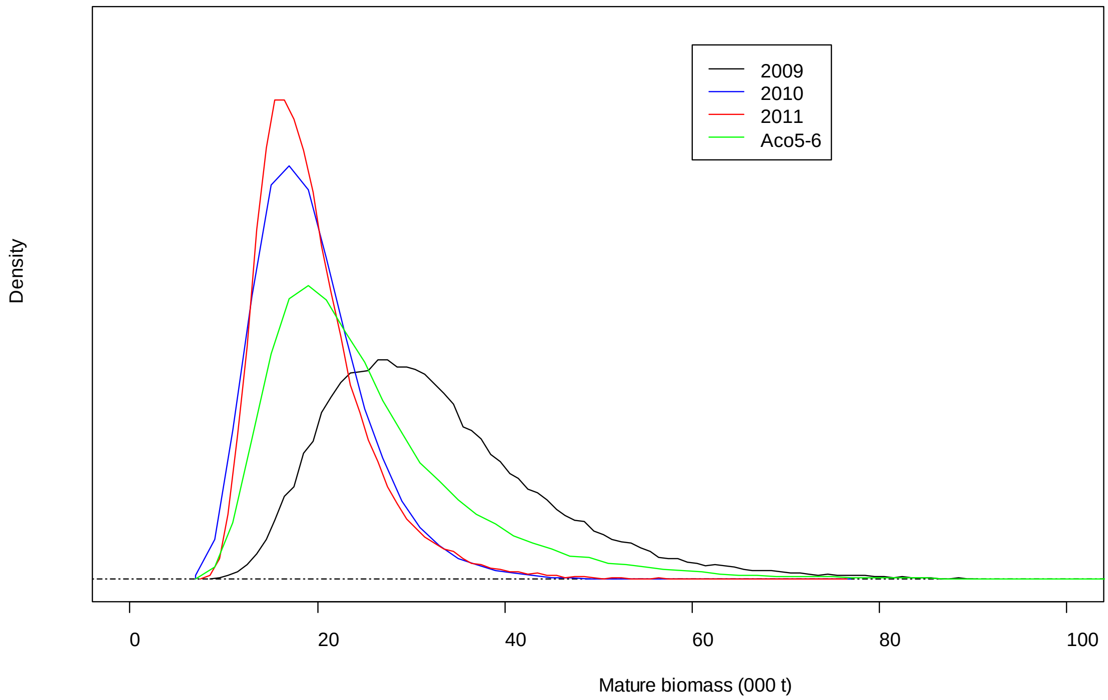


Figure 3: Estimated mature biomass for 2009-2011 and the minimum acoustic biomass model (Aco5-6).

The 2010 and 2011 distributions are almost identical and have a similar mode and median to the minimum acoustic distribution (Table 7, Figure 3). These three distributions are shifted to the left compared to the 2009 distribution, but all of the distributions overlap (Figure 3). The distribution for the average biomass in 2009-2011 is very similar to the minimum acoustic distribution (Table 7, Figure 4).

The average 2009-2011 distribution suggests that current biomass is greater than 10% B_0 and shows a high probability that it is above 20% B_0 (Table 8). The median estimate is below the target as is approximately 75% of the distribution (Table 9, Figure 4). The average 2009-2011 distribution is very similar to the minimum acoustic distribution except it has lower variance with more of its distribution between 20-30% B_0 (54% compared to 41% from Table 9).

Table 8: Summary statistics for 2009-2011 average stock-status distribution-estimate and the minimum acoustic distribution-estimate. In both cases it is assumed that B_0 = 91 000 t (the point estimate from the 2000 assessment).

Model	Median *B* (%B_0)	P(*B* >10%B_0)	P(*B* >20%B_0)	P(*B* >30%B_0)
Av. 2009-2011	25	1.00	0.80	0.26
Aco5-6	25	1.00	0.73	0.32

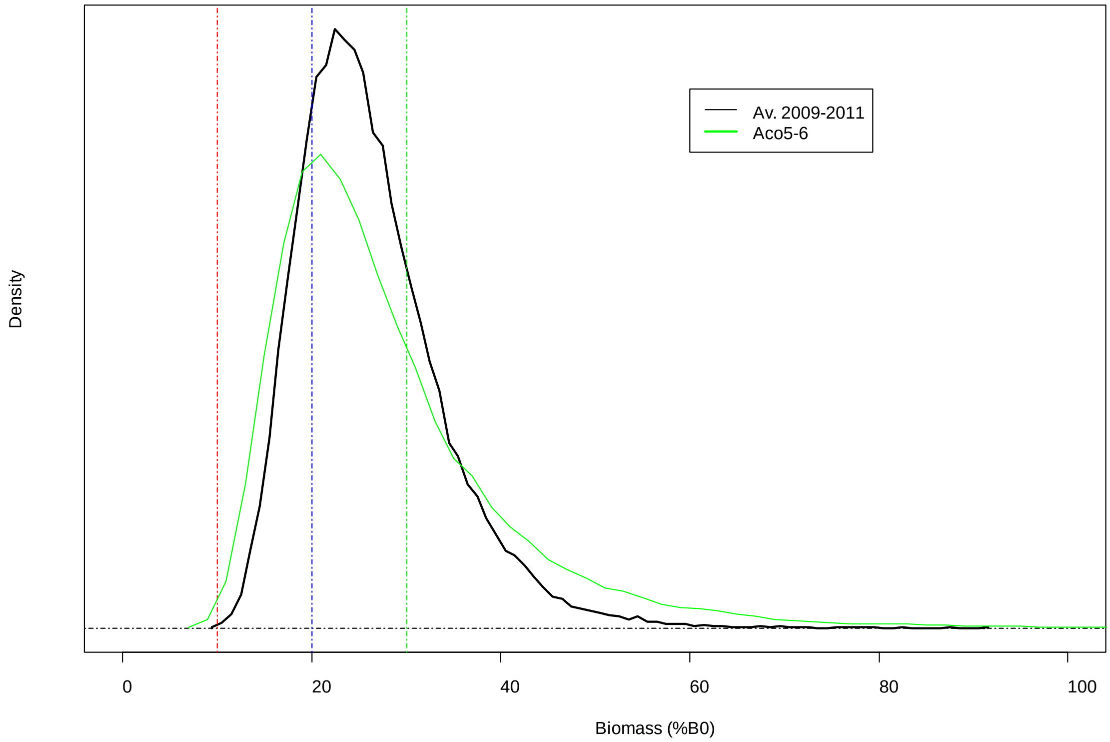


Figure 4: Estimated stock status from the average 2009-2011 distribution and the minimum acoustics distribution (Aco5-6). The hard and soft limits at 10% B_0 and 20% B_0 are shown as vertical lines together with the target at 30% B_0.

4.5 Estimation of yields

The average 2009-2011 and minimum acoustic distribution estimates (Aco5-6) of mature biomass were used to provide current yield estimates by applying the rule "*F* = *M*" to mature biomass. That is, *CAY* = 0.045 B_{mature} (i.e., the distribution-estimate of *CAY* is obtained by multiplying each sample in the mature biomass distribution by 0.045). The current TAC (525 t) is to the left of the 95% confidence interval for both distributions (Table 9).

Table 9: Estimated *CAY* from the average 2009-2011 distribution and the minimum acoustics distribution (Aco5-6) using *F* = *M* (0.045). The median, mean, and 95% confidence interval (C.I.) for *CAY* are given for each distribution.

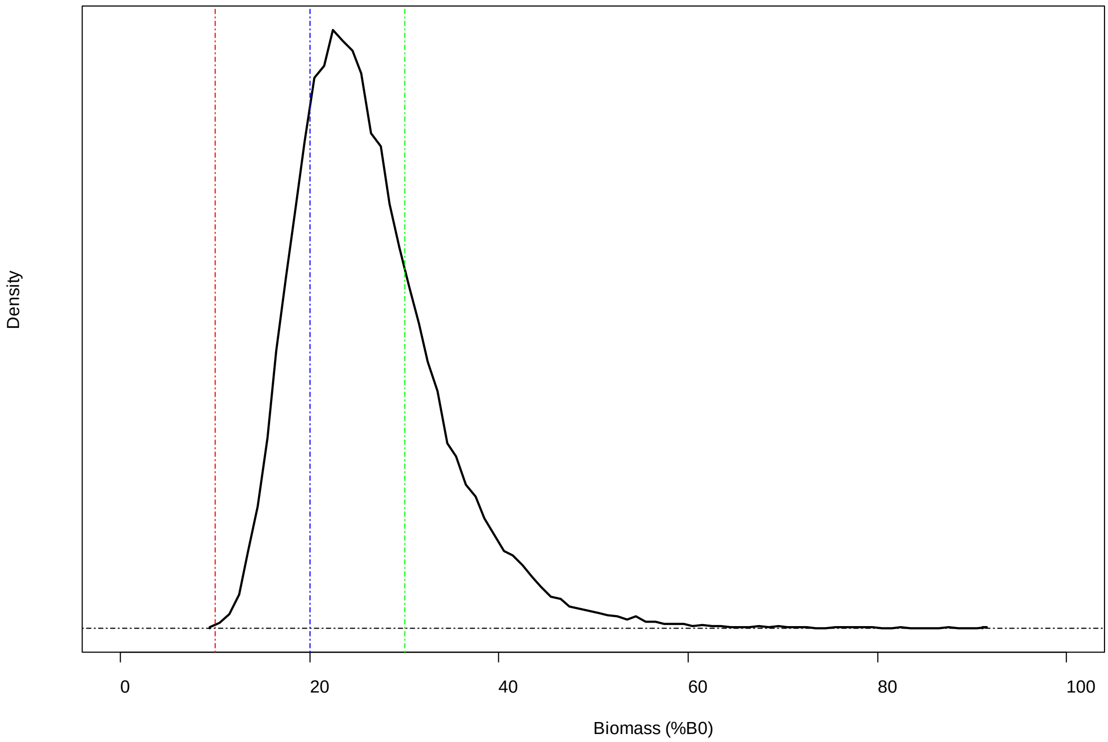
Model	Median *CAY* (t)	Mean *CAY* (t)	95% C.I.
Av. 2009-2011	1020	1070	610–1820
Aco5-6	1020	1140	540–2450

5. STATUS OF THE STOCK

For this stock, B_{MSY} is interpreted as the mean biomass under a *CAY* policy (B_{MAY}), which is estimated to be 30% B_0.

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	A distribution estimate of the average mature biomass from 2009-2011.
Reference Points	Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Biomass is estimated to be 25% B_0. The biomass is Unlikely (< 40%) to be at or above the target
Status in relation to Limits	The biomass is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Estimated stock status from the average 2009-2011 distribution. The hard and soft limits at 10% B_0 and 20% B_0 are shown as vertical lines together with the target at 30% B_0

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined steeply through the 1980s and did not appear to have increased by 2000 when the fishery was closed. Survey results from 2009-2011 suggest that biomass has increased since the closure. The 2009 spawning population mainly consisted of new recruits (average age 33 years).
Recent Trend in Fishing Mortality or Proxy	The fishery was reopened in 2010-11.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock has probably been increasing since the fishery closure in

	2000.
Probability of Current Catch or TACC causing decline below Limits	The current TACC of 500 t is below the 95% confidence interval for *CAY* under an *F*=*M* policy. Such catch levels are Very Unlikely (< 10%) to cause a decline in current stock status in the short term.

Assessment Methodology		
Assessment Type	Type 2 - Partial quantitative stock assessment	
Assessment Method	Acoustic and trawl survey results combined to produce absolute abundance estimates	
Assessment Dates	Latest assessment: 2012	Next assessment: 2013
Overall assessment quality rank		
Main data inputs (rank)	Acoustic and trawl survey results 2009-2011.	
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	The 2010 status of the stock was based on an estimate which used only acoustic data from two plumes seen in the 2009 survey. The current assessment uses the same methods applied to trawl and acoustic survey results from the 2009-2011 surveys.	
Major Sources of Uncertainty	- Target strength - Trawl vulnerability.	

Qualifying Comments
-
Fishery Interactions
Historically, the main bycatch species were deepwater dogfish, spiky oreos and ribaldo. Incidental interactions and associated mortality are noted for deepwater sharks, deepsea skates and corals. Since the fishery has been re-opened with a low level of catch, fishing is during the spawning season with little bycatch.

6. FOR FURTHER INFORMATION

Annala J.H., Sullivan K.J., O'Brien C.J., Iball S.D. (Comps.) 1998. Report from the Fishery Assessment Plenary, May 1998: stock assessments and yield estimates. 409 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Annala J.H., Sullivan K.J., O'Brien C.J (Comps.) 2000. Report from the Fishery Assessment Plenary, May 2000: stock assessments and yield estimates. 495 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Clark M.R. 1991. Assessment of the Challenger Plateau (ORH 7A) orange roughy fishery for the 1991/92 fishing year. New Zealand Fisheries Assessment Research Document 1991/2. 19p.

Clark M.R. 1992. Assessment of the Challenger Plateau (ORH 7A) orange roughy fishery for the 1992/93 fishing year. New Zealand Fisheries Assessment Research Document 1992/6. 14p.

Clark M.R., O'Driscoll R.L., Macaulay G. 2005. Distribution, abundance, and biology of orange roughy on the Challenger Plateau: results of a trawl and acoustic survey, June-July 2005 (THH0501). NIWA Client Report WLG2005-64.

Clark M.R., O'Driscoll R.L., Macaulay G., Bagley N.W., Gauthier S. 2006. Distribution, abundance, and biology of orange roughy on the Challenger Plateau: results of a trawl and acoustic survey, June-July 2006. NIWA Client Report WLG2006-83.

Clark M.R., Tracey D.M. 1994. Changes in a population of orange roughy, *Hoplostethus atlanticus*, with commercial exploitation on the Challenger Plateau, New Zealand. Fishery Bulletin, U.S. 92: 236-253.

Cordue P.L. 2010. Estimation of absolute biomass from the 2009 trawl and acoustic survey of Challenger orange roughy. ISL Client Report. *For* Deepwater Group Ltd. 24p.

Cordue 2012. Estimation of absolute biomass from the time series of trawl and acoustic surveys of Challenger orange roughy. ISL Client Report. *For* MAF. 30p.

Doonan I.J., Parkinson D., Gauthier S. 2010. Abundance, distribution, and biology of orange roughy on the southwest Challenger Plateau (area ORH 7A): results of a trawl and acoustic survey, June-July 2010. NIWA Client Report WLG2010-63.

Doonan I., Horn P., Krusic-Golub K. 2012. Estimated age of orange roughy in Challenger (ORH 7A) in 1987 compared to that in 2009. DWWG Document 2012-04, 20p

Dunn M.R., Cordue P.L., Langley A., Stokes K. 2010. Review of data and potential stock assessment approaches for orange roughy on the Challenger Plateau (ORH 7A). Draft N.Z. Fisheries Assessment Report. 41 p.

Field K.D. 1999 Assessment of the Challenger Plateau (ORH 7A) orange roughy fishery for the 1998-99 fishing year. New Zealand Fisheries Assessment Research Document 1999/9. 19p.

Field K.D., Clark M.R. 1996. Assessment of the ORH 7A orange roughy fishery for the 1996-97 fishing year. New Zealand Fisheries Assessment Research Document 1996/20. 16p.

Field K.D., Francis R.I.C.C. 2001. CPUE analysis and stock assessment of the Challenger Plateau orange roughy stock (ORH 7A) for the 2000-01 fishing year. New Zealand Fisheries Assessment Research Document 2001/25. 19p.

Francis R.I.C.C. 1990. A maximum likelihood stock reduction method. New Zealand Fisheries Assessment Research Document 1990/4. 12p.

Francis R.I.C.C. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27p.

Francis R.I.C.C., Robertson D.A., Clark M.R., Coburn R.P. 1992. Assessment of the ORH 3B orange roughy fishery for the 1992-93 fishing year. New Zealand Fisheries Assessment Research Document 1992/4. 46p.

Francis R.I.C.C., Clark M.R., Coburn R.P., Field K.D., Grimes P.J. 1995. Assessment of the ORH 3B orange roughy fishery for the 1994-95 fishing year. New Zealand Fisheries Assessment Research Document 1995/4. 44p.

Hampton I. 2010. Re-analysis of data from acoustic surveys of orange roughy on the Challenger Plateau (Area ORH7A) in 2005, 2006 and 2009. DWWG document 2010/38. 9p.

Hampton I., Boyer D.C., Leslie R.W., Nelson J.C., Soule M.A., Tilney R.L. 2012. Acoustic and trawl estimates of orange roughy (*Hoplostethus atlanticus*) biomass on the southwest Challenger Plateau, June/July 2011. Draft N.Z. Fisheries Assessment Report. 45p.

NIWA & FRS 2009. Abundance, distribution, and biology of orange roughy on the southwest Challenger Plateau (area ORH7A): results of a trawl and acoustic survey, June-July 2009. NIWA Client Report: 2009-59. FRS Client Report. 73 p.

Tracey D., Horn P., Marriott P., Krusic-Golub K., Gren C., Gili R. and Mieres L.C. 2007. Orange Roughy Ageing Workshop: otolith preparation and interpretation. Draft report to DWWG.

ORANGE ROUGHY WEST COAST SOUTH ISLAND (ORH 7B)

1. FISHERY SUMMARY

1.1 Commercial fisheries

From 1 October 2007 the TACC for this stock was reduced to 1 t. Previously the fishery was centred on an area near the Cook Canyon in statistical areas 033, 034 and 705. Up until 1996-97 approximately 80% of the catch was taken in winter (June-July) when fish form aggregations for spawning. From 1997-98 onwards about 50% of the catch was taken in winter. Reported domestic landings and TACCs are shown in Table 1, while the historical landings and TACC for ORH 7B are depicted in Figure 1.

Table 1: Reported landings (t) of orange roughy and TACCs (t) for ORH 7B from 1983-84 to 2010-11. QMS data from 1986-present.

Fishing year	Reported landings	TACC
1983-84*	2	-
1984-85*	282	-
1985-86*	1 763	1 558
1986-87*	1 446	1 558
1987-88	1 413	1 558
1988-89	1 750	1 708
1989-90	1 711	1 708
1990-91	1 683	1 708
1991-92	1 604	1 708
1992-93	1 139	1 708
1993-94	701	1 708
1994-95	290	1 708
1995-96	446	430
1996–97	425	430
1997–98	330	430
1998–99	405	430
1999-00	284	430
2000-01	161	430
2001-02	95	110
2002-03	90	110
2003-04	119	110
2004-05	106	110
2005-06	77	110
2006-07	125	110
2007-08	6.0	1
2008-09	1.4	1
2009-10	42	1
2010-11	0.1	1

*FSU data.

Catches in the early-mid 1990s (especially 1994-95) were well below the TACC. The TACC was reduced to 430 t for the 1995-96 fishing year, and then was reduced further to 110 t from 1 October 2001.

1.2 Recreational fisheries

There is no known recreational fishery for orange roughy in this area.

1.3 Customary non-commercial fisheries

There is no known customary non-commercial fishing for orange roughy in this area.

1.4 Illegal catch

There is no quantitative information available on illegal catch.

1.5 Other sources of mortality

There is no quantitative information available on other sources of mortality in this fishery.

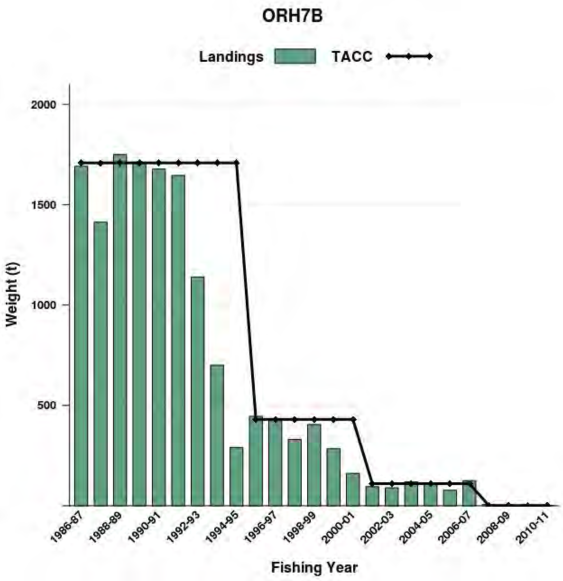


Figure 1: Historical landings and TACC for ORH 7B (Auckland East). Note that this figure does not show data prior to entry into the QMS.

2. STOCKS AND AREAS

There are no new data which would alter the stock boundaries given in previous assessment documents.

Orange roughy in this fishery are thought to be a single stock. Genetic studies have shown that samples of Cook Canyon orange roughy are significantly different from Challenger Plateau and Puysegur Bank samples. Moreover, the size structure and parasite composition differ from fish on the Challenger Plateau. Spawning occurs at a similar time to fish on the Challenger Plateau and the Puysegur Bank.

3. STOCK ASSESSMENT

The previous assessment for this stock was carried out in 2004 and is summarised in the 2006 Plenary Report. Biomass was estimated to be 17% B_0 (95% confidence interval 14-23%) when CPUE was assumed directly proportional to abundance.

An updated assessment was attempted in 2007 with the addition of catch data up to 2005-06 and new standardised CPUE indices. The Working Group rejected the assessment on the basis of the poor fit to the CPUE data. The effect was similar to the result from the 2004 assessment; namely a slow rebuild in recent years, which was not supported by the CPUE data.

3.1 Estimates of fishery parameters and abundance

Commercial catch and effort data are available from 1985 and were examined using both an unstandardised and a standardised analysis. Unstandardised catch rates have declined substantially over the course of the fishery but have shown no clear trend in recent years (Table 2).

Most recent effort in the fishery has been by small, inshore vessels. Since 2001-02, when the TAC was dropped to 110 t, effort (in vessel days) has decreased except for in 2004-05 when there was an increase. The average distance towed in the last four years is more than twice its initial level.

Up until 1996-97 approximately 70% of the estimated catch was recorded on TCEPR forms. In 1997-98 this decreased to 20% and now nearly all the catch is recorded on CELR form. Because of this change in the fleet composition, and associated difficulties with vessel linkage across years, it was decided to split the standardised CPUE analysis into two series: (i) using TCEPR data from 1985-86 through to 1996-97, and (ii) using CELR data from 1990-91 through to 2005-06. In addition, in order to increase vessel linkage across years, it was decided to use all months of data not just that from the winter fishery (June-July) as has been done for previous standardisations.

Table 2: Summary of groomed data from TCEPR and CELR forms.

Fishing year	Number of vessel days	Number of tows	Total estimated catch (t)	Mean daily catch rate (t/tow)	Mean daily catch rate (t/h)
1985-86	138	357	1 544	4.5	2.9
1986-87	132	405	1 250	4.0	2.7
1987-88	132	420	1 250	3.4	2.3
1988-89	133	368	827	2.5	1.6
1989-90	123	356	1 282	4.5	5.6
1990-91	208	632	1 657	2.8	3.3
1991-92	238	810	1 601	2.0	1.4
1992-93	258	784	1 128	1.5	2.3
1993-94	298	708	660	1.1	0.9
1994-95	162	361	320	0.9	1.6
1995-96	66	150	275	2.2	1.7
1996-97	90	182	244	1.3	7.5
1997-98	96	228	170	0.7	0.3
1998-99	188	566	359	0.6	0.2
1999-00	213	647	259	0.4	0.1
2000-01	149	442	162	0.4	0.1
2001-02	117	282	76	0.3	0.1
2002-03	97	292	112	0.4	0.2
2003-04	90	252	118	0.4	0.2
2004-05	121	393	102	0.3	0.1
2005-06	87	257	73	0.3	0.2

The standardised analysis for the TCEPR data used catch per tow in a linear regression model. Indices from this model (Table 3, Figure 2) show a steep decline after the first two years, followed by a more gradual decline and a slight increase in catch rates in 1995-96 and 1996-97.

Table 3: Standardised CPUE indices (relative year effect) based on TCEPR data with number of vessel tows from 1985-86 to 1996-97.

Year	CPUE index	CV	Number of tows	Year	CPUE index	CV	Number of tows
1985-86	1.99	0.20	153	1991-92	0.48	0.23	231
1986-87	2.13	0.23	150	1992-93	0.29	0.23	230
1987-88	1.11	0.26	212	1993-94	0.14	0.25	341
1988-89	0.58	0.22	310	1994-95	0.13	0.27	172
1989-90	0.61	0.22	236	1995-96	0.51	0.33	37
1990-91	0.76	0.23	238	1996-97	0.41	0.26	104

The standardised analysis for the CELR data used daily catch in a linear regression model. Indices from this model (Table 4, Figure 2) show a steep decline for the first four years, followed by an increase to a peak in 1995-96, and subsequent low catch rates after then.

Table 4: Standardised CPUE indices (relative year effect) based on CELR data with number of days from 1990-91 to 2005-06.

Year	CPUE index	CV	Number of days	Year	CPUE index	CV	Number of days
1990-1991	2.17	0.27	110	1999-2000	0.34	0.27	131
1991-1992	1.11	0.27	108	2000-2001	0.34	0.28	88
1992-1993	0.74	0.27	126	2001-2002	0.33	0.28	73
1993-1994	0.28	0.28	81	2002-2003	0.61	0.26	67
1994-1995	0.53	0.30	46	2003-2004	0.59	0.25	75
1995-1996	1.16	0.33	29	2004-2005	0.35	0.24	114
1996-1997	0.53	0.38	19	2005-2006	0.36	0.26	80
1997-1998	0.36	0.30	52				
1998-1999	0.39	0.28	112				

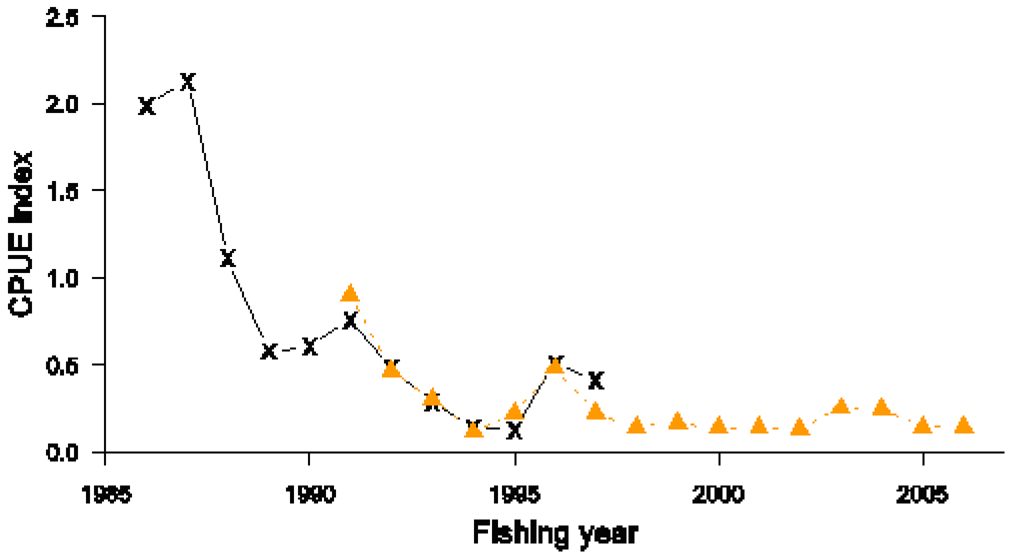


Figure 2: The CPUE indices based on: (i) TCEPR data (solid line and crosses) covering 1985-86 to 1996-97, and (ii) CELR data (triangles and dashed line) covering 1990-91 to 2005-06. The CELR index has been scaled so that it has the same mean value as the TCEPR index in the years that they overlap.

3.2 Biomass estimates

No estimates of current biomass are available. Based on previous stock assessments using CPUE data the TACC was cut back severely from about 1700 t in 1994-95 to 110 t in 2000-01. By the late 1990s the stock was believed to be well below B_{MSY} (17% B_0 in the 2004 assessment). Despite the large reduction in annual removals from the stock since 2001-02 recent catch rates have not increased over the last 5 years.

An updated assessment was attempted in 2007 with the addition of catch data up to 2005-06 and new standardised CPUE indices (Figure 2) based on TCEPR data (1986 to 1997) and a separate CELR series (1991 to 2006). These data were incorporated in a Bayesian stock assessment with deterministic recruitment to estimate stock size. The Working Group rejected the assessment on the basis of the poor fit to the recent CPUE data. The model was insensitive to the recent CPUE data and predicted a rebuild (driven by the recruitment assumptions) that is not supported by any observations in the fishery.

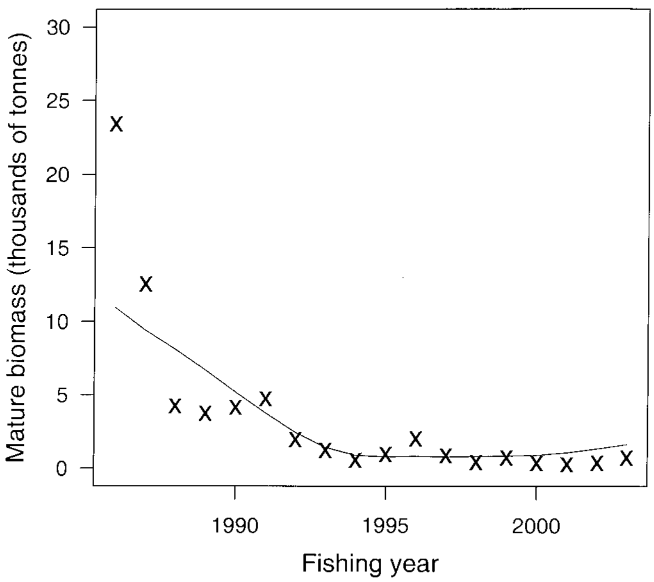


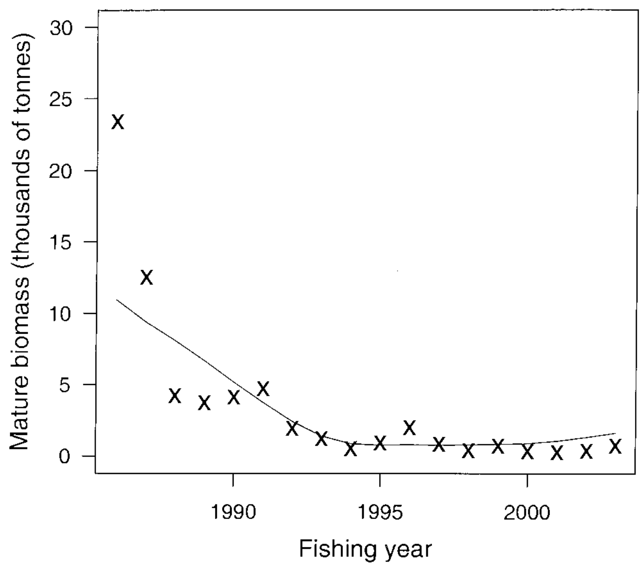
Figure 3: Biomass trajectory derived from Maximum Posterior Density (MPD) estimate of the model parameters (2004 stock assessment). The biomass trajectory is shown by the solid line; crosses denote the CPUE index scaled to biomass.

4. STATUS OF THE STOCK

Stock Structure Assumptions
The ORH7B stock has been treated as a single spawning stock located around the Cook Canyon area. It is assessed and managed separately from other stocks and is assumed to be non-mixing with orange roughy stocks outside of the Cook Canyon area.

Stock Status	
Year of Most Recent Assessment	2004
Assessment Runs Presented	One base case.
Reference Points	Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2004} was estimated to be 17% B_0, Very Unlikely (< 10%) to be at or above the target.
Status in relation to Limits	B_{2004} was Likely (> 60%) to be below the Soft Limit and Unlikely (< 40%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Biomass trajectory derived from Maximum Posterior Density (2004 stock assessment model)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown, but biomass is thought to be very low.
Recent Trend in Fishing Mortality or Proxy	The fishery has been effectively closed since October 2007.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2004)	
Stock Projections or Prognosis	Stable at current catch level
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Already below the Soft Limit Hard Limit: Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Type 1 - Quantitative stock assessment	
Assessment Method	Age-structured model with Bayesian estimation of posteriors.	
Main data inputs	- Catch history - CPUE indices (1985-2003)	
Period of Assessment	Latest assessment: 2004	Next assessment: Unknown
Changes to Model Structure and Assumptions	- CPUE indices based on mean catch per hour as opposed to previous measure of mean catch per tow.	
Major Sources of Uncertainty	- Recruitment assumed to be deterministic. - CPUE assumed to be directly proportional to stock biomass in base model.	

Qualifying Comments (2010)
A further assessment was attempted in 2007 with updated information; however, this was rejected by the working group as the model was insensitive to the CPUE data. The model indicated that the stock had been rebuilding since the mid 1990s, a trend not supported by any observations in the fishery. The fishery was closed from 1 October 2007 and stock size is expected to increase.

Fishery Interactions
Historically, the main bycatch species were oreos and deepwater dogfish. Bycatch species of concern included deepwater sharks, deepsea skates, seabirds and corals. The fishery is currently closed.

5. FOR FURTHER INFORMATION

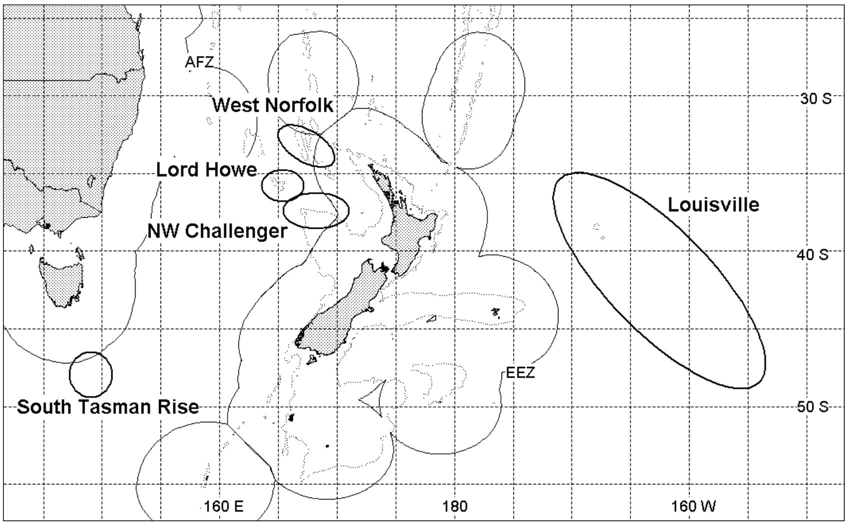
Annala J.H., Sullivan K.J., O'Brien C.J., Smith N., WMcL., Graying S.M. (Comps.) 2003. Report from the Fishery Assessment Plenary, May 2003: stock assessments and yield estimates. 616p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Clark M.R., Tracey D.M., 1988. Assessment of the west coast South Island and northern North Island orange roughy fisheries. New Zealand. Fisheries Assessment Research Document 1988/20. 11p.

Clark M.R., Field K.D. 1995. Assessment of the ORH 7B orange roughy fishery for the 1995-96 fishing year. New Zealand Fisheries Assessment Research Document 1995/19. 15p.

O'Driscoll R.L. 2001. Assessment of the west coast South Island orange roughy fishery (ORH 7B) for the 2001-02 fishing year. New Zealand. Fisheries Assessment Research Document 2001/31. 29p.

ORANGE ROUGHY OUTSIDE THE EEZ (ORHET)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Fisheries outside the EEZ in the New Zealand region occur on ridge systems and seamount chains in the Tasman Sea and southwest Pacific Ocean. There are 5 main fishing areas: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge (see figure above).

Fisheries outside the EEZ developed firstly on the “Westpac Bank” close to the main fishing grounds on the southwest Challenger Plateau in the early-mid 1980s. This is included in the stock area of ORH 7A, and so is not covered here. Further exploration in the region resulted in discoveries of commercial fisheries on the Lord Howe Rise in 1987-88, Northwest Challenger Plateau in 1988-89, Louisville Ridge in 1993-94, South Tasman Rise in 1997-98, and West Norfolk Ridge in 2001-02 (Table 1).

Table 1: Estimated catches (t) of orange roughy for ORH ET fisheries from 1987-88 to 2007-08. (Data from New Zealand (FSU, QMS), Australia (AFMA), and various sources for other countries. Note the fishing year for South Tasman Rise is March to February, all others are October to September).

Fishing year	Lord Howe	NW Challenger	Louisville	West Norfolk	South Tasman	Total ET
1987-88	4 000	5	0	0	0	4 005
1988-89	2 430	297	0	0	0	2 727
1989-90	927	425	0	0	0	1 352
1990-01	282	123	0	0	0	405
1991-02	859	620	0	0	0	1 479
1992-03	2 300	2 463	0	0	0	4 763
1993-04	840	1 731	689	0	0	3 260
1994-05	761	1 138	13 252	0	0	15 151
1995-06	5	500	8 816	0	0	9 321
1996-07	139	332	3 209	0	5	3 685
1997-08	26	397	1 404	0	3930	5 757
1998-09	440	961	3 164	0	705	5 270
1999-00	52	473	1 369	0	4 110	6 004
2000-01	428	1 228	1 598	10	830	4 094
2001-02	120	2 075	1 004	649	170	3 729
2002-03	272	1 010	1 296	94	110	2 782
2003-04	324	654	1 419	90	3	2 490
2004-05	430	464	1 510	277	55	2 736
2005-06	240	201	675	727	12	1 855
2006-07	40	96	323	552	0	1 011

Catch totals include data from New Zealand and Australian vessels available from tow by tow fishing records, with estimated catches added for vessels from Japan, USSR, Korea, Norway, South Africa and China. Catch statistics are likely to be incomplete.

These fisheries have been unregulated, with the exception of the South Tasman Rise area, where catches by Australian and New Zealand vessels have at times been restricted by a TAC imposed under a Memorandum of Understanding between the two countries. The South Tasman Rise fishery is now formally closed.

South Pacific Regional Fisheries Management Organisation

Following adoption of the SPRFMO interim measures in May 2007, specific high sea fishing permits for the SPRFMO Area were implemented for 2007-08. Table 2 shows the number of vessels and orange roughy catch for the last 3 years in all areas of SPRFMO.

Table 2: Catch(t) and effort data for orange roughy from New Zealand vessels for the SPRFMO Area 2007 to 2009. Note that year is calendar year.

Year	Number of Vessels	Number of tows	Lord Howe	Challenger	Louisville	West Norfolk	Other	All areas
2007	8	415	34	36	280	515	0	866
2008	4	208	380	31	0	426	0	837
2009	6	545	403	261	0	233	31	928

Lord Howe Rise

Commercial quantities of orange roughy were found by Japanese vessels in winter 1988, and New Zealand vessels joined the fishery the following year. A number of countries fished the Rise in the late 1980s, but since then it has been largely a New Zealand and Australian fishery. Tows were relatively long at the start of the fishery, when most fishing effort was on the flat ground of the broad platforms. However, shorter tows have become more common associated with a shift onto rough ground and small hill features in the area. Levels of catch and effort decreased to low levels in the mid 1990s, but in recent years have tended to increase, along with unstandardised catch rates (Table 3).

Table 3: Catch and effort data from NZ vessels for the Lord Howe Rise.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
1988-89	181	766	3.0	4.2	5.2	1.5
1989-90	63	127	2.9	2.0	1.0	0.3
1990-91	14	52	2.9	3.7	2.0	0.7
1991-92	70	479	1.7	6.8	7.6	2.5
1992-93	825	1 363	1.3	1.7	3.6	1.2
1993-94	1 263	777	0.9	0.6	1.9	0.8
1994-95	110	61	1.2	0.6	0.5	0.2
1995-96	26	5	0.7	0.2	0.5	0.2
1996-97	179	44	0.8	0.2	0.8	0.3
1997-98	57	15	0.3	0.3	1.8	0.5
1998-99	138	48	1.0	0.3	0.5	0.2
1999-00	121	34	1.1	0.3	1.3	0.5
2000-01	136	145	0.7	1.1	2.9	1.0
2001–02	191	110	0.7	0.6	2.3	0.7
2002–03	280	208	0.5	0.7	4.2	1.4
2003–04	207	180	0.7	0.9	4.7	1.6
2004-05	218	255	0.6	1.2	6.4	2.0
2005-06	71	123	0.4	1.7	15.8	5.2
2006-07	40	34	0.5	0.8	3.4	1.1

A reduced data set has been examined for 22 vessels that have fished for several years in the area up until 2005-06 (Table 4). CPUE peaked in 1991-92, declined rapidly to low levels from 1994-95 to 1998-99, and has increased over the last 5 years. Most fishing now takes place in the period from May to July.

Northwest Challenger Plateau

New Zealand and Norwegian vessels began working the northwestern margins of the Challenger Plateau in the late 1980s. Fishing initially was on relatively flat bottom but from 1990 onwards developed more on small hill and pinnacle features, and mean tow length became relatively short (Table 5). Effort declined during the mid 1990s but increased substantially in 2000-01. Tow length increased also, as the fishery moved eastwards along the northern flanks of the Plateau in towards the

EEZ. The hill fishery has decreased. Effort has also extended southwards along the western margins of the Challenger Plateau, although catches there have been small.

Table 4: Unstandardised CPUE indices for core vessels from Lord Howe Rise.

Fishing year	Number of tows	Catch (t)	t/tow	t/n.mile	t/hr
1988-89	72	291	4.1	0.5	1.5
1989-90	63	128	2.0	0.3	1.0
1990-91	16	52	3.3	0.6	1.8
1991-92	76	481	6.3	2.3	7.1
1992-93	539	1 108	2.1	1.2	3.7
1993-94	897	618	0.7	0.7	1.7
1994-95	109	60	0.6	0.2	0.5
1995-96	29	5	0.2	0.2	0.5
1996-97	184	45	0.2	0.3	0.8
1997-98	58	15	0.3	0.5	1.7
1998-99	49	3	0.1	0	0.1
1999-00	77	28	0.4	0.7	1.9
2000-01	127	146	1.2	1.1	3.2
2001-02	162	106	0.7	0.8	2.6
2002–03	269	206	0.8	1.4	4.4
2003–04	148	144	0.9	1.5	4.4
2004-05	87	170	2.0	3.8	12.0
2005-06	40	97	2.4	7.4	22.8

Table 5: Catch and effort data from NZ vessels for Northwest Challenger.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
1988-89	33	107	3.2	3.3	1.5	0.5
1989-90	40	25	2.4	0.6	0.6	0.2
1990-91	4	1	0.2	0.3	1.5	0.4
1991-92	56	230	0.5	4.1	12.8	3.7
1992-93	1 370	2 250	0.8	1.6	3.9	1.2
1993-94	1 499	1 394	1.1	0.9	1.4	0.5
1994-95	877	1 138	0.8	1.3	5.7	2.0
1995-96	270	500	1.0	1.9	10.0	3.4
1996-97	385	332	0.8	0.9	3.5	1.2
1997-98	215	228	0.7	1.1	6.0	2.0
1998-99	707	838	0.8	1.2	4.2	1.4
1999-00	598	335	1.0	0.6	2.6	0.9
2000-01	1 002	944	2.6	0.9	1.5	0.5
2001-02[1]	2 431	1 863	3.9	0.8	1.4	0.5
2002–03[1]	1 979	948	3.8	0.5	0.9	0.3
2003–04	869	495	3.5	0.6	1.0	0.3
2004-05	1 007	442	4.7	0.4	0.7	0.2
2005-06	399	200	5.2	0.5	0.6	0.2
2006-07	77	36	4.6	0.5	0.4	0.1

[1] Aggregated daily data are included in the vessel, tow, and catch totals, excluded from catch rate.

Table 6: CPUE indices for core vessels from all seasons.

			Unstandardised CPUE		
Fishing year	Number of tows	Catch (t)	t/tow	t/nmile	% zero catch
1992-93	474	819	1.7	0.9	20
1993-94	1 115	1 343	1.2	0.6	42
1994-95	869	1 136	1.3	2.0	39
1995-96	266	499	1.9	3.5	36
1996-97	379	330	0.9	1.2	41
1997-98	211	227	1.1	2.0	35
1998-99	463	622	1.3	1.3	25
1999-00	430	190	0.4	0.6	29
2000-01	997	940	0.9	0.5	15
2001-02	2 098	1 633	0.6	0.5	10
2002-03	1 822	896	0.5	0.3	12
2003-04	786	464	0.6	0.3	9
2004-05	828	385	0.5	0.3	7
2005-06	324	164	0.5	0.2	4

Unstandardised CPUE for vessels that have fished the area for several years through until 2005-06 has declined over time (Table 6). Average catch per tow has been less than 1 t since 2000, even though the success of catching orange roughy (expressed as % of zero catch trawls) has improved.

Catch rates in the hill fishery (winter, tow duration less than 30 minutes), have decreased from a peak at around 4 t/tow in the mid 1990s to less than 1 t. Effort in June during recent years has been low.

The fishery has for many years now been worked solely by New Zealand and Australian vessels, mostly between April and July.

West Norfolk Ridge

This is a recent fishery that followed exploratory fishing inside the EEZ on the West Norfolk Ridge (ORH 1). In 2001-02 Australian vessels were involved as well as New Zealand vessels. Catches quickly increased to almost 300 t, but then dropped substantially the following year (Table 7). Catches were low for 2 years but have increased since as new hills along the ridge were fished.

Table 7: Catch and effort data from NZ vessels for the West Norfolk Ridge orange roughy fishery.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
2000-01	1	0.2				
2001–02	297	586	0.3	2.0	9.0	3.0
2002–03	91	35	0.3	0.4	2.4	0.8
2003–04	90	88	0.5	1.0	2.3	0.8
2004-05	248	274	0.4	1.1	4.5	1.5
2005-06	337	727	0.4	2.2	19.7	6.6
2006-07	215	543	0.3	2.5	12.7	4.0

Fishing has been spread over the year, although highest catch rates have occurred in June and July, especially in 2005-06 and 2006-07.

Louisville Ridge

The Louisville Ridge is a chain of more than 60 seamounts extending for over 4000 km southeast from the Kermadec Ridge. Fishing began in 1993-94 in the central part of the ridge, and spread both northwest and southeast in subsequent years. The fishery has comprised largely New Zealand vessels, although vessels from Australia, China, Russia, Ukraine, Korea and Japan are known to have fished the ridge also (mainly in the first few years). The New Zealand catch peaked in 1994-95 at over 11 000 t (Table 8), and, until the last two years, has generally been between 1000 and 1500 t. Both catch and effort decreased substantially in 2005-06 and 2006-07. Catch rates have varied, and shown no consistent trend, either overall or divided into sub-areas (Table 9).

Table 8: Catch and effort data from NZ vessels for the Louisville Ridge.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
1993-94	134	189	1.4	1.4	1.5	0.6
1994-95	4 294	11 340	0.7	2.6	10.6	4.2
1995-96	4 024	8 764	0.7	2.2	7.4	3.0
1996-97	1 849	3 209	0.8	1.7	5.3	2.1
1997-98	787	1 404	0.5	1.8	14.2	4.8
1998-99	1 093	3 025	0.5	2.7	14.2	5.2
1999-00	918	1 369	0.5	1.5	11.4	3.8
2000-01	749	1 598	0.5	2.1	18.0	2.3
2001–02	889	1 004	0.6	1.1	7.4	2.4
2002–03	736	1 296	0.4	1.8	13.8	4.6
2003–04	1 336	1 419	0.4	1.1	8.7	2.9
2004-05	745	1 510	0.4	2.0	17.2	5.6
2005-06	581	669	0.6	1.2	6.2	2.0
2006-07	283	323	0.5	1.1	8.5	2.6

Table 9: Average catch rate (tonnes per tow) of orange roughy in winter months (June to August) by New Zealand vessels from the Louisville Ridge, by sub-area from 1993–94 to 2005–06.

	Full Area	North	Central	South
1993–94	1.9	-	1.9	-
1994–95	2.7	3.9	2.6	11.0
1995–96	3.6	6.0	2.1	3.9
1996–97	2.1	1.4	2.0	3.5
1997–98	2.0	1.9	2.4	0.7
1998–99	2.7	2.1	2.9	1.7
1999–00	1.8	2.1	1.6	2.8
2000–01	2.3	2.6	2.0	1.9
2001–02	1.3	0.9	2.3	3.9
2002–03	1.9	1.7	1.2	5.3
2003–04	1.1	0.7	1.4	1.8
2004-05	2.1	1.8	1.6	2.9
2005-06	1.1	1.0	1.0	1.6

CPUE, from individual seamounts shows variable patterns. The fishery on some seamounts has lasted only a few years, while on others it has continued, or fluctuated over time. Seamounts in the northwestern and southeastern sections of the Ridge have not sustained consistent catches, and some localised depletion has occurred.

South Tasman Rise

Exploratory fishing south of Tasmania located aggregations of orange roughy on the South Tasman Rise just outside the Australian Fishing Zone (AFZ) in late 1997. The fishery rapidly increased in the next 4 years (Table 10), with Australian and New Zealand vessels working several small hill features on the Rise. However, New Zealand vessels have not fished the South Tasman Rise since 2000-01. Effort has dropped continuously since 2001-02, and mean catch per tow in 2004-05 was about 1 t/tow. Note that insufficient vessels have fished since 2005-06 to enable presentation of catch or effort summaries.

Table 10: Catch and effort data from the South Tasman Rise (combined Australian and New Zealand data).

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)
1996-97	61	4	0.6	0.1	0.5
1997-98	1 132	3 930	0.7	3.5	17.4
1998-99	1 332	1 705	0.6	1.3	10.4
1999-00	1 086	3 360	0.5	3.1	21.1
2000-01	1 155	830	0.4	0.7	6.7
2001–02	201	170	0.8	1.0	3.5
2002–03	164	110	0.5	0.9	7.9
2003–04	67	2	0.3	0.1	0.4
2004–05	47	55	0.3	1.2	14.7

The fishery was formally regulated by a Memorandum of Understanding between Australia and New Zealand from December 1998. A precautionary TAC of 2100 t was applied, increased to 2400 t in 2000-01, and then progressively reduced to 600 t for 2004-05. The fishery was closed to all trawling in 2007.

1.2 Summary of trends in commercial fisheries

Since the high seas fishing permits for the SPRFMO Area were implemented in 2007-08 the number of bottom trawl vessels actively fishing has varied from 4-8 vessels. Catch levels have decreased for all fisheries since they began, but after a period in the late 1990s-early 2000s when the total catch by New Zealand vessels was relatively consistent at 2000-2500 t, catch has declined over the last 3 years to less than 1000 t. Trends in catch and effort have been difficult to interpret given changes in the vessel composition over time and the areas fished between years.

Mean catch rates for the Lord Howe Rise have been variable in recent years as the fishery has moved to hill features. The fishery appears to have become more consistent from year to year following a period of low catch and effort in the mid 1990s. The orange roughy catch in the Northwest Challenger Plateau fishery has declined substantially in the last few years. Unstandardised CPUE has been at relatively low levels since 2000-01, and there has been a shift towards long tows on the flat. The

Louisville Ridge fishery has been the largest of those in the New Zealand region, but catch and effort levels have declined substantially since 2004-05. Catch rates have dropped from 2004-05, but are still broadly similar to those in earlier years. The patterns on individual seamounts differ, with some appearing stable, while others have declined. The West Norfolk Ridge fishery developed rapidly in 2001–02, and after an initial decrease in catch and effort, these increased in 2004-05 as new sites were fished. Catches increased substantially in 2005-06, and relatively large catches and high catch rates continued in 2006-07. The fishery on the South Tasman Rise decreased to very low levels during the early 2000s, and was closed in 2007. New Zealand vessels have not fished the Rise since 2001.

1.3 Recreational fisheries
There is no known non-commercial fishery for orange roughy in these areas.

1.4 Customary non-commercial fisheries
No customary non-commercial fishing for orange roughy is known in these areas.

1.5 Illegal catch
In most of these areas, there are no regulations regarding limits on catch in international waters. The South Tasman Rise region has been subject to catch restrictions for Australian and New Zealand vessels under a Memorandum of Understanding between the two countries. In 1999-2000 vessels registered in South Africa and Belize fished the region. The estimated catch of at least 750 t has been included in the catch total for that year. No other information is available on any possible illegal catch on the South Tasman Rise, or the Westpac Bank region of ORH 7A.

1.6 Other sources of mortality
There may be some overrun of reported catch because of fish loss with trawl gear damage, ripped nets, discards, and conversion factor inaccuracies. In a number of other orange roughy fisheries, a current level of 5% has been applied (higher in the past). No corrections are made here because of limited information on the sources which may differ with each fishery.

2. STOCKS AND AREAS

The five fishing grounds are all regarded as separate stocks.

The Lord Howe Rise and Northwest Challenger Plateau fisheries are based on fish that have a different size structure, different age/size at maturity, similar timing of spawning, and a geographical separation of about 120 n miles. Their genetic make-up differs from fish on the southwest Challenger Plateau (ORH 7A). Morphometric differences have also been shown between orange roughy from Lord Howe and Puysegur Bank areas.

Orange roughy on the South Tasman Rise are regarded as a straddling stock with fish inside the AFZ.

The Louisville Ridge is a long seamount chain, and little is known about stock structure within the area. There are several known spawning sites, and it would seem likely that there could be multiple stocks or sub-populations along the ridge.

The fishery on the West Norfolk Ridge outside the EEZ is continuous with that carried out on ridge peaks and seamount features inside the EEZ.

3. STOCK ASSESSMENT

There are currently no accepted stock assessments for these orange roughy fisheries outside the EEZ. Several have been attempted (for Lord Howe, Northwest Challenger Plateau, and Louisville Ridge) based on catch per unit effort data, but these have not been accepted as sufficiently robust by the Deepwater Fishery Assessment Working Group. This was generally on account of highly variable levels of effort and catch between years within each of the fisheries, which can make the use of CPUE as an index of abundance uncertain.

4. STATUS OF THE STOCKS

The status of the stocks is unknown. Catch and effort levels have decreased substantially in some of the grounds in the last few years, and unstandardised CPUE has declined in a number of areas. However, it is not known if recent catch levels are sustainable, or whether they will allow the stocks to move towards a size that will support the *MSY*.

5. FOR FURTHER INFORMATION

Anderson O.F. 2006. A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2003-04 fishing year. New Zealand Fisheries Assessment Report 2006/16. 25 p.

Clark M.R. 2003. Estimation of orange roughy biomass on the Louisville Ridge: application of “Seamount Meta-analysis” results. Final Research Report to the Ministry of Fisheries for ORH2002/03. (Unpublished report held by MFish, Wellington.)

Clark M.R. 2004. Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2002-03 fishing year. New Zealand Fisheries Assessment Report 2004/51 36 p.

Clark M.R. 2006a. Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2003-04 fishing year. New Zealand Fisheries Assessment Report 2006/25. 37 p.

Clark M.R. 2006b. Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2004-05 fishing year. New Zealand Fisheries Assessment Report 2006/56. 38 p.

Clark M.R. 2008. Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2005-06 fishing year. New Zealand Fisheries Assessment Report 2008/12. 45 p.

Clark M.R., Anderson O.F. 2001. The Louisville Ridge orange roughy fishery: an update of commercial catch-effort data and CPUE analysis of the fishery to the end of the 1999-2000 fishing year. New Zealand Fisheries Assessment Report 2001/74. 31 p.

Clark M.R., Anderson O.F. 2003. The Louisville Ridge orange roughy fishery: an analysis of commercial catch-effort data and stock assessment of the fishery to the end of the 2000-01 fishing year. New Zealand Fisheries Assessment Report 2003/3. 26 p.

Clark M.R., O’Driscoll R.L. 2002. Descriptive analysis of orange roughy fisheries in the Tasman Sea outside the New Zealand EEZ: Lord Howe Rise, Northwest Challenger Plateau, and South Tasman Rise from 1986-87 to the end of the 2000-01 fishing year. New Zealand Fisheries Assessment Report 2002/59. 26 p.

Clark M., Tilzey R. 1996. A summary of stock assessment information for orange roughy fisheries on the Lord Howe Rise: 1996. Bureau of Resource Sciences, Canberra. 23 p. (Available from BRS, P.O. Box E11, Canberra, Australia).

Clark M., Tilzey R. 2001. A summary of commercial catch and effort information for the orange roughy (*Hoplostethus atlanticus*) fishery on the South Tasman Rise from 1987 to 1999. New Zealand Fisheries Assessment Report 2001/3. 16 p.

O’Driscoll R.L. 2001. CPUE analysis of orange roughy fisheries outside the New Zealand EEZ: Lord Howe Rise and Northwest Challenger Plateau, to the end of the 1999-2000 fishing year. New Zealand Fisheries Assessment Report 2001/36. 26 p.

O’Driscoll R.L. 2003. Catch-per-unit-effort analysis of orange roughy fisheries outside the New Zealand EEZ: Lord Howe Rise and Northwest Challenger Plateau to the end of the 2001–02 fishing year. New Zealand Fisheries Assessment Report 2003/36. 38 p.

Smith P.J., Robertson S., Horn P., Bull B., Anderson O., Stanton B.R., Oke C.S. 2002. Multiple techniques for determining stock relationships between orange roughy, *Hoplostethus atlanticus*, fisheries in the eastern Tasman Sea. Fisheries Research 58: 119-140.

Tilzey R. 2000. South Tasman Rise trawl fishery. *In*: Caton, A.,McLoughlin, K. (eds) Fishery status reports 1999: resource assessments of Australian Commonwealth fisheries. BRS, Canberra.

Wayte S., Bax N., Clark M., Tilzey R. 2003. Analysis of orange roughy catches on the South Tasman Rise, 1997-2002. Report provided to the Orange Roughy Assessment Group. 14 p. (Unpublished report held by CSIRO, Hobart.)

OREOS (OEO)

(*Allocyttus niger*, *Allocyttus verucosus*, *Neocyttus rhomboidalis* and *Pseudocyttus maculatus*)

1. INTRODUCTION

The main black oreo and smooth oreo fisheries have been assessed separately and individual reports produced for each as follows:

1. OEO 3A black oreo and smooth oreo
2. OEO 4 black oreo and smooth oreo
3. OEO 1 and OEO 6 black oreo and smooth oreo

2. BIOLOGY

2.1 Black oreo

Black oreo have been found within a 600 m to 1300 m depth range. The geographical distribution south of about 45° S is not well known. It is a southern species and is abundant on the south Chatham Rise, along the east coast of the South Island, the north and east slope of Pukaki Rise, the Bounty Platform, the Snares slope, Puysegur Bank and the northern end of the Macquarie Ridge. They most likely occur right round the slope of the Campbell Plateau.

Spawning occurs from late October to at least December and is widespread on the south Chatham Rise. Mean length at maturity for females, estimated from Chatham Rise trawl surveys (1986-87, 1990, 1991-93) using macroscopic gonad staging, is 34 cm TL.

They appear to have a pelagic juvenile phase, but little is known about this phase because only about 12 fish less than 21 cm TL have been caught. The pelagic phase may last for 4-5 years to lengths of 21-26 cm TL.

Unvalidated age estimates were obtained for Chatham Rise and Puysegur-Snares samples in 1995 and 1997 respectively using counts of the zones (assumed to be annual) observed in thin sections of otoliths. These estimates indicate that black oreo is slow growing and long lived. Maximum estimated age was 153 years (45.5 cm TL fish). Australian workers used the same methods, i.e., sections of otoliths, and reported similar results A von Bertalanffy growth curve was fitted to the Puysegur samples only (Table 1). Estimated age at maturity for females was 27 years.

A first estimate of natural mortality (*M*), 0.044 (yr^{-1}), was made in 1997 using the Puysegur growth data only. This estimate is uncertain because it appeared that the otolith samples were taken from a well fished part of the Puysegur area.

Black oreo appear to settle over a wide range of depths on the south Chatham Rise, but appear to prefer to live in the depth interval 600-800 m that is often dominated by individuals with a modal size of 28 cm TL.

2.2 Smooth oreo

Smooth oreo occur from 650 m to about 1500 m depth. The geographical distribution south of about 45° S is not well known. It is a southern species and is abundant on the south Chatham Rise, along the east coast of the South Island, the north and east slope of Pukaki Rise, the Bounty Platform, the Snares slope, Puysegur Bank and the northern end of the Macquarie Ridge. They most likely occur right round the slope of the Campbell Plateau.

Spawning occurs from late October to at least December and is widespread on the south Chatham Rise in small aggregations. Mean length at maturity for females, estimated from Chatham Rise trawl surveys (1986-87, 1990, 1991-93) using macroscopic gonad staging, is 40 cm TL.

They appear to have a pelagic juvenile phase, but little is known about this phase because only about six fish less than 16 cm TL have been caught. The pelagic phase may last for 5-6 years to lengths of 16-19 cm TL.

Unvalidated age estimates were obtained for Chatham Rise and Puysegur-Snares fish in 1995 and 1997 respectively using counts of the zones (assumed to be annual) observed in thin sections of otoliths. These estimates indicate that smooth oreo is slow growing and long lived. Maximum estimated age was 86 years (51.3 cm TL fish). Australian workers used the same methods, i.e., sections of otoliths, and reported similar results. A von Bertalanffy growth curve was fitted to the age estimates from Chatham Rise and Puysegur-Snares fish combined and the parameters estimated for the growth curve are in Table 1. Estimated age at maturity for females was 31 years.

An estimate of natural mortality, 0.063 (yr^{-1}), was made in 1997. The estimate was from a moderately exploited population of fish from the Puysegur region. The Puysegur fishery started in 1989-90 and by August-September 1992 (when the otoliths were sampled) about 24% of the smooth oreo catch from 1989-90 to 1995-96 had been taken. Future estimates of *M* should, if possible, be made from an unexploited population.

There are concentrations of recently settled smooth oreo south and south west of Chatham Island, although small individuals (16-19 cm TL) occur widely over the south Chatham Rise at depths of 650-800 m.

Table 1: Biological parameters used for black oreo and smooth oreo stock assessments. Values not estimated indicated by (-).

Fishstock		**Estimate**	
1. Natural Mortality - *M* (yr^{-1})	Females	Males	Unsexed
Black oreo	0.044	0.044	0.044
Smooth oreo	0.063	0.063	
2. Age at recruitment - A_r (yr)			
Black oreo	-	-	-
Smooth oreo	21	21	
3. Age at maturity A_M (yr)			
Black oreo	27	-	-
Smooth oreo	31	-	

Table 1 continued:

4. von Bertalanffy parameters

	Females			Males			Unsexed		
	$L_{¥(cm, TL)}$	k(yr^{1})	t_0 (yr)	$L_{¥(cm, TL)}$	k(yr^{1})	t_0 (yr)	$L_{¥(cm, TL)}$	k(yr^{1})	t_0 (yr)
Black oreo	39.9	0.043	-17.6	37.2	0.056	-16.4	38.2	0.05	-17.0
Smooth oreo	50.8	0.047	-2.9	43.6	0.067	-1.6			

5. Length-weight parameters (Weight = a(length)^{b} (Weight in g, length in cm fork length))

	Females		Males		Unsexed	
	a	b	a	b	a	b
Black oreo	0.008	3.28	0.016	3.06	0.0078	3.27
Smooth oreo	0.029	2.90	0.032	2.87		

	Females	Males	Unsexed
6. Length at recruitment (cm, TL)			
Black oreo	-	-	-
Smooth oreo	34	-	
7. Length at maturity (cm, TL)			
Black oreo	34	-	-
Smooth oreo	40	-	-
8. Recruitment variability (σ_R)			
Black oreo	0.65	0.65	0.65
Smooth oreo	0.65	0.65	
9. Recruitment seeepness			
Black oreo	0.75	0.75	0.75
Smooth oreo	0.75	0.75	
10. Fishing mortality (F_{max} (yr^{-1}))			
Black oreo	0.9	0.9	-
Smooth oreo	0.9	0.9	
11. Max exploitation (E_{max} (yr^{-1}))			
Black oreo	-	-	0.67

3. STOCKS AND AREAS

3.1 Black oreo

Stock structure of Australian and New Zealand samples was examined using genetic (allozyme and mitochondrial DNA) and morphological counts (fin rays, etc.). It was concluded that the New Zealand samples constituted a stock distinct from the Australian sample based on “small but significant difference in mtDNA haplotype frequencies (with no detected allozyme differences), supported by differences in pyloric caeca and lateral line counts”. The genetic methods used may not be suitable tools for stock discrimination around New Zealand.

A New Zealand pilot study examined stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4 & OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Lateral line scale and pyloric caeca counts were different between samples from OEO 6 and the other three areas. The relative abundance of three parasites differed significantly between all areas. Otolith shape from OEO 3A samples was different to that from OEO 1 and OEO 4, but OEO 1, OEO 4 and OEO 6 otolith samples were not morphologically different. Genetic, otolith microchemistry, and settlement zone analyses showed no regional differences.

3.2 Smooth oreo

Stock structure of Australian and New Zealand samples was examined using genetic (allozyme and mitochondrial DNA) and morphological counts (fin rays, etc.). No differences between New Zealand and Australian samples were found using the above techniques. A broad scale stock is suggested by these results but this seems unlikely given the large distances between New Zealand and Australia. The genetic methods used may not be suitable tools for stock discrimination around New Zealand.

A New Zealand pilot study examined stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4 & OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Otolith shape from OEO 1 and OEO 6 was different to that from OEO 3A and OEO 4 samples. Weak evidence from parasite data, one gene locus and otolith microchemistry suggested that northern OEO 3A samples were different from other areas. Lateral line scale and otolith settlement zone counts showed no differences between areas.

These data suggest that the stock boundaries given in previous assessment documents should be retained until more definitive evidence for stock relationships is obtained, i.e., retain the areas OEO 1, OEO 3A, OEO 4, and OEO 6 (see the figure on the first page of the Oreos assessment report above).

The three species of oreos (black oreo, smooth oreo, spiky oreo, and warty oreo) are managed as if they were one stock. Each species could be managed separately. They have different depth and geographical distributions, different stock sizes, rates of growth, and productivity.

4. FISHERY SUMMARY

4.1 Commercial fisheries

Commercial fisheries occur for black oreo (BOE) and smooth oreo (SSO). Oreos are managed as a species group, which includes spiky oreo (SOR). The Chatham Rise (OEO 3A and OEO 4) is the main fishing area, but other fisheries occur off Southland on the east coast of the South Island (OEO 1/OEO 3A), and on the Pukaki Rise, Macquarie Ridge, and Bounty Plateau (OEO 6).

Total reported landings of oreos and TACs are shown in Table 2, while Figure 1 depicts the historical landings and TACC values for the main OEO stocks. OEO 3A and OEO 4 were introduced to the QMS in 1982-83, while OEO 1 and OEO 6 were introduced later in 1986-87. Total oreo catch from OEO 4 exceeded the TAC from 1991-92 to 1994-95 and was close to the TAC from 1995-96 to 2000-01 (Table 2). Catch remained high in OEO 4 while the orange roughy fishery has declined. The OEO 4 TAC was reduced from 7000 to 5460 t in 2001-02 but was restored to 7000 t in 2003-04. The oreo catch from OEO 3A was less than the TAC from 1992-93 to 1995-96, substantially so in 1994-95 and 1995-96. The OEO 3A TAC was reduced from 10 106 to 6600 t in 1996-97. A voluntary agreement between the fishing industry and the Minister of Fisheries to limit catch of smooth oreo from OEO 3A to 1400 t of the total oreo TAC of 6600 t was implemented in 1998-99. Subsequently the total OEO 3A TAC was reduced to 5900 t in 1999-00, 4400 in 2000-01, 4095 in 2001-02 and 3100 t in 2002-03. Catch from the Sub-Antarctic area (OEO 6) increased substantially in 1994-95 and exceeded the TAC in 1995-96. The OEO 6 TAC was increased from 3000 to 6000 t in 1996-97. There was also a voluntary agreement not to fish for oreos in the Puysegur area which started in 1998-99. OEO 1 was fished under the adaptive management programme up to the end of 1997-98. The OEO 1 TAC reverted back to pre-adaptive management levels from 1998-99.Catches have declined since then, and from 1 October 2007 the TACC was reduced to 2500 t, and other sources of mortality were allocated 168 t.

Reported estimated catches by species from tow by tow data recorded in catch and effort logbooks (Deepwater, TCEPR, and CELR) and the ratio of estimated to landed catch reported are given in Table 3.

Table 2: Total reported landings (t) for all oreo species combined by Fishstock from 1978-79 to 2010-11 and TACs (t) from 1982-83 to 2010-11.

Fishing	OEO 1		OEO 3A		OEO 4		OEO 6	
year	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1978-79*	2 808	-	1 366	-	8 041	-	17	-
1979-80*	143	-	10 958	-	680	-	18	-
1980-81*	467	-	14 832	-	10 269	-	283	-
1981-82*	21	-	12 750	-	9 296	-	4 380	-
1982-83*	162	-	8 576	10 000	3 927	6 750	765	-

Table 2 [Continued].

Fishing year	OEO 1 Landings	OEO 1 TAC	OEO 3A Landings	OEO 3A TAC	OEO 4 Landings	OEO 4 TAC	OEO 6 Landings	OEO 6 TAC
1983-83#	39	-	4 409	#	3 209	#	354	-
1983-84†	3 241	-	9 190	10 000	6 104	6 750	3 568	-
1984-85†	1480	-	8 284	10 000	6 390	6 750	2 044	-
1985-86†	5 390	-	5 331	10 000	5 883	6 750	126	-
1986-87†	532	4 000	7 222	10 000	6 830	6 750	0	3 000
1987-88†	1 193	4 000	9 049	10 000	8 674	7 000	197	3 000
1988-89†	432	4 233	10 191	10 000	8 447	7 000	7	3 000
1989-90†	2 069	5 033	9 286	10 106	7 348	7 000	0	3 000
1990-91†	4 563	5 033	9 827	10 106	6 936	7 000	288	3 000
1991-92†	4 156	5 033	10 072	10 106	7 457	7 000	33	3 000
1992-93†	5 739	6 044	9 290	10 106	7 976	7 000	815	3 000
1993-94†	4 910	6 044	9 106	10 106	8 319	7 000	983	3 000
1994-95†	1 483	6 044	6 600	10 106	7 680	7 000	2 528	3 000
1995-96†	4 783	6 044	7 786	10 106	6 806	7 000	4 435	3 000
1996-97†	5 181	6 044	6 991	6 600	6 962	7 000	5 645	6 000
1997-98†	2 681	6 044	6 336	6 600	7 010	7 000	5 222	6 000
1998-99†	4 102	5 033	5 763	6 600	6 931	7 000	5 287	6 000
1999-00†	3 711	5 033	5 859	5 900	7 034	7 000	5 914	6 000
2000-01†	4 852	5 033	4 577	4 400	7 358	7 000	5 932	6 000
2001-02†	4 197	5 033	3 923	4 095	4 864	5 460	5 737	6 000
2002-03†	3 034	5 033	3 070	3 100	5 402	5 460	6 115	6 000
2003-04†	1 703	5 033	2 856	3 100	6 735	7 000	5 811	6 000
2004-05†	1 025	5 033	3 061	3 100	7 390	7 000	5 744	6 000
2005-06†	850	5 033	3 333	3 100	6 829	7 000	6 463	6 000
2006-07†	903	5 033	3 073	3 100	7 211	7 000	5 926	6 000
2007-08†	947	2 500	3 092	3 100	7 038	7 000	5 902	6 000
2008-09†	582	2 500	2 848	3 100	6 907	7 000	5 540	6 000
2009-10†	464	2 500	3 550	3 350	7 047	7 000	5 730	6 000
2010-11†	381	2 500	3 370	3 350	7 061	7 000	3 610	6 000

Table 2 [Continued].

Fishing year	Totals Landings	Totals TAC
1978-79*	12 231	-
1979-80*	11 791	-
1980-81*	25 851	-
1981-82*	26 514	-
1982-83*	13 680	17 000
1983-83#	8 015	#
1983-84†	22 111	17 000
1984-85†	18 204	17 000
1985-86†	16 820	17 000
1986-87†	15 093	24 000
1987-88†	19 159	24 000
1988-89†	19 077	24 233
1989-90†	18 703	25 139
1990-91†	21 614	25 139
1991-92†	21 718	25 139
1992-93†	23 820	26 160
1993-94†	23 318	26 160
1994-95†	18 291	26 160
1995-96†	23 810	26 160
1996-97†	24 779	25 644
1997-98†	21 249	25 644
1998-99†	22 083	24 633
1999-00†	22 518	23 933
2000-01†	22 719	22 433
2001-02†	18 721	20 588
2002-03†	17 621	19 593
2003-04†	17 105	21 133
2004-05†	17 220	21 133
2005-06†	17 475	21 133
2006-07†	17 113	21 133
2007-08†	16 979	18 600
2008-09†	15 877	18 600
2009-10†	16 791	18 850
2010-11†	14 422	18 860

Source: FSU from 1978-79 to 1987-88; QMS/MFish from 1988-89 to 2005-06. *, 1 April to 31 March. #, 1 April to 30 September. Interim TACs applied. †, 1 October to 30 September. Data prior to 1983 were adjusted up due to a conversion factor change

Table 3: Reported estimated catch (t) by species (smooth oreo (SSO), black oreo (BOE) by Fishstock from 1978-79 to 2007-08 and the ratio (percentage) of the total estimated SSO plus BOE, to the total reported landings (from Table 1). -, less than 1. No catch split available for 2008-09.

	SSO				BOE			
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6
1978-79*	0	0	0	0	9	0	0	0
1979-80*	16	5 075	114	0	118	5 588	566	18
1980-81*	1	1 522	849	2	66	8 758	5 224	215
1981-82*	21	1 283	3 352	2	0	11 419	5 641	4 378
1982-83*	28	2 138	2 796	60	6	6 438	1 088	705
1983-83#	9	713	1 861	0	1	3 693	1 340	354
1983-84†	1 246	3 594	4 871	1 315	1 751	5 524	1 214	2 254
1984-85†	828	4 311	4 729	472	544	3 897	1 651	1 572
1985-86†	4 257	3 135	4 921	72	1 060	2 184	961	54
1986-87†	326	3 186	5 670	0	163	4 026	1 160	0
1987-88†	1 050	5 897	7 771	197	114	3 140	903	0
1988-89†	261	5 864	6 427	-	86	2 719	1 087	0
1989-90†	1 141	5 355	5 320	-	872	2 344	439	-
1990-91†	1 437	4 422	5 262	81	2 314	4 177	793	222
1991-92†	1 008	6 096	4 797	2	2 384	3 176	1 702	15
1992-93†	1 716	3 461	3 814	529	3 768	3 957	1 326	69
1993-94†	2 000	4 767	4 805	808	2 615	4 016	1 553	35
1994-95†	835	3 589	5 272	1 811	385	2 052	545	230
1995-96†	2 517	3 591	5 236	2 562	1 296	3 361	364	1 166
1996-97†	2 203	3 063	5 390	2 492	2 578	3 549	530	1 950
1997-98†	1 510	4 790	5 868	2 531	1 027	1 623	811	1 982
1998-99†	2 958	2367	5 613	3 462	820	3 147	844	1 231
1999-00†	2 533	1 733	5 985	4 306	970	3 943	628	1 043
2000-01†	4 012	1 648	5 924	4 183	332	3 005	799	1 128
2001-02†	2 973	1 769	3 806	4 470	697	2 378	515	983
2002-03†	2 521	1 395	4 105	3 941	481	1 636	868	1 640
2003-04†	1 046	1 244	5 082	3 767	458	1 590	973	1 496
2004-05†	665	1 447	5 848	3 840	234	1 594	851	1 580
2005-06†	529	1 354	5 145	3 289	265	1 770	763	2 616
2006-07†	530	1 220	5 863	2 214	263	1 651	795	3 071
2007-08†	407	1 482	6 150	2 182	429	1 521	592	3 022

Year	Total estimated	Estimated landings (%)
1978-79*	9	-
1979-80*	11 495	98
1980-81*	16 637	64
1981-82*	26 096	98
1982-83*	13 259	97
1983-83#	7 971	100
1983-84†	21 769	99
1984-85†	18 004	99
1985-86†	16 644	99
1986-87†	14 531	96
1987-88†	19 072	100
1988-89†	16 444	86
1989-90†	15 471	83
1990-91†	18 708	87
1991-92†	19 180	88
1992-93†	18 640	78
1993-94†	20 599	88
1994-95†	14 719	81
1995-96†	20 093	84
1996-97†	21 755	88
1997-98†	20 142	95
1998-99†	20 442	93
1999-00†	21 142	94
2000-01†	21 031	93
2001-02†	17 591	94
2002-03†	16 587	94
2003-04†	15 656	92
2004-05†	16 059	93
2005-06†	15 731	90
2006-07†	15 607	91
2007-08†	15 785	93

Source: FSU from 1978-79 to 1987-88 and MFish from 1988-89 to 2006-07
* 1 April to 31 March. #, 1 April to 30 September. †, 1 October to 30 September.

Descriptive analyses of the main New Zealand oreo fisheries were updated with data from 2006-07 in 2008. Standardised CPUE analyses of black and smooth oreo have been updated as follows:

- smooth oreo in OEO 3A in 2009
- black oreo in OEO 4 in 2009
- black oreo in OEO 6 (Pukaki) in 2009
- smooth oreo OEO 6 (Bounty) in 2008
- black oreo in OEO 3A in 2008
- smooth oreo in OEO 4 in 2007
- smooth oreo in Southland (OEO 1 and OEO 3A)in 2007
- smooth oreo OEO 6 (Pukaki) in 2006

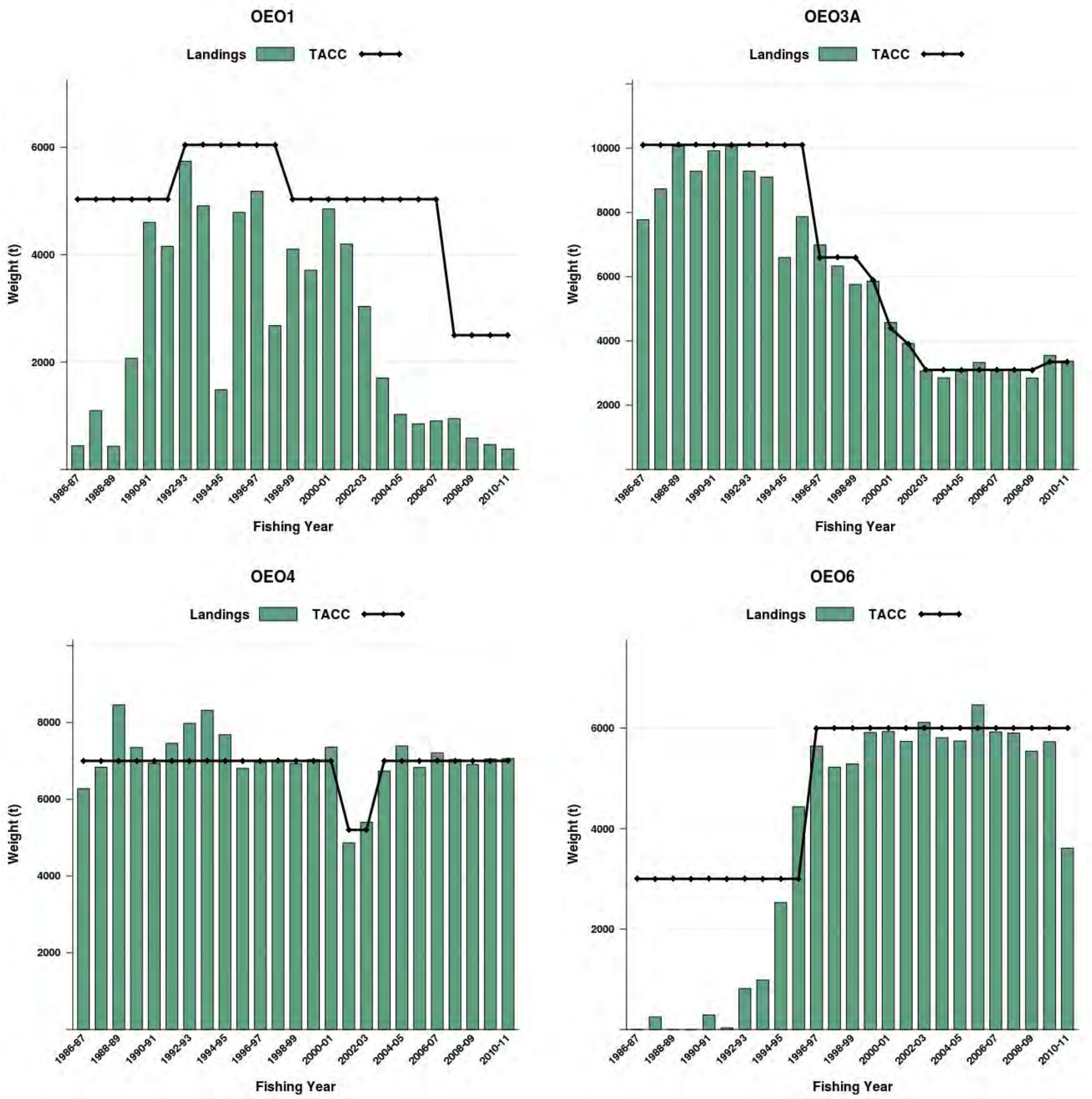


Figure 1: Historical landings and TACC for the four main OEO stocks. From top left to bottom right: OEO1 (Central East - Wairarapa, Auckland, Central Egmont, Challenger, Southland, South East Catlin Coast), OEO3A (South East Cook Strait/Kaikoura/Strathallan), OEO4 (South East Chatham Rise), and OEO6 (Sub-Antarctic). Note that these figures do not show data prior to entry into the QMS.

4.2 Recreational fisheries

There are no known recreational fisheries for black oreo and smooth oreo.

4.3 Customary non-commercial fisheries

There is no known customary non-commercial fishing for black oreo and smooth oreo.

4.4 Illegal catch
Estimates of illegal catch are not available.

4.5 Other sources of mortality
Dumping of unwanted or small fish and accidental loss of fish (lost codends, ripped codends, etc.) were features of oreo fisheries in the early years. These sources of mortality were probably substantial in those early years but are now thought to be relatively small. No estimate of mortality from these sources has been made because of lack of hard data and because they now appear to be small. Estimates of discards of oreos were made for 1994-95 and 1995-96 from MFish observer data. This involved calculating the ratio of discarded oreo catch to retained oreo catch and then multiplying the annual total oreo catch from the New Zealand EEZ by this ratio. Estimates were 207 and 270 t for 1994-95 and 1995-96 respectively.

5. ENVIRONMENTAL & ECOSYSTEM CONSIDERATIONS

This section was updated with new tables for the May 2012 Fishery Assessment Plenary based on reviews of similar chapters by the Aquatic Environment Working Group. This summary is from the perspective of the deepwater trawl fisheries for orange roughy, oreos, and cardinalfish; a more detailed summary from an issue-by issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review (http://fs.fish.govt.nz/Page.aspx?pk=113&dk=22982).

5.1 Role in the ecosystem
Not yet considered.

5.2 Incidental catch (fish and invertebrates)
Anderson (2011) summarised the bycatch of orange roughy and oreo trawl fisheries from 1990–91 to 2008–09. For orange roughy trawls since 2005–06, orange roughy accounted for about 84% of the total observed catch and the remainder comprised mainly oreos (10%), hoki (0.4%), and cardinalfish (0.3%). About 240 other species or species groups were recorded by observers, including various deepwater dogfishes (1.8%), rattails (1.0%), morid cods (0.8%), and slickheads (0.3%). For oreo trawl since 2002, oreos accounted for about 92% of the observed catch and the remainder was mainly orange roughy (3.5%), hoki (0.6%), and ling (0.3%). About 240 other species or species groups were recorded, including deepwater dogfish (1.2%), rattails (1.0%), morid cods (0.1%), and slickheads (0.1%). No information is available for cardinalfish.

5.3 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 or caught on a hook but not brought onboard the vessel, Middleton & Abraham 2007, Brothers *et al*. 2010).

5.3.1 Marine mammal interactions
Trawlers targeting orange roughy or oreos occasionally catch NZ fur seals (which were classified as "Not Threatened" under the NZ Threat Classification System in 2010, Baker *et al*. 2010). Between 2002–03 and 2009–10, there were 14 observed captures of NZ fur seals in orange roughy, oreo, and cardinalfish trawl fisheries. In the 2009/10 fishing year there were no observed captures (Table 4) but there were 4 (95% c.i.: 0 - 13) estimated captures, with the estimates made using a statistical model (Thompson & Abraham 2012). All observed fur seals captures occurred in the SubAntarctic region. The average rate of capture for these years was 0.10 per 100 tows (range 0 to 0.25). This is a low rate compared with that in the hoki fishery (1.5 to 5.6 per 100 tows).

Table 4: 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 2009–10. 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. Data from Thompson & Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

		Observed				Estimated		
	Tows	No.obs	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	8 871	1 378	15.5	0	0.00	4	0 - 11	99.9
2003–04	8 005	1 261	15.8	2	0.16	7	2 - 16	99.9
2004–05	8 417	1 617	19.2	4	0.25	17	5 - 53	99.8
2005–06	8 305	1 294	15.6	2	0.15	12	3 - 32	99.8
2006–07	7 367	2 323	31.5	2	0.09	3	2 -6	99.9
2007–08	6 730	2 811	41.8	4	0.14	8	4 - 20	100.0
2008–09	6 131	2 373	38.7	0	0.00	4	0 - 14	100.0
2009–10	6 011	2 133	35.5	0	0.00	4	0 - 13	99.9

5.3.2 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,c, 2005a, 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 5). In the 2009/10 fishing year there were 19 observed captures of birds in orange roughy, oreo, and cardinalfish trawl fisheries at a rate of 0.9 birds per 100 observed tows (Thompson & Abraham 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 0.4 birds per 100 tows, a low rate relative to trawl fisheries for squid (13.3 birds per 100 tows), scampi (3.53 birds per 100 tows) and hoki (2.2 birds per 100 tows) over the same years.

Table 5: Number of tows by fishing year and observed seabird captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002–03 to 2009–10. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Data from Thompson & Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

	Tows	No. obs	% obs	Captures	Rate
2002–03	8 871	1 378	15.5	0	0.00
2003–04	8 005	1 261	15.8	3	0.24
2004–05	8 417	1 617	19.2	20	1.24
2005–06	8 305	1 294	15.6	7	0.54
2006–07	7 367	2 323	31.5	1	0.04
2007–08	6 730	2 811	41.8	5	0.18
2008–09	6 131	2 373	38.7	8	0.34
2009–10	6 011	2 133	35.5	19	0.89

Salvin's albatross were the most frequently captured albatross (48% of observed albatross captures) but seven different species have been observed captured since 2002–03. Cape petrels were the most frequently captured other bird (63%, Table 6). 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 (MFish 2006). The 2006 notice mandated that all trawlers >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).

Table 6: Number of observed seabird captures in orange roughy, oreo, and cardinalfish fisheries, 2002–03 to 2009–10, 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 *et al*. 2011 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for orange roughy, oreo, and cardinalfish. Other data from Thompson & Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

Species	Risk ratio	Chatham Rise	East Coast South Island	Sub-Antarctic	Stewart-Snares Shelf	Total
Salvin's albatross	2.49	11	2	3	0	16
Chatham Island albatross	2.71	7	0	0	0	7
White capped albatross	0.83	4	0	0	0	4
Southern Buller's albatross	1.28	3	0	0	0	3
Gibson's albatross	1.25	1	0	0	0	1
Northern royal albatross	2.21	1	0	0	0	1
Shy albatross	–	0	0	1	0	1
Total albatrosses		**27**	**2**	**4**	**0**	**33**
Cape petrels	0.76	9	10	0	0	19
Grey petrel	0.39	2	0	1	0	3
Common diving petrel	0.00	2	0	0	0	2
Sooty shearwater	–	0	1	0	1	2
Northern giant petrel	3.00	1	0	0	0	1
Storm petrels	–	1	0	0	0	1
White chinned petrel	0.79	0	1	0	0	1
White-faced storm petrel	0.00	1	0	0	0	1
Total other birds		**16**	**12**	**1**	**1**	**30**

5.4 Benthic interactions

Orange roughy, oreo, and cardinalfish are taken using bottom trawls and 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 and Wood 2012), and 94% were between 700 and 1 200 m depth (Baird *et al*. 2011).

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 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 Aquatic Environment and Biodiversity Annual Review (2012).

5.5 Other considerations

None

6. FOR FURTHER INFORMATION

Abraham E.R., Thompson F.N. 2011. Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09 New Zealand Aquatic Environment and Biodiversity Report No. 80.

Anderson O.F. 2011. Fish and invertebrate bycatch and discards in orange roughy and oreo fisheries from 1990–91 until 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 67.

Baird S.J. 2004a. Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999-2000. New Zealand Fisheries Assessment Report 2004141.56 p.

Baird SJ. 2004b. Incidental capture of seabird species in commercial fisheries in New Zealand waters,2000-01. New Zealand Fisheries Assessment Report 2004158.63 p.

Baird S.J. 2004c. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001-02. New Zealand Fisheries Assessment Report 2004160.51 p.

Baird S.J 2005. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002-03. New Zealand Fisheries Assessment Report 200512.50 p.

Baird S.J., Smith M.H. 2007. Incidental capture of New Zealand fur seals (Arctocephalus forsteri) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. New Zealand Aquatic Environment and Biodiversity Report No. 14. 98 p.

Baird S.J., Wood B.A., *et al*. 2011. Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989-90 to 2004-05. New Zealand Aquatic Environment and Biodiversity Report 73. 143 p.

Baird S.J., Wood B.A. 2012. Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with sealoor contact. New Zealand Aquatic Environment and Biodiversity Report 89. 43 p.

Baker C.S., Chilvers B.L., Constantine R., DuFresne S., Mattlin R.H., van Helden A., Hitchmough R. 2010. Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. New Zealand Journal of Marine and Freshwater Research 44: 101-115.Ballara, S.L.; Anderson, O.F. (2009). Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 38. 102 p.

Brothers N., Duckworth A.R., Safina C., Gilman E.L. 2010. Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. PloS One 5: e12491. doi: 10.1371/journal.pone.001249

Clark M.R., Anderson O.F., Gilbert D.J. 2000. Discards in trawl fisheries for southern blue whiting, orange roughy, hoki, and oreos in waters around New Zealand. NIWA Technical Report 71. 73p.

Coburn R.P., McMillan P.J. 2006. Descriptions of the black oreo and smooth oreo fisheries in OEO 1, OEO 3A, OEO 4, and OEO 6 from 1977-78 to the 2004-05 fishing years. New Zealand Fisheries Assessment Report 2006/60. 70p.

Coburn R.P., McMillian P.J., Gilbert D.J. 2007. Inputs for a stock assessment of smooth oreo, Pukaki Rise (part of OEO 6). New Zealand Fisheries Assessment Report 2007/23. 32p

Doonan I.J., McMillan P.J., Hart A.C. 1997. Revision of smooth oreo life history parameters. New Zealand Fisheries Assessment Research Document 1997/9. 11p.

Doonan I.J., McMillian P.J., Hart A.C. 2008. Aeging of smooth oreo otoliths for stock assessment. New Zealand Fisheries Assessment Report 2008/08. 29p.

Doonan I.J., McMillan P.J., Kalish J.M., Hart A.C. 1995. Age estimates for black oreo and smooth oreo. New Zealand Fisheries Assessment Research Document. 1995/14. 26p.

Hart A.C., McMillan P.J. 2006. A summary of observer biological information on the New Zealand black oreo and smooth oreo fisheries from 1979-80 to 2004-05. New Zealand Fisheries Assessment Report 2006/55. 39p.

Hermsen, J.M.; Collie, J.S.; Valentine, P.C. (2003). Mobile fishing gear reduces benthic megafaunal production on Georges Bank Mar. Ecol. Prog. Ser. 260: 97-108

Hiddink J.G., Jennings S., Kaiser M.J., Queiros A.M., Duplisea D.E., Piet G.J. 2006. Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. Can. J. Fish. Aquat. Sci. 63:721–36

Leathwick J.R., Rowden A., Nodder S., Gorman R., Bardsley S., Pinkerton M., Baird S.J., Hadfield M., Currie K., Goh A. 2009. Benthic-optimised marine environment classification for New Zealand waters. Final Research Report project BEN2006/01. 52 p.

McKenzie A. 2007. Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6). New Zealand Fisheries Assessment Report 2007/34. 27p.

McMillan P.J., Doonan I.J., Hart A.C. 1997. Revision of black oreo life history parameters. New Zealand Fisheries Assessment Research Document 1997/8. 13p.

Rice J. 2006. Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Smith P., Proctor C., Robertson S., McMillan P., Bull B., Diggles B. 2000. Stock relationships of black oreo in New Zealand waters. Final Research Report for Ministry of Fisheries Research Project DEE9801. Objective 1 (Part two). 79p.

Smith P., McMillan P., Proctor C., Robertson S., Knuckey I., Diggles B., Bull B. 1999. Stock relationships of smooth oreo in New Zealand waters. Final Research Report for Ministry of Fisheries Research Project DEE9801. 76p.

Stewart B.D., Smith D.C. 1994. Development of methods to age commercially important dories and oreos. Final Report to the Fisheries Research and Development Corporation.

Ward R.D., Elliot N.G., Yearsley G.K., Last P.R. 1996. Species and stock delineation in Australasian oreos (Oreosomatidae). Final Report to Fisheries Research and Development Corporation. 144p.

OREOS - OEO 3A BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESSMENT

The smooth oreo stock assessment is unchanged from 2009. The black oreo stock assessment is updated with the 2008 assessment.

4.1 Introduction

The following assumptions were made in the stock assessment analyses carried out by NIWA to estimate biomasses and yields for black oreo and smooth oreo.

(a) The acoustic abundance estimates were unbiased absolute values.
(b) The CPUE analyses provided indices of abundance for either black oreo or smooth oreo in the whole of OEO 3A. Most of the oreo commercial catches came from the CPUE study areas. Research trawl surveys indicated that there was little habitat for, and biomass of, black oreo or smooth oreo outside those areas.
(c) The ranges used for the biological values covered their true values.
(d) Varying the maximum fishing mortality (F_{MAX}) from 0.5 to 3.5 altered B_0 for smooth oreo in OEO 3A by only about 6% in the 1996 assessment, so only one assumed value (0.9) was used in all the analysis of OEO 3A smooth oreo. Only one assumed value (0.67) for the maximum exploitation rate (E_{MAX}) was used in the NIWA OEO 3A black oreo analysis.
(e) Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
(f) Catch overruns were 0% during the period of reported catch.
(g) The populations of black oreo and smooth oreo in OEO 3A were discrete stocks or production units.
(h) The catch histories were accurate.

4.1.1 Black oreo

The assessment was updated in 2008 and used new absolute abundance estimates and length data from the 2006 acoustic survey, a revised maturity ogive, revised and updated catch history, relative abundance estimates from an updated and revised post-GPS standardised CPUE analyses, and revised observer length frequencies. This replaced the 2004 assessment.

The population was modelled using three spatial areas to cope with the spatial structure observed in the catch and length data. The three spatial areas included: a northern area that contained small fish and was generally shallow (Area 1), a southern area that contained large fish and was generally deeper (Area 3), and a transition area (Area 2) that lay between Areas 1 and 3. Age dependant migration was allowed in the model to move the fish between the areas.

4.1.2 Smooth oreo

A new assessment of smooth oreo in OEO 3A was completed in 2009. This used a CASAL age-structured population model employing Bayesian methods. Input data included research and observer-collected length data, one absolute abundance estimate from a research acoustic survey carried out in 1997 (TAN9713), and three relative abundance indices from standardised catch per unit effort analyses.

4.2 Black oreo

NIWA CASAL spatial model

An age structured, CASAL model employing Bayesian statistical techniques was used, The model assumed Baranov fishing mortality, but had a maximum exploitation rate (0.80) instead of a maximum instantaneous fishing mortality. A revised maturity ogive was estimated outside the model. Deterministic recruitment was assumed. Fish recruit to the population at age one.

The model estimated initial recruitment (mid-water only), the CV of the length-at-age, migration parameters to move fish from mid-water to area 1, from Area 1 to 2, and from Area 2 to 3, and process errors on both the observer and acoustic survey length frequency data sets. Input data for each area for the 2008 stock assessment included: new absolute abundance estimates and length data from the 2006 acoustic survey and previous estimates from the 1997 and 2002 acoustic surveys; revised and updated catch history, unchanged relative abundance estimates from pre-GPS and revised and updated relative abundance estimates from post-GPS standardised CPUE analyses, revised and updated observer length frequencies, unchanged growth parameter estimates. Observed lengths in the commercial fishery were compiled for each area grouped over years (up to five) where enough data were available and the absolute abundance at length from the acoustic surveys was converted to a length frequency using fixed length-weight parameters.

The base case analysis excluded trawl survey relative abundance data and trawl survey length frequencies. Migration was assumed to be unidirectional, meaning fish could move from mid-water to Area 1, or from Area 1 to Area 2 or from Area 2 to Area 3 in one year, but not move back. The migration rate was dependent on age and in one run it was dependent on the current biomass of the area the fish were moving to.

Growth was defined by a mean length at each age class in the model (1 to 70 years) for both sexes combined, and an associated CV (estimated as 0.077 from the age-length data) and was assumed to be constant over the age classes. Growth data for black oreo split into two groups at about age five years corresponding to the pre- and post-settlement life stages. Mean length-at-age was calculated separately for pre-and post-settlement fish and linear interpolation was used to join the curves. For post-settlement fish a local regression with a width spanning 2/3 of the data was fitted to all fish greater than 20 cm and mean length at ages 7 to 70 years was calculated from this fit. For pre-settlement fish a straight line was taken through the origin and the mean length for fish less than 20 cm length. Linear interpolation was used to calculate the mean length at ages 1 to 4 years. Mean length for ages 5 and 6 years was calculated by linear interpolation between those at 4 and 7 years.

The base case model used all data inputs. Additional model runs investigated the effect of using the length data only, the length data and acoustic abundance estimates only, the length data and pre-GPS data only, the length data and the post-GPS data only, one length frequency only, no length data, fixed migration rates and values, and estimating the year class strength using 5 degrees of freedom.

Revised maturity ogive

The previous maturity ogive was estimated in 2002 using von Bertalanffy growth parameters and it also did not take into account the length-at-age distribution. A new analysis used OEO 3A spawning season research trawl survey data from 1986 and 1987 to estimate the maturity rates by age by fitting the length ogive and length frequencies of mature and non-mature fish to that predicted by a simple population model (growth, constant recruitment, fixed *M*, and *F*). Maturity rates were represented by a capped logistic with parameters A_m (rates cap), a50L (age at 50% of A_m), and A50.95 (ages from 50% to 95% level). Errors were estimated by bootstrapping the trawl survey data within strata.

Simulations were used to evaluate the estimation procedure when assumptions were violated. The estimated parameters were (F = 0): A_m = 1, A50 = 37.7 yr, and A50.96 = 0.5 yr. The age ogive was almost knife-edge at 38 yr.

Partition of the main fishery into 3 areas

The main fishery area was split into three areas: a northern area that contained small fish and was generally shallow (Area 1), a southern area that contained large fish in the period before 1993 and which was generally deeper (Area 3), and a transition area (Area 2) that lay between Areas 1 and 3 (Figure 1).

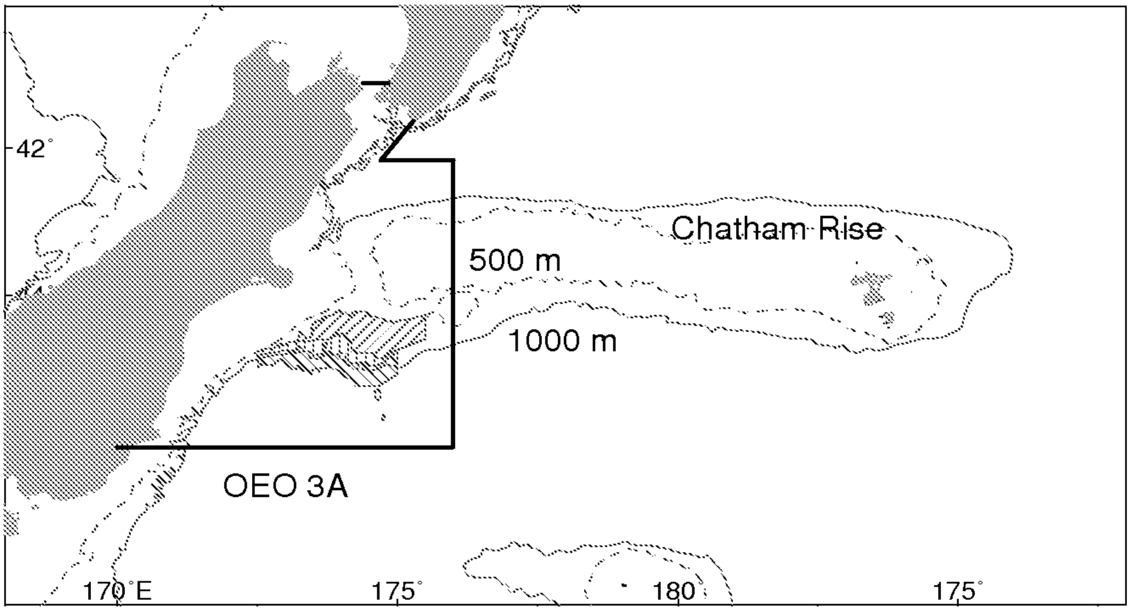


Figure 1: The three spatial areas used in the CASAL model and 2002 acoustic abundance survey. Area 1 at the top with right sloping shading; Area 2 in the middle with vertical shading; Area 3 at the bottom with left sloping shading. The thick dark line enclosed management area OEO 3A.

The boundary between Areas 1 and 2 was defined in terms of the northern edge of the area that enclosed 90% of the total catch from the fishery. Areas 2 and 3 contained most of the fishery while Area 1 consisted of lightly fished and unfished ground. The boundary between Areas 2 and 3 was defined by the 32.5 cm contour in mean fish length for data before 1993 so that the fishery is split into an area containing smaller fish and another that has larger fish. The population outside the main fishery was assumed to follow the same relative dynamics.

4.2.1 Estimates of fishery parameters and abundance

Catches by area

Catches were partitioned into the three areas by scaling up the estimated catch of black oreo from each area to the total reported catch (see Tables 2 and 3 in the Fishery Summary section at the beginning of the Oreos report) and are given in Table 1.

Table 1: Black oreo catch (t) for each fishing year in the three spatial model areas, rounded to the nearest 10 t.

Year	Total	Area 1	Area 2	Area 3	Year	Total	Area 1	Area 2	Area 3
1972-73	†3 440	110	2 010	1 320	1990-91	4 770	890	2 310	1 580
1973-74	†3 800	130	2 220	1 460	1991-92	3 450	300	1 290	1 870
1974-75	†5 100	170	2 970	1 960	1992-93	4 960	230	2 810	1 920
1975-76	†1 260	40	730	480	1993-94	4 160	340	2 510	1 320
1976-77	†3 880	130	2 260	1 490	1994-95	2 400	120	1 560	720
1977-78	†5 750	190	3 350	2 210	1995-96	3 760	200	2 530	1 030
1978-79	720	20	420	270	1996-97	3 750	450	2 190	1 110
1979-80	5 740	430	2 670	2 650	1997-98	1 600	170	590	840
1980-81	12 640	80	8 260	4 300	1998-99	3 290	160	2 450	680
1981-82	11 460	100	6 400	4 960	1999-00	4 070	160	2 780	1 120
1982-83	8 290	510	4 940	2 840	2000-01	2 960	100	2 010	850

Table 1 [Continued].

Year	Total	Area 1	Area 2	Area 3	Year	Total	Area 1	Area 2	Area 3
1983-84	7 410	300	4 200	2 910	2001-02	2 250	60	1 530	660
1984-85	3 930	150	1 510	2 270	2002-03	1 660	100	1 260	300
1985-86	2 190	10	920	1 260	2003-04	1 600	250	840	500
1986-87	4 030	30	1 970	2 020	2004-05	1 600	80	1 040	490
1987-88	3 140	40	1 940	1 160	2005-06	1 890	60	1 480	350
1988-89	3 230	170	2 490	570	2006-07	1 770	50	970	740
1989-90	2 830	620	1 050	1 160					

† Soviet catch, assumed to be mostly from OEO 3A and to be 50:50 black oreo: smooth oreo.

Observer length frequencies by area

Catch at length data collected by observers in Areas 1, 2, and 3 were extracted from the obs_lfs database. Within each area, groups of years were identified where each group spanned no more than five years. This procedure aimed to get adequate sample sizes to derive combined length frequencies and to use as much of the data as possible. Only one sample, from Area 1 in 1995-96, was not included (Table 2). Derived length frequencies for each group were calculated from the sample length frequencies weighted by the catch weight of each sample.

Research acoustic survey length frequencies by area

The 1997, 2002 and new 2006 acoustic survey abundance at length data were converted to a length frequency using the combined sexes fixed length-weight relationship (“unsexed” in Table 1, Biology section above) to convert the abundance to numbers at length. Lengths below 25 cm and greater than 38 were pooled, Table 3.

Table 2: Number of observer commercial tows where black oreo was measured for length frequency. Excluded tows had less than 30 fish measured (13), extreme mean lengths (2) and missing catch information (3). -, no data.

Year	Number of tows in the length frequency					
	Area 1	Group no.	Area 2	Group no.	Area 3	Group no.
1978-79	-	-	-	-	-	-
1979-80	-	-	9	1	35	1
1980-81	-	-	-	-	-	-
1981-82	-	-	-	-	-	-
1982-83	-	-	-	-	-	-
1983-84	-	-	-	-	-	-
1984-85	-	-	-	-	-	-
1985-86	-	-	-	-	1	2
1986-87	-	-	2	2	6	2
1987-88	-	-	3	2	6	2
1988-89	3	1	32	2	7	2
1989-90	8	1	9	2	2	3
1990-91	1	1	5	2	8	3
1991-92	-	-	-	-	11	3
1992-93	-	-	-	-	-	-
1993-94	-	-	22	3	4	4
1994-95	-	-	-	3	6	4
1995-96	1	-	3	3	3	4
1996-97	-	-	1	3	1	4
1997-98	13	2	-	-	7	4
1998-99	2	2	-	-	1	5
1999-00	2	2	52	4	57	5
2000-01	1	2	83	4	47	5
2001-02	-	-	18	4	14	5
2002-03	-	-	12	4	-	-
2003-04	2	3	18	-	-	-
2004-05	9	3	1	5	-	-
2005-06	1	3	7	5	-	-
2006-07	4	3	32	5	-	-

Absolute abundance estimates from the 1997, 2002, and 2006 acoustic surveys

Absolute estimates of abundance for black oreo are available from three acoustic surveys of oreos carried out from 10 November to 19 December 1997 (TAN9713), 25 September to 7 October 2002 (TAN0213), and 17-30 October 2006 (TAN0615). The 1997 survey covered the “flat” with a series of random north-south transects over six strata at depths of 600-1200 m. Seamounts were also sampled using parallel and “starburst” transects. Targeted and some random (background) trawling was carried out to identify targets and to determine species composition. The 2002 survey was limited to flat ground with 77 acoustic transect and 21 mark identification tows completed. The 2006 survey was very similar to the 2002 survey and covered the flat with 78 transects and 22 tows. The estimated total abundance (immature plus mature) for each area is shown in Table 4.

Table 3: Research length frequency proportions for the model area for the 1997, 2002, and 2006 acoustic surveys.

			1997			2002			2006
Length (cm)	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
25	0.015	0.013	0.009	0.022	0.016	0.008	0.009	0.017	0.015
26	0.035	0.027	0.019	0.039	0.030	0.013	0.026	0.035	0.032
27	0.113	0.061	0.029	0.051	0.038	0.018	0.066	0.073	0.055
28	0.165	0.090	0.038	0.085	0.062	0.029	0.118	0.105	0.077
29	0.153	0.104	0.064	0.117	0.091	0.044	0.152	0.143	0.113
30	0.143	0.105	0.065	0.139	0.119	0.060	0.175	0.153	0.132
31	0.131	0.119	0.089	0.123	0.122	0.086	0.156	0.157	0.154
32	0.102	0.121	0.105	0.137	0.133	0.127	0.117	0.136	0.169
33	0.046	0.094	0.098	0.112	0.123	0.141	0.073	0.089	0.119
34	0.041	0.086	0.097	0.065	0.084	0.138	0.059	0.056	0.076
35	0.029	0.058	0.083	0.054	0.064	0.100	0.032	0.026	0.037
36	0.015	0.043	0.091	0.021	0.052	0.104	0.014	0.009	0.014
37	0.006	0.037	0.080	0.015	0.025	0.049	0.001	0.001	0.004
38	0.006	0.042	0.131	0.020	0.041	0.083	0.003	0.001	0.003

Table 4: Total (immature plus mature) black oreo abundance estimates (t) for the 1997, 2002, and 2006 acoustic surveys for the three model areas in OEO 3A.

Abundance (CV %)	Area 1	Area 2	Area 3	Total
1997	148 000 (29)	10 000 (26)	5240 (25)	163 000 (26)
2002	43 300 (31)	15 400 (27)	4710 (38)	64 000 (22)
2006	56 400 (37)	16 400 (30)	5880 (34)	78 700 (30)

Relative abundance estimates from standardised CPUE analysis

Standardised CPUE indices were obtained for each area. Because of the apparent changes in fishing practice attributable to the introduction of GPS, the data were split into pre- and post-GPS series. There are no new pre-GPS data or analyses so the indices used in the 2004 assessment are unchanged. There were major changes in the fishery from 1998-99 to 2001-02 when there were TACC reductions and the start of a voluntary industry catch limit on smooth oreo (1998-99) so two new post-GPS series were developed. The first of these was from 1992-93 to 1997-98 (early series) and the second was from 2002-03 to 2006-07 (late series) with data from the intervening years ignored. The catch and effort data were restricted to all tows that targeted or caught black oreo in OEO 3A up to and including the 2006-07 fishing year. Data were restricted to the spatial analysis study area and were included in the analyses if there were at least three years with more than 50 catches of black oreo. Data were excluded if only one vessel caught 80% or more of the black oreo catch in a year.

The basic analysis used a two-part model which separately analysed the tows that caught black oreo using a linear regression applied to log-transformed data, termed the log-linear regression (positive catch regression), and a binomial part which used a Generalised Linear Model with a logit link for the proportion of successful tows (zero catch regression). The log-linear and binomial index values for each year were multiplied together to give a combined index. The variables considered in the analyses included year, latitude, longitude, depth, season, time, target species, vessel, sun altitude and moon phase. The modified model incorporated an interaction term for year and area that enabled the CPUE from each of the three areas to be analysed. The method gave a unique index for each year by taking the means of the model predicted values for each combination of year and area for the model with a fishing year-area interaction term.

The following analyses were performed:

1. Analysis for area 1 used a single part model only (log-linear regression). No binomial model analysis was required because there were very few zero tows.

2. Analysis with year/area interaction was applied to Areas 2 and 3 for pre- and post-GPS data separately. Two part (log-linear and binomial) models were employed for the pre-GPS series. The single part (log-linear) model was used for the post-GPS series because there was very little post-GPS target fishing for black oreo and therefore very few zero catch tows.

The indices and CV estimates are in Table 5.

Table 5: OEO 3A black oreo pre-GPS and post-GPS time series of standardised catch per unit effort indices and jack-knife CV estimates (%) that were used in the base case.. -, no estimate.

Fishing	Pre-GPS						Post-GPS					
Year	Area1		Area2		Area3		Area1		Area2		Area3	
	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1979-80	-	-	1.45	39	1.52	125	-	-	-	-	-	-
1980-81	-	-	1.84	17	2.55	15	-	-	-	-	-	-
1981-82	-	-	1.71	22	2.15	9	-	-	-	-	-	-
1982-83	-	-	1.41	8	1.80	14	-	-	-	-	-	-
1983-84	-	-	0.99	8	1.04	19	-	-	-	-	-	-
1984-85	-	-	0.95	27	0.99	12	-	-	-	-	-	-
1985-86	-	-	0.63	31	0.66	33	-	-	-	-	-	-
1986-87	-	-	0.81	22	0.88	36	-	-	-	-	-	-
1987-88	-	-	0.45	20	0.49	23	-	-	-	-	-	-
1988-89	-	-	0.72	21	0.23	44	-	-	-	-	-	-
1989-90	-	-	-	-	-	-	-	-	-	-	-	-
1990-91	-	-	-	-	-	-	-	-	-	-	-	-
1991-92	-	-	-	-	-	-	-	-	Early series			
1992-93	-	-	-	-	-	-	-	-	1.62	14	2.46	20
1993-94	-	-	-	-	-	-	-	-	1.17	17	1.20	15
1994-95	-	-	-	-	-	-	-	-	0.96	13	0.82	17
1995-96	-	-	-	-	-	-	-	-	0.89	15	0.68	22
1996-97	-	-	-	-	-	-	-	-	1.06	18	0.96	17
1997-98	-	-	-	-	-	-	-	-	0.58	47	0.64	63
1998-99	-	-	-	-	-	-	-	-	-	-	-	-
1999-00	-	-	-	-	-	-	-	-	-	-	-	-
2000-01	-	-	-	-	-	-	-	-	-	-	-	-
2001-02	-	-	-	-	-	-	Late series					
2002-03	-	-	-	-	-	-	0.72	42	1.05	21	0.91	44
2003-04	-	-	-	-	-	-	1.06	31	1.19	19	1.05	27
2004-05	-	-	-	-	-	-	1.71	38	0.83	27	0.88	25
2005-06	-	-	-	-	-	-	1.23	37	1.11	22	0.88	41
2006-07	-	-	-	-	-	-	0.63	83	0.86	22	1.34	25

4.2.2 Biomass estimates

A MCMC chain of 1500 was used which was derived from systematically sub-sampling every 1000th point after a burn-in of 500 iterations. The chain appeared to have converged for the main parameters, but a second chain gave a shift in the distribution of the virgin biomass of about 3000 t. However, this difference is only about 4 % of the estimated median. The process errors in the acoustic and observer length frequencies were also set to their MPD values. Base case biomass estimates (medians of the posterior distribution) are in Table 6. The vulnerable biomass estimates are the same as the total biomass estimates in Areas 2 plus 3.

Table 6: Base case biomass estimates (rounded to nearest 100 t). Vulnerable biomass is the sum of the total biomass in Areas 2 and 3. All estimates are mid-year. - not estimated.

	Area 1			Area 2			Area 3			Total		
Biomass	B_0	B_{2007}	B_{2007}/B_0	B_0	B_{2007}	B_{2007}/B_0	B_0	B_{2007}	B_{2007}/B_0	B_0	B_{2007}	B_{2007}/B_0
Mature	20 200	18 700	92	24 100	5 180	22	42 900	1 190	3	87 400	25 200	29
Vulnerable	-	-	-	-	-	-	-	-	-	86 600	15 000	17
Total	79 500	74 100	93	39 200	12 800	33	47 300	2 130	5	166 000	89 200	54

The fits of the abundance estimates to the MPD solution of the base case are generally good (Figure 2), but they do not fit to the last two acoustic estimates in Area 3 or the first two in Area 1.

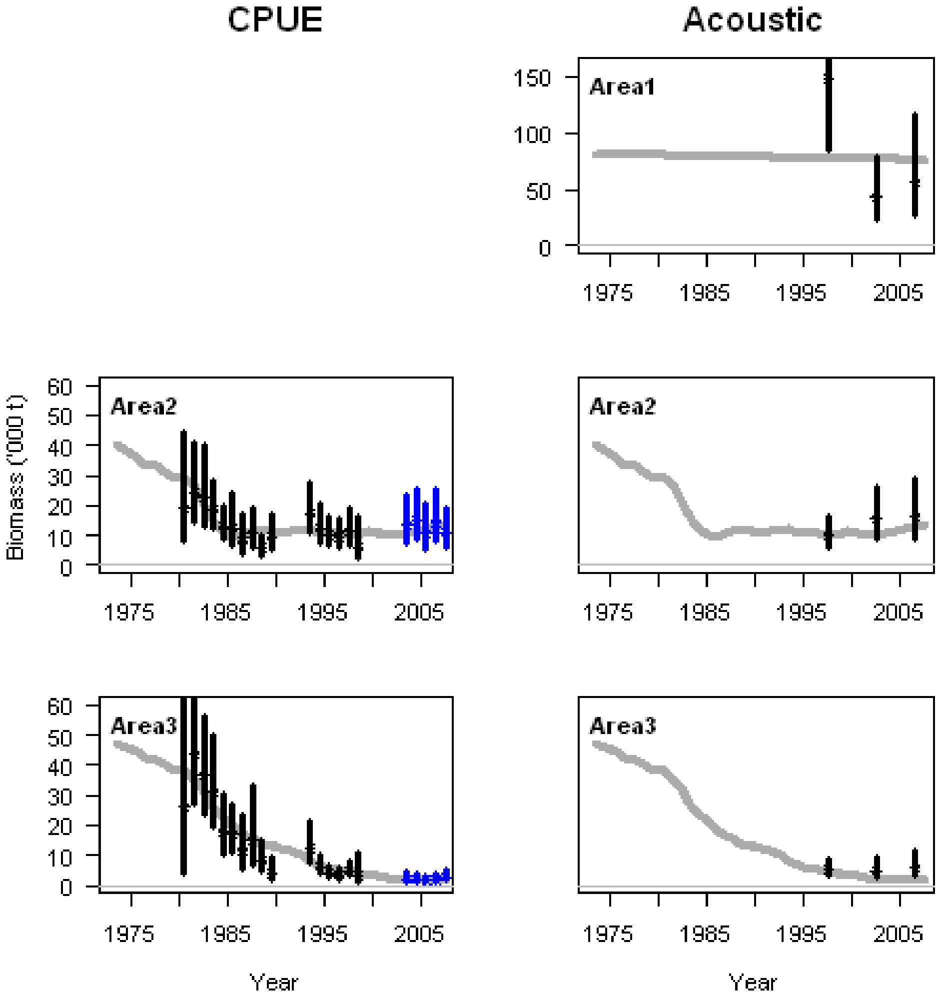


Figure 2: The fit of the abundance observations (CPUE and the absolute acoustic estimates) for each area to the predicted total biomass trajectories for the 2008 assessment of black oreo in OEO 3A (MPD solution, base case). The vertical lines are the 95% confidence intervals. The CPUE series were adjusted by their estimated catchability so that they are in absolute biomass units.

Sensitivity of the model to data sources

Except when no LF data were used, biomass estimates from all the sensitivity runs were not substantially different from the base case, Table 7.

Table 7: Estimated mature $B_{2001\text{-}02}/B_0$ (%) and $B_{2006\text{-}07}/B_0$ (%) for the MPD sensitivity runs. Base case in bold.

RUN1	Post-GPS CPUE series are not split into two
RUN2 (Base case)	**All data**
RUN3	Density dependent migration allowed
ACO.only	Data restricted to acoustic abundances + all LF data
preCPUE.only	Data restricted to pre-GPS CPUE series + all LF data
postCPUE.only	Data restricted to post-GPS CPUE + all LF data
LFs.only	Data restricted to LF data only
Recruits	Estimate recruit deviates
OneLF	Restrict LF data to one year
No LF	No LF data used
FixMig	No LF data used, but migration and selectivities fixed to their estimates from the base case
RUN1 OLD MATURITY	Run1 using previous maturity ogive.

Table 7 [Continued].

Area	RUN1	**RUN2**	RUN3	ACO.only	preCPUE.only	postCPUE.only	LFs.only	Recruits	OneLF	No LF	FixMig	RUN1 OLD MATURITY
TOTAL 2001-02	31	**30**	29	29	28	31	31	30	30	14	32	48
TOTAL 2006-07	32	**31**	30	31	29	32	32	32	31	17	34	50
Area 1 2001-02	93	**93**	89	93	93	93	93	94	93	93	93	95
Area 1 2006-07	93	**93**	88	93	92	93	93	94	93	93	93	95
Area 2 2001-02	17	**16**	18	15	14	10	10	23	18	19	18	25
Area 2 2006-07	22	**21**	23	21	20	17	17	30	25	25	23	32
Area 3 2001-02	4	**3**	3	3	1	1	1	2	5	6	5	6
Area 3 2006-07	4	**3**	4	3	1	1	1	4	5	6	5	6

4.2.4 Other factors

Yield estimates would be under-estimated if reported catch was less than the actual catch. Low reported catch could be caused by discarding of unwanted and small fish, particularly black oreo in the early days of the fishery and also by lost bags. Estimates of discards of oreos were made for 1994-95 and 1995-96 from MFish observer data and were 207 and 270 t, respectively. Estimates of discards at other times were not made but may have been substantial for black oreo in the mid 1980s. Yield estimates may also be under-estimated if there was a change over time in the proportion of oreo catch that was not reported.

4.3 Smooth oreo

2009 assessment

The stock assessment analyses were conducted using the CASAL age-structured population model employing Bayesian statistical techniques. The 2005 assessment was updated by including five more years of catch, CPUE and observer length data, and used two new series of post-GPS standardised CPUE, one before and the second after major TACC and catch limit changes. The modelling took account of the sex and maturity status of the fish and treated OEO 3A as a single smooth oreo fishery, i.e., no sub-areas were recognised. The base case model used the 1997 absolute acoustic abundance estimate, pre-GPS and early and late post-GPS series of standardised CPUE indices, and the mean natural mortality estimate (0.063 yr^{-1}). Acoustic and observer length frequencies were used in a preliminary model run to estimate selectivity and the base case fixed these selectivity estimates but did not use the length frequencies. Other cases investigated the sensitivity of the model to data sources including: use of the upper and lower 95% confidence interval values for estimates of natural mortality (0.042-0.099 yr^{-1}); use of only the left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model.

4.3.1 Estimates of fishery parameters and abundance

Catch history

Table 8: Reconstructed catch history (t)

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1972-73	†3 440	1981-82	1 288	1990-91	5 054	1999-00	1 789
1973-74	†3 800	1982-83	2 495	1991-92	6 622	2000-01	1 621
1974-75	†5 100	1983-84	3 979	1992-93	4 334	2001-02	1 673
1975-76	†1 260	1984-85	4 351	1993-94	4 942	2002-03	1 412
1976-77	†3 880	1985-86	3 142	1994-95	4 199	2003-04	1 254
1977-78	†5 750	1986-87	3 190	1995-96	4 022	2004-05	1 457
1978-79	650	1987-88	5 905	1996-97	3 239	2005-06	1 445
1979-80	5 215	1988-89	6 963	1997-98	4 733	2006-07	1 306
1980-81	2 196	1989-90	6 459	1998-99	2 474	2007-08	1 526

† Soviet catch, assumed to be mostly from OEO 3A and to be 50 : 50 black oreo : smooth oreo.

The estimated catches were scaled up to the total reported catch (see Tables 2 and 3 in the Fishery Summary section at the beginning of the Oreos report) and are given in Table 8.

Observer length frequencies

Observer length data were extracted from the observer database. These data represent proportional catch at length and sex. All length samples were from the CPUE study area (see Figure 4). Only samples where 30 or more fish were measured, and the catch weight and a valid depth were recorded, were included in the analysis. Data from adjacent years were pooled because of the paucity of data in some years. The pooled length frequencies were applied in the model at the year that the median observation of the grouped samples was taken (Table 9).

Table 9: Observer length frequencies; numbers of length samples (tows sampled), number of fish measured, groups of pooled years, and the year that the length data were applied in the stock assessment model. -, not applicable.

Year	Number of length samples	Number of fish measured	Year group code	Year the grouped data were applied
1979-80	32	3 499	1	Applied
1980-81	0	0	-	-
1981-82	0	0	-	-
1982-83	0	0	-	-
1983-84	0	0	-	-
1984-85	0	0	-	-
1985-86	1	106	2	-
1986-87	4	387	2	-
1987-88	10	1 300	2	Applied
1988-89	14	1 512	2	-
1989-90	0	0	-	-
1990-91	26	2 978	3	Applied
1991-92	9	919	3	-
1992-93	0	0	-	-
1993-94	13	1 365	4	Applied
1994-95	7	752	4	-
1995-96	2	207	4	-
1996-97	3	365	5	-
1997-98	13	1 720	5	-
1998-99	5	770	5	-
1999-00	77	7 595	5	Applied
2000-01	93	9 389	6	Applied
2001-02	20	3 030	7	Applied
2002-03	14	1 427	8	Applied
2003-04	4	321	8	-
2004-05	9	840	8	-
2005-06	26	3 207	9	Applied
2006-07	2	205	9	-
2007-08	8	816	9	-

Length frequency data from the 1997 acoustic survey

Length data collected during the 1997 survey were used to generate a population length frequency by sex. A length frequency was generated from the trawls in each mark-type and also for the seamounts. These frequencies were combined using the fraction of smooth oreo abundance in each mark-type. The overall frequency was normalised over both male and female frequencies so that the sum of the frequencies over both sexes was 100%. The CV for each length class was given by the regression, log(CV) = 0.86 + 8.75/log(proportion). This regression was estimated from the CVs obtained by bootstrapping the data and provides a smoothed estimate of the CVs. The estimated length frequency is in Figure 3.

Absolute abundance estimates from the 1997 acoustic survey

Absolute estimates of abundance for smooth oreo are available from the acoustic survey on oreos carried out from 10 November to 19 December 1997 (TAN9713) using the same approach as described for OEO 3A black oreo. The abundance estimates used in the 1999 OEO 3A smooth oreo assessment were revised in 2005 using new target strength estimates for smooth oreo, black oreo and a number of bycatch species. The revised estimate was 25 200 t with a CV of 23% (1999 estimate was 35 100 t with CV of 27%). There is uncertainty in the estimates of biomass because the acoustic estimate includes smooth oreo in layers that are a mixture of species for which the acoustic method has potential bias problems.

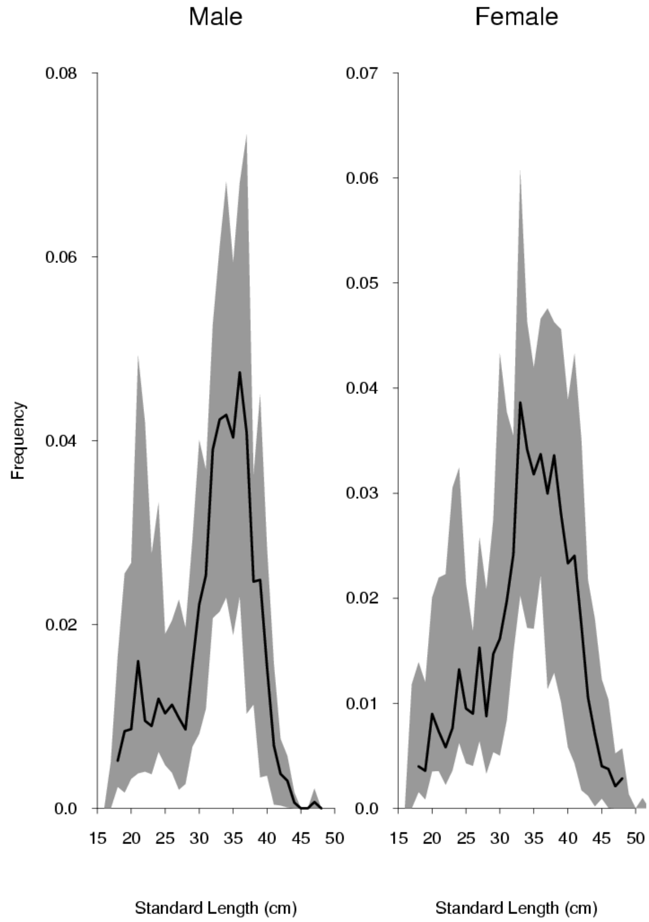


Figure 3: Population length frequency derived from the 1997 acoustic survey data. The bold line is the estimated value and the shaded area is the spread from 300 bootstraps.

Relative abundance estimates from standardised CPUE analysis

The CPUE study area is shown in Figure 4. Three analyses were carried out; a pre-GPS analysis (unchanged from 2005) that included data from 1980-81 to 1988-89 and two new post-GPS analyses that included data from 1992-93 to 1997-98 and 2002-03 to 2007-08. The years from 1998-99 to 2001-02 were not included because a voluntary smooth oreo of catch limit (1400 t) was introduced and substantial oreo TACC reductions were made during that time (6600 to 3100 t). The pre-GPS series trends down, and declines to approximately a third of the initial level over the nine-year period. The early post-GPS trends down but the late post-GPS series trends up and flattens. The base case stock assessment used all three indices (Table 10).

Table 10: CPUE indices by year and jackknife CV (%) estimates from the pre-GPS and the two post-GPS analyses.

	Pre-GPS						Post-GPS	
Year	Index	CV	Year	Index	CV	Year	Index	CV
1980-81	1.00	27	1992-93	1.00	24	2002-03	0.55	23
1981-82	0.82	26	1993-94	0.88	11	2003-04	0.77	22
1982-83	0.72	62	1994-95	0.74	14	2004-05	0.99	22
1983-84	0.59	61	1995-96	0.48	17	2005-06	0.96	31
1984-85	0.72	22	1996-97	0.56	15	2006-07	1.00	20
1985-86	0.61	19	1997-98	0.50	19	2007-08	0.92	21
1986-87	0.46	16						
1987-88	0.42	16						
1988-89	0.26	28						

Fishing Industry members of the Deepwater Fishery Assessment Working Group expressed concern about the accuracy of the historical Soviet catch and effort data (pre-GPS series) and felt that it was inappropriate to use those data in the stock assessment.

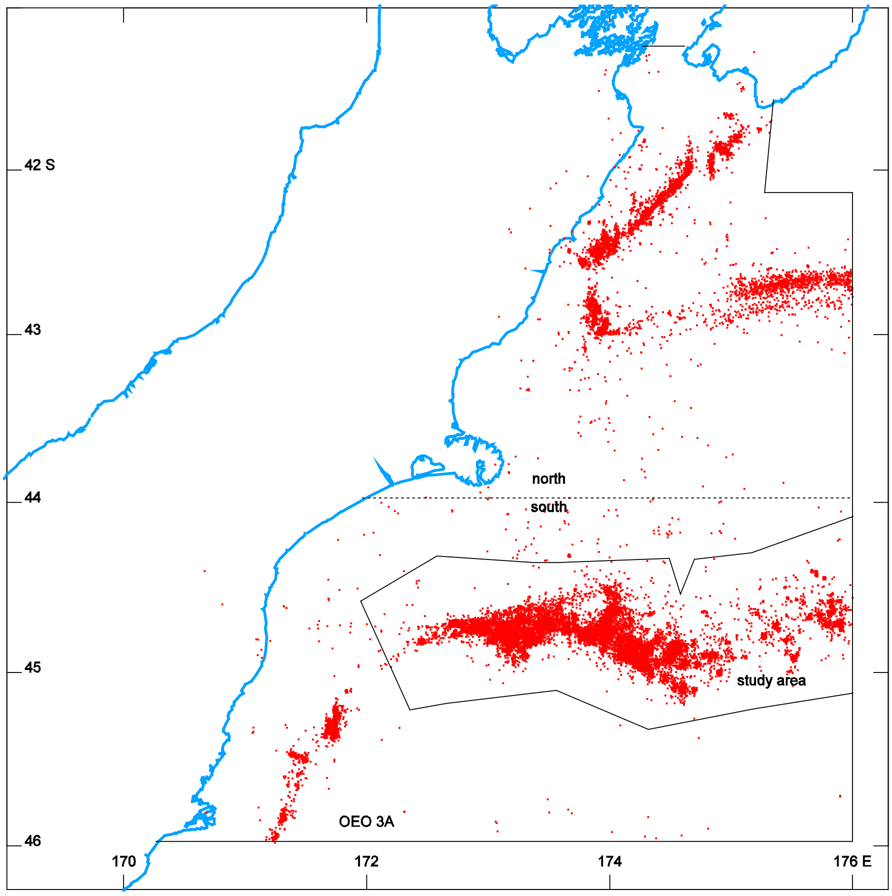


Figure 4: Locations of all tows in OEO 3A with a reported catch of smooth oreo from 1979-80 to 2002-03 (dots). The study area is shown along with the line chosen to split north from south Chatham rise catches.

4.3.2 Biomass estimates

The posterior distributions from the MCMC on the base case are shown in Figure 5. The probability that the current mature biomass (2008-09) and the biomass 5 years out (2013-14) are above 20% B_0 is 1 for both.

Biomass estimates derived from the MCMC are in Table 11. Total mature biomass for 2008-09 was estimated to be 36% of the initial biomass (B_0). Sensitivity case results for the base case using the lower and upper 95% confidence interval value estimates for M gave estimates of current biomass between 26% and 49% of B_0. The sensitivity case that used the left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model gave estimates of current biomass for the mean estimate of M (0.063 yr^{-1}) of 30 % of B_0 while estimates using the lower and upper 95% confidence interval value estimates for M gave estimates of current biomass between 12% and 59% of B_0.

Projections were carried out for 5 years with the current catch limit of 1400 t. The trajectory shows increasing biomass (Figure 5).

4.3.3 Other factors

Because of differences in biological parameters between the species, it would be appropriate to split the current TACC for black oreo and smooth oreo. The WG noted that separate species catch limits are in place to reduce the risk of over- or under-fishing either smooth oreo or black oreo.

The model estimates of uncertainty are unrealistically low. Uncertainties that are not included in the model include:

- the assumption that recruitment is deterministic
- the acoustic index is assumed to be an absolute estimate of abundance

- the selectivity in the base case is fixed at the MPD estimate from the preliminary case where all length data is used
- uncertainty in the estimate of *M*.

In addition, the growth is fixed and known. The WG has previously noted the impact of the different ages of maturity for males and females. Due to the fact that males mature at a much smaller size than females (age at 50% maturity is 18-19 years for males and 25-26 for females), the sex ratio needs to be taken into account when assessing the sustainability of any particular catch level.

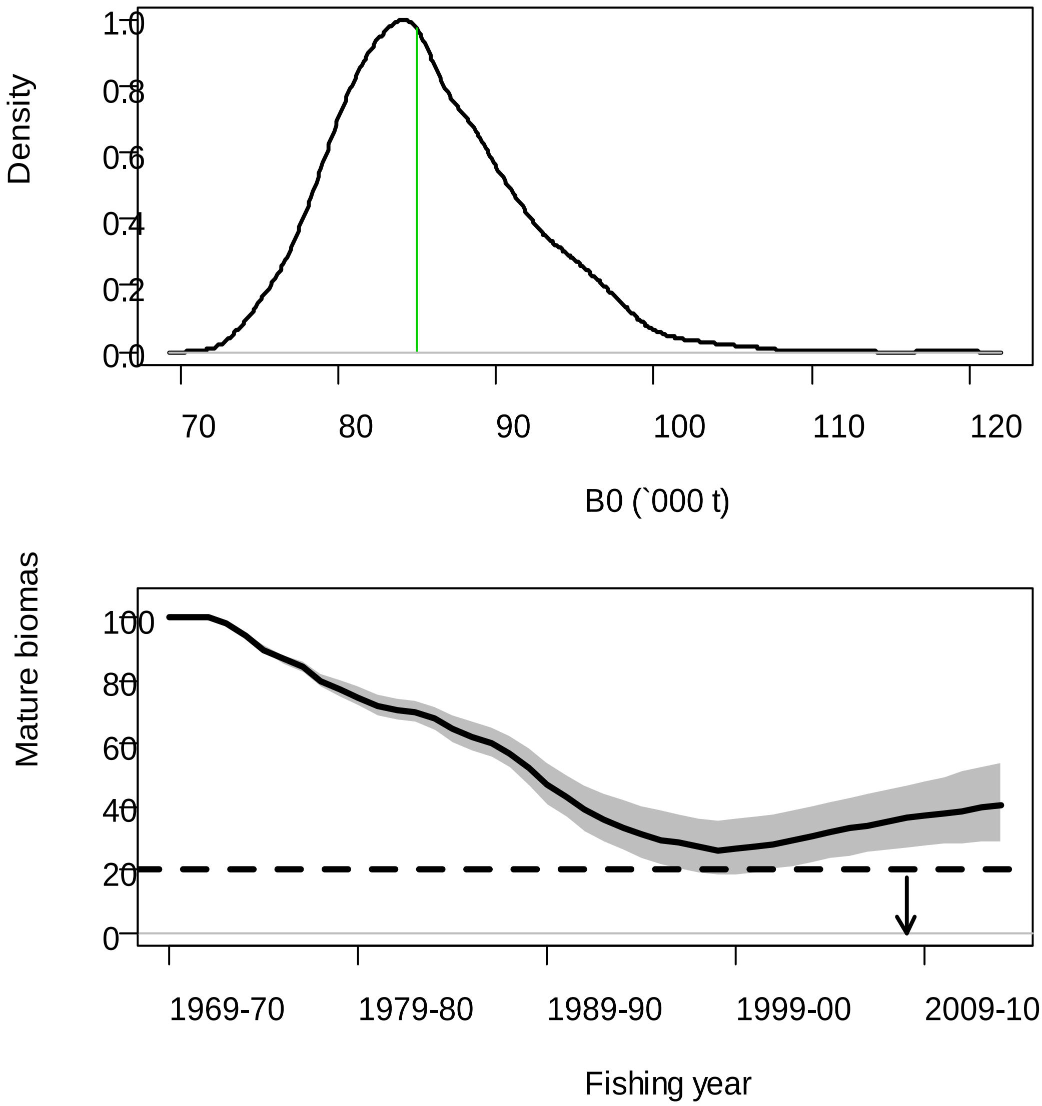


Figure 5: Smooth oreo OEO 3A: posterior distribution for the virgin biomass (top plot) and the mature biomass trajectories as a percentage of virgin biomass (bottom plot) from the MCMC analysis of the "NoLF" case with M = 0.063 (base case). In the top plot, the vertical line is the median of the distribution. In the bottom plot, the grey area is the point-wise 95% confidence intervals of the trajectories and the solid line is the median.

Table 11: Base case (bold) and sensitivity (†) case biomass estimates.

	***M* = 0.063**			†*M* = 0.042			†*M* = 0.099		
	Median	**CI.05**	**CI.95**	Median	CI.05	CI.95	Median	CI.05	CI.95
B_0	**85 000**	**77 300**	**96 500**	97 700	90 100	110 000	68 500	60 300	79 600
B_cur	**30 900**	**22 400**	**43 000**	26 300	18 000	38 800	33 800	25 000	45 500
B_cur(%B_0)	**36**	**29**	**45**	27	20	35	49	41	57

Left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model:

	†*M* = 0.063			†*M* = 0.042			†*M* = 0.099		
	Median	CI.05	CI.95	Median	CI.05	CI.95	Median	CI.05	CI.95
B_0	77 400	74 800	80 200	82 800	81 600	84 200	82 300	76 700	89 200
B_cur	23 100	19 900	26 400	10 200	8 480	12 100	48 800	42 900	56 200
B_cur(%B_0)	30	27	33	12	10	14	59	56	63

5. STATUS OF THE STOCKS

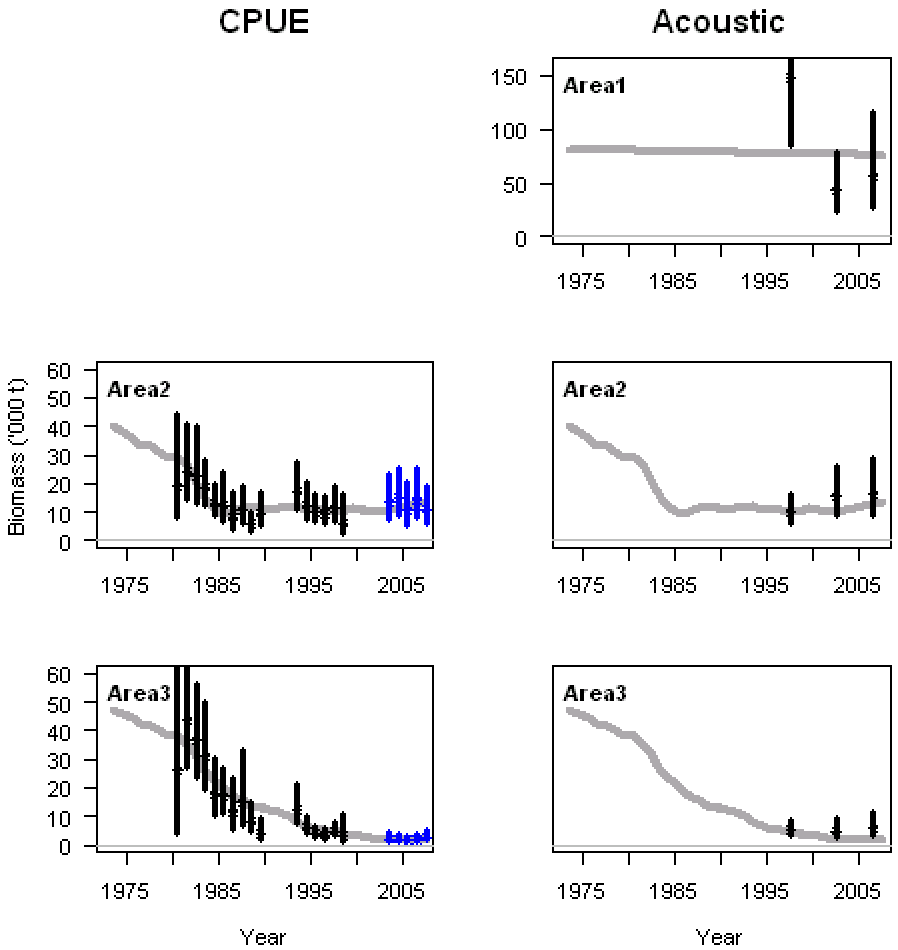
The smooth oreo stock assessment is unchanged from 2009. The black oreo stock assessment is updated with the 2008 assessment.

Stock Structure Assumptions
The two oreo stocks in FMA 3A are assessed separately but managed as a single stock. For both the black and smooth oreo stocks it is assumed there is potential mixing with stocks outside of the OEO3A area.

- **OEO3A (Black Oreos)**

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	One base case
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	For the base case, B_{2007} was estimated to be about 29% B_0; the stock was estimated to be Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	Overall the population was Unlikely (< 40%) to be below the Soft Limit and Unlikely (< 40%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



The fit of the CPUE and acoustic abundance estimates for each area to the predicted total biomass trajectories for the 2007 assessment of black oreo in OEO 3A (MPD solution, base case). The vertical lines are the 95% confidence intervals.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appeared to be stabilising in the latter years of the assessment after significant decline in the late 1980s.
Recent Trend in Fishing Mortality or Proxy	Catch has decreased with TACC since the early 1990s and remained low and relatively constant over the final 7-8 years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2008)	
Stock Projections or Prognosis	None because of uncertainties in the assessment.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology	
Assessment Type	Level 1 - Quantitative Stock Assessment
Assessment Method	Age-structured CASAL spatial model with Bayesian estimation of posterior distributions.
Main data inputs	Updated data - Three acoustic surveys (1997, 2002, 2006), CPUE abundance - Length frequency - Catch history - Estimates/Assumptions of: recruitment, migration from length

	data, growth, *M* New information from: - Pre- and post-settlement growth - Age-dependent migration rates	
Period of Assessment	Latest assessment: 2008	Next assessment: 2012
Changes to Model Structure and Assumptions	- Process error now incorporated for CPUE estimates, acoustic length frequencies and Observer length frequencies. - Length at age CVs now estimated - Recruitment to mid-water assumed to occur at 1 year and then to Area 1 with one-way migration.	
Major Sources of Uncertainty	- Yield estimates from the early period of the fishery may be underestimated with discards of up to 270t calculated - Uncertainty in estimates of natural mortality (*M*) - Recruitment is assumed to be deterministic - Migration rates estimated from length data	

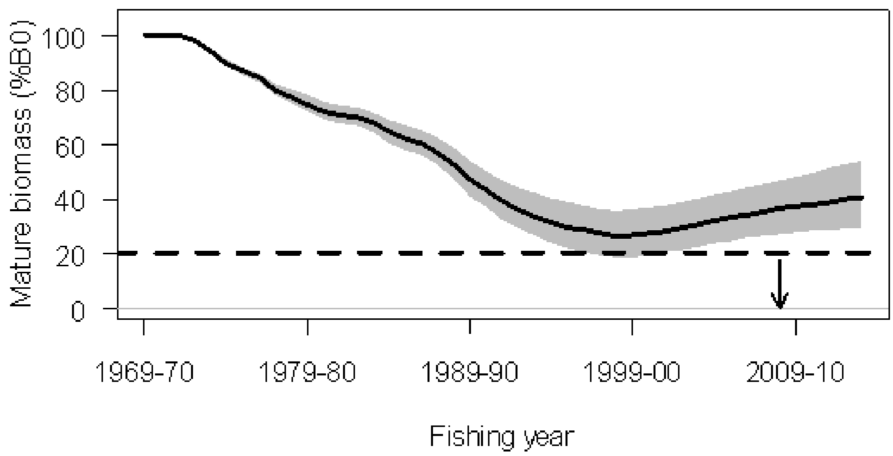
Qualifying Comments
-

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO3A (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	One base case and 5 sensitivity runs
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	For the base case, B_{2009} was estimated at 36% B_0, About as Likely as Not (40-60%) to be at or above the target.
Status in relation to Limits	B_{2009} is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Mature biomass trajectories as a percentage of virgin biomass from the base case. The grey area is the point-wise 95% confidence intervals of the trajectories and the solid line is the median.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is projected to have been increasing since the late 1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2009)		
Stock Projections or Prognosis	The biomass is expected to increase over the next 5 years given the current catch limit of 1400 t.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)	
Assessment Methodology		
Assessment Type	Level 1 - Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- One acoustic absolute abundance estimate (1997) - 3 standardised CPUE indices (1981-82 to 1988-89, 1992-93 to 1997-98, 2002-03 to 2007-08) - Natural mortality estimate (0.063) - Selectivity estimated from acoustic and observer length frequencies New information from previous (2005) assessment: - Updated with additional catch, CPUE, observer length data collected since last assessment - 2 new standardised post-GPS CPUE series	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- The single acoustic index (1997) is assumed to be an absolute estimate of abundance - Sex ratio needs to be taken into account, as males mature at a much smaller size than females. - Recruitment is assumed to be deterministic. - Uncertainty in the estimates of natural mortality (*M*). - Selectivity is fixed in the base case at the MPD estimate from the preliminary study.	

Qualifying Comments
-

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

6. FOR FURTHER INFORMATION

Coburn R.P., Doonan I.J., McMillan P.J. 1999. Black oreo abundance indices from standardised catch per unit of effort data for OEO 3A. New Zealand Fisheries Assessment Research Document 1999/32. 18p.

Coburn R.P., Doonan I.J., McMillan P.J. 2006. Smooth oreo OEO 3A abundance estimates from standardised catch per unit of effort data, 1979-80 to 2002-03. New Zealand Fisheries Assessment Report 2006/35. 38p.

Coburn R.P., McMillian P.J., Gilbert D.J. 2007. Inputs for a stock assessment of smooth oreo, Pukaki Rise (part of OEO 6). New Zealand Fisheries Assessment Report 2007/23. 32p

Cordue P.L. 1996. A model-based method for bounding virgin biomass using a catch history, relative biomass indices, and ancillary information. New Zealand Fisheries Assessment Research Document 1996/8. 48p.

Doonan I.J., McMillian P.J., Hart A.C. 2008. Aeging of smooth oreo otoliths for stock assessment. New Zealand Fisheries Assessment Report 2008/08. 29p.

Doonan I.J., McMillan P.J. 2001. A non-parametric age selectivity ogive for OEO 3A black oreo for 2001-02. New Zealand Fisheries Assessment Report 2001/40. 17p.

Doonan I.J., Coburn R.P., McMillan P.J., Hart A.C. 2004. Assessment of OEO 3A black oreo for 2002-03. New Zealand Fisheries Assessment Report 2004/52. 54p.

Doonan I.J., McMillan P.J., Coburn R.P., Hart A.C. 2003. Assessment of OEO 4 smooth oreo for 2002-03. New Zealand Fisheries Assessment Report 2003/50. 55p.

Doonan I.J., McMillan P.J., Hart A.C., Coombs R.F. 2003. Smooth oreo abundance estimates from the October-November 2001 acoustic survey of the south Chatham Rise (OEO 4). New Zealand Fisheries Assessment Report 2003/26. 21p.

Doonan I.J., McMillan P.J., Coburn R.P., Hart A.C. 1999a. Assessment of OEO 3A smooth oreo for 1999-2000. New Zealand Fisheries Assessment Research Document 1999/45. 21p.

Doonan I.J., McMillan P.J., Coburn R.P., Hart A.C. 1999b. Assessment of OEO 3A black oreo for 1999-2000. New Zealand Fisheries Assessment Research Document 1999/52. 30p.

Doonan I.J., Coombs R.F., McMillan P.J., Dunn A. 1998. Estimate of the absolute abundance of black and smooth oreo in OEO 3A and 4 on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project OEO9701. 47p.

Doonan I.J., McMillan P.J., Coburn R.P., Hart A.C., Cordue P.L. 1995. Assessment of smooth oreo for 1995. New Zealand Fisheries Assessment Research Document 1995/12. 31p.

Doonan I.J., McMillan P.J., Coburn R.P., Hart A.C. 1997. Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1997. New Zealand Fisheries Assessment Research Document 1997/21. 26p.

Doonan I.J., McMillan P.J., Coburn R.P., Hart A.C. 1996. Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1996. New Zealand Fisheries Assessment Research Document 1996/17. 21p.

Francis R.I.C.C. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27p.

McKenzie A. 2007. Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6). New Zealand Fisheries Assessment Report 2007/34. 27p.

McMillan P.J., Doonan I.J., Hart A.C., Coburn R.P. 1998. Oreo stock assessment. Final Research Report for Ministry of Fisheries Research Project OEO9702. 16p.

McMillan P.J., Hart A.C. 1991. Assessment of black and smooth oreos for the 1991-92 fishing year. New Zealand Fisheries Assessment Research Document 1991/10. 29p.

Smith M.H., Doonan I.J., McMillan P.J., Hart A.C. 2006. Black oreo abundance estimates from the September-October 2002 acoustic survey of the south Chatham Rise (OEO 3A). New Zealand Fisheries Assessment Report 2006/33. 20p.

OREOS – OEO 4 BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESMENT

4.1 Introduction
In 2012, a new stock assessment for smooth oreos in OEO 4 was presented.

4.2 Black oreo
Investigations were carried out in 2009 using age-based single sex single step preliminary models in CASAL. The data used in these models were four standardised CPUE indices (pre and post GPS in the east and west), and observer length frequencies. Growth and maturity were also estimated in some of the runs.

4.2.1 Estimates of fishery parameters and abundance

Absolute abundance estimates from the 1998 acoustic survey
Absolute estimates of abundance were available from an acoustic survey on oreos which was carried out from 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812). Transects on flat ground were surveyed to a stratified random design and a random sample of seamounts were surveyed with either a random transect (large seamounts) or a systematic "star" transect design. For some seamounts the flat ground nearby was also surveyed to compare the abundance of fish on and near the seamount either by extending the length of the star transects or by extra parallel transects. Acoustic data were collected concurrently for flat and seamounts using both towed and hull mounted transducers. The OEO 4 survey covered 59 transects on the flat and 29 on seamounts. A total of 95 tows were carried out for target identification and to estimate target strength and species composition. *In situ* and swimbladder samples for target strength data were collected and these have yielded revised estimates of target strength for both black oreo and smooth oreo.

Acoustic abundance estimates for recruit black oreo from seamounts and flat for the whole of OEO 4 are in Table 1. About 59% of the black oreo abundance came from the background mark-type. This mark-type is not normally fished by the commercial fleet and this implies that the abundance estimate did not cover the fish normally taken by the fishery. In addition the scaling factor to convert the acoustic area estimate to the trawl survey area estimate was 4.3, i.e., the acoustic survey area only had about 23% of the abundance. The magnitude of this ratio suggests that the size of the area surveyed was borderline for providing a reliable abundance estimate.

Relative abundance estimates from standardised CPUE analyses – 2009 analysis
The CPUE analysis method involved regression based methods on the positive catches only. Sensitivities were run where the zero catch tow and the positive catch tow data were analysed separately to produce positive catch and zero catch indices. All data were included, whether they were target or bycatch fisheries, with the target offered to the model (and not accepted).

Table 1: OEO 4 recruit black oreo seamount, flat, and total acoustic abundance estimates (t) and recruit CV (%) based on knife-edge recruitment (23 years).

	Abundance (t)	CV (%)
Seamount	127	91
Flat	13 800	56
Total	13 900	55

The best data-split was investigated using the Akaike Information Criteria (AIC) on a number of potential regressions. Four indices were subsequently used, pre- and post-GPS in the east and west areas respectively. These two areas are very distinct: the west consists of flat fishing and the east of hill fishing, the west area was fished 10 years prior to the east, and there has been a move by the fishery since the early 1990s from the west to the east. However, despite of all these differences, the two series present almost identical patterns of decline in relative standardised CPUEs from the time their exploitation started in earnest (1980 in the west and 1992 in the east) which would suggest that for this fishery CPUE might be a reasonable index of abundance (because less influenced by technology, fishing patterns, hills or flats etc).

The standardised CPUE series and c.v.s are described in Table 2. Over comparable time periods and data sets, the trends from the updated series were similar to those from the 2000 analyses (Coburn *et al.* 2001). The west CPUE reduced to between 5% of 1980 value and 15% of 1981 value by 1990. The post-GPS west series is either flat or slightly increasing. The east CPUE reduced to 4% of 1984 value and 21% of 1985 value by 1990 even though catches were low. The post-GPS east series showed a further steep initial decline with total reduction to 15% of 1993 values by 2008.

Table 2: OEO 4 black oreo standardised CPUE analyses in 2009 (expressed in t / tow).

	pre-GPS east		pre-GPS west			post-GPS east		post-GPS west	
fishing year	index	cv	index	cv	fishing year	index	cv	index	cv
1980			8.97	0.17	1993	0.71	0.15	0.73	0.41
1981			4.00	0.11	1994	0.63	0.13	0.45	0.32
1982			2.24	0.10	1995	0.31	0.15	0.41	0.31
1983			2.20	0.09	1996	0.21	0.15	0.28	0.27
1984	0.47	0.95	1.54	0.10	1997	0.24	0.12	0.61	0.27
1985	0.41	0.28	1.51	0.07	1998	0.20	0.11	0.45	0.23
1986	0.38	0.32	1.28	0.10	1999	0.16	0.12	0.46	0.23
1987	0.65	0.30	0.67	0.10	2000	0.17	0.12	0.68	0.25
1988	0.10	0.18	0.54	0.13	2001	0.14	0.08	0.62	0.24
1989	0.02	0.20	0.48	0.12	2002	0.18	0.07	0.47	0.29
					2003	0.13	0.06	0.49	0.24
					2004	0.13	0.06	0.93	0.24
					2005	0.14	0.07	0.91	0.26
					2006	0.13	0.07	0.68	0.26
					2007	0.12	0.07	1.00	0.27
					2008	0.10	0.09	0.88	0.24

Relative abundance estimates from trawl surveys

The estimates, and their CVs, from the four standard *Tangaroa* south Chatham Rise trawl surveys are treated as relative abundance indices (Table 3).

Table 3: OEO 4 black oreo research survey abundance estimates (t). *N* is the number of stations. Estimates were made using knife-edge recruitment set at 33 cm TL. Previously knife-edge recruitment was set at 27 cm and estimates of abundance based on that value are also provided for comparison.

Year	Mean abundance		CV (%)	*N*
	27 cm	33 cm		
1991	34 407	13 065	40	105
1992	29 948	12 839	46	122
1993	20 953	6 515	30	124
1995	29 305	9 238	30	153

Observer length frequencies
Observer length frequencies were available for about 20% of the yearly catch from 1989 to 2008. Analyses conducted on these data indicated they were not representative of the spatial spread of the fishery. When stratified by depth, the length frequencies had double-modes, centred around 28 cm and 38 cm, with inconsistent trends in the modes between years. Alternative stratification by subarea, hill, etc, did not resolve the problem; some tows showed bimodality. These patterns in length frequencies were an issue because the yearly shifts in length frequencies and double mode cannot be representative of the underlying fish population since black oreo is a slow growing long-lived fish. They are more likely linked with discrete spatial sub-groups of the population.

A similar double mode was reported for some strata in the same area from the 1994 Tangaroa trawl survey (Tracey & Fenaughty 1997). It is likely that there is further spatial stock structure that is currently unaccounted for.

4.2.2 Biomass estimates
The 2009 stock assessment of OEO 4 black oreo was inconclusive as assessment models were unable to represent the observer length frequency structure, and were considered unreliable. The CPUE was fitted satisfactorily under a two-stock model but could not be fitted in a single homogeneous stock model. However, the WG agreed that:

1. The CPUE indices are consistent with a two-stock structure or at least a minimally-mixing single stock.
2. The updated CPUE estimates were probably a reasonable indicator of abundance (at the spatial scale of the east and west analyses).

4.2.3 Estimation of Maximum Constant Yield (*MCY*)
In 2000, *MCY* was estimated using the equation, $MCY = c*Y_{AV}$ (Method 4). There was no trend in the annual catches, nominal CPUE, or effort from 1982–83 to 1987–88 so that period was used to calculate the *MCY* estimate (1200 t). The *MCY* calculation was not updated in 2009.

4.2.4 Estimation of Current Annual Yield (*CAY*)
CAY cannot be estimated because of the lack of current biomass estimates.

4.3 Smooth oreo

Biomass and yield estimates for smooth oreo were made using a CASAL age-structured population model with Bayesian estimation, incorporating deterministic recruitment, life history parameters (Table 1 of the Biology section at the beginning of the Oreos report), and catch history up to 2009-10. In previous assessments (Doonan *et al*. 2008, 2003, 2001), the stock area was split at 178° 20′ W into a west and an east fishery based on an analysis of research trawl results and commercial catches. Data fitted in the model included acoustic survey abundance estimates, standardised CPUE indices, observer length data from the commercial fishery and the acoustic survey length data.

The 2012 assessment initially updated the base case of the 2007 assessment with recent catch data (Table 5), a new acoustic absolute abundance estimate from a survey carried in 2009 (Table 6), updated observer length data, standardised CPUE (Table 8), and length data from the acoustic survey. The updated model had similar results to the previous assessment, with current spawning biomass estimated to be about 46% of the virgin level. However, some of the issues seen in previous assessments remained: the length frequency data seemed to be in conflict with the abundance data; the west post-GPS standardised CPUE showed an opposite trend to the east CPUE and was inconsistent with the acoustic abundance indices.

Oreo catch data showed marked changes in fishing patterns over time. Large catches first started in the west and then progressed east over time and appeared to represent successive exploitation of new areas. Previously exploited areas in the west did not sustain high catches over time. The target species and the type of fishing also changed over time with smooth oreo the target species in the west on flat, dropoff, and seamounts from the late 1970s, with a gradual change to target fishing for orange roughy on seamounts in the east from the late 1980s. Since the late 1990s, there has been an increase in target fishing for smooth oreo in the east, with more fish being caught as a target species than as bycatch. Given these changes in the fishery, the Deepwater Working Group decided that using CPUE as an index of abundance should be discontinued.

With no CPUE indices being included the 2012 assessment could be simplified into a one area model using just the acoustic abundances. To limit the extra uncertainty in “layer” marks which contained the pre-recruited fish, the abundance estimates were re-calculated as vulnerable abundance. Selectivities for both the commercial fishery and acoustic survey were assumed to be length-based and knife-edged at 33 cm derived from the distribution of the observer length commercial data. Acoustic abundance data were fitted as relative abundances using a log-normal likelihood with no additional process error. The model assumed a fixed M (0.063).

Three sets of vulnerable abundance indices were calculated: two were based on the ratio of adult to total biomass calculated using the length data from the surveys and assuming a length cut-off of 33 cm or 34 cm, and the other was based on the acoustic mark types that are fished for smooth oreo. Two model runs were reported: model 3.2 was fitted to the time series based on the length cut-off of 33 cm and model 5.2 was fitted to the time series based on the fished marks (Table 4). An alternative model using the length cut-off of 34 cm produced similar results to model 3.2 and therefore was not reported.

Informed priors were assumed for the survey catchability coefficient (q). For the time series based on fished marks, a lognormal prior LN(-0.22, 0.3) was assumed. The prior was based on the estimated ranges of a number of factors: the ratio of mean target strength to the true target strength of smooth oreo (approximately a factor of 1.58), the ratio of the QMA scaling-factor to true scaling-factor which was used to scale to acoustic abundance estimate from the acoustic survey area to the QMA area (approximately 1.11 with a range between 1.03 and 1.25), and the proportion of vulnerable biomass in the adult acoustic marks estimated from the ratio of adult abundance estimates based on the 33 cm length cut-off and estimates based on fished marks from the four surveys (approximately 0.8 with a range between 0.6 and 1.0). Combining the three factors, the median value for the prior on q was estimated to be 0.8 and the range between 0.34 and 1.71, and this can be represented very closely by a lognormal distribution LN(-0.22, 0.3). For the time series based on the length cut-offs, a lognormal prior LN(0, 0.3) was assumed (it has the median value of 1 but the same cv). The argument being that the additional variance associated with target strength bias in the layers is similar to the variance from the adult-proportion uncertainty (a convenient assumption).

The following assumptions were made in the stock assessment analyses:

(a) Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
(b) Catch overruns were 0% during the period of reported catch.
(c) The population of smooth oreo in OEO 4 was a discrete stock or production unit.
(d) The catch history was accurate.

Bayesian procedures were used in the assessment to estimate the uncertainties in model estimates of biomass for all model runs using the following procedure:

1. Model parameters were estimated using maximum likelihood and the prior probabilities;
2. Samples from the joint posterior distribution of parameters were generated with the Monte Carlo Markov Chain procedure (MCMC) using the Hastings-Metropolis algorithm;
3. A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by its median, 5th and 95th percentiles for parameters of interest.

Bayesian estimates were based on the median of a 5.5 million long MCMC sampled at each 500th value, with the first 10% excluded.

Table 4: Descriptions of the two model runs reported for the 2012 smooth oreo assessment. LN, lognormal distribution with mean and standard deviation (log space) given in the bracket.

Model run	Description
3.2	Adult acoustic estimates using a length cut-off at 33 cm, estimating q with a LN(0, 0.3) prior
5.2	Adult acoustic estimates using the fished marks, estimating q with a LN(-0.22, 0.3) prior

4.3.1 Estimates of fishery parameters and abundance

The 2012 assessment incorporated the catch history and the adult acoustic abundance indices based on either the length cut-off of 33 cm or fished marks. The updated CPUE indices, observer length data, and acoustic length data were not included in the 2012 assessment model.

Catch history

A catch history for OEO 4 was developed by scaling the estimated catch to the QMS values, Table 5.

Table 5: Catch history for OEO 4 smooth oreo (t)

Year	OEO 4	Year	OEO 4
1978–79	1 321	1994–95	6 936
1979–80	112	1995–96	6 378
1980–81	1 435	1996–97	6 359
1981–82	3 461	1997–98	6 248
1982–83	3 764	1998–99	6 030
1983–84	5 759	1999–00	6 357
1984–85	4 741	2000–01	6 491
1985–86	4 895	2001–02	4 291
1986–87	5 672	2002–03	4 462
1987–88	7 764	2003–04	5 656
1988–89	7 223	2004–05	6473
1989–90	6 789	2005–06	5955
1990–91	6 019	2006–07	6363
1991–92	5 508	2007–08	6422
1992–93	5 911	2008–09	6090
1933–94	6 283	2009–10	6118

Absolute abundance estimates from the 1998, 2001, 2005, and 2009 acoustic surveys

Absolute estimates of abundance were available from four acoustic surveys:

(i) 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812);
(ii) 16 October to 14 November 2001 using *Tangaroa* for acoustic work (voyage TAN0117) and *Amaltal Explorer* (voyage AEX0101) for trawling;
(iii) 3–22 November 2005 using *Tangaroa* for acoustic work (voyage TAN0514) and 3–20 November 2005 using *San Waitaki* (SWA0501) for mark identification trawling;
(iv) 2–18 November 2009 using *Tangaroa* for acoustic work (voyage TAN0910) and 2–18 November 2009 using *San Waitaki* (SWA0501) for mark identification trawling.

Acoustic abundance estimates for total smooth oreo from seamounts and flat for the whole of OEO 4 are in Table 6. The 1998 and 2001 estimates for the mixed species mark-types were adjusted to match the larger contribution for non-smooth oreo species in these mark types from the trawl net used in 2005.

Table 6: Estimated total smooth ore abundance (t) from acoustic surveys in 1998, 2001, 2005, and 2009 by east, west and for the combined area. CVs are in brackets (%).

	1998	2001	2005	2009
West	22 600 (52)	43 000 (35)	32 200 (31)	28 100 (51)
East	127 000 (37)	183 000 (22)	91 800 (30)	46 900 (35)
Total	146 600 (33)	218 165 (22)	115 500 (28)	66 500 (36)

One of the major uncertainties in the assessment is the amount of smooth oreo estimated to be in the layers (about 72% of the total abundance for the 1998 acoustic survey, 47% for the 2001 survey, about 45% for the 2005 survey, and about 61% for the 2009 survey). The contribution of large (greater than 31 cm) smooth oreo to the total backscatter in these layers was typically less than 10% of the total abundance, with the remainder composed of a number of associated bycatch species and smaller smooth oreo in 1998 and 2001. The contribution made by the suite of other fish species present in the layers adds to the overall uncertainty in the biomass estimates from the assessment. The contribution of large smooth oreo to the total backscatter in the schools was typically greater than 75% in 1998 and 2001. Therefore, the smooth oreo abundance estimates from the schools were considered to be better estimated than the equivalent estimates from the layers.

Abundance of vulnerable smooth oreo was estimated using two different methods. The first method used the length cut-off from the surveys determined from a mid-point (33 to 34 cm) of the mode of the commercial length distribution. Biomass estimates were produced for length cut-offs of both 33 and 34 cm. The second method was based on the biomass estimated from only three mark types: deep schools, shallow schools, and hill marks. These estimates were made for the whole area (Table 7).

Table 7: Estimated abundance (t) for the combined area based on a length cut-off of 33 or 34 cm, or on the vulnerable acoustic marks from acoustic surveys in 1998, 2001, 2005, and 2009. CVs are in brackets (%).

Year	Biomass (> 33 cm)	Biomass (> 34 cm)	Biomass (marks)
1998	69 673 (33)	59 855 (33)	65 679 (26)
2001	102 017 (19)	88 417 (19)	81 633 (26)
2005	70 304 (22)	61 056 (22)	63 237 (25)
2009	55 441 (30)	49 760 (31)	26 953 (26)

Observer length frequencies

Observer length data were extracted from the observer database. These data were stratified by season (October-March and April-September) and area (west/east). The length frequencies were combined over strata by the proportion of catch in each stratum.

The scaled length frequencies were used to determine the length cut-offs (above) for estimating the adult abundance, but was not otherwise included in the assessment model

Relative abundance estimates from standardised CPUE analyses

Table 8: OEO 4 smooth oreo time series of combined and positive catch abundance indices from standardised CPUE analyses used in the assessment.

Year	Combined index	Jackknife CV
(a) Target SSO pre-GPS (east + west but mainly west data)		
1981–82	1.40	15
1982–83	1.36	19
1983–84	1.04	21
1984–85	0.84	20
1985–86	1.00	44
1986–87	0.99	28
1987–88	0.89	20
1988–89	0.68	22
(c) Bycatch post-GPS (east)		
1992–93	1.79	37
1993–94	1.53	25
1994–95	1.38	16
1995–96	1.09	60
1996–97	1.72	17
1997–98	1.10	22
1998–99	1.19	24
1999–00	1.28	76
2000–01	1.03	17
2001–02	0.92	16
2002–03	1.05	18
2003–04	1.09	44
2004–05	0.71	26
2005–06	0.60	16
2006–07	0.86	33
2007–08	0.63	31
2008–09	0.61	25
2009–10	0.56	33

Year	Combined	Jackknife CV
(b) Target OEO/SSO post-GPS (west)		
1992–93	0.46	27
1995–96	0.50	36
1996–97	0.90	15
1997–98	0.76	70
1998–99	0.74	18
1999–00	0.98	32
2000–01	0.92	16
2001–02	0.99	47
2002–03	1.32	24
2003–04	1.25	23
2004–05	1.55	28
2005–06	1.33	26
2006–07	1.22	15
2007–08	1.49	12
2008–09	1.20	46
2009–10	1.27	10

The CPUE analysis method was the same as that described above (Section 4.2) for OEO 4 black oreo except that a revised method was used to convert the index values to a canonical form by dividing each value by the geometric mean of the index series following the suggestion of Francis (1999) and resulted in the index value for the reference year being a value other than 1. Annual CVs for the combined indices were estimated using a jackknife technique (Doonan *et al*. 1995a) but the method was revised by using the canonical index values to calculate the jackknife CV values and resulted in the reference year CV having a value other than 0. The target SSO pre-GPS series (Table 8 a) used data from the both east and west areas but most of the data were from the west. The update of the previous assessment used east and west indices (Table 8 a, b, & c), but these are not included in the final 2012 assessment.

4.3.2 Biomass estimates

The final assessment runs presented here are runs 3.2 and 5.2 (Table 4). Estimated parameters for both cases appeared to achieve MCMC convergence.

The estimates of biomass are shown in Table 9 (and Figure 1). The median estimate of current mature biomass was 41% for the model using the abundance series based on the 33 cm length cut-off, and 33% B_0 for the model based on fished marks.. The biomass estimates generally have wide 90% confidence bounds (Figure 2).

The vulnerable abundance based on fished marks were similar to those using the length cut-offs for the 1998, 2001, and 2005 surveys, but was much lower for the 2009 survey (Table 7). The reason is not clear but could be that a considerable proportion of vulnerable biomass was contributed by the layer mark. As a result, current biomass estimates for the model based on fished marks were less optimistic.

Estimated exploitation rates were low but appeared to have steadily increased over recent years (Figure 4). The median of current exploitation rate was estimated to be about 8% for model 3.2 and about 12% for model 4.2.

MPD estimates of survey catchability *q* were close to the median of the assumed prior and the posterior distributions of *q* were similar to their prior distributions for both model 3.2 and 5.2 (Figure 5). Model results appeared to be strongly driven by the assumed prior for *q*; when the assumed value of *q* was halved or doubled the posterior distributions from the model were very similar to the prior distributions. The range of estimates for the catchability coefficient *q* was based on limited information on target strength, the QMA scaling-factor, and the proportion of vulnerable biomass in the vulnerable acoustic marks, and therefore is likely to be imprecise.

The current stock size was estimated to be 26–55% and 18–49% for models 3.2 and 5.2 respectively. These estimated bounds may not represent the true level of uncertainty in the stock assessment. There are a number of structural assumptions in the model that result in the true uncertainty of the model biomass estimates being underestimated. These include the assumption that there was no variability in recruitment (deterministic recruitment was used).

Table 9: Mature biomass, estimates for OEO 4 smooth oreo.

	MCMC 3.2			MCMC 5.2		
	5%	Median	95%	5%	Median	95%
B_0	132 000	166 000	225 000	118 000	146 000	193 000
$B_{current}$	34 000	67 000	125 000	22 000	48 000	94 000
$B_{current}$ ($\%B_0$)	0.26	0.41	0.55	0.18	0.33	0.49

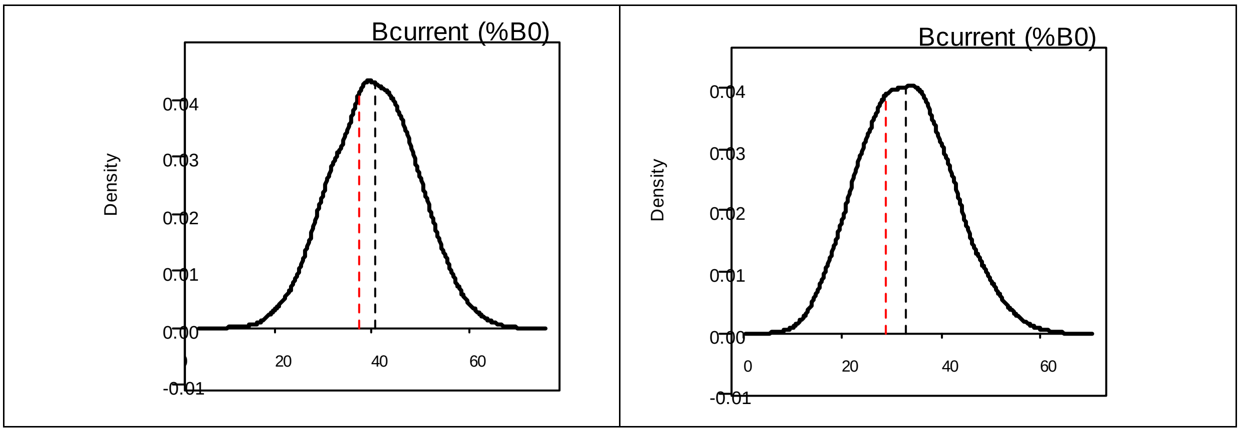


Figure 1: Bayesian posterior distribution of current mature biomass estimates as a percentage of virgin biomass for model 3.2 (left) and 5.2 (right). The black dashed line is the median of the MCMC posterior distribution; the red dashed line is the MPD point estimate.

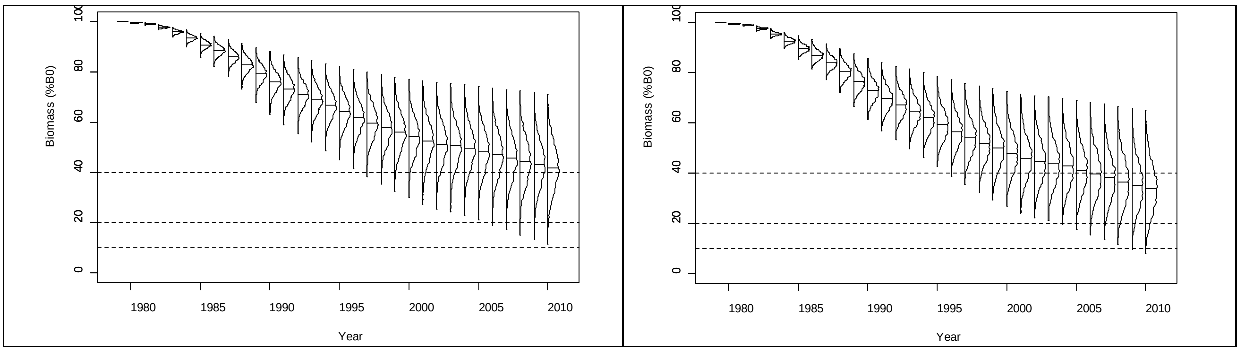


Figure 2: Bayesian posterior distribution of mature biomass as a percentage of B_0 for model 3.2 (left) and 5.2 (right). Dashed lines represent the target (40% B_0), soft limit (20% B_0), and hard limit (10%B_0) respectively.

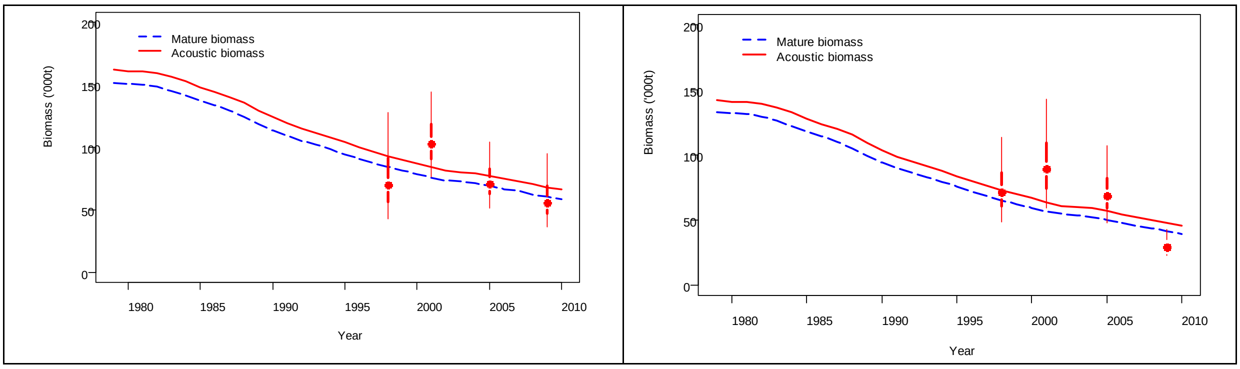


Figure 3: MPD fits of the vulnerable abundance time series for model 3.2 (left) and 5.2 (right). Points are the acoustic estimates scaled by catchability coefficient to abundance. Curved lines are the model estimates of biomass (t): solid top line is the abundance that the acoustics measures and dashed line is the mature abundance. Vertical thinner error bars for acoustic are ± 2 S.D., the thicker bars are ± 1 S.D.

4.3.3 Estimation of Maximum Constant Yield (*MCY*)

No estimates of *MCY* are available.

4.4.4 Estimation of Current Annual Yield (*CAY*)

No estimates of *CAY* are available.

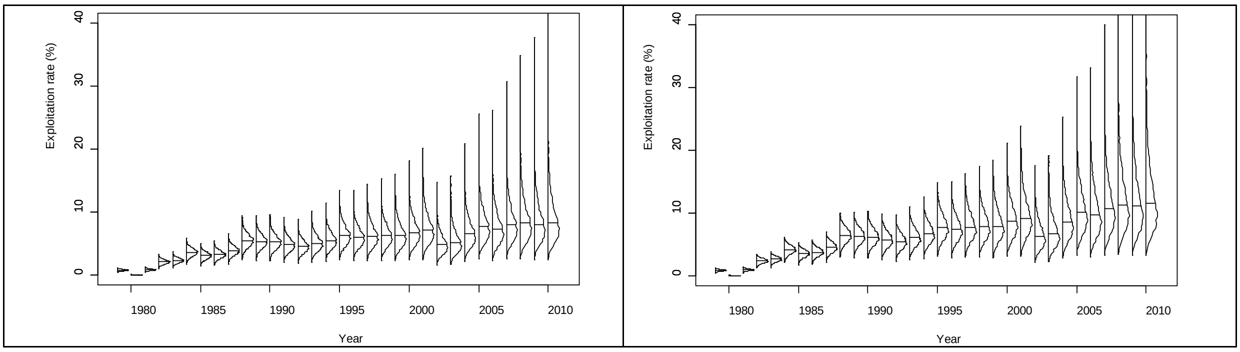


Figure 4: Bayesian posterior distribution of exploitation rate for model 3.2 (left) and 5.2 (right).

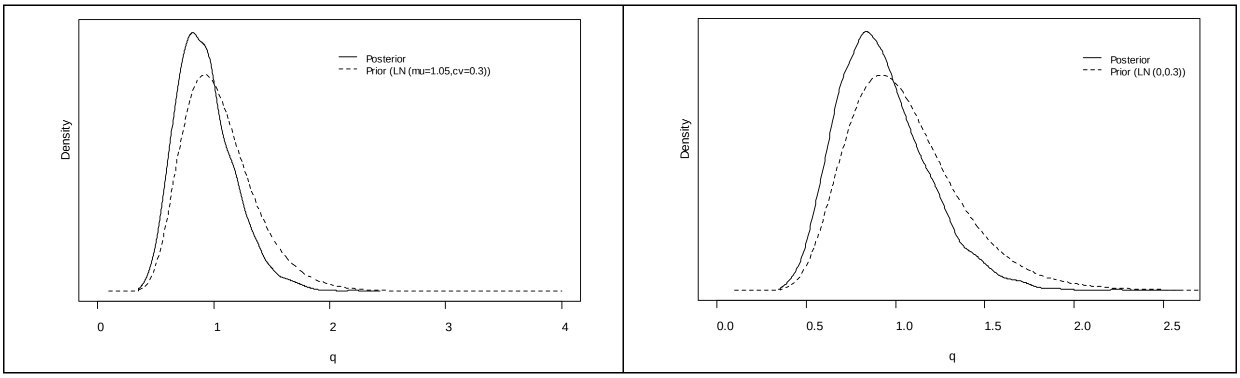


Figure 5: Bayesian posterior distribution of survey catchability q and the prior for model 3.2 (left) and 5.2 (right).

4.3.6 Other factors that may modify assessment results

The WG considered that there were a number of other factors that should be considered in relation to the stock assessment results presented here:

- There are also a number of factors that are outside the model and the analyses that add uncertainty to the model estimates of biomass. These include the sensitivity of the acoustic biomass estimate to the low value of the target strength of smooth oreo, and uncertainty in the estimates of *M* and growth rates.

- Age frequencies estimated from the 1998 and 2005 acoustic surveys suggest the possibility of poor recruitment to 1 year olds from 1986 up to 1995, the youngest cohort that would be seen in the 2005 acoustic data (Doonan *et al*. 2008). These cohorts would enter the fishery (at about age 23) from 2009 to 2018. However, age data from 1993 & 1994 trawl surveys on the eastern end of the south Chatham Rise were ambiguous (Doonan & McMillan 2011).

- This assessment suggests that there is no immediate sustainability issue for OEO 4 smooth oreo, but the large decline in the 2009 acoustic abundance indices suggests that future monitoring of the stock would be wise.

5. STATUS OF THE STOCKS

There is a new stock assessment in 2012 for the smooth oreo stock.

Stock Structure Assumptions

The two oreo stocks on the Chatham Rise are assessed separately but managed as a single stock. For black oreos the population has been found to be genetically similar to other oreo stocks and it is likely that some mixing occurs. Smooth oreos are assumed to be distinct from OEO1+6 stocks but may mix with the 3A stock.

- **OEO4 (Black Oreos)**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	No quantitative stock assessment model
Reference Points	Target(s): 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status Unknown	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been stable for the last 5 years, after initial substantial decline during the 1980s and 1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2 – Partial quantitative stock assessment	
Assessment Method	Age-based model in CASAL	
Main data inputs	- 4 standardised CPUE indices (pre/post GPS and east/west) - Observer length frequencies	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- Assessments unable to represent observer length frequency data. - CPUE could be fitted to a two-stock model but not a homogenous model. - A portion of the abundance estimates were based on data from areas not normally covered by the trawl fishery, and the surveyed area was scaled by a factor of 4.3 – the area surveyed was borderline for providing a reliable abundance estimate.	

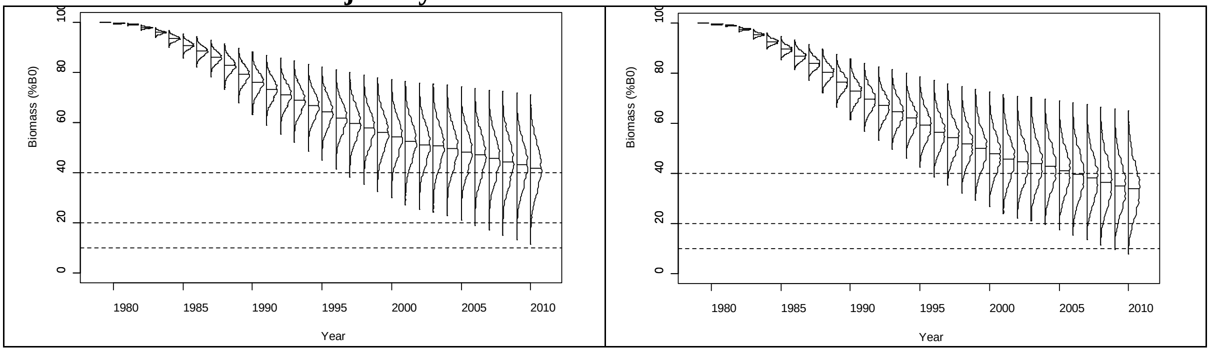
Qualifying Comments
The WG agreed that the stock might be split into east and west areas that were independent or at least minimally mixing for future assessments.

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO4 (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Two model runs fitted to two alternative vulnerable acoustic abundance estimates (model 3.2 and 5.2)
Reference Points	Target(s): 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2010} was estimated at 41% B_0 for model 3.2, and 33% B_0 for model 5.2. B_{2010} is as likely as not to be at or above the target
Status in relation to Limits	B_{2010} is Unlikely (< 40%) to be below the Soft limit and very Unlikely (<10%) to be below Hard Limits

Historical Stock Status Trajectory and Current Status



Spawning stock biomass trajectory for model 3.2 (left) and 5.2 (right).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to be steadily decreasing
Recent Trend in Fishing Mortality or Proxy	Estimated exploitation rates were low but appeared to have steadily increased over recent years
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Age frequencies estimated from the 1998 and 2005 acoustic surveys suggest the possibility of poor recruitment into the fishery from 2009 to 2018.

Projections and Prognosis	
Stock Projections or Prognosis	No model projections were made due to uncertainty in the assessment, however, there is concern that the current downward trend may continue.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology and Evaluation		
Assessment Type	Type 1 – Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2011	Next assessment: Unknown
Overall assessment quality rank	2 – Medium or Mixed Quality: assessment results are strongly driven by the assumed prior on q	
Main data inputs (rank)	- Four estimates of abundance from acoustic surveys (1998, 2001, 2005, 2009) - Observer length data (not used, except to provide a length	1 – High Quality

	cutoff for vulnerable fish)	1 – High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: the nature of the fishery has changed over time, particularly the ratio of targeting to bycatch
Changes to Model Structure and Assumptions	Simplified to a single-area, single fishery model with deterministic recruitment	
Major Sources of Uncertainty	Recruitment assumed to be deterministic. Uncertainties in the assumptions used to determine the prior for the survey catchability (*q*): estimated target strength scaling factor from the trawl survey area to acoustic area scaling factor from acoustic area to the QMA area proportion of vulnerable biomass in the fished marks	

Qualifying Comments
The biomass estimate based on adult marks declined in the 2009 survey

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species include deepwater sharks and rays, seabirds and deepwater corals.

6. FOR FURTHER INFORMATION

Bull, B.; Francis, R.I.C.C.; Dunn, A.; Gilbert, D.J. 2002. CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v1.02.2002/10/21. NIWA Technical Report 117. 199 p.

Coburn,RP., Doonan IJ., McMillan PJ. 2001. Smooth oreo abundance indices from standardised catch per unit of effort data for OEO 4. New Zealand Fisheries Assessment Report 2001/11. 39p.

Coburn RP., Doonan IJ., McMillan PJ. 2001. Black oreo abundance indices from standardised catch per unit of effort data for OEO 4. New Zealand Fisheries Assessment Report 2001/39. 24p.

Doonan IJ., McMillan PJ. 2011. Final Research Report for Ministry of Fisheries Research Project OEO2009-01. 10p.

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. 2008. Assessment of OEO 4 smooth oreo for 2006--07. New Zealand Fisheries Assessment Report 2008/40. 45 p.

Doonan IJ., McMillan PJ., Coburn RP., Hart AC. 2003. Assessment of OEO 4 smooth oreo for 2002–03. New Zealand Fisheries Assessment Report 2003/50. 55p.

Doonan IJ., McMillan PJ., Coburn RP., Hart AC. 2001. Assessment of OEO 4 smooth oreo for 2000–01. New Zealand Fisheries Assessment Report 2001/21. 37p.

Doonan IJ., McMillan PJ., Coburn RP., Hart AC. 2001. Assessment of OEO 4 black oreo for 2000–01. New Zealand Fisheries Assessment Report 2001/30. 32p.

Doonan IJ., McMillan PJ., Hart AC. 2001. The use of mean length data for stock assessments of black oreo and smooth oreo in OEO 4. New Zealand Fisheries Assessment Report 2001/34. 16p.

Doonan, I.J.; McMillan, P.J.; Hart, A.C. 2008. Ageing of smooth oreo otoliths for stock assessment. New Zealand Fisheries Assessment Report 2008/8. 29 p.

Doonan IJ., Coombs RF., McMillan PJ., Dunn A. 1998. Estimate of the absolute abundance of black and smooth oreo in OEO 3A and 4 on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project OEO9701. 47p.

Doonan IJ., McMillan PJ., Coburn RP., Hart AC. 1997. Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1997. New Zealand Fisheries Assessment Research Document 1997/21. 26p.

Doonan IJ., McMillan PJ., Coburn RP., Hart AC. 1996. Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1996. New Zealand Fisheries Assessment Research Document 1996/17. 21p.

Doonan IJ., McMillan PJ., Coburn RP., Hart AC., Cordue PL. 1995. Assessment of smooth oreo for 1995. New Zealand Fisheries Assessment Research Document 1995/12. 31p.

Francis RICC. 1999. The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 1999/42. 30p.

Francis RICC. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27p.

McMillan PJ., Doonan IJ., Hart AC., Coburn RP 1998. Oreo stock assessment. Final Research Report for Ministry of Fisheries Research Project OEO9702. 16p.

McMillan PJ., Doonan IJ., Coburn RP., Hart AC. 1996. Is the south Chatham Rise trawl survey providing an index of smooth oreo abundance in OEO 4?. New Zealand Fisheries Assessment Research Document 1996/16. 18p.

McMillan PJ., Hart AC. 1991. Assessment of black and smooth oreos for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 1991/10. 29p.

OREOS - OEO 1 AND OEO 6 BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESSMENT

4.1 Introduction

A new assessment is reported here for Southland (OEO 1/OEO 3A), while the previously reported assessments for Pukaki Rise black oreo, Pukaki smooth oreo and Bounty Plateau smooth oreo (only MPD results) are repeated.

4.2 Southland smooth oreo fishery

This assessment was updated in 2007 and applies only to the study area as defined in Figure 1 and does not include areas to the north (Waitaki) and east (Eastern canyon) of the main fishing grounds.

This fishery is mostly in OEO 1 on the east coast of the South Island but catches occur at the northern end of the fishery straddle and cross the boundary line between OEO 1 and OEO 3A at 46ºS. This is an old fishery with catch and effort data available from 1977-78. Smooth oreo catch from Southland was about 480 t (mean of 2003-04 to 2005-06). There is an industry catch limit of 400 t smooth oreo implemented after the previous (2003) assessment. There were no fishery-independent abundance estimates, so relative abundance estimates from pre- and post-GPS standardised CPUE analyses and length frequency data collected by MFish (SOP) and Orange Roughy Management Company (ORMC) observers were used.

The following assumptions were made in this analysis.

1. The CPUE analysis indexed the abundance of smooth oreo in the study area of OEO 1/3A.
2. The length frequency samples were representative of the population being fished.
3. The ranges used for the biological values covered their true values.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
5. The population of smooth oreo in the study area was a discrete stock or production unit.
6. Catch overruns were 0% during the period of reported catch.
7. The catch histories were accurate.
8. The maximum fishing pressure (U_{MAX}) was 0.58.

An age-structured CASAL model employing Bayesian statistical techniques was developed. A two-fishery model was employed with a split into deep and shallow fisheries because of a strong relationship found between smaller fish in shallow water and large fish in deeper water. The boundary between deep and shallow was 975 m. The 2007 analysis used 5 extra years of catch and observer length frequency data compared to the 2003 assessment. The model was partitioned by the sex and maturity status of the fish and used population parameters previously estimated from fish sampled on the Chatham Rise and Puysegur Bank fisheries. The maturity ogive used was estimated from Chatham Rise research samples.

4.2.1 Estimates of fishery parameters and abundance

Catch history

A catch history (Table 1) was derived using declared catches of OEO from OEO 1 (see Table 2 in the Fishery Summary section at the beginning of the Oreos report) and tow-by-tow records of catch from the study area (Figure 1). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the SSO taken. It was assumed that the reported landings provided the best information on total catch quantity and that the tow-by-tow data provided the best information on the species and area breakdown of catch.

Table 1: Catch history of smooth oreo from Southland. Rounded to the nearest 10 t.

Fishing year	Shallow	Deep	Fishing year	Shallow	Deep
1977-78	210	0	1992-93	410	250
1978-79	10	0	1993-94	220	150
1979-80	40	0	1994-95	80	150
1980-81	0	0	1995-96	600	500
1981-82	0	0	1996-97	440	70
1982-83	0	0	1997-98	320	230
1983-84	480	660	1998-99	480	620
1984-85	170	510	1999-00	650	480
1985-86	480	3 760	2000-01	400	610
1986-87	30	160	2001-02	580	1 470
1987-88	130	860	2002-03	130	1 320
1988-89	0	240	2003-04	330	420
1989-90	210	430	2004-05	140	290
1990-91	410	420	2005-06	120	140
1991-92	530	380			

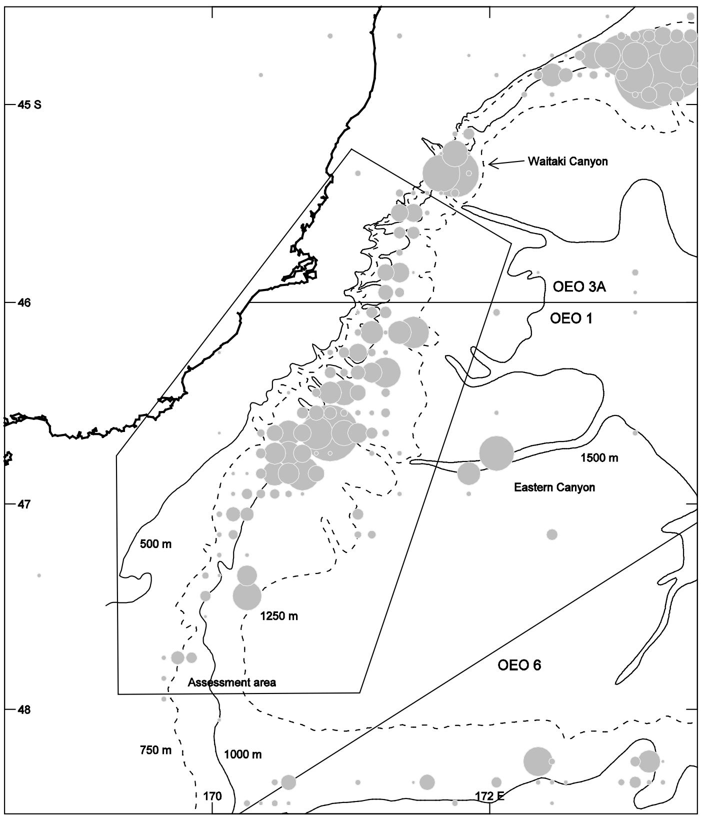


Figure 1: Smooth oreo estimated catch from all years to (and including) 2005-06. The area was divided into cells that are 0.1 degrees square and catches were summed for each cell. Circles proportional in area to the catch are plotted centred on the cells. Catches less than 10 tonnes per cell are not shown. Circles are layered so smaller circles are never hidden by larger ones. The assessment area and bottom topography are also shown.

Length data

All SOP records where smooth oreo were measured from within the assessment area are shown in Table 2: 78 samples were shallow and 51 deep. Only 13 shallow and 4 deep samples were collected before 1999-2000 (Table 2). Composite length frequency distributions were calculated for each year. Each sample was weighted by the catch weight of the tow from which the sample was taken. This was modified slightly by estimating the number of fish that would be in a unit weight of catch and multiplying by that.

Table 2: Summary of length frequency data for smooth oreo available for the study area. Year group, year applied, and the total number of length frequencies for the shallow and deep year groups.

Year group	Year applied	No. of lfs
Shallow		
a=1993-94 to 1997-98	1995-96	13
b=1999-2000	1999-00	30
c=2000-01 to 2001-02	2001-02	22
d=2002-03 to 2005-06	2004-05	13
Deep		
e=1997-98 to 2001-02	2001-02	27
f=2002-03 to 2004-05	2003-04	21

Relative abundance estimates from CPUE analyses

The standardised CPUE analyses used a two part model which separately analysed the tows which caught smooth oreo using a log-linear regression (referred to as the positive catch regression) and a binomial part which used a Generalised Linear Model with a logit link for the proportion of successful tows (referred to as the zero catch regression). The binomial part used all the tows, but considered only whether or not the species was caught and not the amount caught. The yearly indices from the two parts of the analysis (positive catch index and zero catch index) were multiplied together to give a combined index. The pre-GPS data covered the years from 1983-84 to 1987-88, was left unmodified from 2003, and was used as an index of the deep fishery as most fishing in that period was deep (Table 3). The post-GPS data covered 1992-93 to 2005-06 split into shallow and deep fisheries but the indices for the last two years (2004-05, 2005-06) were dropped because catch was constrained by the industry catch limit of 400 t for smooth oreo introduced after the 2003 assessment (Table 4).

Table 3: Smooth oreo pre-GPS combined index estimates by year, and jackknife CV estimates from analysis of all tows in the study area that targeted smooth oreo, black oreo, or unspecified oreo.

Year	Combined index	Jackknife CV (%)
1983-84	1.75	22
1984-85	1.65	29
1985-86	1.19	33
1986-87	0.48	23
1987-88	0.61	27

Table 4: Smooth oreo post-GPS combined index estimates by year, and jackknife CV estimates from analysis of all tows in the study area that targeted smooth oreo, black oreo, or unspecified oreo.

	Shallow		Deep	
Fishing year	Index (kg/tow)	Bootstrap CV (%)	Index (kg/tow)	Bootstrap CV (%)
1992-93	1 489	57	1 401	73
1993-94	956	47	916	53
1994-95	1 521	72	428	121
1995-96	1 173	37	1 862	84
1996-97	511	84	2 117	41
1997-98	1 477	39	502	59
1998-99	939	42	915	50
1999-00	842	44	611	48
2000-01	758	46	385	72
2001-02	573	44	658	53
2002-03	303	48	406	76
2003-04	480	57	719	218

4.2.2 Biomass estimates

Biomass estimates were made based on a Markov Chain Monte Carlo analysis which produced a total of about 1.4 million iterations was generated. The first 100 000 iterations were discarded and every 1000th point was retained, giving final converged chain of about 1300 points.

Biomass estimates for the base case are given in Table 5. These biomass estimates are uncertain because of the reliance on commercial CPUE data for abundance indices.

Table 5: Biomass estimates (t) for the base case.

		5%	median	mean	95%	CV (%)
Free parameters						
Virgin mature biomass (B_0)		15 600	17 400	17 900	21 700	12
Selectivity, shallow	a1	17.2	19.0	19.0	21.0	6
	sL	3.9	4.8	4.8	5.8	12
	sR	5.9	8.3	8.4	11.2	20
Selectivity, deep	a50	22.1	26.0	26.2	30.8	10
	to95	1.9	7.1	7.0	11.0	37
Derived quantities						
Current mature biomass (% initial)		19	27	28	41	25
Current selected shallow biomass (% initial)		56	65	65	73	8
Current selected deep biomass (% initial)		12	20	22	36	36

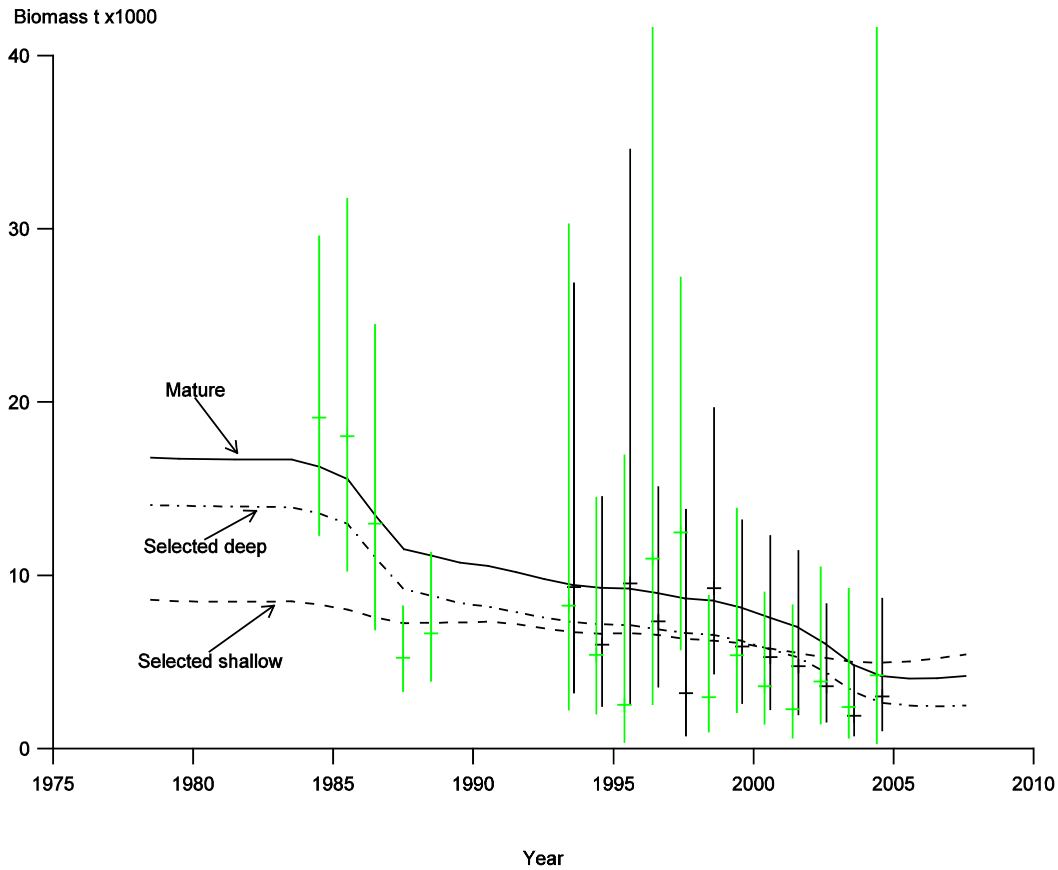


Figure 2: Predicted biomass trajectories for the 2007 base case assessment. Mature biomass and selected biomass for the shallow and deep fisheries. Also shown are the CPUE indices from the pre- and post-GPS analysis for the deep fishery (in gray) and the post-GPS analyses for the shallow fishery (in black). CPUE indices are shown with +/- 2 s.e. confidence interval indicated by the vertical lines (the post-GPS CPUE data are slightly offset to avoid over plotting). The CPUE data were scaled by catchability coefficients to match the biomass scale.

4.3 Pukaki Rise smooth oreo fishery (part of OEO 6)

This is the first assessment for this fishery (developed in 2006) and applies only to the assessment area as defined in Figure 3. This is the main smooth oreo fishery in OEO 6 with mean annual catches of about 1700 t from 1995-96 to 2004-05, taken mainly by New Zealand vessels. There was also a small early Soviet fishery (1980-81 to 1985-86) with mean annual catches of less than 100 t. There were no fishery-independent abundance estimates, so relative abundance estimates from a post-GPS standardised CPUE analysis and length frequency data collected by MFish (SOP) and Orange Roughy Management Company (ORMC) observers were considered. Biological parameter values estimated for Chatham Rise and Puysegur Bank smooth oreo were used in the assessment because there are no research data from Pukaki Rise.

The following assumptions were made in this analysis.

1. The CPUE analysis indexed the abundance of smooth oreo in the Pukaki Rise (OEO 6) assessment area.
2. The length frequency samples were representative of the population being fished.
3. The ranges used for the biological values covered their true values.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
5. The population of smooth oreo in the assessment area was a discrete stock or production unit.
6. Catch overruns were 0% during the period of reported catch.
7. The catch histories were accurate.
8. The maximum exploitation rate (E_{MAX}) was 0.58.
9. The prior for stock size was bounded at an upper limit of 100 000 t.

Data inputs included catch history, relative abundance estimates from a standardised CPUE analysis, and length data from SOP and ORMC observers. The observational data were incorporated into an age-based Bayesian stock assessment (CASAL) with deterministic recruitment to estimate stock size. The stock was considered to reside in a single area, with a partition by sex. Age groups were 5-70 years, with a plus group of 70+ years.

The length-weight and length-at-age population parameters are from fish sampled on the Chatham Rise and Puysegur Bank fisheries (Table 1, Biology section). Fish sampled from the Puysegur Bank fishery are used for the natural mortality estimate (Table 1). The maturity ogive is from fish sampled on the Chatham Rise, and the age at which 50% are mature is between 18 and 19 years for males and between 25 and 26 years for females.

4.3.1 Estimates of fishery parameters and abundance

Catch history

A catch history was derived using declared catches of OEO from OEO 6 (Table 2 in the “Fishery summary” section of the Oreos report above) and tow-by-tow records of catch from the assessment area (Figure 3). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the SSO taken. It was assumed that the reported landings provided the best information on total catch quantity and that the tow-by-tow data provided the best information on the species and area breakdown of catch. There may be unreported catch from before records started, although this is thought to be small. Before the 1983-84 fishing year the species catch data were combined over years to get an average figure that was then applied in each of those early years. For the years from 1983-84 onwards, each year’s calculation was made independently. The catch history used in the population model is given in Table 7.

Table 7: Catch history of smooth oreo from the Pukaki Rise fishery assessment area. Catches are rounded to the nearest 10 t.

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1980-81	30	1988-89	0	1996-97	1 650	2004-05	1 370
1981-82	20	1989-90	0	1997-98	1 340		
1982-83	0	1990-91	10	1998-99	1 370		
1983-84	640	1991-92	0	1999-00	2 270		
1984-85	340	1992-93	70	2000-01	2 580		
1985-86	10	1993-94	0	2001-02	2 020		
1986-87	0	1994-95	130	2002-03	1 340		
1987-88	180	1995-96	1 360	2003-04	1 660		

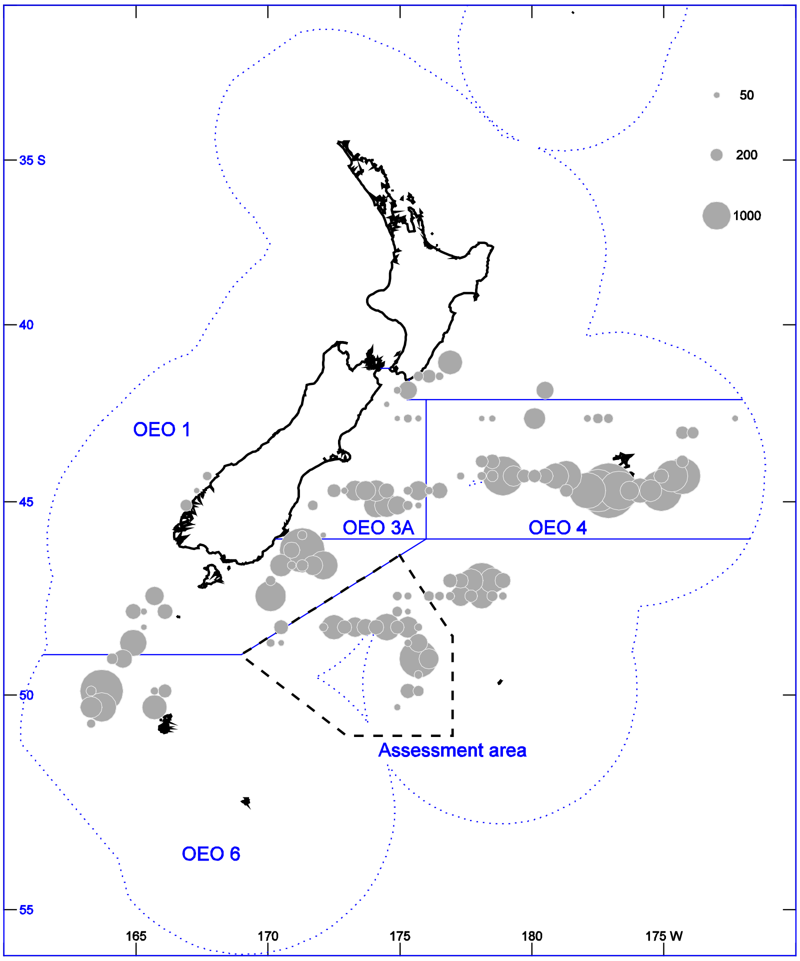


Figure 3: The Pukaki Rise fishery assessment area (polygon) abutting the north boundary of OEO 6. The circles are proportional to the mean of smooth oreo estimated catches (t) from the last 5 years (2000-01 to 2004-05) plotted by summing the catches over 0.4 x 0.4 degree grids. The dotted line is the EEZ.

Length data

Smooth oreo length frequency data collected by SOP and ORMC observers are available from the last eight years (Table 8). An in-depth analysis indicated that these data were reasonably representative of the fishery in terms of spatial, depth and temporal coverage in those years that had adequate data. The depths fished by the sampled fleet varied between years so the length data were stratified by depth resulting in shallow (less than 900 m), middle (900-990 m) and deep strata (greater than 990 m). The data from adjacent years were also grouped because some years had few samples. The resulting length frequencies are shown in Figure 4. There is a trend towards a flatter distribution over the last three grouped distributions (2000-01, 02, and 03-05).

Table 8: Summary of length frequency data for smooth oreo available for the assessment area. The table shows the number of tows sampled by year, the sample source, and the year group. -, no data.

	Year group	Number of tows sampled		
Year		ORMC	SOP	All
1997-98	98-99	-	15	15
1998-99	98-99	64	9	73
1999-00	00-01	5	36	41
2000-01	00-01	37	17	54
2001-02	2	42	22	64
2002-03	03-05	4	12	16
2003-04	03-05	-	19	19
2004-05	03-05	-	19	19
Totals		152	149	301

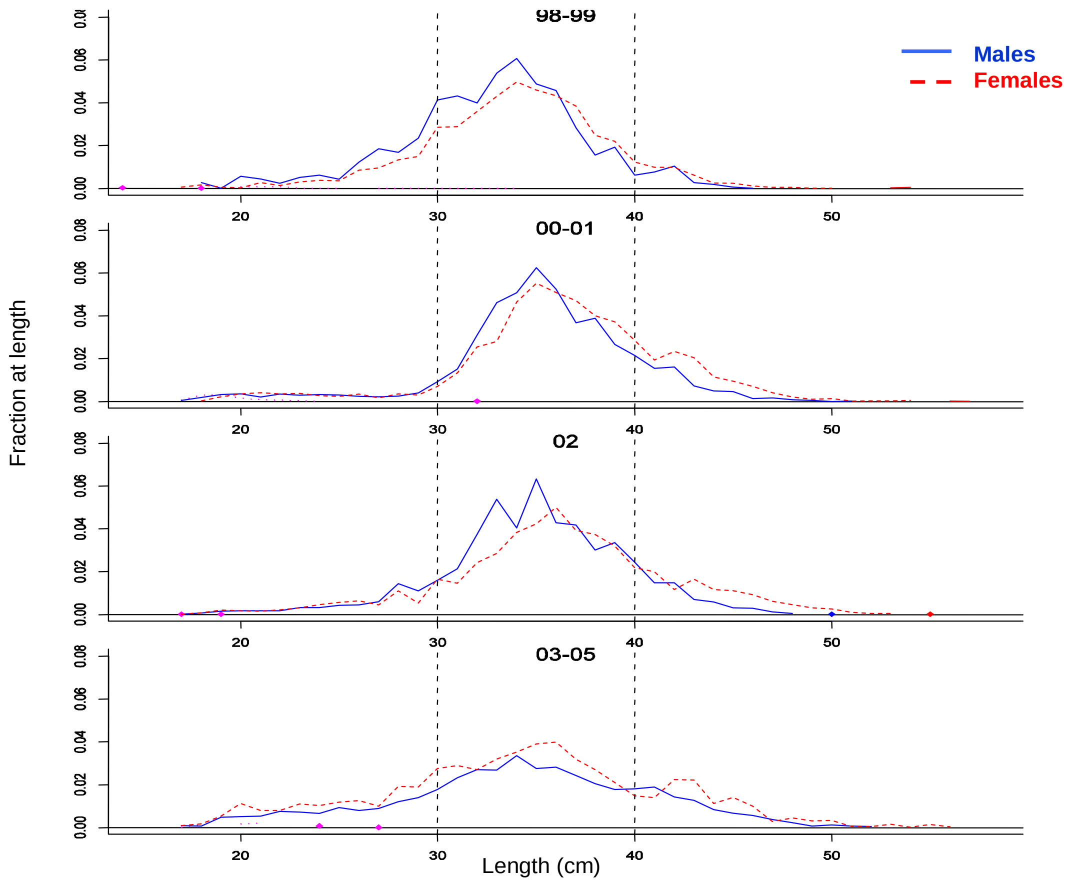


Figure 4: Length frequencies for Pukaki Rise smooth oreo, stratified by depth (see text), and grouped by years.

Relative abundance estimates from CPUE analyses

There was a small early Soviet fishery (1980-81 to 1985-86) with too few data for a standardised CPUE analysis. The New Zealand vessel fishery (1995-96 to 2004-05) was used to analyse standardised CPUE.

This new standardised CPUE analysis of Pukaki Rise smooth oreo used regression based methods similar to those in previous oreo CPUE analyses but because the fraction of zero tows were low (Table 9) only a positive catch model was used. The annual CVs for the index were estimated using bootstrap methods. The data used are summarised in Table 9.

The regression model chosen as the final run included vessel, time of year (day), depth, and axis-position (point on a line drawn through the fishery that follows the 1000 m contour around the Pukaki Rise), and excluded data from vessels that fished for less than three years. Target species was chosen as a predictor variable in initial runs but was excluded in the final run because it is believed that it is not accurately reported. The final run index declines (Table 10).

Table 9: Summary of data used as input to the standardised CPUE analysis for New Zealand vessels.

Year	No. of tows	No. of vessels	Estimated catch (t)	Mean t/tow	Zero catch tows (%)
1995-96	278	9	1 170	4.2	1
1996-97	402	10	1 490	3.7	1
1997-98	356	10	1 190	3.4	5
1998-99	377	12	1 230	3.3	7
1999-00	591	9	2 070	3.5	7
2000-01	651	9	2 310	3.5	8
2001-02	415	7	1 920	4.6	1
2002-03	533	9	1 240	2.3	5
2003-04	585	9	1 520	2.6	2
2004-05	712	12	1 300	1.8	5

Table 10: Final run CPUE index estimates by year, and bootstrap CV estimates from analysis of all tows in the assessment area that caught smooth oreo.

Year	Standardised CPUE index	
	kg/tow	CV
1995-96	3 339	0.316
1996-97	2 266	0.417
1997-98	1 421	0.421
1998-99	1 143	0.243
1999-00	969	0.272
2000-01	1 260	0.319
2001-02	1 247	0.27
2002-03	804	0.451
2003-04	735	0.829
2004-05	243	0.768

4.3.2 Biomass estimates

In all model runs the length-frequency data were poorly fitted, even if selectivity was allowed to vary with depth. This may be due to the use of growth parameters that were derived from another area or to other modelling problems, and is an issue that should be further investigated in the future. In the meantime, the length frequency data were omitted from the stock assessment and the model was fitted to the CPUE data alone. The age at 50% selectivity (a_{50}) was assumed to be knife-edged at 19 yr, corresponding to a fish size of approximately 33 cm. For this model, the MPD estimate of virgin mature biomass (B_0) was 17 400 t, and the current mature biomass was 22% B_0 (Figure 5).

MCMC runs resulted in extremely skewed distributions of B_0 and $B_{CURRENT}$ with right hand tails extending to very high biomass levels. Based on comparisons with other smooth oreo stocks (e.g., OEO 4), and the observation that the standardised CPUE has declined rapidly even though catches have been relatively small, a modified prior which truncated B_0 at an upper limit of 100 000 t was adopted. This gave a median estimate of B_0 of 24 000 t (90% confidence intervals 16 000 - 78 000 t) and a median estimate of $B_{CURRENT}$ of 9800 t (2400 - 64 000 t). Because of the wide confidence intervals, the current status (%B_0) is highly uncertain with a median of 42% but 90% confidence intervals of 15 - 82% (Table 11 and Figure 6).

4.3.3 Yield estimates

Estimates of the Maximum Average Yield (*MAY*) were based on calculations performed for the Southland smooth oreo stock, which has similar life history characteristics (e.g., assumed natural mortality and steepness, and length-age and weight-age relationships) (Coburn *et al*. 2003). For Southland, the *MAY* was estimated to be 2.3% of the median mature virgin biomass. Applying this value to the estimates of B_0 in Table 11 gives a median estimate of *MAY* for Pukaki smooth oreo of 550 t, with 90% confidence intervals 370-1800 t.

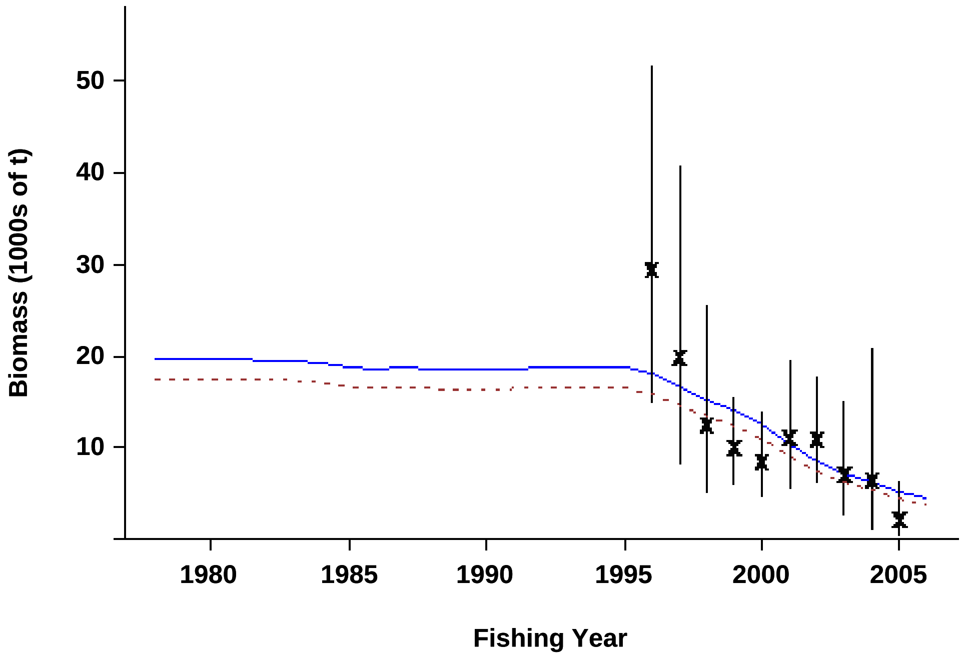


Figure 5: Model run based on CPUE data only, with a_{50} set at 19 yr. The crosses show the CPUE data (vertical lines are the 95% confidence intervals for the indices) and their fits to the vulnerable biomass trajectory (solid line). The dashed line shows the mature biomass trajectory. Fits and trajectories are from MPD estimates.

Table 11: Mid-year mature biomass estimate (median, with 90% confidence intervals in parentheses) for the model run with only CPUE data. $B_{CURRENT}$ is the mid-year mature biomass in 2006.

Run	B_0(t)	$B_{CURRENT}$(t)	$B_{CURRENT}$(% B_0)
Only CPUE	24 000 (16 000-78 000)	9 800 (2 400-64 000)	42 (15-82)

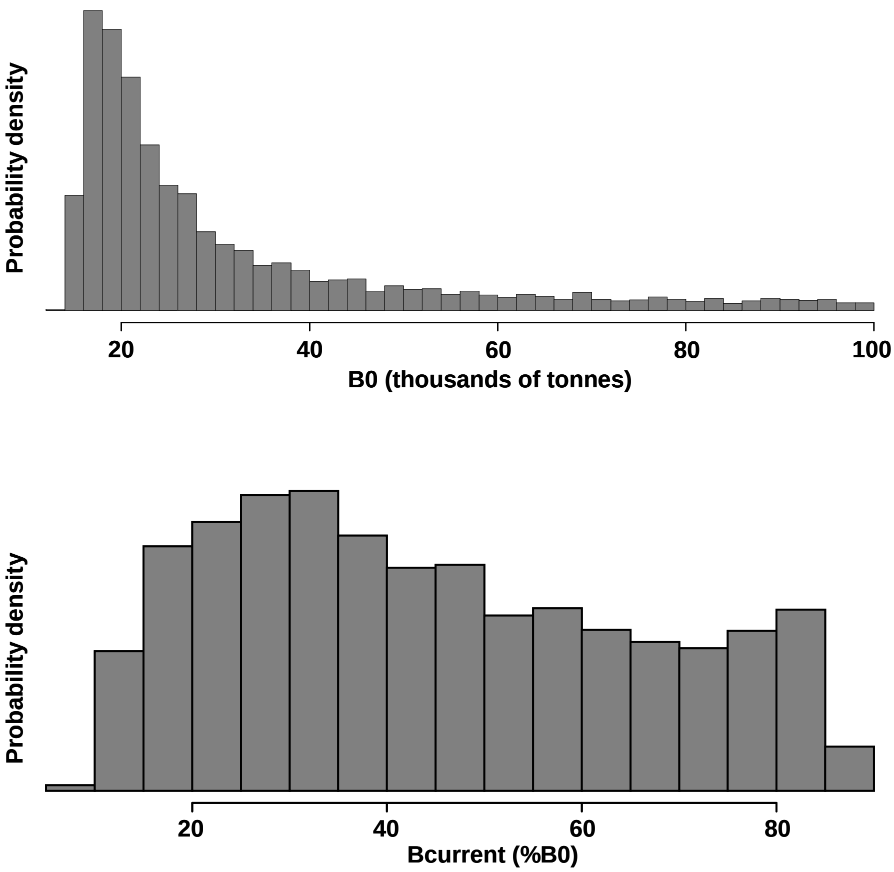


Figure 6: Posterior densities for mature biomass estimates (virgin biomass, and current biomass as a percentage of virgin biomass).

4.3.4 Projections
No projections were made because of the uncertainty in this assessment.

4.4 Bounty Plateau smooth oreo fishery (part of OEO 6)
The first assessment for this fishery was developed in 2008 and applies only to the study area as defined in Figure 7. There were no fishery-independent abundance estimates, so relative abundance estimates from a post-GPS standardised CPUE analysis and length frequency data collected by MFish (SOP) and Orange Roughy Management Company (ORMC) observers were considered. Biological parameter values estimated for Chatham Rise and Puysegur Bank smooth oreo were used in the assessment because there are no research data from Bounty Plateau.

The following assumptions were made in this analysis.

1. The CPUE analysis indexed the abundance of smooth oreo in the Bounty Plateau (OEO 6) assessment area.
2. The length frequency samples were representative of the population being fished.
3. The biological parameters values used (from other assessment areas) are close to the true values.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
5. The population of smooth oreo in the assessment area was a discrete stock or production unit.
6. Catch overruns were 0% during the period of reported catch.
7. The catch histories were accurate.
8. The maximum exploitation rate (E_{MAX}) was 0.58.

Data inputs included catch history, relative abundance estimates from a standardised CPUE analysis, and length data from SOP and ORMC observers. The observational data were incorporated into an age-based Bayesian stock assessment (CASAL) with deterministic recruitment to estimate stock size. The stock was considered to reside in a single area, with a partition by sex. Age groups were 1-70 years, with a plus group of 70+ years.

The length-weight and length-at-age population parameters are from fish sampled on the Chatham Rise and Puysegur Bank fisheries (Table 1, Biology section). The natural mortality estimate is based on fish sampled from the Puysegur Bank fishery. The maturity ogive is from fish sampled on the Chatham Rise, and the age at which 50% are mature is between 18 and 19 years for males and between 25 and 26 years for females.

4.4.1 Estimates of fishery parameters and abundance

Catch history

Table 12: Catch history (t) of smooth oreo from the Bounty Plateau fishery assessment area. Catches are rounded to the nearest 10 t.

Year	Catch	Year	Catch
1983-84	620	1996-97	610
1984-85	0	1997-98	650
1985-86	0	1998-99	1 200
1986-87	0	1999-00	870
1987-88	10	2000-01	550
1988-89	0	2001-02	980
1989-90	0	2002-03	1 530
1990-91	20	2003-04	1 420
1991-92	0	2004-05	2 190
1992-93	110	2005-06	1 790
1993-94	490	2006-07	670
1994-95	1 450	2007-08	670
1995-96	900		

A catch history was derived using declared catches of oreos from OEO 6 (Table 2 in the "Fishery summary" section of the Oreos report above) and tow-by-tow records of catch from the assessment area (Figure 7). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the SSO taken. The catch history used in the population model is given in Table 12.

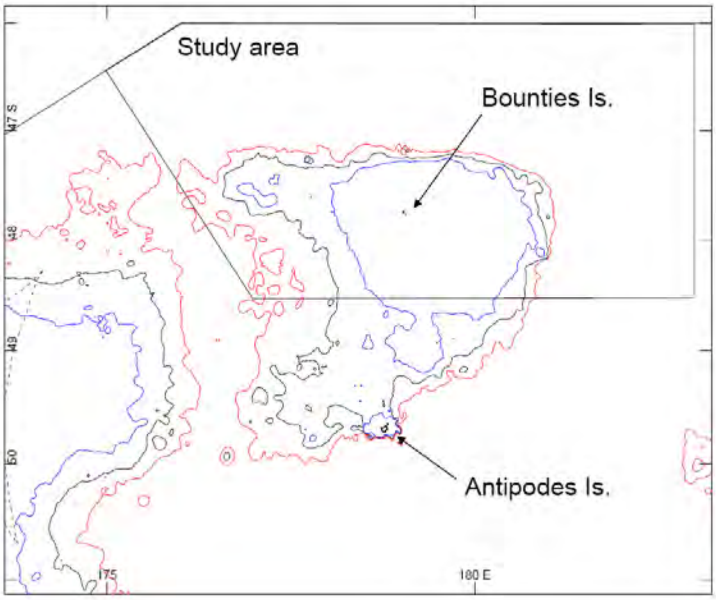


Figure 7: The Bounty Plateau fishery assessment study area.

Length data

Smooth oreo length frequency data collected by SOP and ORMC observers are available from the last twenty eight years. An in-depth analysis indicated that these data were reasonably representative of the fishery in terms of spatial, depth and temporal coverage in those years that had adequate data. Length frequencies were based on tows from the core area (a subset of the study area where about 80% of the catch is take). The data from adjacent years were grouped because some years had few samples (Table 13). The resulting length frequencies are shown in Figure 8. In the final model runs the 1994-95 year of the length frequency series was omitted as it contained very few samples.

Table 13: Core length analysis Year group, year applied and the number of length frequencies. Smooth oreo sample catch weight, fishery catch and sample catch as percentage of the fishery.

Year group	Year applied	No. of lfs	Catch sampled (t)	Fishery catch (t)	% fishery sampled
1991-92 to 1995-96	1994-95	7	88	1 505	6
1998-99 to 1999-2000	1998-99	30	246	1 121	22
2000-2001 to 2002-03	2001-02	25	398	2 261	18
2003-04 to 2004-05	2004-05	29	261	2 280	11
2005-06	2005-06	32	379	1 121	34
2006-07 to 2007-08	2006-07	17	168	494	34

Relative abundance estimates from CPUE analyses

The small early Soviet fishery had too few data for a standardised CPUE analysis. The standardised CPUE analysis was from the the New Zealand vessel fishery and only included those vessels that had fished at least three years. Just a single vessel puts in significant continuous effort from 1995-2007, with the rest of the vessels effort confined to mainly either 1995-2000 (early) or 2001-2007 (late). Because of this, in addition to the single standardised CPUE covering the entire time period, two separate standardised CPUE indices were calculated covering the early and late periods.The final indices are shown in Tables 14 and 15.

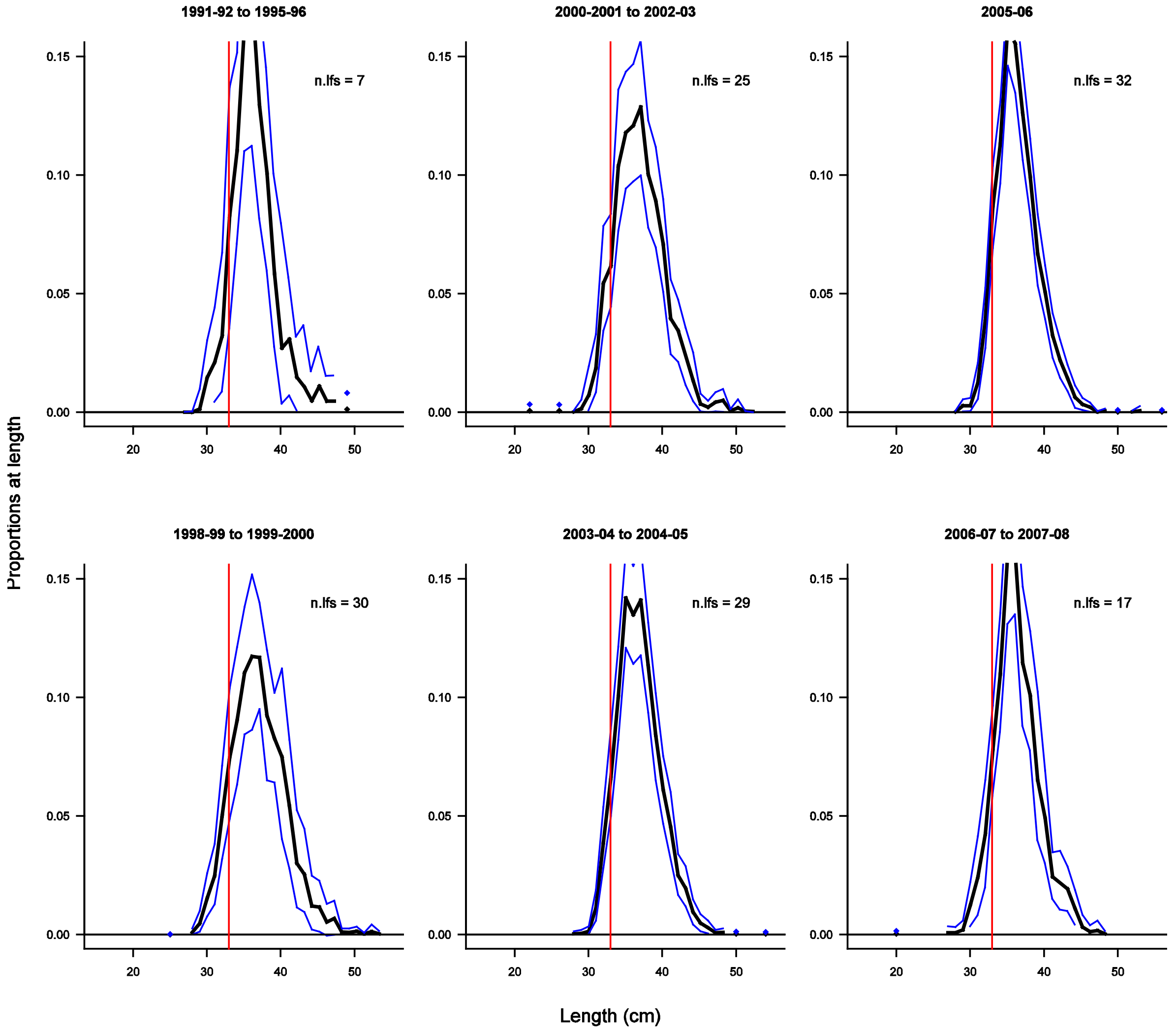


Figure 8: Length frequency distribution plots for core data only (thick lines) with 95% confidence interval (thin lines)

Table 14: Early and late period CPUE combined index estimates by year, and bootstrap CV estimates.

Year	Kg/tow	CV	Late period	Kg/tow	CV
1995-96	3551	0.423	2000-01	850	0.487
1996-97	3322	0.496	2001-02	2976	0.274
1997-98	2306	0.980	2002-03	1489	0.243
1998-99	781	0.391	2003-04	1727	0.260
1999-2000	1536	0.306	2004-05	1604	0.227
			2005-06	1386	0.310
			2006-07	966	0.232

Table 15: Single period CPUE combined index estimates by year, and bootstrap CV estimates.

Year	Kg/tow	CV
1995-96	7472	0.286
1996-97	4453	0.735
1997-98	3366	1.264
1998-99	1444	0.406
1999-2000	2835	0.286
2000-01	2817	0.436
2001-02	632	0.680
2002-03	1973	0.663
2003-04	1296	0.615
2004-05	1284	0.445
2005-06	1289	0.563
2006-07	1056	1.200

4.4.2 Biomass estimates

In all preliminary model runs the length-frequency data series were not well fitted to, and gave a strong but contrasting biomass signal relative to the CPUE indices. Therefore, for final model runs, the length frequency data was down-weighted by using just the 1999 length frequency.

The base case model used early and late period CPUE indices, and the 1999 length frequency data, and current mature biomass was estimated to be 33% of a virgin biomass of 17 400 t (Figure 9).

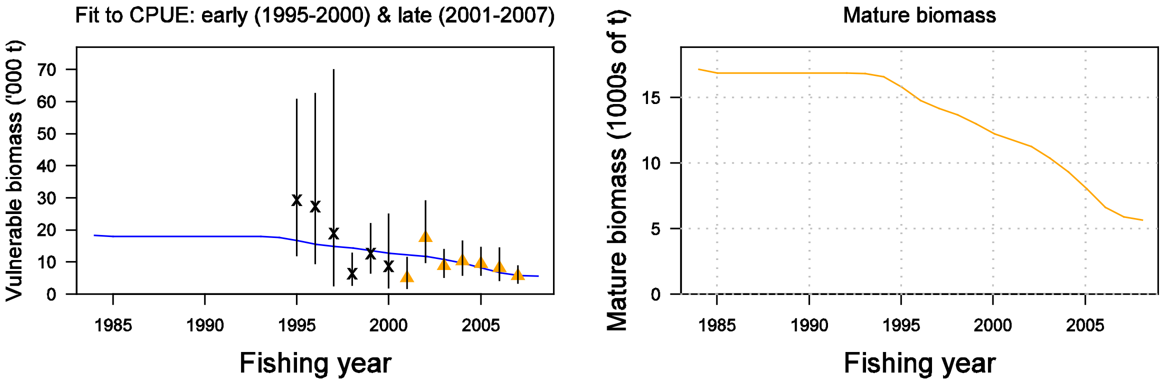


Figure 9: Model run showing the MPD fit to the CPUE data (vertical lines are the 95% confidence intervals for the indices) and the trajectory of mature biomass.

Two sensitivity model runs were carried out with the 1999 length frequency data dropped from the model, but retaining the fishery selectivity estimated using the length data. The first used the early and late period CPUE indices and current biomass was estimated to be 39% of a virgin biomass of 19 300 t. In the second, the single CPUE series covering the same period was used and current biomass was estimated to be 17% of a virgin biomass of 13 900 t. No MCMC runs were carried out with the base case model as the sensitivity run showed that the assessment was quite different if the CPUE analysis was not split into two series.

Biomass estimates are uncertain because of the reliance on commercial CPUE data, the use of biological parameter estimates from other oreo stocks, and because of contrasting biomass signals from using either a single or split CPUE indices.

4.4.3 Projections

No projections were made because of the uncertainty in the assessment.

4.5 Pukaki Rise black oreo stock (part of OEO 6)

This 2009 assessment was the first for this stock applying to the area defined in Figure 10. In 2009, this was the largest black oreo fishery in the New Zealand EEZ with mean (1994-95 to 2007-08) annual catches of 1800 t, but with over 3000 t taken in the previous two years, mainly by New Zealand vessels. There was an early Soviet fishery (1980-81 to 1984-85) with mean annual catches of about 1700 t. Fishery-independent abundance estimates were not available, so a series of relative abundance indices, based on an analysis of post-GPS standardised CPUE, have been developed. Length frequency data collected by MFish (SOP) and Orange Roughy Management Company (ORMC) observers were included in the model. The assessment used biological parameter values estimated for Chatham Rise and Puysegur Bank black oreo because no biological data from Pukaki Rise are available.

The following assumptions were made in this assessment.

1. The CPUE is an index of abundance of black oreo in the Pukaki Rise (OEO 6) assessment area.
2. The length frequency samples were representative of the population being fished.
3. The ranges used for the biological values covered their true values.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.

5. The population of black oreo in the assessment area was a discrete stock or production unit.
6. The catch histories were accurate with no assumed overruns.
7. The maximum exploitation rate (E_{MAX}) was 0.80.
8. The prior for stock size was bounded at an upper limit of 150 000 t.

Data inputs included catch history, relative abundance estimates from a standardised CPUE analysis, and length data from SOP and ORMC observers. The observational data were incorporated into an age-based Bayesian stock assessment (CASAL) with deterministic recruitment to estimate stock size. Life history parameters are from Table 1 of the Biology section at the beginning of the Oreo report.

4.5.1 Estimates of fishery parameters and abundance

Catch history

A catch history for black oreo was derived (Table 16) using declared catches of OEO from OEO 6 (Table 2 in the "Fishery summary" section of the Oreos report above) and tow-by-tow records of catch from the assessment area (Figure 10). The catch history used in the population model is given in Table 16.

Table 16: Catch history (t) of black oreo from the Pukaki Rise fishery assessment area.

Year	Catch	Year	Catch	Year	Catch
1978-79	17	1988-89	0	1998-99	1 181
1979-80	5	1989-90	0	1999-00	1 061
1980-81	283	1990-91	15	2000-01	1 158
1981-82	4 180	1991-92	27	2001-02	988
1982-83	1 084	1992-93	27	2002-03	1 701
1983-84	1 150	1993-94	10	2003-04	1 530
1984-85	1 704	1994-95	242	2004-05	1 588
1985-86	46	1995-96	1 352	2005-06	2 811
1986-87	0	1996-97	2 413	2006-07	3 434
1987-88	0	1997-98	2 244	2007-08	3 346

Length data

Black oreo length frequency data collected by SOP and ORMC observers are available from the last twelve years (Table 17). An analysis indicated that there was a trend in fish size across years (with smaller mean lengths in more recent years) and with depth (deeper fish being larger). The length data were considered reasonably representative of the fishery in terms of spatial, depth and temporal coverage for those years that had adequate data. The length data were stratified into two depth bins: shallow (less than 900 m), and deep strata (greater than 900 m). Length data from adjacent years were grouped because of the low number of samples in some years (Figure 11). There is no trend in mean length over the first six year-groups, but fish sizes appear to be generally smaller in the later year-groups with the mode of the distributions shifting to the left in the plots for 2005-06, 2006-07, and 2007-08.

Table 17: Summary of length frequency data for black oreo available from the assessment area. The table shows the number of tows sampled by year, the sample source, and the year group.

		Number of tows sampled		
Year	Year group	SOP	ORMC	All
1996-97	97-98	7	0	7
1997-98	97-98	25	0	25
1998-99	99-00	7	44	51
1999-00	99-00	6	0	6
2000-01	01-02	8	18	26
2001-02	01-02	2	8	10
2002-03	03-05	7	2	9
2003-04	03-05	18	0	18
2004-05	03-05	21	0	21
2005-06	06	21	42	63
2006-07	07	154	11	165
2007-08	08	31	9	40
Total		307	134	441

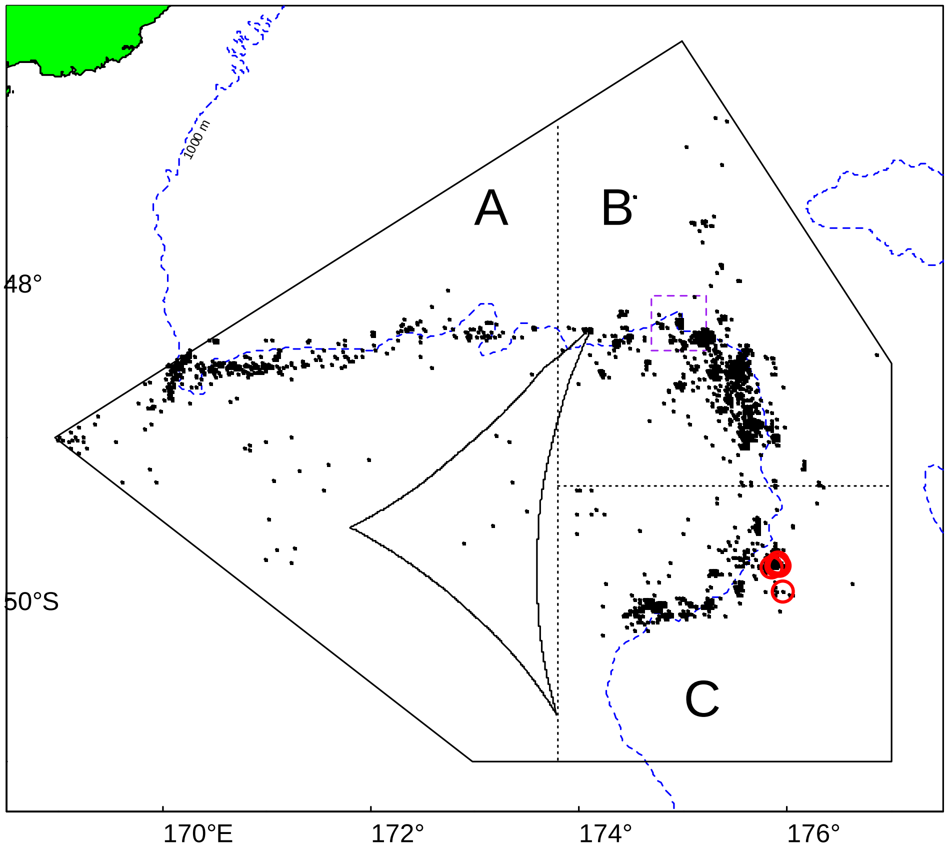


Figure 10: The Pukaki Rise fishery black oreo assessment area (polygon) abutting the boundary of OEO 6/OEO 1 in the north-west. The dots show tows positions where black oreo catch was reported from 1980-81 to 2007-08. A, B, and C are the three areas defined in the standardised CPUE analysis.

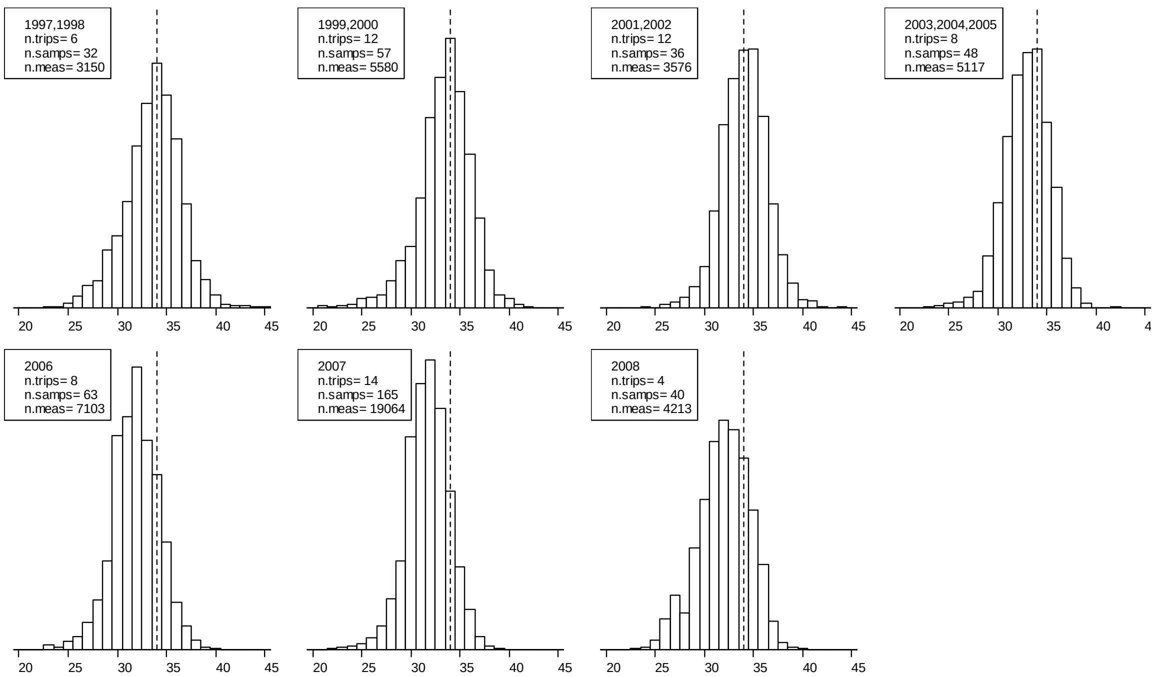


Figure 11: Observer length frequencies for Pukaki Rise black oreo, stratified by depth (see text), and grouped by years (in the legends 1997=1996-97 etc.). The vertical dashed lines indicate the approximate overall mean length as an aid to comparing the distributions.

Relative abundance estimates from CPUE analyses

The fishery taking Pukaki Rise black oreo divides into two distinct periods: a pre-GPS period 1980-81 to 1984-85 when much of the catch was taken by Soviet and Korean vessels, and a post-GPS period, 1995-96 to 2007-08 when most of the catch was taken by New Zealand vessels. The intervening period was characterised by low catches and the introduction of GPS technology in the fleet. Standardisation of CPUE for the pre-GPS period was attempted but rejected due to poor linkage of vessels across years and the shifting of fishing effort between areas.

The standardised CPUE analysis of Pukaki Rise black oreo was therefore based on the post-GPS period and used regression based methods similar to those in previous oreo CPUE analyses but, because the fraction of zero tows was low, only a positive catch model was used. The annual CVs for the index series used in the assessment model were derived from the regression model standard errors. The analysis was restricted to data from vessels fishing in the eastern areas (B and C in Figure 10) with a minimum of 20 successful tows for black oreo in at least three years. Tows originating from a set of ten features identified (by the catch history) as mainly orange roughy or smooth oreo features and which targeted these two species were not used. The selected explanatory variables in this model were depth, tow duration, and area, and the resultant indices showed a decline over the period. The number of tows and CPUE indices are summarised in Table 18.

Table 18: Summary of data used as input to the standardised core target CPUE analysis, CPUE index values and CVs by year as used in the assessment model.

Year	No. of tows	CPUE index	CV	Year	No. of tows	CPUE index	CV
1995-96	63	1.91	0.11	2002-03	303	1.13	0.14
1996-97	55	1.50	0.15	2003-04	324	1.17	0.13
1997-98	187	1.58	0.11	2004-05	294	0.89	0.17
1998-99	221	1.35	0.12	2005-06	465	1.05	0.14
1999-00	242	0.94	0.17	2006-07	618	0.90	0.15
2000-01	189	1.21	0.14	2007-08	747	0.78	0.18
2001-02	167	1.17	0.15				

4.5.2 Biomass estimates

The base case (NoLF) employed a two-step approach, estimating the fishery selectivities from the observer length data during the first phase followed by a second estimation phase where the selectivities were fixed at the MPD values from the first phase and estimating the biomass-related parameters solely on the basis of the CPUE relative biomass indices. The WG chose a base case with M fixed at its best estimate (0.044). Other cases investigated the sensitivity of the model to alternative fixed values for M, representing the range of plausible values for this parameter (0.029 and 0.066) and the influence of the length frequency data (M fixed at 0.044). The three NoLF MCMC runs used a prior on B_0 which limited this parameter to a maximum of 150 000 t, based on estimates of B_0 from other oreo fisheries. In the base case, the current status ($\%B_0$) is highly uncertain with a median of 44% and 95% confidence intervals of 19-80% (Table 19, Figure 12).

Table 19: Mid-year mature biomass estimates (medians) and 95% confidence intervals for the base case model run. $B_{CURRENT}$ is the mid-year mature biomass in 2009, V=vulnerable biomass.

	NoLF, M=0.044		
Biomass estimates	Median	5% CI	95% CI
B_0	40 900	26 900	116 000
$B_{CURRENT}$	18 000	5 060	92 400
$B_{CURRENT}$ ($\%B_0$)	44	19	80
V_0	39 700	26 200	113 000
$V_{CURRENT}$	18 600	6 110	90 600
$V_{CURRENT}$ ($\%V_0$)	47	23	81

4.5.3 Yield estimates

No yield estimates were made.

4.5.4 Projections

Projections were made using the base case model, assuming deterministic recruitment and the current catch (3346 t) for the next five years (Figure 12). The estimated probability of the biomass being less than 20% B_0 went from 0.06 in 2008-09 to 0.47 in 2013-14.

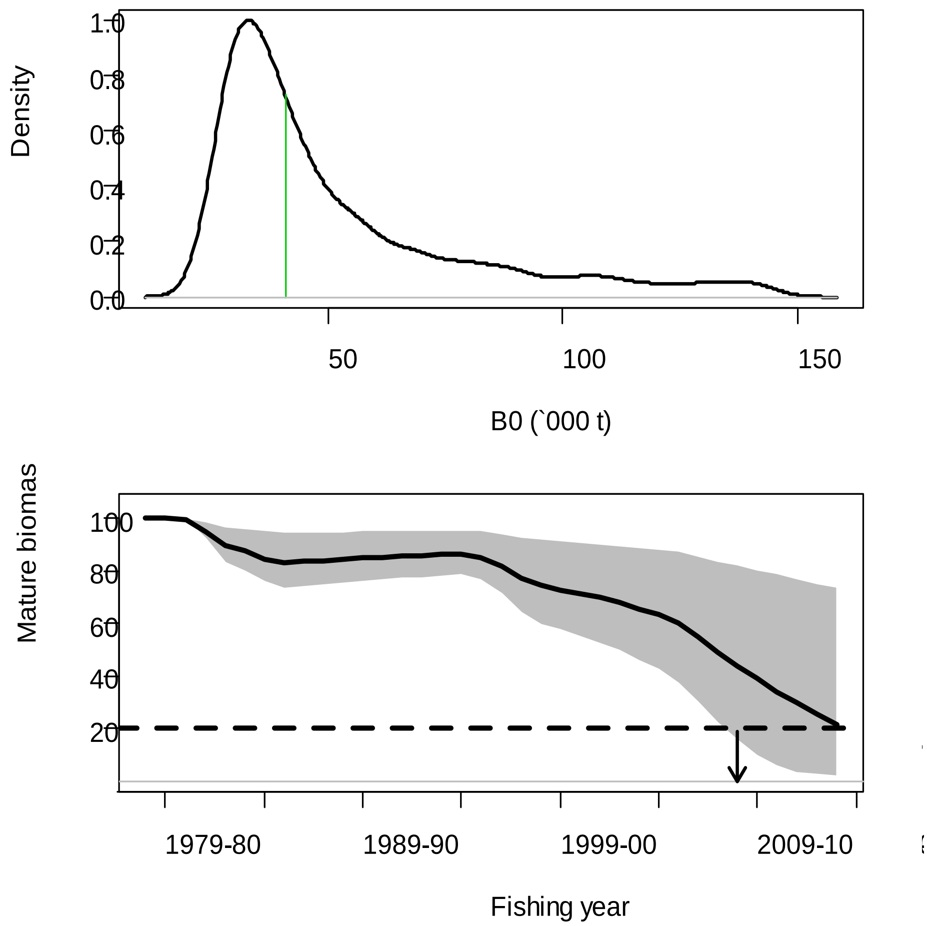


Figure 12: Biomass estimates (B_0) and fishery projections of mature biomass (as %B_0) for the next five fishing years (to 2013-14) for the basecase,. A prior on B_0 limited it to a maximum of 150 000 t. Catch levels were assumed constant at the current level (3346 t).

4.6 Other oreo fisheries in OEO 1 and OEO 6

4.6.1 Estimates of fishery parameters and abundance

Relative abundance estimates from trawl surveys

Two comparable trawl surveys were carried out in the Puysegur area of OEO 1 (TAN9208 and TAN9409). The 1994 oreo abundance estimates are markedly lower than the 1992 values (Table 20).

4.6.2 Biomass estimates

Estimates of virgin and current biomass are not yet available.

4.6.3 Estimation of Maximum Constant Yield (*MCY*)

MCY cannot be estimated because of the lack of current biomass estimates for the other stocks.

4.6.4 Estimation of Current Annual Yield (*CAY*)

CAY cannot be estimated because of the lack of current biomass estimates for the other stocks.

4.6.5 Other factors

Recent catch data from this fishery may be of poor quality because of area misreporting.

Table 20: OEO 1. Research survey abundance estimates (t) for oreos from the Puysegur and Snares areas. N is the number of stations. Estimates for smooth oreo were made based on a recruited length of 34 cm TL. Estimates for black oreo were made using knife-edge recruitment set at 27 cm TL.

	Mean biomass	Lower bound	Upper bound	CV (%)	N
Smooth oreo					
Puysegur area (strata 0110-0502)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	1 397	736	2 058	23	82
1994	529	86	972	41	87
Snares area (strata 0801-0802)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	2 433	0	5 316	59	8
1994	118	0	246	54	7
Black oreo					
Puysegur area (strata 0110-0502)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	2 009	915	3 103	27	82
1994	618	0	1 247	50	87
Snares area (strata 0801-0802)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	3 983	0	8 211	53	8
1994	1 564	0	3 566	64	7

5. STATUS OF THE STOCKS

New assessment results are reported here for the 2007 Southland assessment.

Stock Structure Assumptions

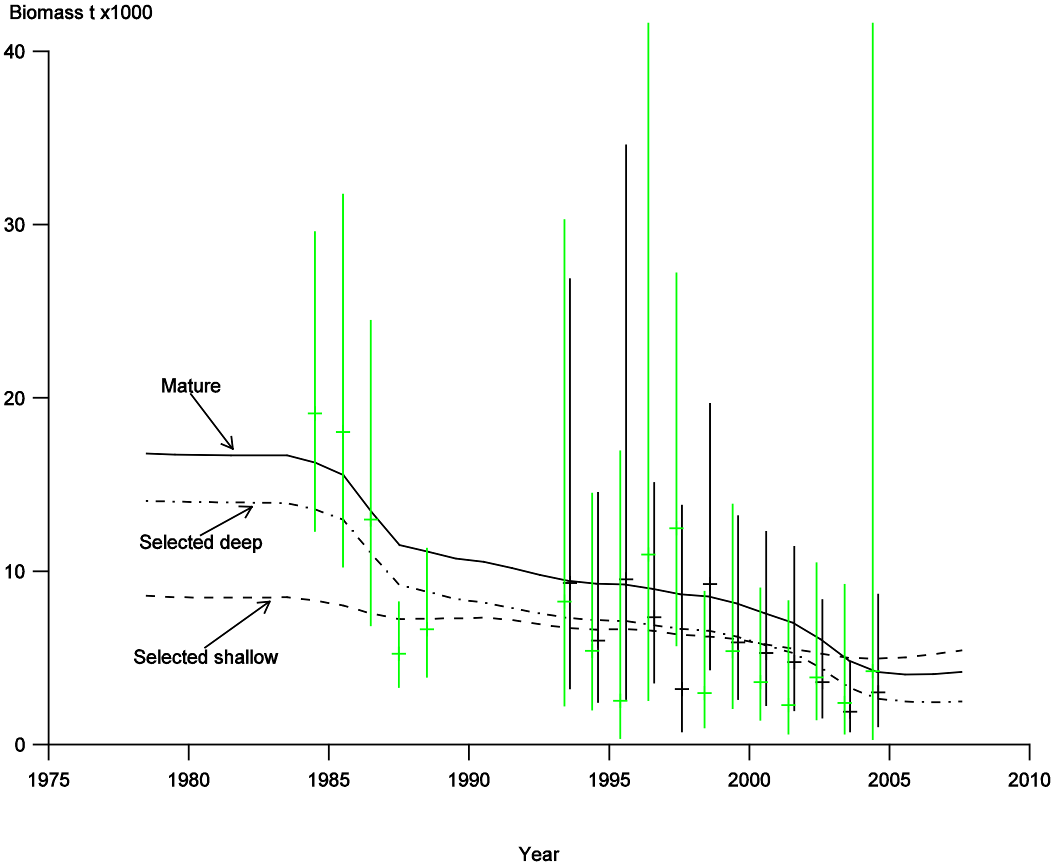
Oreos in the OEO1+6 FMAs are managed as a single stock but assessed as 4 separate stocks, separated by species and geography.

The Southland smooth oreo stock is based along the east coast of the south island in OEO1 but extends slightly into OEO3. It does not include the Waitaki and Eastern canyon areas but is likely to have some level of mixing with other smooth oreo fishstocks. The Pukaki Rise smooth oreo stock comprises the major part of OEO6 stocks and is centered on its namesake. Some mixing with other smooth oreo fishstocks is thought to occur. The Bounty Plateau smooth oreo stock is located across the Bounty Plateau and the Bounty Islands. Some mixing is thought to occur with other smooth oreo fishstocks.

The Pukaki Rise black oreo stock is the main black oreo fishstock in OEO6 and the largest black oreo fishstock in the New Zealand EEZ. It extends the entire length of the Rise towards OEO1. It is assessed separately to other fishstocks but managed as a part of OEO6. Black oreos on the Pukaki Rise are thought to be non-mixing with other black oreo fishstocks.

- **OEO1+3A Southland (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2007
Assessment Runs Presented	One base case only
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2007} was estimated at 27% B_0, Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	B_{2007} was estimated to be Unlikely (< 40%) to be below the Soft Limit and Very Unlikely(< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status

Predicted biomass trajectories for the 2007 base case assessment. Mature biomass and selected biomass for the shallow and deep fisheries. Also shown are the CPUE indices from the pre- and post-GPS analysis for the deep fishery (in gray) and the post-GPS analyses for the shallow fishery (in black). CPUE indices are shown with +/- 2 s.e. confidence interval indicated by the vertical lines (the post-GPS CPUE data are slightly offset to avoid over plotting). The CPUE data were scaled by catchability coefficients to match the biomass scale.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has been declining at a steady rate since the late 1980s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	None because of assessment uncertainty.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology	
Assessment Type	Type 1 - Quantitative Stock Assessment
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.
Main data inputs	- Length-frequency data collected by SOP and ORMC observers - A second, earlier fishery based on Soviet vessels was included in the assessment using historical catch data. - Standardised CPUE indices were derived from the historical and modern datasets.

Period of Assessment	Latest assessment: 2007	Next assessment: 2012
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- Scarcity of observer length frequency data - Poor quality area catch data due to significant misreporting - Lack of fishery-independent abundance estimates creates reliance on commercial CPUE data.	

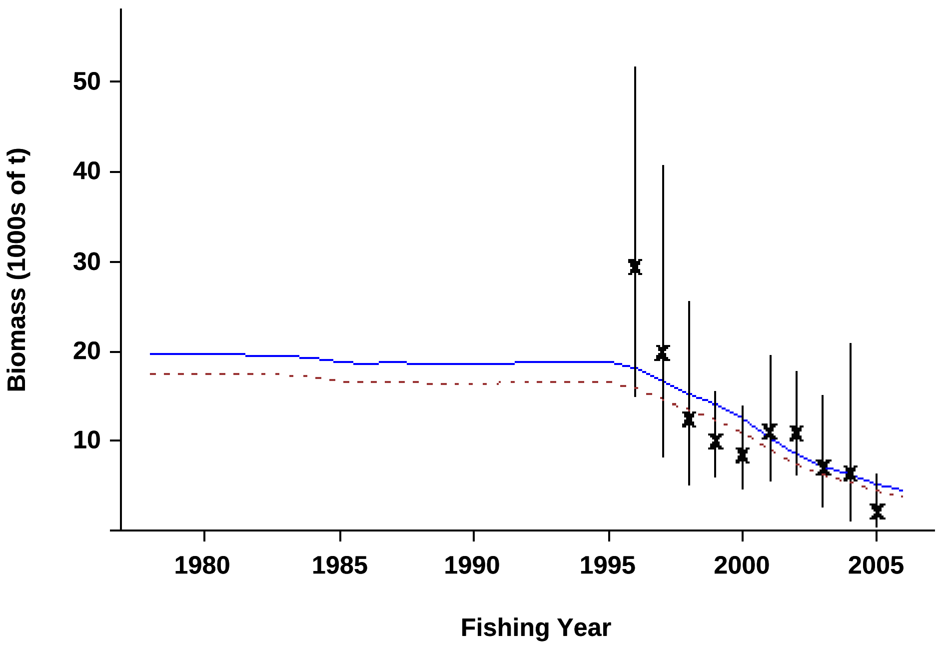
Qualifying Comments

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO6 Pukaki Rise (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2006
Assessment Runs Presented	A base case with 4 sensitivities.
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	For the base case, B_{2006} was estimated at 42% B_0. B_{2006} is About as Likely as Not (40-60%) to be at or above the target.
Status in relation to Limits	B_{2006} is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Model run based on CPUE data only, with a_{50} set at 19 yr. The crosses show the CPUE data (vertical lines are the 95% confidence intervals for the indices) and their fits to the vulnerable biomass trajectory (solid line). The dashed line shows the mature biomass trajectory. Fits and trajectories are from MPD estimates.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been declining since 1996

Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	No projections were made due to the uncertainties in the assessment.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Type 1 - Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Catch history - Standardised CPUE abundance estimates - Length data (SOP, ORMC observers)	
Period of Assessment	Latest assessment: 2006	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	- Lack of fishery-independent biomass estimates creates reliance on commercial CPUE data - Lack of biological parameters specific to Smooth Oreo in the target area - data from Chatham Rise/Puysegur Bank had to be substituted instead.	

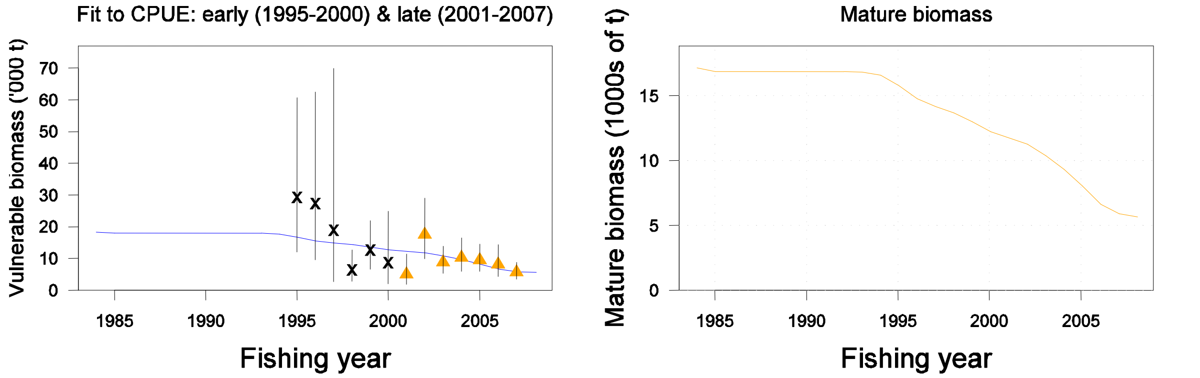
Qualifying Comments
None

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO6 Bounty Plateau (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	A base case with 2 sensitivity runs
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Targe	B_{2008} was estimated at 33% B_0; Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	B_{2008} is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Model run showing the MPD fit to the CPUE data (vertical lines are the 95% confidence intervals for the indices) and the trajectory of mature biomass.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been decreasing rapidly since 1995.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	No projections were made because of the uncertainty of the assessment.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Type 1 - Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Catch history - Abundance estimates derived from a standardised CPUE - Length data from SOP and ORMC observers	
Period of Assessment	Latest assessment: 2008	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Reliance on commercial CPUE data - To estimate biological parameters, data was used from different stocks (Puysegur Bank + Chatham Rise) to the target stock - Using a single CPUE index vs. split indices give contrasting biomass signals.	

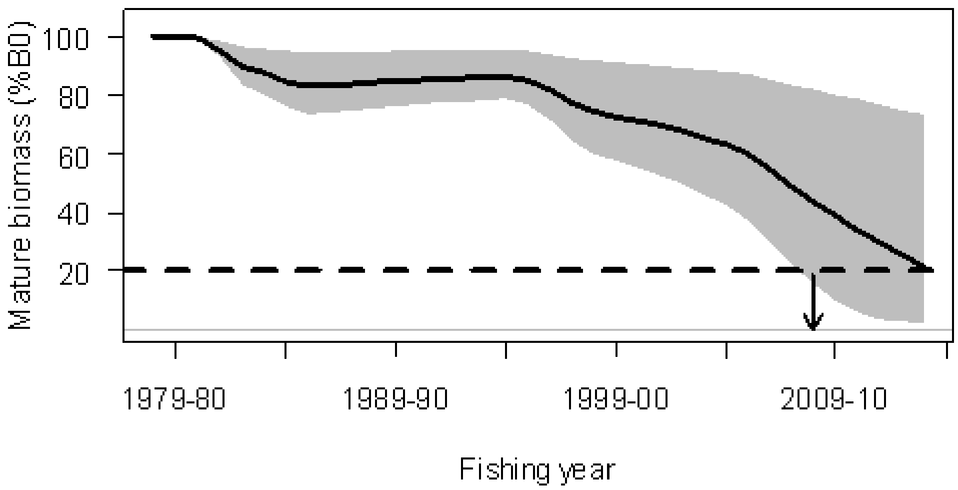
Qualifying Comments

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO6 Pukaki Rise (Black Oreos)**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	A base case and 3 sensitivity runs
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2009} was estimated at 44% B_0. B_{2009} is About as Likely as Not (40-60%) to be at or above the target.
Status in relation to Limits	B_{2009} was estimated to be Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (<10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Black Oreo Pukaki Rise Stock - Mature biomass trajectories as a percentage of virgin biomass from the analysis of the "NoLF" case with M = 0.044 (base case). The grey area is the point-wise 95% confidence intervals of the trajectories and the solid line is the median.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been decreasing since the 1980s with a major decline starting about 1995.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2009)	
Stock Projections or Prognosis	Biomass is likely to decline in the next 5 years if catches are maintained at the 2007-08 level (3346 t). Estimated probability of the biomass being less than 20% B_0 went from 0.06 in 2008-09 to 0.47 in 2013-14.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: About as Likely as Not (40-60%) Hard Limit: Unknown

Assessment Methodology	
Assessment Type	Type 1 - Quantitative Stock Assessment
Assessment Method	Age-structured CASAL model

Main data inputs	- Catch history data

	- Abundance estimates derived from a standardised CPUE - Length data from SOP and ORMC observers	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Lack of fisheries-independent data causes reliance on commercial CPUE data. - Lack of biological parameter estimates specific to Black Oreo in this assessment area.	

Qualifying Comments

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

6. FOR FURTHER INFORMATION

Coburn R.P., Doonan I.J., McMillan P.J. 2002. CPUE analyses for the Southland black oreo and smooth oreo fisheries, 1977-78 to 1999-2000. New Zealand Fisheries Assessment Report 2002/3. 28 p.

Coburn R.P., Doonan I.J., McMillan P.J. 2002. CPUE analyses for the major black oreo and smooth oreo fisheries in OEO 6, 1980-81 to 1999-2000. New Zealand Fisheries Assessment Report 2002/6. 29 p.

Coburn R.P., Doonan I.J., McMillan P.J. 2003. Stock assessment of smooth oreo in the Southland fishery (OEO 1 and 3A) for 2003. New Zealand Fisheries Assessment Report 2003/62. 32 p.

Coburn R.P., Doonan I.J., McMillan P.J. 2008. A stock assessment of smooth oreo in Southland (part of OEO 1 & OEO 3A). New Zealand Fisheries Assessment Report 2008/37. 43 p.

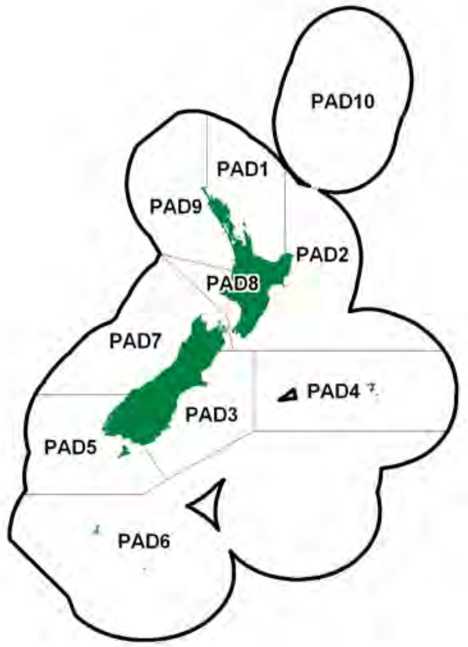
Coburn R.P., McMillan P.J., Gilbert D.J. 2007. Inputs for a stock assessment of smooth oreo, Pukaki Rise (part of OEO 6). New Zealand Fisheries Assessment Report 2007/23. 3 2p

McKenzie A. 2007. Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6). New Zealand Fisheries Assessment Report 2007/34. 27p.

McMillan P.J., Coburn R.P., Hart A.C., Doonan I.J. 2002. Descriptions of black oreo and smooth oreo fisheries in OEO 1, OEO 3A, OEO 4, and OEO 6 from 1977-78 to the 2000-01 fishing year. New Zealand Fisheries Assessment Report. 2002/40.

PADDLE CRABS (PAD)

(Ovalipes catharus)
Papaka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Paddlecrabs were introduced into the QMS from 1 October 2002 with recreational and customary non-commercial allowances, TACCs and TACs summarised in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs for paddle crabs, by Fishstock.

Fishstock	Recreational Allowance	Customary non-Commercial Allowance	TACC	TAC
PAD 1	20	10	220	250
PAD 2	10	5	110	125
PAD 3	8	2	100	110
PAD 4	4	1	25	30
PAD 5	4	1	50	55
PAD 6	0	0	0	0
PAD 7	4	1	100	105
PAD 8	4	1	60	65
PAD 9	20	10	100	130
PAD 10	0	0	0	0

Commercial interest in paddle crabs was first realised in New Zealand in 1977-78 when good numbers of large crabs were caught off Westshore Beach, Napier in baited lift and set-pots. Annual catches have varied, mainly due to marketing problems, and estimates are likely to be conservative. Landings increased in the early fishery, from 775 kg in 1977 to 306 t in 1985, and 403 t in 1995-96 but have since decreased to 132 t in the most recent year. Paddle crabs are known to be discarded from inshore trawl operations targeting species such as flatfish, and this may have resulted in under-reporting of catches. Crabs are marketed live, as whole cooked crabs, or as crab meat. Attempts were made to establish a soft-shelled crab industry in New Zealand in the late 1980s.

Bycatch is commonly taken during trawl, dredge and setnetting operations. Catch rates vary considerably with method, season and area, and there is no clear seasonal trend to paddle crab landings. It is likely that catches are related to the availability of fishers and/or market demands. Commercial landings from 1989-90 until present are shown in Table 2, while Figure 1 shows the historical landings and TACC for the six main PAD stocks.

Table 2: Reported landings (t) of paddle crabs by QMA and fishing year, from CLR and CELR$_{landed}$ data from 1989-90 to 2010-11.

QMA	PAD1		PAD2		PAD3		PAD4		PAD5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1989-90	20	-	57	-	38	-	< 1	-	< 1	-
1990-91	34	-	37	-	26	-	0	-	6	-
1991-92	96	-	32	-	31	-	< 1	-	< 1	-
1992-93	175	-	14	-	36	-	0	-	< 1	-
1993-94	277	-	18	-	46	-	0	-	< 1	-
1994-95	237	-	6	-	36	-	< 1	-	< 1	-
1995-96	183	-	5	-	18	-	< 1	-	1	-
1996-97	165	-	25	-	36	-	0	-	1	-
1997-98	158	-	126	-	18	-	< 1	-	13	-
1998-99	195	-	197	-	21	-	< 1	-	2	-
1999-00	265	-	21	-	27	-	1	-	14	-
2000-01	32	-	10	-	17	-	0	-	0	-
2001-02	221	-	34	-	22	-	0	-	2	-
2002-03	145	220	65	110	18	100	< 1	25	< 1	50
2003-04	239	220	46	110	20	100	0	25	0	50
2004-05	163	220	44	110	30	100	0	25	0	50
2005-06	109	220	49	110	11	100	0	25	< 1	50
2006-07	53	220	21	110	13	100	0	25	3	50
2007-08	86	220	9	110	19	100	0	25	< 1	50
2008-09	36	220	14	110	37	100	0	25	1	50
2009-10	35	220	17	110	37	100	0	25	< 1	50
2010-11	49	220	18	110	47	100	0	25	<1	50

QMA	PAD6		PAD7		PAD8		PAD9		PAD10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1989-90	0	-	94	-	22	-	0	-	0	-
1990-91	0	-	68	-	12	-	0	-	0	-
1991-92	0	-	83	-	21	-	0	-	0	-
1992-93	0	-	59	-	24	-	0	-	0	-
1993-94	0	-	49	-	27	-	5	-	0	-
1994-95	0	-	71	-	46	-	< 1	-	0	-
1995-96	55	-	82	-	58	-	< 1	-	< 1	-
1996-97	25	-	106	-	44	-	< 1	-	1	-
1997-98	7	-	63	-	25	-	< 1	-	< 1	-
1998-99	10	-	59	-	34	-	0	-	1	-
1999-00	14	-	45	-	50	-	0	-	< 1	-
2000-01	0	-	0	-	< 1	-	0	-	0	-
2001-02	22	-	33	-	24	-	0	-	0	-
2002-03	< 1	0	42	100	11	60	0	100	0	0
2003-04	0	0	50	100	17	60	< 1	100	0	0
2004-05	0	0	40	100	14	60	1	100	0	0
2005-06	0	0	48	100	14	60	1	100	0	0
2006-07	0	0	32	100	11	60	< 1	100	0	0
2007-08	0	0	47	100	7	60	0	100	0	0
2008-09	0	0	35	100	11	60	< 1	100	0	0
2009-10	0	0	17	100	13	60	0	100	0	0
2010-11	0	0	11	100	14	60	0	100	0	0

QMA	Total	
	Landings	TACC
1989-90	231	-
1990-91	183	-
1991-92	264	-
1992-93	308	-
1993-94	423	-
1994-95	397	-
1995-96	403	-
1996-97	403	-
1997-98	410	-
1998-99	519	-
1999-00	437	-
2000-01	59	-
2001-02	358	-
2002-03	281	765
2003-04	372	765
2004-05	292	765
2005-06	232	765
2006-07	132	765
2007-08	168	765

QMA	Total	
	Landings	TACC
2008-09	134	765
2009-10	120	765
2010-11	140	765

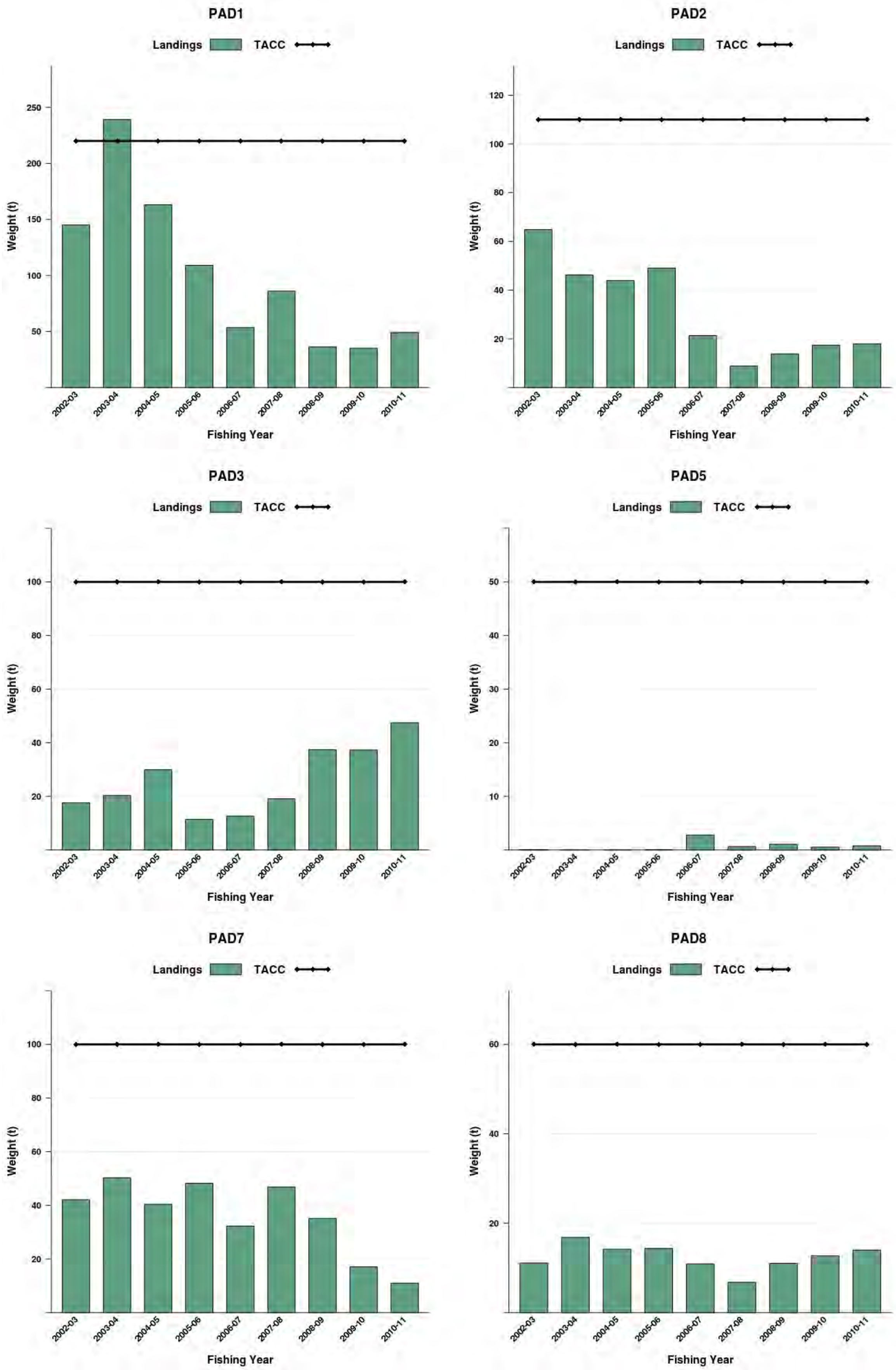


Figure 1: Historical landings and TACC for the six main PAD stocks. From top left to bottom right: PAD1 (Auckland East), PAD2 (Central East), PAD3 (south East Coast), PAD5 (Southland), PAD7 (Challenger), and PAD8 (Central Egmont). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
Preliminary data from the 1996 National Marine Recreational Fishing Survey indicate that paddle crabs are seldom caught (NIWA unpublished). Paddle crabs are taken as a bycatch of beach and estuarine seining and in setnets throughout much of their geographical range.

1.3 Customary non-commercial fisheries
There is no quantitative information on the current level of customary non-commercial catch.

1.4 Illegal catch
There is no quantitative information available on the current level of illegal catch.

1.5 Other sources of mortality
There is no quantitative information available on other sources of mortality, although unknown quantities of paddle crabs have been discarded from commercial fishing operations such as the inshore trawl setnet and dredge fisheries.

2. BIOLOGY

The paddle crab is found off sandy beaches, and in harbours and estuaries throughout mainland New Zealand, the Chatham Islands, and east and south Australia. They are abundant from the intertidal zone to at least 10 m depth, although they do occur in much deeper water. Paddle crabs are mainly active in early evening or at night, when they move into the shallow intertidal zone to feed.

Paddle crabs are versatile and opportunistic predators. They feed mainly on either molluscs or crustaceans, but also on polychaetes, several fish species, cumaceans, and occasionally on algae. A high proportion of the molluscs eaten are *Paphies* species. These include: tuatua (*P. subtriangulata);* pipi (*P. australis);* and toheroa (*P. ventricosa).* The burrowing ghost shrimp *Callianassa filholi,* isopods and amphipods are important crustacean prey items. Cannibalism is common, particularly on small crabs and during the winter moulting season.

Anecdotal information suggests there has been a significant increase in paddle crab numbers since the 1970s. Concern has been expressed as to the impact of an increased number of paddle crabs on bivalve shellfish stocks in coastal waters. Feeding studies have shown that although paddle crabs do eat large adult toheroa and other shellfish, they more usually eat bivalve shellfish spat which are found in abundance.

Mating generally occurs during winter and spring (May to November) in sheltered inshore waters. Female paddle crabs can only mate when they are soft-shelled. Male crabs protect and carry pre-moult females to ensure copulation. Female crabs are thought to migrate to deeper water to spawn over the warmer months (September to March). After spawning the eggs are incubated until they hatch. *Ovalipes catharus* has an extended larval life characterised by eight zoea stages and a (crab-like) megalopa. The larvae are thought to live offshore in deeper water, migrating inshore in the megalopa stage to settle from January to May.

Two spawning mechanisms have been observed in *O. catharus*. In Wellington, Tasman Bay, and Canterbury, spawning does not appear to be synchronised and females may spawn several times during the season (non-synchronous spawning). In Blueskin Bay, Otago, paddle crabs are group-synchronous, with one clutch of eggs developing to maturity over winter, and spawned from September to February.

Annual fecundity is determined by the number of eggs per brood (brood fecundity) and the number of broods per year. Both these parameters are size dependent and highly variable. Brood fecundity estimates vary considerably geographically from between 82 000 - 638 000 in Wellington waters, to 100 000 - 1 200 000 in Canterbury waters, and 931 000 - 2 122 807 in Otago waters. The number of broods per year also varies geographically from 1.2-3.3 in Wellington waters, to 1.2-2.2 in Canterbury waters, and 1 brood per year in Otago waters (group synchronous spawning).

O. catharus is a relatively large and fast growing species of *Ovalipes.* In Canterbury waters, paddle crabs reach a maximum size of 130 mm carapace width (CW - males only) after 13 postlarval moults and 3 to 4 years after settlement. Other studies have reported maximum sizes up to 150 mm CW. In Wellington waters, crabs of approximately 100 mm carapace width, of either sex, would be at least 3 years old, while larger crabs could be 4 or 5 years old.

The differences in growth rate, size at first maturity, and fecundity (particularly the number of broods) appear to be largely environmentally regulated. At lower temperatures and higher latitudes, paddle crabs grow slower, mature at a larger size, have a shorter breeding season, and produce fewer broods per year.

Estimates of biological parameters relevant to stock assessment are presented in Table 3.

Table 3: Estimates of biological parameters

Fishstock				**Estimate**	**Source**
1. Natural mortality (females only)					
(Percentage mortality at each instar stage)					
Instar		Tasman Bay (QMA 7)		Canterbury (QMA 3)	
8		15.3		15.0	Osborne (1987)
9		31.2		30.0	
10 (68-75 mm CW)		78.1		39.1	
11		30.7		38.9	
12		55.6		18.2	
13 (> 100 mm CW)		100		100	
2. weight = a + b log CW (carapace width)					
		Females		Males	
Canterbury (QMA3)	a	b	a	b	Davidson & Marsden (1987)
	-3.32	2.79	-3.46	2.89	

3. STOCKS AND AREAS

It is not known whether biologically distinct stocks occur, although this seems unlikely given that the species is found throughout New Zealand waters, and from tagging experiments, appears to be highly migratory. There is probably also widespread larval dispersal as larvae spend two months offshore in deeper water (to at least 700 m). Genetically distinct populations may occur in isolated areas such as the Chatham Islands and Australia.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance
None are available at present.

4.2 Biomass estimates
No estimates of current or virgin biomass are available. The landings, CPUE, and area data are considered too unreliable or incomplete to allow modelling.

4.3 Estimation of Maximum Constant Yield (*MCY*)
MCY cannot be estimated.

4.4 Estimation of Current Annual Yield (*CAY*)
CAY cannot be estimated because of the lack of current biomass estimates.

4.5 Other yield estimates and stock assessment results
None are available at present.

5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available. Landings have fluctuated significantly in most QMAs, mainly due to market variations. Paddle crabs are abundant throughout most of their range and the fishery is probably only lightly exploited.

Yield estimates, TACCs and reported landings for the 2010-11 fishing year are summarised in Table 4.

Table 4: Summary of TACCs (t), and reported landings (t) of paddle crabs for the most recent fishing year.

Fishstock		QMA	2010-11 TACC (t)	2010-11 landings (t)
PAD 1	Auckland (East)	1	220	49
PAD 2	Central (East)	2	110	18
PAD 3	South-east (Coast)	3	100	47
PAD 4	South-east (Chatham)	4	25	0
PAD 5	Southland	5	50	0.7
PAD 6	Sub-Antarctic	6	0	0
PAD 7	Challenger	7	100	11
PAD 8	Central (West)	8	60	14
PAD 9	Auckland (West)	9	100	0
PAD 10	Kermadec	10	0	0
Total			765	140

6. FOR FURTHER INFORMATION

Armstrong J.H. 1985. Aspects of the biology of the swimming crab, *Ovalipes catharus* (White, 1843) in the Otago region. Unpublished MSc thesis, University of Otago, Dunedin.

Clark M.R. 1978. Aspects of the population biology of the swimming crab *Ovalipes catharus* (White, 1843) (Crustacea; Decapoda; Portunidae) in the Plimmerton Area, Wellington. Unpublished BSc (Hons). Zoology Department, Victoria University, Wellington. 115p.

Davidson R.J. 1987. Natural food and predatory activity of the paddle crab, *Ovalipes catharus.* Unpublished MSc thesis. Zoology Department, University of Canterbury, Christchurch, New Zealand. 110p.

Davidson R.J., Marsden I.D. 1987. Size relationships and relative growth of the New Zealand swimming crab *Ovalipes catharus* (White, 1983). Journal of Crustacean Biology 7: 308-317.

Haddon M. 1988. Impact of paddle crabs on shellfish. Catch 15: 9-11.

Kung H.T. 1973. Some aspects of the biology of the swimming crab *Ovalipes catharus* (White, 1843) in Paremata Harbour, New Zealand. Unpublished MSc thesis, Victoria University, Wellington.

McLay C.L. 1988. Brachyura and crab-like Anomura of New Zealand. Leigh Laboratory Bulletin No: 22, University of Auckland. 463p.

NZFIB 1996. The New Zealand seafood industry economic review 1994-1996. New Zealand Fishing Industry Board, Wellington. 65p.

Osborne T.A. 1987: Life history and population biology of the paddle crab, *Ovalipes catharus.* Unpublished PhD thesis. Zoology Department, University of Canterbury, Christchurch, New Zealand. 156p.

Stead D. 1983. Paddle crab investigations. Catch 10: 14-15.

Stead D. 1984. Crab fishery expansion possible. Catch 11: 13-14.

Stevens D.W. 1999. A summary of biology and commercial landings and a stock assessment of paddle crabs *Ovalipes catharus* White, 1843 (Crustacea, Portunidae) in New Zealand waters. New Zealand Fisheries Research Assessment Document 1999/18. 26p.

Sullivan M., Lang G. 1995. Fisheries Law, Brooker's, Wellington.

Wear R.G. 1988a. Paddle crab fishery has potential in New Zealand. Catch 15: 11p.

Wear R.G. 1988b. Paddle crabs eat small shellfish. Catch 15: 12-13.

Wear R.G., Haddon M. 1987. Natural diet of the crab *Ovalipes catharus* (Crustacea, Portunidae) around central and northern New Zealand. Marine Ecology (Progress series) 35: 39-49.

PARORE (PAR)

(Girella tricuspidata)
Parore

1. FISHERY SUMMARY

Parore was introduced into the Quota Management System (QMS) on 1 October 2004 with the TACs, TACCs and allowances shown in Table 1.

Table 1: TACs (t), TACCs (t) and allowances (t) for parore.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
PAR 1	6	3	4	61	74
PAR 2	1	1	0	2	4
PAR 9	2	1	1	21	25
PAR 10	0	0	0	0	0
Total	9	5	5	84	103

1.1 Commercial fisheries

Parore is principally caught as a bycatch in the grey mullet, flatfish and trevally setnet fisheries in northern New Zealand. Most of the catch comes from eastern Northland and the Firth of Thames (FMA 1) and the Kaipara and Manukau Harbours (FMA 9) (Figure 1). Highest catch rates occur during September to October. Few parore are caught in the other FMAs. Reported landings and TACCs for Parore are given in Tables 2 and 3.

Fishers may confuse the codes PAR (parore) and POR (porae) when reporting catches, but given that both species occur in shallow northern waters, misreporting is difficult to discern.

Table 2: Reported landings (t) of parore by FMA, fishing years 1989-90 to 2003-04.

	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 7	FMA 8	FMA 9
1989-90	18	< 1	0	0	< 1	< 1	0	< 1
1990-91	81	2	< 1	< 1	< 1	< 1	< 1	0
1991-92	100	< 1	< 1	0	0	2	0	0
1992-93	109	< 1	< 1	0	< 1	< 1	0	0
1993-94	95	< 1	0	< 1	0	< 1	< 1	0
1994-95	95	< 1	< 1	0	0	< 1	0	3
1995-96	89	< 1	0	0	0	< 1	< 1	9
1996-97	70	< 1	< 1	< 1	0	3	< 1	6

Table 2 [Continued].

	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 7	FMA 8	FMA 9
1997-98	73	< 1	< 1	0	0	< 1	< 1	5
1998-99	73	< 1	< 1	< 1	0	< 1	< 1	6
1999-00	79	< 1	< 1	0	< 1	< 1	< 1	4
2000-01	91	< 1	< 1	0	0	< 1	< 1	9
2001-02	67	1	< 1	0	< 1	< 1	0	3
2002-03	89	0	0	0	0	0	0	4
2003-04	49	< 1	< 1	0	0	0	< 1	6

Table 3: Reported domestic landings (t) of Parore Fishstock and TACC, fishing years 2004-05 to 2010-11.

Fishstock		PAR 1		PAR 2		PAR 9		
FMA		1		2,3,4,5,6,7&8		9		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004-05	42	61	< 1	2	14	21	56	84
2005-06	48	61	< 1	2	15	21	63	84
2006-07	52	61	< 1	2	10	21	61	84
2007-08	57	61	< 1	2	11	21	68	84
2008-09	59	61	< 1	2	20	21	79	84
2009-10	70	61	< 1	2	22	21	92	84
2010-11	62	61	< 1	2	18	21	80	84

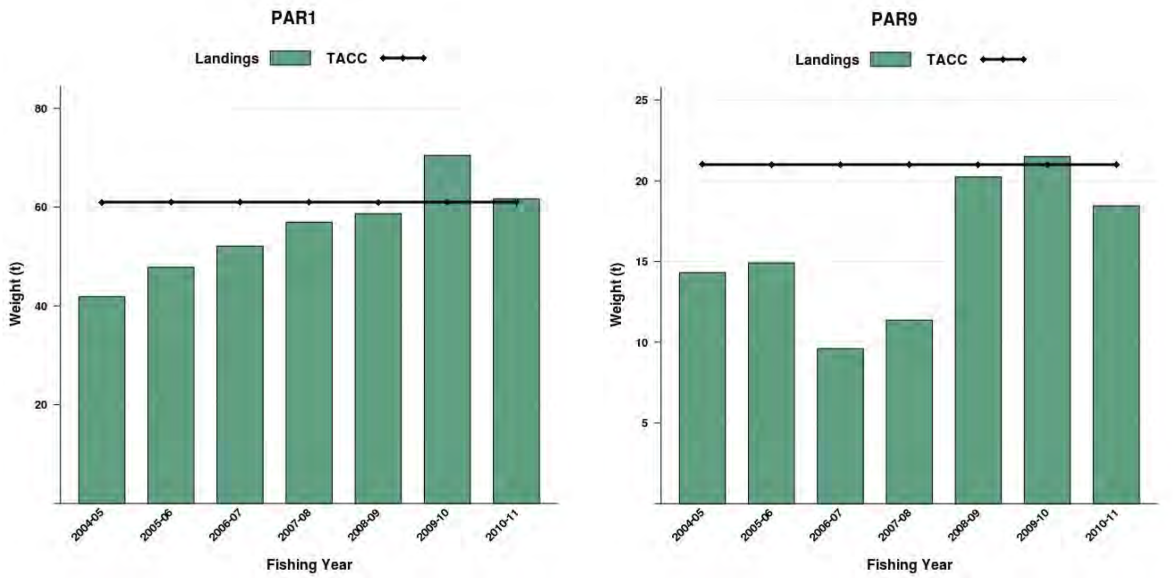


Figure 1: Historical landings and TACC for the two main PAR stocks. On the left: PAR 1 (Auckland East) and PAR 9 (Auckland West). Note that these figures do not show data prior entry into the QMS.

1.2 Recreational fisheries

The National Marine Recreational Fishing surveys in 1994, 1996, and 2000 do not provide estimates of recreational catches of parore. There is likely to be some recreational catch in northern areas as a bycatch when targeting other species such as snapper, trevally, and mullet. These catches are most likely taken by setnetting, as well as being targeted opportunistically by spear fishing. Parore is considered to be a low value recreational species and current catches are likely to be low.

Non-commercial catches are likely to increase in the future arising from the increasing human population in northern New Zealand, and the likely increase in the number of recreational fishers. Increased targeting may also occur as parore are considered good eating.

1.3 Customary non-commercial fisheries

There is no quantitative information on customary harvest levels of parore. Customary fishers are likely to catch small quantities of parore when targeting other species such as snapper, trevally, and mullet. Parore is considered to be a low value customary species and current catches are likely to be low.

2. BIOLOGY

Parore (*Girella tricuspidata*) occur along both east and west coasts of the North Island, from North Cape to Cook Strait (Anderson *et al*. 1998). It has not been recorded around the Chatham Islands. They usually occur in schools, ranging from half a dozen to several hundred individuals. Although there is evidence that large individuals display territorial behaviour on some reef systems, work in Australia has shown that parore are capable of moving distances of hundreds of kilometres (Pollock 1981).

Parore grow to a maximum size of at least 600 mm, but most adult fish are around 300 - 400 mm in length. The maximum age for this species on the North Island east coast, as estimated by scale ring counts (validated by seasonal increments), is 10 years (Morrison 1990). As scales tend to provide underestimates of the age of older fish, maximum age could be considerably higher. Growth is relatively rapid in the first year of life, with fish reaching a size of ~ 100 mm at age one. Fish reach a length of 300 mm by age five, at which time growth slows. Growth rates between males and females, and open coast and estuarine populations, appear similar. No growth studies have been undertaken on the west coast of the North Island, but large parore (~ 600 mm) are sometimes taken in harbour set-nets as bycatch.

Parore reach sexual maturity at a length of 280 mm and spawning takes place in late spring to early summer (Morrison 1990). Larvae are neustonic, occurring near the ocean’s surface, often in association with drifting material such as seaweed clumps.

Juveniles enter estuaries in January at a length of ~ 11 mm. They are initially found on seagrass meadows and beds of Neptune’s Necklace (*Hormosira banksii*) on shallow reefs, but after 3-4 months move down the estuary to other habitats e.g., brown kelp beds. At approximately one year old, they move out to coastal reefs in the immediate vicinity of estuary mouths and over the following 2-3 years move to reef systems further off- and along-shore (Morrison 1990).

Parore are important herbivores in coastal systems and may play a significant role in structuring algal assemblages (Morrison 1990). Juvenile parore have been found in the stomachs of kahawai and John dory.

There is no fishery independent information to determine the stock status of parore. Biomass estimates cannot be determined for this species with existing data.

3. STOCKS AND AREAS

There is insufficient biological information available on this species to indicate the existence of separate stocks around New Zealand. However, reliance on localized nursery areas suggests that more than one biological stock may exist.

4. STOCK ASSESSMENT

There has been no scientific assessment of the maximum sustainable yield for parore stocks.

5. STATUS OF THE STOCK

Estimates of current and reference biomass are not available. It is not known if recent catch levels or TACs are sustainable. The status of PAR 1, 2 and 9 relative to B_{MSY} is unknown.

TACCs and reported landings of parore by Fishstock, for the 2010-11 fishing year, are summarised in Table 4.

Table 4: Summary of TACCs (t) and reported landings (t) of parore for the most recent fishing year.

Fishstock		FMA	2010-11 Actual TACC	2010-11 Reported landings
PAR 1	Auckland (East)	1	61	62
PAR 2	South East, Southland, Sub-Antarctic, Central, Challenger	2,3,4,5,6,7&8	2	< 1
PAR 9	Auckland (West)	9	21	18
Total			84	80

6. FOR FURTHER INFORMATION

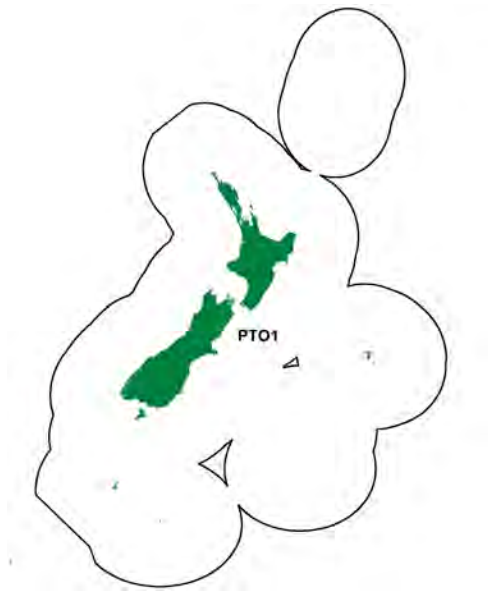
Anderson O.F., Bagley N.W., Hurst R.J., Francis M.P., Clark M.R., McMillan P.J. 1998. Atlas of New Zealand fish and squid distributions from research bottom trawls. NIWA Technical Report: 42. 303p.

Morrison M.A. 1990. Ontogenetic shifts in the ecology of the parore, *Girella tricuspidata*. Unpublished MSc thesis, University of Auckland. 66p.

Pollock B.R. 1981. Age determination and growth of luderick, *Girella tricuspidata* (Quoy and Gaimard), taken from Moreton Bay, Australia. J. Fish. Biol. 19: 475-485.

PATAGONIAN TOOTHFISH (PTO)

(*Dissostichus eleginoides*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Patagonian toothfish, *Dissostichus eleginoides*, was introduced into the QMS on 1 October 2010. The Total Allowable Catch (TAC), Total Allowable Commercial Catch (TACC), recreational, customary and other mortality allowances issued for Patagonian toothfish (PTO) on entering the QMS are given in Table 1.

Table 1: Total Allowable Catch (TAC, t), Total Allowable Commercial Catches (TACC, t), customary non-commercial (t), recreational, and other mortality allowances for PTO on entering the QMS on 1 October 2010.

Fishstock	TAC	TACC	Customary Non-commercial	Recreational	Other Mortality
PTO 1	50	49.5	0	0	0.5

Internationally, fishing for Patagonian toothfish started in the 1950s in the Pacific Ocean off the coast of Chilé. Catch was initially comprised of juveniles that were seen as a bycatch in the shallow trawl fishery. The development of long-line gear capable of fishing deepwater led to the development of the fishery off Chilé in the mid 1980s, and the rapid spread to the Patagonian shelf and South Georgia in the Atlanitc, and Kerguelen in the Indian Ocean. Technological advancements along with a high price per kg for toothfish lead to a rapid expansion of the fishery within territorial seas and the CCAMLR region, with catches increasing from 5 000 t in 1984 to 40 000 t in 1992 (Collins *et al.* 2006).

Within the NZ EEZ, prior to 1 October 2004, PTO were subject to a management regime were a special permit was needed to undertake exploratory fishing. During this time four exploratory fishing trips were undertaken between 1996 and 2003 catching less than 30 t (Table 2). After 2004 access to PTO was managed as part of a non-QMS regime. During 2009 two fishing trips where toothfish were targeted, resulted in just over 20 t of catch. Within the EEZ most fishing to date has taken place along the northern end of the Macquarie ridge, around the southern periphery of the Campbell Plateau and on the Bounty Plateau. In all less than 50 t have been taken since 1994/95. Catch landings for PTO within the EEZ can be found in Table 2.

PTO is also caught in the Ross Sea fisheries managed by CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) from Antarctica to the south of the New Zealand EEZ. The Ross Sea region fisheries have been developing since the late 1990s with the majority of the catch comprising the sympatric Antarctic toothfish, *Dissostichus mawsoni* (Horn 2002).

Table 2: Reported PTO landings (t) reported from 1994-95 to 2010-11 within the EEZ. - indicates nil catches recorded.

Fishing Year	PTO 1
1994-95	0.1
1995-96	18.6
1996-97	4.1
1997-98	< 0.1
1999-00	1.0
2000-01	< 0.1
2001-02	0.2
2002-03	0.1
2003-04	3.3
2004-05	< 0.1
2005-06	< 0.1
2006-07	0.1
2007-08	-
2008-09	20.5
2009-10	-
2010-11	22.7

1.2 Recreational fisheries
There is no known recreational fishery for PTO.

1.3 Customary non-commercial fisheries
There is no information on customary non-commercial catch for PTO.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch for PTO within the New Zealand EEZ. In the neighbouring CCAMLR subarea 88.1, (which is outside the New Zealand EEZ), no illegal vessels has been reported in subareas with considerable numbers of PTO (i.e., Subarea 88.1A) since PTO entered the QMS in 2010.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality.

2. BIOLOGY
Toothfish are large Notothenids and are endemic to Antarctic and Sub-Antarctic waters. There are two species of toothfish, the Antarctic toothfish, *Dissostichus mawsoni*, which is generally confined to the waters around the Antarctic continent, and the Patagonia toothfish, *Dissostichus eleginoides*, which are found further north around the sub-Antarctic islands and widely distributed around the 40-60° Southern latitudes (Collins *et al*. 2010, Horn 2002). There is limited overlap between distributions of the two species. In the Ross Sea the main area of overlap is thought to occur between latitudes 62.5°S and 65°S.

D. eleginoides can grow to over 2 m long and weigh over 150 kg. Large individuals are thought to be 40-50 years old. PTO grow relatively quickly until around 10 years of age, at which point females continue to grow faster than males. Females reach maturity around 110-130 cm in comparison to males thought to mature at 90-100 cm. Although growth rates differ between genders, there seem to be comparable maximum age for males and females (Horn 2002). Von Bertalanffy growth parameters can be found listed in Table 2.

Toothfish feed on a variety of other fish, octopods, squid and crustaceans and change their feeding pattern with age. Juveniles, which live in relatively shallow water (< 200 m), are pelagic predators and feed primarily on small fish and amphipods. As adults, PTO move deeper (> 500m) and feed on deep dwelling species such as hoki (*Macruronus magellanicus*) and southern blue whiting (*Micromesistius australis*), and have exhibited scavenging behaviour (Garcia de la Rosa *et al*. 1997).

Spawning is believed to occur between June and September (Kock & Kellerman 1991), with a peak in July/August, but has been found to vary with stock location. Spawning is believed to occur in deep water, around 1000 m, producing pelagic eggs and pelagic larval stages. Embryogenesis is quite rapid (~ 3.5 months) and larvae switch to a demersal habitat around 100 mm in size or 1 year of age (North 2002, Collins *et al*. 2010)

Juvenile toothfish have been located around Macquarie Island. As they grow individuals are assumed to move both north-east, into the New Zealand EEZ, and south-east down the Macquarie Ridge into the northern CCAMLR region.

Table 3: Estimates of biological parameters of Patagonian toothfish (PTO)

Fishstock						Estimate	Source
1. von Bertalanffy growth parameters							
			Females			Males	
Macquarie Ridge	K	t_0	$L\infty$	K	t_0	$L\infty$	
PTO 1	0.0850	-0.3500	158.7	0.1180	0.0800	134.3	Horn (2002)

3. STOCKS AND AREAS

Patagonian toothfish occur around sub Antarctic islands and seamounts between the 40 and 60°S including the southern region of New Zealand’s EEZ (Horn 2002). There is evidence indicating that the New Zealand PTO resource is part of a straddling stock also found in Australia’s abutting EEZ around Macquarie Island.

A tagging study on Patagonian tooth fish found one fish, captured in early 2009 on the northern extension of the Macquarie Ridge inside the NZ EEZ, recaptured in the Macquarie Island fishing zone in mid 2009. Another fish tagged within the Macquarie Island fishing zone was recaptured from the northern CCAMLR region in the Ross Sea.

There is still uncertainty regarding the distribution of PTO within the EEZ and the potential size of the resource. Although recent fishing activity has achieved catch rates considered commercially viable, more information is needed on stock structure, biology and abundance.

4. STOCK ASSESSMENT

There are no estimates of fishery parameters, abundance, or biomass for Patagonian toothfish within the New Zealand EEZ at this time.

5. STATUS OF THE STOCKS

The status of the PTO stock within the New Zealand EEZ is unknown.

6. FOR FURTHER INFORMATION

Abellan L.J.L. 2005. Patagonian toothfish in international waters of the southwest Indian Ocean (Statistical Area 51). *CCAMLR Science* 12, 207-214

Aguayo M. 1992. Preliminary analysis of the growth of *Dissostichus eleginoides* from the austral zone of Chile and South Georgia. *CCAMLR WG-FSA* 92/30,1-9

Andrews A.H., Brooks C.M., Ashford J.R., Krusic-Golub K., Duhamel G., Belchier M., Lundstrom C., Cailliet G.M. 2010. Lead-radium dating of Patagonian toothfish (*Dissostichus eleginoides*) reveals spatial variation in ageing bias on the Kerguelen Plateau. *Marine and Freshwater Research* (In Press)

Appleyard S.A., Ward R.D., Williams R. 2002. Population structure of the Patagonian toothfish around Heard, McDonald and Macquarie Islands. *Antarctic Science* 14, 364-373

Appleyard S.A., Williams R., Ward R.D., 2004. Population genetic structure of Patagonian toothfish in the west Indian Ocean sector of the Southern Ocean.*CCAMLR Science* 11, 21-32

Arana P. 2009. Reproductive aspects of the Patagonian toothfish (*Dissostichus eleginoides*) off southern Chile. *Latin American Journal of Aquatic Research* 37, 381-394

Arkhipkin A., Brickle P, Laptikhovsky V. 2003. Variation in the diet of the Patagonian toothfish with size, depth and season around the Falkland Islands. *Journal of Fish Biology* 63, 428-441

Ashford J., Duhamel G., Jones C., Bobko S. 2005a. Age, growth and mortality of Patagonian toothfish (*Dissostichus eleginoides*) caught off Kerguelen. *CCAMLR Science* 12, 29-41

Ashford J., Jones C. 2007. Oxygen and carbon stable isotopes in otoliths record spatial isolation of Patagonian toothfish (*Dissostichus eleginoides*). *Geochimica Et Cosmochimica Acta* 71, 87-94

Collins M.A., Brickle P., Brown J., Belchier M. 2010. The Patagonian toothfish: biology, ecology, and fishery. *Advances in Marine Biology* 58, 227-289

Collins M.A, Everson I, Paterson R, Bagley P.M, Yau C, Belchier M, Hawkins S. 2006. I*n situ* observations of the scavenging fauna of the South Georgia slope. In: Shotton R (ed) Deep Sea 2003: Conference on the Governance and Management of Deep-sea Fisheries Part 2: Conference poster papers and workshop papers. FAO, Rome, p 45-53

Collins M.A., Shreeve R.S., Fielding S., Thurston M.H. 2008. Distribution, growth, diet and foraging behaviour of the yellow-fin notothen *Patagonotothen guntheri* on the Shag Rocks shelf (Southern Ocean). *Journal of Fish Biology* 72, 271-286

Smitt F.A. 1898. Poissons de l'expedition scientifique a la terra de feu. *Bihang till Kongl Svenska Vetenskaps-Akademiens Handlingar Brand* 4, 1-80

Garcia de la Rosa S.B, Sanchez F., Figueroa D. 1997. Comparative feeding ecology of Patagonian toothfish (*Dissostichus eleginoides*) in the South-western Atlantic. *CCAMLR Science* 4, 105-124

Ghigliotti L., Mazzei F., Ozouf-Costaz C., Bonillo C., Williams R., Cheng C.H.C., Pisano E., 2007. The two giant sister species of the Southern Ocean, *Dissostichus eleginoides* and *Dissostichus mawsoni*, differ in karyotype and chromosomal pattern of ribosomal RNA genes. *Polar Biology* 30, 625-634

Gon O, Heemstra P.C. 1990. Fishes of the Southern Ocean. J.L.B. Smith Institute of Ichthyology, Grahamstown, 462 pp

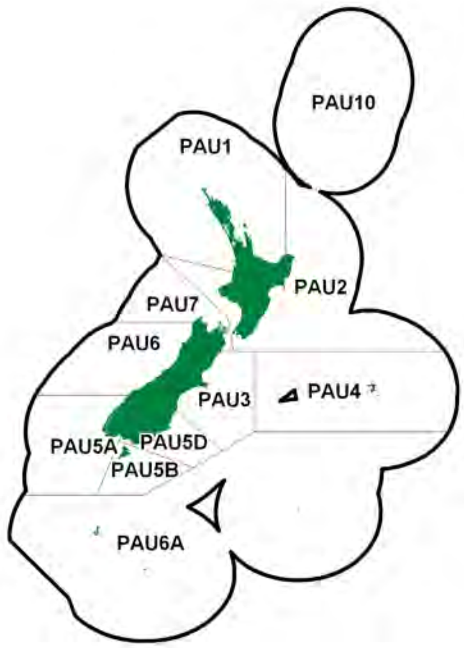
Horn P.L. 2002. Age and growth of Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in waters from the New Zealand subantarctic to the Ross Sea, Antarctica. *Fisheries Research* 56, 275-287

Kock K.H., Kellermann A. 1991. Reproduction in Antarctic notothenioid fish. *Antarctic Science* 3, 125-150

North A.W. 2002. Larval and juvenile distribution and growth of Patagonian toothfish around South Georgia. *Antarctic Science* 14, 25-31

PAUA (PAU)

(*Haliotis iris, Haliotis australis*)
Paua



1. INTRODUCTION

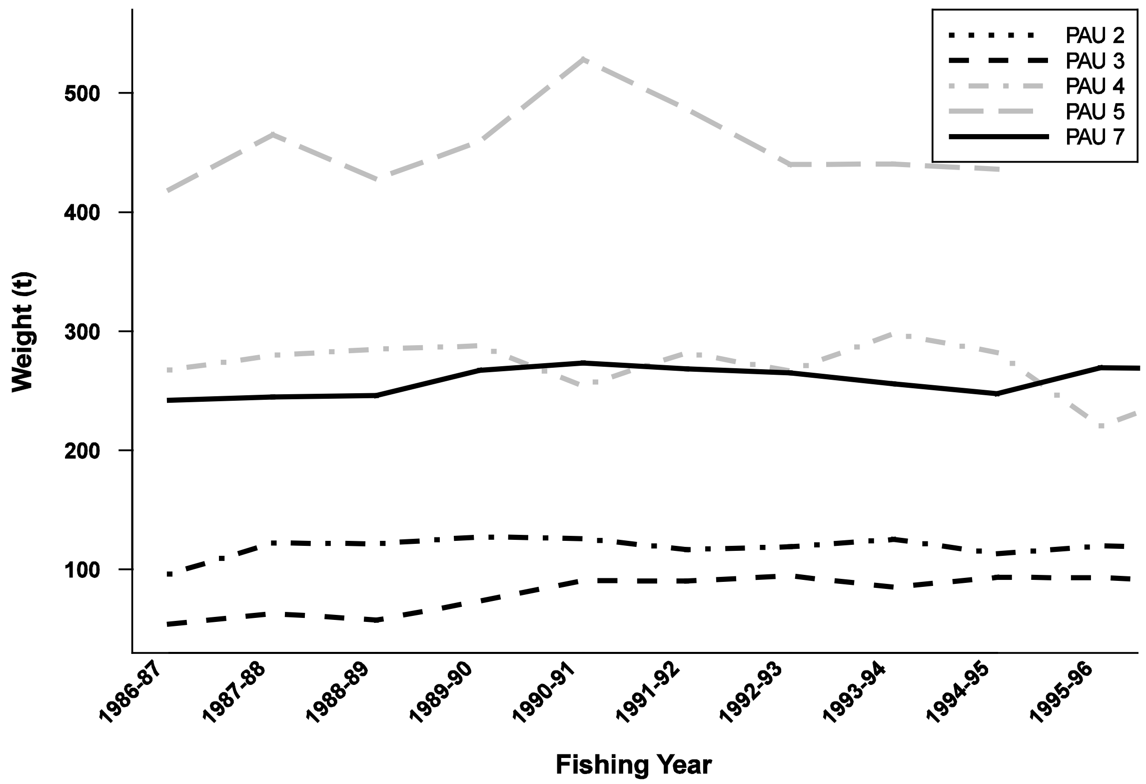
Specific Working Group reports are given separately for PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D and PAU 7. The TACC for PAU 1, PAU 6 and PAU 10 is 1.93 t, 1 t and 1 t respectively. Commercial landings for PAU 10 since 1983 have been 0 t.

1.1 Commercial fisheries

The commercial fishery for paua dates from the mid-1940s. In the early years of this commercial fishery the meat was generally discarded and only the shell was marketed, however by the late 1950s both meat and shell were being sold. Since the 1986-87 fishing season, the fishery has been managed with an individual transferable quota system and a total allowable commercial catch (TACC) for each of the eight Quota Management Areas.

Fishers gather paua by hand while free diving (use of underwater breathing apparatus is not permitted). Most of the catch is from the Wairarapa coast southwards: the major fishing areas are in the South Island, Marlborough (PAU 7), Stewart Island (PAU 5A, 5B and 5D) and the Chatham Islands (PAU 4). Virtually the entire commercial fishery is for the black-foot paua, *Haliotis iris*, with a minimum legal size for harvesting of 125 mm shell length. The yellow-foot paua, *H. australis* is less abundant than *H. iris* and is caught only in small quantities; it has a minimum legal size of 80 mm. Catch statistics include both *H. iris* and *H. australis*.

Figure 1 shows the historical landings for the main PAU stocks. On 1 October 1995 PAU 5 was divided into 3 separate QMAs: PAU 5A, PAU 5B and PAU 5D. Up until the 2002 fishing year, catch was reported by general statistical areas, however from 2002 onwards, a more finely scaled system of paua specific statistical areas were put in place throughout each QMA (refer to the QMA specific Working Group reports).



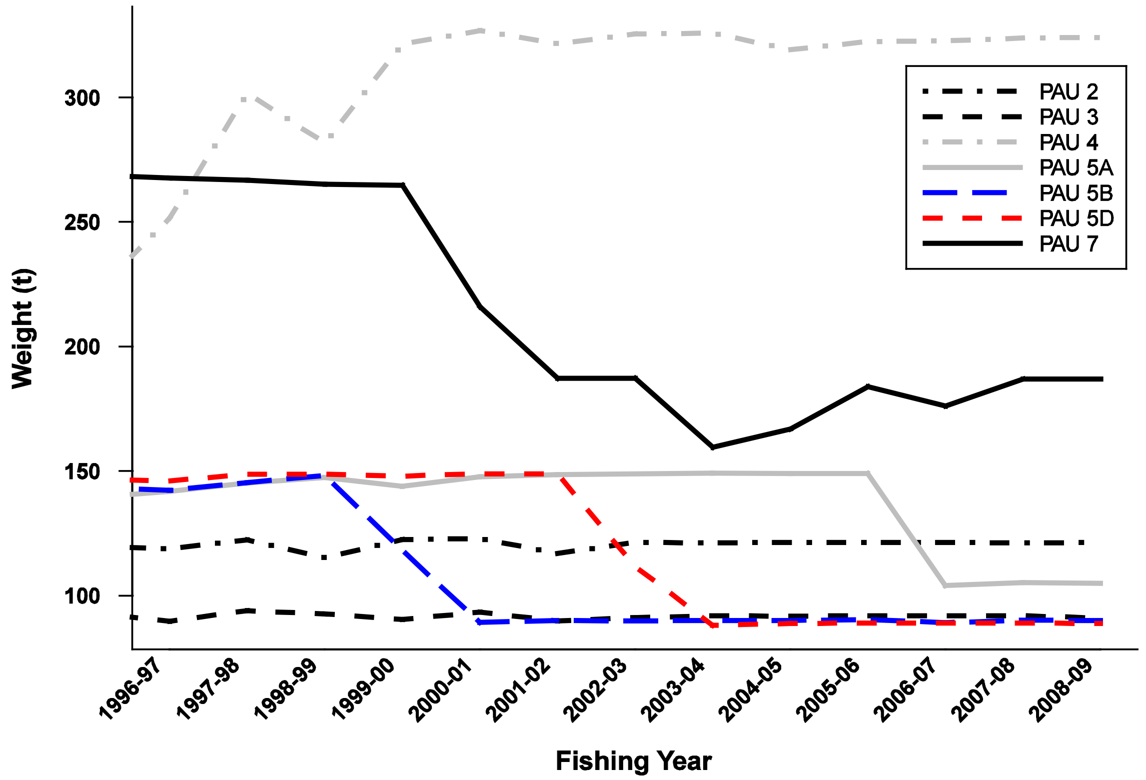


Figure 1: Historic landings for the major paua QMAs from 1983-84 to 1995-96 (top) and from 1996-97 to 2009-10 (lower).

Landings for PAU 1, PAU 6, PAU 10 and PAU 5 (prior to 1995) are shown in Table 1. For information on landings specific to other paua QMAs refer to the specific Working Group reports.

Table 1: TACCs and reported landings (t) of paua by Fishstock from 1983-84 to 2010-11.

	PAU 1		PAU 5		PAU 6		PAU 10	
PAU	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983-84*	1	-	550	-	0.00	-	0.00	-
1984-85*	0	-	353	-	3.00	-	0.00	-
1985-86*	0	-	228	-	0.00	-	0.00	-
1986-87*	0.01	1.00	418.9	445	0.00	1.00	0.00	1.00
1987-88*	0.98	1.00	465	448.98	0.00	1.00	0.00	1.00
1988-89*	0.05	1.93	427.97	449.64	0.00	1.00	0.00	1.00
1989-90	0.28	1.93	459.46	459.48	0.00	1.00	0.00	1.00
1990-91	0.16	1.93	528.16	484.94	0.23	1.00	0.00	1.00
1991-92	0.27	1.93	486.76	492.06	0.00	1.00	0.00	1.00
1992-93	1.37	1.93	440.15	442.85	0.88	1.00	0.00	1.00
1993-94	1.05	1.93	440.39	442.85	0.10	1.00	0.00	1.00
1994-95	0.26	1.93	436.13	442.85	18.21H	1.00	0.00	1.00
1995-96	0.99	1.93	-	-	28.62H	1.00	0.00	1.00
1996-97	1.28	1.93	-	-	0.11	1.00	0.00	1.00
1997-98	1.28	1.93	-	-	0.00	1.00	0.00	1.00
1998-99	1.13	1.93	-	-	0.00	1.00	0.00	1.00
1999-00	0.69	1.93	-	-	1.04	1.00	0.00	1.00
2000-01	1.00	1.93	-	-	0.00	1.00	0.00	1.00
2001-02	0.32	1.93	-	-	0.00	1.00	0.00	1.00
2002-03	0.00	1.93	-	-	0.00	1.00	0.00	1.00
2003-04	0.05	1.93	-	-	0.00	1.00	0.00	1.00
2004-05	0.27	1.93	-	-	0.00	1.00	0.00	1.00
2005-06	0.45	1.93	-	-	0.00	1.00	0.00	1.00
2006-07	0.76	1.93	-	-	1.00	1.00	0.00	1.00
2007-08	1.14	1.93	-	-	1.00	1.00	0.00	1.00
2008-09	0.47	1.93	-	-	1.00	1.00	0.00	1.00
2009-10	0.20	1.93	-	-	1.00	1.00	0.00	1.00
2010-11	0.12	1.93	-	-	1.00	1.00	0.00	1.00

H experimental landings
* FSU data

1.2 Recreational fisheries

There is a large recreational fishery for paua. Estimated catches from telephone and diary surveys of recreational fishers (Teirney *et al*. 1997, Bradford 1998, Boyd & Reilly 2004, Boyd *et al.* 2004) are shown in Table 2. In 1996-97 sufficient diary data were available for an estimate in PAU 5D only (Bradford 1998, NIWA unpublished data). The Marine Recreational Fisheries Technical Working Group (RFTWG) has reviewed the harvest estimates from the national surveys. Due to a methodological error in the methodology, the harvest estimates for 1991-92 to 1993-94 and 1996-97 are not considered to be reliable. The harvest estimates for the 1999-2000 and 2000-01 surveys may be very inaccurate and some implausibly high. This may be due to a number of factors including the accuracy of the mean weight used to derive total harvest weight from the estimated numbers of paua caught by diarists, and the small number of diarists harvesting the stock in some areas. However relative comparisons can be made between stocks within the surveys.

Table 2: Estimated annual harvest of paua (t) by recreational fishers*.

Fishstock	PAU 1	PAU 2	PAU 3	PAU 5	PAU 5D	PAU 6	PAU 7
1991-92	-	-	35-60	50-80	-	-	-
1992-93	-	37-89	-	-	-	0-1	2-7
1993-94	29-32	-	-	-	-	-	-
1995-96	10-20	45-65	-	20-35	-	-	-
1996-97	-	-	-	N/A	22.5	-	-
1999-00	40-78	224-606	26-46	36-70	26-50	2-14	8-23
2000-01	16-37	152-248	31-61	70-121	43-79	0-3	4-11

*1991-1995 Regional telephone/diary estimates, 1995/96, 1999/00 and 2000/01 National Maine Recreational Fishing Surveys.

1.3 Customary fisheries

There is an important customary use of paua by Maori for food, and the shells have been used extensively for decorations and fishing devices. Limited data is available for reported customary landings in PAU 3; however no information is available for current levels of customary take for any other paua QMA. Kaitiaki are now in place in many areas and estimates of customary harvest can be expected in the near future.

1.4 Illegal catch
Current levels of illegal harvests are not known. In the past, annual estimates of illegal harvest for some Fishstocks have been provided by MFish compliance based on seizures. In the current paua stock assessments, nominal illegal catches are used.

1.5 Other sources of mortality
Paua may die from wounds caused by removal desiccation or osmotic and temperature stress if they are bought to the surface. Sub-legal paua may be subject to handling mortality by the fishery if they are removed from the substrate to be measured. Further mortality may result indirectly from being returned to unsuitable habitat or being lost to predators or bacterial infection. Gerring (2003) observed paua (from PAU 7) with a range of wounds in the laboratory and found that only a deep cut in the foot caused significant mortality (40% over 70 days). In the field this injury reduced the ability of paua to right themselves and clamp securely onto the reef, and consequently became more vulnerable to predators. The tool generally used by divers in PAU 7 is a custom made stainless steel knife with a rounded tip and no sharp edges. This design makes cutting the paua very unlikely (although abrasions and shell damage may occur). Gerring (2003) estimated that in PAU 7, 37% of paua removed from the reef by commercial divers were undersize and were returned to the reef. His estimate of incidental mortality associated with fishing in PAU 7 was 0.3% of the landed catch. Incidental fishing mortality may be higher in areas where other types of tools and fishing practices are used. Mortality may increase if paua are kept out of the water for a prolonged period or returned onto sand. To-date, the stock assessments developed for paua have assumed that there is no mortality associated with capture of undersize animals.

2. BIOLOGY

Paua are herbivores which can form large aggregations on reefs in shallow subtidal coastal habitats. Movement is over a sufficiently small spatial scale that the species may be considered sedentary. Paua are broadcast spawners and spawning is thought to be annual. Habitat related factors are an important source of variation in the post-settlement survival of paua. Growth, morphometrics, and recruitment can vary over short distances and may be influenced by factors such as wave exposure, habitat structure, availability of food and population density. A summary of generic estimates for biological parameters for paua are presented in Table 3. Parameters specific to individual paua QMAs are reported in the specific Working Group reports.

Table 3: Estimates of biological parameters for paua (H. *iris*).

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
All		0.02-0.25	Sainsbury (1982)
2. Weight = a (length)^b (weight in kg, shell length in mm)			
	a = 2.99E^{--08}	b = 3.303	Schiel & Breen (1991)

3. STOCKS AND AREAS

Using both mitochondrial and microsatellite markers Will & Gemmell (2008) found high levels of genetic variation within samples of *H. Iris* taken from 25 locations spread throughout New Zealand. They also found two patterns of weak but significant population genetic structure. Firstly, *H. iris* individuals collected from the Chatham Islands were found to be genetically distinct from those collected from costal sites around the North and South Islands. Secondly a genetic discontinuity was found loosely associated with the Cook Strait region. Genetic discontinuities within the Cook Strait region have previously been identified in sea stars, mussels, limpets, and chitons and are possibly related to contemporary and/or past oceanographic and geological conditions of the region. This split may have some implications for management of the paua stocks, with populations on the south of North Island, and north of South Island likely warranting management as separate entities; a status they already receive under the zonation of the current fisheries regions, PAU 2 in the North Island, and PAU 7 on the South Island.

4. STOCK ASSESSMENT

The dates of the most recent survey or stock assessment for each QMA are listed in Table 4.

Table 4: Recent survey and stock assessment information for each paua QMA

QMA	Type of survey or assessment	Date	Comments
PAU 1	No surveys or assessments have been undertaken		
PAU 2	Relative abundance estimate using standardised CPUE index based on commercial catch	2007	Standardised CPUE increased between 1992 and 2000 and has remained fairly stable up to 2007.
PAU 3	Relative abundance estimate using standardised CPUE index based on commercial catch	2007	Standardised CPUE decreased between 1990 and 1992 and has since remained fairly stable up to 2007.
PAU 4	Quantitative assessment using a Bayesian length based model	2004	In February 2010 the Shellfish Working Group (SFWG) agreed that due to the lack of adequate data as input into the Bayesian length-based model, a stock assessment for PAU 4 using this model was not appropriate.
PAU 5A	Quantitative assessment using a Bayesian length based model	2010	The 2010 stock assessment was conducted over two subareas of the QMA. The SFWG was satisfied that the stock assessment for both the Southern and Northern areas was reliable based on the available data. It was agreed by the SFWG that the range of estimated indicators for both the base case and hyperstability models used in the Northern area assessment were acceptable, but where within the range of estimates the actual status of the fishery is located is not clear.
PAU 5B	Quantitative assessment using a Bayesian length based model	2007	Spawning biomass was more likely to increase than decrease under levels of total catch and was likely to remain below S_{AV} for the next three years. Recruited biomass showed a tendency to decrease and remain below B_{AV}. For recruited biomass, however, it could not be concluded strongly that current biomass was less than the B_{AV} reference level.
PAU 5D	Quantitative assessment using a Bayesian length based model	2006	The stock assessment results were equivocal. In 2006 the Working Group noted the future direction of recruited biomass was uncertain because of the range of possible results that were dependent on modelling decisions.
PAU 6	Biomass estimate	1996	This fishery has a TACC of 1 t
PAU 7	Quantitative assessment using a Bayesian length based model	2012	The SFWG agreed the stock assessment was reliable based on the available data. Currently, spawning stock biomass is estimated at 22% B_0 Results suggest an increase to 23.4% B_0 in over the next three years at current levels of catch.
PAU 10	No surveys or assessments have been undertaken		

4.1 Estimates of fishery parameters and abundance

For further information on fishery parameters and abundance specific to each paua QMA refer to the specific Working Group report.

In 2008 standardised CPUE indices were constructed to assess relative abundance in PAU 2 and PAU 3. In QMAs where quantitative stock assessments have been undertaken, standardised CPUE is also used as input data for the Bayesian length-based stock assessment model. There is however a large amount of literature on abalone which suggests CPUE may not be proportional to abundance as it is possible to maintain high catch rates despite a falling biomass. This occurs because paua tend to aggregate and divers move among areas to maximise their catch rates. Therefore, any apparent stability in CPUE should be interpreted with caution.

In PAU 4, 5A, 5B, 5D and 7 the relative abundance of paua has also been estimated from independent research diver surveys (RDS). In PAU 7, seven surveys have been completed over a number of years but only two surveys have been conducted in PAU 4. In 2009 and 2010 several reviews were conducted (Cordue P.L. (2009) and Haist V.(in press)) to assess; i) the reliability of the research diver survey index as a proxy for abundance; and ii) if the RDS data when used in the paua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. The reviews concluded that:

- Due to inappropriate survey design the RDS data appear to be of very limited use for constructing relative abundance indices
- There was clear non-linearity in the RDS index, the form of which is unclear and could be potentially complex.
- CVs of RDS index 'year' effects are likely to be underestimated, especially at low densities
- Different abundance trends among strata reduces the reliability of RDS indices, and the CVs are likely not to be informative about this
- It is unlikely the assessment model can determine the true non-linearity of the RDS index-abundance relationship because of the high variability in the RDS indices
- The non-linearity observed in the RDS indices is likely to be more extreme at low densities, so the RDSI is likely to mask trends when it is most critical to observe them.
- Existing RDS data is likely to be most useful at the research stratum level.

4.2 Biomass estimates

Biomass was estimated for PAU 6 in 1996 (McShane *et al*. 1996). However the survey area was only from Kahurangi Point to the Heaphy River.

Biomass has been estimated, as part of the stock assessments, for PAU 4, 5A, 5B, 5D and 7 (Table 4). For further information on biomass estimates specific to each paua QMA refer to the specific Working Group report.

4.3 Estimation of Maximum Constant Yield (*MCY*)

The only estimate of *MCY* is for PAU 6 (McShane *et al*. 1996). This QMA has a TACC of 1 t

MCY has not been estimated for any other fishstocks.

4.4 Estimation of Current Annual Yield (*CAY*)

The only estimate of *CAY* available is for the area from Kahurangi Point to the Heaphy River in PAU 6 (McShane *et al*. 1996).

CAY was not estimated for any other fishstocks.

5. STATUS OF THE STOCKS

The status of paua stocks PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D and PAU 7 are given in the relevant Working Group reports.

6. FOR FURTHER INFORMATION

Andrew N. Francis M., Eds. 2003. The Living Reef: the ecology of New Zealand's Living Reef. Nelson, Craig Potton Publishing.

Andrew N.L., Breen P.A., Naylor J.R., Kendrick T.H., Gerring P.K. 2000a. Stock assessment of paua *Haliotis iris* in PAU 7 in 1998-99. New Zealand Fisheries Assessment Report. 2000/49.

Andrew N.L., Naylor J.R., Gerring P., Notman P.R., 2000b. Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and 5D. New Zealand Fisheries Assessment Report 2000/3: 21p.

Andrew N.L., Naylor J.R., Gerring P. 2000c. A modified timed-swim method for paua stock assessment. New Zealand Fisheries Assessment Report 2000/4: 23p.

Andrew N.L., Naylor J.R., Kim S.W. 2002. Fishery independent surveys of the relative abundance and size-structure of paua (*Haliotis iris*) in PAU 5B and PAU 5D. New Zealand Fisheries Assessment Report. 2002/41.

Annala J.H., Sullivan K.J., O'Brien C., Iball S. (Comps.) 1998. Report from the Fishery Assessment Plenary, May 1998: Stock assessments and yield estimates. 409p. Unpublished report held in NIWA library, Wellington.

Boyd R.O., Reilly J.L. 2004. 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. Draft New Zealand Fisheries Assessment Report 2004

Boyd R.O., Gowing L., Reilly J.L. 2004. 2000-2001 National Marine Recreational Fishing Survey: diary results and harvest estimates. Draft New Zealand Fisheries Assessment Report 2004/xx: xp.

Bradford E. 1998. Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16: 27p.

Breen P.A., Andrew N.L., Kendrick T.H. 2000a. Stock assessment of PAU 5B for 1998–99. New Zealand Fisheries Assessment Report 2000

Breen P.A., Andrew N.L., Kendrick T.H. 2000b. Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. New Zealand Fisheries Assessment Report. 2000/33.

Breen P.A., Andrew N.L., Kendrick T.H. 2000c. The 2000 stock assessment of paua (*Haliotis iris*) in PAU 5B using an improved Bayesian length-based model. New Zealand Fisheries Assessment Report. 2000/48.

Breen P.A., Andrew N.L., Kim S.W. 2001. The 2001 stock assessment of paua *Haliotis iris* in PAU 7. New Zealand Fisheries Assessment Report. 2001/55.

Breen P.A., Kim S.W. 2004. The 2004 stock assessment of paua *Haliotis iris* in PAU 5A. New Zealand Fisheries Assessment Report. 2004/40.

Breen P.A., Kim S.W. 2005. The 2005 stock assessment of paua *Haliotis iris* in PAU 7. New Zealand Fisheries Assessment Report. 2005/47.

Breen P.A., Kim S.W. 2007. The 2006 stock assessment of paua (*Haliotis iris*) stocks PAU 5A (Fiordland) and PAU 5D (Otago). New Zealand Fisheries Assessment Report. 2007/09.

Breen P.A., Smith A.N. 2008. The 2007 stock assessment of paua (*Haliotis iris*) stock PAU 5B (Stewart Island). New Zealand Fisheries Assessment Report. 2008/05.

Breen P.A., Smith A.N. 2008. Data used in the 2007 stock assessment for paua (*Haliotis iris)* stock 5B (Stewart Island). New Zealand Fisheries Assessment Report. 2008/06.

Cordue P.L. 2009. Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45p

Elvy D., Grindley R., Teirney L. 1997. Management Plan for Paua 5. Otago Southland Paua Management Working Group Report 57p. (Held by Ministry of Fisheries, Dunedin.)

Francis R.I.C.C. 1990. A maximum likelihood stock reduction method. New Zealand Fisheries Assessment Research Document 1990/4: 8p.

Gerring P.K. 2003. Incidental fishing mortality of paua (Haliotis iris) in PAU 7. New Zealand Fisheries Assessment Report 2003/56: 13p.

Kendrick T.H., Andrew N.L. 2000. Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5A, 5B, and 5D. New Zealand Fisheries Assessment Report. 2000/47.

McShane P.E. 1992. Paua fishery assessment 1992. New Zealand Fisheries Assessment Research Document 1992/3: 26p.

McShane P.E. 1996. Patch dynamics and effects of exploitation on abalone (*Haliotis iris*) populations. Fisheries Research 25: 191-199.

McShane P.E., Mercer S., Naylor R. 1993. Paua (*Haliotis* spp.) fishery assessment 1993. New Zealand Fisheries Assessment Research Document 1993/6: 22p.

McShane P.E., Schiel D.R., Mercer S.F., Murray T. 1994a. Morphometric variation in *Haliotis iris* (Mollusca:Gastropoda): analysis of 61 populations. New Zealand Journal of Marine and Freshwater Research 28: 357-364.

McShane P.E., Mercer S.F., Naylor J.R., Notman P.R. 1994b. Paua fishery assessment 1994. New Zealand Fisheries Assessment Research Document 1994/16: 47p.

McShane P.E., Mercer S.F., Naylor J.R. 1994c. Spatial variation and commercial fishing of New Zealand abalone (*Haliotis iris* and *H. australis*). New Zealand Journal of Marine and Freshwater Research 28: 345-355.

McShane P.E., Naylor J.R. 1995. Small-scale spatial variation in growth, size at maturity, and yield- and egg-per-recruit relations in the New Zealand abalone *Haliotis iris*. .New Zealand Journal of Marine and Freshwater Research 29: 603-612.

McShane P.E., Mercer S.F., Naylor J.R., Notman P.R. 1996. Paua (*Haliotis iris*) fishery assessment in PAU 5, 6, and 7. New Zealand Fisheries Assessment Research Document. 1996/11.

Naylor J.R., Andrew N.L. 2000. Determination of growth, size composition, and fecundity of paua at Taranaki and Banks Peninsula. New Zealand Fisheries Assessment Report. 2000/51.

Naylor J.R., Andrew N.L. 2002. Determination of paua growth in PAU 2, 5A, 5B, and 5D. New Zealand Fisheries Assessment Report. 2002/34.

Naylor J.R., Notman P.R., Mercer S.F., Gerring P. 1998. Paua (*Haliotis iris*) fishery assessment in PAU 5, 6, and 7. New Zealand Fisheries Assessment Research Document. 1998/05.

Naylor J.R., Andrew N.L., Kim S.W. 2003. Fishery independent surveys of the relative abundance, size-structure and growth of paua (*Haliotis iris*) in PAU 4. New Zealand Fisheries Assessment Report. 2003/08.

Naylor J.R., Kim S.W. 2004. Fishery independent surveys of the relative abundance and size-structure of paua *Haliotis iris* in PAU 5D. New Zealand Fisheries Assessment Report. 2004/48.

Pirker J.G. 1992. Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165p.

Sainsbury K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. New Zealand Journal of Marine and Freshwater Research 16: 147-161.

Schiel D.R., Breen P.A. 1991. Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris. Fishery Bulletin 89:* 681-691.

Schwarz A.R. Cole, *et al*. 2006. Impacts of terrestrial runoff on the biodiversity of rocky reefs, New Zealand Aquatic Environment Biodiversity Report No. 7.

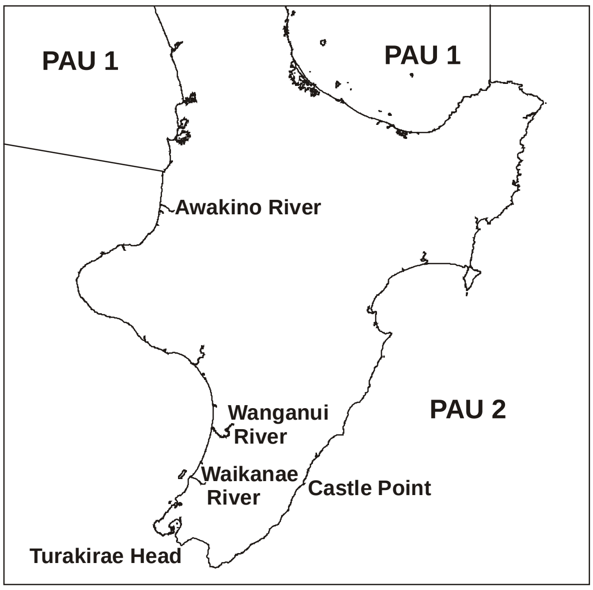
Teirney L.D., Kilner A.R., Millar R.E., Bradford E., Bell J.D. 1997. Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15: 43p.

Vignaux M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987-92. New Zealand Fisheries Assessment Research Document 1993/14. 23p.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PAUA (PAU 2) – Wairarapa / Wellington / Taranaki

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

PAU 2 was introduced into the Quota Management System in 1986-87 with a TACC of 100 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased to 121.19 t in 1989 and has remained unchanged to the current fishing year (Table 1). There is no TAC for this QMA: before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 2 since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986 - 1989	-	-	-	-	100
1989 - present	-	-	-	-	121.19

1.1 Commercial fisheries

The fishing year runs from 1 October through 30 September. Most of the commercial catch comes from the Wairarapa and Wellington South coasts between Castle Point and Turakirae Head. The western area between Turakirae Head and the Waikanae River is closed to commercial fishing.

On 1 October 2001 it became mandatory to report catch and effort using fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program (Figure 1). These reporting areas were subsequently adopted on MFish PCELRs.

1.2 Recreational fisheries

For further information on recreational fisheries refer to the introductory PAU Working Group Report.

Because paua around Taranaki are naturally small and never reach the minimum legal size (MLS) of 125 mm, a new MLS of 85 mm was introduced for recreational fishers from 1 October 2009. The new length is on a trial basis for five years and applies between the Awakino and Wanganui rivers.

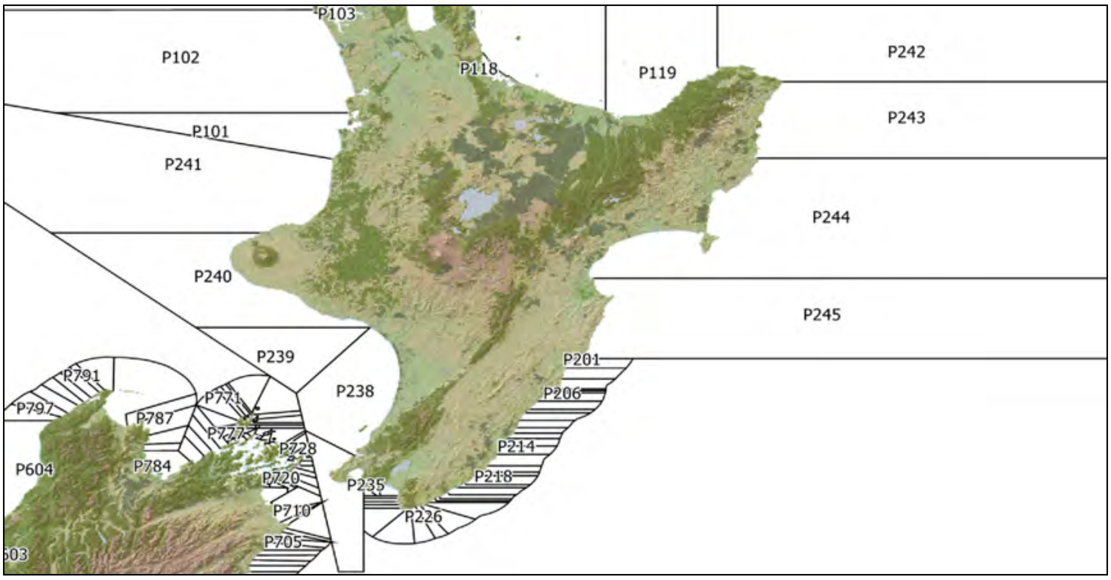


Figure 1: Map of fine scale statistical reporting areas for PAU 2.

Landings for PAU 2 are shown in Table 2.

Table 2: TACC and reported landings (t) of paua in PAU 2 from 1983-84 to 2010-11.

Year	Landings	TACC
1983–84*	110	–
1984–85*	154	–
1985–86*	92	–
1986–87*	96.2	100
1987–88*	122.11	111.33
1988–89*	121.5	120.12
1989–90	127.28	121.19
1990–91	125.82	121.19
1991–92	116.66	121.19
1992–93	119.13	121.19
1993–94	125.22	121.19
1994–95	113.28	121.19
1995-96	119.75	121.19
1996-97	118.86	121.19
1997-98	122.41	121.19
1998-99	115.22	121.19
1999-00	122.48	121.19
2000-01	122.92	121.19
2001-02	116.87	121.19
2002-03	121.19	121.19
2003-04	121.06	121.19
2004-05	121.19	121.19
2005-06	121.14	121.19
2006-07	121.20	121.19
2007-08	121.06	121.19
2008-09	121.18	121.19
2009-10	121.13	121.19
2010-11	121.18	121.19

* FSU data.

1.3 Customary fisheries

For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

It is widely believed that the level of illegal harvesting is high around Wellington and on the Wairarapa coast. For further information on illegal catch refer to the introductory PAU Working Group Report.

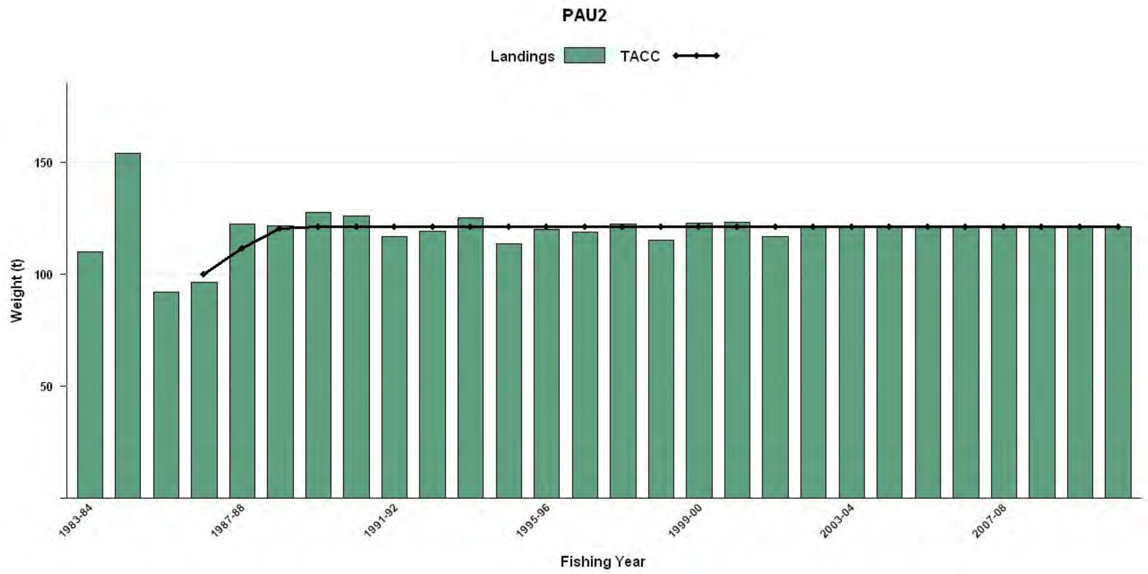


Figure 2: Historical landings and TACC for PAU2 from 1983-84 to 2010-11. QMS data from 1986-present.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of published estimates of biological parameters for PAU 2 is presented in Table 3.

Table 3: Estimates of biological parameters (*H. iris*)

Area		**Estimate**	**Source**
1. Size at maturity (shell length)			
Wellington	50% mature	71.7 mm	Naylor *et al.* (2006)
Taranaki	50% mature	58.9 mm	Naylor & Andrew (2000)
2. Fecundity = a (length)^b (eggs, shell length in mm)			
Taranaki	a = 43.98	b = 2.07	Naylor & Andrew (2000)
3. Exponential growth parameters (both sexes combined)			
Wellington	g_{50}	30.58 mm	Naylor *et al.* (2006)
	g_{100}	14.8 mm	
Taranaki	G_{25}	18.4 mm	Naylor & Andrew (2000)
	G_{75}	2.8 mm	

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. RELATIVE ABUNDANCE INDEX

A standardised CPUE index based on commercial catch was constructed covering the 1990 to 2007 fishing years (McKenzie *et al.* 2009). The index was based on CELR data for 1990 to 2001, and PCELR data collapsed into CELR format for 2002 to 2007, with units of kg per diver day. The index shows a decline from 1990 to 1992, increasing to 2000, then fluctuating but essentially constant since (Table 4, Figure 3). A large portion of PAU 2, including the Wellington south coast, is closed to commercial fishing. This means that the CPUE series collected from the commercial catch and effort data are exclusive of this large area. Given that it is widely believed that the level of illegal harvesting is high around Wellington, the abundance of paua in the fishery as a whole will not be captured very well by the CPUE index, which will only reflect abundance outside of the closed area. This is a cause for concern if stocks in the closed area are being depleted.

CPUE is difficult to use as an estimate of abundance due to its ability to mask serial depletion. Serial depletion occurs when fishers deplete an unfished or lightly fished bed therefore maintaining or increasing their catch rates, CPUE stays high while the biomass is actually decreasing. CPUE should be treated with caution as index of abundance.

Table 4: The standardised CPUE for PAU 2 1990-2007.

Fishing year	Number of records	Standardised CPUE	CV
1990	288	111	0.11
1991	413	91	0.10
1992	320	86	0.10
1993	286	96	0.11
1994	253	92	0.10
1995	220	107	0.11
1996	230	108	0.11
1997	228	111	0.11
1998	141	139	0.12
1999	191	155	0.12
2000	188	162	0.12
2001	180	138	0.12
2002	140	149	0.12
2003	153	157	0.12
2004	148	166	0.12
2005	148	147	0.12
2006	166	156	0.12
2007	166	147	0.12

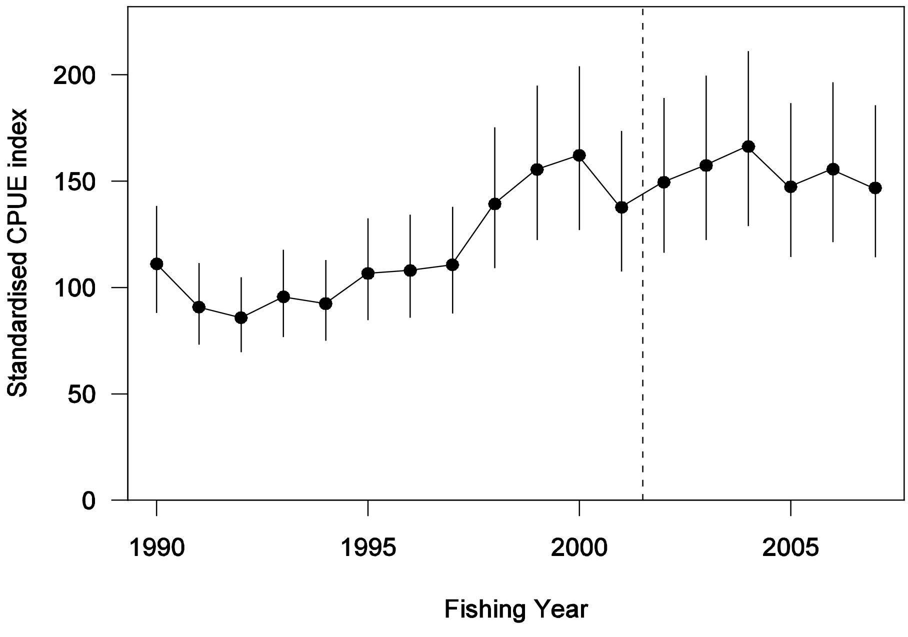


Figure 3: Standardised CPUE index for PAU 2 1990-2007 with 95% confidence intervals. The vertical line delineates between CELR and PCELR data

5. STATUS OF THE STOCKS

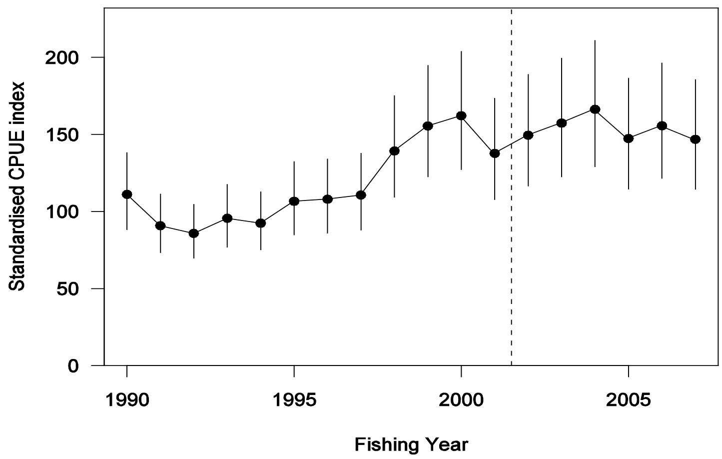
Stock Structure Assumptions

A genetic discontinuity between North Island and South Island paua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

- **PAU 2 -** *Haliotis iris*

Stock Status	
Year of Most Recent Assessment	2007
Assessment Runs Presented	Standardised CPUE index
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS)
Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Standardised CPUE index for PAU 2 1990-2007 with 95% confidence intervals. The vertical line delineates between CELR and PCELR data.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	N/A
Recent Trend in Fishing Mortality or proxy	N/A
Other Abundance Indices	Standardised CPUE increased between 1992 and 2000 and has since remained fairly stable up to 2007.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	No stock assessment has been undertaken for this stock.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	N/A	
Assessment Method	N/A	
Main data inputs	N/A	
Period of Assessment	Latest assessment: N/A	Next assessment: N/A
Changes to Model Structure and Assumptions	N/A	
Major Sources of Uncertainty	N/A	

Qualifying Comments
CPUE is not generally considered to be a reliable indicator of the status of abalone stocks and may not reflect abundance. A large portion of PAU 2, including the Wellington south coast, is closed to commercial fishing. This means that the CPUE series collected from the commercial catch and effort data are exclusive of this large area and therefore the abundance of paua in the fishery as a whole will not be captured very well by the CPUE index.

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew N.L., Naylor J.R., Gerring P. 1999. A modified timed-swim method for paua stock assessment. New Zealand Fisheries Assessment Report 2000/4. 23p.

Breen P.A., Kim SW., Andrew N.L. 2003. A length-based Bayesian stock assessment model for abalone. Marine and Freshwater Research 54(5): 619-634.

Breen P.A., Kim S.W. 2004. The 2004 stock assessment of paua (*Haliotis iris*) in PAU 4. New Zealand Fisheries Assessment Report 2004/55. 79p.

Chen Y., Breen P.A., Andrew N.L. 2000. Impacts of outliers and mis-specification of priors on Bayesian fish stock assessment. Canadian Journal of Fisheries and Aquatic Science. 57: 2293-2305.

Gerring P.K., Andrew N.L., Naylor J.R. 2003. Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. New Zealand Fisheries Assessment Report 2003/56: 13p.

Kendrick T.H., Andrew N.L. 2000. Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5a, PAU 5B, and PAU 5D. New Zealand Fisheries Assessment Report 2000/47: 25p.

McKenzie A, Naylor J.R., Smith N.H. 2009. Characterisation of PAU 2 and PAU 3. Final Research Report. 58p. (Unpublished report)

Naylor J.R., Andrew N.L., Kim S.W. 2003. Fishery independent surveys of the relative abundance, size-structure, and growth of paua (*Haliotis iris*) in PAU 4. New Zealand Fisheries Assessment Report 2003/08. 16p.

Pirker J.G. 1992. Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165p.

Sainsbury K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris.* 1. Population structure, growth, reproduction and mortality. New Zealand Journal of Marine and Freshwater Research 16: 147-161.

Schiel D.R. 1992. The paua (abalone) fishery of New Zealand. In: Shepherd SA., Tegner MJ., Guzman del Proo S. eds., Abalone of the World: Biology, fisheries, and culture. Blackwell Scientific, Oxford.

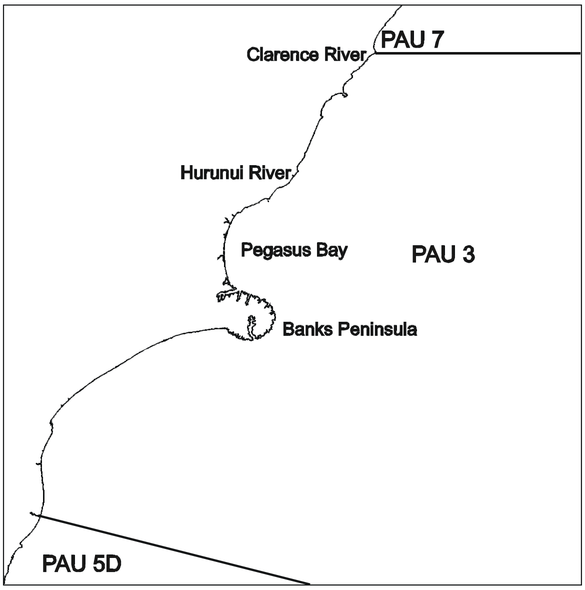
Schiel D.R., Breen P.A. 1991. Population structure, ageing and fishing mortality of the New Zealand abalone Haliotis iris. Fishery Bulletin 89: 681-691.

Vignaux M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987-92. New Zealand Fisheries Assessment Research Document 1993/14. 23p.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PAUA (PAU 3) – Canterbury / Kaikoura

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

1.1 Commercial fisheries

PAU 3 was introduced into the Quota Management System in 1986-87 with a TACC of 57 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased to 91.62 t in 1995 and has remained unchanged to the current fishing year (Table 1). There is no TAC for this QMA: before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 3 since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986 - 1995	-	-	-	-	57
1995 - present	-	-	-	-	91.62

The fishing year runs from 1 October through 30 September. Most of the commercial catch comes from the northern part of the QMA between the northern end of Pegasus Bay and the Clarence River, and from the southern side of Banks Peninsula.

On 1 October 2001 it became mandatory to report catch and effort using fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program (Figure 1). These reporting areas were subsequently adopted on MFish PCELRs.

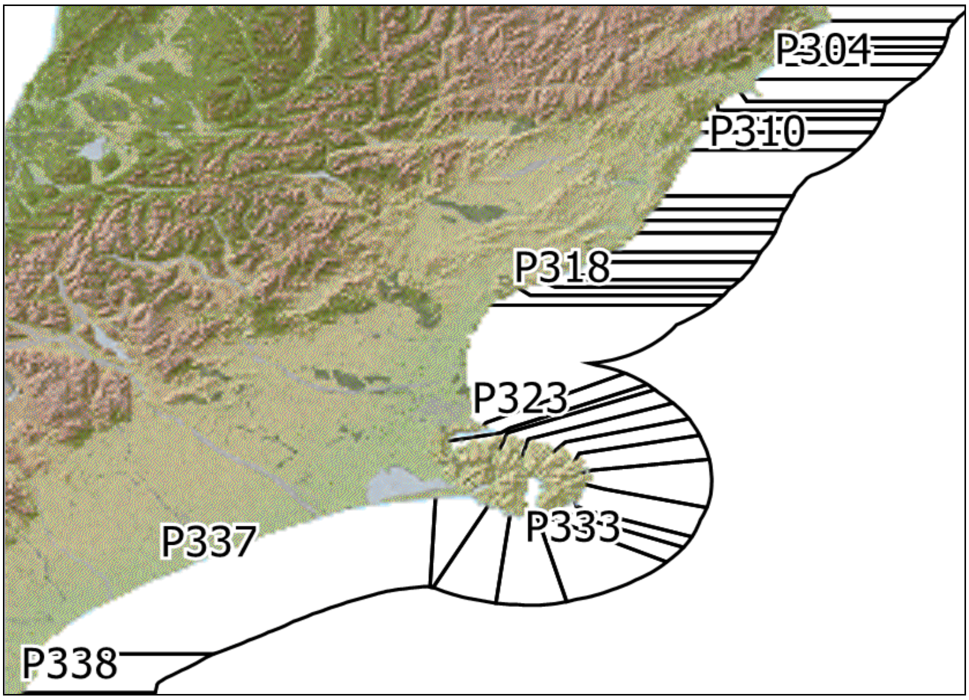


Figure 1: Map of fine scale statistical reporting areas for PAU 3.

Landings for PAU 3 are shown in Table 2.

Table 2: TACC and reported landings (t) of paua in PAU 3 from 1983-84 to 2010-11.

Year	Landings	TACC
1983–84*	114	–
1984–85*	92	–
1985–86*	51	–
1986–87*	54.02	57
1987–88*	62.99	60.49
1988–89*	57.55	66.48
1989–90	73.46	69.43
1990–91	90.68	77.24
1991–92	90.25	91.5
1992–93	94.52	91.5
1993–94	85.09	91.5
1994–95	93.26	91.5
1995-96	92.89	91.62
1996-97	89.65	91.62
1997-98	93.88	91.62
1998-99	92.54	91.62
1999-00	90.3	91.62
2000-01	93.19	91.62
2001-02	89.66	91.62
2002-03	90.92	91.62
2003-04	91.58	91.62
2004-05	91.43	91.62
2005-06	91.6	91.62
2006-07	91.61	91.62
2007-08	91.67	91.62
2008-09	90.84	91.62
2009-10	91.61	91.62
2010-11	90.4	91.62

* FSU data.

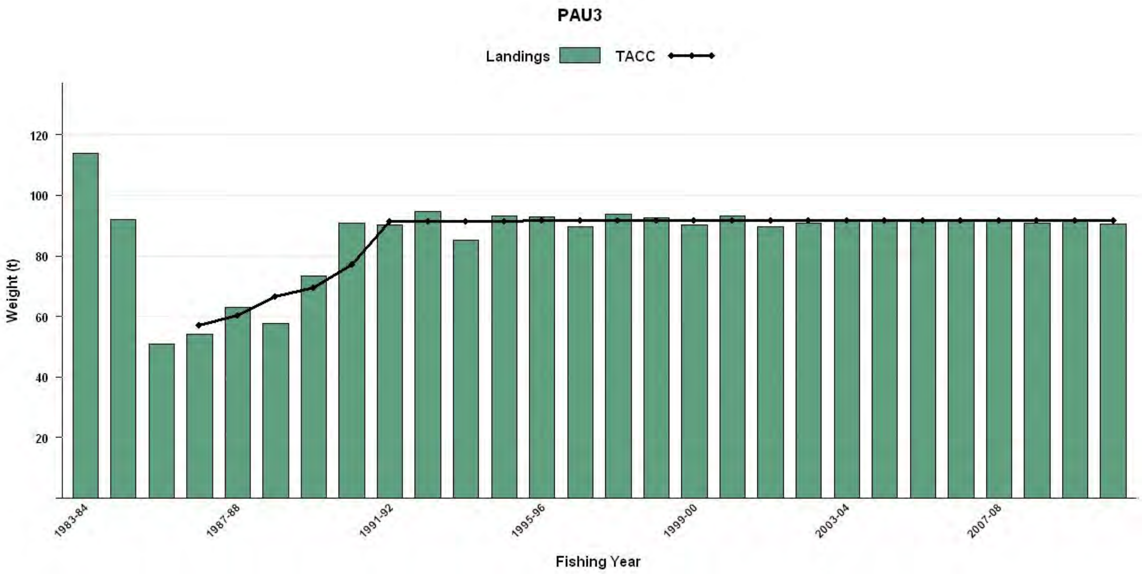


Figure 2: Historical landings and TACC for PAU3 from 1983-84 to 2010-11. QMS data from 1986-present.

1.2 Recreational fisheries

For further information on recreational fisheries refer to the introductory PAU Working Group Report.

1.3 Customary fisheries

Estimates of customary catch for PAU 3 over the period of their reliable availability are shown in Table 3. Landings do not include the area between the Hurunui River and the South Shore (just north of Banks Peninsula), as Tangata Tiaki have not yet been appointed there. Many tangata whenua also harvest paua under their recreational allowance and these are not included in records of customary catch.

Table 3: Reported customary landings (t) of paua in PAU 3 from 2000-01 to 2008-09. Landings data exclude the area between the Hurunui and Pegasus Bay.

Year	Landings (t)
2000/01	1.64
2001/02	4.88
2002/03	3.84
2005/06	1.89
2006/07	4.56
2007/08	5.79
2008/09	8.13

1.4 Illegal catch

For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of published estimates of biological parameters for PAU 3 is presented in Table 3.

Table 3: Estimates of biological parameters (*H. iris*) in PAU 3.

Fishstock		**Estimate**	**Source**
1. Natural mortality (M)			
Peraki Bay		0.02-0.25	Sainsbury (1982)
2. von Bertalanffy Growth parameters			
Peraki Bay	L_∞ = 131.9	K = 0.164	Sainsbury (1982)
Kaikoura	L_∞ = 146.2	K = 0.31	Poore (1972)
3. Size at maturity (shell length)			
50% mature (Banks Peninsula)		75.5 mm	Naylor & Andrew (2000)
4. Fecundity = a (length)^b (eggs, shell length in mm)			
Banks Peninsula	a = 7.75 x 10^{-4}	b = 4.64	Naylor & Andrew (2000)
Fecundity = 0.17 (weight) - 1.528 (eggs x 10^{-6}, gms)			

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

A standardised CPUE index based on commercial catch was constructed covering the 1990 to 2007 fishing years (McKenzie *et al*. 2009). The index was based CELR data for 1990 to 2001, and PCELR data collapsed into CELR format for 2002 to 2007, with units of kg per diver day. The index shows a decline from 1990 to 1992, but has remained fairly stable since (Table 4, Figure 3).

There is a large literature for abalone suggesting that CPUE is difficult to use to estimate abundance because of serial depletion, which happens when fishers deplete unfished or lightly fished beds and maintain their catch rates: CPUE stays high while the biomass is actually decreasing. CPUE should be treated with caution as index of abundance.

Table 4: The standardised CPUE for PAU 3 1990-2007.

Fishing year	Number of records	Standardised CPUE	CV
1990	227	153	0.14
1991	252	111	0.12
1992	263	97	0.11
1993	238	120	0.11
1994	260	105	0.11
1995	293	100	0.11
1996	225	104	0.11
1997	219	113	0.11
1998	235	112	0.11
1999	187	127	0.11
2000	210	116	0.10
2001	294	107	0.10
2002	283	113	0.10
2003	276	102	0.10
2004	266	115	0.10
2005	267	105	0.10
2006	242	127	0.10
2007	244	108	0.10

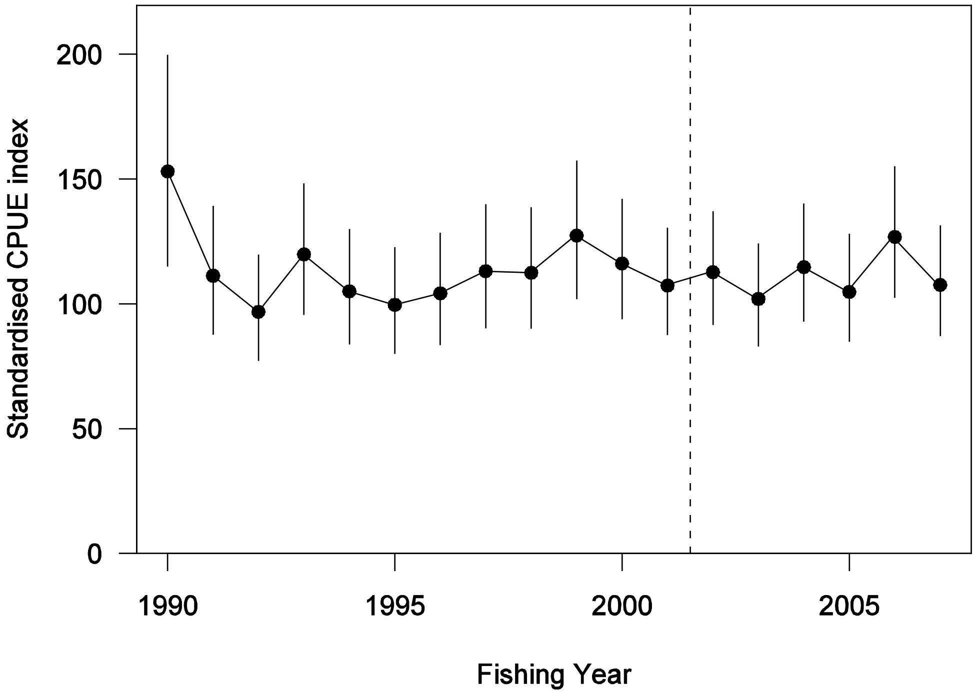


Figure 3: Standardised CPUE index for PAU 3 1990-2007 with 95% confidence intervals. The vertical line delineates between CELR and PCELR data.

5. STATUS OF THE STOCKS

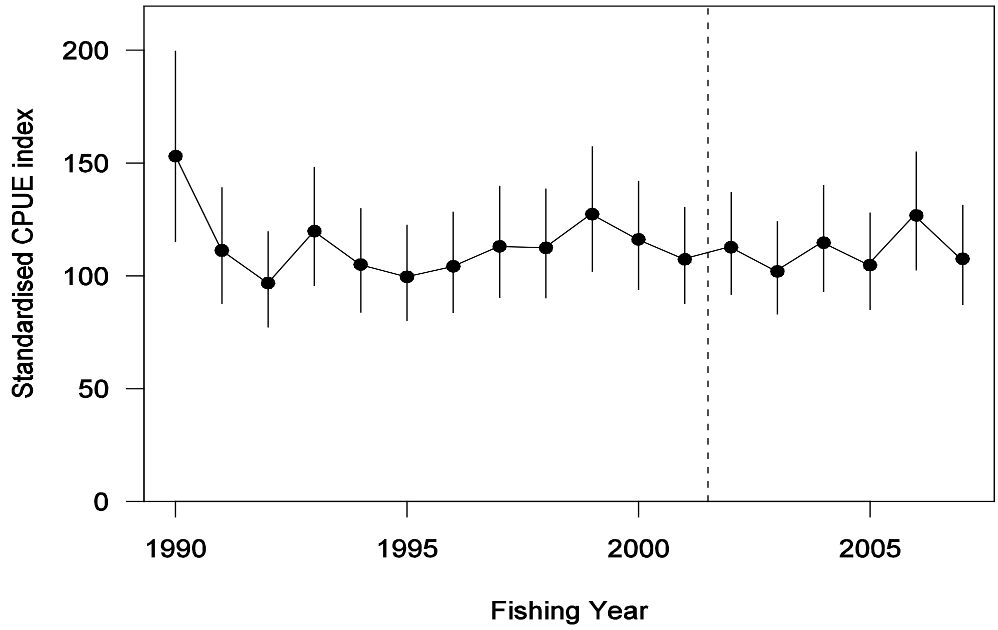
Stock Structure Assumptions

A genetic discontinuity between North Island and South Island paua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

- **PAU 3 -** *Haliotis iris*

Stock Status	
Year of Most Recent Assessment	No stock assessment has been undertaken for this stock
Assessment Runs Presented	Standardised CPUE index
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS)
Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40 %) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Standardised CPUE index for PAU 3 1990-2007 with 95% confidence intervals. The vertical line delineates between CELR and PCELR data.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	N/A
Recent Trend in Fishing Mortality or proxy	N/A
Other Abundance Indices	Standardised CPUE decreased between 1990 and 1992 and has since remained fairly stable up to 2007.
Trends in Other Relevant Indicators or Variables	N/A

Projections and Prognosis	
Stock Projections or Prognosis	No stock assessment has been undertaken for this stock.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	N/A	
Assessment Method	N/A	
Main data inputs	N/A	
Period of Assessment	Latest assessment: N/A	Next assessment: N/A
Changes to Model Structure and Assumptions	N/A	
Major Sources of Uncertainty	N/A	

Qualifying Comments
-

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Gerring P.K., Andrew N.L., Naylor J.R. 2003. Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. New Zealand Fisheries Assessment Report 2003/56: 13p.

Kim S.W. 2004. CPUE analysis of fine-scale logbook data for PAU 3. Ministry of Fisheries Research Report PAU 2001/01 Obj. 7. Unpublished report held at NIWA library, Wellington.

McKenzie A., Naylor J.R., Smith N.H. 2009. Characterisation of PAU 2 and PAU 3. Final Research Report. 58p. (Unpublished report)

Naylor J.R., Andrew, N.L. 2000. Determination of growth, size composition, and fecundity of paua at Taranaki and Banks Peninsula. New Zealand Fisheries Assessment Report. 2000/51. 25 p.

Pirker J.G. 1992. Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165p.

Poore G.C.B. 1972. Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda). 3. Growth. *New Zealand Journal of Marine and Freshwater Research* 6, 534-59.

Poore G.C.B. 1973. Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda). 4. Reproduction. *New Zealand Journal of Marine and Freshwater Research 7* (1&2), 67-84

Sainsbury K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris.* 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research 16*: 147-161.

Schiel D.R. 1992. The paua (abalone) fishery of New Zealand. In: Shepherd SA., Tegner MJ., Guzman del Proo S. eds., Abalone of the World: Biology, fisheries, and culture. Blackwell Scientific, Oxford.

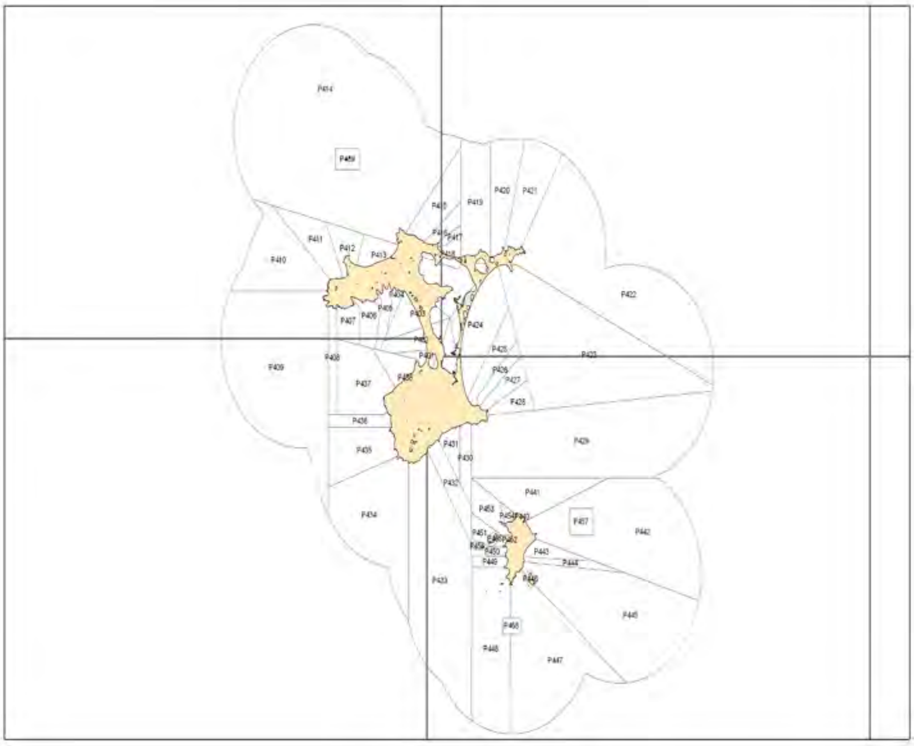
Schiel D.R., Breen PA. 1991. Population structure, ageing and fishing mortality of the New Zealand abalone Haliotis iris. Fishery Bulletin 89: 681-691.

Vignaux M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987-92. New Zealand Fisheries Assessment Research Document 1993/14. 23p.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PAUA (PAU 4) – Chatham Islands

(Haliotis iris)
Paua



1. FISHERY SUMMARY

PAU 4 was introduced to the Quota Management System in 1986-87 with a TACC of 261 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased in 1995-96 to 326 t and has remained unchanged to the current fishing year (Table 1). There is no TAC for this QMA: before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 4 since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986 - 1995	-	-	-	-	261
1995- present	-	-	-	-	326

1.1 Commercial fisheries

The fishing year runs from 1 October through 30 September. On 1 October 2001 it became mandatory to report catch and effort using fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program (see figure above). These reporting areas were subsequently adopted on MFish PCELRs. On 1 October 2009 the commercial fishery voluntarily adopted a minimum harvest size of 127 mm, on 1 October 2010 they agreed to shelve 20% of the ACE and reseed 200 000 juvenile paua to specific areas around PAU 4.

At the beginning of the 2009-10 fishing year, reporting of catch in PAU 4 was changed from reporting in green weight to reporting in meat weight. The TAC, TACC and allowances are still reported in green weight but fishers are now required to report green weight catch based on the meat weight measured by the licensed fish receiver (LFR). The meat weight to green weight conversion factor is 2.50 (equivalent to 40% meat weight recovery). The change was made to curb the practice of converting meat weight to landed green weight after shucking to obtain artificially high recovery rates. It was also made to encourage catch spreading by making it commercially viable for fishers to harvest areas where shells are heavily fouled and meat weight recovery is low. Heavy fouling on shells is a problem that occurs in a number of areas around the Chatham Islands. Landings for PAU 4 are shown in Table 2.

Table 2: TACC and reported landings (t) of paua in PAU 4 from 1983-84 to 2010-11.

Fishstock	Landings	TACC
1983-84*	409	-
1984-85*	278	-
1985-86*	221	-
1986-87*	267.37	261
1987-88*	279.57	269.08
1988-89*	284.73	270.69
1989-90	287.38	287.25
1990-91	253.61	287.25
1991-92	281.59	287.25
1992-93	266.38	287.25
1993-94	297.76	287.25
1994-95	282.10	287.25
1995-96	220.17	326.54
1996-97	251.71	326.54
1997-98	301.69	326.54
1998-99	281.76	326.54
1999-00	321.56	326.54
2000-01	326.89	326.54
2001-02	321.64	326.54
2002-03	325.62	326.54
2003-04	325.85	326.54
2004-05	319.24	326.54
2005-06	322.53	326.54
2006-07	322.76	326.54
2007-08	323.98	326.54
2008-09	324.18	326.54
2009-10	323.57	326.54
2010-11	262.15	326.54

* FSU data.

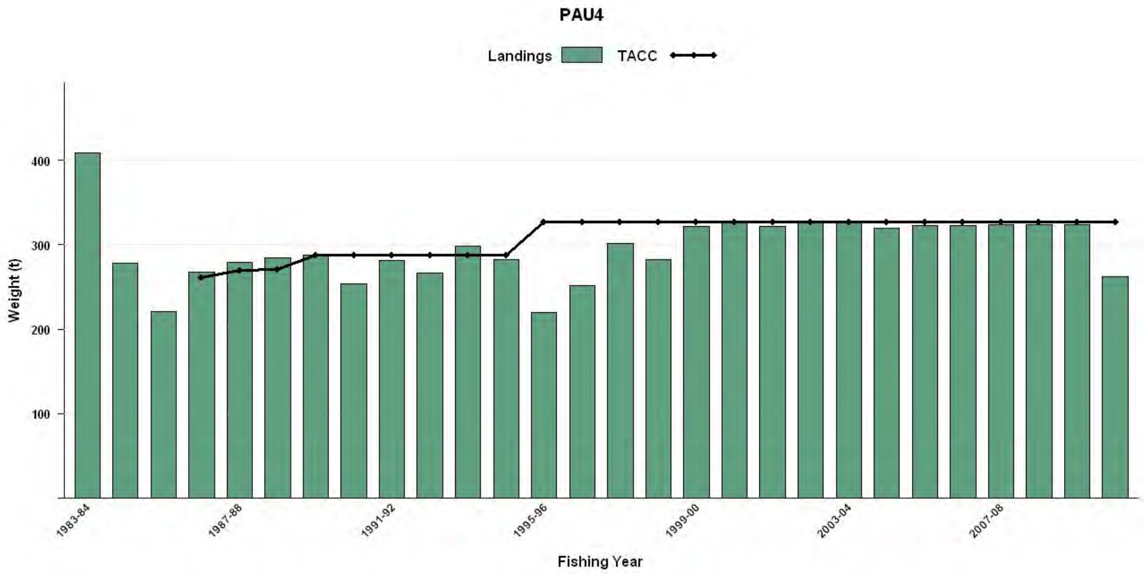


Figure 2: Historical landings and TACC for PAU4 from 1983-84 to 2010-11. QMS data from 1986-present.

1.2 Recreational fisheries

There are no estimates of recreational catch for PAU 4. The 1996, 1999-2000 and 2000-01 national marine recreational fishing surveys did not include PAU 4.

1.3 Customary fisheries

There are no estimates of customary catch for PAU 4. For the 2004 stock assessment this catch was assumed to be zero. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

There are no estimates of illegal catch for PAU 4. For the 2004 stock assessment this catch was assumed to be zero. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality
For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY
For further information on paua biology refer to the introductory PAU Working Group Report.

3. STOCKS AND AREAS
For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance
A standardised CPUE analysis for PAU 4 (Fu 2010) from 1989-90 to 2007-08 was completed in February 2010.

The Shellfish Working Group (SFWG) agreed that, because of extensive misreporting of catch in PAU 4, catch and effort data from the Fisheries Statistical Unit and from the CELR and PCELR forms might be misleading in CPUE analyses and therefore, CPUE cannot be used as an index of abundance in this fishery.

4.2 Stock assessment 2004
The last stock assessment for PAU 4 was completed in 2004 (Breen & Kim 2004). A Bayesian length-based stock assessment model was applied to PAU 4 data to estimate stock status and yield. A reference period from 1991-93 was chosen: this was a period after which exploitation rates increased and then leveled off, and after which biomass declined somewhat and then stabilised. It was not intended as a target. Assessment results suggested that then-current recruited biomass was just above $B_{AV,}$ but with high uncertainty (83% to 125%). and current spawning biomass appeared higher than S_{AV}, (130%), but with cautions related to maturity ogives. Projections suggested that 2007 recruited and spawning biomasses could be above B_{AV}, but this was uncertain.

The SFWG advised that major uncertainties in the assessment required the results to be treated with great caution. The major uncertainties included very sparse research diver survey data, misreported CELR and PCELR data, growth and length frequency data most likely not being representative of the whole population and the assumption that CPUE was an index of abundance.

In February 2010 the SFWG agreed that, because of the lack of adequate data as input into the Bayesian length-based model, a stock assessment for PAU 4 using this model was not appropriate.

4.3 Biomass estimates
There are no current biomass estimates for PAU 4.

4.4 Estimation of Maximum Constant Yield (*MCY*)
No estimate of *MCY* has been made for PAU 4.

4.5 Estimation of Current Annual Yield (*CAY*)
No estimate of *CAY* has been made for PAU 4.

5. STATUS OF THE STOCKS

Stock Structure Assumptions
H. iris individuals collected from the Chatham Islands were found to be genetically distinct from those collected from costal sites around the North and South Islands (Will & Gemmell 2008).

- **PAU 4 - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2004
Assessment Runs Presented	2004
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS)
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Historical Stock Status Trajectory and Current Status: In 2010 the SFWG rejected CPUE as an index of abundance, therefore the 2004 stock assessment (Breen & Kim 2004) is no longer considered reliable.	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	N/A
Recent Trend in Fishing Mortality or Proxy	N/A
Other Abundance Indices	N/A
Trends in Other Relevant Indicators or Variables	N/A

Projections and Prognosis		
Stock Projections or Prognosis	The 2004 stock assessment is no longer considered reliable	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	Level 1: Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Main data inputs	CPUE, RDSI, CSLF, RDLF, catch history	
Period of Assessment	Latest assessment: 2004	Next assessment: Unknown
Changes to Model Structure and Assumptions	CPUE Catch history split	
Major Sources of Uncertainty	Potential bias in RDSI CPUE as a reliable index of abundance Data are not completely accurate Model is homogeneous Model assumptions may be violated	

Qualifying Comments
The 2004 full quantitative stock assessment is no longer considered reliable

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Breen P.A., Kim S.W. 2004. The 2004 stock assessment of paua (*Haliotis iris*) in PAU 4. New Zealand Fisheries Assessment Report 2004/55. 79p.
Fu D. 2010. Summary of catch and effort data and standardised CPUE analyses for paua (*Haliotis iris*) in PAU 4, 1989-90 to 2007-08. Fisheries Research Report 2008/01. 50p
Naylor J.R., Andrew NL., Kim SW. 2003. Fishery independent surveys of the relative abundance, size-structure, and growth of paua (*Haliotis iris*) in PAU 4. New Zealand Fisheries Assessment Report 2003/08. 16p.

Pirker J.G. 1992. Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165p.

Sainsbury K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. New Zealand Journal of Marine and Freshwater Research 16: 147-161.

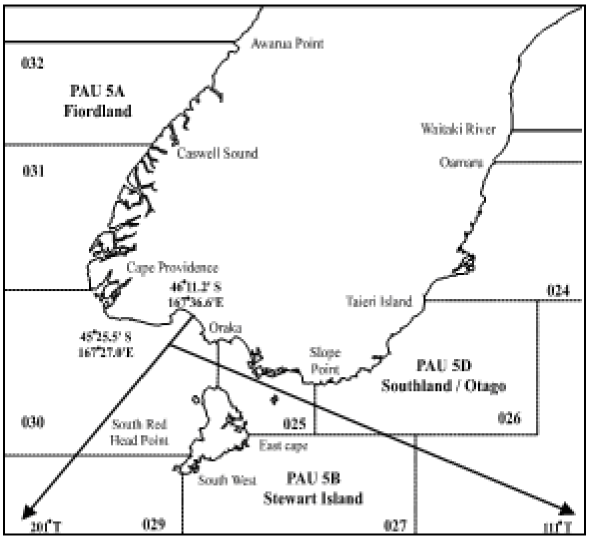
Schiel D.R. 1992. The paua (abalone) fishery of New Zealand. In: Shepherd SA., Tegner MJ., Guzman del Proo S. eds., Abalone of the World: Biology, fisheries, and culture. Blackwell Scientific, Oxford.

Schiel D.R., Breen P.A. 1991. Population structure, ageing and fishing mortality of the New Zealand abalone Haliotis iris. Fishery Bulletin 89: 681-691.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PAUA (PAU 5A) – Fiordland

(Haliotis iris)
Paua



1. FISHERY SUMMARY

Prior to 1995, PAU 5A was part of the PAU 5 QMA, which was introduced to the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t by the 1991-92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994-95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see the figure above) and the TACC was divided equally among them; the PAU 5A quota was set at 148.98 t.

There is no TAC for PAU 5A (Table 1): before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC. No allowances have been made for customary, recreational or other mortality

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5A since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986 - 1991*	-	-	-	-	445
1991 - 1994*	-	-	-	-	492
1994 - 1995*	-	-	-	-	442.8
1995 - present	-	-	-	-	148.98

*PAU 5 TACC figures

1.1 Commercial fisheries

The fishing year runs from 1 October to 30 September.

On 1 October 2001 it became mandatory to report catch and effort using fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program (Figure 1). These reporting areas were subsequently adopted on MFish PCELRs. On 1 October 2010 the commercial fishery voluntarily adopted two different minimum harvest sizes of 128 mm and 133mm specific to statistical areas F07 to F14 and F15 to F49 respectively. The minimum legal size of 125mm remains in statistical areas F1 to F06.The commercial fishery have also placed different voluntary harvest caps on six separate voluntary management strata (Figure 1).

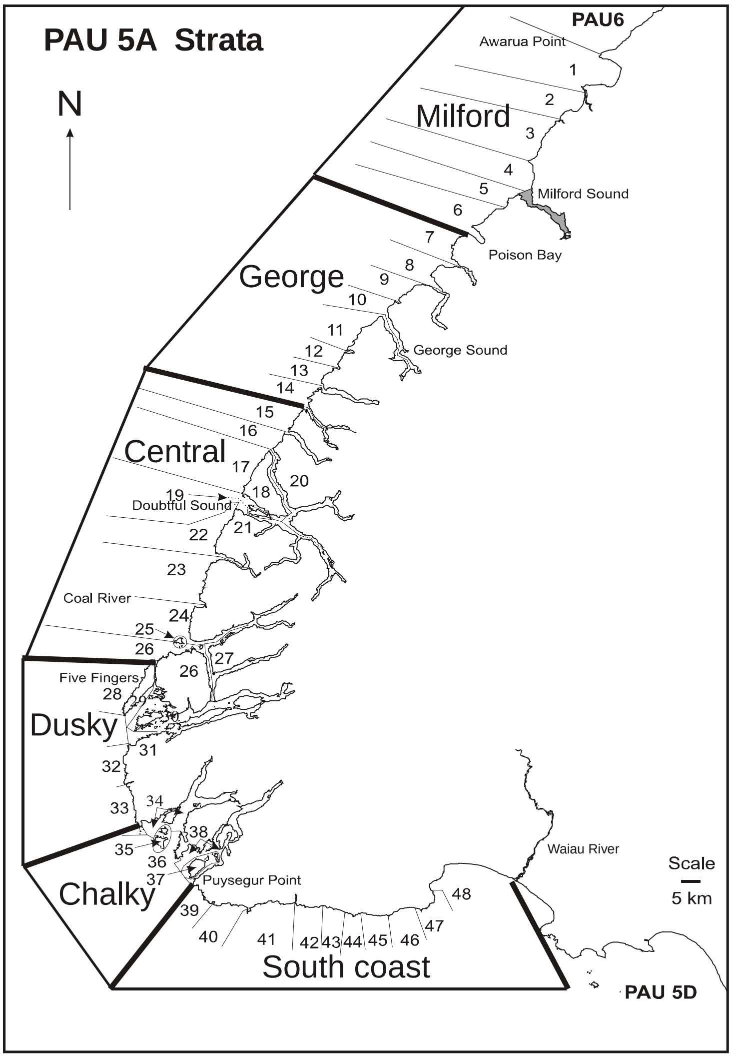


Figure 1: Map of statistical areas, fine scale statistical areas and voluntary management strata in PAU 5A.

Landings for PAU 5A are shown in Table 2. Landings for PAU 5 are reported in the introductory PAU Working Group Report.

Table 2: TACC and reported landings (t) of paua in PAU 5A from 1995-96 to 2010-11 from MHR returns.

Year	Landings	TACC
1995-96	139.53	148.98
1996-97	141.91	148.98
1997-98	145.22	148.98
1998-99	147.36	148.98
1999-00	143.91	148.98
2000-01	147.70	148.98
2001-02	148.53	148.98
2002-03	148.76	148.98
2003-04	148.98	148.98
2004-05	148.95	148.98
2005-06	148.92	148.98
2006-07	104.03	148.98
2007-08	105.13	148.98
2008-09	104.82	148.98
2009-10	105.74	148.98
2010-11	104.40	148.98

1.2 Recreational fisheries

For the purpose of the stock assessment model, the Shellfish Working Group (SFWG) agreed to assume that the 1974 recreational catch was 1 t, increasing linearly to 2 t in 2005. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

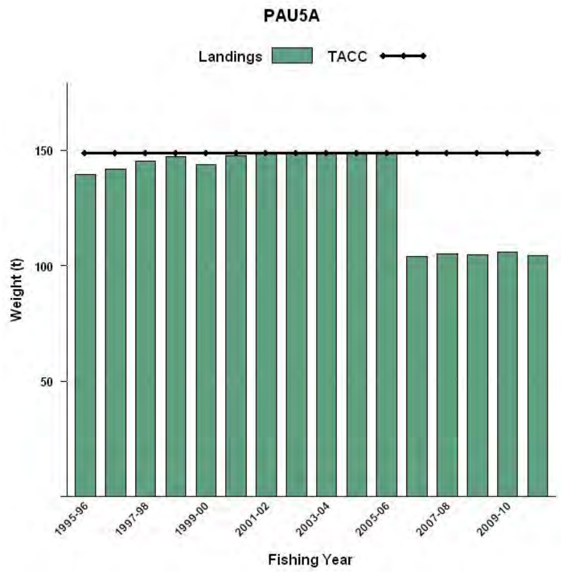


Figure 2: Landings and TACC for PAU5A from 1995-96 to 2010-11. For historical PAU5 landings prior to 1995-96 refer to the PAU introduction chapter, Figure 1 and Table 1.

1.3 Customary fisheries

For the purpose of the stock assessment model, the SFWG agreed to assume that customary catch has been constant at 1 t. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

There are no estimates of illegal catch for PAU 5A. For the purpose of the stock assessment model, the SFWG agreed to assume that illegal catches have been a constant 5 t. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. Biological parameters derived using data collected from PAU 5A are summarised in Table 3. Size-at-maturity, natural mortality and annual growth increment parameters were estimated within the assessment model.

Table 3: Estimates of biological parameters (*H. iris*). All estimates are external to the model.

Stock area		Estimate	Source
1. Weight = a (length)^b (weight in kg, shell length in mm)			
PAU 5A	a = 2.99E-08	b = 3.303	Schiel & Breen (1991)
2. Size at maturity (shell length)			
PAU 5A	50% mature	93 mm	Samples from Dusky, George, and Milford areas
	95% mature	109 mm	(Fu *et al*. 2010)
3. Estimated annual increments (both sexes combined)			Samples from Central, Dusky, George, Chalky and
PAU 5A	At 75 mm	25.2 mm	the South Coast (Fu *et al*. 2010)
	At 120 mm	6.9 mm	

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

The stock assessments for PAU 5A have previously been carried out at the QMA level. In 2010 the Shellfish Working Group decided to conduct the stock assessment for the two subareas of PAU 5A separately: a southern area including the Chalky and South Coast strata, and a northern area including the Milford, George, Central, and Dusky strata (Figure 1). The division was based on the availability of data, and differences in exploitation history and management initiatives.

4.1 Estimates of fishery parameters and abundance

Standardised CPUE data from CELR and PCELR records shows a steady decline in CPUE in the Southern areas from 1990 to 2008, but appears to have increased since then (Figure 3, Upper graphs). CPUE shows a general increase in the northern areas from 1990 to 2003 but declined in 2004 and remained relatively stable since (Figure 3, Lower graphs). The stock assessment assumes that commercial CPUE is proportional to abundance; however, this may not be the case for paua stocks because serial depletion tends to maintain catch rates despite a declining biomass. Apparent stability in CPUE must therefore be interpreted with caution.

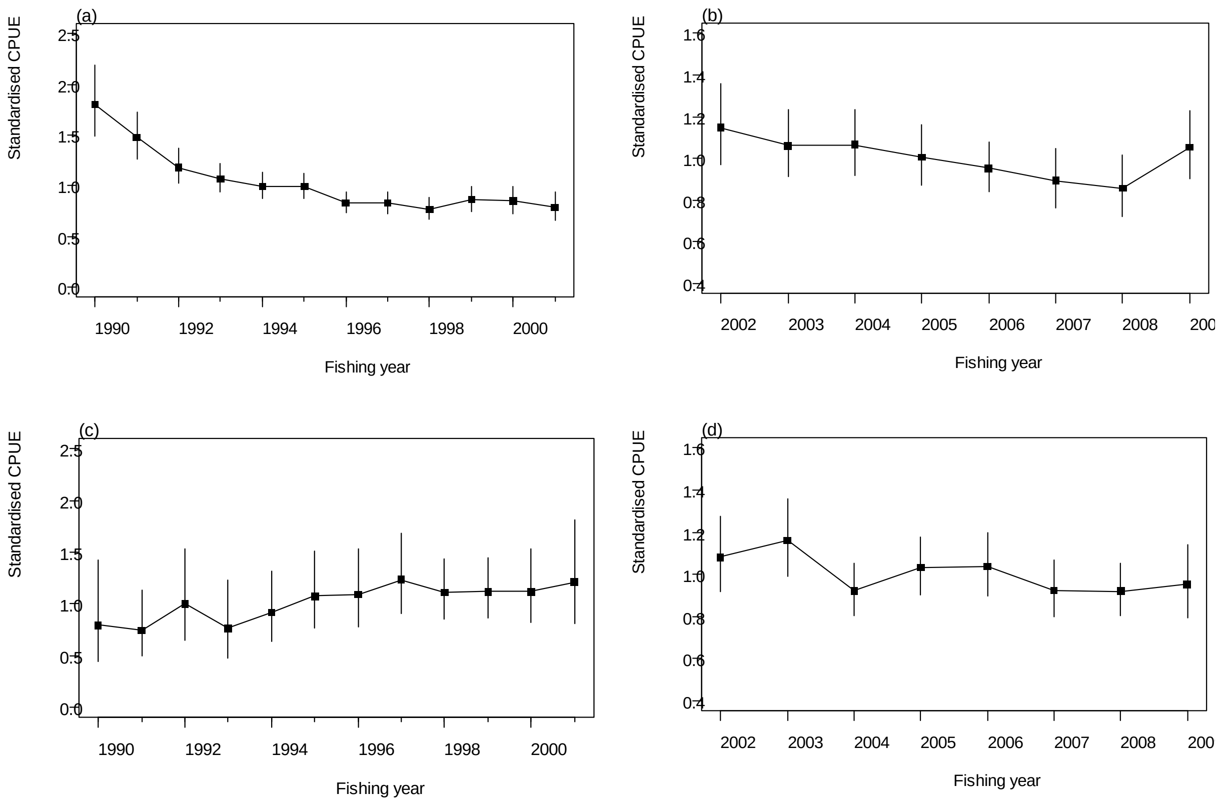


Figure 3: Standardised CPUE indices for the southern area of PAU 5A based on the CELR 1990–2001 (a) and PECLR 2002–2009 (b), and for the northern area based on CELR 1990–2001 (c) and PECLR 2002–2009 (d).

The abundance of paua in PAU 5A was also estimated from research diver surveys in 1996, 2002, 2003, 2006, and 2008–2010. Not every stratum was surveyed in each year, and before 2005-06 surveys were conducted only in the area from Dusky south (Table 4). Concerns about the reliability of this data as an estimate of relative abundance instigated several reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed i) the reliability of the research diver survey index as a proxy for abundance and ii) whether the RDSI, when used in the paua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. Both reviews suggest that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report.

4.2 Biomass Estimates

The 2010 assessment for the southern (Fu & McKenzie 2010a) and northern (Fu & McKenzie 2010b) areas of PAU 5A incorporated revision of the length-based model first used in 1999 for PAU 5B (Breen *et al*. 2000a), and used in revised form for subsequent assessments in many paua stocks (Breen *et al*. 2003, Breen & Kim 2005, McKenzie & Smith 2009). For more information on the model structure and the data used refer to Fu & McKenzie (2010/35, 2010/36 & 2010/46).

The model partitioned the paua stock into a single sex population, with length classes from 70 mm to 170 mm, in groups of 2 mm. The stock was assumed to reside in a single, homogeneous area. The partition accounted for numbers of paua by length class within an annual cycle, where movement between length classes was determined by the growth parameters. Paua entered the partition following recruitment and were removed by natural mortality and fishing mortality.

The model simulates the population dynamics from 1965 to the current fishing year. Catches were available for 1974-2010 (commercial catch in 2010 was assumed to be the harvest cap), and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. Recruitment is modeled as an estimated baseline value with estimated annual deviations. No explicit stock-recruitment relationship was modelled in this assessment.

Maturity does not feature in the population partition. The model estimated proportions mature with the inclusion of length-at-maturity data. Growth and natural mortalities were also estimated within the model.

The models used two selectivities: the commercial fishing selectivity and research diver survey selectivity, both assumed to follow a logistic curve. From 2007 onward, the commercial fishing selectivity was shifted by 5 mm for the southern area assessment, and 2 mm for the northern area assessment, following voluntary changes in the minimum harvest size.

A point estimate of the mode of the joint posterior distribution (MPD) serves as the starting point for the Bayesian estimations and as the basis for some sensitivity tests. Markov Chain Monte Carlo (MCMC) simulations are used to estimate the marginal posterior distributions of model parameters, indicators and state of the stock. Indicators are based on current and projected states of the stock, and comparisons with a reference period, for both spawning and recruited biomass.

For both the Northern and Southern areas the data fitted in the assessment model were: (1) a standardised CPUE series based on the early CELR data, (2) a standardised CPUE series covering based on recent PCELR data, (3) a standardised research diver survey index (RDSI), (4) a research diver survey proportions-at-lengths series, (5) a commercial catch sampling length frequency series, (6) tag-recapture length increment data, and (7) maturity-at-length data. The catch history used as the model input included commercial, recreational, customary, and illegal catch. It was assumed that 80% of the non-commercial catch was taken from the southern area of PAU 5A, with the remainder being taken from the northern area.

For the Southern area the commercial catch history estimates were made under assumptions concerning the split of the catch between sub-stocks of PAU 5, and between subareas within PAU 5A. The base case model run has assumed 40% of the catch in Statistical Area 030 were taken from PAU 5A between 1985 and 1996. Estimates made under alternative assumptions (a lower bound of 18% and an upper bound of 61%) were used in sensitivity trials. The maturity and growth data included in the model were based on samples collected throughout PAU 5A, and the abundance and length frequency data were from Chalky and South Coast. The CPUE indices between 1990 and 2001 were based on catch effort data from Statistical Area 030. Only four years of catch sampling length frequencies (2002-2005) were included in the base case, as the sampling coverage is low since then and dubious before then. The additional catch sampling data were used in sensitivity trials.

For the Northern area the commercial catch history estimates between 1984 and 2010 were based on reported catch from Statistical Area 031 and 032, and estimates before 1984 were made using assumptions about the split of the catch between subareas within PAU 5A. The split proportions were inferred from the total estimated catch between 1984 and 95 from Statistical Areas 030, 031, and 032, assuming that 18% (upper bound), 40% (base case), or 61% (lower bound) of the annual catch in 030 was taken from PAU 5A. The maturity and growth data included in the model were based on samples collected throughout PAU 5A, and the abundance and length frequency data were from Milford, George, Central, and Dusky. As for the southern area assessment only four years of catch sampling length frequencies (2002-2005) were included, as the sampling coverage has been low since then and is unreliable before 2002. The decision was made following the southern area assessment.

A base case model was chosen by the SFWG for each of the assessments. For the southern area, the base case used the catch vector estimated under the base case assumption (the lower bound and upper bound estimates were investigated in sensitivities), and included CSLF data for 2002-2005 (the full CSLF series were used in the sensitivity). Recruitment deviations were estimated for 1986-2006. The commercial fishing selectivity was shifted by 5 mm after 2007 in line with the increase of the minimum harvest size (MHS). Each dataset was weighted so that the standard deviations of the normalised residuals were close to 1.0 for each dataset.
For the northern area, the base case used the catch vector estimated under the base case assumption and included CSLF data for 2002-2005. Recruitment deviations were estimated for 1982-2006. The initial run suggested that the model fitted poorly to the recent CPUE indices. Therefore two alternative runs were proposed: a base case model which up-weighted the recent CPUE series, and a hyperstability model which assumed a non-linear relationship between CPUE and vulnerable biomass. Another source of uncertainty relates to changes in fishing selectivity due to an increase in Minimum Harvest Size in 2007, which varied by region. The base case and hyperstability model assumed a shift of fishing selectivity by 2 mm since 2007, with alternatives of 3 and 4 mm investigated in sensitivity trials.

The assessment reported B_{init}, the spawning stock biomass at the end of initialisation phase, and B_0 the equilibrium spawning stock biomass assuming that recruitment is equal to the average recruitment from the period for which recruitment deviation were estimated. B_0 will differ from B_{init} if estimated average recruitment deviates from base recruitment. The assessment used the ratio of current and projected spawning stock biomass ($B_{current}$ and B_{2012}) to B_0 as preferred indicators of stock status (B_{init} was considered to have little biological meaning). The assessment also reported $B^r_{current}$, B^r_{init}, and B^r_0 being the current, initial, and virgin recruit-sized biomass respectively.

Recent practice has been to define a reference period in which biomass was stable, catches were good and the exploitation rate was sustainable. However, different biomass trajectories in sensitivity runs suggested that this approach was inappropriate for this assessment. Therefore S_{AV} and B_{AV} were not used as indicators in this assessment.

Projections were made until 2012 (a three- and two-year projection for the southern and northern area assessment respectively). Recruitments for projections were obtained by randomly re-sampling model estimates from 1996 until 2006. Catch assumed in the projection included the 2009-10 harvest cap and the estimates for recreational, customary and illegal harvest. Catches were not fully taken if the corresponding exploitation rate exceeded the upper bound of 0.65. For the northern area assessment, projections made under current catch levels suggested that biomass is likely to decrease over the next two years, therefore additional projections were made assuming reduced catch levels, and the model output $Pr(B_{2012} > B_{2010})$, the probability that projected spawning biomass in 2012 would be higher than in 2010.

4.2.1 Stock assessment results

Southern Area

For the southern area, the base case fitted most data credibly. However, it was unable to fit the steep decline in the CPUE between 1990 and 1994, and was also unable to explain the inter-annual changes in the observed RDSI. The estimates of recruitment were lower than average in the late 1980 and about average through the 1990s. Exploitation rate was generally below 0.4 but was variable. The exploitation rate has been high since the late 1990s, but showed decreases over the last few years, in line with the reduction of catch levels.

The summaries of indicators from the base case for the southern area assessment are shown in Table 4. The median of the posterior of B_0 was estimated to be 1155 t. The posterior trajectory of spawning stock biomass is shown in Figure 4. Current estimates from the base case suggest that the spawning stock population in 2009 (B_{current}) was about 35% (28-42%) B_0, and recruit-sized stock abundance ($B^r_{cureent}$) was about 24% (19-29%) of the initial state (B^r_0).

The projection suggested that the stock abundance will continue to increase over the next three years and the spawning stock biomass in 2012 is projected to be about 39% (31-50%) of B_0, or 14% (2-26%) more than current levels (Table 5). Based on the 1000 posterior samples, the probability that the spawning stock biomass will decrease in three year's time is less than 7%.

The Effects of using alternative catch history estimates (upper and lower-bound) were also investigated. The MPD estimates of $B_{current}$ ranged from 30% to 52% of B_0 for those estimates.

Table 4: Summaries of the marginal posterior distributions of indicators for the base case of the southern area assessment. Columns show the 5th and 95th quantiles, median, minimum and maximum of each distribution. Biomass is in tonnes.

	Min	5%	Median	95%	Max
B_0	996	1066	1155	1252	1345
B_{init}	906	962	1025	1088	1152
$B_{\min}$	285	331	382	447	513
$B_{current}$	288	338	397	478	567
$B_{current} / B_0$	0.24	0.28	0.35	0.42	0.49
B^r_0	844	913	1007	1111	1206
B^r_{init}	776	835	894	945	999
$B^r_{\min}$	140	172	204	251	300
$B^r_{current}$	170	201	237	286	349
$B^r_{current} / B^r_0$	0.16	0.19	0.24	0.29	0.36
$U_{current}$	0.15	0.18	0.22	0.25	0.29

Table 5: Summary of key indicators from the projection for the base case of the southern area assessment: projected biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass, respectively.

Projection	2009	2010	2011	2012
% B_0	34.6 (27.3-43.9)	35.6 (27.8-45.2)	37.5 (29.3-47.7)	39.4 (30.9-50)
% B^r_0	20.7 (16.3-25.8)	21.5 (16.7-27.1)	22.2 (17.1-28.4)	23.2 (17.9-30)
% $B_{current}$	100 (100-100)	103 (99-107)	108 (100-117)	114 (102-126)
% $B^r_{current}$	100 (100-100)	104 (99-110)	108 (100-117)	112 (103-123)

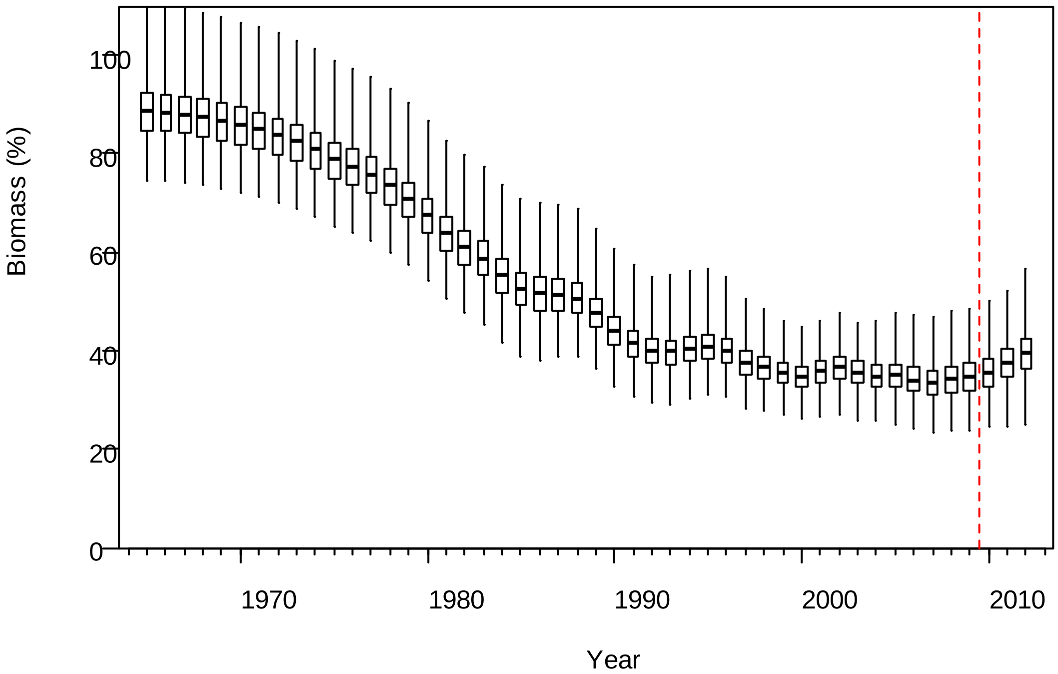


Figure 4: Posterior distributions of spawning stock biomass (including projection) as a percentage of B_0 for the southern area assessment. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2012 for each model assuming current catch level.

Northern area

The base case model suggested that recruitment was lower than average in the early 1980s and above average through the 1990s, and that the exploitation rate has increased since the mid 1990s, and remained at relatively high levels over the last few years. The initial run of the base case model suggested that the model fitted poorly to the recent CPUE indices. Therefore two alternative runs were proposed by the SFWG: a base case model which up-weighted the recent CPUE series, and a hyperstability model which assumed a non-linear relationship between CPUE and vulnerable biomass.

The summaries of indicators from the base case are shown in Table 6. The estimated spawning stock population in 2010 ($B_{current}$) is 41% (34-50%) B_0, and the recruit-sized stock abundance ($B^r_{current}$) is 26% (21-33%) of initial state (B^r_0). Estimates from the hyperstability model suggest that $B_{current}$ is 26% (21-35%) B_0, and $B^r_{current}$ is 16% (12-22%) of B^r_0 (Table 7).

Table 6: Summaries of the marginal posterior distributions of indicators for the base case of the northern area assessment. Columns show the 5th and 95th quantiles, median, minimum and maximum of each distribution. Biomass is in tonnes.

	Min	5%	Median	95%	Max
B_0	913	960	1012	1065	1123
B_{init}	727	782	858	961	1065
$B_{current}$	300	351	417	498	580
$B_{current}/B_0$	0.29	0.35	0.41	0.49	0.54
B^r_0	694	737	787	843	926
B^r_{init}	545	613	670	734	809
$B^r_{current}$	150	175	207	250	305
$B^r_{current}/B^r_0$	0.18	0.22	0.26	0.31	0.38
$U_{current}$	0.22	0.27	0.31	0.36	0.41

Table7: Bayesian median and 95% credible intervals of key indicators for the hyperstability model for the northern area assessment. Biomass is in tonnes.

Model	B_0 (t)	B^r(t)	B_{2010} (% B_0)	B^r_{2010} (%B^r_0)
Hyperstability	989 (923-1065)	805 (727-887)	26.4 (20.5-34.7)	16.1 (11.8-22.3)

Assuming greater selectivity shifts of 2 to 4mm since 2007 led to more optimistic estimates of stock status:, the median of B_{current} (%B_0) ranged from 41% to 50% for the base case, and from 26% to 30% for the hyperstability model . The posterior trajectories of spawning stock biomass for the base case and hyperstability models are shown in Figures 5 & 6.

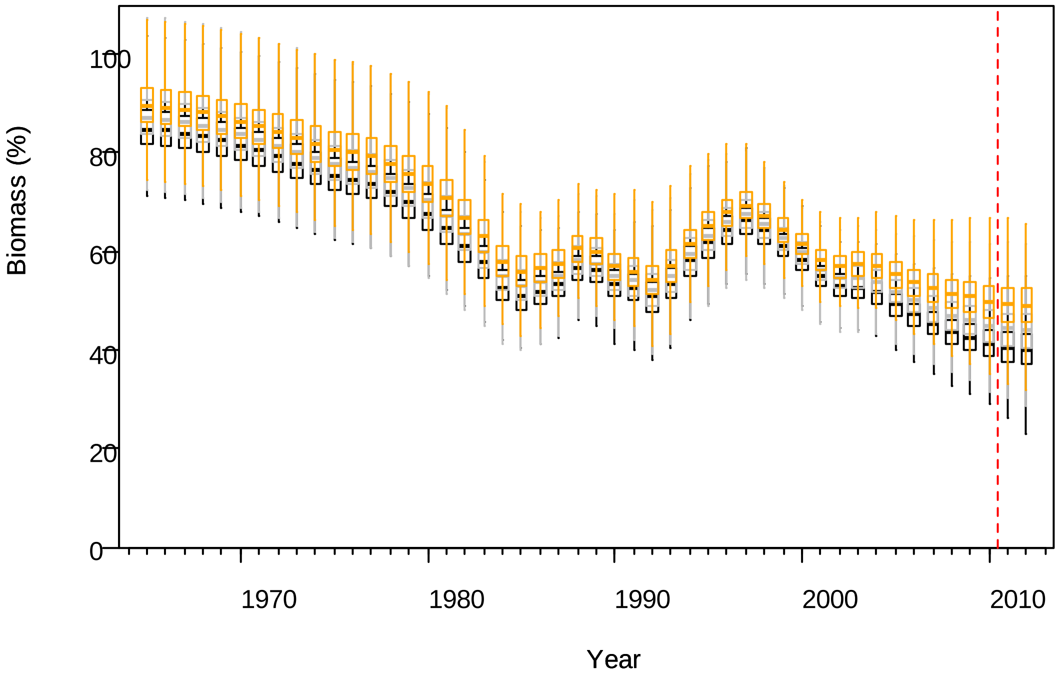


Figure 5 Posterior distributions of spawning stock biomass trajectory for base case (black), 6.1 (gray), and 6.2 (orange) for the northern area assessment. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2012 for each model assuming current catch level. Model 6.1 and 6.2, base case but commercial selectivity shifted by 3 and 4 mm respectively from 2007.

The projection made for the base case suggested that the stock abundance will decrease slightly over the next two years. The projected spawning stock biomass in 2012 has a median of 40% of B_0, about 3% less than current level (Table 8). The probability that the spawning stock biomass will increase in two year's time (Pr{ $B_{2012} > B_{current}$ }) is about 22%. The hyperstability model predicted a larger decline in abundance, with B_{2012} predicted to be 6% less than current state (Table 8). Projections made with alternative future catches suggested that Pr{ $B_{2012} > B_{current}$ } will increase with reduced catch levels. For the base case, Pr{ $B_{2012} > B_{current}$ } will be greater than 50% if the catch is reduced by 10 t each year for the next two years; for the hyperstability model, catch shelving of up to 20 t each year is required. Projections made with larger selectivity shifts have all predicted declines in future stock abundance, but generally with smaller risks.

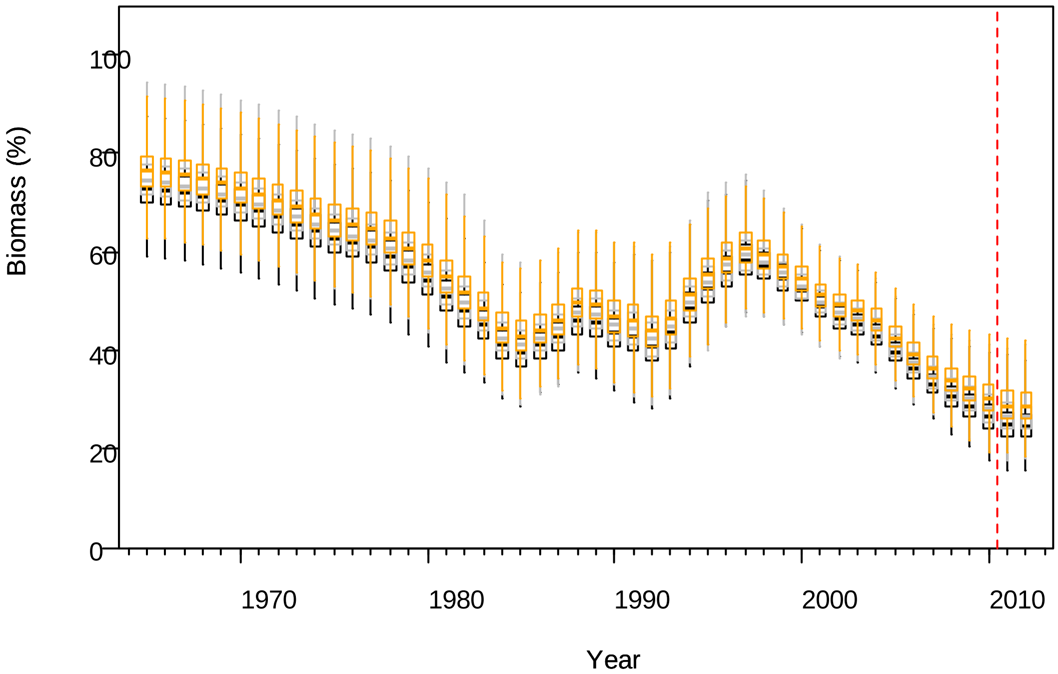


Figure 6: Posterior distributions of spawning stock biomass trajectory for hyperstability model (black), 8.1 (gray), and 8.2 (orange). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2012 for each model assuming current catch level. Model 8.0 and 8.2, hyperstability model but commercial selectivity shifted by 3 and 4 mm respectively from 2007.

Table 8: Bayesian median and 95% credible intervals of key indicators of projection assuming various future catch levels, the base case and hyperstability models for the northern area assessment.

Model	Catch	B_{2012} (% B_0)	B_{2012} (% B_{2010})	$Pr(B_{2012} > B_{2010})$
Base case	74 330	40.0 (31.8-49.5)	0.97 (0.89-1.05)	0.218
	69 330	40.7 (32.5-50.2)	0.99 (0.91-1.06)	0.364
	64 330	41.4 (33.2-50.8)	1.00 (0.93-1.08)	0.520
Hyperstability	74 330	24.7 (19.1-33.3)	0.94 (0.82-1.06)	0.140
	64 330	25.4 (19.1-34.7)	0.97 (0.85-1.07)	0.278
	54 330	26.8 (19.7-36.1)	1.01 (0.89-1.12)	0.598

The Shellfish Working Group was satisfied that the stock assessment for both the Southern and Northern areas of PAU 5A was reliable based on the available data. It was agreed by the SFWG that the range of estimated indicators for both the base case and hyperstability models used in the Northern area assessment were acceptable, but where within the range of estimates the actual status of the fishery is located is not clear.

4.3 Estimation of Maximum Constant Yield (*MCY*)

No estimate of *MCY* has been made for PAU 5A.

4.4 Estimation of Current Annual Yield (*CAY*)

No estimate of *CAY* has been made for PAU 5A.

4.5 Other factors

A number of factors affected the overall validity of the assessment.

There were uncertainties in the estimated catch history for PAU 5A and its subareas before 1995. The results from the southern area assessment suggested that estimates of stock status are sensitive to the range of assumptions made for the estimated catch history. For the northern area of PAU 5A, the commercial catch history is well determined back to 1984, although uncertainty exists for the pre-1984 catch, which is expected to have minor effects on the overall assessment. There is little information on the historical catches in Fiordland, but anecdotal evidence suggested that the catch between 1981 and 1984 was about 60-70 t annually (Storm Stanley pers. comm.). The lower and upper-bound catch estimates used in the assessment may have encompassed many of the uncertainties in the historical catches. In addition, non-commercial catch estimates are also very uncertain, and large differences may exist between the catches assumed and the catch actually taken. In both assessments, the modelled area is treated as if it were a single stock with homogeneous biology, habitat and fishing pressure. It is assumed that:

- recruitment affects the modelled area in the same way
- natural mortality does not vary by size or year in the modelled area
- growth has the same mean and variance in the modelled area, although in reality growth may be stunted in some areas and fast-growing in others

Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on increments observed in several different sites. Similarly, the length frequency data are integrated across samples from many places. An open question is whether a model fitted to data aggregated from a large area, within which smaller populations respond differently to fishing, results in credible estimates of the response of the aggregated sub-populations.

This effect is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others are not fished, recruitment failure can result due to the depletion of spawners, because spawners must breed close to each other, and because the dispersal of larvae may be limited. Recruitment failure is a common observation in abalone fisheries internationally. Local processes may decrease recruitment, an effect that cannot be accounted for in the current model.

A significant source of uncertainty is that fishing may cause spatial contraction of populations or that some populations become relatively unproductive after initial fishing due, for example, to reductions in density that may impede successful spawning. If this happens, the model will overestimate productivity in the population as a whole. Historical catches may have been interpreted in the model as good recruitments, whereas they may actually have been the result of serial depletion.

5. STATUS OF THE STOCKS

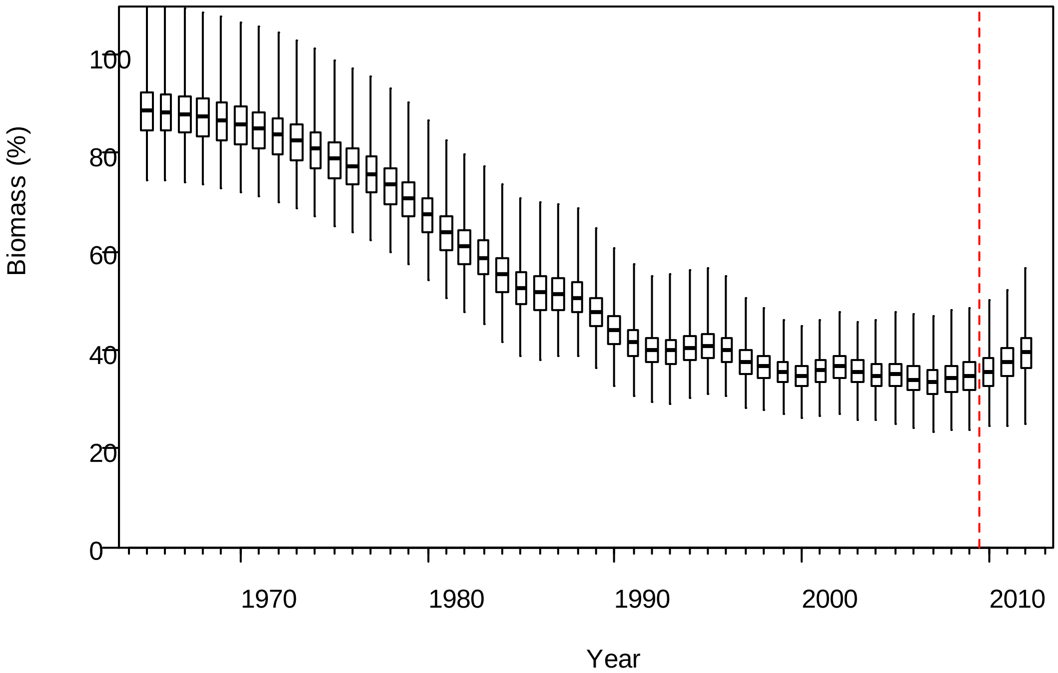
Stock Structure Assumptions
A genetic discontinuity between North Island and South Island paua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

- **PAU 5A - *Haliotis iris***

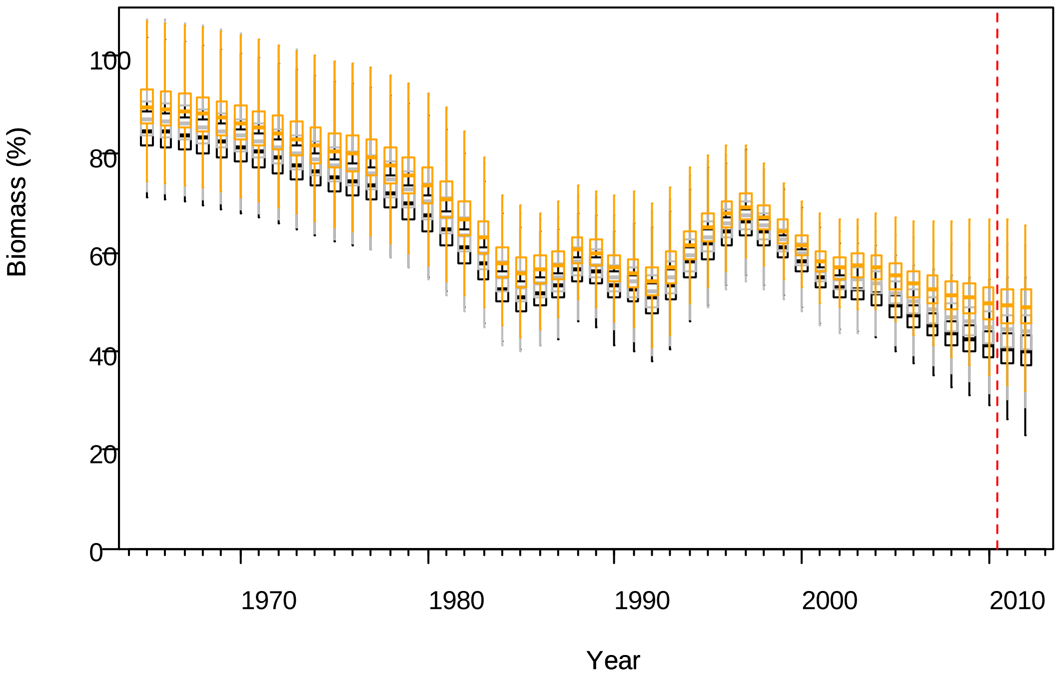
Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	Southern Area: base case model Northern Area: base case and hyperstability models
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS)
Status in relation to Target	Southern Area: Spawning stock biomass was estimated at 35% B_0 Northern Area: Spawning stock biomass was estimated at 41% B_0 by the base case model but only at 26% B_0 by the hyperstability

	model. It was agreed by the SFWG that the range of estimated indicators for both the base case and hyperstability models used in the Northern area assessment were acceptable, but where within the range of estimates the actual status of the fishery is located is not clear.
Status in relation to Limits	Southern Area: Very Unlikely (< 10%) to be below the soft and hard limits. Spawning stock biomass was estimated at 35% B_0 Northern Area: Unlikely (< 40%) to be below the soft limit. Very Unlikely (< 10%) to be below the hard limit.

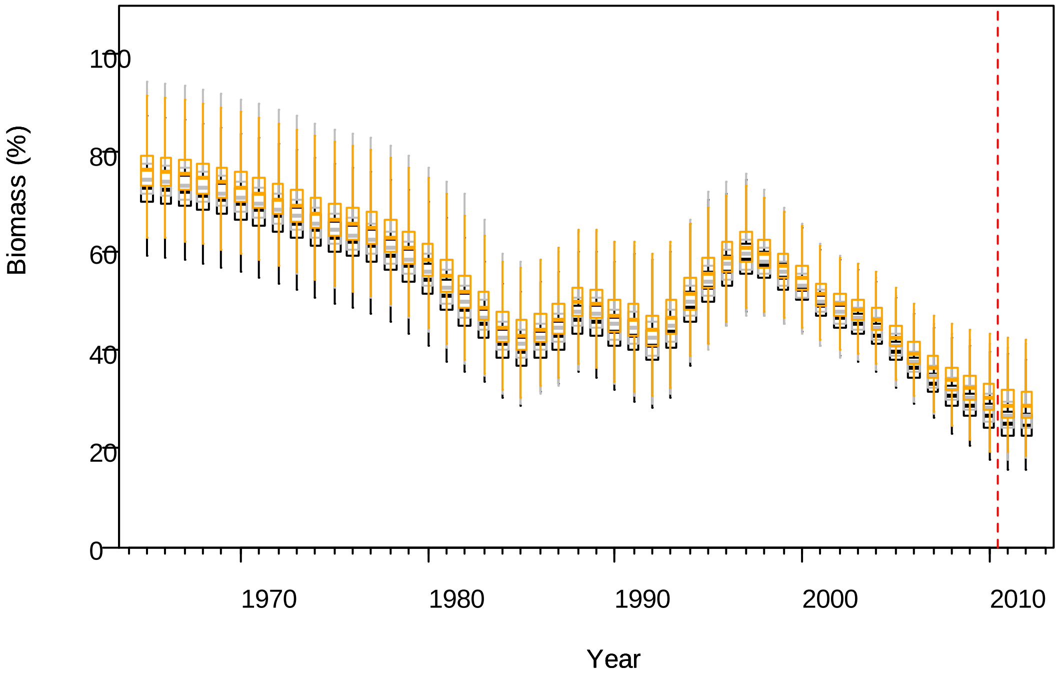
Historical Stock Status Trajectory and Current Status



Posterior distributions of spawning stock biomass (including projection) as a percentage of B_0 for the southern area assessment. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2012 for each model assuming current catch level.



Posterior distributions of spawning stock biomass trajectory for base case (black), 6.1 (gray), and 6.2 (orange) for the northern area assessment. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2012 for each model assuming current catch level. Model 6.1 and 6.2, base case but commercial selectivity shifted by 3 and 4 mm respectively from 2007.



Posterior distributions of spawning stock biomass trajectory for hyperstability model (black), 8.1 (gray), and 8.2 (orange) for the northern area assessment. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2012 for each model assuming current catch level. Model 8.0 and 8.2, hyperstability model but commercial selectivity shifted by 3 and 4 mm respectively from 2007.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Southern: Spawning stock biomass generally declined from 2002 to 2007 but has been increasing up to 2009. Northern: Spawning stock biomass has been declined from 1997 until 2010
Recent Trend in Fishing Mortality or Proxy	N/A
Other Abundance Indices	N/A
Trends in Other Relevant Indicators or Variables	N/A

Projections and Prognosis	
Stock Projections or Prognosis	Southern: Spawning stock biomass in 2012 is projected to be about 39% (31-50%) of B_0, or 14% (2-26%) more than current levels. The probability that the spawning stock biomass will decrease in three year’s time is less than 7%. Northern: The base case model projected spawning stock biomass in 2012 to be 40% of B_0, about 3% less than current level. The probability that the spawning stock biomass will increase by 2012 is about 22%. The hyperstability model predicted a larger decline in abundance, with B_{2012} predicted to be 6% less than current state. Projections made with alternative future catches suggested that

	Pr{ $B_{2012} > B_{current}$ } will increase with reduced catch levels. For the base case, Pr{ $B_{2012} > B_{current}$ } will be greater than 50% if the catch is reduced by 10 t each year for the next two years; for the hyperstability model, catch shelving of up to 20 t each year is required.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Southern - Very Unlikely (< 10%) Northern - Unlikely (< 40%) Hard Limit: Southern - Very Unlikely (< 10%) Northern - Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Full quantitative stock assessment	
Assessment Method	Length-based Bayesian model	
Main data inputs	CPUE, RDSI, CSLF, RDLF, catch history	
Period of Assessment	Latest assessment: 2010	Next assessment: Unknown
Changes to Model Structure and Assumptions	Previous assessment in 2005 was for a single QMA. The QMA was assessed as two separate areas for the 2010 assessment	
Major Sources of Uncertainty	Potential bias in RDSI CPUE as a reliable index of abundance Data are not completely accurate Model is homogeneous Model assumptions may be violated	

Qualifying Comments
-

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew N.L., Naylor J.R., Gerring P. 1999. A modified timed-swim method for paua stock assessment. New Zealand Fisheries Assessment Report 2000/4: 23p.

Andrew N.L., Naylor J.R., Kim S.W. 2002. Fishery independent surveys of the relative abundance and size structure of paua (Haliotis iris) in PAU 5B and 5D. New Zealand Fisheries Assessment Report 2002/41.41 p.

Breen P.A., Kim S.W. 2004. The 2004 stock assessment of paua (*Haliotis iris*) in PAU 5A. New Zealand Fisheries Assessment Report 2004/40: 86p.

Breen P.A., Kim S.W. 2007. The 2006 stock assessment of paua (*Haliotis iris*) stocks PAU 5A (Fiordland) and PAU 5D (Otago). New Zealand Fisheries Assessment Report 2007/09: 164p.

Breen P.A., Kim S.W., Andrew N.L. 2003. A length-based Bayesian stock assessment model for abalone. Marine and Freshwater Research 54(5): 619-634.

Breen P.A., Smith, A.N.H. 2008. Data used in the 2007 assessment for paua (Haliotis iris) stock PAU 5B (Stewart Island). New Zealand Fisheries Assessment Report 2008/6. 45 p.

Cordue P.L. 2009. Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45p

Chen Y., Breen P.A., Andrew N.L. 2000. Impacts of outliers and mis-specification of priors on Bayesian fish stock assessment. Canadian Journal of Fisheries and Aquatic Science. 57: 2293-2305.

Fu D., McKenzie A. 2010. The 2010 stock assessment of paua (Haliotis iris) for Chalky and South Coast in PAU 5A. New Zealand Fisheries Assessment Report 2010/36.

Fu D., McKenzie A. 2010. The 2010 stock assessment of paua (Haliotis iris) for Milford, George, Central, and Dusky in PAU 5A. New Zealand Fisheries Assessment Report 2010/46

Fu D., McKenzie A., Naylor R. 2010. Summary of input data for the 2010 PAU 5A stock assessment. New Zealand Fisheries Assessment Report 20010/35.

Gerring P.K., Andrew N.L., Naylor J.R. 2003. Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. New Zealand Fisheries Assessment Report 2003/56: 13p.

Hart A.M. 2005. Review of paua research surveys. Final Research Report to the Ministry of Fisheries for project SAP2005-02. 20 p (Unpublished report held by the Ministry of Fisheries, Wellington.).

Haist V. 2010. Paua research diver survey: review of data collected and simulation study of survey method. Draft New Zealand Fisheries Assessment Report 2010/xx.

Kendrick T.H., Andrew N.L. 2000. Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5a, PAU 5B, and PAU 5D. New Zealand Fisheries Assessment Report 2000/47: 25p.

McKenzie A., Smith A.N.H. 2009. The 2008 stock assessment of paua (Haliotis iris) in PAU 7. New Zealand Fisheries Assessment Report 2009/34. 84 p

Naylor J. R., Andrew N.L. 2002. Determination of paua growth in PAU 2, 5A, 5B, and 5D. New Zealand Fisheries Assessment Report. 2002/34.

Naylor J. R., Breen P.A. 2008. Fine-scale growth in paua populations. Final Research Report for the Ministry of Fisheries. Project PAU2006/04. 33 p. (Unpublished report held by the Ministry of Fisheries, Wellington.)

Pirker J.G. 1992. Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165p.

Sainsbury K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris.* 1. Population structure, growth, reproduction and mortality. New Zealand Journal of Marine and Freshwater Research 16: 147-161.

Schiel D.R. 1992. The paua (abalone) fishery of New Zealand. In: Shepherd S.A., Tegner MJ., Guzman del Proo S. eds., Abalone of the World: Biology, fisheries, and culture. Blackwell Scientific, Oxford.

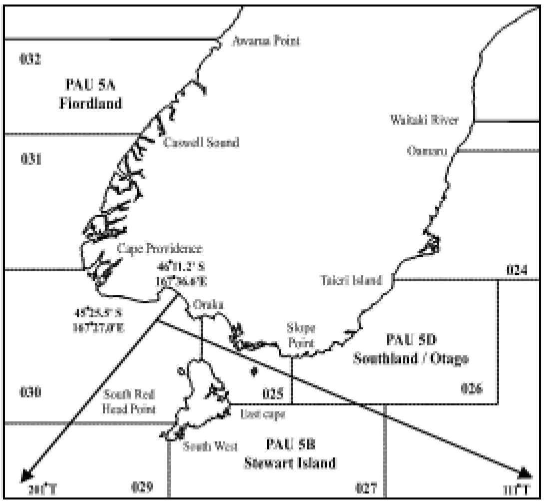
Schiel D.R., Breen P.A.1991. Population structure, ageing and fishing mortality of the New Zealand abalone (*Haliotis iris*). Fishery Bulletin 89: 681-691.

Vignaux M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987-92. New Zealand Fisheries Assessment Research Document 1993/14: 23p.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PAUA (PAU 5B) - Stewart Island

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

Prior to 1995, PAU 5B was part of the PAU 5 QMA, which was introduced to the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t by the 1991-92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994-95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see the figure above) and the TACC was divided equally among them; the PAU 5B quota was set at 148.98 t.

On 1 October 1999 a TAC of 155.98 t was set for PAU 5B, comprising a TACC of 143.98 t (a 5 t reduction) and customary and recreational allowances of 6 t each. The TAC and TACC have been changed since then and an allowance for other mortality has been introduced (Table 1.)

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5B since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986 - 1991*	-	-	-	-	445
1991 - 1994*	-	-	-	-	492
1994 - 1995*	-	-	-	-	442.8
1995 -1999	-	-	-	-	148.98
1999 - 2000	155.9	6	6	-	143.98
2000 - 2002	124.87	6	6	-	112.187
2002 - present	105	6	6	3	90

*PAU 5 TACC figures

1.1 Commercial fishery

The fishing year runs from 1 October to 30 September. Because of concerns about the stock, on 1 October 1999 the Industry agreed to shelve 25 t of quota in addition to the 5 t TACC reduction. This shelving continued into 2000 at a level of about 22 t. Industry decided in 2002 to discontinue quota shelving.

On 1 October 2001 it became mandatory to report catch and effort using fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program

(Figure 1). These reporting areas were subsequently adopted on MFish PCELRs. On 1 October 2010 the commercial fishery voluntarily adopted a minimum harvest size of 135mm for all statistical areas throughout PAU 5B.

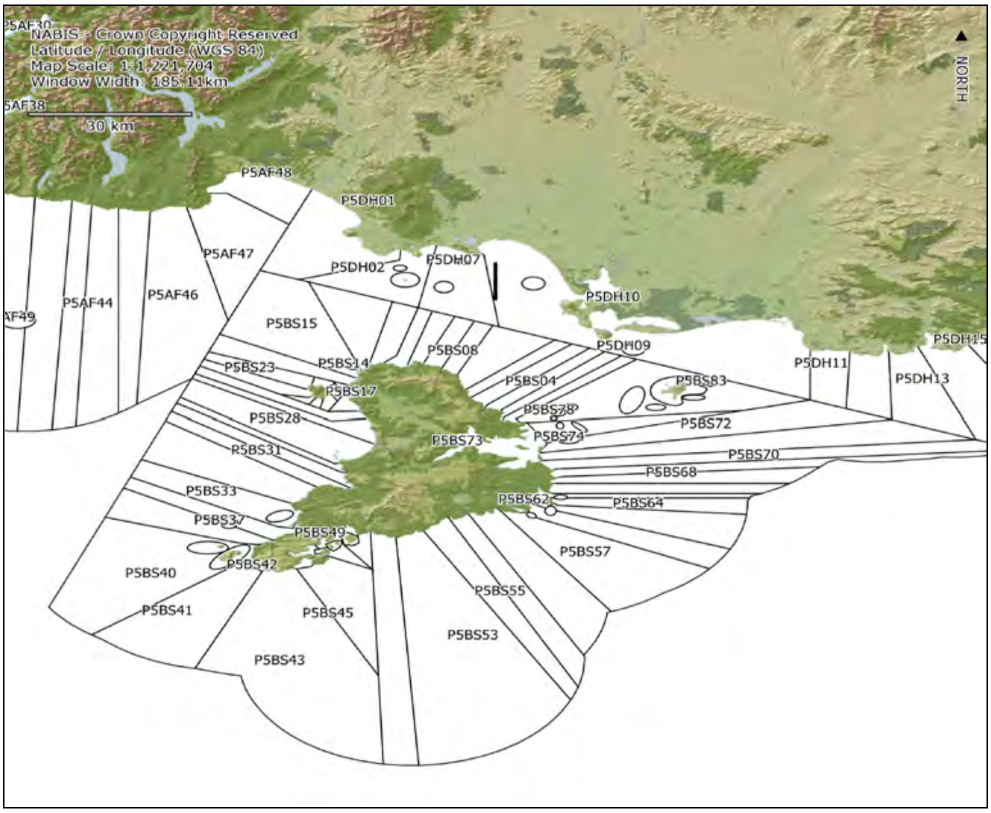


Figure 1: Map of fine scale statistical reporting areas for PAU 5B.

Landings for PAU 5B are shown in Table 2. Landings for PAU 5 are reported in the introductory PAU Working Group Report.

Table 2: TACC and reported commercial landings (t) of paua in PAU 5B, 1995-96 to 2010-11, from QMR and MHR returns.

Year	Landings	TACC
1995-96	144.66	148.98
1996-97	142.36	148.98
1997-98	145.34	148.98
1998-99	148.55	148.98
1999-00	118.07	143.98
2000-01	89.92	112.19
2001-02	89.96	112.19
2002-03	89.86	90.00
2003-04	90.00	90.00
2004-05	89.97	90.00
2005-06	90.47	90.00
2006-07	89.16	90.00
2007-08	90.21	90.00
2008-09	90.00	90.00
2009-10	90.23	90.00
2010-11	89.67	90.00

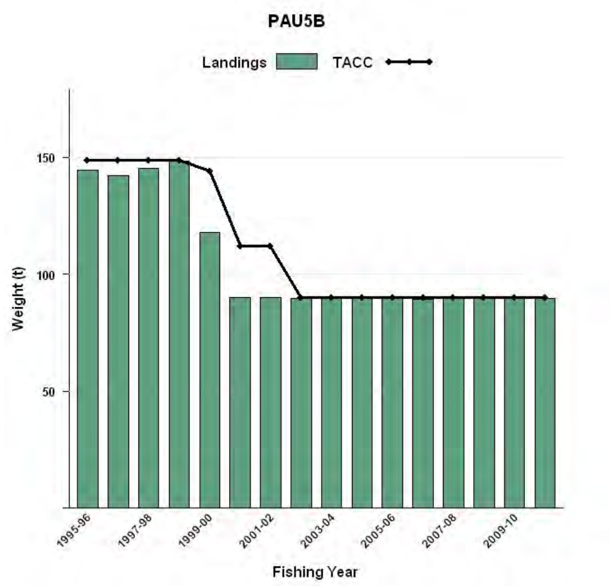


Figure 2: Historical landings and TACC for PAU5B from 1995-96 to 2010-11. For historical PAU5 landings prior to 1995-96 refer to the PAU introduction chapter, Figure 1 and Table 1.

1.2 Recreational fisheries

The Shellfish Fisheries Assessment Working Group (SFWG) agreed to assume for the 2007 assessment that recreational catch was 1 t in 1974, rising linearly to 5 t in 2006. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

1.3 Customary fisheries

The SFWG agreed to assume for the 2007 assessment that customary catch has been 1 t for the whole period modelled. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

Illegal catch was estimated by the Ministry of Fisheries to be 15 t, but “Compliance express extreme reservations about the accuracy of this figure.” The SFWG agreed to assume for the 2007 assessment that illegal catch was zero before 1986, then rose linearly from 5 t in 1986 to 15 t in 2006. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of biological parameters used in the PAU 5B assessment is presented in Table 3.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Standardised CPUE data from FSU, CELR and PCELR records (Table 4) shows a 65% decline between 1987 and 1996, but appears relatively stable in the past decade. The stock assessment assumes that commercial CPUE is proportional to abundance; however, this may not be the case for paua stocks because serial depletion tends to maintain catch rates despite a declining biomass. Apparent stability in CPUE must therefore be interpreted with caution.

Table 3: Estimates of biological parameters (*H. iris*).

Fishstock		**Estimate**	**Source**
1. Natural mortality (M)		0.10 (CV 0.10)	Assumed prior probability distribution
2. Weight = a(length)^b (Weight in g, length in mm shell length).			
		All	
	a	b	
	2.99×10^{-5}	3.303	Schiel & Breen (1991)
3. Size at maturity (shell length)			
		50% maturity at 91 mm	Naylor (NIWA unpub. data)
		95% maturity at 133mm	Naylor (NIWA unpub. data)
4. Growth parameters (both sexes combined)			
	Growth at 75 mm	Growth at 120 mm	Median (5-95% range) of posteriors estimated by the model
	26.1 mm (24.8 to 27.2)	6.9 mm (6.5-7.3)	

Table 4: Standardised catch per unit effort (CPUE) in PAU 5B (kg per diver-day) (Breen & Smith 2008.).The standardised CPUE for 1983-84 to 1994-95 includes data from statistical areas 025 and 030 assigned via the randomisation procedure described by Kendrick & Andrew (2000).

Year	**Standardised CPUE**
1982-83	372.2
1983-84	324.5
1984-85	362.2
1985-86	366.1
1986-87	267.6
1987-88	264.3
1988-89	238.8
1989-90	217.6
1990-91	200.7
1991-92	186.7
1992-93	171.4
1993-94	155.3
1994-95	145.1
1995-96	127.2
1996-97	152.0
1997-98	142.8
1998-99	136.3
1999-00	146.2
2000-01	115.6
2001-02	154.6
2002-03	157.0
2003-04	159.9
2004-05	174.9
2005-06	194.9

The relative abundance of paua in PAU 5B has also been estimated from a number of independent research diver surveys conducted in various years (Andrew *et al*. 2000a, 2000b, 2002; Breen & Smith 2008). Concerns about the reliability of this data as an estimate of relative abundance instigated several reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed i) the reliability of the research diver survey index as a proxy for abundance and ii) whether the RDSI, when used in the paua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. Both reviews suggest that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report.

4.2 Biomass Estimates

The 2007 assessment (Breen & Smith 2008) incorporated revision of the length-based model first used in 1999 for PAU 5B (Breen *et al*. 2000a), and used in revised form for subsequent assessments in many paua stocks (Breen *et al*. 2003, Breen & Kim 2005). For more detailed information on the 2007 stock assessment for PAU 5B refer to Breen & Smith (2008-5 and 2008-6). Markov chain Monte Carlo (MCMC) simulations were used to estimate the marginal posterior distribution of model parameters and reference points (indicators) agreed to by the SFWG.

The model, instead of age uses a number of length bins, with length classes from 70 to 170 mm, in groups of 2 mm. Sexes are not distinguished; the time step is one year for the main dynamics and there is no spatial structure within the area modelled.

Growth is modelled as a stochastic transition matrix calculated from the growth sub-model's estimated parameters, and the estimated relation between expected increment and its standard deviation, based on tagging data. A contribution to the total likelihood function comes from comparison of observed and expected increments in the tagging data.

Recruitment is modelled as a fixed mean with annual deviations, estimated as a vector of parameters. These have an assumed mean and standard deviation; this assumption makes the model Bayesian. No stock-recruit relation is estimated, but projections are made by re-sampling recent estimated recruitments. Commercial and research diver selectivity-at-size is modelled with two estimated parameters.
The relative weights applied to each dataset were adjusted iteratively to obtain standard deviations of normalised residuals equal to unity.

Exploitation rate was calculated from observed catch and model biomass. A point estimate of the mode of the joint posterior distribution (MPD) served as the starting point for the Bayesian estimations and as the basis for sensitivity tests. MCMC simulations were used to estimate the marginal posterior distributions of model parameters.

This model is driven by reported commercial catch estimates from 1974 through 2007 and was fitted to six datasets: two abundance indices - one from commercial catch and effort data (CPUE) and an index from independent research diver surveys (RDSI), two sets of proportion-at-length data - one from commercial catch sampling (CSLF) and one from research diver surveys (RDLF), a tag-recapture dataset and a maturity-at-length dataset.

As well as a base case model a number of sensitivity trails were run including: removing each of five data sets (maturity was not involved) in turn or in combination, using alternative catch series, removing CPUE before 1990, removing the 1994 RDSI datum, and changing the form of the likelihood. Retrospective analyses, in which years of data were sequentially removed and the model refitted, were also used to analyse the sensitivity of the model to data. The model fit the data reasonably well and the sensitivity trials demonstrated that the tag recapture data set was essential to obtaining a reasonable fit. The trails suggested no undue influence of any of the other data sets

Generation of a catch vector required assumptions to be made about the division of catch from statistical areas 25 and 30 to PAU 5B prior to 1995. This problem was described by Kendrick & Andrew (2000). For this purpose, the fishery was divided into three periods: pre-1984, 1984-1995, and post-1995. The 2007 assessment used the 2000 base case series:

1974-1983 52% of PAU 5 landings
1984-1995 75% of areas 25 and 30
1996-2001 As allocated to subdivided QMAs

A vector of standardised CPUE was generated using the raw catch rates as catch per diver-day and a multiple regression model (Vignaux 1993). Records from statistical areas 025 and 030 (see figure at the beginning of this report) were assigned from PAU 5 to PAU 5B using a randomisation procedure described by Kendrick & Andrew (2000). However, the 2007 working group accepted that while the randomisation procedure retains the correct catch totals it does not retain differences in catch rate, and should technically not be used to allocate records to CPUE datasets. To assess possible bias in the CPUE series resulting from use of the randomisation procedure, a standardisation was also done with pre-1997 records from areas 025 and 030 omitted. The base case standardisation model accounted for 36% of the total variation in observed CPUE and deviated little from the pattern of decline in raw CPUE through time (Figure 3). Omission of the area 025 and 030 records caused relatively little change in standardised CPUE (Figure 3 "subset") and the working group therefore did not consider it necessary to repeat the assessment with the subset CPUE series.

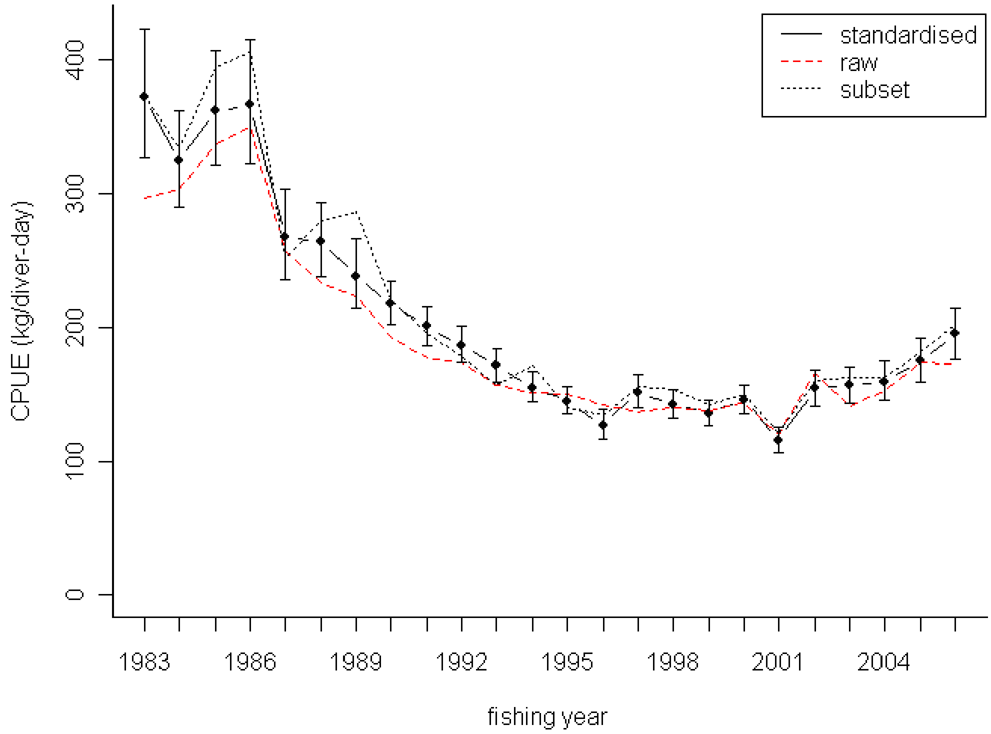


Figure 3: Standardised and raw CPUE index, with an additional line representing the standardised CPUE index recalculated with a data subset in which all records from areas 025 and 030, randomly allocated to PAU 5B by Kendrick & Andrew (2000), were removed.

The agreed reference points used for the 2007 assessment were the average spawning and recruited biomass, S_{AV} and B_{AV} respectively, from a reference period, 1985 to 1987, chosen because in those years spawning and recruited biomass had stabilised following 'fishing down' that began in the early 1970s (Figure 4). The assessment also used the current spawning and recruited biomass (S_{07} and B_{07}) and the minimum spawning and recruited biomass observed in the model's population trajectory: S_{MIN} and B_{MIN} (Figure 4). Projections were made for three years using resampled recruitment and the current catch estimates.

The assessment suggested that biomass estimates at the time of the assessment (S_{07} and B_{07}) were well above the minimum reference levels S_{MIN} and B_{MIN}. Projected biomass (S_{10} and B_{10}) appeared highly likely to remain above S_{MIN} and B_{MIN}: in the projections, biomass never fell below B_{MIN} or S_{MIN} (Table 5). Exploitation rate (U_{07}) was estimated at 9.3%

The 2007 assessment suggested that both spawning and recruited biomass were below the target levels S_{AV} and B_{AV}. Spawning biomass was estimated at 75% of S_{AV}, while recruited biomass was estimated as 87% of B_{AV} (Table 5).

Projections suggested that spawning biomass was likely (61% probability), to increase under levels of total catch at the time of the analysis (Figure 4, Table 5), but was likely to remain below S_{AV} for the next three years. In contrast, recruited biomass was likely to decrease, (54% probability), and remain below B_{AV} (90% probability). For recruited biomass, however, it could not be concluded strongly that current biomass was less than the B_{AV} reference level because the marginal posterior distribution of B_{07} overlapped B_{AV} and because B_{07} approached B_{AV} in sensitivity trials.

Table 5: Performance indicators derived from posterior distributions generated from the base case assessment. *B* is recruited biomass (paua greater than 125 mm shell length) in tonnes, *S* is spawning biomass (based on numbers-at-size and maturity-at-size) in tonnes and U is exploitation rate. S_{AV} and B_{AV} are the mean biomass estimates in tonnes for 1985-87. The lower part of the table shows the percentage of MCMC runs in which the indicated condition was true. The table shows 5th percentile, median and 95th percentile for the parameters indicated.

Parameter	0.05	Median	0.95
U_{07}	7.6%	9.3%	11.1%
U_{10}	7.5%	9.3%	11.4%
S_{MIN}	807	993	1 277
S_{AV}	1 688	1 982	2 409
S_{07}	1 224	1 487	1 853
S_{10}	1 196	1 528	1 954
B_{MIN}	495	622	818
B_{AV}	1 073	1 280	1 580
B_{07}	924	1 120	1 386
B_{10}	905	1 120	1 390
S_{07}/S_{MIN}	133.3%	149.3%	168.2%
S_{07}/S_{AV}	66.3%	75.1%	84.9%
S_{10}/S_{MIN}	126.5%	153.0%	184.2%
S_{10}/S_{AV}	63.3%	76.9%	92.3%
S_{10}/S_{07}	90.4%	102.1%	116.0%
B_{07}/B_{MIN}	159.6%	179.1%	203.2%
B_{07}/B_{AV}	76.8%	87.3%	99.7%
B_{10}/B_{MIN}	150.3%	178.3%	214.3%
B_{10}/B_{AV}	73.0%	87.1%	103.9%
B_{10}/B_{07}	91.7%	99.5%	108.4%
$S_{10}<S_{07}$		38.3%	
$S_{10}<S_{AV}$		98.9%	
$S_{10}<S_{MIN}$		0.0%	
$B_{10}<B_{07}$		53.5%	
$B_{10}<B_{AV}$		90.2%	
$B_{10}<B_{MIN}$		0.0%	

4.3 Estimation of Maximum Constant Yield (*MCY*)

No estimate of *MCY* has been made for PAU 5B.

4.4 Estimation of Current Annual Yield (*CAY*)

No estimate of *CAY* has been made for PAU 5B.

4.5 Other yield estimates and stock assessment results

No projections of stock status under alternatives to the current TACC and minimum legal size were done.

4.6 Other factors

Variation in results among the various sensitivity trials can be much higher than variability within an MCMC trial. The main sensitivities identified were the catch series, early CPUE data and data weighting issues, all of which affect the outcomes to some extent.

The commercial catch before 1974 is unknown, the proportion of PAU 5 catch taken from PAU 5B before 1995 is uncertain, and differences may exist between the commercial catches assumed in the stock assessment and what was taken. In addition, non-commercial catch estimates are poorly determined and could be substantially different from what were assumed by the SFWG, although non-commercial catches appear to be generally small compared with commercial catch. The illegal catch is particularly poorly estimated.

The tag-recapture data may not reflect fully the average growth and range of growth in PAU 5B. Length frequency data collected from the commercial catch may not represent the commercial catch with high precision.

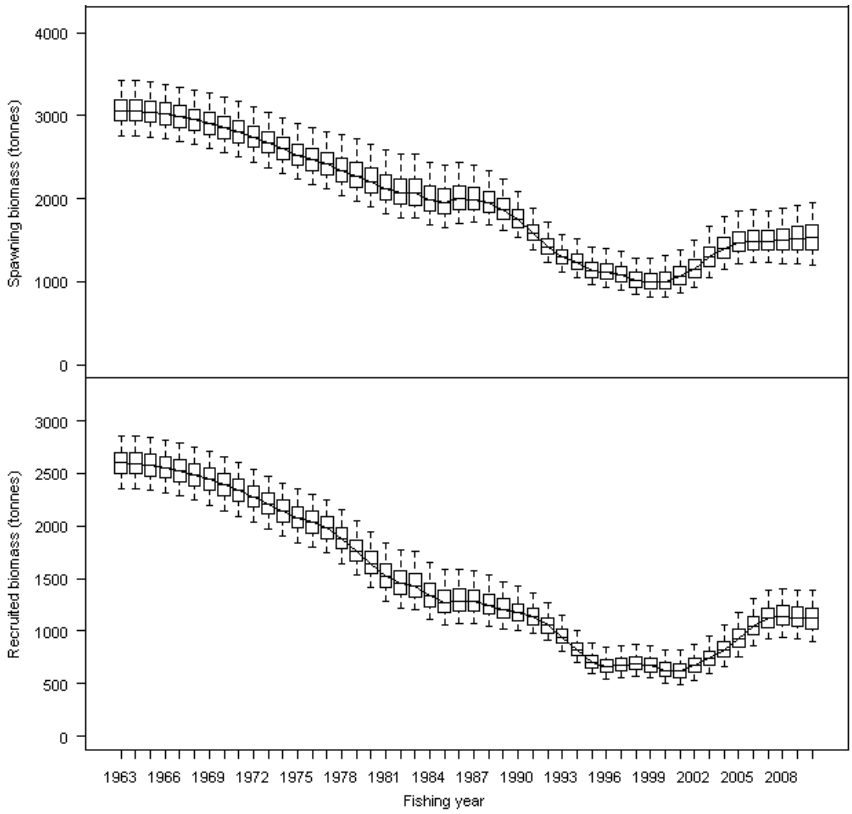


Figure 4: The posterior biomass trajectories for recruited (Upper) and spawning (Lower) biomass for the base case for PAU 5B. For each year, the figure shows the median of the posterior (solid line), the 25th and 75th percentiles (box) and 5th and 95th percentiles of the posterior (dashed vertical line).

The model treats the PAU 5B stocks as if it were a single stock with homogeneous biology, habitat and fishing pressures. The model assumes spatial homogeneity in recruitment, spatial and temporal homogeneity in natural mortality, and assumes that growth has the same mean and variance in all places and all years.

Heterogeneity in growth can be a problem for this kind of model (Punt 2003). Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on increments observed in several different places; similarly the length frequency data are integrated across samples from many places.

The effect is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, recruitment failure can result because of the depletion of spawners, because spawners must breed close to each other and because the dispersal of larvae is unknown and may be limited. Recruitment failure is a common observation in overseas abalone fisheries. So local processes may decrease recruitment, which is an effect that the current model cannot account for.

An assumption made by the model is that CPUE is an index of abundance. There is a large literature for abalone suggesting that CPUE is difficult to use in abalone stock assessments because of serial depletion, which happens when fishers deplete unfished or lightly fished beds and maintain their catch rates: CPUE stays high while the biomass is actually decreasing. Even when CPUE is not fitted by the model, the model does not address serial depletion.

Fishing may cause spatial contraction of populations (Shepherd & Partington 1995), or some populations may become relatively unproductive after initial fishing (Gorfine & Dixon 2000). If this happens, the model will overestimate productivity in the population as a whole. Past recruitments estimated by the model might instead have been the result of serial depletion.

5. STATUS OF THE STOCK

Stock Structure Assumptions

A genetic discontinuity between North Island and South Island paua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

- **PAU 5B - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2007
Assessment Runs Presented	Base case MCMC and MCMC sensitivity trial
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) The 2007 assessment did not estimate $B_{0.}$ The model did estimate where the 2007 biomass was relative to the reference points B_{AV} and S_{AV} (includes years 1985 to 1987).
Status in relation to Target	In 2007 stock status was Very Unlikely (< 10%) to be at or above the S_{AV} target; and was Very Unlikely (< 10%) to beat or above the B_{AV} target
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status

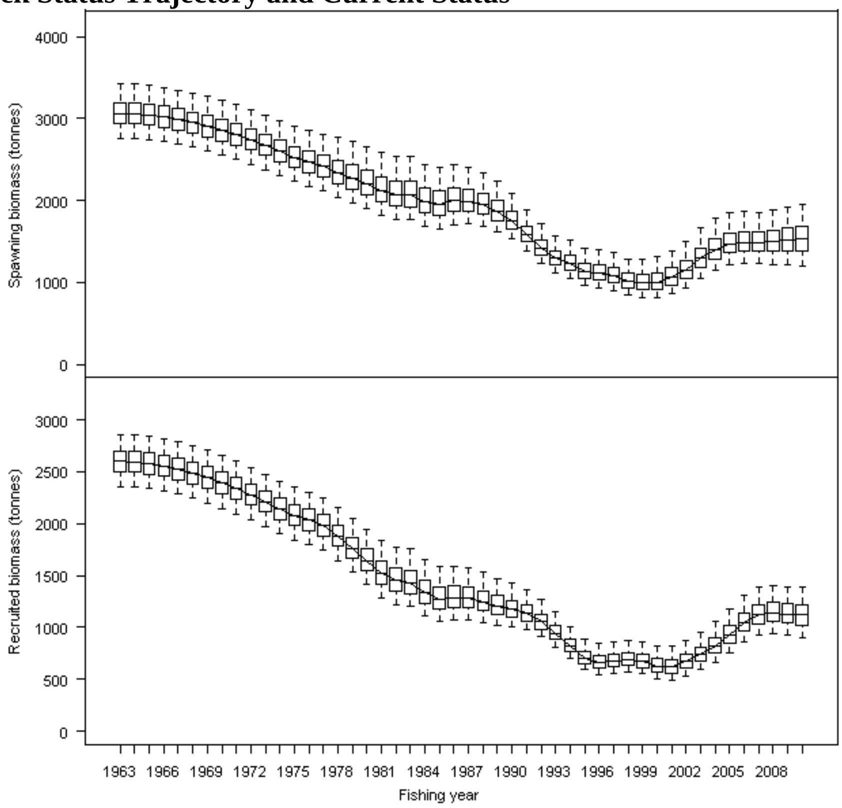


Figure 1: The posterior biomass trajectories for recruited (Upper) and spawning (Lower) biomass for the base case for PAU 5B. For each year, the figure shows the median of the posterior (solid line), the 25th and 75th percentiles (box) and 5th and 95th percentiles of the posterior (dashed vertical line).

Fishery and Stock Trends		
Recent Trend in Biomass or Proxy	Recruited biomass increased between 2001 to 2007 and spawning biomass increased from 2000 to 2005 and was stabile until 2007.	
Recent Trend in Fishing Mortality or Proxy	Unknown	
Other Abundance Indices	-	
Trends in Other Relevant Indicators or Variables	-	
Projections and Prognosis		
Stock Projections or Prognosis	Spawning stock biomass was likely to increase and recruited biomass was as likely as not to decrease relative to the target	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	Full quantitative stock assessment	
Assessment Method	Length based Bayesian model	
Main data inputs	CPUE, RSDI, CSLF, RDLF, tag recapture data, maturity at length data	
Period of Assessment	Latest assessment: 2007	Next assessment: unknown
Changes to Model Structure and Assumptions	N/A	
Major Sources of Uncertainty	Potential bias in RDSI CPUE as a reliable index of abundance Data are not completely accurate Model is homogeneous Model assumptions may be violated	

Qualifying Comments
-

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew N.L., Naylor J.R., Gerring P., Notman P.R. 2000a. Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and 5D. New Zealand Fisheries Assessment Report 2000/3. 21p.

Andrew N.L., Naylor J.R., Gerring P. 2000b. A modified timed-swim method for paua stock assessment. New Zealand Fisheries Assessment Report 2000/4. 23p.

Andrew N.L., Naylor J.R., Kim S.W., Doonan I.J. 2002. Fishery independent surveys of the relative abundance and size-structure of paua (*Haliotis iris*) in PAU 5B and PAU 5D. New Zealand Fisheries Assessment Report 2002/41. 25p.

Bradford E. 1998. Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27p.

Breen P.A., Andrew N.L., Kendrick T.H. 2000a. Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. New Zealand Fisheries Assessment Report 2000/33. 37p.

Breen P.A., Andrew N.L., Kendrick T.H. 2000b. The 2000 stock assessment of paua (*Haliotis iris*) in PAU 5B using an improved Bayesian length-based model. New Zealand Fisheries Assessment Report 2000/48. 36p.

Breen P.A, Andrew N.L., Kim S.W. 2001. The 2001 stock assessment of paua (*Haliotis iris*) in PAU 7. New Zealand Fisheries Assessment Report 2001/55. 53p.

Breen P.A., Kim S.W, Andrew N.L. 2003. A length-based Bayesian stock assessment model for abalone. Marine and Freshwater Research 54(5): 619-634.

Breen P.A., Kim S.W. 2005. The 2005 stock assessment of paua (*Haliotis iris*) in PAU 7. New Zealand Fisheries Assessment Report 2005/47. 114p.

Breen P.A., Smith A.N.H. 2008. The 2007 assessment for paua (*Haliotis iris)* stock PAU 5B (Stewart Island). New Zealand Fisheries Assessment Report 2008/05. 64p

Cordue P.L. 2009. Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45p

Gerring P.K. 2003. Incidental fishing mortality of paua (Haliotis iris) in the PAU 7 commercial fishery. New Zealand Fisheries Assessment Report 2003/56.

Gorfine H.K. and Dixon C.D. 2000. A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. Journal of Shellfish Research 19: 515-516.

Haist V. 2010. Paua research diver surveys: review of data collected and simulation study of survey method. New Zealand Fisheries Assessment Report. 2010/ 54p.

Kendrick T.H., Andrew N.L. 2000. Catch and effort statistics and a summary of standardised CPUE indices for paua (Haliotis iris) in PAU 5A, 5B, and 5D. New Zealand Fisheries Assessment Report 2000/47. 25p.

Punt A.E. 2003. The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. Fisheries Research 65: 391-409.

Schiel D.R., Breen P.A. 1991. Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris*. Fishery Bulletin 89: 681-691.

Shepherd S.A., Partington D. 1995. Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. Marine and Freshwater Research 46: 669-680.

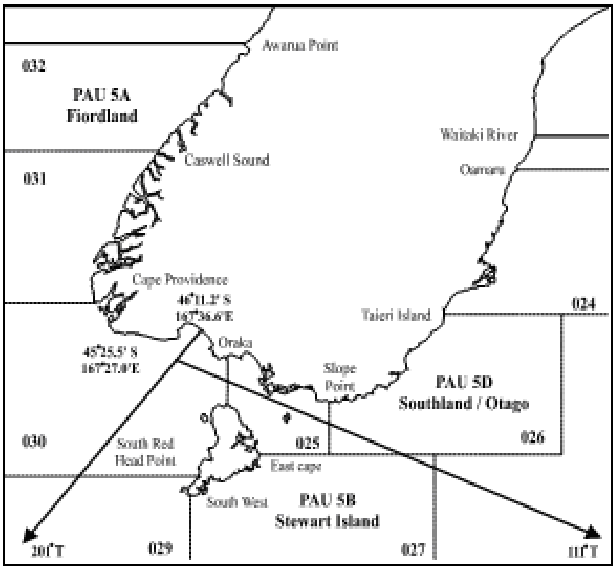
Teirney L.D., Kilner A.R., Millar R.E., Bradford E., Bell J.D. 1997. Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43p.

Vignaux M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987-92. New Zealand Fisheries Assessment Research Document 1993/14. 23p.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PAUA (PAU 5D) - Southland / Otago

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

Prior to 1995, PAU 5D was part of the PAU 5 QMA, which was introduced to the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t by the 1991-92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994-95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see figure above) and the TACC was divided equally among them; the PAU 5D quota was set at 148.98 t.

On 1 October 2002 a TAC of 159 t was set for PAU 5D, comprising a TACC of 114 t, customary and recreational allowances of 3 t and 22 t respectively and an allowance of 20 t for other mortality. The TAC and TACC have been changed since then but customary, recreational and other mortality allowances have remained unchanged (Table 1).

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5D since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986 - 1991*	-	-	-	-	445
1991 - 1994*	-	-	-	-	492
1994 - 1995*	-	-	-	-	442.8
1995 -2002	-	-	-	-	148.98
2002 - 2003	159	3	22	20	114
2003- present	134	6	6	-	89

*PAU 5 TACC figures

1.1 Commercial fishery

The fishing year runs from 1 October to 30 September. On 1 October 2001 it became mandatory to report catch and effort using fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program (Figure 1). These reporting areas were subsequently adopted on MFish PCELRs. On 1 October 2010 the commercial fishery voluntarily adopted two different minimum harvest sizes of 128 mm and 130 mm specific to statistical areas

H38-H43 and H1 to H37 respectively. The minimum legal size of 125 mm remains in statistical areas H44 to H47. The commercial fishery have also voluntarily closed 4 specific areas within PAU 5D to commercial harvesting.

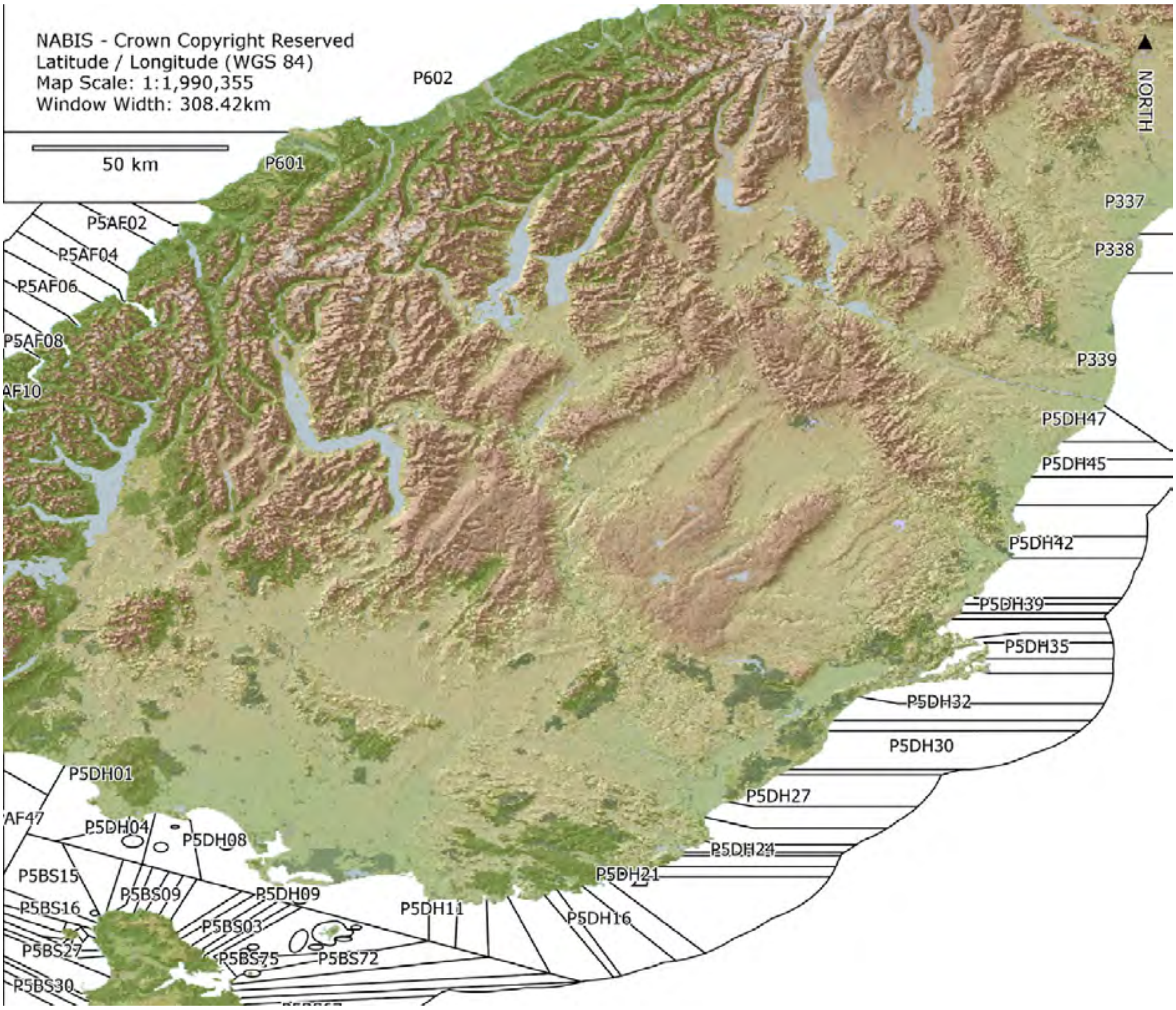


Figure 1: Map of fine scale statistical reporting areas for PAU 5D

Landings for PAU 5D are shown in Table 2. Landings for PAU 5 are reported in the introductory PAU Working Group Report.

Table 2: TACC and reported landings (t) of paua in PAU 5D from 1995-96 to 2010-11. Data were estimated from CELR and QMR returns.

Year	Landings	TACC
1995-96	167.42	148.98
1996-97	146.6	148.98
1997-98	146.99	148.98
1998-99	148.78	148.98
1999-00	147.66	148.98
2000-01	149.00	148.98
2001-02	148.74	148.98
2002-03	111.69	114.00
2003-04	88.02	89.00
2004-05	88.82	89.00
2005-06	88.93	89.00
2006-07	88.97	89.00
2007-08	88.98	89.00
2008-09	88.77	89.00
2009-10	89.45	89.00
2010-11	88.70	89.00

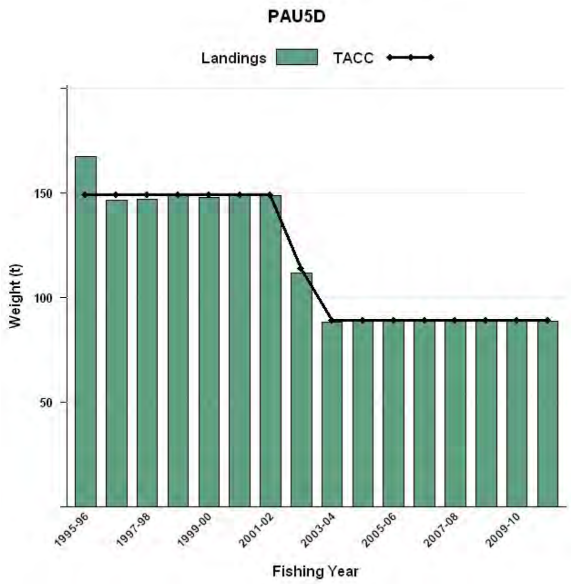


Figure 2: Historical landings and TACC for PAU5D from 1995-96 to 2010-11. For historical PAU5 landings prior to 1995-96 refer to the PAU introduction chapter, Figure 1 and Table 1.

1.2 Recreational fisheries
For the purpose of the stock assessment model, the SFWG agreed to assume that the 1974 recreational catch was 2 t increasing linearly 10 t by 2005. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

1.3 Customary fisheries
For the purpose of the stock assessment model, the SFWG agreed to assume that the customary catch has been constant at 2 t for PAU 5D. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch
Illegal catch was estimated by the Ministry of Fisheries to be 20 t. For the purpose of the stock assessment model, the SFWG agreed to assume that illegal catches have been constant at 10 t for PAU 5D. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality
For further information on other sources of mortality refer to the introductory PAU Working Group Report

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of biological parameters used in the PAU 5D assessment is presented in Table 3.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

Table 3: Estimates of biological parameters (*H. iris*).

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
		0.114 (0.095-0.140)	Median (5-95% range) of posterior estimated by the model (run 053)
2. Weight = a(length)^b (Weight in g, length in mm shell length)			
All	a	b	
	2.99×10^{-5}	3.303	Schiel & Breen (1991)
3. Size at maturity (shell length)			
		50% maturity at 80 mm (78-81)	Median (5-95% range) of posterior estimated by the model
		95% maturity at 93mm (89-98)	Median (5-95% range) of posterior estimated by the model
4. Estimated annual increments (both sexes combined)			
	at 75 mm	at 120 mm	Median (5-95% range) of posteriors estimated by the model
	19.6 (18.8-20.8)	8.2 (7.9-8.7)	

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

CPUE is available from two series of data: the CELR until 2001 and the subsequent PCELR series from 2002 onwards. The first series has coarse area and effort information: three statistical areas and diver effort by day; the second series has 47 small reporting areas and effort is recorded as diver hours, and the divers are also identified in the second series. The second series can be treated as a separate series by using an extra parameter for catchability. For the 2006 PAU 5D assessment, the SFWG agreed to standardise CPUE as a single series. The working group also suggested not using FSU data in future assessments, omitting the CPUE indices before 1989 in the stock assessment

Standardised CPUE was updated for the combined CELR and PCELR series (1990-2008), with the PCELR data collapsed to the CELR format (Fu 2010). A separate CPUE series were also developed using only the finer-scale PCELR data (2002-08).

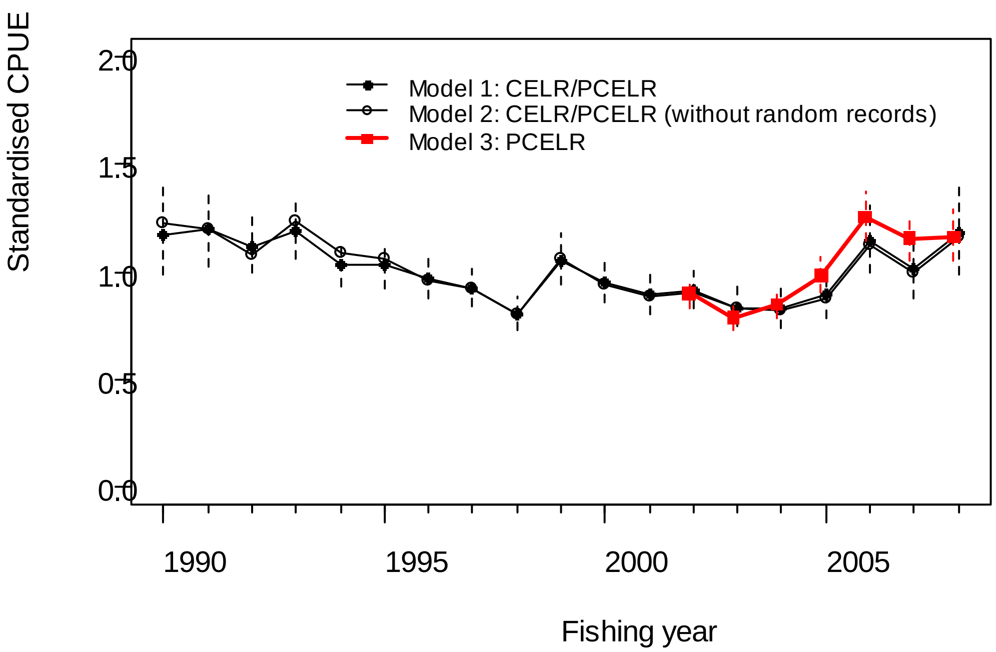


Figure 3: Standardised CPUE indices for PAU 5D: Model 1 and 2 are for the combined CELR and PCELR series (Model 2 has excluded CELR records which were randomly allocated to PAU 5F); Model 3 are for the fine-scale PCELR series. Vertical bars indicate the 95% confidence interval of the standardised indices for model 1 and 3.

CPUE in PAU 5D declined through the early 2000s (except for an increase in 1999), followed by a steady increase until 2006. Excluding records which were assigned to PAU 5D through a randomisation procedure made little difference to this CPUE series (Figure 3). The CPUE based on the fine-scale PCELR data also showed a generally increasing trend though 2006, and have remained relatively flat until 2008.

In some circumstances commercial CPUE may not be proportional to abundance because it is possible to maintain catch rates of paua despite a declining biomass. This occurs because paua tend to aggregate and divers move among areas to maximise their catch rates. Apparent stability in CPUE should therefore be interpreted with caution.

4.2 Biomass Estimates

The model used for the 2006 assessment of PAU 5D (Breen & Kim 2007) was the same model used for the 2005 assessment of PAU 7 (Breen & Kim 2005). The model was published by Breen *et al*. (2003). The PAU 5D assessment was considered inconclusive by the Shellfish Working Group. The Working Group considered the results to be equivocal. The Working Group noted that the results were equivocal and that the future direction of recruited biomass was uncertain because of the range of possible results that were dependent on modelling decisions. It was not known if the catch or the TACC levels would allow the stocks to move towards a size that would support the maximum sustainable yield.

4.3 Estimation of Maximum Constant Yield (*MCY*)

No estimate of *MCY* has been made for PAU 5D.

4.4 Estimation of Current Annual Yield (*CAY*)

No estimate of *CAY* has been made for PAU 5D.

4.5 Other yield estimates and stock assessment results

Only the current catch was used in projections.

4.6 Other factors

The assessment results had more uncertainty than that reflected in the posterior distributions. Most uncertainty was associated with the RDLF data set, and much uncertainty also stems from the choice of growth model.

Another source of uncertainty is the data. The commercial catch before 1974 is unknown and, although we think the effect is minor, major differences may exist between the catches we assume and what was actually taken. In addition, non-commercial catch estimates are poorly determined and could be substantially different from what was assumed, although generally non-commercial catches appear to be relatively small compared with commercial catch. The estimate of illegal catch in particular is uncertain.

Tag-recapture data may not reflect fully the average growth and range of growth in this population. Similarly, length frequency data collected from the commercial catch may not represent the commercial catch with high precision. The research diver survey data comprise five surveys, with large changes in the index that the model has trouble fitting. Length frequencies from these surveys are the source of much uncertainty in the model fitting.

In 2009 and 2010 several reviews were conducted by Cordue (2009) and Haist (2010) to asses: i) the reliability of the research diver survey index as a proxy for abundance and ii) if the RDS data, when used in the paua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. The outcome of both reviews suggests that outputs from paua stock assessments, that used the RDS data as input into the model, should be treated with caution. For a summary of the conclusions from the reviews refer to the PAU intro Working Group Report.

The model treats the whole of the assessed area of PAU 5D as if it were a single stock with homogeneous biology, habitat and fishing pressures. The model assumes homogeneity in recruitment and natural mortality, and that growth has the same mean and variance. However it is known that paua in some areas have stunted growth, and others are fast-growing.

Heterogeneity in growth can be a problem for this kind of model (Punt 2003). Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on increments observed in several different places; similarly the length frequency data are integrated across samples from many places.

The effect is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, recruitment failure can result because of the depletion of spawners, as because spawners must breed close to each other and the dispersal of larvae is unknown and may be limited. Recruitment failure is a common observation in overseas abalone fisheries, so local processes may decrease recruitment, an effect that the current model cannot account for.

The assumption made by the model that CPUE is an index of abundance is questionable. Literature on abalone suggests that CPUE is difficult to use in abalone stock assessments because of serial depletion. This can happen when fishers can deplete unfished or lightly fished beds and maintain their catch rates, thus CPUE stays high while the biomass is actually decreasing. In this assessment, the degree of hyperstability appeared reasonably well determined.

Another source of uncertainty is that fishing may cause spatial contraction of populations (Shepherd & Partington 1995), or that some populations become relatively unproductive after initial fishing (Gorfine & Dixon 2000). If this happens, the model will overestimate productivity in the population as a whole. Past recruitments estimated by the model might instead have been the result of serial depletion.

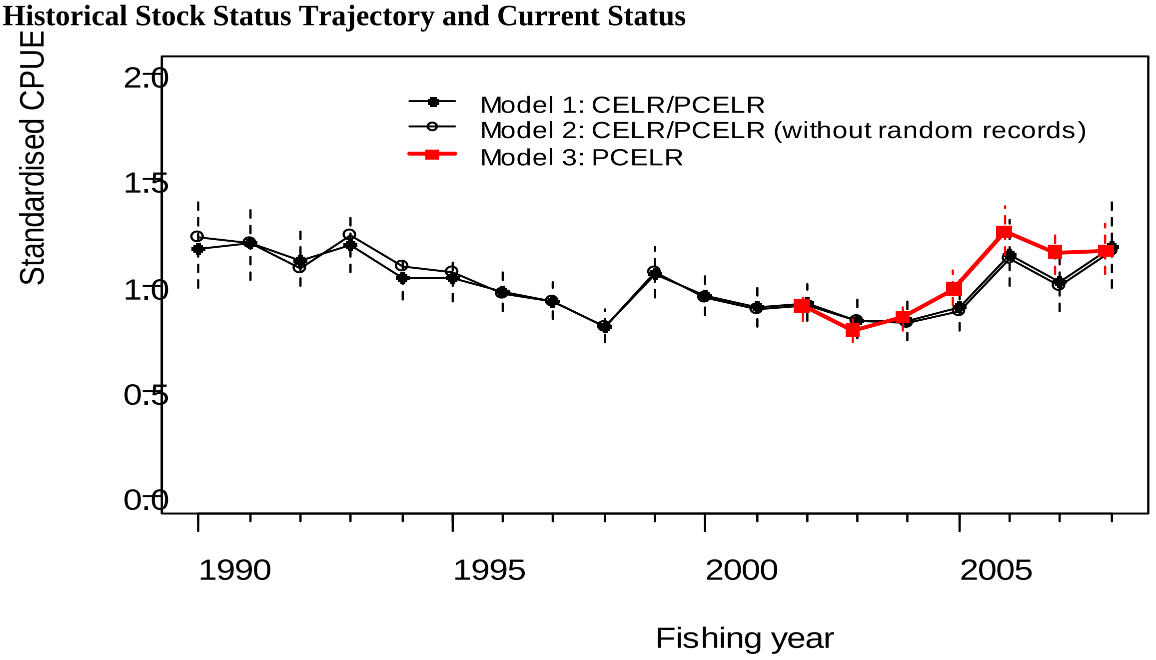
5. STATUS OF THE STOCK

Stock Structure Assumptions
A genetic discontinuity between North Island and South Island paua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

- **PAU 5D - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	The 2006 assessment has not been presented because it was considered inconclusive by the Shellfish Working Group.
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS)
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices for PAU 5D: Model 1 and 2 are for the combined CELR and PCELR series (Model 2 has excluded CELR records which were randomly allocated to PAU 5F); Model 3 are for the fine-scale PCELR series. Vertical bars indicate the 95% confidence interval of the standardised indices for model 1 and 3.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Mortality or Proxy	-
Other Abundance Indices	Standardised CPUE generally declined until the early 2000s, followed by a steady increase until 2006 and has remained relatively flat until 2008.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The Working Group at the time (2007) noted that the stock assessment results were equivocal and that the future direction of recruited biomass was uncertain because of the range of possible results that were dependent on modelling decisions.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Attempted Full quantitative stock assessment	
Assessment Method	Length base Bayesian model	
Main data inputs	CPUE, RSDI, CSLF, RDLF, tag recapture data, maturity at length data	
Period of Assessment	Latest assessment: 2009	Next assessment: 2013
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Potential bias in RDSI CPUE as a reliable index of abundance Data are not completely accurate Model is homogeneous	

	Model assumptions may be violated Assessment applies only to areas open to commercial fishing

Qualifying Comments
-

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew N.L., Naylor J.R., Gerring P., Notman PR. 2000a. Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and 5D. New Zealand Fisheries Assessment Report 2000/3. 21p.

Andrew N.L., Naylor J.R., Gerring P. 2000b. A modified timed-swim method for paua stock assessment. New Zealand Fisheries Assessment Report 2000/4. 23p.

Andrew N.L., Kim S.W., Naylor J.R., Gerring P., Notman P.R. 2002. Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and PAU 5D. New Zealand Fisheries Assessment Report 2002/3. 21p.

Breen P.A., Andrew N.L., Kendrick T.H. 2000a. Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. New Zealand Fisheries Assessment Report 2000/33. 37p.

Breen P.A., Andrew N.L., Kendrick T.H. 2000b. The 2000 stock assessment of paua (*Haliotis iris*) in PAU 5B using an improved Bayesian length-based model. New Zealand Fisheries Assessment Report 2000/48. 36p.

Breen P.A., Kim S.W. 2005. The 2005 stock assessment of paua (*Haliotis iris*) in PAU 7. New Zealand Fisheries Assessment Report 2005/47. 114p.

Breen P.A., Kim S.W. 2007. The 2006 stock assessment of paua (*Haliotis iris*) stocks PAU 5A (Fiordland) and PAU 5D (Otago). New Zealand Fisheries Assessment Report 2007/09. 164p.

Breen P.A., Kim S.W., Andrew NL. 2003. A length-based Bayesian stock assessment model for abalone. Marine and Freshwater Research 54(5): 619-634.

Cordue P.L. 2009. Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45p

Elvy D., Grindley R., Teirney L. 1997. Management Plan for Paua 5. Otago Southland Paua Management Working Group Report. 57pp. (Held by Ministry of Fisheries, Dunedin).

FU D. 2010. Summary of catch and effort data and standardised CPUE analyses for paua (*Haliotis iris*) in PAU 5A, PAU 5B and PAU 5D, 1989-90 to 2007-08. New Zealand Fisheries Assessment Report 2010 91p.

Gerring P.K. 2003. Incidental fishing mortality of paua (*Haliotis iris*) in PAU 7. New Zealand Fisheries Assessment Report 2003/56. 13p.

Gorfine H.K., Dixon C.D. 2000. A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. Journal of Shellfish Research 19: 515-516.

Haist V. 2010. Paua research diver surveys: review of data collected and simulation study of survey method. New Zealand Fisheries Assessment Report. 2010 54p.

Kendrick T.H., Andrew N.L. 2000. Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5A, 5B, and 5D. New Zealand Fisheries Assessment Report 2000/47. 25p.

McShane P.E., Naylor J.R. 1995. Small-scale spatial variation in growth, size at maturity, and yield- and egg-per-recruit relations in the New Zealand abalone (*Haliotis iris*). New Zealand Journal of Marine and Freshwater Research 29: 603-612.

Pirker J.G. 1992. Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165p.

Punt A.E. 2003. The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. Fisheries Research 65: 391-409.

Sainsbury K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. New Zealand Journal of Marine and Freshwater Research 16: 147-161.

Schiel D.R. 1989. Paua fishery assessment 1989. New Zealand Fishery Assessment Research Document 1989/9. 20p.

Schiel D.R. 1992. The paua (abalone) fishery of New Zealand. *In* Shepherd SA., Tegner MJ., Guzman del Proo S. [Ed}, Abalone of the World: Biology, fisheries, and culture. Blackwell Scientific, Oxford.

Schiel D.R., Breen P.A. 1991. Population structure, ageing and fishing mortality of the New Zealand abalone (*Haliotis iris*). Fishery Bulletin 89: 681-691.

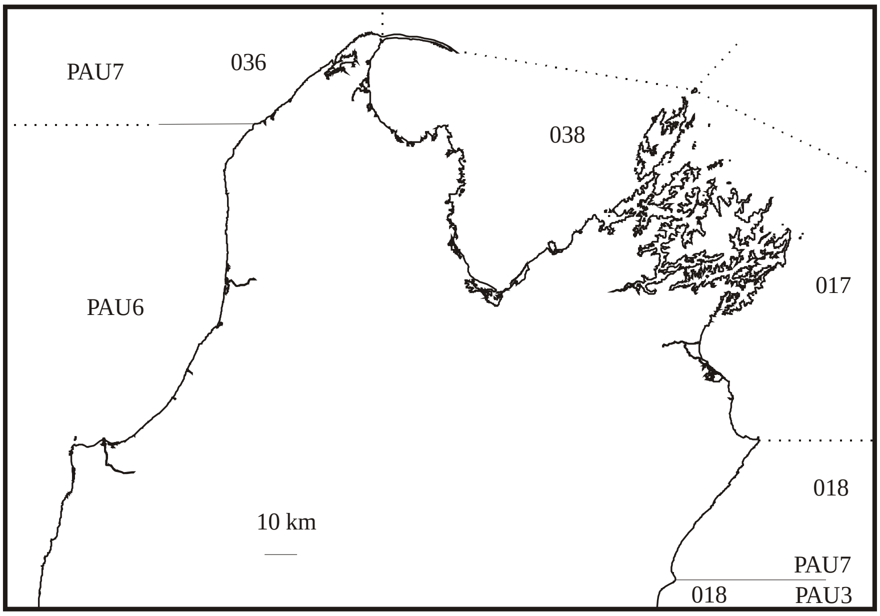
Shepherd S.A., Partington D. 1995. Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. Marine and Freshwater Research 46: 669-680.

Vignaux M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987-92. New Zealand Fisheries Assessment Research Document 1993/ 14. 23p.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PAUA (PAU 7) – Marlborough

(Haliotis iris)
Paua



1. FISHERY SUMMARY

PAU 7 was introduced into the Quota Management System in 1986–87 with a TACC of 250 t. As a result of appeals to the Quota Appeal Authority the TACC increased to 267.48 t by 1989. On 1st October 2001 a TAC of 273.73 t was set with a TACC of 240.73 t, customary and recreational allowances of 15 t each and an allowance of 3 t for other mortality. On 1 October 2002 the TAC was reduced to 220.24 t and the TACC was set at 187.24 t. No changes were made to the customary, recreational or other mortality allowances (Table 1).

Table 1. Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 7 since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986-89	-	-	-	-	250.00
1989-2001					267.48
2001-02	273.73	15	15	3	240.73
2002 - present	220.24	15	15	3	187.24

1.1 Commercial fisheries

The fishing year runs from 1 October to 30 September. In 2001-02 concerns about the status of the PAU 7 fishery led to a decision by the commercial sector to voluntarily shelve 20% of the TACC for that fishing year. In 2003–04 to 2006–07, the industry shelved 15% of the TACC each fishing year.

On 1 October 2001 it became mandatory to report catch and effort from fine-scale reporting areas developed by the New Zealand Paua Management Company for their voluntary logbook program (Figure 1). These reporting areas were subsequently adopted on MFish PCELRs. On 1 October 2010 the commercial fishery voluntarily adopted minimum harvest sizes ranging from 125-130 mm spread over a number of voluntary management sub areas within the QMA.

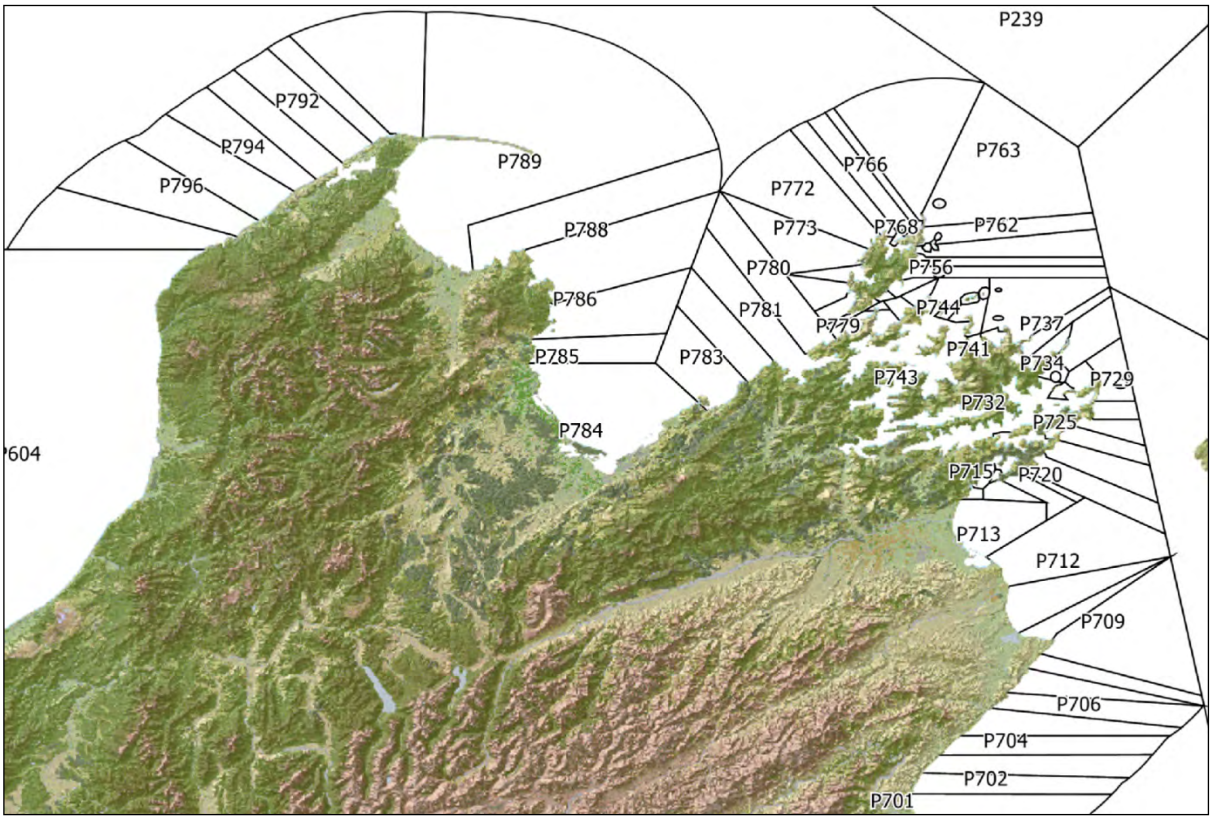


Figure 1: Map of fine scale statistical reporting areas for PAU 7.

Landings for PAU 7 are shown in Table 2.

Table 2: Reported Landings and TACC of paua in PAU 7 from 1983–84 to 2010–11. The last column shows the TACC after shelving has been accounted for.

Year	Landings (kg)	TACC (t)	After shelving	Year	Landings (kg)	TACC (t)	After shelving
1973-74	147 440	-	-	1993-94	255 472	266.17	266.17
1974-75	197 910	-	-	1994-95	247 108	266.17	266.17
1975-76	141 880	-	-	1995-96	268 742	267.48	267.48
1976-77	242 730	-	-	1996-97	267 594	267.48	267.48
1977-78	201 170	-	-	1997-98	266 655	267.48	267.48
1978-79	304 570	-	-	1998-99	265 050	267.48	267.48
1979-80	223 430	-	-	1999-00	264 642	267.48	267.48
1980-81	490 000	-	-	2000-01	215 920	267.48	*213.98
1981-82	370 000	-	-	2001-02	187 152	240.73	240.73
1982-83	400 000	-	-	2002-03	187 222	187.24	187.24
1983-84	330 000	-	-	2003-04	159 551	187.24	*159.15
1984-85	230 000	-	-	2004-05	166 940	187.24	*159.15
1985-86	236 090	-	-	2005-06	183 363	187.24	*159.15
1986-87	242 180	250	250	2006-07	176 052	187.24	*159.15
1987-88	255 944	250	250	2007-08	186 845	187.24	187.24
1988-89	246 029	250	250	2008-09	186 846	187.24	187.24
1989-90	267 052	263.53	263.53	2009-10	187 022	187.24	187.24
1990-91	273 253	266.24	266.24	2010-11	187 240	187.24	187.24
1991-92	268 309	266.17	266.17				
1992-93	264 802	266.17	266.17				

* Voluntary shelving

1.2 Recreational fisheries

For the purpose of the stock assessment, the Shellfish Fisheries Assessment Working Group (SFWG) agreed to assume that recreational catch was 5 t in 1974 and that it increased linearly to 15 t in 2000, and then remained at 15 t. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

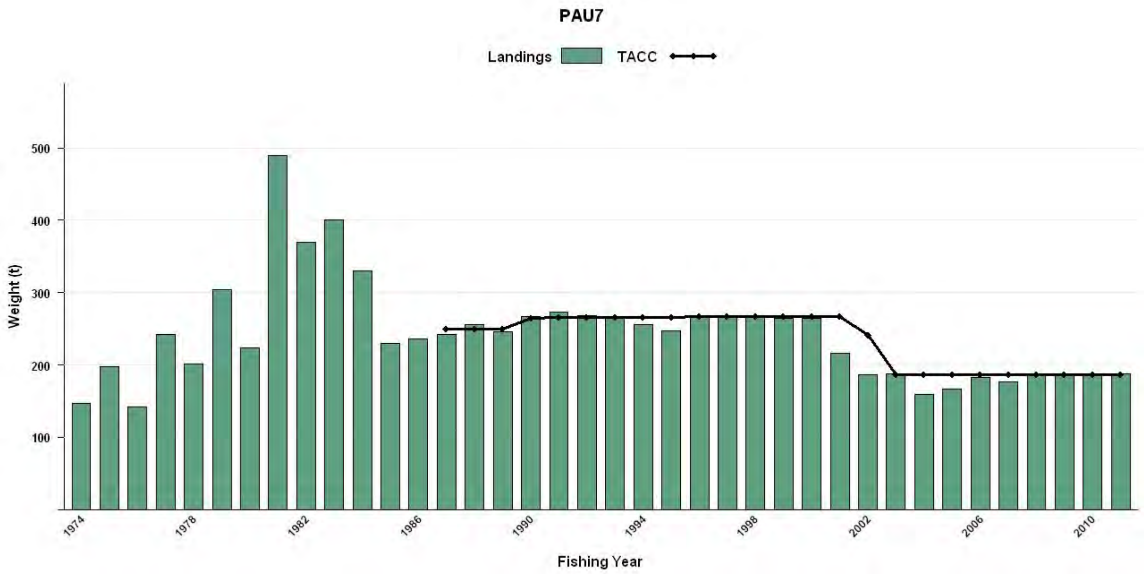


Figure 2: Historical landings and TACC for PAU7 from 1973-74 to 2010-11. QMS data from 1986-present.

1.3 Customary fisheries

For the purpose of the stock assessment the SFWG agreed to assume that customary catch was 4 t in 1974, increasing linearly to 10 t between 1974 and 2000, and then remained at 10 t. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

For the purpose of the stock assessment the SFWG agreed to assume that illegal catch was 1 t in 1974 and that it increased linearly to 15 t between 1974 and 2000, remaining at 15 t from 2000 through 2005, and then decreased linearly to 7.5 t in 2008. For projections the Working Group agreed to assume that illegal catch would remain at 7.5 t. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

Previous discussions by the SFWG have suggested that handling mortality may have been in the past between 15% and 40%. It is difficult to model past handling mortality without more information on selectivity and mortality rates of returned animals. The Working group agreed that handling mortality would not be factored into the model. For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of biological parameters used in the PAU 7 assessment is presented in Table 3.

3. STOCKS AND AREAS

PAU 7 is managed as a single stock. A genetic discontinuity between North Island and South Island paua populations has been found approximately around the area of Cook Strait (Will & Gemmell 2008). For further information on stocks and areas refer to the introductory PAU Working Group Report.

Table 3: Estimates of biological parameters (*H. iris*)

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
All		0.02–0.25	Sainsbury (1982)
PAU 7	0.14 (0.13–0.15)	Median (5%–95% C.L.)	estimated by the assessment model
2. Weight = a (length)^b (weight in g, shell length in mm)			
	a = 2.59E–08	b = 3.322	Schiel & Breen (1991)
3. Size at maturity (shell length)			
50% mature	90.7(89.9–91.5) mm	Median (5%–95% C.L.)	estimated by the assessment model
length at 95% mature - 50% mature	11.6(9.6–13.4) mm	Median (5%–95% C.L.)	estimated by the assessment model
4. Exponential growth parameters (both sexes combined)			
g_{75}	25.8(23.0–28.7) mm	Median (5%–95% C.L.)	estimated by the assessment model: growth increment of animal with initial length of 75 mm.
g_{120}	5.5 (5.1–5.8) mm	Median (5%–95% C.L.)	estimated by the model: growth increment of animal with initial length of 120 mm.

4. STOCK ASSESSMENT

The stock assessment is implemented as a length-based Bayesian estimation model, with point estimates of parameters based on the mode of the joint posterior distribution, and uncertainty of model estimates investigated using the marginal posterior distributions generated from Markov chain-Monte Carlo simulations. The 2011 assessment was restricted to Statistical Areas 017 and 038 which include most (over 90%) of recent catch**.**

4.1 Estimates of fishery parameters and abundance indices

Parameters estimated in the assessment model and their assumed Bayesian priors are summarized in Table 4.

Table 4: A summary of estimated model parameters, lower bound, upper bound, type of prior, (*U*, uniform; *N*, normal; *LN* = lognormal), mean and c.v. of the prior.

Parameter	Prior	μ	c.v.	Bounds	
				Lower	Upper
ln(*R0*)	*U*	–	–	5	50
M (Natural mortality)	*LN*	0.1	0.35	0.01	0.5
g_1*(Mean growth at 75 mm)*	*U*	–	–	1	50
g2(Mean growth at 75 mm)	*U*	–	–	0.01	50
φ *(cv of mean growth)*	*U*	–	–	0.001	1
$Ln(q^I)$ (catchability cofficient of CPUE)	*U*	–	–	-30	0
$Ln(q^J)$ (c*atchability cofficient of PCPUE)*	*U*	–	–	-30	0
$Ln(q^k)$ (catchability cofficient of RDSI)	*U*	–	–	-30	0
L_{50} (Length at 50% maturity)	*U*	–	–	70	145
$L_{95\text{-}50}$(Length beteen 50% and 95% maturity)	*U*	–	–	1	50
T_{50}(Length at 50% selectivty for the divery survey)	*U*	–	–	70	125
$T_{95\text{-}50}$(Length between 50% and 95% selectivty for the divery survey)	*U*	–	–	0.001	50
D_{50}(Length at 50% selectivty for the divery survey)	*U*	–	–	70	145
$D_{95\text{-}50}$(Length between 50% and 95% selectivty for the divery survey)	*U*	–	–	0.01	50
□ (Recruiment deviations)	*N*	0	0.4	-2.3	2.3
h (CPUE shape parameter)	*U*	–	–	0.01	2

The observational data were:

1. A standardised CPUE series covering 1983–2001 based on FSU/CELR data.
2. A standardised CPUE series covering 2002–2011 based on PCELR data.
3. A standardised research diver survey index (RDSI).
4. A research diver survey proportions-at-lengths series (RDLF).
5. A commercial catch sampling length frequency series (CSLF).

6. Tag-recapture length increment data.
7. Maturity at length data.

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2011 stock assessement used two sets of standardised CPUE indices: one based on FSU/CELR data covering 1983–2001, and another based on PCELR data covering 2002–2011. For both series, standardised catch per unit effort (CPUE) analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, and they were entered into the model in the order that gave the maximum decrease in the Akaike Information Criterion (AIC). Predictor variables were accepted into the model only if they explained at least 1% of the deviance.

The standardised index of FSU/CELR series from the 2005 assessment is re-presented here, as the SFWG agreed that it was not necessary to update this series. The unit of catch used was the total estimated daily catch for a vessel. As the diver-hours field on the CELR forms contains a high number of errors, the unit of effort used was the total number of diver days (total number of divers on a vessel for a day). Records were restricted to those from vessels that fished the top 75% of catch in any given year, and from areas 017 and 038. The standardised index is shown in the left panel of Figure 3.

PCELR data were extracted in October 2011 for the time frame 1 October 2001 to 31 September 2011.The Shellfish Working Group suggested that the Fisher Identification Number (FIN) be used in the standardisation instead of vessel. The reason for this is that the FIN is associated with a permit holder who may employ a suite of grouped vessels, which implies that there could be linkage in the catch rates among vessels operated under a single FIN. It was decided to use criteria which specified a minimum number of records (PCELRs and CELRs) per year for a minimum number of years for selecting FIN permit holders for the model. The selected criteria were at least 40 records per year for a minimum of four years. This reduced the number of FIN permit holders from 72 to 20, but retained 76% of the original catch over 2002–2011.

To ensure there were sufficient data to estimate fine scale statistical area and diver effects in the standardisation, only those fine scale statistical areas and divers with at least 10 diver days were retained. This dropped the number of fine scale statistical areas from 54 to 45, and the number of divers from 379 to 82 (51% of divers have just one dive-day).

The standardisation was done on the natural log of catch per diver day. Variables offered to the model were diver, diving condition, fishing duration FIN (Fisher identification number), fishing year, month and statistical area; no interactions were included in the model and fishing year was forced to be in the model as an explanatory variable. The standardised index is shown in the right panel of Figure 3.

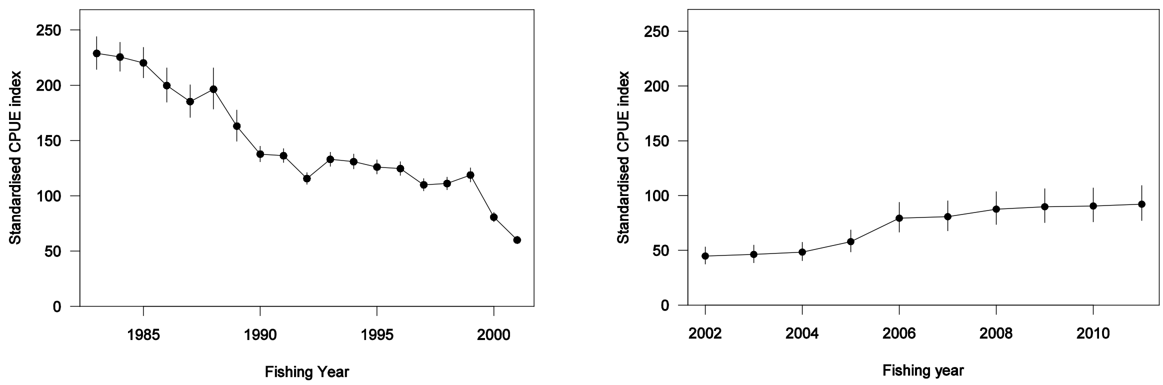


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR/FSU series (left) and the recent PCELR series (right).

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of paua in PAU 7 was also estimated from a number of independent research diver surveys (RDSI) undertaken in various years between 1992 and 2005. Concerns about the reliability of these data to estimate relative abundance instigated several reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed i) the reliability of the research diver survey index as a proxy for abundance and ii) whether the RDSI, when used in the paua stock assessment models, results in model outputs that adequately reflect the status of the stocks. Both reviews suggested that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report. Relative abundance estimates from research diver surveys are shown in Figure 4.

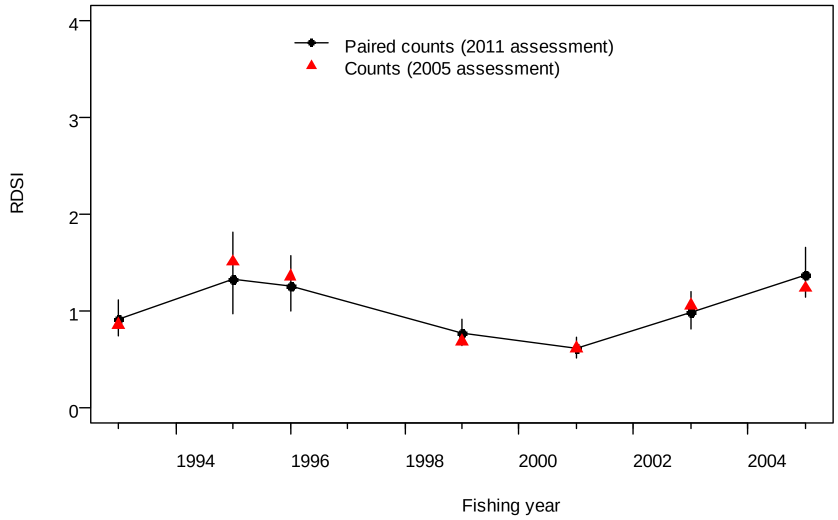


Figure 4: The standardised RDSI from the negative-binomial GLM models fitted to paired diver counts for surveys in Statistical Areas 017 and 038 within PAU 7.

4.2 Stock assessment methods

The 2012 PAU 7 stock assessment (Fu 2012, Fu *et al.* 2012) used the length-based model first used in 1999 for PAU 5B (Breen *et al.* 2000a) and revised for subsequent assessments in PAU 7 (Andrew *et al.* 2000, Breen & Kim 2003, Breen & Kim 2005 and Fu 2012). The model was described in Breen *et al.* (2003).

The model structure assumed a single sex population residing in a single homgeneous area, with length classes from 70 mm to 170 mm, in groups of 2 mm. Growth is length-based, without reference to age, mediated through a growth transition matrix that describes the probability of each length class to change at each time step.Paua entered the partition following recruitment and were removed by natural mortality and fishing mortality. The assessment addresses only Areas 017 and 038 within PAU 7. These areas supported most (more than 90%) of the catch until recently, and all of the available data originate from these two areas, but the relationship between this subset of PAU 7 and the remainder of PAU 7 is uncertain.

The model simulates the population dynamics from 1965 to 2011. Catches were available for 1974-2011, and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. The stock-recruitment relationship is unknown for paua, but is likely to be weak or equivocal (Shepherd *et al.* 2001). A relationship may exist on small scales, but not be apparent when large-scale data are modelled (Breen *et al.* 2003). No explicit stock-recruitment relationship was modelled in previous assessments;

however, the Shellfish Working Group agreed to use a Beverton-Holt stock-recruitment relationship with a steepness (*h*) of 0.75 for this assessment.

Maturity is not required in the population partition. The model estimated proportions mature with the inclusion of length-at-maturity data. Growth and natural mortalities were also estimated within the model.

The models used two selectivities: the commercial fishing selectivity and research diver survey selectivity, both assumed to follow a logistic curve and to reach an asymptote.

The assessment was conducted in several steps. First, the model was fitted to the data with arbitrary weights on the various data sets. The weights were then iteratively adjusted to produce balanced residuals among the datasets where the standardised deviation of the normalised residuals was close to one for each dataset. The fit obtained is the mode of the joint posterior distribution of parameters (MPD). Next, from the resulting fit, Markov chain-Monte Carlo (MCMC) simulations were made to obtain a large set of samples from the joint posterior distribution. From this set of samples, forward projections were made with a set of agreed indicators obtained. Sensitivity trials were explored by comparing MPD fits made with alternative model assumptions.

A base case model (1.0) was chosen by the Shellfish Working Group for the assessment: the tag-recapture data from all areas (except for D'Urville) were included, growth parameters were estimated within the model using an exponential growth curve, the weighting of the proportion-at-length data was determined using the TA1.8 method (Francis 2011), and maturity data from Northern faces were excluded. The base case model also assumed a steepness of 0.75 for the stock-recruitment relationship and estimated the CPUE shape parameter. The base case and sensitivities are summarised in Table 5.

The assessment reported:

- B_0 (the equilibrium spawning stock biomass assuming that recruitment is equal to the average recruitment from the period for which recruitment deviation were estimated)
- the mid-season spawning and recruited biomass for 2011 ($B_{current}$ and $B^r_{current}$), and for the projected period (B_{proj} and B^r_{proj}), and from a reference period, 1985–87. The latter was a period that had been previously chosen because the biomass was relatively stable. The means of values from the three years were called B_{ref} and B^r_{ref} for spawning and legal biomass respectively. Legal biomass is the biomass of paua above the legal size limit (currently 125 mm).
- % B_0 Ratio of current and projected spawning biomass to B_0
- % B_{ref} Ratio of current and projected spawning biomass to B_{ref}
- Pr(>B_{ref}) Probabilities that current and projected spawning biomass greater than B_{ref}
- Pr(>$B_{current}$) Probabilities that projected spawning biomass greater than $B_{current}$
- Pr(<20% B_0) Probabilities that projected spawning biomass is less than 20% B_0
- Pr(<10% B_0) Probabilities that projected spawning biomass is less than 10% B_0
- %B^r_0 Ratio of current and projected legal biomass to B^r_0
- %B^r_{ref} Ratio of current and projected legal biomass to B^r_{ref}
- Pr(>B^r_{ref}) Probabilities that current and projected legal biomass greater than B^r_{ref}
- Pr(>$B^r_{current}$) Probabilities that projected legal biomass greater than $B^r_{current}$

Recruitments for projections were obtained by randomly re-sampling model estimates from 1996 until 2006. Projections were run at four different levels of catch: the current TACC, and reductions of 10%, 15% and 20%.

4.2.1 Stock assessment results

Current estimates from the base case suggested that spawning stock population in 2011 ($B_{current}$) was about 22% (19–26%) of the unfished level (B_0), and vulnerable ($B^r_{current}$) was about 10% (8–12%) of the initial state (B^r_0) (Figure 5, Table 6). Model projections made for three years, assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock abundance will slightly increase to about 23.4% (17–32%) B_0 over the next three years (Table 7). Projections made with alternative catch levels showed that the spawning stock abundance will increase to about 24.4%, 25.0%, and 25.5% B_0 respectively, if the current TACC was to be reduced by 10%, 15% and 20% (Table 7).

Table 5: Summary descriptions for base case and sensitivity model runs

Model runs	Descriptions
0.0 (Initial model)	Iterative reweighting, assumed h of 0.75 and U^{max} of 0.8, estimated h
1.0 (Base case)	TA1.8 weighting method, assumed h of 0.75 and U^{max} of 0.8, estimated h
1.1	1.0, but fixed CPUE shape parameter (*??*) at 1
1.2	1.0, but assuming steepness (h) of 1
1.3	1.0, but assuming steepness (h) of 0.5
1.4	1.0, but assuming maximum exploitation rate (U^{max}) of 0.9
1.5	1.0, but assuming maximum exploitation rate (U^{max}) of 0.65
2.0	1.0, fixed growth parameters at low values
3.0	1.0, fixed growth parameters at high values

The base case model appeared to have represented most observational data well, and there is no obvious indication of lack of fit. The CPUE shape parameter was estimated to be less than 1, suggesting possible hyper-stability in the relationship between CPUE and abundance. However, model results changed very little when a linear relationship between CPUE and abundance was assumed.

Model sensititivity runs which assumed different values for the stock-recruitment steepness (h) parameter appeared to compensate for the differences in the stock-recruitment relationship with changes in R_0, recruitment deviations, and natural mortality. Estimates of current stock status were similar between these model runs, although there were some differences in the size of the estimated B_0.

Table 6: Summary of the marginal posterior distributions from the MCMC chain from the base case (1.0). The columns show the 5th and 95th percentiles, and the medians. Biomass is in tonnes.

	5%	Median	95%	MPD estimate
B_0	3905	4242	4541	4156
B_{ref}	1299	1426	1561	1359
$B_{current}$	790	933	1115	877
$B_{current}/B_0$	0.19	0.22	0.26	0.21
$B_{current}/B_{ref}$	0.56	0.66	0.78	0.65
B_0^r	3063	3417	3719	3368
B_{ref}^r	669	816	971	777
$B_{current}^r$	261	334	428	313
$B_{current}^r/B_0^r$	0.08	0.10	0.12	0.09
$B_{current}^r/B_{ref}^r$	0.32	0.41	0.54	0.40
$U_{current}$	0.33	0.41	0.49	0.43

The base case assumed a maximum exploitation rate (U_{max}) of 0.8 and there were two years (2001 and 2003) in which the exploitation rate was estimated to be at the bound. When U_{max} was assumed to be 0.65, the estimated exploitation rates for 2001 and 2003 were also at the bound; when U_{max} was assumed to be 0.9, the estimated exploitation rate for 2003 was at the bound. However, biomass estimates were similar among all these runs.

The base case assessment estimated growth parameters within the model using the tag-recapture data. The fits to the tag-recapture data appear adequate, but are likely to have been influenced by the proportion-at-length data as well. Sensitivity runs, which assumed alternative growth parameters (fixed at values representing either a fast or slow growth rate), led to significant changes to the estimates of abundance, but had poor fits to the proportion-at-length data.

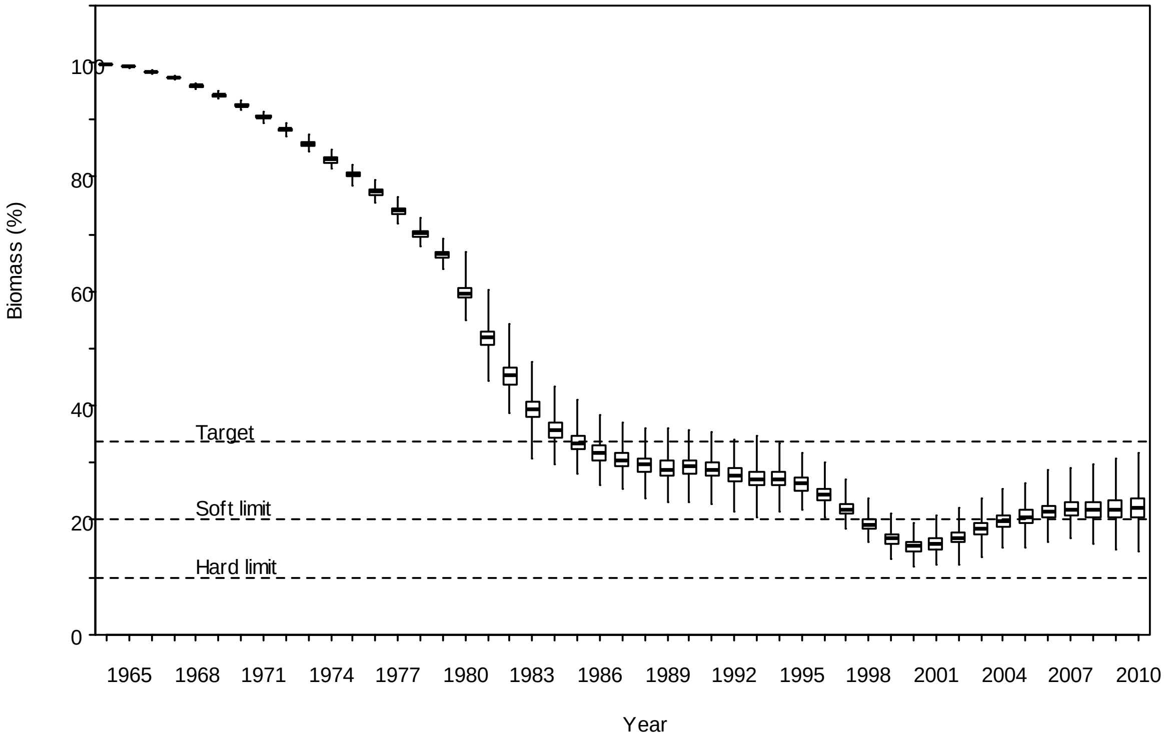


Figure 5: Posterior distributions of spawning stock biomass as a percentage of virgin level from MCMC 1.0. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The target is the median reference biomass (33.6% B_0).

The base case estimated growth parameters within the model incorporating the tag-recapture data. The fits to the tag-recapture data appear adequate, but are likely to have been influenced by the proportion-at-length data. Sensitivity runs assuming alternative growth parameters (fixed at values representing either a fast or slow growth rate) led to significant changes to the estimates of abundance, but had poor fits to the proportion-at-length data.

4.5 Estimation of Maximum Constant Yield (*MCY*)
No estimate of *MCY* has been made for PAU 7.

4.6 Estimation of Current Annual Yield (*CAY*)
No estimate of *CAY* has been made for PAU 7.

4.7 Other factors
The stock assessmen tmodel assumed homogeneity in recruitment, that natural mortality does not vary by size or year, and that growth has the same mean and variance throughout the entire area. However, it is known that paua fisheries are spatially variable and that apparent growth and maturity in paua populations can vary over very short distances. Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on tagging data collected from a range of different locations. Similarly, the length frequency data are integrated across samples from many places. The effect of this integraion across local areas is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, local recruitment failure can result due to the limited dispersal range of this species. Recruitment failure is a common observation in overseas abalone fisheries. Fishing may also cause spatial contraction of populations (e.g., Shepherd & Partington 1995), and some populations appear to become relatively unproductive after initial fishing

(Gorfine & Dixon 2000). If this happens, the assessment will overestimate productivity in the population as a whole. It is also possible that good recruitments estimated by the model might have been the result of serial depletion.

Table 7: Projections to 2014 of the key indicators (from the base case MCMC) with future commercial catch set to 100%, 90%, 85%, and 80% of the TACC. Key indicators are spawning stock biomass (*B*) and recruited biomass (*rB*) and include % of virgin biomass and % biomass from a reference period (B_{ref}) and the probability of being above current biomass or below default limits

Projection	2011	2014 Current TACC	2014 90% TACC	2014 85% TACC	2014 80% TACC
$\%B_0$	22.1 (18.0-27.2)	23.4 (16.5-31.5)	24.4 (17.5-32.6)	25.0(18.0-33.1)	25.5 (18.5-33.6)
$\%B_{ref}$	65.5 (53.7-80.5)	69.3 (49.4-942)	72.4 (52.5-97.4)	74.0(54.1-99.0)	75.6 (55.7-100.6)
$Pr(> B_{ref})$	0.000	0.008	0.015	0.021	0.029
$Pr(>B_{current})$		0.671	0.796	0.854	0.897
$Pr(<20\%B_0)$	0.173	0.176	0.112	0.086	0.063
$Pr(<10\%B_0)$	0.000	0.000	0.000	0	0
$\%rB_0$	9.8 (0.073-0.130)	10.5 (6.2-15.9)	11.7 (7.4-17.1)	12.3(8.0-17.7)	12.9 (8.6-18.4)
$\%rB_{ref}$	41.2 (30.0-56.6)	43.9 (26.3-67.6)	49.0 (30.9-73.2)	51.6(33.3-76.1)	54.2 (35.6-79.0)
$Pr(> rB_{ref})$	0.000	0.000	0.000	0.000	0.000
$Pr(>rB_{current})$		0.679	0.926	0.975	0.995

CPUE provides information in the model on changes in relative abundance. However, CPUE is generally considered to be a poor index of stock abundance for paua, due to divers' ability to maintain catch rates by moving from area to area despite a decreasing biomass (hyperstability). Breen *et al.* (2003) argued that standardised CPUE might monitor changes of abundance in a fully exploited fishery, and that declines in the CPUE most likely reflected a decline in the population. PAU 7 is generally considered to be a fully developed fishery: the exploitation rate in Statistical Areas 017 and 038 is known to have been high and there are unlikely to be many unfished areas within the area.

Commercial catch length frequencies provide information on changes in population structure under fishing pressure. However, if serial depletion has occurred and fishers have moved from area to area, samples from the commercial catch may not correctly represent the population of the entire stock. For PAU 7, there has been a long time-series of commercial catch sampling and the spatial coverage of the available samples is generally considered to be adequate throughout the years.

The utility of research diver survey indices to provide relative abundance information has been an ongoing concern in the SFWG. Cordue (2009) identified issues associated with diver surveys based on the timed swim approach and questioned their adequacy as indices of relative abundance. Haist (2010) suggested that the existing RDSI data were likely to be more useful at a stratum level. The general consensus is that the index-abundance relationship from the research diver survey is likely to be nonlinear, and cannot easily be quantified in a stock assessment.

5. STATUS OF THE STOCKS

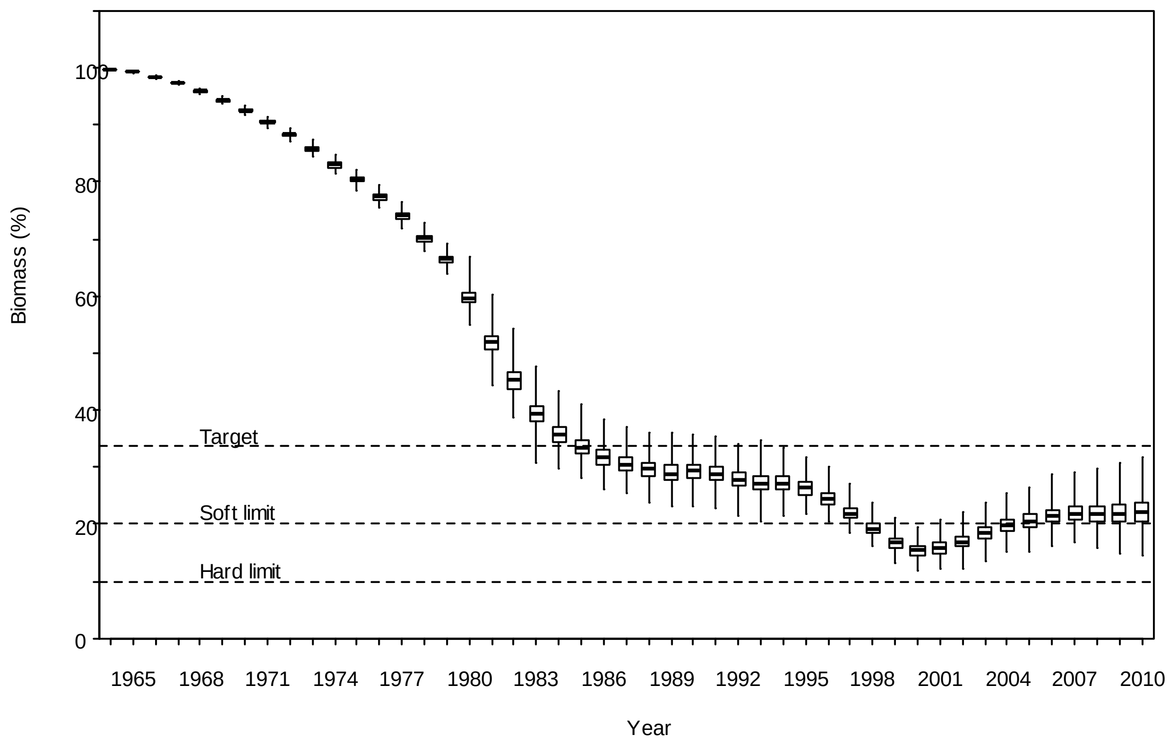
Stock Structure Assumptions

The 2012 assessment was conducted for Statistical Areas 017 and 038 only, but these include most (more than 90%) of the recent catch.

- **PAU 7-** *Haliotis iris*

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Base case MCMC
Reference Points	Interim Target: B_{ref} (average spawning biomass from 1985-1987) = 33.6% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Spawning stock biomass was estimated to be 66% B_{ref} and is Very Unlikely (<10%) to be at or above the interim target
Status in relation to Limits	Spawning stock biomass was estimated to be 22% B_0, and is About as Likely as Not (40-60%) to be below the soft limit and Unlikely (<40%) to be below the hard limit

Historical Stock Status Trajectory and Current Status



Posterior distributions of spawning stock biomass as a percentage of virgin level from MCMC 1.0. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The target is the median reference biomass (33.6% B_0).

Projections and Prognosis	
Stock Projections or Prognosis	Three year projections indicate that spawning and recruited biomass are likely to increase but are Very Unlikely (<10%) to be at or above the target by this time.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: About as Likely as Not (40-60%) Hard Limit: Unlikely (<40%)

Assessment Methodology & Evaluation	
Assessment Type	Full quantitative stock assessment

Assessment Method	Soft Limit: About as Likely as Not (40-60%) Hard Limit: Unlikely (< 40%)	
Assessment Dates	Latest: 2012	Next: 2015
Overall assessment quality rank	Data weighting (LF only) and steepness	
Main data inputs (rank)	- CPUE - Research diver survey indices - Commercial catch length frequency - Research diver length frequency - Tag-recapture data - Maturity at length data	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Data weighting (LF only) and steepness	
Major Sources of Uncertainty	Spatial heterogeneity not incorporated Potential hyperstability in CPUE Potential for localised recruitment failure	

Qualifying Comments
No account has been taken of the voluntary closure of areas affected by “greening”. Stock projections also do not account for reduced production due to potential closed areas in the future, which are likely to slow or reverse projected increases in stock size.

Fishery Interactions
N/A

6. FOR FURTHER INFORMATION

Andrew N.L., Breen P.A., Kendrick T.H., Naylor J.R. 2000. Stock assessment of PAU 7 for 1998–99. New Zealand Fisheries Assessment Report 2000/48. 22 p.

Andrew N.L., Naylor J.R., Gerring P. 1999. A modified timed–swim method for paua stock assessment. New Zealand Fisheries Assessment. Report 2000/4. 23 p.

Breen P.A., Kim S.W. 2003. The 2003 stock assessment of paua (*Haliotis iris*) in PAU 7. New Zealand Fishery Assessment Report. 2003/41. 119 p.

Breen P.A., Kim S.W., Andrew NL. 2003. A length-based Bayesian stock assessment model for abalone. Marine and Freshwater Research 54(5): 619-634.

Breen P.A., Kim SW. 2005. The stock assessment of paua (*Haliotis* iris) in PAU 7. New Zealand Fisheries Assessment Report. 2005/47. 114p.

Cordue P.L. 2009. Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45p

Chen Y., Breen P.A., Andrew N.L. 2000. Impacts of outliers and mis–specification of priors on Bayesian fish stock assessment. Canadian Journal of Fisheries and Aquatic Science. 57: 2293–2305.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 15.

Fu D. 2012. The 2011 stock assessment of paua (*Haliotis iris*) for PAU 7. *New Zealand Fisheries Assessment Report* (in Press). 57p.

Fu D., McKenzie A., Naylor R. 2012. Summary of input data for the PAU 7 stock assessment for the 2010–11 (in press).

Gerring P., Andrew N.L., Naylor J.R. 2003. Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. New Zealand Fisheries Assessment Report. 2003/56: 13 p.

Gorfine H.K., Dixon C.D. 2000. A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. Journal of Shellfish Research 19: 515–516.

Haist V. 2010. Paua research diver surveys: review of data collected and simulation study of survey method. New Zealand Fisheries Assessment Report. 2010/ 54p.

McKenzie A. 2004. Alternative CPUE standardization for PAU 7. NIWA Client Report WLG2004-74. 18pp.

McKenzie A. 2010. CPUE standarisationfor PAU 7 in 2010. NIWA Client Report, WLG2010-29. 12pp.

McKenzie A., Smith A.N.H. 2009. Data inputs for the PAU 7 stock assessment in 2008. New Zealand Fisheries Assessment Report. 2009/33. 34pp.

McKenzie A. Smith. A.N.H. 2009. The 2008 stock assessment of paua (*Haliotis* iris) in PAU 7. New Zealand Fisheries Assessment Report. 2009/34. 86p.

McShane P.E., Naylor J.R. 1995. Small–scale spatial variation in growth, size at maturity, and yield– and egg–per–recruit relations in the New Zealand abalone *Haliotis iris*. .New Zealand Journal of Marine and Freshwater Research 29: 603–612.

Pirker J.G. 1992. Growth, shell–ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Punt A.E. 2003. The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. Fisheries Research 65: 391–409.

Sainsbury K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris.* 1. Population structure, growth, reproduction and mortality. New Zealand Journal of Marine and Freshwater Research 16: 147–161.

Schiel D.R. 1989. Paua fishery assessment 1989. New Zealand Fishery Assessment Research Document 1989/9: 20 p.

Schiel D.R. 1992. The paua (abalone) fishery of New Zealand. *In* Shepherd, S.A., Tegner, M.J., Guzman del Proo, S. (eds.), Abalone of the World: Biology, fisheries, and culture. Blackwell Scientific, Oxford.

Schiel D.R., Breen P.A.1991. Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris*. Fishery Bulletin 89: 681–691.

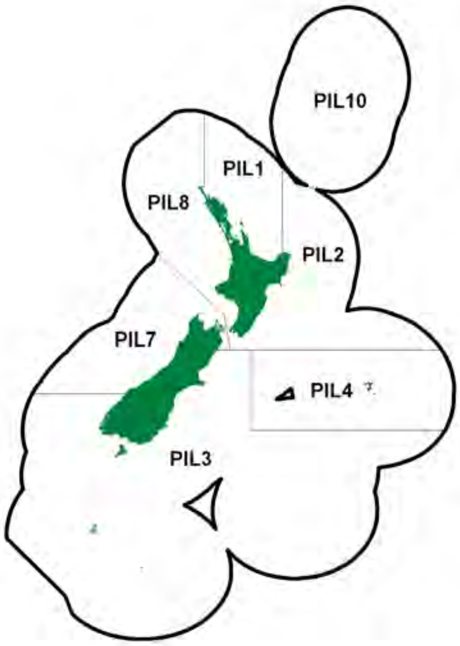
Shepherd S.A., Partington D. 1995. Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. Marine and Freshwater Research 46: 669–680.

Vignaux M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987–92. New Zealand Fisheries Assessment Research Document 1993/14. 23 pp.

Will M.C., Gemmell N.J. 2008. Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37p

PILCHARD (PIL)

(*Sardinops sagax*)
Mohimohi



1. FISHERY SUMMARY

Pilchards were introduced into the QMS in October 2002 with allowances, TACCs and TACs as shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs by Fishstock.

Fishstock	Recreational Allowance	Customary Non-commercial Allowance	TACC	TAC
PIL 1	20	10	2 000	2 030
PIL 2	10	5	200	215
PIL 3	5	2	60	67
PIL 4	3	2	10	15
PIL 7	10	5	150	165
PIL 8	10	5	65	80
PIL 10	0	0	0	0

1.1 Commercial fisheries

Pilchards occur around most of New Zealand, however, commercial fisheries have only developed in north-eastern waters (east Northland to Bay of Plenty), and in Tasman Bay and Marlborough Sounds at the north of the South Island.

The first recorded commercial landings of pilchards were in 1931 (Table 2), but a minor fishery existed before this. Informal sales, mainly as bait, or as food for zoos and public aquariums, were unreported. A fishery for pilchard developed in the Marlborough Sounds in 1939 and operated through the war years providing canned fish for the armed forces. Landings reached over 400 t in 1942, but the fishery was unsuccessful for a variety of reasons and ceased in 1950. Between 1950 and 1990 landings were generally less than 20 t, intermittently reaching 70–80 t.

From 1990–91 the northeastern fishery was developed by vessels using both lampara nets and purse seines (Table 3). Lampara netting was the main method in the first couple of years, and continued at a low level through the 1990s. From 1993-94 onwards, purse seining became the dominant method. A diminishing catch (less than 10 t annually) was caught by beach seine. Almost all the pilchard catch (particularly in the northeastern fishery) is targeted. A small catch (less than 10 t annually), has been recorded as a bycatch of jack mackerel. Total annual landings increased steadily from 1990 as the fishery developed in northeastern waters, reaching over 1200 t in 1999-00, and almost 1500 t in 2000-01. Since that time landings have fluctuated between 670 t (2008-09) and 1 320 t (2003-04), generally directly linked to the amount of targeted effort in PIL 1. Landings in PIL 8 have fluctuated between 34 t and 153 t since this stock was introduced to the QMS, exceeding the TACC (65 t) in four of the last six years. The recent increase in catches in PIL 8 since 1999-2000 is thought to be in part the result of previously unreported catches now being reported due to the species being introduced to the QMS. Figure 1 depicts the historical landings and TACC values for the main PIL stocks.

Table 2: Reported total New Zealand landings (t) of pilchard from 1931 to 1990.

Year	Landings	Year	Landings	Year	Landings	Year	Landings	Year	Landing	Year	Landing
1931	5	1941	168	1951	0	1961	17	1971	1	1981	17
1932	4	1942	418	1952	9	1962	2	1972	8	1982	32
1933	2	1943	219	1953	0	1963	0	1973	70	1983	-
1934	0	1944	218	1954	0	1964	1	1974	19	1984	-
1935	0	1945	74	1955	0	1965	3	1975	2	1975	49
1936	0	1946	61	1956	4	1966	3	1976	6	1986	29
1937	0	1947	5	1957	2	1967	9	1977	20	1987	70
1938	0	1948	46	1958	8	1968	10	1978	6	1988	6
1939	10	1949	11	1959	7	1969	15	1979	4	1989	1
1940	93	1950	0	1960	8	1970	83	1980	41	1990	2

Source: Annual reports on fisheries and subsequent MAF data.

A 2000 t annual Commercial Catch Limit (CCL) was introduced for FMA 1 from 01 October 2000. The CCL was subject to a logbook programme, a catch spreading arrangement and the avoidance of areas of particular importance to non-commercial fishers. The CCL was superseded when the PIL 1 stock was introduced to the QMS with a TACC of 2000 t on 1st October 2002.

Table 3: Reported landings (t) of pilchard by Fishstock from 1990-91 to 2010-11.

QMA	PIL 1		PIL 2		PIL 3		PIL 7		PIL 8		**Total**
	Landin	TACC	Landing	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings
1990-91	15	-	0	-	0	-	9	-	< 1	-	25
1991-92	59	-	0	-	0	-	< 1	-	0	-	59
1992-93	163	-	2	-	0	-	0	-	0	-	164
1993-94	258	-	0	-	0	-	0	-	1	-	259
1994-95	317	-	0	-	0	-	< 1	-	< 1	-	317
1995–96	168	-	< 1	-	0	-	2	-	0	-	170
1996–97	419	-	0	-	0	-	2	-	< 1	-	421
1997–98	440	-	0	-	0	-	1	-	0	-	447
1998–99	785	-	0	-	< 1	-	2	-	1	-	788
1999–00	1 227	-	0	-	0	-	4	-	< 1	-	1 231
2000–01	1 290	-	0	-	0	-	12	-	188	-	1 491
2001–02	574	-	0	-	0	-	93	-	129	-	796
2002–03	792	2 000	0	200	0	60	8	150	153	65	953
2003-04	1 284	2 000	0	200	< 1	60	1	150	34	65	1 320
2004-05	853	2 000	0	200	< 1	60	< 1	150	106	65	959
2005-06	892	2 000	< 1	200	< 1	60	2	150	116	65	1 010
2006-07	808	2 000	0	200	0	60	11	150	45	65	864
2007-08	635	2 000	0	200	0	60	10	150	71	65	716
2008-09	644	2 000	< 1	200	0	60	3	150	23	65	670
2009-10	599	2 000	0	200	4	60	10	150	54	65	667
2010-11	319	2 000	< 1	200	<1	60	2	150	12	65	333

1.2 Recreational fisheries

Recreational fishers seldom target pilchards, except perhaps for bait. Bait is generally bought in commercially frozen packs (the main product of the commercial fishery). Pilchard may be caught accidentally in small mesh nets that are set or dragged to catch mullet, or on small hooks fished from wharves. They are rarely reported as a catch in recreational fishing activities. An estimate of the recreational harvest is not available.

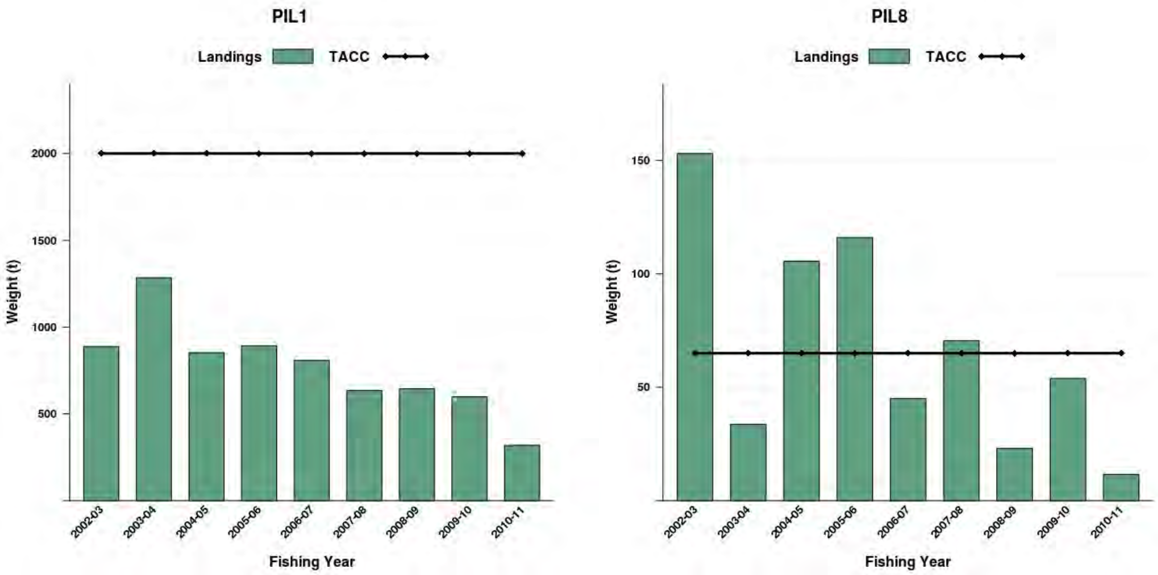


Figure 1: Historical landings and TACC for the two main PIL stocks. Left to right: PIL1 (Auckland East), and PIL8 (Central Egmont, Auckland West). Note that these figures do not show data prior to entry into the QMS.

1.3 Customary non-commercial catch
Pilchards were known by the early Maori as mohimohi, and could have been taken in fine mesh nets, but there are very few accounts of pilchard capture and use. An estimate of the current customary non-commercial catch is not available.

1.4 Illegal catch
There is no known illegal catch of pilchards.

1.5 Other sources of mortality
Some accidental captures by vessels purse seining for jack mackerel or kahawai may be discarded if no market is available. Pilchard mortality is known to be high in some places as a result of scale loss resulting from net contact.

2. BIOLOGY

The taxonomy of *Sardinops* is complex. The New Zealand pilchard was previously identified as *Sardinops neopilchardus*, but there is now considered to be a single species, *S. sagax*, with several regional subspecies or populations.

Pilchard are generally found inshore, particularly in gulfs, bays, and harbours. They display seasonal changes in abundance (e.g. locally abundant in Wellington Harbour during spring), reflecting schooling and dispersal behaviour, localised movement, and actual changes in population size. The geographical extent of their movements in New Zealand is unknown.

Their vertical distribution in the water column varies, but on the inner shelf they move between the surface and the seafloor. Pilchards form compact schools (know as ‘meatballs’), particularly during summer, and these are heavily preyed upon by larger fishes, seabirds, and marine mammals and are thought to form an important part of the diet for many species. There have been no biological studies that are directly relevant to the recognition of separate stocks.

Spawning is recorded from many coastal regions over the shelf during spring and summer. The pelagic eggs are at times extremely abundant.

Otolith readings suggest pilchard are relatively fast growing and short-lived. They reach a maximum length of about 25 cm, and perhaps 9 years, but the main size range is of 10–20 cm fish, 2 to 6 years old. Maturity is probably at age 2.

A study on the feeding of Northland pilchards found that phytoplankton was probably the dominant food, but organic detritus was also important, and small zooplankton - mainly copepods - were taken and at times were the main component. Feeding by females diminished during the spawning season.

Although they generally comprise single-species schools, pilchards associate with other small pelagic fishes, particularly anchovy. In northern waters they also occur with juvenile jack mackerel, and in southern waters with sprats.

During the 1990s pilchard populations were severely impacted by natural mass mortalities, generally attributed to a herpes virus. The first outbreak occurred in Australia and New Zealand in 1995 and Australia experienced another outbreak in 1998.

Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters.

Fishstock		**Estimate**	**Source**
1. Natural mortality (*M*)			
PIL 1		$M = 0.66$	NIWA, unpublished estimate[1]
PIL 1		$M = 0.46$	NIWA, unpublished estimate[2]
2. Weight = a (length)^b			
		Both sexes combined	
PIL 1	a = 2.2	b = 3.3	Paul *et al.* (2001)[3]
PIL 7	a = 3.7	b = 3.3	Baker (1972)[4]

Notes:
1. Hoenig’s rule-of-thumb estimate, maximum age = 7 years.
2. Hoenig’s rule-of-thumb estimate, maximum age = 10 years.
3. Fork length in mm, weight in g, n = 493.
4. Standard length in mm, weight in g, n = 660.

3. STOCKS AND AREAS

No biological information is available on which to make an assessment on whether separate pilchard biological stocks exist in New Zealand (in Australia there is evidence of small differences between some populations off the southwest coast).

Pilchard and anchovy are often caught together. Pilchard Fishstock boundaries are fully aligned with those for anchovy.

4. STOCK ASSESSMENT

There have been no stock assessments of New Zealand pilchard.

4.1 Estimates of fishery parameters and abundance

No fishery parameters are available.

4.2 Biomass estimates

No estimates of biomass are available.

4.3 Estimation of Maximum Constant Yield (*MCY*)

(i) Northeast North Island (PIL 1)

MCY has been estimated using the equation $MCY = cY_{AV}$ (Method 4). The most appropriate Y_{AV} was considered the average of landings for the three years 1998–99 to 2000–01. Although a brief period, three years represents at least half the exploited life span for this species. The mean of these landings is 1101 t. With provisional values of *M* about 0.4 or 0.6, the value of c becomes 0.6 (i.e. high natural variability).

1998–99 to 2000–01 *MCY* = 0.6 * 1101 t = 661 t (rounded to 660 t)

However, the *MCY* approach is considered to be of limited value for pilchards, because this fishery has been developing rapidly, was historically infrequently targeted, and since 2000 has been subject to a CCL and more recently a TACC. The level of risk to the stock by harvesting the northeast North Island population at the estimated *MCY* value cannot be determined.

(ii) Tasman Bay/Marlborough Sounds (PIL 7)

MCY cannot be estimated for this region because the fishery has been largely unexploited since the 1940s, and no appropriate biological parameters exist.

(iii) Other regions

MCY cannot be estimated because of insufficient information, and absence of fisheries.

4.4 Estimation of Current Annual Yield (*CAY*)
Current biomass cannot be estimated, so *CAY* cannot be determined.

4.5 Other yield estimates and stock assessment results
No information is available.

4.6 Other factors
It is likely that pilchard, although not strongly migratory, will vary considerably in their regional abundance over time. The larger vessels in the fleet that targets them are capable of travelling moderate distances to the best grounds. Thus, while the resource may have a relatively localised distribution, the catching sector of the fishery does not. Should the pilchard fishery continue to develop, it is likely to become one component of a set of fisheries for small pelagic species (anchovy, sprats, and small jack mackerels). Mixed catches will be inevitable.

Pilchard is abundant in some New Zealand regions. However, it is unlikely that the biomass is comparable to the very large stocks of pilchard (sardine) in some world oceans where strong upwelling promotes high productivity. It is more likely that the New Zealand pilchard comprises abundant but localised coastal populations, comparable to those of southern Australia. They appear to be adaptable feeders, able to utilise food items from organic detritus through phytoplankton to zooplankton. East Northland is a region where under neutral to El Niño conditions moderately productive upwelling predominates, but in La Niña years downwelling and oceanic water incursion will limit recruitment and may affect adult condition and survival.

In those regions of the world where small pelagic fishes are particularly abundant and have been well studied, there is often a reciprocal relationship between the stock size of pilchard and anchovy, as well as great variability in their overall abundance. Many pilchard/anchovy fisheries have undergone boom-and-bust cycles.

In both Australia and New Zealand, pilchard have been affected by mass mortality events, the two in Australia are estimated to have each killed over 70% of the adult fish. The mortality rate of the 1995 event in New Zealand is not known, but was high. In combination, these features of the pilchard's biology suggest that the yield from the New Zealand stock will be variable, both short-term (annual) and long-term (decadal).

5. STATUS OF THE STOCKS

No estimates of current biomass are available. Recent catches from northeast North Island, and the TACC for PIL 1 are higher than the 660 t *MCY* estimate (apart from the 2001–02 landings of 498 t). However the *MCY* estimate is considered unreliable. It is not known if the current catches or TACCs are sustainable.

Yield estimates, TACCs and reported landings by Fishstock are summarised in Table 5.

Table 5: Summary of yield estimates (t), TACCs (t), and reported landings (t) of pilchards for the most recent fishing year.

Fishstock		FMA	*MCY* Estimates	2010-11 Actual TACC	2010-11 Reported landings
PIL 1	Auckland (East)	1	660	2 000	319
PIL 2	Central (East)	2	–	200	<1
PIL 3	South-east (Coast)/Southland & Sub-Antarctic	3, 5 & 6	–	60	<1
PIL 4	South-east (Chatham)	4	–	10	0
PIL 7	Challenger	7	–	150	2
PIL 8	Central (West)/Auckland (West)	8, 9	–	65	12
PIL 10	Kermadec	10	–	0	0
Total				2 485	333

6. FOR FURTHER INFORMATION

Baker A.N. 1972. Reproduction, early life history, and age-growth relationships of the New Zealand pilchard, *Sardinops neopilchardus* (Steindachner). Fisheries Research Bulletin No. 5. 64 p.

Jacobson L.D., De Oliveira J.A.A., Barange M., Cisneros-Mata, Félix-Uraga R., Hunter J.R., Kim J.Y., Matsuura Y., Ñiqueen M., Porteiro C., Rothschild B., Sanchez R.P., Serra R., Uriarte A., Wada T. 2001. Surplus production, variability, and climate change in the great sardine and anchovy fisheries. Canadian Journal of Fisheries and Aquatic Sciences 58(9): 1891–1903.

Paul L.J., Bradford-Grieve J.M., Tasker R.A., Chang F.H., Manning M.J. 2005. Guts, gill rakers, and ENSO oceanography: a pilot study on feeding patterns in the New Zealand pilchard, Sardinops sagax, off east Northland. Final Research Report for Ministry of Fisheries Research Project PIL2003/01, Objective 1. 30 p. (Unpublished Report held by the Ministry of Fisheries, Wellington).

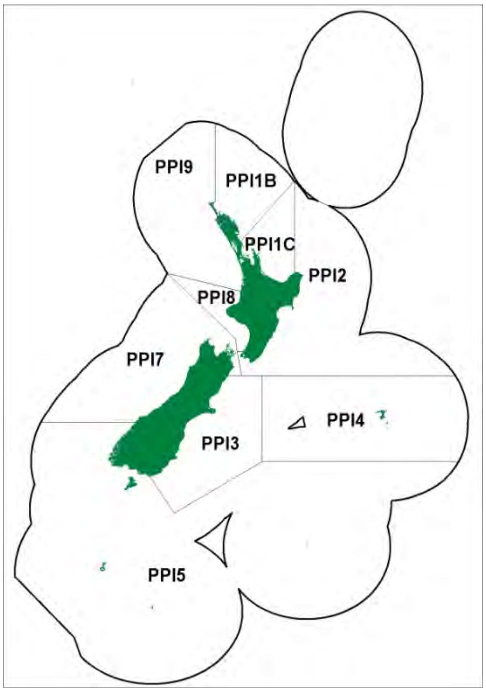
Paul L.J., Taylor P.R., Parkinson D.M. 2001. Pilchard (*Sardinops neopilchardus*) biology and fisheries in New Zealand, and a review of pilchard (*Sardinops*, *Sardina*) biology, fisheries, and research in the main world fisheries. New Zealand Fisheries Assessment Report 2001/37. 44 p.

Schwartzlose R.A., Ahleit J., Bakun A., Baumgartner T.R., Cloete R., Crawford R.J.M., Fletcher W., Green-Ruiz Y., Hagen E., Kawasaki T., Lluch-Belda D., Lluch-Cota S.E., MacCall A.D., Matsuura Y., Nevarez-Martínez M.O., Parrish R.H., Roy C., Serra R., Shust K.V., Ward M.N., Zuzunaga J.Z. 1999. Worldwide large-scale fluctuations of sardine and anchovy populations. South African Journal of Marine Science 21: 289–347.

Ward T.M., Hoedt F., McLeay L., Dimmlich W.F., Kinloch M., Jackson G., McGarvey R., Rogers P.J., Jones K. 2001. Effects of the 1995 and 1998 mass mortality events on the spawning biomass of sardine, *Sardinops sagax*, in South Australian waters. ICES Journal of Marine Science 58(4): 865–875.

Pipi (PPI)

(*Paphies australis*)
Pipi



1. FISHERY SUMMARY

Pipi are important shellfish both commercially and for non-commercial fishers. PPI 1A (which is located in Whangarei harbour and mapped in the following PPI1A section) was introduced into the Quota Management System (QMS) on 1 October 2004, the other PPI stocks listed in Table 1 were introduced in October 2005. The total TAC introduced to the QMS was 713 t. This consisted of a 204 t TACC, an allocation of 242 t for both recreational allowance and customary allowance and 25 t allowance for other sources of mortality (Table 1). No changes have occurred to the TAC since. The fishing year is from 1 October to 30 September and commercial catches are measured in greenweight. The largest commercial fishery is in PPI 1A and the largest recreational fishery is in PPI 1C.

Table 1: Recreational, Customary non-commercial allocations, TACs and TACCs (t) for pipi.

Fishstock	Recreational Allowance	Customary non-commercial allowance	Other sources of mortality	TACC	TAC
PPI 1A	25	25	0	200	250
PPI 1B	76	76	8	0	160
PPI 1C	115	115	10	3	243
PPI 2	3	3	1	0	7
PPI 3	9	9	1	0	19
PPI 4	1	1	1	0	3
PPI 5	1	1	1	0	3
PPI 7	1	1	1	1	4
PPI 8	1	1	1	0	3
PPI 9	10	10	1	0	21
Total	242	242	25	204	713

Regulations require that all commercial gathering is to be done by hand. Fishers typically use a mask and snorkel. There is no minimum legal size (MLS) for pipi, although fishers probably favor larger pipi (> 60 mm shell length). There is no apparent seasonality in the pipi fishery, as pipi are available for harvest year-round. Some commercial catch is taken from PPI 1C (Table 2 and Figure 1) but the great majority of commercial catch is reported from PPI 1A and this will be dealt with in a separate section.

New Zealand operates a mandatory shellfish quality assurance programme for all bivalve shellfish commercial growing or harvesting areas for human consumption. Shellfish caught outside this programme can be sold only for bait. This programme is based on international best practice and managed by the New Zealand Food Safety Authority (NZFSA), in cooperation with the District Health Board Public Health Units and the shellfish industry[1] and is summarised below. Before any area can be used to grow or harvest bivalve shellfish public health officials survey both the water catchment area to identify any potential pollution issues and microbiologically sampling water and shellfish over at least a 12-month period, so all seasonal influences are explored. This information is evaluated and, if suitable, the area classified and listed by NZFSA for harvest. There is then a requirement for regular monitoring of the water and shellfish flesh to verify levels of microbiological and chemical contaminants. Management measures stemming from this testing include closure after rainfall, to deal with microbiological contamination from runoff. Natural marine biotoxins can also cause health risks so testing also occurs for this at regular intervals. If toxins are detected above the permissible level the harvest areas are closed until the levels fall below the permissible level. Products are also traceable so the source and time of harvest can always be identified in case of contamination.

Table 2: Reported commercial landings of pipi (t greenweight) from PPI 1C from 2004-05 to 2010-11.

Year	Reported landings (t)	Limit (t)
2004-05	0	3
2005-06	0.86	3
2006-07	1.69	3
2007-08	1.80	3
2008-09	0.38	3
2009-10	0.62	3
2010-11	0	3

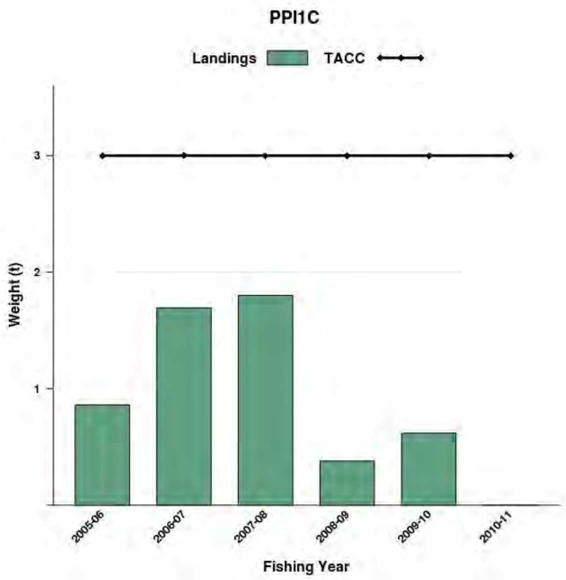


Figure 1: Historical landings and TACC for PPI 1C (Hauraki Gulf and the Bay of Plenty). Note that this figure does not show data prior to entry into the QMS.

[1]. For full details of this programme, refer to the Animal Products (Regulated Control Scheme-Bivalve molluscan Shellfish) Regulations 2006 and the Animal Products (Specifications for Bivalve Molluscan Shellfish) Notice 2006 (both referred to as the BMSRCS), at:
http://www.foodsafety.govt.nz/industry/sectors/seafood/bms/growers-harvesters.htm

1.2 Recreational fisheries

The recreational fishery is harvested entirely by hand digging. Large pipi 50 mm (maximum shell length) or greater are probably preferred. The 1996, 1999-00, and 2000-01 National Marine Recreational Fishing Surveys recorded recreational harvests for pipi in FMA 1. The estimated numbers of pipi harvested were 2.1, 6.6, and 7.2 million respectively but no mean harvest weight was available to convert these harvest estimates to tonnages. 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. No recreational harvest estimates specific to the Mair Bank pipi fishery are available but the recreational harvest of pipi is likely to be small compared with commercial landings there.

1.3 Customary fisheries

In common with many other intertidal shellfish, pipi are very important to Maori as a traditional food. However, no reliable quantitative information on the level of customary take is available.

1.4 Illegal catch

No quantitative information on the level of illegal catch is available.

1.5 Other sources of mortality

No quantitative nationwide information on the level of other sources of mortality is available.

2. BIOLOGY

The pipi (*Paphies australis*) is a common burrowing bivalve mollusc of the family Mesodesmatidae. Pipi are distributed around the New Zealand coastline, including the Chatham and Auckland Islands (Powell 1979), and are characteristic of sheltered beaches, bays and estuaries (Morton & Miller 1968). Pipi are tolerant of moderate wave action, and commonly inhabit coarse shell sand substrata in bays and at the mouths of estuaries where silt has been removed by waves and currents (Morton & Miller 1968). They have a broad tidal range, occurring intertidally and subtidally in high-current harbour channels to water depths of at least 7 m (Dickie 1986a, Hooker 1995a), and are locally abundant, with densities greater than 1000 m^2 in certain areas (Grace 1972).

Pipi reproduce by free-spawning, and most individuals are sexually mature at about 40 mm shell length (SL) (Hooker & Creese 1995a). Gametogenesis begins in autumn, and by late winter many pipi have mature, ready-to-spawn gonads (Hooker & Creese 1995a). Pipi have an extended breeding period from late winter to late summer, with greatest spawning activity occurring in spring and early summer. Fertilised eggs develop into planktotrophic larvae, and settlement and metamorphosis occur about three weeks after spawning (Hooker 1997). In general, pipi have been considered sedentary when settled, although Hooker (1995b) found that pipi may utilise water currents to disperse actively within a harbour. The trigger for movement is unknown, but this ability to migrate may have important implications to their population dynamics.

Pipi growth dynamics are not well known. Growth appears to be fairly rapid, at least in dynamic, high-current environments such as harbour channels. Hooker (1995a) showed that pipi at Whangateau Harbour (northeastern New Zealand) grew to about 30 mm in just over one year (16-17 months), reached 50 mm after about three years, and grew very slowly after attaining 50 mm. There was a strong seasonal component to growth, with rapid growth occurring in spring and summer, and little growth in autumn and winter. Williams *et al*. (2007) used Hooker's (1995a) tag-recapture and length frequency time series data to generate formal growth estimates for Whangateau Harbour pipi (Table 3). Estimates are available also from time series of size frequencies on sheltered Auckland beaches (Table 3; Morrison & Browne 1999, Morrison *et al*. 1999), although these estimates were likely to have been poorly estimated due to variability in the length data. Growth on the intertidal section of Mair bank was estimated by (Pawley *et al.* In Press) using the results of a notch-tagging experiment in

2009-10. These estimates are likely to underestimate growth of pipi in the commercial fishery because tagged shells came from the intertidal zone and harvesting is conducted primarily in the subtidal (where growth is expected to be quicker).

Little is known about the natural mortality or maximum longevity of pipi. Haddon (1989) suggested pipi are unlikely to live much more than 10 years, and used assumed maximum ages of 10, 15 and 20 years old to estimate maximum constant yield for Mair Bank pipi in 1989. The estimation of the rate of instantaneous natural mortality (M) is difficult for pipi owing to the immigration and emigration of individuals from different areas. As the timing and frequency of these movements are largely unknown, the separation of mortality from movement effects is likely to be problematic. Williams *et al*. (2007) assumed values of M = 0.3, 0.4, and 0.5 to estimate yields for Mair Bank in 2005-06.

Table 3: Estimates of biological parameters for pipi.

Growth		Location	Year	Source
L_∞ (mm SL)	K			
57.3	0.46	inner Whangateau Harbour site	1992-93	Williams *et al*. (2006)
63.9	0.57	Whangateau Harbour entrance	1992-93	Williams *et al*. (2006)
41.1	0.48	Cheltenham Beach, North Shore	1997-98	Morrison *et al*. (1999)
58.9	0.15	Mill Bay, Manukau Harbour	1997-98	Morrison *et al*. (1999)
84.6	0.09	Mill Bay, Manukau Harbour	1998-99	Morrison & Browne (1999)
Natural mortality				
M = 0.3-0.5 (assumed values)		-	-	Williams *et al*. (2007)
Size at maturity				
40 mm SL		Whangateau Harbour	-	Hooker & Creese (1995a)

3. STOCKS AND AREAS

Little is known of the stock structure of pipi. A study of biological connectivity that is currently underway includes pipi, but no results have been reported at the time of this report.

4. STOCK ASSESSMENT

There is a stock assessment for PPI 1A.

5. STATUS OF THE STOCKS

There were negligible reported landings in 2010-11 for any PPI stocks except PPI 1A (which is reported separately). The status of all PPI stocks other than PPI 1A are unknown, but are assumed to be close to virgin biomass.

TACCs and reported landings in stocks other than PPI 1A are summarized in Table 4.

Table 4: Summary of TACCs (t) and reported landings (t) of pipis (excluding PPI 1A) for the most recent fishing year.

Fishstock	2010-11 Actual TACC	2010-11 Reported landings
PPI 1C	3	0
PPI 3	0	0
PPI 7	1	0

6. FOR FURTHER INFORMATION

Cranfield H.J., Michael K.P., Stotter D. 1993. Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 47 p.

Dickie B.N. 1986a. Physical and biological survey of a subtidal *Paphies australis* population in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 4. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Dickie B.N. 1986b. Topographic survey of three intertidal *Paphies australis* habitats in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 2. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Fournier D.A., Sibert J.R., Majkowski J., Hampton J. 1990. MULTIFAN: a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyi*). Canadian Journal of Fisheries and Aquatic Sciences 47: 301-317.

Francis R.I.C.C. 1988. Maximum likelihood estimation of growth and growth variability from tagging data. New Zealand Journal of Marine and Freshwater Research 22(1): 43-51.

Grace R.G. 1972. The benthic ecology of the entrance to the Whangateau Harbour, Northland, New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand.

Haddon M. 1989. Biomass estimate of the pipi *Paphies australis* on Mair Bank, Whangarei Harbour. 23 p. (Unpublished draft report to MAF Fisheries North, Auckland, New Zealand).

Hooker S.H. 1995a. Life history and demography of the pipi *Paphies australis* (Bivalvia: Mesodesmatidae) in northeastern New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand. 230 p.

Hooker S.H. 1995b. Preliminary evidence for post-settlement movement of juvenile and adult pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). Marine and Freshwater Behaviour and Physiology 27(1): 37-47.

Hooker S.H. 1997. Larval and postlarval development of the New Zealand pipi, *Paphies australis* (Bivalvia : Mesodesmatidae). Bulletin of Marine Science 61(2): 225-240.

Hooker S.H., Creese R.G. 1995a. The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). I. Temporal patterns of the reproductive cycle. Journal of Shellfish Research 14(1): 7-15.

Hooker S.H., Creese R.G. 1995b. The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). II. Spatial patterns of the reproductive cycle. Journal of Shellfish Research 14(1): 17-24.

Morrison M.A., Browne G.N. 1999. Intertidal shellfish population surveys in the Auckland region, 1998-99, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/43. 21 p. (Unpublished report held in NIWA library, Wellington).

Morrison M.A., Pawley M.D.M., Browne G.N. 1999. Intertidal surveys of shellfish populations in the Auckland region, 1997-98, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/25. 25 p.

Morton J.E., Miller M.C. 1968. The New Zealand Sea Shore. Collins, Auckland, New Zealand. 653 p.

OtterResearch (1992). MULTIFAN 32(f). User's Guide and Reference Manual. Otter Research Ltd., Nanaimo, Canada. 67 p.

Powell A.W.B. 1979. New Zealand Mollusca: Marine, Land and Freshwater Shells. Collins, Auckland, New Zealand. 500 p.

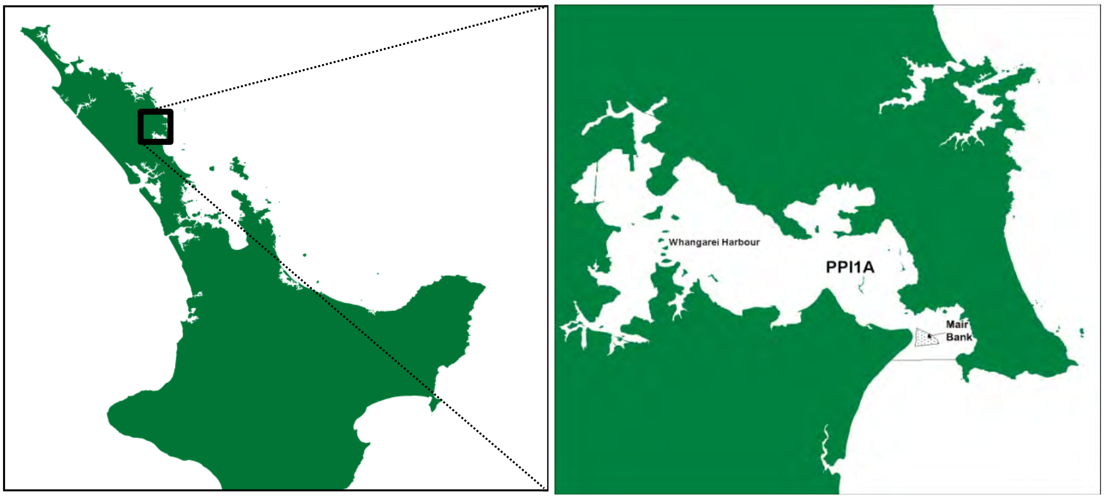
Sullivan K.J., Mace P.M., Smith N.W.M., Griffiths M.H., Todd P.R., Livingston M.E., Harley S.J., Key J.M., Connell A.M. (Comps.) (2005). Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792 p. (Unpublished report held in NIWA library, Wellington).

Venus G.C. 1984. *Paphies australis* (pipis) in Whangarei Harbour. Whangarei Harbour Study Technical Report No. 6. 60 p. (Unpublished technical report coordinated by the Northland Harbour Board).

Williams J.R., Cryer M., Hooker S.H., Smith M.D., Watson T.G., MacKay G., Tasker R. 2007 Biomass survey and stock assessment of pipi (*Paphies australis*) on Mair Bank, Whangarei Harbour, 2005. New Zealand Fisheries Assessment Report. 2007/03, 29 p.

PPI (PPI 1A) Mair Bank (Whangarei Harbour)

(*Paphies australis*)
Pipi



1. FISHERY SUMMARY

Pipi 1A was introduced into the Quota Management System (QMS) on 1 October 2004 with a TAC of 250 t, comprising a TACC of 200 t, customary and recreational allowances of 25 t each. These limits have remained unchanged since.

1.1 Commercial fisheries

Prior to the introduction of pipi, in Whangarei Harbour (PPI 1A) and FMA PPI 1, to the QMS in 2004, the commercial fishery area was defined in regulation as that area within 1.5 nautical miles of the coastline from Home Point, at the northern extent of the Whangarei Harbour entrance, to Mangawhai Heads, south of the harbour. Commercial fishers tend to gather pipi from the seaward edge of Mair Bank, particularly the southern end, and avoid the centre of the bank itself where there is a lot of shell debris. Regulations require that all gathering be done by hand, and fishers typically use a mask and snorkel. There is no minimum legal size (MLS) for pipi, although a sample measured from the commercial catch in PPI 1A in 2005 suggested that fishers favour larger pipi (> 60 mm SL, Williams *et al.* 2007). Pipi are available for harvest year-round, so there is no apparent seasonality in the fishery.

Over 99% of the total commercial landings of pipi in New Zealand have been from general statistical area 003 and PPI 1. In the most recent years, where a distinction has been made, virtually all the landings have been from PPI 1A (Whangarei Harbour). Total commercial landings of pipi reported by Licensed Fish Receiver Returns (LFRRs) have remained reasonably stable through time, averaging 187 t annually in New Zealand since 1986-87 (Table 1). The highest recorded landings were in 1991-92 (326 t). There is no evidence of any consistent seasonal pattern in either the level of effort or catch per unit effort (CPUE) in the pipi fishery. CPUE in the pipi targeted fishery increased between 1989-90 and 1992-93, was then relatively stable up to 2002-03 but increased in 2003-04 and 2004-05 (Williams *et al.* 2007). No CPUE information has since been analysed.

Prior to the introduction of PPI 1A to the QMS there were nine permit holders for Whangarei Harbour. No new entrants have entered the fishery since 1992 when commercial access to the fishery was constrained by the general moratorium on granting new fishing permits for non-QMS fisheries. Access to the fishery has, however, been restricted through other regulations since the mid-1980s, and more formally since 1988. Under previous non-QMS management arrangements, there was a daily catch limit of 200 kg per permit holder, meaning that, collectively, the nine permit holders could, theoretically, take 657 t of pipi per year. The permit holders have indicated that annual harvest quantities have been considerably less than the potential maximum, because of the relatively low market demand for commercial product rather than the availability of the resource. On 1 October 2004, pipi in Whangarei Harbour (PPI 1A) were introduced into the QMS, and the nine existing permits were replaced with individual transferable quotas. The 200 kg daily catch limit no longer applies. A total allowable catch (TAC) of 250 t was set, comprised of a total allowable commercial catch (TACC) of 200 t, a customary allowance of 25 t, and a recreational allowance of 25 t. Figure 1 shows the historical landings and TACC values for PPI1A.

Table 1: Reported commercial landings (from Licensed Fish Receiver Returns; LFRR) of pipi (t greenweight) in New Zealand since 1986-87. Prior to the introduction of PPI 1A to the QMS on 1 October 2004, the fishery was limited by daily limits which summed to 657 t greenweight in a 365 day year, but there was no explicit annual restriction. A TACC of 200 t was set for PPI 1A on 1 October 2004.

Year	Reported landings (t)	Limit (t)	Year	Reported landings (t)	Limit (t)
1986-87	131	657	1999-00	143	657
1987-88	133	657	2000-01	184	657
1988-89	134	657	2001-02	191	657
1989-90	222	657	2002-03	191	657
1990-91	285	657	2003-04	266	657
1991-92	326	657	2004-05	206	200
1992-93	184	657	2005-06	137	200
1993-94	258	657	2006-07	135	200
1994-95	172	657	2007-08	142	200
1995-96	135	657	2008-09	131	200
1996-97	146	657	2009-10	136	200
1997-98	122	657	2010-11	87	200
1998-99	130	657			

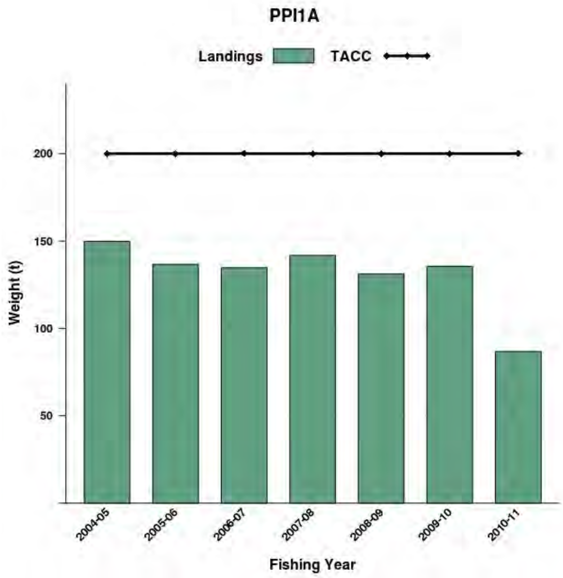


Figure 1: Historical landings and TACC for PPI1A (Whangarei Harbour). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
This is covered in the general pipi section.

1.3 Customary non-commercial fisheries
This is covered in the general pipi section.

1.4 Illegal catch

This is covered in the general pipi section.

1.5 Other sources of mortality

There is some concern about the possibility of changes in bank stability that could arise from operations other than fishing in Whangarei Harbour (e.g., harbour dredging, port developments), which could lead to changes in the pipi fishery. Radical changes to the local hydrology could affect the size or substratum of Mair Bank with consequent effects on its pipi population. Also, as suspension feeders, pipi may be adversely affected by increased sediment loads in the water column.

2. BIOLOGY

This is covered in the general pipi section.

3. STOCKS AND AREAS

Little is known of the stock structure of pipi. A study of biological connectivity that is currently underway includes pipi, but no results have been reported at the time of this report. The commercial fishery based on Mair Bank in Whangarei Harbour (PPI 1A) forms a geographically discrete area and it is assumed for management purposes to be a separate stock.

4. STOCK ASSESSMENT

Stock assessment for Mair Bank pipi was conducted in 2005 and 2010 using absolute biomass surveys, and yield per recruit and spawning stock biomass per recruit modelling.

4.1 Estimates of fishery parameters and abundance

Estimates of the fishing mortality reference point $F_{0.1}$ are available from yield per recruit modeling (Table 2). Parallel spawning stock biomass per recruit modeling was conducted to estimate the SSBPR corresponding with each estimate of $F_{0.1}$. These estimates are sensitive to the assumed value of natural mortality (M) and uncertainty in pipi growth parameters.

Table 2: Estimates of the reference rate of fishing mortality $F_{0.1}$ and corresponding spawning stock biomass per recruit at three different assumed rates of natural mortality (M) for two harvest strategies ('no restriction' and 'current'). SL, shell length (at recruitment). Estimates from Williams *et al*. (2007).

'No restriction' strategy (harvest pipi of a size that maximizes YPR)					
Assumed M	Optimal age at recruitment (y)	SL (mm)	$F_{0.1}$	YPR (g)	SSBPR (%)
0.3	3	52	0.437	4.93	44
0.4	2.75	51	0.550	3.50	45
0.5	2.5	49	0.648	2.58	45
'Current' strategy (harvest pipi 60 mm and over)					
Assumed M	Age at recruitment (y)	SL (mm)	$F_{0.1}$	YPR (g)	SSBPR (%)
0.3	5	60	0.564	3.98	62
0.4	5	60	0.755	2.41	70
0.5	5	60	0.949	1.47	76

4.2 Biomass estimates

Virgin biomass (B_0) and the biomass that will support the maximum sustainable yield (B_{MSY}) are unknown for Mair Bank pipi. Only three biomass estimates have been made for the Mair Bank pipi population: in 1989 using a grid survey, in 2005 using stratified random sampling and in 2010 using a systematic random start. The 1989 estimate of 2245 t (± 10%) can be considered conservative because only the intertidal area of the bank was surveyed, and pipi are known to exist in the shallow subtidal area of the bank. Estimates of biomass are available for Mair Bank and are sensitive to the assumed size at recruitment (Table 3).

Table 3: Estimated recruited biomass (*B*) of pipi on Mair Bank in 2005 and 2010 for different assumed sizes at recruitment to the fishery. Source: Williams *et al*. (2007) and Pawley *et al.* (*in press*).

Year	Assumed shell length at recruitment (mm)	Intertidal stratum		Subtidal stratum		Mair Bank Total	
		B (t)	*C.V.* (%)	*B* (t)	*C.V.* (%)	*B* (t)	*C.V.* (%)
2005	1 (total biomass)	3 602	11.4	6 940	19.5	10 542	13.4
2005	40	3 569	11.4	6 922	19.5	10 490	13.4
2005	45	3 434	11.4	6 791	19.6	10 226	13.6
2005	50	2 986	11.3	5 989	20.1	8 975	14.0
2005	55	2 022	11.1	3 855	23.8	5 877	16.0
2005	60	1 004	13.1	2 013	37.5	3 017	25.4
2010	1 (total biomass)	2 233	17.4	2 218	33.0	4 452	15.2
2010	50	2 001	18.1	1 889	36.0	3 890	16.6
2010	60	1 751	18.3	1 393	33.7	3 145	17.4

4.3 Estimation of Maximum Constant Yield (*MCY*)

Maximum Constant Yield (*MCY*) was estimated using method 2 (see the guide to biological reference points in the introduction chapter of this plenary document):

$$\mathrm{MCY} = 0.5F_{0.1}B_{av}$$

where $F_{0.1}$ is a reference rate of fishing mortality and B_{av} is the historical average recruited biomass (estimated as the mean recruited biomass from the 2005 and 2010 surveys). *M* is assumed to be 0.3 and the corresponding $F_{0.1}$ is 0.564 (Williams *et al.* 2007 revised version). The size at recruitment is assumed to remain at 60 mm and the corresponding B_{av} is 3081 t.

$$\mathrm{MCY} = 0.5 \times 0.564 \times 3081 = 869\ \mathrm{t}$$

This estimate of *MCY* would have a c.v. at least as large as those associated with the 2005 and 2010 estimates of recruited biomass (17–25%), and is sensitive to the assumed size at recruitment to the fishery, the assumed natural mortality, and to uncertainty in $F_{0.1}$ (arising from the considerable uncertainty in model input values for growth and *M*) (Table 4).

Table 4: Sensitivity of maximum constant yield (*MCY*, method 2) to estimates of size at recruitment and the assumed natural mortality, *M*. B_{av}, the historical average recruited biomass, was estimated for two sizes at recruitment (50 and 60 mm SL) using the 2005 and 2010 survey data.

SL at recruitment (mm)	B_{av}	*M*	$F_{0.1}$	*MCY* (t)
50	6433	0.3	0.40	1 300
		0.4	0.54	1 729
		0.5	0.68	2 182
60	3081	0.3	0.56	869
		0.4	0.76	1 163
		0.5	0.95	1 462

4.4 Estimation of Current Annual Yield (*CAY*)

CAY was not estimated because there is no estimate of current biomass.

4.5 Other yield estimates and stock assessment results

None

4.6 Other factors

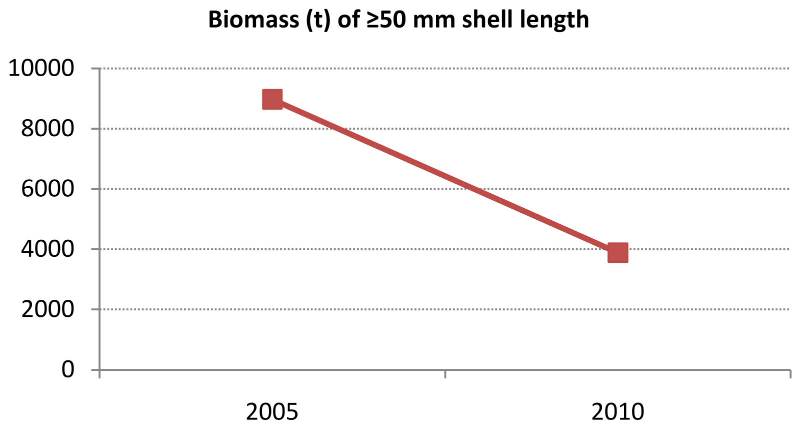
None

5. STATUS OF THE STOCKS

Stock Structure Assumptions

For the purpose of this assessment PPI 1A is assumed to be a discrete stock.

Stock Status	
Year of Most Recent Assessment	2012
Reference Points	Target(s): Default 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Likely (> 60%) to be above target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below limit. Hard Limit: Very Unlikely (< 10%) to be below limit.
Historical Stock Status Trajectory and Current Status	



Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Complete surveys were conducted in 2005 and 2010. These surveys showed similar recruited biomass (>60 mm SL) but the total and spawning stock biomass (>40 mm SL) were both substantially higher in 2005 than in 2010
Recent Trend in Fishing Mortality or Proxy	Landings continue to be substantially less than estimates of *MCY*

Projections and Prognosis	
Stock Projections or Prognosis	Stock size is Likely (> 60%) to remain above the target biomass under current catches and TACCs.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Reference rate of fishing mortality applied to absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2012	Next assessment: 2013
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Two absolute abundance	

	estimates (quadrat surveys). - Biological parameters for YPR/SSBPR models.	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	None since the 2005 assessment.	
Major Sources of Uncertainty	Growth for the subtidal portion of this population is poorly known. The available data come from other areas or the intertidal portion, both of which can be expected to support slower growth than the area where the fishery occurs. This, together with poor information on M and the size at recruitment to the fishery, makes the YPR modeling and reference rate of fishing mortality very uncertain.	
Qualifying Comments		
Recruitment appears from the 2005 and 2010 survey length frequency distributions to be variable. This may lead to larger variations in the spawning and recruited biomass than the estimates of biomass suggest		
Fishery Interactions		
This is a hand-gathering fishery with no substantial bycatch or other interactions.		

6. FOR FURTHER INFORMATION

Cranfield H.J., Michael K.P., Stotter D. 1993. Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 47 p.

Dickie B.N. 1986a. Physical and biological survey of a subtidal *Paphies australis* population in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 4. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Dickie B.N. 1986b. Topographic survey of three intertidal *Paphies australis* habitats in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 2. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Fournier D.A., Sibert J.R., Majkowski J., Hampton J. 1990. MULTIFAN: a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyi*). Canadian Journal of Fisheries and Aquatic Sciences 47: 301-317.

Francis R.I.C.C. 1988. Maximum likelihood estimation of growth and growth variability from tagging data. New Zealand Journal of Marine and Freshwater Research 22(1): 43-51.

Grace R.G. 1972. The benthic ecology of the entrance to the Whangateau Harbour, Northland, New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand.

Haddon M. 1989. Biomass estimate of the pipi *Paphies australis* on Mair Bank, Whangarei Harbour. 23 p. (Unpublished draft report to MAF Fisheries North, Auckland, New Zealand).

Hooker S.H. 1995a. Life history and demography of the pipi *Paphies australis* (Bivalvia: Mesodesmatidae) in northeastern New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand. 230 p.

Hooker S.H. 1995b. Preliminary evidence for post-settlement movement of juvenile and adult pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). Marine and Freshwater Behaviour and Physiology 27(1): 37-47.

Hooker S.H. 1997. Larval and postlarval development of the New Zealand pipi, *Paphies australis* (Bivalvia : Mesodesmatidae). Bulletin of Marine Science 61(2): 225-240.

Hooker S.H., Creese R.G. 1995a. The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). I. Temporal patterns of the reproductive cycle. Journal of Shellfish Research 14(1): 7-15.

Hooker S.H., Creese R.G. 1995b. The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). II. Spatial patterns of the reproductive cycle. Journal of Shellfish Research 14(1): 17-24.

Morrison M.A., Browne G.N. 1999. Intertidal shellfish population surveys in the Auckland region, 1998-99, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/43. 21 p. (Unpublished report held in NIWA library, Wellington).

Morrison M.A., Pawley M.D.M., Browne G.N. 1999. Intertidal surveys of shellfish populations in the Auckland region, 1997-98, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/25. 25 p.

Morton J.E., Miller M.C. 1968. The New Zealand Sea Shore. Collins, Auckland, New Zealand. 653 p.

OtterResearch (1992). MULTIFAN 32(f). User's Guide and Reference Manual. Otter Research Ltd., Nanaimo, Canada. 67 p.

Pawley M.D, Hannaford O., Morgan K. (In Press) Biomass survey and stock assessment of pipi (*Paphies australis*) on Mair and Marsden Bank, Whangarei Harbour, 2010. Draft Fisheries Assessment Report

Powell A.W.B. 1979. New Zealand Mollusca: Marine, Land and Freshwater Shells. Collins, Auckland, New Zealand. 500 p.

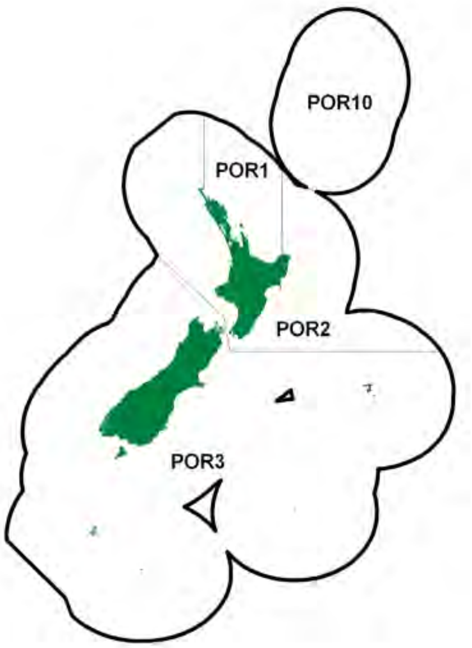
Sullivan K.J., Mace P.M., Smith N.W.M., Griffiths M.H., Todd P.R., Livingston M.E., Harley S.J., Key J.M., Connell A.M. (Comps.) (2005). Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792 p. (Unpublished report held in NIWA library, Wellington).

Venus G.C. 1984. *Paphies australis* (pipis) in Whangarei Harbour. Whangarei Harbour Study Technical Report No. 6. 60 p. (Unpublished technical report coordinated by the Northland Harbour Board).

Williams J.R., Cryer M., Hooker S.H., Smith M.D., Watson T.G., MacKay G., Tasker R. 2007 Biomass survey and stock assessment of pipi (*Paphies australis*) on Mair Bank, Whangarei Harbour, 2005. New Zealand Fisheries Assessment Report. 2007/03, 29 p.

PORAE (POR)

(*Nemadactylus douglasii*)
Porae



1. FISHERY SUMMARY

Porae was introduced into the Quota Management System on 1 October 2004 with the following TACs, TACCs and allowances (Table 1). These have not been changed.

Table 1: TACs (t), TACCs (t) and allowances (t) for porae.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
POR 1	6	3	4	62	75
POR 2	1	1	1	6	9
POR 3	1	1	1	2	5
POR 10	1	1	1	1	4
Total	9	6	7	71	93

1.1 Commercial fisheries

Commercial catches of porae throughout New Zealand are generally small (Table 2 & Table 3). Annual catches in FMA 1, where the majority of porae are caught, have approximately halved since the early 1990s. Catches in FMAs 2, 3, 7, and 9 have remained low. No catches have been reported from FMAs 4, 5, or 6.

Porae is principally caught as a bycatch in inshore setnet fisheries in northern New Zealand. It is generally taken in association with snapper and trevally in east Northland and Coromandel, and tarakihi and blue moki around Gisborne. Small quantities are taken by bottom longline and trawl fisheries targeting snapper off east Northland and Ninety Mile Beach.

Landings are typically < 10 t and the proportion of vessels reporting catches has declined steadily during the 1990s. Fishers may confuse the codes PAR (parore) and POR (porae) when reporting catches, but given that both species occur in shallow northern waters, misreporting is difficult to discern.

Table 2: Reported landings (t) of porae by FMA, fishing years 1989-90 to 2003-04.

	FMA 1	FMA 2	FMA 3	FMA 7	FMA 8	FMA 9	FMA 10
1989-90	98	4	< 1	< 1	< 1	0	0
1990-91	115	2	0	0	< 1	4	0
1991-92	121	5	< 1	0	0	3	0
1992-93	121	8	0	1	< 1	< 1	0
1993-94	77	12	2	0	< 1	1	< 1
1994-95	109	5	0	0	< 1	1	< 1
1995-96	94	8	< 1	< 1	< 1	4	0
1996-97	80	7	< 1	1	< 1	2	0
1997-98	75	4	< 1	< 1	< 1	3	0
1998-99	58	3	3	< 1	< 1	1	0
1999-00	55	4	< 1	2	< 1	1	0
2000-01	64	2	1	< 1	< 1	2	0
2001-02	55	3	1	< 1	< 1	< 1	0
2002-03	62	2	< 1	0	< 1	2	0
2003-04	32	2	< 1	< 1	< 1	2	0

Table 3: Reported domestic landings (t) and TACC by Porae Fishstock, fishing years 2004-05 to 2010-11.

Fishstock		POR 1		POR 2		POR 3		POR 10		
FMA		1		2, 8&9		3,4,5,6&7		10		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004-05	52	62	5	6	< 1	2	0	1	57	71
2005-06	47	62	2	6	< 1	2	0	1	49	71
2006-07	64	62	9	6	0	2	0	1	73	71
2007-08	45	62	7	6	< 1	2	0	1	53	71
2008-09	52	62	5	6	0	2	0	1	57	71
2009-10	57	62	11	6	< 1	2	0	1	68	71
2010-11	65	62	7	6	< 1	2	0	1	72	71

1.2 Recreational fisheries

Recreational fishers are likely to catch porae whilst targeting species such as snapper, tarakihi and trevally with either hook and line or setnet. Opportunistic targeting of porae is also likely when spearfishing.

1.3 Customary non-commercial fisheries

There is no quantitative information on customary non-commercial harvest levels of porae. Customary non-commercial fishers are likely to catch small quantities of porae when targeting other species such as snapper, tarakihi and trevally.

2. BIOLOGY

Porae (*Nemadactylus douglasii*) is a common inshore species of northern New Zealand (Kermadec Islands, west Auckland and Northland, east Northland, Hauraki Gulf, and the Bay of Plenty). It is also found at some localities as far south as Kapiti Island, Cook Strait and Kaikoura over the summer months, but has not been recorded around the Chatham Islands. Porae also occurs in southeast Australia (New South Wales to Tasmania), where it is known as the grey or rubberlip morwong.

Porae are generally found on reef/sand interfaces in 10-60 m depth, but have been recorded at 100 m. This diurnal species tends to aggregate to form small to large groups over sandy areas. Adults are thought to occupy distinctive home ranges, with individuals residing in the same area for many years. A study along the east coast of Northland recorded an average of 200 porae for each kilometre of rocky coastline.

Very little is known about the biology of this species. They spawn in late summer and autumn, and have an extended planktonic postlarval stage. Juveniles settle to the seafloor at 8-10 cm long. Although they attain a maximum length of at least 70 cm, the average size is 40−60 cm. They live to at least 30 years and growth is believed to slow substantially at maturity (Ayling & Cox 1984, Francis 2001).

3. STOCKS AND AREAS

There is no biological information to suggest separate stocks around New Zealand. However, evidence of residential behaviour and the fact that they are long-lived, suggests that localised depletion is likely to occur.

4. STOCK ASSESSMENT

There is no fishery independent stock assessment information to determine the stock status of porae. Biomass estimates have not been determined for porae.

5. STATUS OF THE STOCK

Estimates of current and reference biomass are not available. It is not known if recent catch levels or TACs are sustainable. The status of POR 1, 2 and 3 relative to B_{MSY} is unknown.

TACCs and reported landings for the 2010-11 fishing year are summarised in Table 4.

Table 4: Summary of TACCs (t) and reported landings (t) of porae for the most recent fishing year.

Fishstock		FMA	2010-11 Actual TACC	2010-11 Reported landings
POR 1	Auckland (East)	1	62	65
POR 2	Central (East)	2	6	**7**
POR 3	South east, Southland, sub-Antarctic, Challenger	3,4,5,6,7, 8 &9	2	0.1
POR 10	Kermedec	10	1	0
Total			71	72

6. FOR FURTHER INFORMATION

Ayling T., Cox G.J. 1984. Collins guide to the sea fishes of New Zealand. Collins, Auckland. 343p.

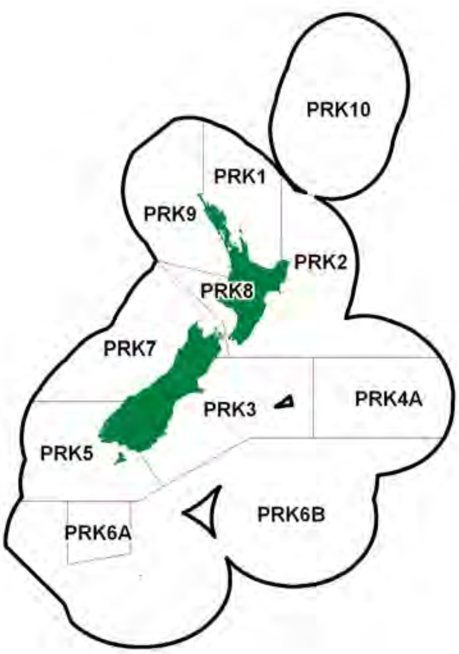
Francis M. 2001. Coastal fishes of New Zealand. An identification guide. Reed Books, Auckland. 103p. + pls.

Stewart P. 1993. Morwong, *Nemadactylus* species. *In* Kailola *et al*. (Eds), Australian fisheries resources. pp. 324-326. Bureau of Resource Sciences, Canberra. 422p.

Thompson S. 1981. Fish of the Marine Reserve. A guide to the identification and biology of common coastal fish of north-eastern New Zealand. Leigh Laboratory, University of Auckland. 364p.

PRAWN KILLER (PRK)

(*Ibacus alticrenatus*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Prawn killer (*Ibacus alticrenatus*) was introduced to the Quota Management System on 1 October 2007, with a combined TAC of 37.4 t and TACC of 36 t. There are no allowances for customary non-commercial or recreational fisheries, and 1.4 t was allowed for other sources of mortality. PRK is almost all taken as a bycatch in the scampi target trawl fishery in SCI 1 and SCI 2. Reported catches in PRK 1 have a maximum of 42 t in 1992-93. Landings in PRK 2 are minimal with a maximum of 8 t in 2002-03 (Table 1). Landings are likely to be less than total catches due to unreported discarding.

Table 1: TACCs and reported landings (t) of Prawn killer by Fishstock from 1990-91 to 2010-11 from CELR and CLR data. FMAs are shown as defined in 2007-08.

	PRK 1		PRK 2		PRK 3		PRK 4A		PRK 5		PRK 6A	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990-91	11.59	-	0	-	0	-	0	-	0	-	0	-
1991-92	3.34	-	0.48	-	0	-	0	-	0	-	0	-
1992-93	42.24	-	6.86	-	0	-	0	-	0	-	0	-
1993-94	10.95	-	0.03	-	0	-	0	-	0	-	0	-
1994-95	0.52	-	0	-	0	-	0	-	0	-	0	-
1995-96	1.78	-	0	-	0	-	0	-	0	-	0	-
1996-97	23.13	-	0	-	0	-	0	-	0	-	0	-
1997-98	0	-	0	-	0	-	0	-	0	-	0	-
1998-99	0	-	0.19	-	0	-	0	-	0	-	0	-
1999-00	0.08	-	0	-	0	-	0	-	0	-	0	-
2000-01	0	-	0	-	0	-	0	-	0	-	0	-
2001-02	6.05	-	0.37	-	0	-	0	-	0	-	0	-
2002-03	20.99	-	8.09	-	0	-	0	-	0	-	0	-
2003-04	24.35	-	0.57	-	0.01	-	0.01	-	0	-	0	-
2004-05	3.25	-	1.15	-	0	-	0	-	0	-	0	-
2005-06	2.25	-	0.20	-	0	-	0	-	0	-	0	-
2006-07	4.6	-	0.10	-	0	-	0	-	0	-	0	-
2007-08	5.36	24.5	0.92	3.5	0.01	1	0.02	1	0	1	0	1
2008-09	0.22	24.5	0.08	3.5	0	1	0	1	0	1	0	1
2009-10	0.75	24.5	0.029	3.5	0.001	1	0	1	0	1	0	1
2010-11	3.55	24.5	0.078	3.5	0	1	0.002	1	0	1	0	1

Table 1 continued:

	PRK 6B		PRK 7		PRK 8		PRK 9		TOTAL	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990-91	0	-	0	-	0	-	0	-	11.58	-
1991-92	0	-	0	-	0	-	0	-	3.82	-
1992-93	0.02	-	0	-	0	-	0	-	49.12	-
1993-94	0	-	0	-	0	-	0	-	10.98	-
1994-95	0	-	0	-	0	-	0	-	0.52	-
1995-96	0	-	0	-	0	-	0	-	1.78	-
1996-97	0	-	0	-	0	-	0	-	23.13	-
1997-98	0	-	0	-	0	-	0	-	0	-
1998-99	0	-	0	-	0	-	0	-	0.19	-
1999-00	0	-	0	-	0	-	0	-	0.08	-
2000-01	0	-	0	-	0	-	0	-	0	-
2001-02	0	-	0	-	0	-	0	-	6.42	-
2002-03	0	-	0	-	0	-	0	-	29.08	-
2003-04	0	-	0	-	0	-	0	-	24.94	-
2004-05	0	-	0	-	0	-	0	-	4.40	-
2005-06	0	-	0.01	-	0	-	0.01	-	2.47	-
2006-07	0	-	0.03	-	0	-	0	-	4.73	-
2007-08	0	1	1.2	1	0	1	0	1	7.51	36
2008-09	0	1	0.88	1	0	1	0	1	1.18	36
2009-10	0	1	0.484	1	0	1	0	1	1.267	36
2010-11	0	1	0.692	1	0.008	1	0	1	4.334	36

1.2 Recreational fisheries
There is no known non-commercial fishery for prawn killer.

1.3 Customary non-commercial fisheries
There is no known customary non-commercial fishery for prawn killer.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch of prawn killer.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although analysis of benthic invertebrate samples and the distribution of trawl tows in the Bay of Plenty (PRK 1) suggests that this species is negatively affected by trawling.

2. BIOLOGY

Ibacus alticrenatus is widely distributed around the New Zealand coast, principally in depths of 80-300 m. Prawn killers are found on soft sediment seafloors, where they dig into the substrate and cover themselves with sediment.

There is not much information about growth and development of *I. alticrenatus* in New Zealand waters, but females are thought to mature at a carapace length of about 40 mm. Information from Australia suggests this species has relatively low fecundity (1 700 - 14 800 eggs, increasing with size) and spawns annually. Larval development takes 4-6 months, an intermediate duration for a Scyllarid lobster. Females of other *Ibacus* species reach maturity ~2 years after settlement and longevity is suggested to be 5 years or more.

Although the following species might be caught as part of the prawn killer catch — *Ibacus brucei, Antipodarctus aoteanus,* and *Scyllarus mawsoni* , which is thought to be rare.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on those used for scampi. However, there is no biological information on stock structure, recruitment patterns, or other biological characteristics which might indicate stock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any prawn killer fishstock.

4.2 Biomass estimates

There are no biomass estimates for any prawn killer fishstock.

4.3 Estimation of Maximum Constant Yield (*MCY*)

There are no estimates of *MCY* for any prawn killer fishstock.

4.4 Estimation of Current Annual Yield (*CAY*)

There are no estimates of *CAY* for any prawn killer fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any prawn killer fishstock. It is not known whether prawn killer stocks are at, above, or below a level that can produce *MSY*.

6. FOR FURTHER INFORMATION

Atkinson J.M., Boustead N.C. 1982 “The complete larval development of the scyllarid lobster *Ibacus alticrenatus* Bate, 1888 in New Zealand waters”. *Crustaceana* 42: 275-287.

Booth J.D., Webber W.R., Sekiguchi H., Coutures E. 2005 “Diverse larval recruitment strategies within the Scyllaridae. *New Zealand Journal of Marine and Freshwater Research* 39: 581-592.

Brown D.E., Holthuis L.B. 1998 “The Australian species of the genus *Ibacus* (Crustacea: Decapoda: Scyllaridae), with the description of a new species and addition of new records”. *Zool. Meded. (Leiden)* 72(10): 113-141.

Cryer M., Hartill B., O’Shea S. 2002 “Modification of marine benthos by trawling: toward a generalization for the deep ocean?” *Ecological Applications*, 12(6): 1824-1839.

Haddy J.A., Courtney A.J., Roy D.P. 2005 “Aspects of the reproductive biology and growth of Balmain bugs (*Ibacus* spp.) (Scyllaridae)”. *Journal of Crustacean Biology*, 25(2): 263-273.

QUEEN SCALLOPS (QSC)

(*Zygochlamys delicatula*)

1. FISHERY SUMMARY

Queen scallops were introduced into the QMS in October 2002, with a current TACC (unchanged since its introduction) of 380 t and a 20 t allowance for other sources of fishing related mortality. The fishing year runs from the 1 October to the 30 September and the catch is reported in greenweight.

1.1 Commercial fisheries

The QSC 3 fishery initially developed in the 1984–85 fishing year; it is a small-scale fishery with only a few fishing vessels involved (Michael & Cranfield 2001). Queen scallops (*Zygochlamys delicatula*) are predominantly harvested commercially off the Otago coast, in depths of 130–200 m (predominately 150-200m) near the edge of the continental shelf. Reported landings from this fishery peaked at 711 t in the 1985–86 fishing year. Annual landings in most recent years have been less than 200 t, although this catch level is more likely associated with economic, than biological, factors. The TACC was set in 2002 at a slightly higher than the level of recent landings but lower than the non-QMS competitive catch limit of 750 t which applied to FMA 3 from 1990–91. Reported landings of queen scallops are given in Table 1, whereas Figure 1 shows historical landings and TACC for QSC 3. Queen scallops are trawled for using specialised gear (including a relatively light ‘tickler’ chain or wire to induce swimming) and the catch is sorted both mechanically and by hand (Michael & Cranfield 2001, R. Belton pers. comm.).

1.2 Recreational fisheries

There is no known recreational fishery for queen scallops.

1.3 Customary fisheries

There is no known customary harvest of queen scallops.

1.4 Illegal catch

Current levels of illegal harvest are not known.

1.5 Other sources of mortality

No quantitative estimate of other sources of mortality is available. Some grading of catch may occur (queen scallops may be returned to the sea) and an allowance of 20 t for potential mortality has been set within the current TAC.

Table 1: Reported landings (t greenweight) of queen scallops (QSC) by FMA, QMA and fishing year by all methods trawl and dredge) 1989–90 to 2010-11 from Quota Management Reports (QMR), Monthly Harvest Returns (MHR) and Catch Effort Landing Returns (CELR landed and CELR estimated).

	QSC3			FMA3	FMA5
Fishing year	Catch (QMR/MHR)	TACC*	Estimated catch (TCEPR/CELR)	Landings (CELR/CLR)	Landings (CELR/CLR)
1989–90	11.9	-	288.1	-	-
1990–91	61.8	-	238.3	-	22.9
1991–92	77.4	-	193.7	-	-
1992–93	0.4	-	104.7	-	-
1993–94	1.1	-	133.6	-	-
1994–95	23.6	-	146.9	-	-
1995–96	4.5	-	149.5	-	0.2
1996–97	20.9	-	118.0	-	6.6
1997–98	56.0	-	208.3	-	6.0
1998–99	85.9	-	81.7	-	-
1999–00	180.2	-	176.8	-	-
2000–01	162.2	-	162.1	-	-
2001–02	223.7	-	168.9	-	-
2002–03	139.0	380	-	-	-
2003–04	114.0	380	-	-	-
2004–05	35.1	380	-	-	-
2005–06	18.6	380	-	-	-
2006–07	6.5	380	-	-	-
2007–08	9.5	380	-	-	-
2008–09	48.7	380	-	-	-
2009–10	25.3	380	-	-	-
2010–11	2.8	380	-	-	-

* QMS introduction 1 October 2002

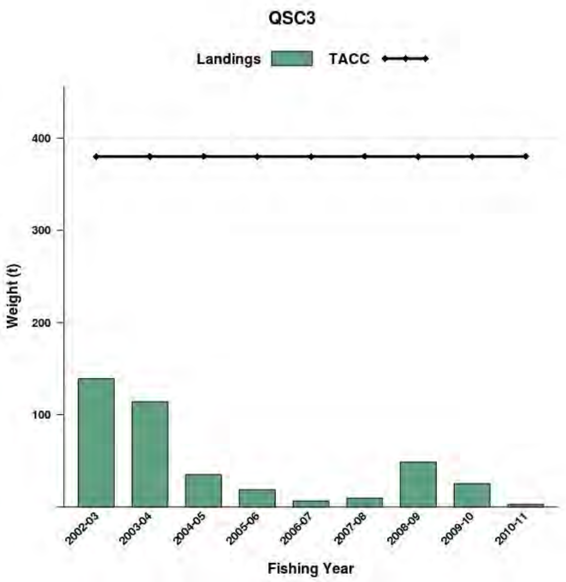


Figure 1: Historical landings and TACC for QSC 3 (South East Coast, Southland). Note that these figures do not show data prior to entry into the QMS.

2. BIOLOGY

The New Zealand queen scallop (*Zygochlamys delicatula*) is also known as the southern queen scallop, southern fan scallop, and gem scallop. This small pectinid species is distributed on the outer continental shelf along the east coast of the South Island, from Kaikoura down to Macquarie Island. There are nine other species in the genus, none of which have attracted commercial interest, probably because of their small size. Similar species such as *Chlamys islandica* and *Chlamys varia* support important fisheries in other countries. New Zealand queen scallops are distributed from Kaikoura to the southern islands including the Snares, Bounty, Antipodes, and Macquarie Islands. There are no records of live queen scallops being caught north of Kaikoura, or on the west coast of the South Island.

A dredge survey off Otago in October 1983 showed queen scallops were distributed in long patches orientated along the slope of the continental shelf. They were most abundant in depths beyond 130 m, on the plateau between the Taiaroa and Papanui Canyons, and south. North of the Taiaroa Canyon catches diminished steadily towards the Karitane Canyon; few were caught north of the canyon. Only low numbers of queen scallops were caught in depths shallower than 110 m.

Juvenile queen scallops are frequently found attached to fragments of bryozoa and other biogenic debris, including the shells of other scallops and the dredge oyster. Height frequency distributions of samples show size composition of the population differs with area, and it is inferred that settlement probably varies spatially and temporally. The estimated 40–50 days larval life may result in queen scallop larvae being well mixed, both vertically and horizontally, in the water column. Predation of newly settled spat may also affect the pattern of recruitment and add to the variability in year class representation.

Estimates of growth for New Zealand queen scallops suggest they become sexually mature at four years for males and five years for females. As length is slightly less than height, queen scallops are estimated to reach the minimum takeable size of 50 mm at about eight years. However, growth estimates are uncertain, with information from tagging studies suggesting queen scallops enter the fishery much earlier, at three to five years.

3. STOCKS AND AREAS

Queen scallops are distributed throughout the QSC 3 area. From harvest records the scallops inhabit waters between 130 to 200 m. The extent to which various beds or populations are separate reproductively or functionally is not known.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

No estimates of fishery parameters or abundance are available at present.

4.2 Biomass estimates

A trawl survey, (Jiang *et al*. 2005) carried out in February - April 2004, provided estimates of relative total and recruited biomass (shells $\geq$ 50 mm) available from the fished area of QSC 3, from Moeraki to just north of the Nuggets within the depth range 130 to 200 m, which covers 90% of the fished area within QSC 3 (Table 2). These estimates assumed that the efficiency of the survey trawl was 100%. However trawl efficiency is unlikely to be 100% and in other scallop fisheries can vary significantly depending on dredge and substrate type. Consequently estimates of current absolute biomass cannot be estimated. The Shellfish Working Group had concerns over methodology and conduct of the survey, and that the reported survey CVs may not be reliable.

Table 2: Estimated scallop biomass (recruit and pre-recruit) (t) in fished areas of QSC 3 February-April 2004.

Biomass Recruit (CV)	Biomass (CV) Pre-recruit	Total Biomass (CV)
1 950.8 (18.2)	363.6 (21.48)	2 314.4 (18.22)

4.3 Estimation of Maximum Constant Yield (*MCY*)

As absolute biomass has not been estimated, *MCY* cannot be estimated

4.4 Estimation of Current Annual Yield (*CAY*)

CAY cannot be estimated.

5. STATUS OF THE STOCKS

Stock structure assumptions

QSC 3 is assumed to be a single stock

- QSC - *Zygochlamys delicatula*

Stock Status	
Year of Most Recent Assessment	2004
Assessment Runs Presented	Recruited biomass (shells ≥ 50 mm)
Reference Points	Target: Undefined Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	N/A
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status Unknown	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Landings are less than a quarter of the TACC and have generally been declining since 2002–03.

Projections and Prognosis		
Stock Projections or Prognosis	Unknown	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	None	
Assessment Method	N/A	
Main data inputs	-	
Period of Assessment	-	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Landings are thought to have been declining in recent times due to economic rather than biological factors.

Fishery Interactions
Concerns over interactions between dredge fishing and complex habitats

Table 3: Summary of TACCs (t) and reported landings (t) of Queen scallops for the most recent fishing year.

Fishstock	QMA	*MCY*	*CAY*	Current year Actual TACC	Current year Reported landings
QSC 3	3	NA	NA	380	3

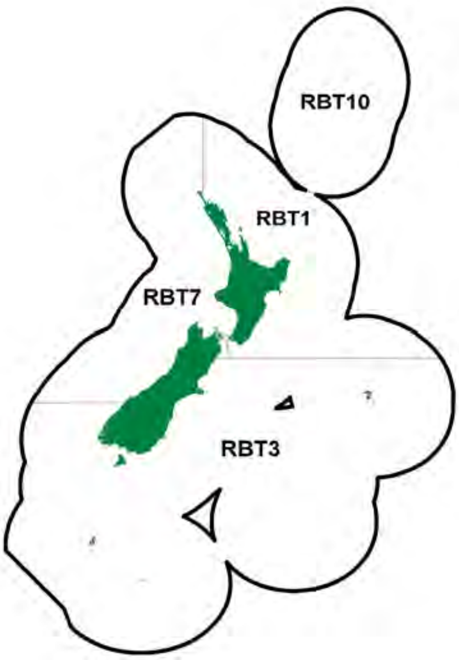
6. FOR FURTHER INFORMATION

Jiang W., Gibbs M., Hatton S. 2005. Stock assessment of the queen scallop fishery in QSC3. Final Fisheries Research Report for Ministry of Fisheries project QSC2002/01: Stock assessment of the queen scallop fishery in QSC3.

Michael K.P., Cranfield H.J. 2001. A summary of the fishery, commercial landings, and biology of the New Zealand queen scallop, *Zygochlamys delicatula* (Hutton, 1873). New Zealand Fisheries Assessment Report 2001/68. 25p.

REDBAIT (RBT)

(*Emmelichthys nitidus*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Redbait (*Emmelichthys nitidus*) was introduced to the Quota Management System on 1 October 2009, with a combined TAC of 5316 t and TACC of 5050 t. There are no allowances for customary non-commercial or recreational fisheries, and 266 t was allowed for other sources of mortality. RBT is mainly taken as bycatch of the jack mackerel target trawl fishery, with some taken in the squid and barracouta fisheries. In the last 7 years, 3.1% of the catch of redbait has been taken in a target fishery, although this is increasing and 11% of the 2007-08 catch was targeted. Reported total catches have ranged from 2185 to 4308 tonnes since 2001-02. TACs, allowances and TACCs from 1 October 2009 are reported in Table 1. Table 2 and Figure 1 show historical landings from 2001-02 to 2010-11, reported by newly defined QMAs.

Table 1: TACs, allowances and TACCs of redbait.

Fishstock	Other mortality	Customary non-commercial and recreational	TACC	TAC
RBT 1	1	0	19	20
RBT 3	115	0	2 190	2 305
RBT 7	150	0	2 841	2 991
RBT 10	0	0	0	0

Table 2: Reported landings (t) of redbait by Fishstock from 2001-02 to 2010-11 from MHR data. QMAs are shown as defined for 2009-11.

	RBT 1		RBT 3		RBT 7		RBT 10			
FMA	1, 2		3, 4, 5, 6		7, 8, 9		10		Total	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2001-02	1	-	1 638	-	1 669	-	0	-	3 308	-
2002-03	1	-	1 219	-	2 113	-	0	-	3 333	-
2003-04	1	-	1 535	-	2 771	-	0	-	4 307	-
2004-05	1	-	676	-	1 507	-	0	-	2 184	-
2005-06	3	-	2 016	-	1 936	-	0	-	3 955	-
2006-07	3	-	1 098	-	1 506	-	0	-	2 607	-
2007-08	5	-	560	-	2 376	-	0	-	2 941	-
2008-09	10	-	1 808	-	1 649	-	0	-	3 467	-
2009-10	9	19	886	2 190	170	2 841	0	0	1 066	5 050
2010-11	21	19	284	2 190	713	2 841	0	0	1 017	5 050

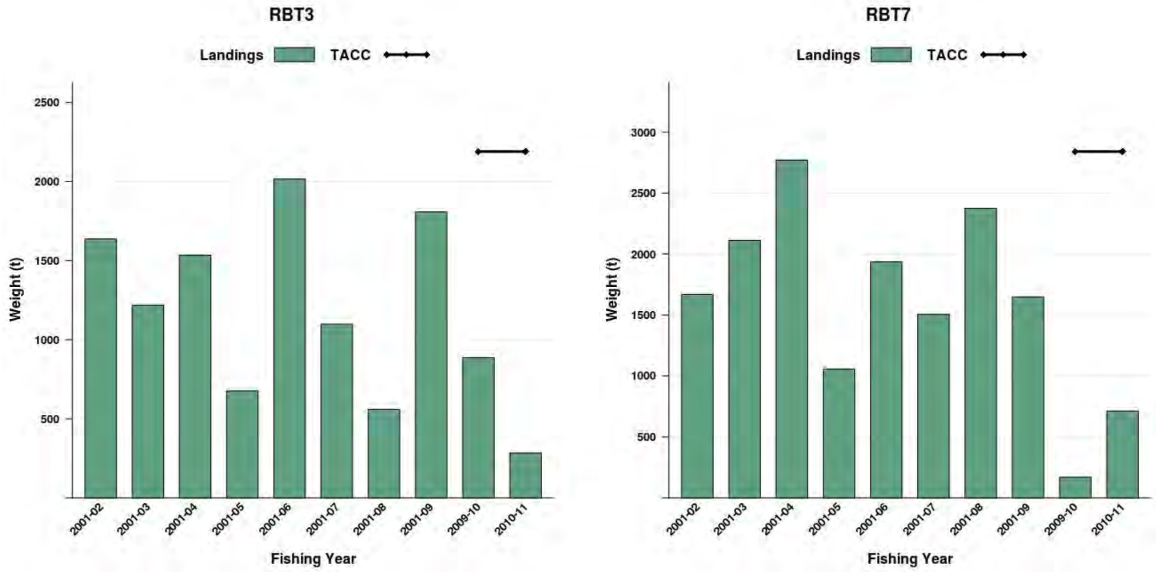


Figure 1: Historical landings and TACC for the two main RBT stocks. From left: RBT3 (South East Coast) and RBT7 (Challenger).

1.2 Recreational fisheries
There is no known non-commercial fishery for redbait.

1.3 Customary non-commercial fisheries
There is no known customary non-commercial fishery for redbait.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch of redbait.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality.

2. BIOLOGY

Emmelichthys nitidus is a schooling, bathypelagic species that is closely related to rubyfish. It is widely distributed around New Zealand in depths from 85 to 500m. Juveniles are found at the surface and adults near the bottom in deeper waters, including seamounts.

There is not much information about growth and development of redbait although they reach a maximum length of 50 cm and a maximum age of 10 years. Spawning is thought to last 2-3 months during spring, with 50% mature at 24 cm FL and 2-3 years. Table 3 shows estimated biological parameters for redbait.

Table 3: Estimates of biological parameters for redbait

Fishstock		Estimate		Source
1. von Bertalanffy growth parameters				
		Combined sexes		
RBT (ALL)	L_∞	k	t_0	
	28.7	0.56	-0.36	Taylor (2009)

3. STOCKS AND AREAS

There is no information about stock structure, recruitment patterns, or other biological characteristics that would indicate stock boundaries. As the catch of redbait has been mainly (66%) from bycatch in the jack mackerel trawl fisheries, management boundaries have been set the same as those used for jack mackerel.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any redbait fishstock.

4.2 Biomass estimates

There are no biomass estimates for any redbait fishstock.

4.3 Estimation of Maximum Constant Yield (*MCY*)

There are no estimates of *MCY* for any redbait fishstock.

4.4 Estimation of Current Annual Yield (*CAY*)

There are no estimates of *CAY* for any redbait fishstock.

6. STATUS OF THE STOCKS

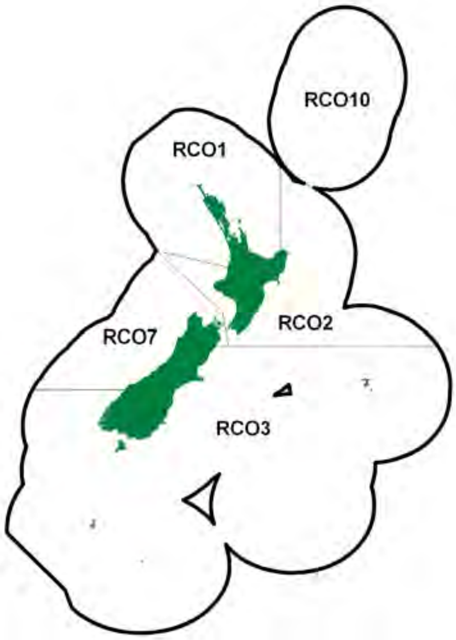
There are no estimates of reference or current biomass for any redbait fishstock. It is not known whether redbait stocks are at, above, or below a level that can produce *MSY*.

7. FOR FURTHER INFORMATION

Taylor P.R. 2009. A summary of information on redbait *Emmelichthys nitidus*. Draft Final Research Report for Ministry of Fisheries Project SAP2008-18.

RED COD (RCO)

(*Pseudophycis bachus*)
Hoka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Red cod are targeted primarily by domestic trawlers in the depth range between 30 and 200 m and are also a bycatch of deepwater fisheries off the southeast and southwest coasts of the South Island. The domestic red cod fishery is seasonal, usually beginning in November and continuing to May or June, with peak catches around January and May. During spring and summer, red cod are caught inshore before moving into deeper water during winter.

Reported annual catches by nation from 1970 to 1986-87 are given in Table 1. RCO entered the QMS in 1986, foreign vessel catches declined and were negligible by 1987-88.

Table 1: Reported annual catch (t) of red cod by nation from 1970 to 1986-87.

	New Zealand		Foreign licensed				Combined Total
Fishing year	Domestic	Chartered	Japan	Korea	USSR	Total	
1970*	760	-	995	-	-	995	1 755
1971*	393	-	2 140	-	-	2 140	2 533
1972*	301	-	2 082	-	< 100	2 182	2 483
1973*	736	-	2 747	-	< 100	2 847	3 583
1974*	1 876	-	2 950	-	< 100	3 050	4 926
1975*	721	-	2 131	-	< 100	2 231	2 952
1976*	948	-	4 001	-	600	4 601	5 549
1977*	2 690	-	8 001	1 358	§2 200	11 559	14 249
1978-79*	5 343	124	2 560	151	51	2 762	8 229
1979-80*	5 638	883	537	259	116	912	7 433
1981-82*	3 210	387	474	70	102	646	4 243
1982-83*	4 342	406	764	675	52	1 493	6 241
1983-83†	3 751	390	149	401	3	553	4 694
1983-84†	10 189	1 764	1 364	480	49	1 893	13 846
1984-85†	14 097	2 381	978	829	7	1 814	18 292
1985-86†	9 035	1 014	739	147	5	891	10 940
1986-87‡	2 620	1 089	197	4	59	261	3 969

1970-1977 = calendar years; 1978-79 to 1982-83 = 1 April-31 March; 1980-1981=no fishing returns processed this year; 1983-1983 - 1 April-30 September; 1983-84 to 1986-87 - 1 October-30 September; * MAF data; † FSU data; ‡ QMS data § mainly ribaldo and red cod.

Recent reported landings and TACCs of red cod by Fishstock are shown in Table 2, while Figure 1 depicts historical landings and TACC values for the three main RCO stocks.

Table 2: Reported landings (t) of red cod by Fishstock from 1983-84 to 2010-11, and actual TACCs (t) for 1986-87 to 2010-11. The QMS data is from 1986-present.

Fishstock	RCO 1		RCO 2		RCO 3		RCO 7		RCO 10	
FMA (s)	1 & 9		2 & 8		3, 4, 5 & 6		7		10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983-84*	12	-	197	-	9 357	-	3051	-	0	-
1984-85*	9	-	126	-	14 751	-	1 442	-	0	-
1985-86*	6	-	48	-	9 346	-	408	-	0	-
1986-87	5	30	46	350	3 300	11 960	619	2 940	0	10
1987-88	8	40	81	357	2 878	12 182	1 605	2 982	0	10
1988-89	9	40	85	359	7 732	12 362	1 345	3 057	0	10
1989-90	8	42	105	362	6 589	13 018	800	3 105	0	10
1990-91	12	42	68	364	4 630	12 299	839	3 125	0	10
1991-92	26	42	358	364	6 500	12 299	2 220	3 125	0	10
1992-93	46	42	441	364	9 633	12 389	4 083	3 125	0	10
1993-94	44	42	477	364	7 977	12 389	2 992	3125	0	10
1994-95	63	42	762	364	12 603	12 389	3 569	3 125	0	10
1995-96	28	42	584	500	11 038	12 389	3 728	3 125	0	10
1996-97	42	42	396	500	10 056	12 389	3 710	3 125	0	10
1997-98	22	42	192	500	9 972	12 389	2 700	3 125	0	10
1998-99	10	42	282	500	13 926	12 389	2 055	3 125	0	10
1999-00	3	42	130	500	4 824	12 389	633	3 125	0	10
2000-01	5	42	112	500	2 776	12 389	1 538	3 125	0	10
2001-02	6	42	150	500	2 862	12 389	1 409	3 126	0	10
2002-03	8	42	144	500	5 107	12 389	1 657	3 126	0	10
2003-04	11	42	225	500	7 724	12 389	2 358	3 126	0	10
2004-05	21	42	423	500	4 212	12 389	3 052	3 126	0	10
2005-06	24	42	372	500	3 222	12 389	3 061	3 126	0	10
2006-07	25	42	256	500	1 877	12 389	3 409	3 126	0	10
2007-08	12	42	225	500	3 236	4 600	2 984	3 126	0	10
2008-09	12	42	212	500	2 542	4 600	2 131	3 126	0	10
2009-10	14	42	364	500	2 994	4 600	1 864	3 126	0	10
2010-11	19	42	501	500	4 567	4 600	1 603	3 126	0	10

Fishstock		
FMA (s)	Total	
	Landings§	TACC
1983-84*	13 848	-
1984-85*	18 292	-
1985-86*	10 940	-
1986-87	3 970	15 290
1987-88	4 506	15 571
1988-89	9 171	15 828
1989-90	7 502	16 537
1990-91	5 549	15 840
1991-92	9 104	15 840
1992-93	14 203	15 930
1993-94	11 491	15 930
1994-95	16 997	15 930
1995-96	15 350	16 066
1996-97	14 204	16 066
1997-98	12 886	16 066
1998-99	16 273	16 066
1999-00	5 590	16 066
2000-01	4 432	16 066
2001-02	4 427	16 067
2002-03	6 916	16 067
2003-04	10 318	16 067
2004-05	7 708	16 067
2005-06	6 679	16 067
2006-07	5 567	16 067
2007-08	6 457	8 278
2008-09	4 897	8 278
2009-10	5 236	8 278
2010-11	6 691	8 278

*FSU data.
§ Includes landings from unknown areas before 1986-87.

Historically the bulk of the reported landings were taken from RCO 3, in particular the Canterbury Bight and Banks Peninsula areas, but since 2003-04 the RCO 3 fishery has been in decline and the RCO 7 2006-07 landings exceeded the RCO 3 landings for the first time. The red cod fishery is characterised by large variations in catches between years. Research indicates that this interannual variation in catch is due to varied recruitment causing biomass fluctuations rather than a change in catchability. Annual landings have been substantially lower than the TACCs in all QMAs since 1999-00 and, with the exception of the 2003-04 fishing year, total catches have been below 10 000 t. Total landings are at their lowest levels since 2002-03, as a result of substantial declines in catches in RCO 3. The RCO 3 TACC was reduced by 63% from the 1 October 2007 to 4600 t, with the TAC being set at 4930 t (customary, recreational and other sources of mortality were allocated 5, 95 and 230 t respectively). All RCO stocks fisheries have been put on to Schedule 2 of the Fisheries Act 1996. Schedule 2 allows that for certain "highly variable" stocks, the Total Annual Catch (TAC) can be increased within a fishing season. The base TAC is not changed by this process and the "in-season" TAC reverts to the original level at the end of each season. No RCO stocks have yet had an in-season increase.

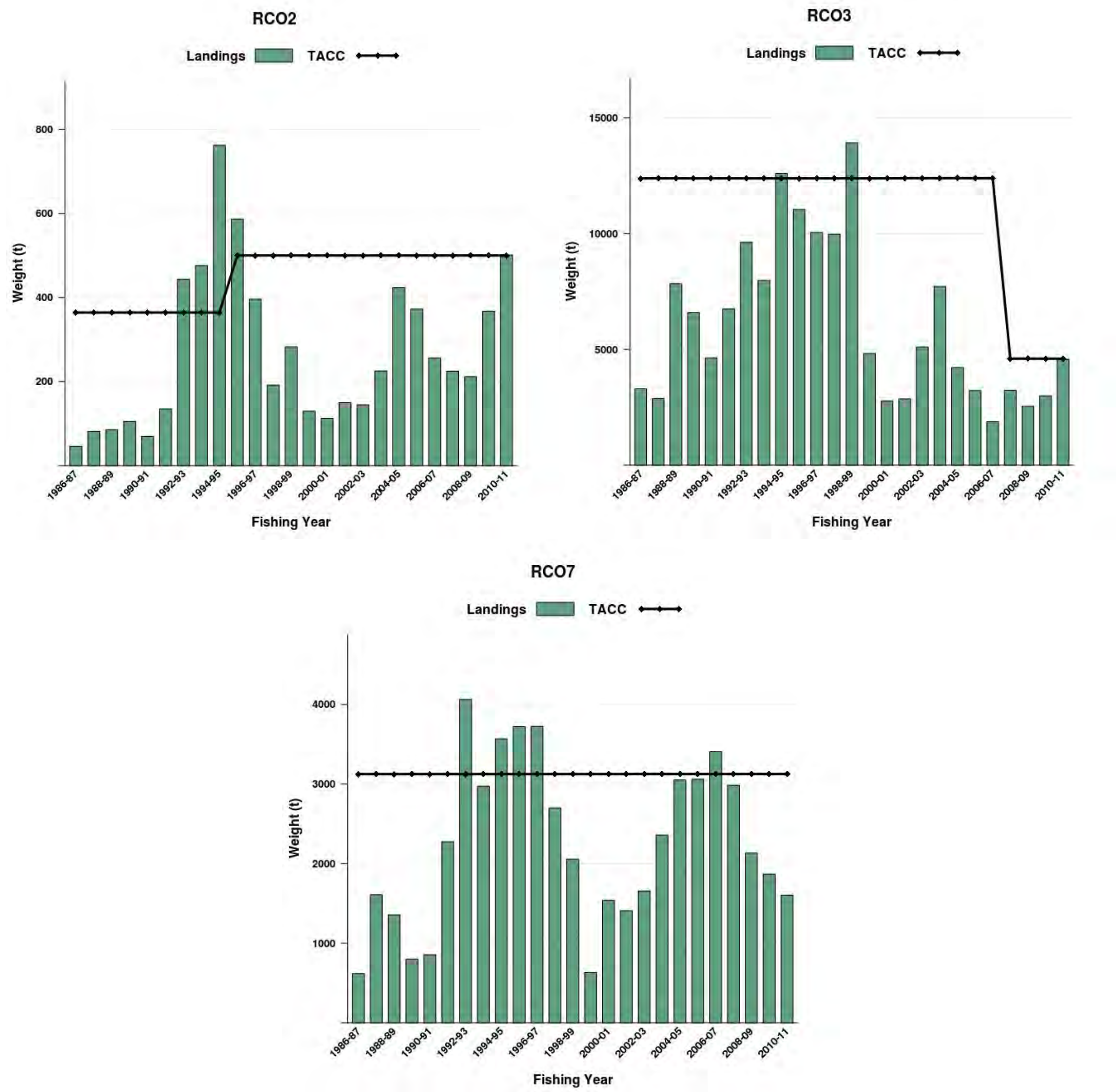


Figure 1: Historical landings and TACC for the three main RCO stocks. From top left: RCO2 (Central East), RCO3 (South East Coast), and RCO7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

Recreational fishers take red cod, particularly on the east coast of the South Island. Results of five separate recreational fishing surveys are shown in Table 3.

Table 3: Estimated number and weight of red cod harvested by recreational fishers, by Fishstock and survey. Surveys were carried out in different years in the Ministry of Fisheries regions: South in 1991-92, Central in 1992-93, North in 1993-94 (Teirney *et al*. 1997) and nationally in 1996 (Bradford 1998) and 1999-00 (Boyd & Reilly 2002). Survey harvest is presented as a range to reflect the uncertainty in the estimates.

Fishstock	Survey	Number	CV %	Estimated harvest range (t)	Estimated point estimate (t)
					1991-92
RCO 3	South	104 000	16	90-120	-
RCO 7	South	1 000	-	0-5	-
					1992-93
RCO 2	Central	151 000	19	105-155	-
RCO 7	Central	1 100	34	5-15	-
1993-94					
RCO 1	North	9000	34	5-15	-
					1996
RCO 1	National	11 000	18	5-15	11
RCO 2	National	88 000	11	80-105	92
RCO 3	National	99 000	10	90-115	103
RCO 7	National	38 000	15	30-50	40
					1999-00
RCO 1	National	21 000	36	5-11	8
RCO 2	National	39 000	25	8-14	11
RCO 3	National	207 000	25	210-349	280
RCO 7	National	23 000	50	5-14	9

A key component of the 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 1999-00 harvest estimates for each Fishstock should be evaluated with reference to the coefficient of variation.

1.3 Customary non-commercial fisheries

Quantitative estimates of the current level of customary non-commercial catch are not available.

1.4 Illegal catch

Quantitative estimates of the level of illegal catch are not available.

1.5 Other sources of mortality

Processing limits on red cod are sometimes imposed to discourage fishers from landing red cod when the species cannot be processed or when markets are poor. This practice has encouraged dumping. Processing limits are currently less of a problem than in earlier years.

2. BIOLOGY

Red cod are a fast-growing, short-lived species with few fish in the commercial fishery older than six years. Red cod grow to about 25 cm total length (TL) in the first year, followed by annual growth increments of around 15, 10 and 5 cm. Growth of sexes is similar for the first two years, after which females tend to grow faster than males and reach a larger overall length. Sexual maturity ranges from 45 to 55 cm TL with a mean value of 52 cm TL for both sexes at an age of 2-3 years. *M* has been estimated to equal 0.76 for both sexes. In 1995, ageing of red cod was validated using marginal zone analysis.

In the 1989-90 to 1992-93 fishing years, 80% of the landings in RCO 3 were 2^+ and 3^+ fish (50-57 cm TL). The sex ratio of the commercial catch during this period was skewed towards females during November (F:M ratio of 3.4:1) with the ratio tending to even out by May. Schools are generally comprised of single age cohorts rather than a mix of age classes.

Spawning in red cod varies with latitude, with spawning occurring later at higher latitudes. In the Canterbury Bight, spawning occurs from August to October. No definite spawning grounds have been identified on the southeast coast, but there is some evidence that red cod spawn in deeper water (> 300-750 m). Running ripe fish were caught on the Puysegur Bank in 600 m during the Southland trawl survey in February 1994. Juvenile red cod are found in offshore waters after the spawning period; however, no nursery grounds are known for this species.

Red cod are seasonally abundant, with schools appearing in the Canterbury Bight and Banks Peninsula area around November. These schools are feeding aggregations and are not found in these waters after about June. Catch data indicates that they move into deeper water after this time. Recruitment is highly variable resulting in large variations in catches between years.

Biological parameters relevant to the stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters for red cod.

Fishstock						**Estimate**	**Source**
1. Natural mortality (*M*)							
RCO 3						0.76	Beentjes (1992)
2. Weight = a(length)^b (Weight in g, length in cm fork length).							
			Females			Males	
		a	b		a	b	
RCO 3		0.00074	3.059		0.0145	2.892	Beentjes (1992)
3. von Bertalanffy growth parameters							
			Females			Males	
	L_∞	k	t_0	L_∞	k	t_0	
RCO 3	76.5	0.41	-0.03	68.5	0.47	0.06	Horn (1995)
RCO 7	79.6	0.49	0.20	68.2	0.53	0.22	Beentjes (2000)

3. STOCKS AND AREAS

The number of red cod stocks is unknown. There are no new data which would alter the stock boundaries given in previous assessment documents.

4. STOCK ASSESSMENT

No recent stock assessments have been carried out on any red cod stocks. Previous assessments were undertaken, however, these are outdated but details appear in previous versions of the Plenary report.

Trawl survey biomass estimates are available from one *Tangaroa* and four *Kaharoa* time series (Table 5, Figures 2, 3 and 4). In 2001, the Inshore FAWG recommended that the summer east coast South Island trawl survey be discontinued due to the extreme variability in the catchability of the target species. The winter series was re-instated in 2007 and will be run initially for 3 consecutive years. The East and West Coast South Island trawl surveys track both biomass and population length structure.

Table 5: Biomass indices (t) and coefficients of variation (CV). (- no data). Vertical and areal availability and vulnerability were assumed to equal 1.0. Pre-recruit biomass are red cod < 41 cm.

Fishstock	Area	Trip code	Date	Biomass	% CV	Pre-recruit biomass	% CV
RCO 2	East coast	KAH 9304	Feb-Mar 1993	913	52	197	31
	North Island	KAH 9402	Feb-Mar 1994	1 298	50	547	52
		KAH 9502	Feb-Mar 1995	469	36	47	34
RCO 3	East coast	KAH 9105	May-Jun 1991	3 545	33	1 787	44
	South Island	KAH 9205	May-Jun 1992	4 527	40	2 277	50
RCO 3	(Winter)	KAH 9306	May-Jun 1993	5 601	29	1 252	50
		KAH 9406	May-Jun 1994	5 803	31	3 625	37
		KAH 9606	May-Jun 1996	4 567	30	664	31
		KAH0705	May-Jun 2007	1 486	25	190	33
		KAH0806	May-Jun 2008	1824	50	1695	50
		KAH0905	May-Jun 2009	1 871	40	1 038	41
RCO 3	Southland	TAN 9301	Feb-Mar 1993	100	68	-	-
		TAN 9402	Feb-Mar 1994	707	68	-	-
		TAN 9502	Feb-Mar 1995	2 554	49	182	66
		TAN 9604	Feb-Mar 1996	33 390	94	736	99
RCO 7	West coast	KAH 9204	Mar-Apr 1992	2 719	13	1 167	17
	South Island	KAH 9404	Mar-Apr 1994	3 169	18	888	25
		KAH 9504	Mar-Apr 1995	3 123	15	1 007	18
		KAH 9701	Mar-Apr 1997	2 546	23	1 353	28
		KAH 0004	Mar-Apr 2000	414	26	-	-
		KAH 0304	Mar-Apr 2003	906	24	290	31
		KAH0503	Mar-Apr 2005	2610	18	501	
		KAH0704	Mar-Apr 2007	1638	19	842	
		KAH0904	Mar-Apr 2009	2 782	25	1 614	27
RCO 3	East coast	KAH 9618	Dec-Jan 1996-97	10 634	23	4 101	23
	South Island	KAH 9704	Dec-Jan 1997-98	7 536	23	4 426	24
	(Summer)	KAH 9809	Dec-Jan 1998-99	12 823	17	3 770	15
		KAH 9917	Dec-Jan 1999-00	6 690	30	2 728	41
		KAH 0014	Dec-Jan 2000-01	1 402	82	1 283	89

4.5 Other factors

There have been large fluctuations in red cod abundance and landings, particularly on the east and west coast of the South Island. This causes problems for the fishers who rely on red cod, and creates additional pressure on the ACE system. Changes in catch rates of red cod, combined with the recovery of other quota species since the introduction of the QMS, has resulted in a catch mix for which some fishers do not have the appropriate quota holdings. Bycatch species while targeting red cod are stargazer, red gurnard, elephant fish, rig, school shark, blue cod, groper and tarakihi. As a result, effort into targeting red cod may be reduced to alleviate bycatch problems, despite the availability of red cod quota.

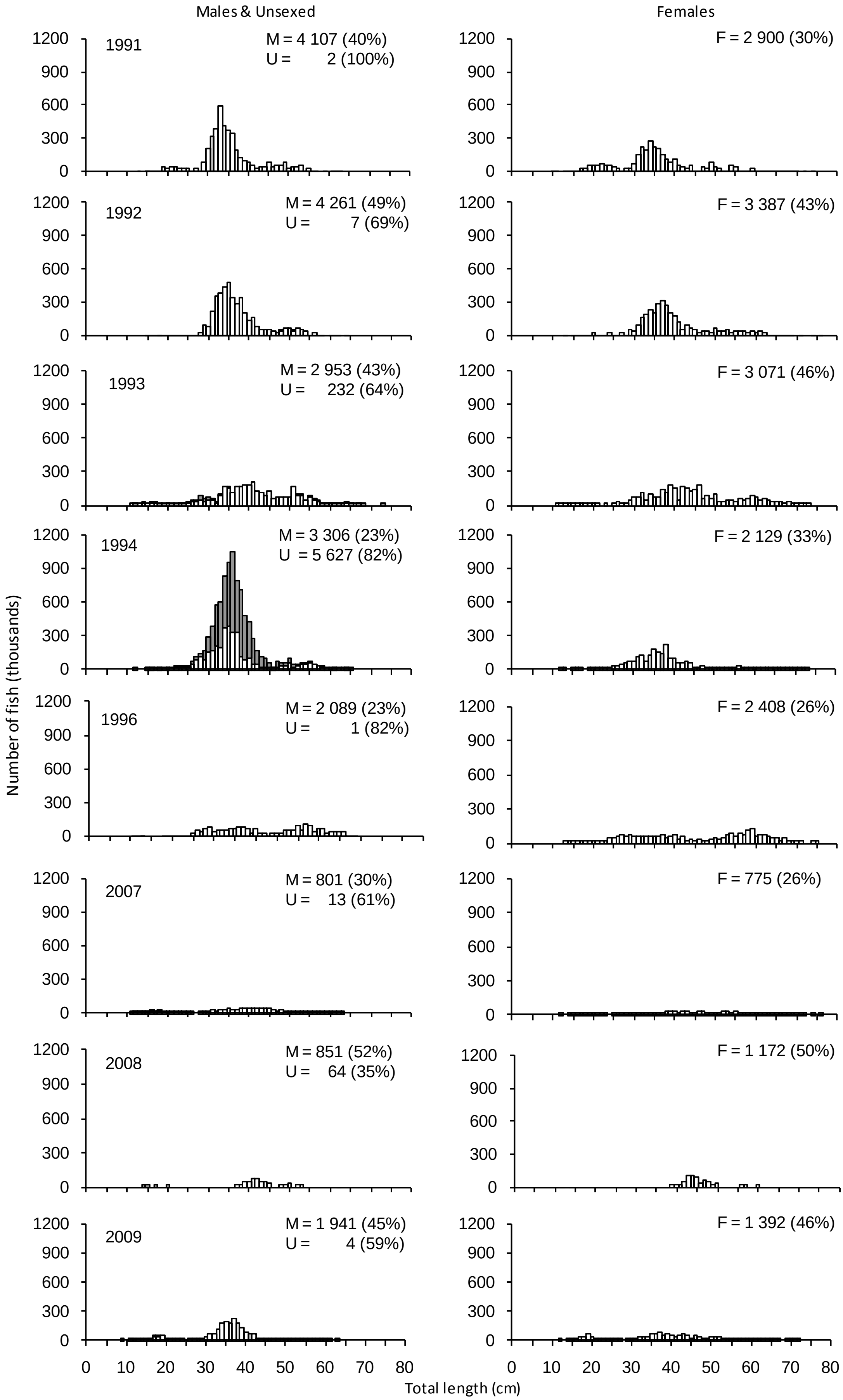


Figure 2: Scaled length frequency distributions for red cod in 30-400 m, for all seven winter ECSI surveys. M, males; F, females; (CV%).

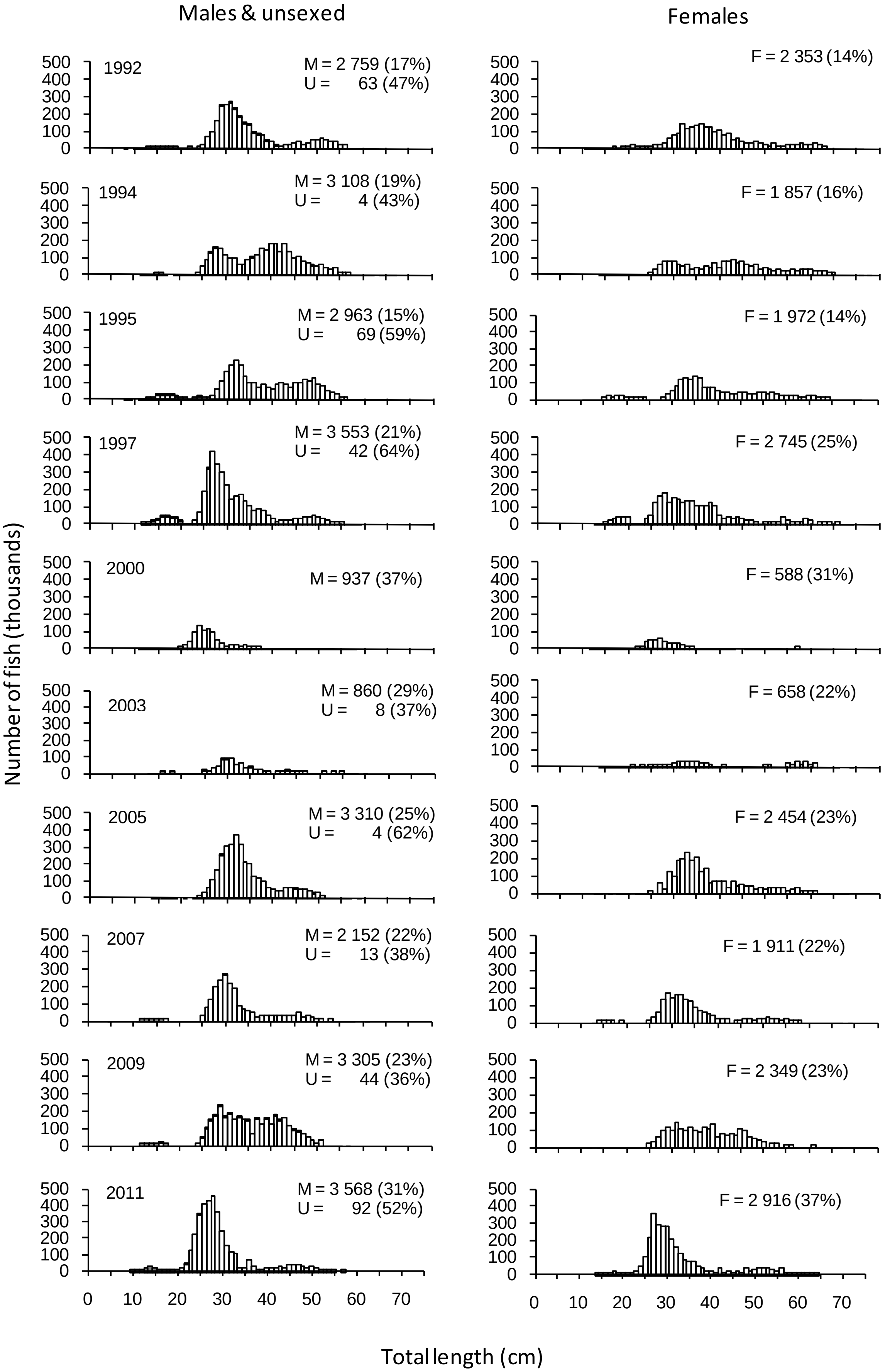


Figure 3: Scaled length frequency distributions for red cod in 30-400 m, for all WCSI surveys. M, males; F, females; U, unsexed (CV%) (Stevenson in press).

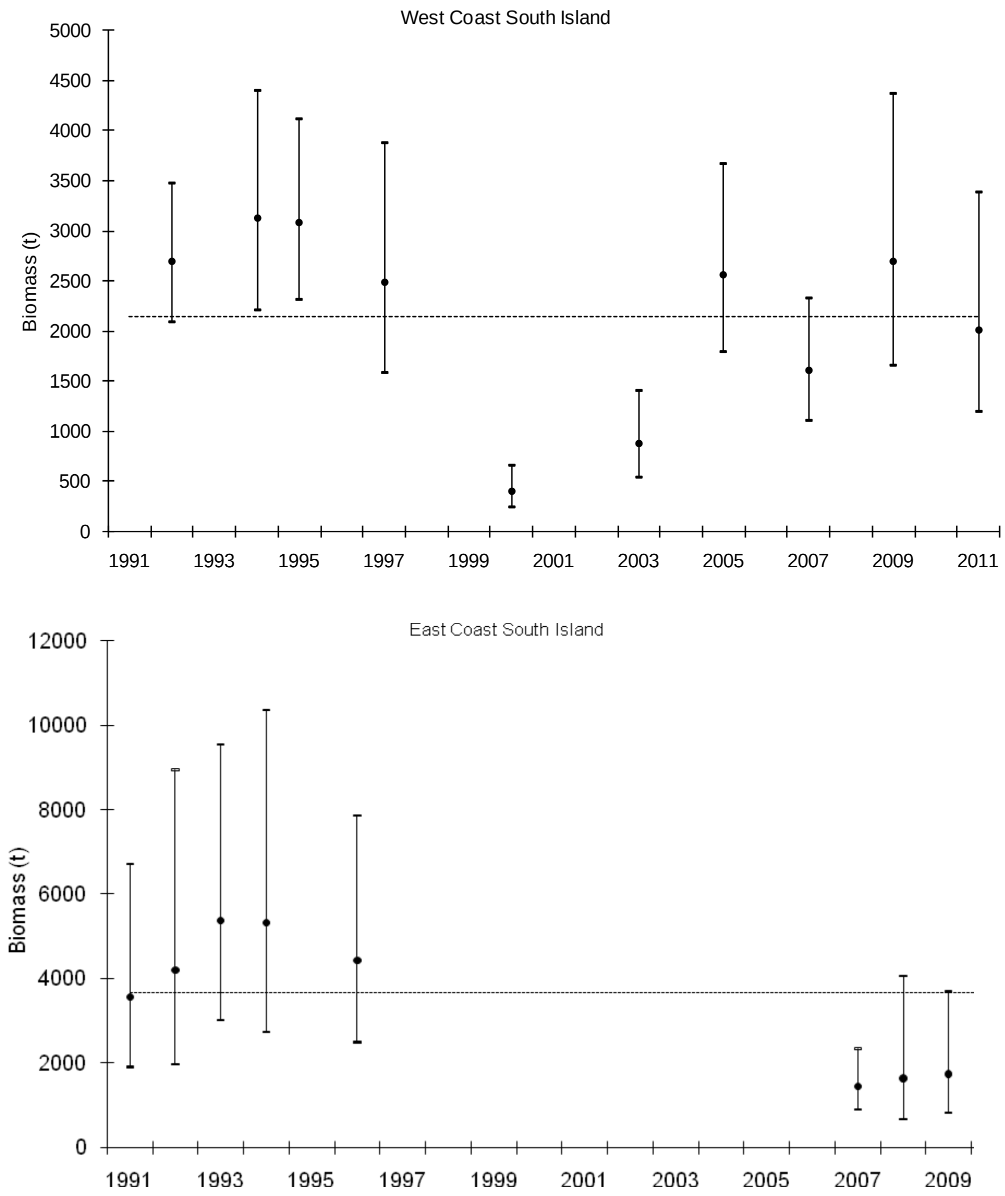


Figure 4: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) and the time series mean (dotted line) from the West (top) and East (bottom) Coast South Island trawl surveys.

5. STATUS OF THE STOCKS

Yearly fluctuations in red cod catch (t) reflect changes in recruitment. Trawl surveys and catch sampling of red cod have shown that the fishery is based almost exclusively on two and three year old fish and is highly dependent on recruitment success.

The disparity between the TACC and reported landings indicates that the TACC is not generally attainable. At the time of the introduction to the QMS, the rationale for introducing and retaining a TACC of this magnitude was to provide the fishing industry with the flexibility to capitalise on years when red cod are plentiful.

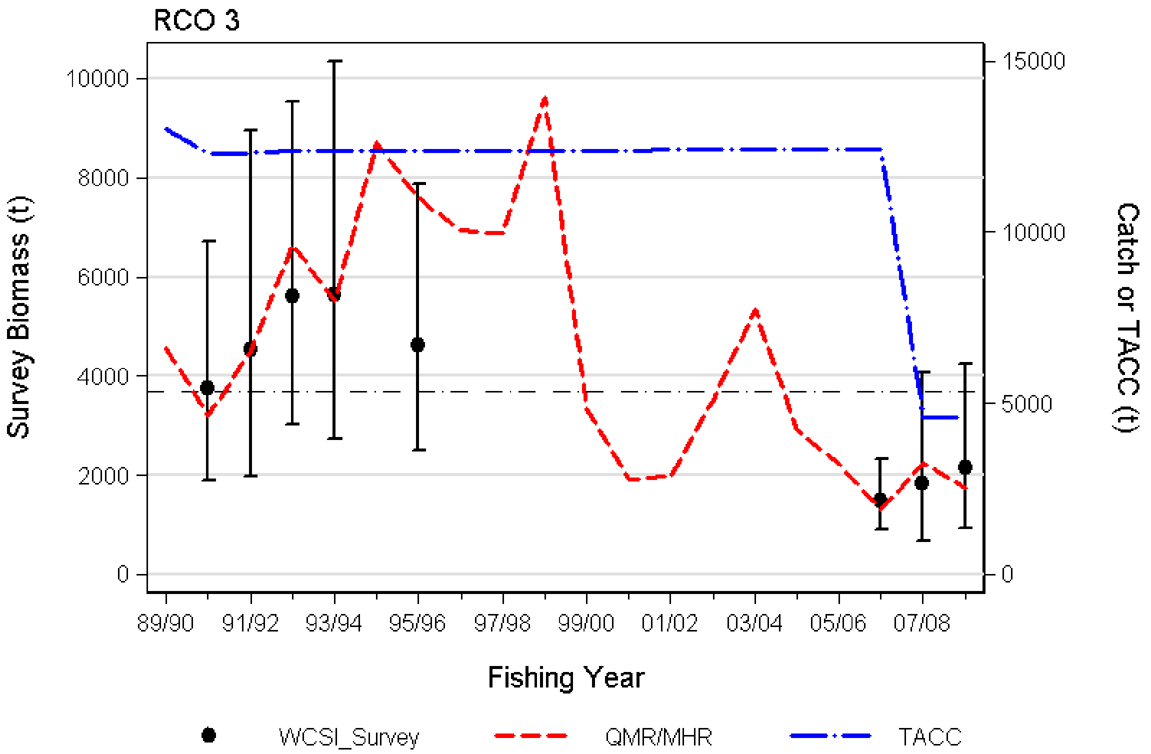
RCO 1 and RCO 2

For RCO 1 and RCO 2 it is not known if the current TACCs and recent catch levels are sustainable or if they are at levels that will allow the stocks to move towards a size that will support the *MSY*.

RCO 3

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	
Reference Points	Target: *MSY*-compatible proxy based on the East Coast South Island trawl survey (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target
Status in relation to Target	Unknown
Status in relation to Limits	Soft limit: Unknown Hard Limit: Unknown

Historical Stock Status Trajectory and Current Status



East Coast South Island survey biomass (points) commercial catch (red dashed line) and TACC (blue dashed line) for the period 1990 to 2009. Horizontal line dashed is the mean biomass index, 1992-2009.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Both catch and survey biomass have declined substantially since the mid 1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	From 1991 to 1994 large recruitment pulses were seen in the survey catch. The most recent three surveys (2007, 2008 and 2009) have not detected any significant recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Biomass estimates from the recently re-instated winter East Coast South Island since 2007 confirm that biomass is low relative to the 1990s.
Probability of Current Catch or TACC causing decline below	Soft Limit: Unknown Hard Limit: Unknown

Limits		
Assessment Methodology and Evaluation		
Assessment Type	Level 2: Trawl survey	
Assessment Method	Accepted biomass index	
Assessment Dates	Latest assessment: 2009	Next assessment: 2011
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the East Coast South Island index was a credible measure of red cod biomass.	
Main data inputs (rank)	Trawl survey biomass estimates and length frequency analysis.	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	-	

Qualifying Comments
-

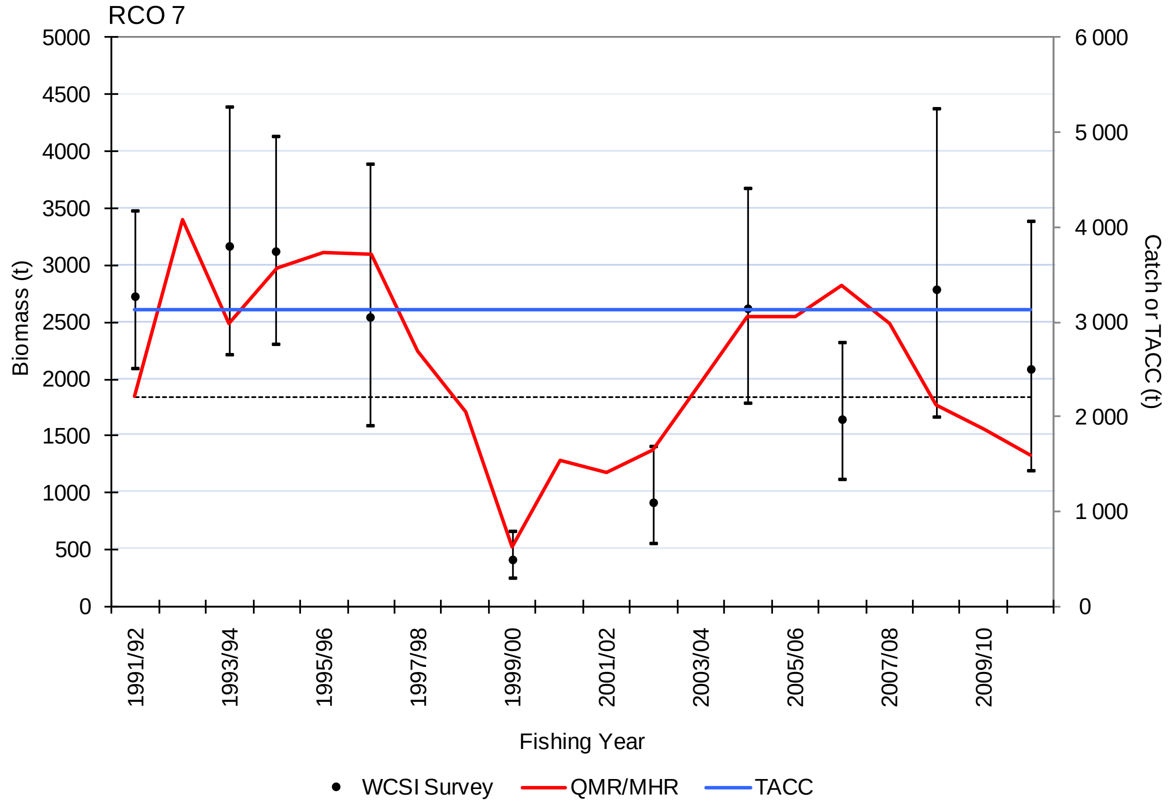
Fishery Interactions
Red cod are landed as bycatch in barracouta, flatfish, squid and tarakihi bottom trawl fisheries and ling, school shark, spiny dogfish, rig, tarakihi and moki setnet fisheries.

RCO 7

Stock Structure Assumptions
Stock boundaries are unknown, but for the purpose of this summary RCO 7 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2009 West Coast South Island trawl survey
Reference Points	Target: *MSY*-compatible proxy based on the West Coast South Island trawl survey (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target
Status in relation to Target	Unknown
Status in relation to Limits	Soft limit: Unknown Hard Limit: Unlikely (< 40%) to be below

Fishery and Stock Trends	
Trend in Biomass or Proxy	Biomass indices have been increasing from a series low in 2000, with the current 2009 index above the long-term mean.
Trend in Fishing Mortality or Proxy	Unknown

Historical survey biomass, Catch and TACC Trajectories	
	
West Coast South Island survey biomass (points) commercial catch (red line) and TACC (blue line) for the period 1990 to 2009. Horizontal line dashed represents the mean biomass index, 1992-2011.	
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Length frequency analysis from the West Coast South Island trawl survey in 2009 show a wide distribution of male fish in 2009.

Projections and Prognosis	
Stock Projections or Prognosis	Based on the broad size composition in the survey, high biomass levels are expected to persist in the short-term.
Probability of Current Catch / TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2: Agreed abundance index	
Assessment Method	Evaluation of survey biomass trends and length frequencies.	
Assessment Date	Latest assessment: 2009	Next assessment: 2013
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the West Coast South Island survey was a credible measure of biomass.	
Main data inputs (rank)	West Coast South Island survey biomass length frequency.	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	N/A	
Major Sources of Uncertainty	-	

Qualifying Comments
-

Fishery Interactions
Red cod are primarily taken in conjunction with the following QMS species: stargazer, red gurnard, tarakihi and various other species in the West Coast South Island target bottom trawl fishery. Smooth skates are caught as a bycatch in this fishery, and the biomass index for smooth skates in the west coast trawl survey has declined substantially since 1997. There may be similar concerns for rough skates but the evidence is less conclusive.

Yield estimates, TACCs and reported landings for the 2010-11 fishing year are summarised in Table 6.

Table 6: Summary of yield estimates (t), TACCs (t) and reported landings (t) of red cod for the most recent fishing year. *MCY*(1) from cY_{AV} method, *MCY*(2) from MIAEL method (range only given).

Fishstock	FMA		*MCY*(1)	*MCY*(2)	2010-11 Actual TACC	2010-11 Reported landings
RCO 1	Auckland (East) (West)	1 & 9	60		42	19
RCO 2	Central (East) (West)	2 & 8		500	500	501
RCO 3	South-East, Southland and Sub-Antarctic	3, 4, 5, & 6	4 400	2 418-13 330	4 600	4 567
RCO 7	Challenger	7	800	2 568-3 452	3 126	1 603
RCO 10	Kermadec	10	-		10	0
Total			5 260		8 278	6 691

6. FOR FURTHER INFORMATION

Annala J.H., Sullivan K.J., O'Brien C., Iball S. (Comps.) 1998. Report from the Fishery Assessment Plenary, May 1998: Stock assessments and yield estimates. 409p. Unpublished report held in NIWA library, Wellington.

Beentjes M.P. 1992. Assessment of red cod based on recent trawl survey and catch sampling data. New Zealand Fisheries Assessment Research Document 1992/16: 41 p.

Beentjes M.P. 1995. Inshore trawl survey of the Canterbury Bight and Pegasus Bay, May-June 1992 (KAH9205). New Zealand Fisheries Data Report No: 55.

Beentjes M.P. 1995. Inshore trawl survey of the Canterbury Bight and Pegasus Bay, May-June 1993 (KAH9306). New Zealand Fisheries Data Report No: 56.

Beentjes M.P. 2000. Assessment of red stocks (RCO 3 and RCO 7) for 1999. Fisheries Assessment Research Report 2000/25: 78p.

Beentjes M.P., Renwick J. 2000. Relationship between red cod recruitment and environmental variables. New Zealand Fisheries Assessment Research Report RCO9801.

Beentjes M.P., Wass R. 1994. Inshore trawl survey of the Canterbury Bight and Pegasus Bay, May-June 1991 (KAH9105). New Zealand Fisheries Data Report No: 48.

Boyd R.O., Reilly J.L. 2002. 1999/2000 national marine recreational fishing survey: harvest estimates. New Zealand Fisheries Assessment Report 2002

Bradford E. 1998. Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research .Document 1998/16: 27 p.

Cordue P.L. 1998a. An evaluation of alternative stock reduction estimators of virgin biomass and the information content of various research survey scenarios. New Zealand Fisheries Assessment Research Document 1998/22: 35 p.

Cordue P.L. 1998b. Designing optimal estimators for fish stock assessment. Canadian Journal of Fisheries and Aquatic Science. 55: 376-386.

Francis R.I.C.C. 1992. Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8.

Habib G. 1975. Aspects of biology of red cod (*Pseudophycis bachus*). (Unpublished Ph.D thesis, University of Canterbury.) 203p.

Horn P. 1995. A validated ageing methodology, and growth parameters for red cod (*Pseudophycis bachus*) off the southeast coast of the South Island, New Zealand. New Zealand Fisheries Assessment Research Document 1995/6: 15 p.

Stevenson M.L. 2007. Inshore trawl surveys of the west coast of the South Island and Tasman and Golden Bays, March-April 2007 (KAH0704). New Zealand Fisheries Assessment Research Document 2007/41: 64 p

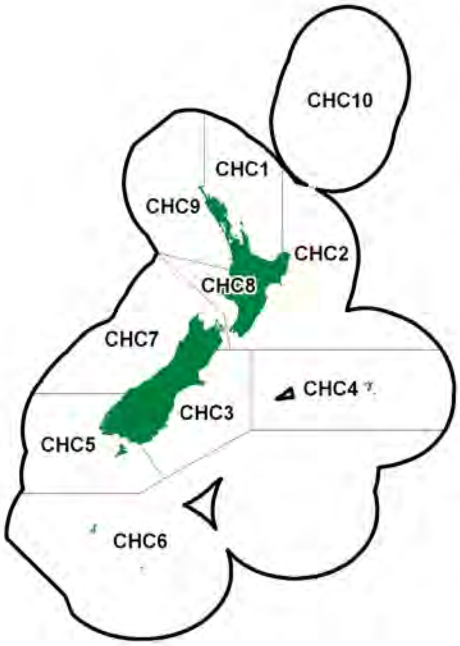
Stevenson M.L. in press. Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March-April 2011. New Zealand Fisheries Assessment Report 2012/xx.

Stevenson M.L., Beentjes M.P. 1999. Inshore trawl survey of the Canterbury Bight and Pegasus Bay, December 1998-January 1999 (KAH9809*)*. NIWA Technical Report No 63: 66 p.

Teirney L.D., Kilner A.R., Millar R.E., Bradford E., Bell J.D. 1997. Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15: 43 p.

RED CRAB (CHC)

(*Chaceon bicolour*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

The red crab (*Chaceon bicolor*) was introduced into the Quota Management System on 1 April 2004 with a combined TAC of 48 t and TACC of 48 t (Table 1). There are no allowances for customary, recreational or other sources of mortality. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. There were no commercial catches of this crab until 2001-02, when landings of about 1.5 t were reported. *C. bicolor*, along with several other deepwater crabs, was the focus of an exploratory fishing (potting) permit during 2000-02. Significant quantities have been found in the Bay of Plenty, east of Great Barrier Island, and east of Northland. The other region fished was the east coast of the North Island south of East Cape, where smaller catches were periodically reported (Table 1). Figure 1 shows the historical landings and TACC for CHC 1.

There are two species of *Chaceon* known from New Zealand waters. *C. yaldwyni* is almost indistinguishable from *C. bicolor*, but is a very rarely caught species from the eastern Chatham Rise (only 3 or 4 specimens have ever been caught).

Table 1: TACCs and reported landings (t) of red crab by Fishstock from 2001-02 to 2010-11 from CELR and CLR data. There have never been any reported landings of red crab from CHC 3-10, so these are not tabulated; though CHC 3-9 have TACCs of 4 t.

	CHC 1		CHC 2		Total	
Fishstock	Landings	TACC	Landings	TACC	Landings	
2001-02	1.132	-	0.065	-	1.27	-
2002-03	0.604	-	0	-	0.604	-
2003-04	0	-	0.009	-	0.009	-
2004-05	0	10	0.215	10	0.215	48
2005-06	0.021	10	0	10	0.021	48
2006-07	0.017	10	0.004	10	0.021	48
2007-08	5.870	10	0.081	10	5.951	48
2008-09	0	10	0.068	10	0.068	48
2009-10	0.985	10	0.071	10	1.056	48
2010-11	5.532	10	0.420	10	5.970	48

*In 2001-02 77.5 kg were reportedly landed, but the QMA is not recorded. This amount is included in the total landings for that year.

1.2 Recreational fisheries

There are no known records of recreational use of this crab.

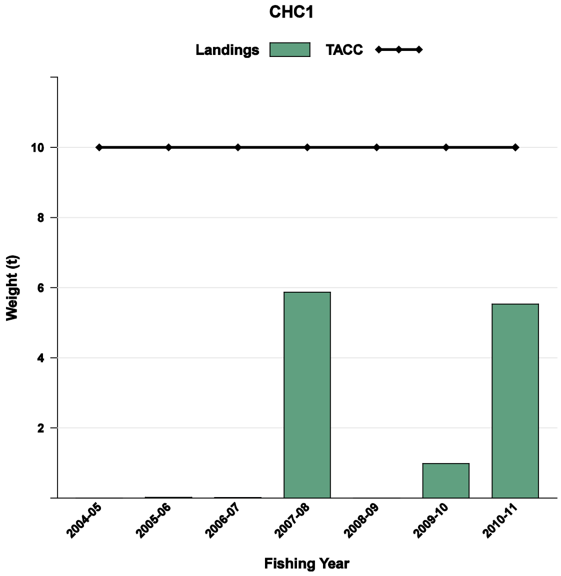


Figure 1: Historical landings and TACC for CHC1 (Auckland East). Note that these figures do not show data prior to entry into the QMS.

1.3 Customary non-commercial fisheries
There are no known records of customary use of this crab.

1.4 Illegal catch
There is no known illegal catch of this crab.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this crab is often taken as a bycatch in orange roughy fishing.

2. BIOLOGY

C. bicolor is a very large, purple and tan to yellowy tan coloured crab that reaches at least 192 mm carapace width (CW). It is found on and north of the Chatham Rise, and particularly along the east coast north of Hawkes Bay to North Cape. It has been found on both hard and soft substrates, but is considered to be a burrowing crab, living in soft sediments. It has been recorded from depths between 800 and 1100 m around New Zealand, and between 275 and 1620 m elsewhere in the Pacific.

C. bicolor was previously referred to as *C.* (sometimes *Geryon*) *quinquedens* and belongs to the family Geryonidae which has an almost world-wide distribution. There is no information on its reproduction, age, growth, or natural mortality in New Zealand waters—which may or may not be similar to the same or similar *Chaceon* species elsewhere.

Geryonid crabs such as *C. bicolor* tend to show partial sex aggregation, females being in shallower water than males. Small crabs are usually found in deeper water than the adults, as a result of juvenile settlement in deep water. There can be both seasonal and ontogenetic movements between depth zones.

Females carry a single clutch of eggs during the winter, which hatch the following summer. Clutch size increases with female size, and egg numbers are of the order of 100 000 to 400 000. The eggs are small (0.5-0.6 mm diameter), suggesting a relatively long larval life, probably resulting in widespread dispersal. Off Western Australia, however, *C. bicolor*, females may be ovigerous at any time of the year. One study off Western Australia found that the lengths at 50% maturity were 90.5 mm and 94 mm carapace length (CL) for females and males respectively.

Pot catches usually yield a very biased sex ratio favouring males, which may be due to the fact that ovigerous females remain buried in the substrate during incubation.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on QMAs, however, there is currently no biological or fishery information which could be used to identify stock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any red crab fishstock.

4.2 Biomass estimates

There are no biomass estimates for any red crab fishstock.

4.3 Estimation of Maximum Constant Yield (*MCY*)

There are no estimates of *MCY* for any red crab fishstock.

4.4 Estimation of Current Annual Yield (*CAY*)

There are no estimates of *CAY* for any red crab fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any red crab fishstock.

6. FOR FURTHER INFORMATION

Dawson E.W., Webber W.R. 1991. The deep-sea red crab *Chaceon* ("*Geryon*"): a guide to information and a reference list of the family Geryonidae. National Museum of New Zealand Miscellaneous Series No. 24.

McLay C.L. 1988. Brachyura and crab-like Anomura of New Zealand. Leigh Laboratory Bulletin No: 22. 463p.

Manning R.B., Dawson E.W., Webber W.R. 1990. A new species of *Chaceon* from New Zealand (Crustacea: Decapoda: Geryonidae). Proceedings of the Biological Society of Washington 103: 602-607.

Manning R.B., Holthuis L.B. 1989. Two new genera and nine new species of geryonid crabs (Crustacea, Decapoda, Geryonidae). Proceedings of the Biological Society of Washington 102: 50-77.

Melville-Smith R. 1982. A brief exploitation of the stone crab Lithodes murrayi (Henderson) off South West Africa, 1979/80. Fisheries Bulletin of South Africa 16: 45-55.

Naylor J.R., Webber W.R., Booth J.D. 2005. A guide to common offshore crabs in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 2.

Smith K.D., Potter I.C., Hall N.G. 2004., Biological and fisheries data for managing the deep-sea crabs *Hypothalassia acerba* and *Chaceon bicolor* in Western Australia. Projects No. 1999/154 and 2001/055. FRDC Australia.

Webber R., Dawson E., Stephenson B. 1989. The deep-sea red crab - a new resource? Professional Fisherman 3(6):10-11.

Ministry for Primary Industries
Manatu Ahu Matua

Pastoral House
25 The Terrace
PO Box 2526, Wellington
New Zealand

mpi.govt.nz