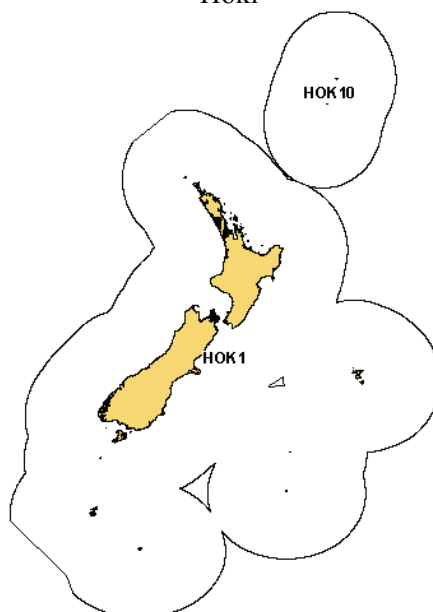


**HOKI (HOK)***(Macruronus novaezelandiae)*

Hoki

**1. FISHERY SUMMARY****1.1 Commercial fisheries**

Historically, the main fishery for hoki operated from mid-July to late August on the west coast of the South Island (WCSI) where hoki aggregate to spawn. The spawning aggregations begin to concentrate in depths of 300–700 m around the Hokitika Canyon from late June, and further north off Westport later in the season. Fishing in these areas continues into September in some years. Since 1988, another major fishery has developed in Cook Strait, where separate spawning aggregations of hoki occur. The spawning season in Cook Strait runs from late June to mid September, peaking in July and August. Small catches of spawning hoki are taken from other spawning grounds off the east coast South Island (ECSI) and late in the season at Puysegur Bank.

Outside the spawning season, when hoki disperse to their feeding grounds, substantial fisheries have developed since the early 1990s on the Chatham Rise and in the Sub-Antarctic. These fisheries usually operate in depths of 400–800 m. The Chatham Rise fishery generally has similar catches over all months except in July-September, when catches are lower due to the fishery moving to the spawning grounds. In the Sub-Antarctic, catches have typically peaked in April-June. Out-of-season catches are also taken from Cook Strait and the east coast of the North Island, but these are small by comparison.

The hoki fishery was developed by Japanese and Soviet vessels in the early 1970s. Catches peaked at 100 000 t in 1977, but dropped to less than 20 000 t in 1978 when the EEZ was declared and quota limits were introduced (Table 1a). From 1979 on, the hoki catch increased to about 50 000 t until an increase in the TACC from 1986 to 1990 saw the fishery expand to a maximum catch in 1987–88 of about 255 000 t (Table 1b). Annual catches ranged between 175 000 and 215 000 t from 1988–89 to 1995–96, increasing to 246 000 t in 1996–97, and peaking at 269 000 t in 1997–98, when the TACC was over-caught by 19 000 t. Catches have since declined as the TACC has been reduced (Table 1b). From 1 October 2007 the TACC has been 90 000 t.

## HOKI (HOK)

**Table 1(a): Reported trawl catches (t) from 1969 to 1987–88, 1969–83 by calendar year, 1983–84 to 1987–88 by fishing year (Oct–Sept). Source – FSU data.**

Year	USSR	Japan	South Korea	New Zealand		Total
				Domestic	Chartered	
1969	–	95	–	–	–	95
1970	–	414	–	–	–	414
1971	–	411	–	–	–	411
1972	7 300	1 636	–	–	–	8 936
1973	3 900	4 758	–	–	–	8 658
1974	13 700	2 160	–	125	–	15 985
1975	36 300	4 748	–	62	–	41 110
1976	41 800	24 830	–	142	–	66 772
1977	33 500	54 168	9 865	217	–	97 750
1978*	†2 028	1 296	4 580	678	–	8 581
1979	4 007	8 550	1 178	2 395	7 970	24 100
1980	2 516	6 554	–	2 658	16 042	27 770
1981	2 718	9 141	2	5 284	15 657	32 802
1982	2 251	7 591	–	6 982	15 192	32 018
1983	3 853	7 748	137	7 706	20 697	40 141
1983–84	4 520	7 897	93	9 229	28 668	50 407
1984–85	1 547	6 807	35	7 213	28 068	43 670
1985–86	4 056	6 413	499	8 280	80 375	99 623
1986–87	1 845	4 107	6	8 091	153 222	167 271
1987–88	2 412	4 159	10	7 078	216 680	230 339

\* Catches for foreign licensed and New Zealand chartered vessels from 1978 to 1984 are based on estimated catches from vessel logbooks. Few data are available for the first 3 months of 1978 because these vessels did not begin completing these logbooks until 1 April 1978.

† Soviet hoki catches are taken from the estimated catch records and differ from official MAF statistics. Estimated catches are used because of the large amount of hoki converted to meal and not recorded as processed fish.

**Table 1 (b): Reported catch (t) from QMS, estimated catch (t) data, and TACC (t) for HOK 1 from 1986–97 to 2007–08. Reported catches include TCEPR and CELF data (from 1989–90), LCER data (from 2003–04), NCELR data (from 2006–07), and TCER and LTCER data (from 2007–08). Estimated catches from 2000–01 have been recalculated to exclude HOKET (hoki caught outside the EEZ).**

Year	Reported catch	Estimated catch	TACC
1986–1987	158 000	175 000	250 000
1987–1988	216 000	255 000	250 000
1988–1989	208 500	210 000	250 000
1989–1990	210 000	210 000	251 884
1990–1991	215 000	215 000	201 897
1991–1992	215 000	215 000	201 897
1992–1993	195 000	195 000	202 155
1993–1994	191 000	190 000	202 155
1994–1995	174 000	168 000	220 350
1995–1996	210 000	194 000	240 000
1996–1997	246 000	230 000	250 000
1997–1998	269 000	261 000	250 000
1998–1999	244 500	234 000	250 000
1999–2000	242 500	237 000	250 000
2000–2001	230 000	224 500	250 000
2001–2002	195 500	195 500	200 000
2002–2003	184 500	180 000	200 000
2003–2004	136 000	133 000	180 000
2004–2005	104 500	102 000	100 000
2005–2006	104 500	100 500	100 000
2006–2007	101 000	96 500	*100 000
2007–2008	89 500	87 500	90 000

\* The available Annual Catch Entitlement (ACE) for the fishery in 2006–07 was 100 425 t.

Note: Discrepancies between QMS data and actual catches from 1986 to 1990 arose from incorrect surimi conversion factors. The estimated catch in those years has been corrected from conversion factors measured each year by Scientific Observers on the WCSI fishery. Since 1990 the new conversion factor of 5.8 has been used, and the total catch reported to the QMS is considered to be more representative of the true level of catch.

The pattern of fishing has changed markedly since 1988–89 when over 90% of the total catch was taken in the WCSI spawning fishery. The catch from the WCSI declined steadily from 1988–89 to 1995–96, increased again to between 90 000 and 107 000 t from 1996–97 until 2001–02, then dropped sharply over the last six years, to the current level of 21 100 t (Table 1c). In Cook Strait, catches increased from 1988–89 to a peak of 67 000 t in 1995–96, declined to a low of 24 200 t in 2001–02, peaked again at 40 900 t in 2003–04, and dropped to 18 200 to 24 800 t in the last four years. Non-spawning catches on the Chatham Rise increased from 1993–94, peaked at about 75 000 t in 1997–98 and 1998–99, then decreased. The Chatham Rise catch of 37 900 t in 2006–07 and 2007–08 was up slightly on catches of 30 700 to 34 100 t in the previous three years. Catches from the

Sub-Antarctic peaked at over 30 000 t in 1999–00 to 2001–02, but declined to between 6200 and 8700 t in 2004–05 to 2007–08. Catches from other areas have remained at relatively low levels (Table 1c).

From 1999–00 to 2001–02, there was a redistribution in catch from eastern stock areas (Chatham Rise, ECSI, ECNI, and Cook Strait) to western stock areas (WCSI, Puysegur, and Sub-Antarctic) (Table 1d). This was initially due to industry initiatives to reduce the catch of small fish in the area of the Mernoo Bank, but from 1 October 2001 was part of an informal agreement with the Minister of Fisheries that 65% of the catch should be taken from the western fisheries to reduce pressure on the eastern stock. This agreement was removed following the 2003 hoki assessment in 2002–03, which indicated that the eastern hoki stock was less depleted than the western stock and effort was shifted back into eastern areas, particularly Cook Strait. From 2004–05 to 2006–07 there was a further agreement with the Minister that only 40% of the catch should be taken from western fisheries. This catch split was achieved in 2006–07. From 1 October 2007 the target catch from the western fishing grounds was further reduced to 25 000 t within the overall TACC of 90 000 t. This target was exceeded in 2007–08, with 30 200 t taken from western areas (Table 1c). Figure 1 shows the historical landings and TACC for HOK1, and also the eastern and western catch components of this stock since 1988–89.

**Table 1 (c): Estimated\* total catch (t) of hoki by area, 1988–89 to 2007–08. Estimated (TCEPR and CELR) catches were scaled to reported (QMR or MHR) catch totals. Data also includes LCER (from 2003–04), and NCELR estimated data (from 2006–07), and TCER and LTCER data (from 2007–08).**

Fishing Year	Spawning fisheries				Non-spawning fisheries				
	WCSI	Puysegur	Cook Strait	ECSI	Sub-Antarctic	Chatham Rise and ECSI	ECNI	Unrep.	Total catch
1988–1989	188 000	3 500	7 000	–	5 000	5 000	–	–	208 500
1989–1990	165 000	8 000	14 000	–	10 000	13 000	–	–	210 000
1990–1991	154 000	4 000	26 500	1 000	18 000	11 500	–	–	215 000
1991–1992	105 000	5 000	25 000	500	34 000	45 500	–	–	215 000
1992–1993	98 000	2 000	21 000	–	26 000	43 000	2 000	3 000	195 000
1993–1994	113 000	2 000	37 000	–	12 000	24 000	2 000	1 000	191 000
1994–1995	80 000	1 000	40 000	–	13 000	39 000	1 000	–	174 000
1995–1996	73 000	3 000	67 000	1 000	12 000	49 000	3 000	2 000	210 000
1996–1997	91 000	5 000	61 000	1 500	25 000	56 500	5 000	1 000	246 000
1997–1998	107 000	2 000	53 000	1 000	24 000	75 000	4 000	3 000	269 000
1998–1999	90 100	3 000	46 500	2 100	24 300	75 600	2 600	–	244 500
1999–2000	101 100	2 900	43 200	2 400	34 200	56 500	1 400	500	242 400
2000–2001	100 600	6 900	36 600	2 400	30 400	50 500	2 100	100	229 900
2001–2002	91 200	5 400	24 200	2 900	30 500	39 600	1 200	–	195 500
2002–2003	73 900	6 000	36 700	7 100	20 100	39 200	900	–	184 700
2003–2004	45 200	1 200	40 900	2 100	11 700	33 600	900	–	135 800
2004–2005	33 100	5 500	24 800	3 300	6 200	30 700	500	100	104 400
2005–2006	38 900	1 500	21 800	700	6 700	34 100	700	–	104 400
2006–2007	33 100	400	20 100	1 000	7 700	37 900	700	–	101 000
2007–2008	21 100	300	18 200	2 400	8 700	37 900	700	–	89 300

\* Estimated catches adjusted pro rata to the reported catch in Table 1(b) for 1988–89 to 2006–07.

– Catch less than 500 t.

**Table 1(d): Proportions of total catch.**

Fishing Year	Spawning fisheries		Non-spawning fisheries	
	West	East	West	East
1988–1989	92%	3%	2%	3%
1989–1990	82%	7%	5%	6%
1990–1991	74%	13%	8%	5%
1991–1992	51%	12%	16%	21%
1992–1993	51%	11%	14%	24%
1993–1994	60%	19%	7%	14%
1994–1995	47%	23%	7%	23%
1995–1996	36%	33%	6%	25%
1996–1997	39%	26%	10%	25%
1997–1998	41%	20%	9%	30%
1998–1999	38%	20%	10%	32%
1999–2000	43%	19%	14%	24%
2000–2001	47%	17%	13%	23%
2001–2002	49%	14%	16%	21%
2002–2003	43%	24%	11%	22%
2003–2004	34%	32%	9%	25%
2004–2005	37%	27%	6%	30%
2005–2006	39%	21%	7%	33%
2006–2007	33%	21%	8%	38%
2007–2008	24%	23%	10%	43%

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From 1986 to 1990 surimi vessels dominated the catches and took about 60% of the annual WCSI catch. However, since 1991, the surimi component of catches has decreased and processing to head and gut, or to fillet product has increased, as has “fresher” catch for shore processing. Although a greater proportion of the total catch is still taken during the spawning season, the hoki fishery now operates throughout the rest of the year as well, producing high quality fillet product from both spawning and non-spawning fisheries. More recently, twin-trawl rigs have been introduced in all hoki fisheries, except Cook Strait and inside the line on the WCSI.

### **Total Allowable Commercial Catch (TACC)**

In the 2007–08 fishing year the TACC for HOK1 was 90 000 t. This TACC applied to all areas of the EEZ except the Kermadec FMA which had a TACC of 10 t. There was an agreement with the Minister of Fisheries that only 25 000 t of the TACC should be taken from western stock areas.

Chartered vessels may not fish inside the 12-mile Territorial Sea and there are various vessel size restrictions around some parts of the coast. On the WCSI, a 25-mile line closes much of the hoki spawning area in the Hokitika Canyon and most of the area south to the Cook Canyon to vessels larger than 46 m overall length. In Cook Strait, the whole spawning area is closed to vessels over 46 m overall length.

The Hoki Fishery Management Company introduced a Code of Practice for hoki target trawling in 2001 with the aim of protecting small fish (less than 60 cm). The main components of this Code of Practice are: 1) a restriction on fishing in waters shallower than 450 m; and 2) a rule requiring vessels to ‘move on’ if there are more than 10% small hoki in the catch. More recently, the Code of Practice has been extended to include seasonal and area closures in spawning fisheries (see section 5.5).

### **2007–08 Hoki fishery**

The overall catch of 89 300 t was 11 700 t lower than in 2006–07 and 700 t lower than the TACC. Catches remained similar to those taken in 2006–07 in the non-spawning fisheries on the Chatham Rise and in the Sub-Antarctic, but declined in the WCSI and Cook Strait spawning fisheries.

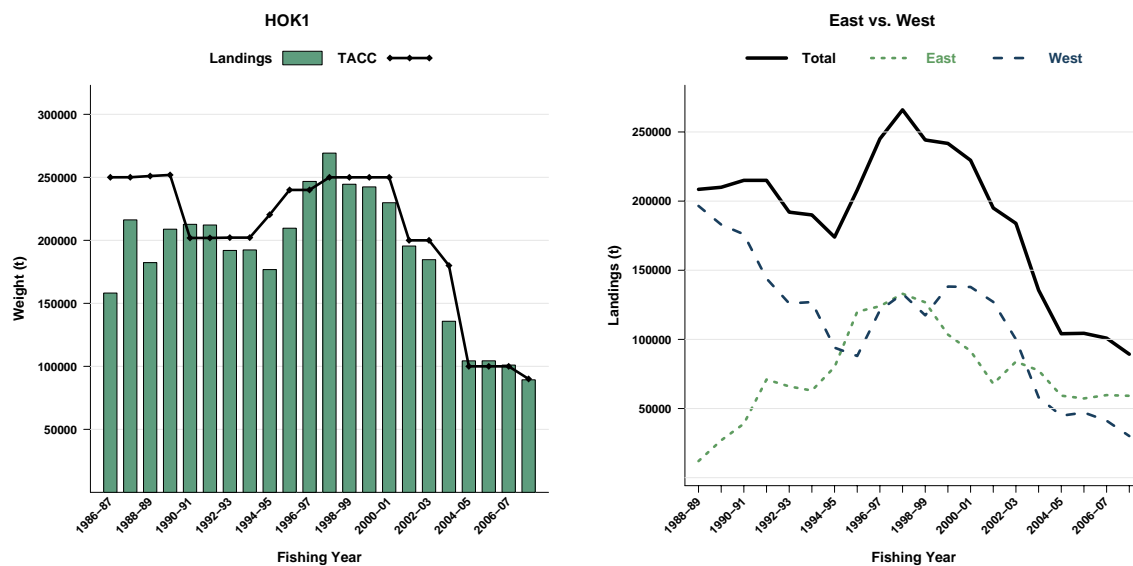
The Chatham Rise was the largest hoki fishery, with 37 900 t taken from this area in 2007–08. The median unstandardised catch in bottom trawls was 0.8 t per hour, which was the same as the two previous years, but higher than in the period from 2000–01 to 2004–05. There has been a general increase in tow duration on the Chatham Rise since the 1990s, with a median tow duration of 4.9 h in 2007–08. The Chatham Rise catch was dominated by small hoki from the 2002–06 year-classes and 48% of the catch by number was fish less than 65 cm (but only 26% less than 60 cm).

The catch on the WCSI declined by 12 000 t to 21 100 t in 2007–08, and was the lowest catch taken from this area since the late 1970s. Catches inside the 25 nm line made up only 4% of the total WCSI catch in 2007–08, down from a peak of 42% of the catch in 2003–04. Unstandardised catch rates in 2007–08 were the highest since 2001–02, with a median catch from all non-zero midwater tows of 3.8 t per hour, and a median tow duration of 1.8 h. Most of the catch on the WCSI was fish from the 2000–06 year classes (ages 2–8), with the mode at ages 5–6 (2002 and 2003 year-classes). About 22% of the WCSI catch by number was less than 65 cm. From 1999–00 to 2003–04, the sex ratio of the WCSI catch was highly skewed, with many more females caught than males. This sex bias has reversed in the last four years as the catch of younger fish has increased, and in 2007–08 only 41% of fish in the catch by numbers were females.

The catch from Cook Strait was only 18 200 t in 2007–08, the lowest level since 1989–90. Unstandardised catch rates in Cook Strait continue to be high, with a median catch rate of 31.9 t per hour in non-zero mid-water tows and a median tow duration of only 0.6 h (equivalent to a median catch of 19.4 t per tow). As on the WCSI, the catch was dominated by young fish from the 2000–05 year-classes (ages 3–8), with some larger older females. The mean length of hoki from Cook Strait in 2007–08 (73 cm) was the lowest in the history of the fishery, and 22% of the catch was fish less than 65 cm.

The catch from the Sub-Antarctic increased slightly to 8700 t in 2007–08. The percentage of the catch taken by the hoki target fishery fell from over 96% in 2003–04 to 70% in 2006–07, but rose to 73% in 2007–08. The remainder of the hoki catch is taken mainly in fisheries targeting ling, squid, silver and white warehou, and hake. Median tow duration has risen to 5.5 hours and the use of twin-trawls has also increased. Although unstandardised catch rates in bottom trawls increased from 0.1 t per hour in 2006–07 to 0.2 t per hour in 2007–08, they remain much lower than in the other hoki fisheries. Catch-at-age estimates showed the Sub-Antarctic catch, like that from the other areas, consisted mainly of fish from the 2000–06 year classes, but there was a higher proportion of larger older fish in the Sub-Antarctic. The proportion of hoki greater than 80 cm has increased substantially from 2005–06 and these larger fish now make up nearly 49% of the catch. Only 14% of the catch was fish less than 65 cm.

As the hoki quota was fully caught before the end of the fishing year, catches in both Puysegur and ECSI in 2007–08 were lower than in some previous years, with 2400 t taken from the ECSI and 300 t from Puysegur.



**Figure 1: Left: Historical landings and TACC for HOK 1 (Entire EEZ except Kermadec). Right: The Eastern and Western components of the total HOK 1 landings (solid line) since 1988-89. Note that these figures do not show data prior to entry into the QMS.**

## 1.2 Recreational fisheries

Recreational fishing for hoki is negligible.

## 1.3 Customary non-commercial fisheries

The level of this fishery is believed to be negligible.

## 1.4 Illegal catch

No information is available about illegal catch.

## 1.5 Other sources of fishing mortality

There are a number of potential sources of additional fishing mortality in the hoki fishery:

In the years just prior to the introduction of the EEZ, when large catches were first reported, and following the increases of the TACC in the mid 1980s, it is likely that high catch rates on the west coast, South Island spawning fishery resulted in burst bags, loss of catch and some mortality. Although burst bags were recorded by some scientific observers, the extent of fish loss has not been estimated, however, the occurrence was at a sufficient level to result in the introduction of a code of practice to minimise losses in this way. Based on observer records from the period 2000-01 to 2006-07, Ballara and Anderson (2008) noted that fish lost from the net during landing accounted for only a small fraction (0 - 14.5%) of the total fish discards each year in the hoki, hake and ling fishery.

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- The use of escape panels or windows part way along the net that was developed to avoid burst bags may also in itself result in some mortality of fish that pass through the window. The extent of these occurrences and the historical and current use of such panels/windows have not been quantified.
- The development of the fishery on younger hoki (2 years and over) on the Chatham Rise from the mid 1990s and the prevalence of small fish in catches on the WCSI in recent years may have resulted in some discarding of small fish.
- Overseas studies indicate that large proportions of small fish can escape through trawl meshes during commercial fishing and that the mortality of escapees can be high, particularly among species with deciduous scales (i.e., that shed easily) such as hoki. Selectivity experiments in the 1970s indicated that the 50% selection length for hoki for a 100 mm mesh codend is about 57–65 cm total length (Fisher 1978, as reported by Massey & Hore 1987). More recent research, using a twin-rig trawler in June 2007, estimated that the 50% selection length was somewhat lower at 41.5 cm with a selection range (length range between 25% and 75% retention) of 14.3 cm (Haist *et al.* 2007). Applying the estimated retention curve to scaled length frequency data for the Chatham Rise fishery, suggested that annually between 47 t (in 1997–98) and 4287 t (in 1995–96) of hoki may have escaped commercial fishing gear. Net damaged adult hoki have been recorded in the WCSI fishery in some years indicating that there may be some survival of escapees. The extent of damage and resulting mortality of fish passing through the net is unknown.

These sources of additional fishing mortality are not incorporated in the current stock assessment.

## 2. BIOLOGY

Hoki are widely distributed throughout New Zealand waters from 34° S to 54° S, from depths of 10 m to over 900 m, with greatest abundance between 200 and 600 m. Large adult fish are generally found deeper than 400 m, while juveniles are more abundant in shallower water. In the January 2003 Chatham Rise trawl survey, exploratory tows with mid-water gear over a hill complex east of the survey area found low density concentrations of hoki in mid-water at 650 m over depths of 900 m or greater in January 2003 (Livingston *et al.* 2004). The proportion of larger hoki outside the survey grounds is unknown. Commercial data also indicate that small catches of older hoki are targeted over other hill complexes outside the survey areas of both the Chatham Rise and Sub-Antarctic (Dunn & Livingston 2004), and are also caught as a bycatch by tuna fishers over very deep water (Bull & Livingston 2000).

The two main spawning grounds on the WCSI and in Cook Strait are considered to comprise fish from separate stocks, based on the geographical separation of these spawning grounds and a number of other factors (see section 3 “Stocks and areas” below).

Hoki migrate to spawning grounds in Cook Strait, WCSI, Puysegur, and ECSI areas in the winter months. Throughout the rest of the year the adults are dispersed around the edge of the Stewart and Snares shelf, over large areas of the Sub-Antarctic and Chatham Rise, and to a lesser extent around the North Island. Juvenile fish (2–4 yrs) are found on the Chatham Rise throughout the year.

Hoki spawn from late June to mid-September, releasing multiple batches of eggs. They have moderately high fecundity with a female of 90 cm TL spawning over 1 million eggs in a season (Schofield & Livingston 1998). Not all hoki within the adult size range spawn in a given year. Winter surveys of both Chatham Rise and Sub-Antarctic have found significant numbers of large hoki with no gonad development, at times when spawning is occurring in other areas. Histological studies of female hoki in the Sub-Antarctic in May 1992 and 1993 estimated that 67% of hoki age 7 years and older in the Sub-Antarctic would spawn in winter 1992, and 82% in winter 1993 (Livingston *et al.* 1997). A similar study repeated in April 1998 found that a much lower proportion (40%) of fish age 7 and older was developing to spawn (Livingston & Bull 2000). Reanalysis of the 1998 data has shown that there is a correlation between stratum and oocyte development (Francis in prep.) A new method to estimate proportion spawning from summer samples of post-spawner hoki is under development (Parker 2007, Grimes & O’Driscoll 2006).

The main spawning grounds are centred on the Hokitika Canyon off the WCSI and in Cook Strait Canyon. The planktonic eggs and larvae move inshore by advection or upwelling (Murdoch 1990; Murdoch, 1992) and are widely dispersed north and south with the result that 0+ and 1-year-old fish can be found in most coastal areas of the South Island and parts of the North Island. The major nursery ground for juvenile hoki aged 2–4 years is along the Chatham Rise, in depths of 200 to 600 m. The older fish disperse to deeper water and are widely distributed on both the Sub-Antarctic and Chatham Rise. Analyses of trawl survey (1991–02) and commercial data suggests that a significant proportion of hoki move from the Chatham Rise to the Sub-Antarctic as they approach maturity, with most movement between ages 3 and 7 years (Bull & Livingston 2000, Livingston *et al.* 2002). Based on a comparison of *Tangaroa* trawl survey data, on a proportional basis (assuming equal catchability between areas), 80% or more of hoki aged 1–2 years occur on the Chatham Rise. Between ages 3 and 7, this drops to 60–80%. By age 8, 35% or less fish are found on the Chatham Rise compared with 65% or more in the Sub-Antarctic. A study of the observed sex ratios of hoki in the two spawning and two non-spawning fisheries found that in all areas, the proportion of male hoki declines with age (Livingston *et al.* 2000). There is little information at present to determine the season of movement, the exact route followed, or the length of time required, for fish to move from the Chatham Rise to the Sub-Antarctic. Bycatch of hoki from tuna vessels following tuna migrations from the Sub-Antarctic showed a northward shift in the incidence of hoki towards the WCSI in May–June (Bull & Livingston 2000). The capture of net-damaged fish on Pukaki Rise following the WCSI spawning season where there had been intense fishing effort in 1989 also provides circumstantial evidence that hoki migrate from the WCSI back to the Sub-Antarctic post-spawning (Jones 1993).

Growth is fairly rapid with juveniles reaching about 27–35 cm TL at the end of the first year. There is considerable variability in growth rates in subsequent years and there has been a trend of increasing size at age in data from both the trawl surveys and the commercial catch since 1983. In the past, hoki reached about 45, 55 and 60–65 cm TL at ages 2, 3, and 4 respectively. More recently, length modes have been centred at 45–50, 60–65, and 70–75 cm TL for ages 2, 3, and 4. Although smaller spawning fish are taken on the spawning grounds, males appear to mature mainly from 60–65 cm TL at 3–5 years, while females mature at 65–70 cm TL. From the age of maturity the growth of males and females differs. Males grow up to about 115 cm TL, while females grow to a maximum of 130 cm TL and up to 7 kg weight. Horn & Sullivan (1996) estimated growth parameters for the two stocks separately (Table 2). Fish from the eastern stock sampled in Cook Strait are smaller on average at all ages than fish from the WCSI. Maximum age is from 20–25 years, and the instantaneous rate of natural mortality in adults is about 0.25 to 0.3 per year.

There is evidence that ageing error causes problems in the estimation of year class strength. For example, the 1989 year class appeared as an important component in the catch at age data at older ages, yet this year class is believed to have been extremely weak in comparison to the preceding 1988 and 1987 year classes. A new ageing protocol has been developed to increase the consistency of hoki age estimation. This has been applied to the survey data from 2000 onwards and to catch samples from 2001 (Francis 2001). Data from earlier samples, however, are still based on the original methodology and otolith readings.

Estimates of biological parameters relevant to stock assessment are shown in Table 2 (but note that natural mortality was estimated in the model in the assessment).

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**Table 2: Estimates of biological parameters.**

Fishstock	Estimate						Source
	Females			Males			
1. Natural mortality ( $M$ )							
HOK 1	0.25			0.30			Sullivan & Coombs (1989)
2. Weight = $a$ (length) <sup>b</sup> (Weight in g, length in cm total length)							
	Both stocks						
	a			b			
HOK1	0.00479			2.89			Francis (2003)
3. von Bertalanffy growth parameters							
	Females			Males			
	K	$t_0$	$L_{\infty}$	K	$t_0$	$L_{\infty}$	
HOK 1 (Western Stock)	0.213	-0.60	104.0	0.261	-0.50	92.6	
HOK 1 (Eastern Stock)	0.161	-2.18	101.8	0.232	-1.23	89.5	

### 3. STOCKS AND AREAS

Morphometric and ageing studies have found consistent differences between adult hoki taken from the two main dispersed areas (Chatham Rise and Southern Plateau), and from the two main spawning grounds in Cook Strait and WCSI (Livingston *et al.* 1992, Livingston & Schofield 1996b, Horn & Sullivan 1996). These differences clearly demonstrate that there are two sub-populations of hoki. Whether or not they reflect genetic differences between the two sub-populations, or they are just the result of environmental differences between the Chatham Rise and Sub-Antarctic, is not known. No genetic differences have been detected with selectively neutral markers (Smith *et al.* 1981, 1996) but a low exchange rate between stocks could reduce genetic differentiation.

Two pilot studies appeared to provide support for the hypothesis of spawning stock fidelity for the Cook Strait and WCSI spawning areas. Smith *et al.* (2001) found significant differences in gill raker counts, and Hicks & Gilbert (2002) found significant differences in measurements of otolith rings, between samples of 3 year-old hoki from the 1997 year-class caught on the WCSI and in Cook Strait. However, when additional year-classes were sampled, differences were not always detected (Hicks *et al.* 2003). It appears that there are differences in the mean number of gill rakers and otolith measurements between stocks, but, due to high variation, large sample sizes would be needed to detect these (Hicks *et al.* 2003).

The Hoki Working Group has assessed the two spawning groups as separate stock units. The west coast of the North and South Islands and the area south of New Zealand including Puysegur, Snares and the Southern Plateau has been taken as one stock unit (the "western stock"). The area of the ECSI, Mernoo Bank, Chatham Rise, Cook Strait and the ECNI up to North Cape has been taken as the other stock unit (the "eastern stock").

### 4. CLIMATE AND RECRUITMENT

Annual variations in hoki recruitment have considerable impact on this fishery and a better understanding of the influence of climate on recruitment patterns would be very useful for the future projection of stock size. However, the link between climate and recruitment is still unknown. Recent analyses (Francis *et al.* 2006) do not support the conclusions of Bull & Livingston (2001) that model estimates of recruitment to the western stock are strongly correlated with the southern oscillation index (SOI). Francis *et al.* (2006) noted that there is a correlation of  $-0.70$  between the autumn SOI and annual estimates of recruitment (1+ and 2+ fish) from the Chatham Rise trawl survey but found this hard to interpret because the survey is an index of the combined recruitment to both the eastern and western stocks.



## 5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

The hoki trawl fishery is extensive throughout the EEZ and the key potential effects of fishing on the environment and the marine ecosystem are considered below. As part of the Marine Stewardship Council certification process in 2001, a risk analysis was carried out to identify threats of the hoki fishery to the environment and ecosystem. The main topics were seabirds, mammals, the benthic environment and communities, target stock and by-catch.

### 5.1 Sea-bed disturbance

Bottom trawling that targets hoki is carried out extensively across the Chatham Rise and in the Sub-Antarctic, in depths of 200–800 m throughout most of the year. The Chatham Rise has been subjected to about twice as much trawling for hoki as the Sub-Antarctic (Table 3), but effort has decreased in both areas in recent years. The west coast spawning grounds have been subjected to a similar number of tows as the Chatham Rise, however, this is largely limited to the spawning season, and tends to be a mid-water fishery. Total effort in Cook Strait has been much less than in other areas and it is also mainly a mid-water fishery. Although mid-water nets may be towed along the seabed bottom contact is substantially less than with bottom trawls. Numbers of tows in all the major fishing grounds in 2007–08 were below mean levels (Table 3). This is mainly the result of quota cuts in the hoki fishery.

**Table 3: Summary of target tow data (TCEPR only) in the hoki fishery from fishing years 1989–90 to 2007–08 (FY, fishing year, MT, mid-water tows, BT, bottom tows).**

Fishing year	West Coast S.I.		Cook Strait		East Coast S.I.		Sub-Antarctic		Chatham Rise	
	MT	BT	MT	BT	MT	BT	MT	BT	MT	BT
1990	6 605	995	877	21	4	0	30	2 101	48	2 027
1991	6 778	1 349	1 846	12	109	7	82	3 918	964	3 488
1992	5 262	791	1 359	6	63	0	114	5 438	461	5 551
1993	5 245	1 523	1 309	10	8	4	444	4 903	1 057	5 270
1994	7 496	1 338	1 761	88	11	1	561	2 036	1 332	3 456
1995	6 860	1 237	1 736	222	20	9	414	2 327	2 172	6 262
1996	5 389	1 569	2 928	769	67	42	423	2 489	2 308	7 963
1997	6 811	1 335	3 110	907	52	59	342	3 427	2 360	9 362
1998	6 480	1 007	1 971	392	57	120	178	4 375	3 798	11 448
1999	5 025	1 565	1 791	369	29	48	426	3 649	2 444	11 450
2000	4 840	1 704	1 749	242	22	24	527	5 917	2 691	9 535
2001	5 512	2 024	1 605	86	108	36	670	5 421	929	9 887
2002	4 393	2 622	843	40	129	66	146	6 431	870	7 847
2003	4 066	2 434	1 522	55	312	197	97	4 390	504	9 294
2004	4 084	1 770	1 526	41	59	14	84	3 020	397	7 221
2005	2 148	1 194	1 055	28	140	34	74	1 421	345	5 020
2006	1 652	1 343	877	23	34	11	77	720	146	4 820
2007	1 076	634	738	8	18	58	28	1 195	65	4 760
2008	599	437	295	178	21	136	36	928	82	4 228
Total	90 321	26 871	28 898	3 497	1 263	886	4 753	64 106	22 973	128 889
Mean	4 754	1 414	1 521	184	67	46	250	3 374	1 209	6 784
Fishery	Spawning		Spawning		Spawning*		Non spawning		Non-spawning	

\* East coast non-spawning tows included in Chatham Rise columns

Studies elsewhere in the world have shown that repeated trawl disturbances alter the benthic community by damaging or removing macro-fauna and encouraging anaerobic bacterial growth (e.g., Norse & Watling 1999, Kaiser *et al.* 2002, Collie *et al.* 2000, Roberts *et al.* 2000). Bottom trawling also tends to homogenise the sediment, which damages the habitat for certain fauna. Benthic processes, such as the transfer of nutrients, remineralisation, oxygenation and productivity, which occur in undisturbed, healthy sediments, are also impaired (e.g., Kaiser *et al.* 2006, De Juan *et al.* 2007, Lohrer *et al.* 2004). Recovery rates depend on several factors, including levels of natural disturbance, the coarseness of the sediment, depth, and the type of benthic community that is disturbed. Coarse sediments and benthic communities that are subject to a lot of natural disturbances by currents or wind have much faster recovery rates than consolidated sediments. Conversely, fine sediments particularly those with slow growing fauna and high longevity usually have slow recovery rates. Rocky substrates with slow growing organisms such as deep-sea corals are also slow to recover. These generalisations apply to most systems studied worldwide, and are likely to apply to

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New Zealand sediments. Some data are available on the macro-benthic communities of the west coast South Island (Probert & Grove 1998) and the Chatham Rise (Probert & McKnight 1993, McKnight & Probert 1997).

Most bottom trawling for hoki on the Chatham Rise and in the Sub-Antarctic occurs over medium grain sediments (sandy silt Chatham Rise, silty clay Sub-Antarctic) although there are some areas of rocky outcrops and foul ground in both areas. Hotspots of more intense effort have been identified, but the impact of hoki bottom trawls on the benthic communities is unknown (Baird *et al.* 2002). New data to map biodiversity and sediments on the Chatham Rise and Challenger Plateau 200-1200 m depths were collected in 2007. Other research to investigate the impacts of fishing on the sea-bed is also underway.

The effects of dumping, burst bags, and the discard of frames and heads on water quality within the area of the west coast spawning ground were considered a potential problem in the mid-1980s. Photographs of the seabed at that time showed an influx of scavenging fauna during the spawning season (Grange 1993), but there was little evidence of anoxic conditions, or even reduced dissolved oxygen levels near or on the seabed (Livingston & Rutherford 1988). Modelling studies to compare the effects of mincing fish waste rather than dumping the waste whole suggested that little would be gained by this practice (Rutherford *et al.* 1987). The problem has largely been alleviated as most vessels now carry meal plants and most offal is processed on-board.

### 5.2 Incidental catch (fish and invertebrates)

There are two main sources of data on catch weights and relative abundance of incidental catch in New Zealand: TCEPR forms provide greenweight catch totals of the top five species on a tow by tow basis, and a daily summary of all species caught. MFish Observer records provide catch weights on all species caught on a tow by tow basis. In addition, fishery independent trawl surveys of the Chatham Rise and Sub-Antarctic provide abundance estimates of all finfish, cartilaginous and squid species, as well as the catch weights of macro-invertebrate species.

Commercial and non-commercial bycatch on the Chatham Rise are described by Livingston *et al.* (2003), and bycatch and discard rates across the fleet were estimated by Anderson *et al.* (2001), Anderson & Smith (2005), and for the combined hoki, hake and ling fishery fisheries from 2000–01 to 2006–07 in Ballara & Anderson (2008). The main commercial bycatch species in hoki target fisheries off the West Coast S.I., Chatham Rise and Sub-Antarctic are hake, ling, silver warehou, and spiny dogfish (Ballara and Anderson 2008). Other main commercial bycatch species on the WCSI also include frostfish and barracouta; and ghostsharks, white warehou, sea perch, look down dory, stargazers and arrow squid on the Chatham Rise and in the Sub-Antarctic. In Cook Strait, the main bycatch species are ling and spiny dogfish. About 470 species or species groups have been identified by observers, the majority of which were non-commercial fish and invertebrate species caught in low numbers (Ballara and Anderson 2008). The main non-commercial fish species were javelinfish and rattails, dogfish, deepwater sharks, other sharks and skates often unspecified but including spiny dogfish and basking shark.

Total bycatch in the hoki, hake and ling fishery ranged from about 36 000 to 58 000 t per year (Ballara & Anderson 2008) with bycatch rates of commercial species highest in Puysegur and lowest in Cook Strait. Non-commercial species bycatch rates were the highest on the Chatham Rise and the lowest for Cook Strait. Bycatch levels indicated that overall total bycatch decreased from 1990–91 to 1993–94, increased to 1999–2000, where it levelled off to 2003–04, and then decreased to a lower level from 2004–05 to 2006–07. Overall total bycatch appears to have been highest the five years from 1999–2000 to 2003–04, and 2004–05 to 2006–07 levels are at similar overall total bycatch in 1996–97. Overlapping bycatch levels are similar to previous studies despite differing definitions of datasets and analyses. Both hake and ling bycatch in the hoki target fishery decreased from 2000–01 to 2006–07. Non-commercial bycatch such as javelinfish and rattails that were previously discarded are now mainly mealed.

Basking sharks, which are a bycatch of the hoki fishery (Francis & Duffy 2002), are on Appendix 2 of CITES (i.e. requiring close monitoring to ensure that international trade does not reduce the wild

population to “a level at which its survival might be threatened by continued harvesting or other influences”), and on Appendix 1 of the Convention on Migratory Species (“endangered”). Both basking shark and deepsea skates (also a bycatch of the hoki fishery) are on the Department of Conservation’s threat classification list.

### 5.3 Incidental Catch (seabirds and mammals)

Seabird and marine mammal captures have been reported by observers and vessel returns in the hoki fishery. Estimation of total captures across the fleet is difficult where observer coverage is unrepresentative and has only been achieved consistently in the west coast and Sub-Antarctic fisheries (Table 4). Ratio estimators are available up to 2002–03 and for 2006–07 and 2007–08. Recent estimates have also used model based estimators which are considered to be more reliable. However, they are not directly comparable to the ratio estimates. The seabird species returned from the hoki fishery for necropsy, in decreasing numbers were; from 2006–07; sooty shearwater, white chinned petrel, Buller’s albatross, Northern Giant petrel, Salvin’s albatross, southern cape pigeon, Southern Giant petrel and white capped albatross (Thompson 2008), and from 2007–08 were; Buller’s albatross, white chinned petrel, sooty shearwater, Fairy prion, flesh footed shearwater and Westland petrel (Thompson 2009). Due to unrepresentative sampling and identification problems estimates of catch are not possible for most species but are possible for the most common bycatch species; sooty shearwaters and white chinned petrels. When estimated, highest catch rates and incident rates were recorded in Puysegur (Baird 2005a).

**Table 4: Estimates of total seabird capture in the hoki fishery 1998–99 to 2005–06 (1998–99 to 2002–03 from Baird 2005, 2003–04 to 2004–05 from Baird and Smith 2007, 2005–06 from Baird and Smith *in press* and 2006–07 to 2007–08 from Abraham and Thompson *in press*). CVs in parentheses; + indicates birds were observed caught but totals were not estimated as coverage was inadequate, \* indicates estimates were made and observer coverage was less than 10%, - indicates no birds were observed caught. All estimates based on ratio-estimations except those denoted with <sup>m</sup> where estimates using model-based predictions. Note that the 2007–08 figures are provisional. ^ indicates estimates for Stewart-Snares shelf only.**

Fishing Year	Chatham Rise	Cook Strait	West Coast South Island	Puysegur	Sub-Antarctic
1998–99	+	+	215 (18)	+	94 (23)
1999–00	+	+	69 (41)	+	209 (19)
2000–01	187 (20)	+	106 (26)	+	209 (27)
2001–02	80 (33)	+	108 (21)	+	155 (46)
2002–03	+	+	130 (27)	92 (53)	47 (43)
2003–04	340 (40)*	-	146 (30) <sup>m</sup>	-	54 (116) <sup>m</sup>
2004–05	194 (35)	182 (46)*	45 (39) <sup>m</sup>	26 (46)	54 (129)* <sup>m</sup>
2005–06	291 (24) <sup>m</sup>	+	28 (63) <sup>m</sup>	-	64 (111) <sup>m</sup>
2006–07	80 (25)	-	29 (32)	-	17 (48) <sup>^</sup>
2007–08	66 (56)	-	33 (22)	-	9 (27) <sup>^</sup>

Mitigation methods such as tori lines, Brady bafflers and offal management are being used in the hoki trawl fishery. Warp mitigation was voluntarily introduced from around 2004 and then made mandatory in April 2006.

Representative and adequate observer coverage has allowed estimation of marine mammal captures across the fleet in some fisheries (Table 5). Over 95% of the mammals observed caught were New Zealand fur seals. A voluntary code of practice to avoid seal captures has been in place since 1988 in the hoki fisheries. Fur seal captures vary by area and year and capture rates appear particularly high in Puysegur (Baird 2005b). Other species caught infrequently on observed vessels targeting hoki include sea lions and dusky dolphins.

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**Table 5: Estimates of fur seal capture in the hoki fishery 1994–95 to 2005–06 from Smith and Baird (2009). For fishing years 1995–96 to 2005–06 all estimates are from model-based predictions, while estimates for 2006–07 and 2007–08 are ratio estimates. CVs in parentheses; + indicates fur seals were observed caught but totals were not estimated as observer coverage was inadequate - no observed captures of fur seals in that strata. The Sub-Antarctic area includes hoki trawls on the Stewart/Snares Shelf as well as in FMA 6. Note that the 2007–08 figures are provisional. ^ indicates data from Stewart-Snares shelf only.**

Fishing Year	Chatham Rise	Cook Strait	Puysegur	WCSI	Sub-Antarctic
1995–96	89 (37)	-	38 (34)	307 (36)	63 (45)
1996–97	177 (33)	162 (97)	46 (39)	710 (26)	65 (40)
1997–98	309 (42)	-	56 (41)	542 (29)	71 (45)
1998–99	187 (37)	30 (86)	79 (38)	660 (27)	125 (42)
1999–00	249 (36)	128 (41)	86 (34)	321 (28)	135 (25)
2000–01	113 (44)	33 (89)	46 (42)	477 (25)	95 (28)
2001–02	138 (38)	94 (40)	52 (33)	433 (27)	87 (38)
2002–03	83 (42)	191 (58)	93 (31)	346 (27)	130 (40)
2003–04	142 (34)	62 (71)	29 (38)	227 (33)	44 (71)
2004–05	132 (36)	35 (95)	8 (43)	193 (32)	44 (62)
2005–06	117 (35)	280 (46)	25 (31)	173 (25)	29 (79)
2006–07	25 (42)	211 (22)	11 (59)	-	-^
2007–08	42 (31)	207 (21)	7 (31)	69 (21)	+^

### 5.4 Community and trophic structure

Hoki dominate the bottom fish community of the upper slope (Francis *et al.* 2002). They generally feed on mesopelagic fish, squids and crustaceans (Clark 1985a & 1985b; Stevens *et al.* in prep). There has been a 4-fold decline in the relative abundance of hoki on the Chatham Rise between 1991 and 2007, and this may have resulted in some effects on the trophic dynamics in the area (Bull *et al.* 2001). A preliminary study of trophic energetics in the Sub-Antarctic using the mass balance model ECOPATH identified the need for quantitative data on prey consumption by dominant fish species such as hoki (Bradford-Grieve *et al.* 2003).

Preliminary results from the Chatham Rise trophic study indicate that hoki predominately eat lantern fishes, particularly *Lampanyctodes hectoris*, and other mid-water fishes (Dunn *et al.*, 2007). They also consume significant quantities of natant decapods, notably pasiphaeid and sergestid shrimps, and euphausiids. The results so far corroborate the findings of Clark (1985a, 1985b) on the diet of hoki from the Campbell Plateau, New Zealand.

The results also show that hoki are prey of stargazers, smooth skates, deep water sharks (spiny dogfish, shovelnose dogfish, school sharks and leafscale gulper sharks), ling and hake. Ling appear to eat hoki that has been discarded and a few other species ingest hoki opportunistically while in the trawl net. There is no evidence that hoki are cannibalistic.

### 5.5 Spawning disruption

Although there has been no research on the disruption of spawning hoki by fishing, the Hoki Fishery Management Company has introduced closures to some spawning grounds as a precautionary measure (HFMC Code of Practice 2004–05). The closed areas include Hokitika Canyon, Puysegur, Pegasus Canyon, and the Narrows Basin in Cook Strait, at certain times of the year.

In the early history of the fishery when most fishing effort was on the west coast spawning fishery, the 25-mile restricted fishing zone protected hoki spawning aggregations in the head of Hokitika Canyon (the prime fishing ground) and other parts of the spawning grounds. The main fishing fleet consisted of large vessels, which operated outside the line both in the Canyon and to the north. There was a steady increase in the catch taken inside the 25-mile line by smaller vessels, from less than 2000 t per year to over 20 000 t per year from 2000–01 (Ballara *et al.* 2006), but this decreased to only 900 t in 2007–08. In Cook Strait, the entire spawning fishery lies inside a 25-mile restricted fishing zone that has been fished since 1988 by smaller vessels in the fleet.

### 5.6 Habitats of special significance

Currently, habitats of special significance have not been formally defined for any fisheries. Previous studies that are potentially relevant to the hoki fishery have already identified areas of importance for spawning, pupping, egg-laying and juveniles of coastal fish (Hurst *et al.* 2000) and deepwater fish, pelagic fish and invertebrates (O'Driscoll *et al.* 2003).

### 5.7 Biodiversity

Few studies to date have focused on biodiversity in the hoki or middle depth fisheries. A comparison of data from middle depth trawl surveys (McClatchie *et al.* 1997) found that species diversity was higher on the Chatham Rise than in the Sub-Antarctic. The only time-trend analysis of these data showed little trend in species diversity on the Chatham Rise from 1992–99 (Bull *et al.* 2001). Intra-specific genetic diversity of hoki has not been studied.

### 5.8 Aquaculture and enhancement

Not relevant to hoki fisheries.

## 6. STOCK ASSESSMENT

A new stock assessment was carried out in 2009 using research time series of abundance indices (trawl and acoustic surveys), proportions at age data from the commercial fisheries and trawl surveys, and estimates of biological parameters. New information included two trawl surveys, one acoustic survey, and updated catch at age data. The proportion spawning data has been re-analysed with the inclusion of more data (from 1993). The general-purpose stock assessment program, CASAL (Bull *et al.* 2008), was used and the approach, which used Bayesian estimation, was similar to that in the 2008 assessment (Francis 2009).

### 6.1 Methods

#### Model structure

The model partitions the population into two sexes, 17 age groups (1 to 17), two stocks [east (E) and west (W)], and four areas [Chatham Rise (CR), West Coast South Island (WC), Sub-Antarctic (SA), and Cook Strait (CS)]. The adult fish of the two stocks do not mix: those from the W stock spawn in WC and spend the rest of the year in SA; the E fish move between their spawning ground, CS, and their home ground, CR. Juvenile fish from both stocks live in CR, but natal fidelity is assumed (i.e., all fish spawn in the area in which they were spawned). The model does not distinguish between mature and immature fish; rather than having a maturity ogive and a single proportion spawning (assumed to be the same for all ages) there is simply a spawning ogive. The reason for this is that we have no direct observations of maturity to put in the model but we do have information about spawners (there are two April/May observations on SA of proportions of females that will spawn that year).

The model's annual cycle divides the fishing year into five time steps and includes four types of migration (Table 6). The first type involves only newly spawned fish, all of which are assumed to move from the spawning grounds (CS and WC) to arrive at CR at time step 2 and approximate age 1.6 y. The second affects only young W fish, some of which are assumed to migrate, at time step 3, from CR to SA. The last two types of migrations relate to spawning. Each year some fish migrate from their home ground (CR for E fish, SA for W fish) to their spawning ground (CS for E fish, WC for W fish) at time step 4. At time step 1 in the following year all spawners return to their home grounds. Both non-spawning fisheries (on CR and SA) were split into two halves to allow some of the catch to be taken before the Whome migration, and some after.

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**Table 6: Annual cycle of the assessment model, showing the processes taking place at each time step, their sequence within each time step, and the available observations (excluding catch-at-age). Any fishing and natural mortality within a time step occur after all other processes, with half of the natural mortality occurring before and after the fishing mortality. An age fraction of, say, 0.25 for a time step means that a 2+ fish is treated as being of age 2.25 in that time step. etc. The last column (“Propn. mort.”) shows the proportion of that time step’s total mortality that is assumed to have taken place when each observation is made.**

Step	Approx. months	Processes	<i>M</i> fraction	Age fraction	Observations	
					Label	Propn. Mort.
1	Oct-Nov	migrations Wreturn: WC→SA, Ereturn: CS→CR	0.17	0.25	–	–
2	Dec-Mar	recruitment at age 1+ to CR (for both stocks)	0.33	0.6	SAsumbio	0.5
		part1, non-spawning fisheries (Ensp1, Wnsp1)			CRsumbio	0.6
3	Apr-Jun	migration Whome: CR→SA	0.25	0.9	SAAutbio	0.1
		part2, non-spawning fisheries (Ensp2, Wnsp2)			pspawn	
4	End Jun	migrations Wspmg: SA→WC, Espmg: CR→CS	0	0.9	–	–
5	Jul-Sep	increment ages	0.25	0	CSacous	0.5
		spawning fisheries (Esp, Wsp)			WCacous	0.5

### Data and error assumptions

Five series of abundance indices were used in the assessment (Table 7). New data were available from an acoustic survey of Cook Strait in August 2008 (O'Driscoll 2009), and trawl surveys of the sub-Antarctic in December 2008 (Bagley & O'Driscoll in prep) and Chatham Rise in January 2009 (Stevens & O'Driscoll in prep).

**Table 7: Abundance indices (\*000 t) used in the stock assessment (\* data new to this assessment). Years are fishing years (1990 = 1989–90). – no data.**

Year	Acoustic survey WCSI, winter WCacous	Trawl survey Sub-Antarctic, December SAsumbio	Trawl survey Sub-Antarctic, April SAutbio	Trawl survey Chatham Rise, January CRsumbio	Acoustic survey Cook Strait, winter CSacous
1988	417	–	–	–	–
1989	249	–	–	–	–
1990	255	–	–	–	–
1991	340	–	–	–	180
1992	345	80	68	120	–
1993	550	87	–	186	583
1994	–	100	–	146	592
1995	–	–	–	120	427
1996	–	–	89	153	202
1997	654	–	–	158	295
1998	–	–	68	87	170
1999	–	–	–	109	243
2000	396	–	–	72	–
2001	–	56	–	60	220
2002	–	38	–	74	320
2003	–	40	–	53	225
2004	–	14	–	53	–
2005	–	18	–	85	132
2006	–	21	–	99	126
2007	–	14	–	70	216
2008	–	46	–	77	167
2009	–	47	–	144	–

The age data used in the assessment (Table 8) are similar to those used in 2008, but with an additional year’s data. The proportion spawning data were revised, based on a more robust analytical method that incorporated an additional year (1993) of data (Francis 2009). The most recent data suggest that the trend, noted in the 2007 Plenary Report, towards a decreasing proportion of older males (age 6 and older) in the W stock has reversed in the subsequent two years (see figure 4 of McKenzie 2009a).

**Table 8: Age data used in the assessment (\* data new to this assessment). Data are from otoliths or from the length-frequency analysis program OLF (Hicks *et al.* 2002). Years are fishing years (1990 = 1989–90).**

Area	Label	Data type	Years	Source of age data
WC	Wspage	Catch at age	1988–08*	otoliths
SA	WnspOLF	Catch at age	1992–94, 96, 99–00	OLF
	Wnspage	Catch at age	2001–04, 06–08*	otoliths
	SAsumage	Trawl survey	1992–94, 2001–09*	otoliths
	SAautage	Trawl survey	1992, 96, 98	otoliths
	pspaw	Proportion spawning	1992, 93*, 98	otoliths
CS	Espage	Catch at age	1988–08*	otoliths
CR	EnspOLF	Catch at age	1992, 94, 96, 98	OLF
	Enspage	Catch at age	1999–08*	otoliths
	CRsumage	Trawl survey	1992–09*	otoliths

The error distributions assumed were robust lognormal (Bull *et al.* 2008) for the at-age data, and lognormal for all other data. The weight assigned to each data set was controlled by the error coefficient of variation (CV). An arbitrary CV of 0.25 (as used by Cordue 2001) was assumed for the proportion spawning observations. Two alternative sets of CVs were used for the biomass indices (Table 9). The “total” CVs represent the best estimates of the uncertainty associated with these data, and were used in initial model runs. For the trawl-survey indices, these were calculated as the sum of an observation-error CV (which was calculated using the standard formulae for stratified random surveys, e.g., Livingston & Stevens 2002) and a process-error CV, which was set at 0.2, following Francis *et al.* (2001) (note that CVs add as squares:  $CV_{total}^2 = CV_{process}^2 + CV_{observation}^2$ ). For the acoustic indices, the total CVs were calculated using a simulation procedure intended to include all sources of uncertainty (O'Driscoll 2002). The observation-error CVs were calculated using standard formulae for stratified random acoustic surveys (e.g., Coombs & Cordue 1995) and include only the uncertainty associated with between-transect (and within-stratum) variation in total backscatter. In some model runs (including all final runs) it was decided to use the observation-error rather than the total CVs for all trawl survey biomass indices as a way of giving more weight to these data.

**Table 9: Coefficients of variation (CVs) used with biomass indices in the assessment. Observation-error CVs were used when it was desired to up-weight a series of indices. Years are fishing years (1990 = 1989–90).**

CRsumbio	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004		
Total	0.21	0.22	0.22	0.21	0.22	0.22	0.23	0.23	0.23	0.22	0.23	0.22	0.24		
Observation	0.08	0.10	0.10	0.08	0.10	0.08	0.11	0.12	0.12	0.10	0.11	0.09	0.13		
	2005	2006	2007	2008	2009										
Total	0.23	0.23	0.22	0.23	0.23										
Observation	0.12	0.11	0.08	0.11	0.11										
SAsumbio	1992	1993	1994	2001	2002	2003	2004	2005	2006	2007	2008	2009			
Total	0.21	0.21	0.22	0.24	0.26	0.24	0.24	0.23	0.24	0.23	0.26	0.24			
Observation	0.07	0.06	0.09	0.13	0.16	0.14	0.13	0.12	0.13	0.11	0.16	0.14			
SAautbio	1992	1996	1998												
Total	0.22	0.22	0.23												
Observation	0.08	0.09	0.11												
CSacous	1991	1993	1994	1995	1996	1997	1998	1999	2001	2002	2003	2005	2006	2007	2008
Total	0.41	0.52	0.91	0.61	0.57	0.40	0.44	0.36	0.30	0.34	0.34	0.32	0.34	0.46	0.30
Observation	0.13	0.15	0.06	0.12	0.09	0.12	0.10	0.10	0.12	0.13	0.17	0.11	0.17	0.26	0.06
WCacous	1988	1989	1990	1991	1992	1993	1997	2000							
Total	0.60	0.38	0.40	0.73	0.49	0.38	0.60	0.60							
Observation	0.22	0.15	0.06	0.14	0.14	0.07	0.10	0.14							

For the at-age data, overall CVs were treated as the sum of a process-error CV and an observation-error CV. The observation CVs for the otolith-based at-age data were calculated by a bootstrap procedure, which includes explicit allowance for age estimation error. No observation-error CVs were available for the OLF-based data from the non-spawning fisheries, so an ad hoc procedure was

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used to derive some, which were forced to be higher than those from the spawning fisheries (Francis 2004). Process-error CVs for the at-age data were estimated within the model for all point estimates. For full Bayesian estimates, these CVs were fixed at their point estimates.

The age ranges used in the model varied amongst data sets (Table 10). In all cases, the last age for these data sets was treated as a plus group.

**Table 10: Age ranges used for at-age data sets.**

Data set	Age range	
	Lower	Upper
Espage, Wspage, SAsumage, SAautage	2	15
Wnspage	2	13
CRsumage, Enspage	1	13
WnspOLF	2	6
EnspOLF	1	6
pspawn	3	9

The catch for each year was divided into the six fisheries of Table 12 according to area and month. This division was done using TCEPR, TCER, CELR, NCELR, LTCER LCER and TLCER data, and the resulting values were then scaled up to sum to the HOK 1 MHR total. The method of dividing the catches (Table 11) is the same as that used in the 2008 assessment, so the catches used in the model (Table 12) are unchanged, except for minor revisions to years 2001 to 2008 (including removing ET catches), and the addition of assumed catches for 2009, which are assumed equal to those for 2008.

**Table 11: Method of dividing annual catches into the six fisheries of Table 6. The small amount of catch reported in the areas west coast North Island and Challenger (typically 100 t per year) was ignored (which means that this catch is pro-rated across all fisheries).**

Area	Oct–Mar	Apr–May	Jun–Sep
West coast South Island; Puysegur	Wsp	Wsp	Wsp
Sub-Antarctic	Wnsp1	Wnsp2	Wnsp2
Cook Strait; Pegasus	Ensp1	Ensp2	Esp
Chatham Rise; east coasts of South Island & North Island; null <sup>1</sup>	Ensp1	Ensp2	Ensp2

<sup>1</sup> no area stated

**Table 12: Catches (t) by fishery and fishing year (1972 means fishing year 1971–72), as used in this assessment. Years are fishing years (1990 = 1989–90).**

Year	Fishery					
	Ensp1	Ensp2	Wnsp1	Wnsp2	Esp	Wsp
1972	1 500	2 500	0	0	0	5 000
1973	1 500	2 500	0	0	0	5 000
1974	2 200	3 800	0	0	0	5 000
1975	13 100	22 900	0	0	0	10 000
1976	13 500	23 500	0	0	0	30 000
1977	13 900	24 100	0	0	0	60 000
1978	1 100	1 900	0	0	0	5 000
1979	2 200	3 800	0	0	0	18 000
1980	2 900	5 100	0	0	0	20 000
1981	2 900	5 100	0	0	0	25 000
1982	2 600	4 400	0	0	0	25 000
1983	1 500	8 500	3 200	3 500	0	23 300
1984	3 200	6 800	6 700	5 400	0	27 900
1985	6 200	3 800	3 000	6 100	0	24 900
1986	3 700	13 300	7 200	3 300	0	71 500
1987	8 800	8 200	5 900	5 400	0	146 700
1988	9 000	6 000	5 400	7 600	600	227 000
1989	2 300	2 700	700	4 900	7 000	185 900
1990	3 300	9 700	900	9 100	14 000	173 000
1991	17 400	14 900	4 400	12 700	29 700	135 900
1992	33 400	17 500	14 000	17 400	25 600	107 200
1993	27 400	19 700	14 700	10 900	22 200	100 100
1994	16 000	10 600	5 800	5 500	35 900	117 200
1995	29 600	16 500	5 900	7 500	34 400	80 100
1996	37 900	23 900	5 700	6 800	59 700	75 900
1997	42 400	28 200	6 900	15 100	56 500	96 900
1998	55 600	34 200	10 900	14 600	46 700	107 100
1999	59 200	23 600	8 800	14 900	40 500	97 500



Table 12 Continued:

Year	Ensp1	Ensp2	Wnsp1	Wnsp2	Esp	Wsp
2000	43 100	20 500	14 300	19 500	39 000	105 600
2001	36700	20100	13300	17100	35100	107500
2002	24900	18800	16900	13500	24700	96700
2003	24300	18800	12300	7800	41400	79900
2004	17900	19000	6400	5300	40800	46300
2005	19200	14000	4400	1900	26200	38600
2006	22000	14800	2000	4700	20500	40400
2007	22400	18500	4200	3500	18800	33600
2008	22000	19400	6500	2200	17800	21400
2009	22000	19400	6500	2200	17800	21400

### Further assumptions

Two key outputs from the assessment are  $B_0$  – the average spawning stock biomass that would have occurred, over the period of the fishery, had there been no fishing – and year-class strengths (YCSs). (The YCS for 1970, say, is for fish which were spawned in the winter of 1970, and which first arrive in the model, in area CR, at age 1.6 y, in about December 1971, which is in model year 1972). Associated with  $B_0$  is an estimated mean recruitment,  $R_0$ , which is used, together with a Beverton-Holt stock-recruit relationship and the YCSs, to calculate the recruitment in each year. The first five YCSs (for years 1970 to 1974) are set equal to 1 (because of the lack of at-age data for the early years), but all the remaining YCSs (for 1975 to 2007) are estimated. The model corrects for bias in estimated YCSs arising from ageing error. YCSs are constrained to average 1 over the years 1975 to 2004, so that  $R_0$  may be thought of as the average recruitment over that period.  $R_0$  and a set of YCSs are estimated separately for each stock. The  $B_0$  for each stock is calculated as the spawning biomass that would occur given no fishing and constant recruitment,  $R_0$ , and  $B_{INIT}$  is set equal to  $B_0$ .

As was the case for the 2008 assessment, the steepness of the stock-recruitment relationship was assumed to be 0.75.

Two alternative approaches are used in modelling natural mortality. In some model runs it is assumed to vary with age (following a double-exponential curve), separately for each sex; in others (where sex is ignored) it is assumed to be independent of age.

The model uses six selectivity ogives (one each for the four fisheries and one each for trawl surveys in areas CR and SA) and three migration ogives (Whome, Espmg, and Wspmng – see Table 6).

Assumed maximum exploitation rates are as agreed to by the Working Group in 2004: 0.5 and 0.67 for the non-spawning and spawning fisheries, respectively. Because the non-spawning fisheries are split into two approximately equal halves a maximum exploitation rate of 0.3 is assumed for each half. This is approximately equivalent to 0.5 for the two halves combined. Penalty functions are used to discourage model fits which exceeded these maxima.

Prior distributions are assumed for all parameters. The main priors used are given in Table 13. In addition, bounds are imposed for parameters with non-uniform distributions. For the catchability parameters these are those calculated by O’Driscoll *et al.* (2002) (who called them overall bounds); for other parameters they are set at the 0.001 and 0.999 quantiles of their distributions. Prior distributions for all other parameters are assumed to be uniform, with bounds that were either natural (e.g., 0,1 for proportion migrating at age), wide enough so as not to affect point estimation, or, for some ogive parameters, deliberately set to constrain the ogive to a plausible shape.

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**Table 13: Assumed prior distributions for key parameters. Parameters are bounds for uniform; mean (in natural space) and CV for lognormal; and mean and SD for normal and beta.**

Parameter	Description	Distribution	Parameters		Reference
log_Bmean_total	$\log(B_{0,E} + B_{0,W})$	uniform	11.6	16.2	
pE (= Bmean_prop_stock1)	proportion unfished stock in E	beta(0.1,0.6) <sup>1</sup>	0.344	0.072	Smith (2004)
recruitment[E].YCS	year-class strengths (E)	lognormal	1	0.95	
recruitment[W].YCS	year-class strengths (W)	lognormal	1	0.95	
q[CSacous].q	catchability, CSacous	lognormal	0.77	0.77	WG Minutes of 24-2-04
q[WCacous].q	catchability, WCacous	lognormal	0.57	0.68	O'Driscoll <i>et al</i> (2002)
q[CRsum].q	catchability, CRsumbio	lognormal	0.15	0.65	O'Driscoll <i>et al</i> (2002)
q[SASum].q	catchability, SASumbio	lognormal	0.17	0.61	O'Driscoll <i>et al</i> (2002)
q[SAAut].q	catchability, SAAutbio	lognormal	0.17	0.61	O'Driscoll <i>et al</i> (2002)
selectivity[Wspsl].shift_a	allows annual shifting of Wspsl	normal	0	0.25	Francis (2006)
natural_mortality.all <sup>2</sup>	$M$	lognormal	0.298	0.153	Smith (2004)
natural_mortality <sup>3</sup>	$M_{\text{male}}$ & $M_{\text{female}}$ , ages 5–9 only	lognormal	0.182	0.509	Cordue (2006)

<sup>1</sup> This is a beta distribution, transformed to have its range from 0.1 to 0.6, rather than the usual 0 to 1.

<sup>2</sup> Used only in runs where  $M$  was independent of age and sex

<sup>3</sup> Used only in runs where  $M$  varied with age and sex

## 6.2 Results

The assessment was done in two steps. First, a set of initial exploratory model runs was carried out. Some of these runs were done before the new data were available and most generated only point estimates (so-called MPD runs, which estimate the mode of the posterior distribution). Their purpose was to provide information to make the decision as to which sets of assumptions should be carried forward and used in the final runs. The final runs were fully Bayesian, producing posterior distributions for all quantities of interest.

### Initial runs

Two sets of analyses were carried out after the new year's data became available (McKenzie 2009a&b). In the 2008 assessment the model was unable to fit the threefold increase in estimated biomass between the 2007 and 2008 surveys in the summer sub-Antarctic series (see SASumbio in Table 7). This biomass increase was sustained in the 2009 survey, and as in the previous assessment, it was decided that all series of trawl survey biomass observations should be upweighted in all final runs in order to improve the fit to the SASumbio series.

### Two final runs

The two final runs adopted by the Working Group are distinguished by the mechanism they used to deal with the problem of the lack of old fish in both fishery-based and survey-based observations (Table 14). Run 1.1 allowed  $M$  (natural mortality) to be dependent on age; run 1.2 allowed the spawning fishery selectivities (Espsl, Wpspl) to be domed. When the domed selectivities were used it was also necessary to combine sexes in the model and make the selectivities age-based (Francis 2005). As in previous years, biomass indices were upweighted when this was necessary to improve fits to these indices. This year, upweighting was done, in all runs, just for the trawl indices.

**Table 14: Distinguishing characteristics for the two final model runs.**

Label	Response to lack of old fish in the observations	Sex in model and selectivities length-based?
1.1	$M$ dependent on age	Yes
1.2	Domed spawning selectivity	No

Bayesian posterior distributions were estimated for each of these runs using a Markov Chain Monte Carlo approach. For each run, three chains of length 2 million were completed, the initial quarter of each chain was discarded, and the remaining samples were concatenated and thinned to produce a posterior sample of size 1000.

The model estimates are summarised in Table 15 (estimates of biomass), Figure 2 (biomass trajectories, and year-class strengths), and Figure 3 (current biomass distributions). Both model runs show that: the biomasses of both stocks were at their lowest points ever in about 2005 and are now increasing; that the W stock is almost certainly more depleted than the E stock; and that the W stock experienced seven years of poor recruitment from 1995 to 2001, inclusive. Recruitment for this

stock is estimated to have been near or above average in only 2 of the last 12 years (Figure 2). There is good agreement on estimates of year-class strengths, except that run 1.2 tends to estimate relatively stronger year classes in the early years and weaker in more recent years, and a weaker year class strength in 2006 for the W stock.

The current status of the W stock is much improved compared to that in the 2008 assessment. In that assessment there was a 0.38 and 0.52 probability that the stock was above 30 %B<sub>0</sub>, whereas the probability for this year is between 0.87 and 0.99 (Figure 3).

**Table 15: Estimates of spawning biomass for the final runs (median of marginal posteriors, with 95% confidence intervals in parentheses). B<sub>CURRENT</sub> is the spawning biomass in mid-season 2008–09.**

Run	B <sub>0</sub> (‘000 t)		B <sub>current</sub> (‘000 t)		B <sub>current</sub> (%B <sub>0</sub> )		
	E	W	E	W	E	W	E+W
1.1	511(446,602)	843(766,954)	244(188,311)	301(219,470)	47(40,56)	36(27,53)	40(34,52)
1.2	831(591,1141)	1046(851,1332)	401(276,575)	410(298,602)	49(40,59)	39(32,49)	43(38,50)

Three measures of fishing pressure (fishing mortality,  $F$ ; exploitation rate,  $U$ ; and percent spawning biomass per recruit, %SPR) are presented because the Working Group could not reach agreement as to which was the most relevant (Figure 4). All three measures were deemed to be more useful than the spawning fisheries exploitation rates that have been presented in previous assessments, because they do not ignore the effect of the non-spawning fisheries, and thus represent the total fishing pressure on each stock. The two rate measures ( $U$  and  $F$ ) are virtually identical, except for the scale on which they are measured.  $F$  is more commonly used by fishery scientists, and has a long history of research into associated target and limit biological reference points with which they can be compared;  $U$  may be more easily interpretable by non-scientists. The two rate measures differ from %SPR in two significant ways. First, they are designed to measure different things: the rates measure the actual pressure on the stock in each year, whereas %SPR measures, for each year, the long-term effect of continuing to fish at the same rate as obtained in that year. Second, because of this difference, the rate measures produce different between-run and between-stock contrasts in fishing pressure. All three measures show higher fishing pressure for run 1.1 than for run 1.2, and also usually higher pressure for the W stock than for the E stock, but these differences are greater for the rate measures than for %SPR.

Brief definitions of the three measures follow. The annual equivalent exploitation rate,  $U_y$ , is calculated as  $\max_{as} \left[ \left( \sum_f C_{asfy} \right) / \left( N_{asy} e^{-0.5M_{as}} \right) \right]$ , where the subscripts  $a$ ,  $s$ ,  $f$ , and  $y$  index age, sex, fishery, and year, respectively,  $C$  is the catch in numbers,  $N$  is the number of fish in the population immediately before the first fishery of the year, and  $M$  is the instantaneous rate of natural mortality. The annual equivalent instantaneous mortality rate,  $F_y$ , is given by  $\max_{as} \sum_t \left[ \log \left( N_{asty}^{pre} / N_{asty}^{post} \right) - M_{as} d_t \right]$ , where  $t$  indexes the within-year time steps in the model,  $d_t$  is the fraction of natural mortality that occurs in time step  $t$ , and  $N^{pre}$  and  $N^{post}$  are the numbers of fish immediately before and after fishing. %SPR for a given year is calculated from two simulation experiments. In the first experiment, fishing is simulated for many years with deterministic recruitment and the same exploitation rates and selectivities that were estimated for that year. Simulations continue until the population reaches equilibrium. The second experiment is the same, but with no fishing. %SPR is the equilibrium spawning biomass per recruit from the first experiment, expressed as a percentage of that from the second experiment. As such, %SPR represents the fishing pressure that would have accrued if the observed recruitment patterns had not happened; i.e. if successive years of poor (or good) recruitment had not been relevant.

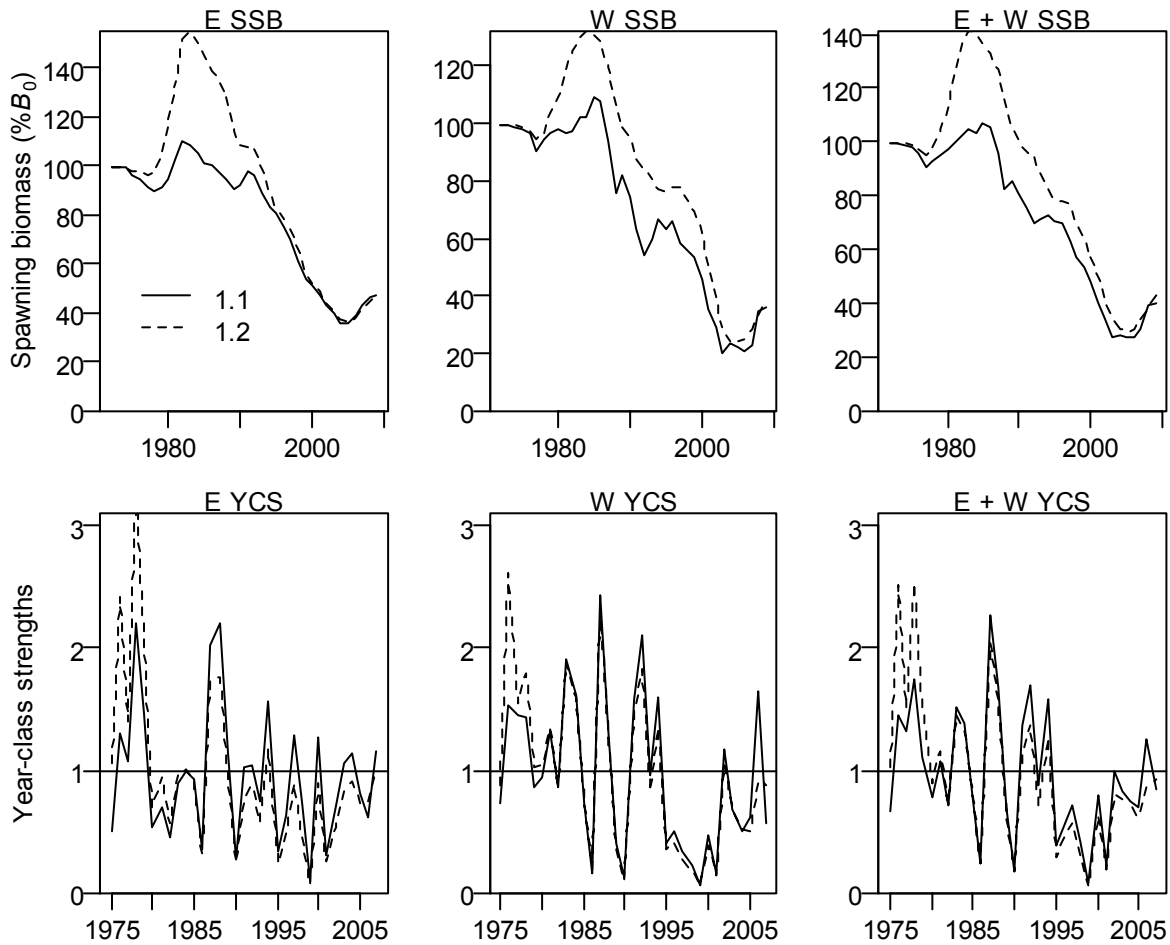


Figure 2: Estimated spawning biomass trajectories (SSB, upper panels) and year-class strengths (YCS, lower panels) for the E (left panels), W (middle panels) and E + W stocks (right panels) from the final model runs. Plotted values are medians of marginal posterior distributions. Years are fishing years (1990 = 1989–90).

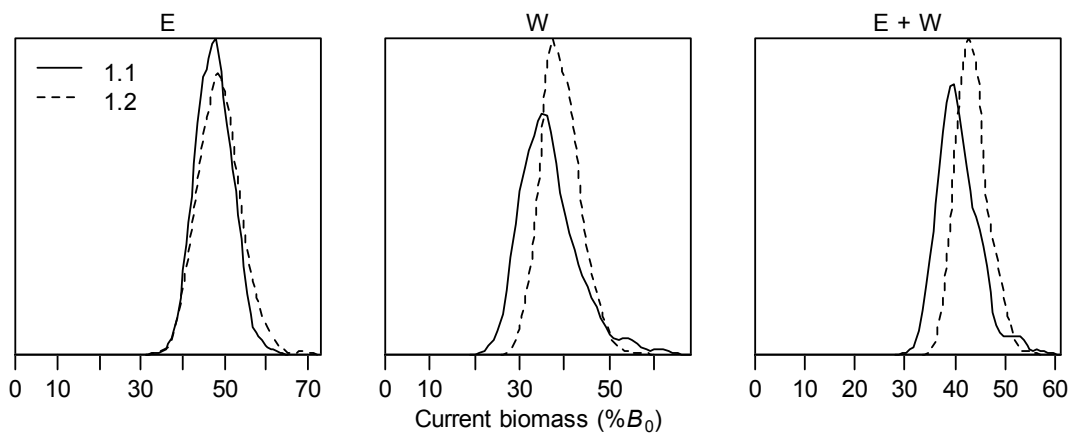


Figure 3: Estimated posterior distributions of current (spawning) biomass ( $B_{2008-09}$ ), expressed as % $B_0$ , for the E (left panel), W (middle panel) and E + W stocks (right panel) from the final model runs.

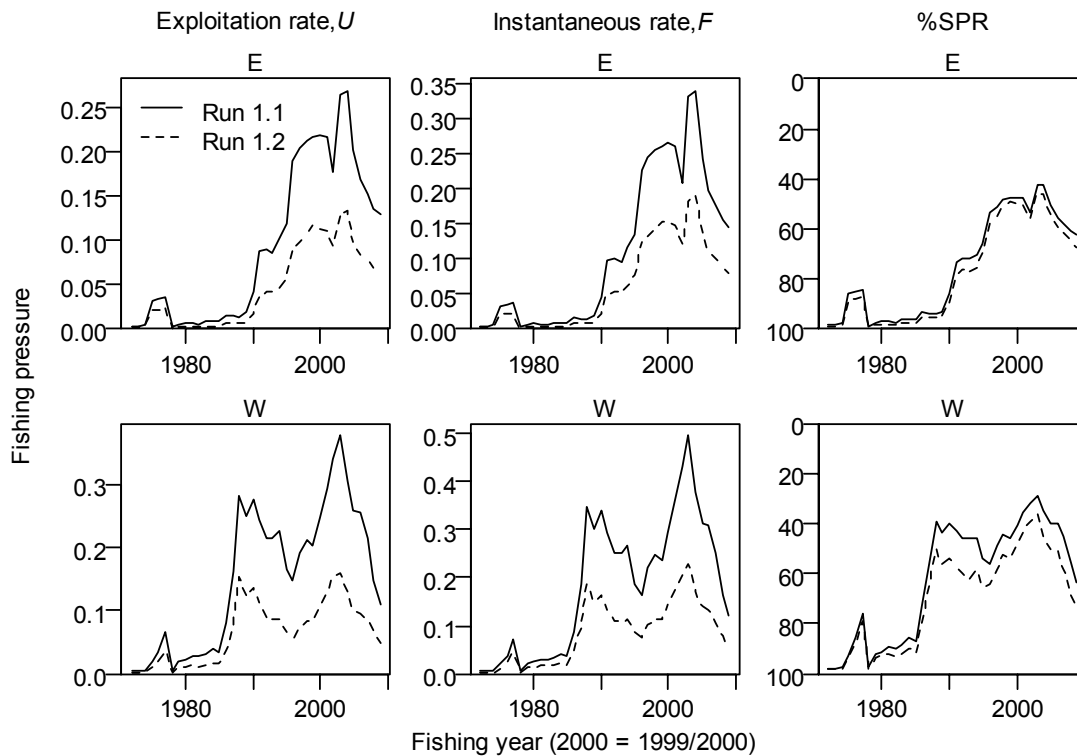


Figure 4: Three alternative measures of fishing pressure, as estimated in runs 1.1 (solid lines) and 1.2 (broken lines) for the E stock (upper panels) and W stock (lower panels): exploitation rates,  $U$  (left panels); instantaneous mortality rates,  $F$  (middle panels); and spawning potential ratio, %SPR (right panels). All measures are MPD estimates.

By all measures, fishing pressure on both stocks was estimated to be at or near all-time highs in 2003 and is now substantially lower (Figure 4). All measures of fishing pressure also indicate that the peak pressure on the W stock was markedly higher than that on the E stock.

### 6.3 Projections

Five-year projections were carried out, for each of the two final runs (1.1 and 1.2), under each of two alternative assumptions about future recruitment: ‘long-term’ (in which future recruitments were selected at random from those estimated for 1975–07) and ‘recent’ (future recruitments selected from 1995–07). The recent recruitment option was considered because of the recent period of below-average recruitment for the western stock, which may persist in the short-term. The eastern stock does not show such poor recruitment in recent years. In all projections, future catches in each fishery were assumed to be the same as for 2009 (i.e., as in the last line of Table 12). The projections indicate that with these assumed catches, the W biomass is likely to increase under either recruitment assumption; the E biomass will increase with long-term recruitment, but stay fairly constant with recent recruitment (Figure 5).

The probabilities of the current (2009) and projected spawning stock biomass being below the hard limit of 10%  $B_0$ , the soft limit of 20%  $B_0$ , and the lower and upper ends of the interim management target range of 35–50%  $B_0$  are presented in Table 16 for the case where future catches remain at 2009 levels. The probability of either stock being less than either the soft or the hard limit over the five year projection period is negligible. Both stocks are projected to be within or above the 35–50%  $B_0$  target range by the end of the projection period.

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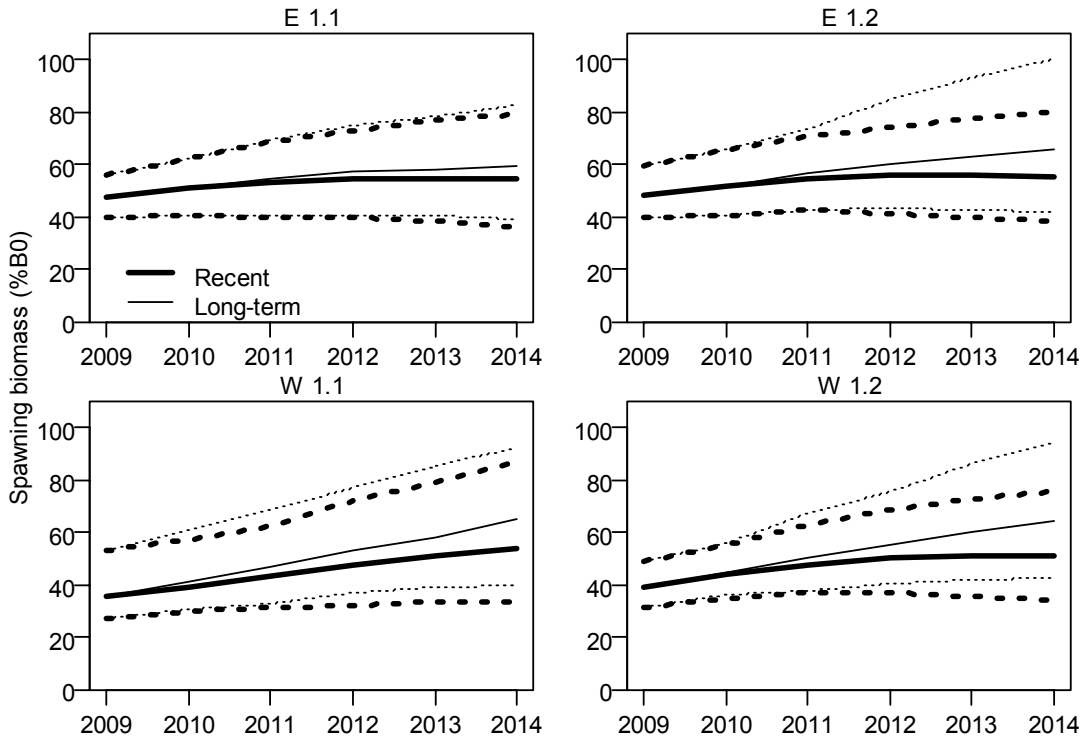


Figure 5: Projected spawning biomass (as %B<sub>0</sub>) assuming long-term (thin lines) or recent (thick lines) recruitment: median (solid lines) and 95% confidence intervals (broken lines).

Table 16: Probabilities (rounded to two decimal places) associated with projections for SSB (%B<sub>0</sub>) in Figure 5.

	RUN 1.1						RUN 1.2					
	2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014
EAST: Long-term recruitment												
P(SSB<10%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<10%B <sub>0</sub> )	0	0	0	0	0
P(SSB<20%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<20%B <sub>0</sub> )	0	0	0	0	0
P(SSB<35%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<35%B <sub>0</sub> )	0	0	0	0	0
P(SSB<50%B <sub>0</sub> )	0.72	0.41	0.25	0.21	0.21	0.19	P(SSB<50%B <sub>0</sub> )	0.59	0.35	0.19	0.12	0.11
EAST: Recent recruitment												
P(SSB<10%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<10%B <sub>0</sub> )	0	0	0	0	0
P(SSB<20%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<20%B <sub>0</sub> )	0	0	0	0	0
P(SSB<35%B <sub>0</sub> )	0	0	0	0	0.01	0.02	P(SSB<35%B <sub>0</sub> )	0	0	0	0	0.01
P(SSB<50%B <sub>0</sub> )	0.72	0.43	0.31	0.30	0.31	0.31	P(SSB<50%B <sub>0</sub> )	0.59	0.36	0.25	0.22	0.25
WEST: Long-term recruitment												
P(SSB<10%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<10%B <sub>0</sub> )	0	0	0	0	0
P(SSB<20%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<20%B <sub>0</sub> )	0	0	0	0	0
P(SSB<35%B <sub>0</sub> )	0.43	0.14	0.04	0.02	0.01	0.01	P(SSB<35%B <sub>0</sub> )	0.15	0.02	0.01	0	0
P(SSB<50%B <sub>0</sub> )	0.96	0.85	0.61	0.38	0.22	0.13	P(SSB<50%B <sub>0</sub> )	0.99	0.83	0.49	0.26	0.16
WEST: Recent recruitment												
P(SSB<10%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<10%B <sub>0</sub> )	0	0	0	0	0
P(SSB<20%B <sub>0</sub> )	0	0	0	0	0	0	P(SSB<20%B <sub>0</sub> )	0	0	0	0	0
P(SSB<35%B <sub>0</sub> )	0.43	0.20	0.08	0.05	0.04	0.04	P(SSB<35%B <sub>0</sub> )	0.15	0.02	0.02	0.01	0.02
P(SSB<50%B <sub>0</sub> )	0.96	0.91	0.78	0.61	0.45	0.37	P(SSB<50%B <sub>0</sub> )	0.99	0.85	0.63	0.47	0.44

#### 6.4 Calculation of $B_{MSY}$

$B_{MSY}$  was calculated, for each stock for each model run (1.1 and 1.2), assuming a harvest strategy in which the exploitation rate for fishery  $f$  was  $mU_{f,2009}$ , where  $U_{f,2009}$  is the estimated 2009 exploitation rate for that fishery, and  $m$  is some multiplier (the same for all fisheries). For each of a series of values of  $m$ , simulations were carried out with this harvest strategy and deterministic recruitment, with each simulation continuing until the population reached equilibrium. For each stock and run, the value of the multiplier,  $m$ , that maximised the equilibrium catch from that stock was found.  $B_{MSY}$  for that stock and run was then defined as the equilibrium biomass (expressed as  $\%B_0$ ) at that value of  $m$ .

Estimates of  $B_{MSY}$  were very similar for the two runs: about  $23\%B_0$  for the E stock, and  $25\%B_0$  for the W stock (Table 17). Sensitivity analyses (not presented) showed that these values changed very little (always by less than  $1\%B_0$ ) when the calculations were repeated using the final runs from the 2008 assessment, or when the harvest strategy was based on exploitation rates from a different year.

**Table 17: Estimates of  $B_{MSY}$  (expressed as  $\%B_0$ ) by stock for runs 1.1 and 1.2.**

Run	Stock	
	E	W
1.1	23.4	25.3
1.2	23.0	24.6

There are several reasons why  $B_{MSY}$ , as calculated in this way, is not a suitable target for management of the hoki fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge including perfect catch and biological information and perfect stock assessments (because current biomass must be known exactly in order to calculate the target catch), a constant-exploitation management strategy with annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders), and perfect management implementation of the TACC and catch splits with no under- or overruns. Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known (Francis 2009). Third, it makes no allowance for extended periods of low recruitment, such as that observed in 1995–2001 for the W stock. Fourth, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below  $20\% B_0$ , the default soft limit according to the Harvest Strategy Standard. Thus, the actual target probably needs to be considerably above this theoretical optimum; but the extent to which it needs to be above has not been determined.

## 7. STATUS OF THE STOCKS

### Stock Structure Assumptions

Hoki are assessed as two intermixing biological stocks, based on the presence of two main areas where spawning takes place simultaneously (Cook Strait and WCSI), and observed and inferred migration patterns of adults and juveniles:

- Adults of the western stock occur on the west coast of the North and South Islands and the area south of New Zealand including Puysegur, Snares and the Southern Plateau;
- Adults of the eastern stock occur on the east coast of the South Island, Cook Strait and the ECNI up to North Cape;
- Juveniles of both biological stocks occur on the Chatham Rise including Mernoo Bank.

Both of these biological stocks lie within the HOK 1 Fishstock boundaries.

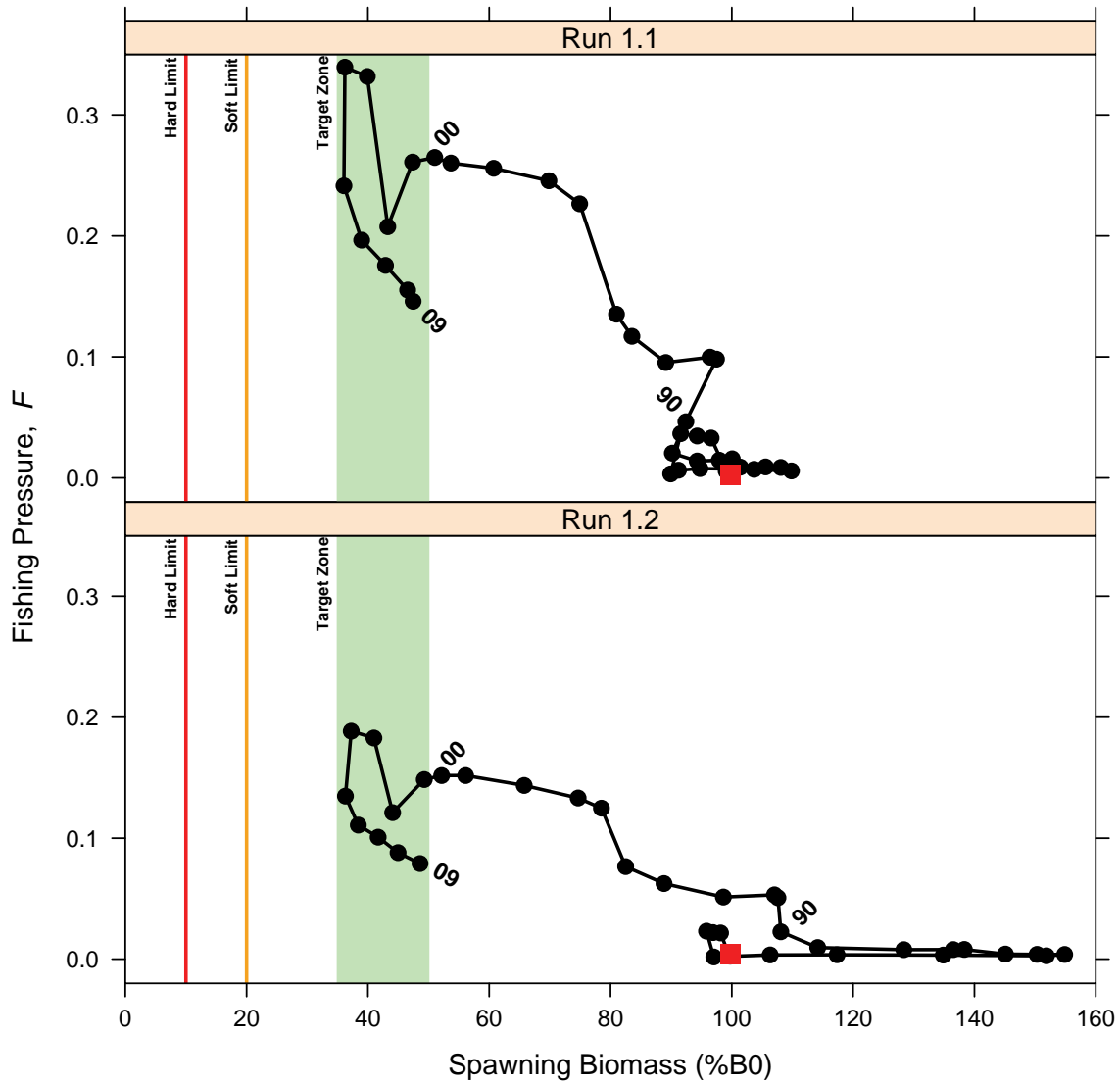
- **Eastern Hoki Stock**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	Two alternate model runs, considered equally plausible, were used to evaluate hoki stock status in this assessment: Model Runs 1.1 and 1.2

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Reference Points	$B_{MSY}$ : 23% $B_0$ Interim Management Target: 35-50% $B_0$ Soft Limit: 20% $B_0$ Hard Limit: 10% $B_0$
Status in relation to Target	$B_{2009}$ was estimated to be about 48% $B_0$ ; Very Likely (> 90% probability) to be above the lower end of the Interim Management Target
Status in relation to Limits	$B_{2009}$ is Virtually Certain (> 99% probability) to be above both the Soft and Hard Limits

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing mortality ( $F$ ) and spawning biomass ( $\%B_0$ ), for the eastern hoki stock from the start of the assessment period in 1972 (represented by a square), to the most recent assessment in 2009. The vertical line at 10%  $B_0$  represents the hard limit, that at 20%  $B_0$  is the soft limit, and the shaded area represents the interim management target range. Biomass estimates are based on MCMC results, while fishing mortality is based on corresponding MPD results.



<b>Fishery and Stock Trends</b>	
Recent Trend in Biomass or Proxy	Estimates of biomass have never been below 36% $B_0$ (in the year 2005). Biomass has subsequently been increasing.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been continuously decreasing since 2004.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recent recruitment (1995-2007) is estimated to be near the long-term average for this stock.

<b>Projections and Prognosis</b>	
Stock Projections or Prognosis	The biomass of the eastern hoki stock is expected to increase slightly over the next 5 years at 2007-08 eastern fishery catch levels.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Very Unlikely Hard Limit: Very Unlikely

<b>Assessment Methodology</b>	
Assessment Type	Level 1 – Quantitative stock assessment
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.
Main data inputs	- Research time series of abundance indices (trawl and acoustic surveys). - Proportions at age data from the commercial fisheries and trawl surveys. - Estimates of biological parameters. New information since the 2008 assessment included two trawl surveys, one acoustic survey, updated catch and catch-at-age data and new proportion spawning data.
Period of Assessment	Latest assessment: 2009      Next assessment: 2010
Changes to Model Structure and Assumptions	None since the 2008 assessment.
Major Sources of Uncertainty	The two Model Runs represent different ways of dealing with the unexplained lack of older fish in commercial catches and surveys; the first estimates natural mortality at age which results in older fish suffering high natural mortality; the second assumes natural mortality does not vary with age but allows dome-shaped selectivity which results in a “cryptic” component of the biomass of older fish. Aside from natural mortality, other major sources of uncertainty include stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions. Uncertainty about the size of recent year classes affects the reliability of stock projections.

<b>Qualifying Comments</b>
None

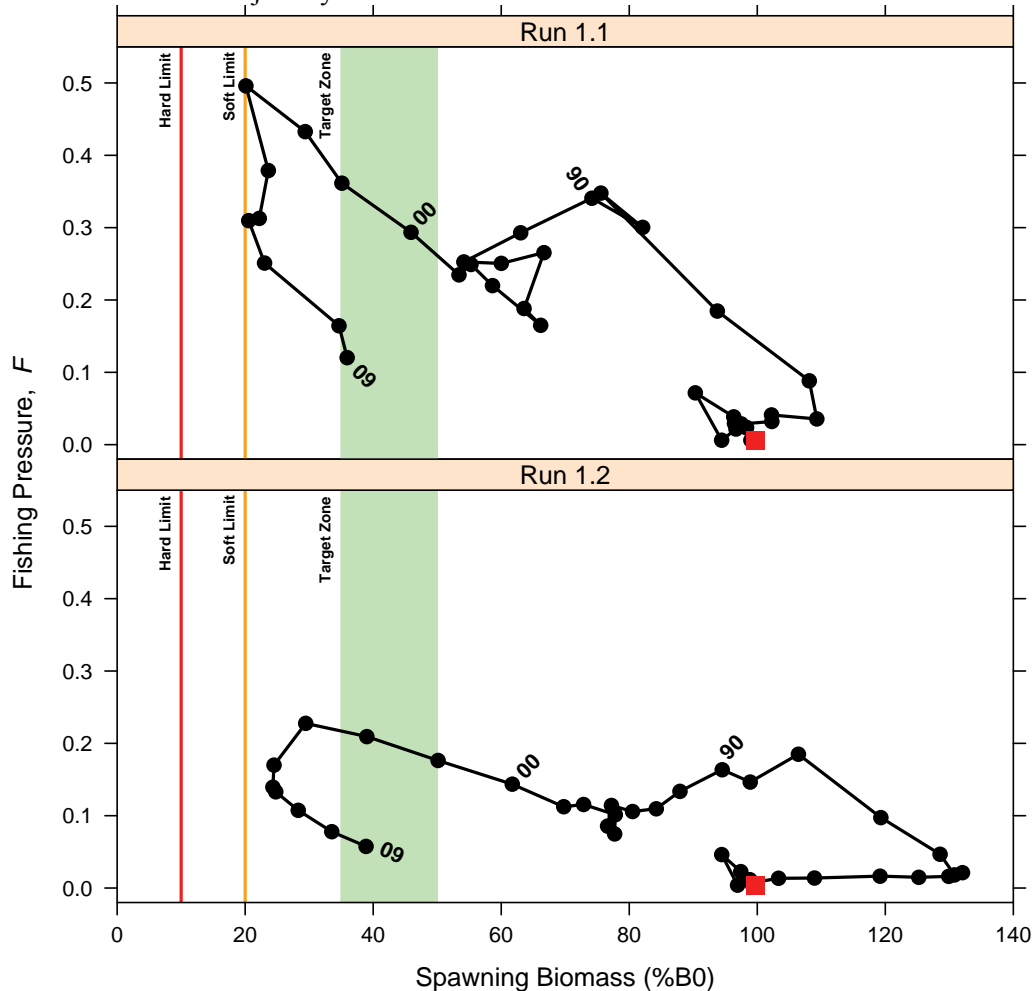
<b>Fishery Interactions</b>
Main bycatch species are hake, ling, silver warehou and spiny dogfish, with lesser bycatches of ghostsharks, white warehou, sea perch and stargazers. Bycatch species of concern include basking sharks, deepsea skates, fur seals and seabirds.

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• Western Hoki Stock

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	Two alternative model runs, considered equally plausible, were used to evaluate hoki stock status in this assessment: Model Runs 1.1 and 1.2
Reference Points	$B_{MSY}$ : 25% $B_0$ Interim Management Target: 35-50% $B_0$ Soft Limit: 20% $B_0$ Hard Limit: 10% $B_0$
Status in relation to Target	<u>Model run 1.1:</u> $B_{2009}$ was estimated to be 36% $B_0$ ; About as Likely as Not (40-60% probability) to be above the lower end of the Interim Management Target <u>Model Run 1.2:</u> $B_{2009}$ was estimated to be 39% $B_0$ ; Likely (> 60% probability) to be above the lower end of the Interim Management Target
Status in relation to Limits	<u>Both Model Runs:</u> $B_{2009}$ Very Likely (> 90% probability) to be above both the Soft and Hard Limits

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing mortality ( $F$ ) and spawning biomass ( $\%B_0$ ), for the western hoki stock from the start of the assessment period in 1972 (represented by a square), to the most recent assessment in 2009. The vertical line at 10%  $B_0$  represents the hard limit, that at 20%  $B_0$  is the soft limit, and the shaded area represents the interim management target range. Biomass estimates are based on MCMC results, while fishing mortality is based on corresponding MPD results.

<b>Fishery and Stock Trends</b>	
Recent Trend in Biomass or Proxy	Biomass is estimated to have increased by 79% from historical lows (20% B <sub>0</sub> for Model Run 1.1 and 24%B <sub>0</sub> for Model Run 1.2) that occurred during the period 2003-06.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been decreasing since 2003.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	This stock experienced an extended period of poor recruitment from 1995 to 2001. Year-classes after 2001 are estimated to be stronger, with two years in which recruitment is estimated to be near or above the long-term average.

<b>Projections and Prognosis</b>	
Stock Projections or Prognosis	The biomass of the western hoki stock is expected to increase over the next 5 years at 2007-08 western fishery catch levels.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Very Unlikely Hard Limit: Very Unlikely

<b>Assessment Methodology</b>	Same as that outlined for the eastern stock above, plus one additional major source of uncertainty; namely, the lack of fit of the models to recent increases in the sub-Antarctic survey estimates of biomass.
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<b>Qualifying Comments</b>
None

<b>Fishery Interactions</b>
Main bycatch species are hake, ling, silver warehou, jack mackerel and spiny dogfish, with lesser bycatches of ghostsharks, white warehou, sea perch and stargazers. Bycatch species of concern include basking sharks, deepsea skates, fur seals and seabirds.

## 8. FOR FURTHER INFORMATION

- Anderson OF., Smith MH. 2005. Fish discards and non-target fish catch in the New Zealand hoki trawl fishery, 1999-2000 to 2002-03. New Zealand Fisheries Assessment Report 2005/3. 37p.
- Anderson OF., Gilbert DJ., Clark MR. 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. 57p.
- Baird SJ. 2005a. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002-03. New Zealand Fisheries Assessment Report 2005/2. 50p.
- Baird SJ. 2005b. Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2002-03. New Zealand Fisheries Assessment Report 2005/12. 35p.
- Baird SJ., Smith MH. 2007. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2003-04 and 2004-05. New Zealand Aquatic Environment and Biodiversity Report No. 9. 108p.
- Ballara SL., Hurst RJ., Cordue PL. 1999. Estimates of natural mortality for hoki. Final Research Report for Ministry of Fisheries Project HOK9801 Objective 10. 11p.
- Baird SJ., Bagley NW., Wood BA., Dunn A., Beentjes M. 2002. The spatial extent and nature of mobile bottom fishing methods within the New Zealand EEZ 1989-90 to 1998-99. Final Research Report for MFish Project ENV2000/05. 36p.
- Baird SJ., Smith MH. (in press). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2005-06. New Zealand Aquatic Environment and Biodiversity Report 2008 No #. 124p.
- Ballara SL., O'Driscoll RL., Bagley NW., Stevens DW., Fu D. 2008. Hoki data collation: a report to the 2008 Hoki Working Group on the hoki trawl and acoustic surveys, catches, CPUE, size, and age structure of the hoki fishery, including the 2005-06 data update. WG HOK 2008/03. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Ballara SL., O'Driscoll RL., Fu D. 2006. Catches, size, and age structure of the 2004-05 hoki fishery, and a summary of input data used for the 2006 stock assessment. New Zealand Fisheries Assessment Report 2006/49. 97p.
- Ballara SL., Phillips NL., Smith MH., Dunn A. 2006. Descriptive analysis of hoki (*Macruronus novaezelandiae*) fisheries on the west coast South Island, Cook Strait, Chatham Rise, and sub-Antarctic, and catch-per-unit-effort analysis of the Chatham Rise hoki fishery for the years 1990-2003. New Zealand Fisheries Assessment Report 2006/19. 57p.
- Booth JD., Baird SJ., Stevenson ML., Bagley NW., Wood BA. 2002. Review of technologies and practices to reduce bottom trawl bycatch and seafloor disturbance in New Zealand. Final Research Report for MFish Project ENV2000/06.
- Bradford-Grieve JM., Probert PK., Baker AN., Best HA., Boyd P., Broekhuizen N., Childerhouse S., Clark M., Hadfield M., Hall JA., Hanchet S., Nodder SD., Safi K., Thompson D., Wilkinson I., Zeldis J. 2003. Pilot trophic model for subantarctic water over the

## HOKI (HOK)

- Southern Plateau, New Zealand: a low biomass, high transfer efficiency system. *Journal of Experimental Marine Biology* 289: 223–262.
- Bull B. 2000. An acoustic study of the vertical distribution of hoki on the Chatham Rise. *New Zealand Fisheries Assessment Report* 2000/05. 60p.
- Bull B., Livingston ME. 2000. Hoki migration patterns: an analysis of commercial catches in New Zealand waters 1985–99. *NIWA Client Report* 2000/63. 49p.
- Bull B., Livingston ME. 2001. Links between climate variation and the year class strength of New Zealand hoki (*Macruronus novaezelandiae*): an update. *New Zealand Journal of Marine and Freshwater Research* 35(5): 871–880.
- Bull B., Livingston ME., Hurst RJ., 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.
- Bull B., Francis RICC., Dunn A., McKenzie A., Gilbert DJ., Smith MH., Bian R. 2008. CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.20-2008/02/14. *NIWA Technical Report* 130. 275 p.
- Clark MR. 1985a. The food and feeding of seven fish species from the Campbell Plateau, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 33: 339–363.
- Clark MR. 1985b. Feeding relationships of seven fish species from the Campbell Plateau, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 19: 365–374.
- Collie JS., Hall SJ., Kaiser MJ., Poiner IR. 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. *Journal of Animal Ecology* 69: 785–798.
- Coombs RF., Cordue PL. 1995. Evolution of a stock assessment tool: acoustic surveys of spawning hoki (*Macruronus novaezelandiae*) off the west coast of South Island, New Zealand, 1985–91. *New Zealand Journal of Marine and Freshwater Research* 29: 175–194.
- Cordue PL. 2001. MIAEL estimation of biomass and fishery indicators for the 2001 assessment of hoki stocks. *New Zealand Fisheries Assessment Report* 2001/65. 59p.
- Cordue PL. 2006. Report on the 13 November 2006 M-prior HWG sub-group meeting. Unpublished report to the Hoki Working Group, dated 17 November 2006
- De Juan S., Thrush SF., Demestre M. 2007. Functional changes as indicators of trawling disturbance on a benthic community located in a fishing ground (NW Mediterranean Sea). *Marine Ecology Progress Series* 334: 117–129.
- Dunn A., Livingston ME. 2004. Update catch-per-unit-effort indices and descriptive analyses for hoki (*Macruronus novaezelandiae*) fisheries on the west coast South Island, Cook Strait, Chatham Rise, and Sub-Antarctic, 1990 to 2002. *New Zealand Fisheries Assessment Report* 2004/35. 55p.
- Dunn M., Connell A., Stevens D. 2007. Preliminary results from Chatham Rise Trophic Study presented at Marine Science Conference, Nelson 2006.
- Francis MP., Duffy C. 2002. Distribution, seasonal abundance and bycatch of basking sharks (*Cetorhinus maximus*) in New Zealand, with observations on their winter habitat. *Marine Biology* 140(4): 831–842, 2002.
- Francis MP., Hurst RJ., McArdle B., Bagley NW., Anderson OF. 2002. New Zealand demersal fish assemblages. *Environmental Biology of Fishes* 62(2): 215–234
- Francis RICC. 2001. Improving the consistency of hoki age estimation. *New Zealand Fisheries Assessment Report* 2001/12. 18p.
- Francis RICC. 2003. Analyses supporting the 2002 stock assessment of hoki. *New Zealand Fisheries Assessment Report* 2003/5. 34p.
- Francis RICC. 2004. Preliminary analyses for the 2004 hoki assessment. WG-Hoki-2004/9. 28p. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Francis RICC. 2005. Assessment of hoki (*Macruronus novaezelandiae*) in 2004. *New Zealand Fisheries Assessment Report* 2005/35. 97p.
- Francis RICC. 2006. Assessment of hoki (*Macruronus novaezelandiae*) in 2005. *New Zealand Fisheries Assessment Report* 2006/3. 96p.
- Francis RICC. 2007. Assessment of hoki (*Macruronus novaezelandiae*) in 2006. *New Zealand Fisheries Assessment Report* 2007/15. 99p.
- Francis RICC. 2008a. Assessment of hoki (*Macruronus novaezelandiae*) in 2007. *New Zealand Fisheries Assessment Report* 2008/4. 109p.
- Francis RICC. 2009. Assessment of hoki (*Macruronus novaezelandiae*) in 2008. *New Zealand Fisheries Assessment Report* 2009/7. 80p.
- Francis RICC., Hurst RJ., Renwick JA. 2001. An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report* 2001/1. 37p.
- Francis RICC., Hadfield MG., Bradford-Grieve JM., Sutton PJH. 2006. Links between climate and recruitment of New Zealand hoki (*Macruronus novaezelandiae*) now unclear. *New Zealand Journal of Marine and Freshwater Research* 40: 547–560.
- Grange K. 1993. Hoki offal dumping on the continental shelf: a preliminary benthic assessment. *New Zealand Marine Sciences Society Review* 35: 15
- Grimes PJ., O'Driscoll RL. 2006. Estimating the proportion of female hoki on the Southern Plateau which spawn each year by microscopic examination of gonad samples. *Final Research Report for Ministry of Fisheries Project MDT2003/01 Objective 6*. 40p.
- Haist V., Hurst RJ., O'Driscoll RL., Middleton DAJ. 2007. Hoki codend retention study. *Final report for Deepwater Group Ltd. Seafood Industry Council, October 2007*. 26p.
- Hicks AC., Gilbert DJ. 2002. Stock discrimination of hoki (*Macruronus novaezelandiae*) based on otolith ring measurements. *New Zealand Fisheries Assessment Report* 2002/2. 31p.
- Hicks AC., Cordue PL., Bull B. 2002. Estimating proportion at age and sex in the commercial catch of hoki (*Macruronus novaezelandiae*) using length frequency data. *New Zealand Fisheries Assessment Report* 2002/43. 51p.
- Hicks AC., Smith PJ., Horn PL., Gilbert DJ. 2003. Differences in otolith measurements and gill raker counts between the two major spawning stocks of hoki (*Macruronus novaezelandiae*) in New Zealand. *New Zealand Fisheries Assessment Report* 2003/7. 23p.
- Horn PL., Sullivan KJ. 1996. Validated aging methodology using otoliths, and growth parameters for hoki (*Macruronus novaezelandiae*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research* 30: 161–174.
- Hurst RJ., Bagley NW., Anderson OF., Francis MP., Griggs LH., Clark MR., Paul LJ. and Taylor, P.R. (2000). Atlas of juvenile and adult fish and squid distributions from bottom and mid-water trawls and tuna longlines in New Zealand waters. *NIWA Technical Report* 84. 162p.
- Jones JB. 1993. Net damage injuries to New Zealand hoki, *Macruronus novaezelandiae*. *New Zealand Journal of Marine and Freshwater Research* 27: 23–30.
- Kaiser MJ., Collie JS., Hall SJ., Jennings S., Poiner IR. 2002. Modification of marine habitats by trawling activities: prognosis and solutions. *Fish and Fisheries* 3: 114–136.
- Kaiser MJ., Clarke KR., Hinz H., Austen MCV., Somerfield PJ., Karakassis I. 2006. Global analysis of response and recovery of benthic biota to fishing. *Marine Ecology Progress Series* 311: 1–14
- Kalish JM., Livingston ME., Schofield KA. 1996. Trace elements in the otoliths of New Zealand blue grenadier (*Macruronus novaezelandiae*) as an aid to stock discrimination. *Marine and Freshwater Research* 47: 537–542.
- Langley AD. 2001. Summary report of biological data collected from the hoki fishery by the Hoki Management Company Limited during the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report* 2001/77. 34p.
- Livingston ME. 2000. Links between climate variation and the year class strength of New Zealand hoki (*Macruronus novaezelandiae*) Hector. *New Zealand Journal of Marine and Freshwater Research* 34: 55–69.

- Livingston ME., Bull B. 2000. The proportion of female hoki developing to spawn on the Southern Plateau, April 1998. New Zealand Fisheries Assessment Report 2000/13. 20p.
- Livingston ME., Renwick J. 2003. Climate change and implication for fisheries. *Seafood New Zealand* 11(11): 40–41.
- Livingston ME., Rutherford K. 1988. Hoki wastes on west coast fishing grounds. *Catch*, March 1988: 16-17.
- Livingston ME., Schofield KA. 1996a. Annual changes in the abundance of hoki and other species on the Chatham Rise, Jan 1992-Jan 1995 and the Southern Plateau, Dec 1991-Dec 1993. N.Z. Fisheries Assessment Research Document 1996/14. 35p.
- Livingston ME., Schofield KA. 1996b. Stock discrimination of hoki (*Macruronus novaezelandiae* Merlucciidae) in New Zealand waters, using morphometrics. *New Zealand Journal of Marine and Freshwater Research* 30: 197–208.
- Livingston ME., Stevens DW. 2002. Review of trawl survey abundance data available as inputs to the hoki stock assessment. New Zealand Fisheries Assessment Report 2002/48. 69p.
- Livingston ME., Stevens DW. 2004. Sampling programme to construct and quantify food webs supporting important fish and invertebrate species in New Zealand waters. Final Research Report for Ministry of Fisheries Research Project ENV2002/07 Obj.1.
- Livingston ME., Schofield KA., Sullivan KJ. 1992. The discrimination of hoki groups in New Zealand waters using morphometrics and age-growth parameters. *New Zealand Fisheries Assessment Research Document* 1992/18. 30p.
- Livingston ME., Vignaux M., Schofield KA. 1997. Estimating the annual proportion of non-spawning adults in the New Zealand hoki, *Macruronus novaezelandiae* Hector. *Fishery Bulletin* 95: 99–113.
- Livingston ME., Bull B., Gilbert DJ. 2000. The observed sex ratios of hoki (*Macruronus novaezelandiae*) in New Zealand, 1983–99. *New Zealand Fisheries Assessment Report* 2000/24. 40p.
- Livingston ME., Bull B., Stevens DW. 2002. Migration patterns during the life-cycle of hoki (*Macruronus novaezelandiae*): an analysis of trawl survey data in New Zealand waters 1991–2002. Final Research Report for Ministry of Fisheries Research Project HOK2000/01 Objective 6.
- Livingston ME., Clark M., Baird SJ. 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 ME., Stevens DW., O'Driscoll RL., Francis RICC. 2004. Trawl survey of hoki and middle depth species on the Chatham Rise, January 2003 (TAN0301). *New Zealand Fisheries Assessment Report* 2004/16. 71p.
- Lohrer DAM., Trush SF., Gibbs M. 2004. Bioturbators enhance ecosystem function through complex biogeochemical interactions. *Nature* 431: 1092-1095
- Macaulay GJ. 2006. Target strength estimates of hoki. Final Research Report for Ministry of Fisheries Project HOK2004/03 Objective 3. 13p.
- Massey BR., Hore AJ. 1987. A preliminary trawl mesh selection study of barracouta (*Thyrstites atun*) Central Fisheries Region Internal Report No. 6. 28p. (Draft report, held by MAFFish Central Region, Napier)
- McClatchie S., Millar RB., Webster F., Lester PJ., Hurst R., Bagley N. 1997. Demersal fish community diversity off New Zealand: Is it related to depth, latitude and regional surface phytoplankton? *Deep-Sea Research I* 44 (4): 647–667.
- McClatchie S., Pinkerton M., Livingston ME. 2005. Relating the distribution of a semi-demersal fish, *Macruronus novaezelandiae*, to their pelagic food supply. *Deep-Sea Research Part I* 52: 1489–1501.
- Mckenzie A. 2009a. Preliminary assessment results for hoki in 2009. WG-HOK-2009/11. 22p. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Mckenzie A. 2009b. Exploratory analyses and MCMC assessment results for hoki in 2009. WG-HOK-2009/15. 12p. (Unpublished report held by Ministry of Fisheries, Wellington.)
- McKnight DG., Probert PK. 1997. Epibenthic communities on the Chatham Rise, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 31:505–513
- Murdoch RC. 1990. Diet of hoki larvae (*Macruronus novaezelandiae*) off Westland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24: 519-527.
- Murdoch RC. 1992. A review of the ecology of hoki *Macruronus novaezelandiae* (Hector), larvae in New Zealand waters. *Bureau of Rural Resources Proceedings* 15: 3-16.
- Murdoch RC., Guo R., McCrone A. 1990. Distribution of hoki (*Macruronus novaezelandiae*) eggs and larvae in relation to hydrography in eastern Cook Strait, September 1987. *New Zealand Journal of Marine and Freshwater Research* 24: 533-543.
- Norse EA., Watling L. 1999. Impacts of mobile fishing gear: the biodiversity perspective. *American Fisheries Society Symposium* 22: 31-40
- O'Driscoll RL. 2002. Review of acoustic data inputs for the 2002 hoki stock assessment. *New Zealand Fisheries Assessment Report* 2002/36. 67p.
- O'Driscoll RL. 2004. Estimating uncertainty associated with acoustic surveys of spawning hoki (*Macruronus novaezelandiae*) in Cook Strait, New Zealand. *ICES Journal of Marine Science* 61: 84–97.
- O'Driscoll RL. 2006. Acoustic survey of spawning hoki in Cook Strait during winter 2005, and revision of hoki acoustic abundance indices for Cook Strait and the west coast South Island. *New Zealand Fisheries Assessment Report* 2006/44. 46p.
- O'Driscoll RL. 2007. Acoustic survey of spawning hoki in Cook Strait and off the east coast South Island in winter 2006. *Fisheries Assessment Report* 2007/21. 52p.
- O'Driscoll, R.L. (2009). Acoustic survey of spawning hoki in Cook Strait and off the east coast South Island during winter 2008. *New Zealand Fisheries Assessment Report* 2009/17. 52 p.
- O'Driscoll RL., Bagley NW. 2001. Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic area 1991–98. NIWA Technical Report 102. 115p
- O'Driscoll RL., Bagley NW. 2006. Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November–December 2005 (TAN0515). *New Zealand Fisheries Assessment Report* 2006/45. 64p.
- O'Driscoll RL., Bagley NW. (in press). Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November–December 2006 (TAN0617). Draft Fisheries Assessment Report.
- Bagley NW., O'Driscoll RL., (in prep). Trawl survey of middle depths species in the Southland and Sub-Antarctic areas, November–December 2008 (TAN0813). Draft Fisheries Assessment Report.
- O'Driscoll RL., Dunford AJ. 2008. Acoustic survey of spawning hoki in Cook Strait during winter 2007. NIWA Client Report WLG2008-1 for The Deepwater Group Ltd. 44p.
- O'Driscoll RL., Macaulay GJ. 2005. Using fish processing time to carry out acoustic surveys from commercial vessels. *ICES Journal of Marine Science* 62: 295–305.
- O'Driscoll R., Hurst R., Livingston M., Cordue P., Starr P. 2002. Report of Hoki Working Group technical meeting 8 March 2002. WG-HOK-2002/27.
- O'Driscoll RL., Booth JD., Bagley NW., Anderson OF., Griggs LH., Stevenson ML., Francis MP. 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. 377p.
- O'Driscoll RL., Bagley NW., Macaulay GJ., Dunford AJ. 2004. Acoustic surveys of spawning hoki off South Island on FV *Independent 1* in winter 2003. *New Zealand Fisheries Assessment Report* 2004/29. 48 p.

## HOKI (HOK)

- Probert PK., Grove SL. 1998. Macrobenthic assemblages of the continental shelf and upper slope off the west coast of South Island, New Zealand. *Journal of the Royal Society of New Zealand* 28:259-280.
- Probert PK., McKnight DG. 1993. Biomass of bathyal macrobenthos in the region of the Subtropical Convergence, Chatham Rise, New Zealand. *Deep-Sea Research* 40: 1003-1007.
- Probert PK., McKnight DG., Grove SL. 1997. Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. *Aquatic Conservation: In, Trophic Relationships in the Marine Environment*. Aberdeen University Press, Aberdeen, 439-452.
- Roberts JM., Harvey SM., Lamont PA., Gage JD., Humphery JD. 2000. Seabed photography, environmental assessment and evidence of deep-water trawling on the continental margin west of the Hebrides. *Hydrobiologia* 441: 173-183
- Rutherford JC., Roper DS., Nagels JW. 1988. A preliminary study of the dispersion of hoki wastes and potential oxygen depletion off the west coast South Island. Unpublished Report prepared for Fisheries Research Division, MAFFISH, Wellington, by the Ministry of Works Water Quality Centre, Hamilton. 36p.
- Schofield KA., Livingston ME. 1998. Ovarian development and the potential annual fecundity of western stock hoki (*Macruronus novaezelandiae*). *New Zealand Journal of Marine and Freshwater Research* 32(1): 147-159.
- Smith MH. 2004. Fitting priors for natural mortality and proportion of virgin hoki biomass in eastern stock. WG-HOK-2004/14. 7p. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Smith PJ., Patchell G., Benson PG. 1981. Genetic tags in the New Zealand hoki *Macruronus novaezelandiae*. *Animal Blood Groups and Biochemical Genetics* 12: 37-45.
- Smith PJ., McVeagh SM., Ede A. 1996. Genetically isolated stocks of orange roughy (*Hoplostethus atlanticus*), but not of hoki (*Macruronus novaezelandiae*), in the Tasman sea and southwest Pacific ocean around New Zealand. *Marine Biology* 125: 783-793.
- Smith PJ., Bull B., McVeagh SM. 2001. Evaluation of meristic characters for determining hoki relationships. Final Research Report for Ministry of Fisheries Research Project HOK1999/05 Objective 1. 10p.
- Stevens DW., O'Driscoll RL. 2007. Trawl survey of hoki and middle depth species on the Chatham Rise, January 2006 (TAN0601). *New Zealand Fisheries Assessment Report 2007/5*. 73p.
- Stevens DW., O'Driscoll RL. (in prep). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2009 (TAN0901). *Draft Fisheries Assessment Report*.
- Stevens DW., O'Driscoll RL., Gauthier S. (in press). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2007 (TAN0701). *Draft Fisheries Assessment Report*.
- Sullivan KJ., Coombs RF. 1989. Hoki stock assessment 1989. *New Zealand Fisheries Assessment Research Document 1989/4*. 26p.
- Vignaux M. 1994. Catch per unit of effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987-93. *New Zealand Fisheries Assessment Research Document 1994/11*. 29p.
- Zeldis JR., Murdoch RC., Cordue PL., Page MJ. 1998. Distribution of hoki (*Macruronus novaezelandiae*) eggs, larvae and adults off Westland, New Zealand, and the design of an egg production survey to estimate hoki biomass. *Canadian Journal of Fisheries and Aquatic Science* 55: 1682-1694