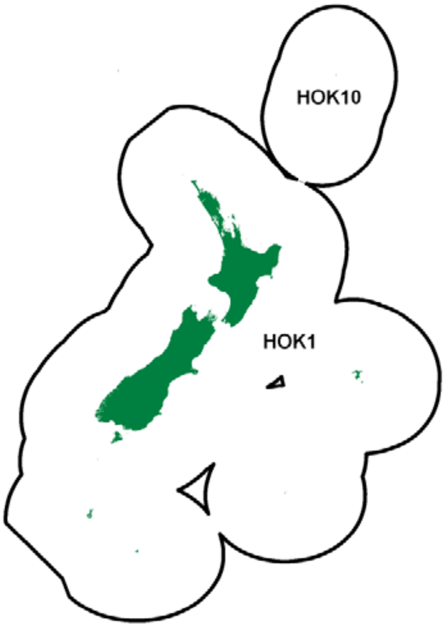
HOKI (HOK)

(*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. Starting in 1988, another major fishery 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 on the Southern Plateau. 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. On the Southern Plateau, 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 1). 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 2).

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. The hoki fishery now operates throughout the year, producing high quality fillet product from both spawning and non-spawning fisheries. Since 1998 twin-trawl rigs have operated in some hoki fisheries.

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 declined, tracking the TACC as it was reduced to address poor stock status, reaching a low of 89 000 t in 2008-09, and increasing again following increases in the TACC over the past three years as stock status has improved (Table 2). The reported catch in 2011-12 was at the level of the TACC of 130 000 t (Table 2).

Table 1: 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.

				New Zealand		
Year	USSR	Japan	South Korea	Domestic	Chartered	Total
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.

The pattern of fishing has changed markedly since 1988-89 when over 90% of the total catch was taken in the WCSI spawning fishery (Tables 3 and 4). This has been due to a combination of TACC changes and re-distribution of fishing effort. 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 seven years, to 20 600 t in 2008-09. The WCSI catch has increased again over the past three years to 54 000 t in 2011-12. This was about 42% of the total catch, making the WCSI the largest hoki fishery for the second year running. In Cook Strait, catches peaked at 67 000 t in 1995-96, but have declined to 14 900 in 2010-11 and 15 900 t 2011-12, the lowest levels since 1989-90. Non-spawning catches on the Chatham Rise peaked at about 75 000 t in 1997-98 and 1998-99, then decreased to a low of 30 700 t in 2004-05, before increasing again to 39 000 t from 2008-09 to 2011-12. The Chatham Rise was the largest hoki fishery from 2006-07 to 2009-10 and contributed about 30% of the total catch in 2011-12. Catches from the Sub-Antarctic peaked at over 30 000 t in 1999-00 to 2001-02, declined to a low of 6200 t in 2004-05 before increasing slowly to 15 000 t by 2011-12 (Table 3).

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 Southern Plateau) (Table 4). 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 responsible for 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 an agreement with the Minister that only 40% of the catch should be taken from western fisheries and 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 both 2007-08 and 2008-09, with about 30 000 t taken from western areas (Table 3). In 2009-10, the target catch from the western fishing grounds was increased to 50 000 t within the overall TACC of 110 000 t, and catches were at about the industry-agreed catch split. The target catch from the western fishing grounds was further increased to 60 000 t in 2010-11 (within the overall TACC of 120 000 t) and 70 000 t in 2011-12 (within the overall TACC of 130 000 t). Western catches in 2010-11 and 2011-12 were 2000 t and 1600 t respectively above industry agreed targets. In the current fishing year (2012-13), the target catch from the western fishing grounds is the same as in 2011-12 at 70 000 t within the overall TACC of 130 000 t. Figure 1 shows the reported landings and TACC for HOK1, and also the eastern and western catch components of this stock since 1988-89.

Table 2: Reported catch (t) from QMS, estimated catch (t) data, and TACC (t) for HOK 1 from 1986-97 to 2011-12. Reported catches are from the QMR and MHR systems. Estimated 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). Catches are rounded to the nearest 500 t.

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	97 500	100 000
2007-2008	89 500	87 500	90 000
2008-2009	89 000	87 500	90 000
2009-2010	107 000	105 000	110 000
2010-2011	118 500	116 000	120 000
2011-2012	130 000	126 000	130 000

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.

Total Allowable Commercial Catch (TACC) and area restrictions

In the 2011-12 fishing year, the TACC for HOK1 was 130 000 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 responsible for fisheries that only 70 000 t of the TACC should be taken from western stock areas. With the allowance for other mortality at 1 300 t and the 20 t allowance for customary and recreational catch, the TAC was 131 340 t in 2011–12 and 2012–13.

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. In November 2007 the Government closed 17 large areas, Benthic Protection Areas (BPAs) to bottom trawling and dredging.

The fishing industry introduced a Code of Practice (COP) for hoki target trawling in 2001 with the aim of protecting small fish (less than 60 cm). The main components of this COP were: 1) a restriction on fishing in waters shallower than 450 m; 2) a rule requiring vessels to 'move on' if there are more than 10% small hoki in the catch; and 3) seasonal and area closures in spawning fisheries. The COP was superseded by Operational Procedures for Hoki Fisheries, also introduced by the fishing industry from 1 October 2009. The Operational Procedures aim to manage and monitor fishing effort within four industry Hoki Management areas, where there are thought to be high abundances of juvenile hoki (Narrows Basin of Cook Strait, Canterbury Banks, Mernoo, and Puysegur). These areas are closed to trawlers >28 m targeting hoki, with increased monitoring when targeting species other than hoki. There is also a general recommendation that vessels move from areas where catches of juvenile hoki (now defined as <55 cm total length) comprise more than 20% of the hoki catch by number.

Table 3: Estimated total catch (t) (scaled to reported QMR or MHR) of hoki by area 1988-89 to 2011-12 and based on data reported on TCEPR and CELR forms from 1988-89, but also include data reported on LCER (from 2003-04), NCELR (from 2006-07) and TCER and LTCER data (both from 2007-08). Catches from 1988-89 to 1997-98 are rounded to the nearest 500 t and catches from 1998-99 to 2011-12 are rounded to the nearest 100 t. Catches less than 100 t are shown by a dash.

	Spawning fisheries				Non-spawning fisheries				
Fishing Year	WCSI	Puysegur	Cook Strait	ECSI	Southern Plateau	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	21 000	300	18 400	2 300	8 700	38 000	600	-	89 300
2008-2009	20 600	200	17 500	1 100	9 800	39 000	600	-	88 800
2009-2010	36 300	300	17 900	700	12 300	39 100	600	-	107 200
2010-2011	48 300	1 200	14 900	1 600	12 600	38 400	1 600	-	118 700
2011-2012	54 000	1 300	15 900	2 500	15 700	39 000	900	-	130 100

Table 4: Proportions of total catch for different fisheries.

	Spawning fisheries		Non-spawning fisheries	
Fishing	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%
2008-2009	23%	21%	11%	45%
2009-2010	34%	17%	12%	37%
2010-2011	42%	14%	11%	34%
2011-2012	43%	14%	12%	31%

2011-12 Hoki fishery

The overall catch of 130 100 t was 11 300 t higher than the catch in 2010–11 but only about 100 t higher than the TACC. Relative to 2010–11, catches in 2011–12 increased in all areas except for the ECNI (Table 3). The increase in the western spawning catch was expected, given the increase in the target catch from western areas from 50 000 t in 2009-10 to 60 000 t in 2010-11.

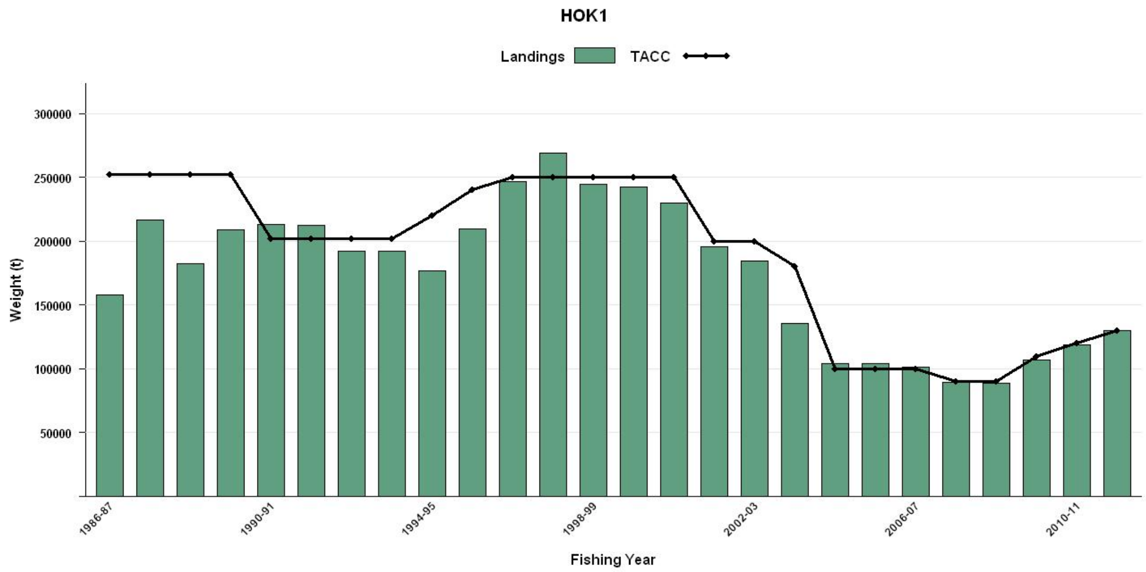
The WCSI was the largest fishery for the second consecutive year, with the WCSI catch increasing by 6000 t to 54 500 t in 2011–12. Catches inside the 25 n. mile line made up 15% of the total WCSI catch in 2011–12, a similar proportion to 2010–11, but down from a peak of 41% of the catch in 2003–04. Unstandardised catch rates on the WCSI in 2011-12 were the second highest in the series, with a median catch rate in all midwater tows targeting hoki of 7.9 t per hour. Most of the hoki caught on the WCSI were fish from the 2003-09 year classes (ages 3-9) and there were few 2 year olds compared to other years. The percentage of hoki aged 7 and older in the catch declined steeply from 68% in 2003-04 to 16% in 2005-06, but has since increased to 37% in 2011–12. Conversely, the percentage of small fish (< 65 cm) by number in the catch decreased from 31% in 2008-09 to 14% in 2011-12. 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 reversed as the catch of younger fish increased in the past 7 years, with males dominating, but the sex ratio of the catch was even in 2011-12. The mean length-at-age for hoki aged from 3–10 on the WCSI has increased since the start of the fishery, but there are signs that this may now be decreasing again.

The Chatham Rise was the second largest hoki fishery, with 39 200 t taken from this area in 2011-12. Over 99% of the Chatham Rise catch was taken in bottom trawls, with the median unstandardised catch rate in bottom trawls targeting hoki of 1.3 t per hour in 2011-12. The Chatham Rise catch was dominated by small hoki from the 2007-09 year-classes (aged 3-5) and 27% of the catch by number was fish less than 65 cm. There was a notable lack of 2 year-old fish (the 2010 year class) caught in 2011–12. Female hoki made up a slightly higher percentage of the Chatham Rise catch than males (53% female).

The catch from Cook Strait of 15 900 t was up by about 900 t from that in 2010-11, but was still the second lowest catch from this fishery since 1989-90. Unstandardised catch rates in Cook Strait continue to be high, with a median catch rate of 15.1 t per hour in midwater tows targeting hoki. There was a broad age distribution from ages 3-10. The sex ratio in the observed Cook Strait catch was skewed towards females (63% female) and only 13% of the fish were less than 65 cm. As on the WCSI, the mean length at age has increased in the Cook Strait fishery, although may now be decreasing.

The catch from the Southern Plateau of 15 800 t in 2011–12 was about 3 000 t higher than in 2010-2011, and the highest since 2002-03. The percentage of the catch from hoki target tows increased to 87% in 2011-12, having fallen as low as 70% in 2006-07. Unstandardised catch rates in bottom trawls targeting hoki also increased slightly to 1.6 t per hour in 2011-12. Catch-at-age estimates showed the Southern Plateau catch, like that from the other areas, consisted mainly of fish from the 2006-09 year classes at ages 3-6. The percentage of fish in the catch less than 65 cm was 30% in 2011-12. As on the WCSI, the sex ratio was even (50% female).

Catches from both Puysegur and the ECSI increased by 200 t to 1 300 t, and by 900 t to 2 500 t respectively in 2011-12. The ECNI catch decreased by 700 t to 900 t.



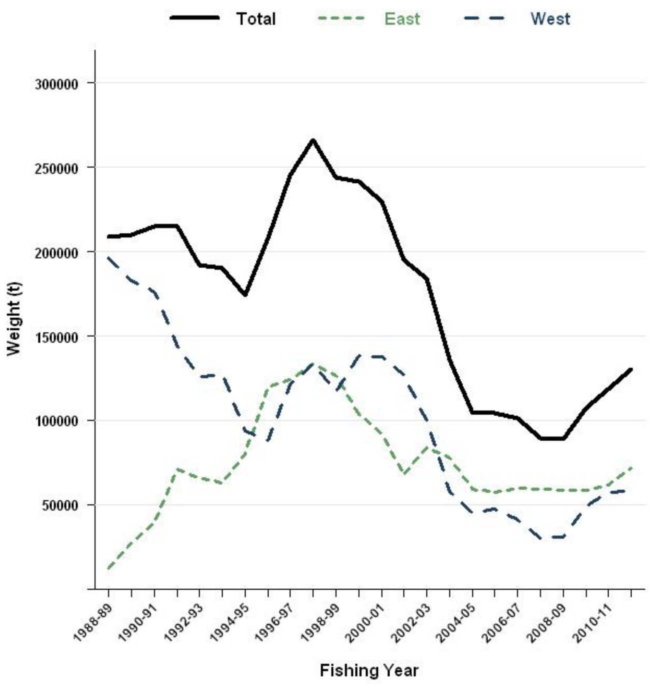


Figure 1: Upper: Reported landings and TACCs for HOK 1 since 1986-87. Lower: The eastern and western components of the total HOK 1 landings since 1988-89. Note that these figures do not show data prior to entry into the QMS.

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.

- 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 hoki 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^{o} S to 54^{o} S, from depths of 10 m to over 900 m, with greatest abundance between 200 and 600 m. Large adult hoki 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 (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 Southern Plateau (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 Southern Plateau 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 the Chatham Rise and Southern Plateau 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 on the Southern Plateau in May 1992 and 1993 estimated that 67% of hoki age 7 years and older on the Southern Plateau 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 2009). 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 Southern Plateau 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 Southern Plateau 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 RV *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 Southern Plateau. 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 Southern Plateau. Bycatch of hoki from tuna vessels following tuna migrations from the Southern Plateau 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 Southern Plateau post-spawning (Jones 1993).

Growth is fairly rapid with juveniles reaching about 27-35 cm TL at the end of the first year. 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 5). 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 0.30 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. An improved ageing protocol was developed to increase the consistency of hoki age estimation and 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 5 (but note that natural mortality was estimated in the model in the assessment).

Table 5: Estimates of fixed biological parameters.

Fishstock						**Estimate**	**Source**
1. Natural mortality (M)							
				Females		Males	
HOK 1				0.25		0.30	Sullivan & Coombs (1989)
2. Weight = a (length)^b (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_∞	K	t_0	L_∞	
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 Southern Plateau, 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). Francis *et al.* (2011) carried out a pilot study to determine whether analyses of stable isotopes and trace elements in otoliths could be useful in testing stock structure hypotheses and the question of natal fidelity. However, none of the six trace elements or two stable isotopes considered unambiguously differentiated the two stocks.

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, any link between climate, oceanographic conditions 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. A more recent analysis supports some climate effect on hoki recruitment but remains equivocal about its strength or form (Dunn *et al*. 2009). Bradford-Grieve & Livingston (2011) collated and reviewed information on the ocean environment on the WCSI in relation to hoki and other spawning fisheries. Hypotheses about which variables drive hoki recruitment were presented, but the authors noted that understanding of the underlying mechanisms and causal links between the WCSI marine environment and hoki year class survival remain elusive.

A baseline report summarising trends in climatic and oceanographic conditions in New Zealand that are of potential relevance for fisheries and marine ecosystem resource management in the New Zealand region has been completed (Hurst *et al*. 2009).

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last reviewed by the Aquatic Environment Working Group for the May 2012 Fishery Assessment Plenary. Tables were updated and minor corrections to the text were made for the May 2013 Fishery Assessment Plenary. This summary is from the perspective of the hoki fishery; a more detailed summary from an issue-by issue perspective is available in the Aquatic Environment & Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

5.1 Role in the ecosystem

Hoki is the species with the highest biomass in the bottom fish community of the upper slope (200–800 m), particularly around the South Island (Francis *et al*. 2002), and is considered to be a key biological component of the upper slope ecosystem. Understanding the predator-prey relationships between hoki and other species in the slope community is important, particularly since substantial changes in the biomass of hoki have taken place since the fishery began. Other metrics including ecosystem indicators can also provide insight into fishery interactions with target and non-target fish populations. For example, changes in growth rate can be indicative of density-dependent compensatory mechanisms in response to changes in population density.

5.1.1 Trophic interactions

On the Chatham Rise, hoki is a benthopelagic and mesopelagic forager, preying primarily on lantern fishes and other mid-water fishes and natant decapods with little seasonal variation (Clark 1985a&b, Dunn *et al*. 2009, Connell 2010, Stevens *et al*. 2011). Hoki show ontogenetic shifts in their feeding preferences, and larger hoki (> 80cm) consume proportionately more fish and squid than do smaller hoki (Dunn *et al*. 2009, Connell 2010). The diet of hoki overlaps with those of alfonsino, arrow squid, hake, javelinfish, Ray's bream, and shovelnose dogfish (Dunn *et al*. 2009). Hoki are prey to several piscivores, particularly hake but also stargazers, smooth skates, several deep water shark species, and ling; (Dunn *et al*. 2009). The proportion of hoki in the diet of hake averages 38% by weight, and has declined since 1992 (Dunn & Horn 2010), possibly because of a decline in the relative abundance of hoki on the Chatham Rise between 1991 and 2007. There is little information about the size of hoki eaten by predators (i.e. specifically whether the hoki are large enough to have recruited to the fishery or not), but this could be an important factor in understanding the interaction with the fishery and the potential for competition.

5.1.2 Ecosystem Indicators

Tuck *et al*. (2009) used data from the Sub-Antarctic and Chatham Rise trawl survey series to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. Species-based indicators appeared the most useful in identifying changes correlated with fishing intensity; Pielou's evenness appears the most consistent but the Shannon-Wiener index, species richness, and Hill's N1 and N2 also showed some promise (Tuck *et al*. 2009). Trends in diversity in relation to fishing are not necessarily downward, and depend on the nature of the community. Size-based indicators did not appear as useful for New Zealand trawl survey series as they have been overseas, and this may be related to the requirement to consider only measured species. In New Zealand, routine measurement of all fish species in trawl surveys was implemented in 2008 and this may increase the utility of size-based indicators in the future.

Between 1992 and 1999 the growth rates of all year classes of hoki increased by 10% in all four fishery areas but it is unclear whether this was a result of reduced competition for food within and among cohorts or some other factor (Bull & Livingston 2000). The abundance of mesopelagic fish, a major prey item for hoki, has the potential to be an indicator of food availability. Recent research using acoustic backscatter data collected during trawl surveys has shown no clear temporal trend in mesopelagic fish biomass on the Chatham Rise between 2001 and 2009, but a decline for the Sub-Antarctic area from 2001 to 2007, followed by an increase in 2008 and 2009. The abundance of mesopelagic fish is consistently much higher on the Chatham Rise than in the Sub-Antarctic, with highest densities observed on the western Chatham Rise and lowest densities on the eastern Campbell Plateau (O'Driscoll *et al.* 2011a). Spatial patterns in mesopelagic fish abundance closely matched the distribution of hoki. O'Driscoll *et al.* (2011a) hypothesise that prey availability influences hoki distribution, but that hoki abundance is being driven by other factors such as recruitment variability and fishing. There was no evidence for a link between hoki condition and mesopelagic prey abundance and there were no obvious correlations between mesopelagic fish abundance and environmental indices.

5.2 Incidental catch (fish and invertebrates)

Based on models using observer and fisher-reported data, total bycatch in the combined hoki, hake and ling trawl fisheries between 2000–01 and 2006–07 ranged from about 36 000 to 58 000 t per year compared with the combined total landed catch of hoki, hake, and ling of 130 000 to 238 000 t) (Ballara *et al*. 2010a; see also Anderson *et al*. 2001, Livingston *et al*. 2003, Anderson & Smith 2005 for previous estimates). 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, jack mackerel and spiny dogfish. In Cook Strait, the main commercial bycatch species are ling and spiny dogfish. Between 2000–01 and 2006–07, hoki, hake, and ling accounted for 87% (77%, 6%, and 4%, respectively) of the total observed catch from trawls targeting these species. These three species made up 88%, 1%, and 2%, respectively, of the catch in target hoki trawls between 2008–09 and 2011–12 (Table 6). The hoki-hake-ling fishery is complex, and changes in fishing practice are likely to have contributed to variability between years (Ballara *et al*. 2010a).

Table 6: Raw catch weight and percentage by weight of species taken in hoki trawls with an observed catch of > 20 t in the 2011–12 fishing year. Data from the central observer database.

Species	2008-09		2009-10		2010-11		2011-12	
	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%
Hoki	19 522	87.2	24 696	87.2	20 600	86.5	32 360	89.1
Ling	548	2.5	624	2.2	555	2.3	975	2.7
Javelinfish	494	2.2	734	2.6	469	2.0	425	1.2
Rattails	334	1.5	572	2.0	403	1.7	441	1.2
Silver warehou	191	0.9	337	1.2	380	1.6	352	1.0
Hake	227	1.0	235	0.8	319	1.3	396	1.1
Spiny dogfish	187	0.8	233	0.8	226	0.9	439	1.2
White warehou	58	0.3	64	0.2	89	0.4	65	0.2
Pale ghost shark	81	0.4	101	0.4	82	0.3	95	0.3
Sea perch	16	0.1	55	0.2	81	0.3	56	0.2
Barracouta	6	0.0	4	0.0	44	0.2	4	0.01
Southern blue whiting	37	0.2	7	0.0	40	0.2	12	0.03
Shovelnose dogfish	35	0.2	29	0.1	38	0.2	26	0.1
Lookdown dory	24	0.1	33	0.1	40	0.2	49	0.1
Ribaldo	27	0.1	39	0.1	33	0.1	26	0.1
Arrow squid	16	0.1	26	0.1	31	0.1	35	0.1
Gemfish	9	0.0	6	0.0	27	0.1	6	0.02
Smooth skate	11	0.1	22	0.1	26	0.1	21	0.1
Stargazer	14	0.1	23	0.1	25	0.1	15	0.04
Others	555	2.5	485	1.7	305	1.3	510	1.4

Total annual discard estimates ranged from about 5 500 to 29 000 t per year between 2000–01 and 2006–07, with the main species being spiny dogfish, rattails, javelinfish, hoki, and shovelnose dogfish (although up to 470 species have been observed in the incidental catch). Discard ratios of commercial species were highest in Cook Strait and Sub-Antarctic and discard ratios of non-commercial species were lowest in Cook Strait. Spiny dogfish was the main QMS species discarded, but hoki, hake, and ling made up 9.7% of total observed discards. About 0.03 kg was discarded per kilogram of hoki, hake, and ling caught (Ballara *et al*. 2010a).

5.3 Incidental catch (seabirds, mammals, and protected fish)

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

New Zealand fur seal interactions

The New Zealand fur seal was classified in 2008 as “Least Concern” by the International Union for Conservation of Nature (IUCN) and in 2010 as “Not Threatened” under the NZ Threat Classification System (Baker *et al.* 2010).

Vessels targeting hoki incidentally catch fur seals (Baird & Smith 2007, Smith & Baird 2009, Thompson & Abraham 2010, Baird 2011). Although the numbers captured have been declining over the past 14 years (Table 7), the rate of capture has no obvious trend. Captures occur mostly in Cook Strait (53%), off the west coast South Island (23%), and east coast South Island, including the western Chatham Rise (16%) (Table 8). Estimated captures of New Zealand fur seals in the hoki fishery have accounted for an average of 49.9% of all fur seals estimated to be caught by trawling in the EEZ between 2002-03 and 2011-12 for those fisheries modelled. This figure should be interpreted with caution because a large proportion of inshore trawl effort not targeting hoki could not be included in the models.

NZ sea lion interactions

The New Zealand (or Hooker’s) sea lion was classified in 2008 as “Vulnerable” by IUCN and in 2010 as “Nationally Critical” under the NZ Threat Classification System. Pup production at the main rookeries has shown a steady decline since the late 1990s.

NZ sea lions are captured only rarely by vessels trawling for hoki (Smith & Baird 2005, 2007 a, b, Thompson & Abraham 2010, Abraham & Thompson 2011), the highest recorded rate in the last 14 years being 0.05 sea lions per 100 tows (Table 9). All observed captures have been close to the Auckland Islands or nearby on the Stewart-Snares shelf.

Seabird interactions

Vessels targeting hoki incidentally catch seabirds. Baird (2005a) summarised observed seabird captures for the fishing years 1998–99 to 2002–03 and calculated total seabird captures for the areas with adequate observer coverage using ratio based estimations. Baird & Smith (2007, 2008) summarised observed seabird captures and used both ratio-based and model-based predictions to estimate the total seabird captures for 2003–04, 2004–05 and 2005–06. Abraham & Thompson (2011) summarised captures of protected species and used model and ratio-based predictions of the total seabird captures for 1989–90 and 2008–09.

In the 2010-11 fishing year there were 53 observed captures of birds in hoki trawl fisheries. It was estimated by a statistical model that there were a total of 307 (95% c.i.: 226 - 419) captures in hoki trawl fisheries (Abraham *et al.* 2013, Table 10). Annual observed seabird capture rates have ranged from 1.31 to 8.34 per 100 tows in the hoki fishery between 1998-99 and 2011-12, without obvious trend. These estimates include all bird species and should be interpreted with caution. The average capture rate in hoki trawl fisheries over the last ten years is about 2.35 birds per 100 tows, a low rate relative to trawl fisheries for scampi (5.1 birds per 100 tows) and squid (12.56 birds per 100 tows) over the same years. The hoki fishery accounted for about 15% of seabird captures in the trawl fisheries modelled by Abraham *et al.* (2013).

Table 7: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in hoki trawl fisheries, 1998–99 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. * Estimates 1998–99 to 2001–02 from Smith & Baird (2009) who estimated captures by area and confidence intervals have not been estimated at this level of aggregation. Estimates are based on methods described in Thompson *et al.* (2013) and will soon be available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002-03 to 2010-11 are based on data version 20120531 and preliminary estimates for 2011-12 are based on data version 20130304.

		Observed				Estimated		
	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.	% inc.
1998-99	32 242	3 558	11.0	84	2.36	919	*	95.6
1999-00	33 061	3 273	9.9	102	3.12	764	*	95.8
2000-01	32 018	3 549	11.1	66	1.86	804	*	97.6
2001-02	27 224	3 274	12.0	110	3.36	844	*	96.3
2002–03	27 786	2 593	9.3	45	1.74	601	335-1 041	99.9
2003–04	22 535	2 346	10.4	49	2.09	707	384-1 249	99.9
2004–05	14 540	2 132	14.7	120	5.63	766	409-1 446	99.9
2005–06	11 589	1 775	15.3	62	3.49	429	217-880	99.9
2006–07	10 604	1 758	16.6	29	1.65	253	119-518	99.9
2007–08	8 785	1 877	21.4	58	3.09	311	152-625	99.9
2008–09	8 174	1 660	20.3	37	2.23	202	95-444	100.0
2009–10	9 966	2 066	20.7	30	1.45	173	88-349	99.9
2010-11	10 403	1 724	16.6	23	1.33	172	79-344	99.9
2011-12	11 332	2 475	21.8	32	1.29	200	98-417	99.9

Table 8: Model estimates (means) of the number of NZ fur seal captures in hoki trawl fisheries by area, 2002–03 to 2010–11. Data version 20120531. Model estimates for 2011-12 were not available at the time of publication.

	Cook	WCSI	ECSI	Fiordland	Stewart-Snares	Chatham	Sub-Antarctic	Total
2002–03	254	162	94	26	20	12	22	590
2003–04	360	195	111	11	18	11	6	712
2004–05	388	206	98	33	28	11	6	770
2005–06	228	109	57	11	13	5	0	423
2006–07	156	34	44	1	18	3	0	256
2007–08	193	45	59	0	7	3	2	309
2008–09	143	24	28	0	9	1	0	205
2009–10	103	29	29	0	12	1	1	175
2010–11	87	41	21	1	5	1	1	157

Observed seabird captures since 2002–03 have been dominated by six species: Salvin’s, white-capped, and southern Buller’s albatrosses make up 41%, 26%, and 24% of the albatrosses captured, respectively; and sooty shearwaters, white-chinned petrels, and cape petrels make up 57%, 14%, and 14% of other birds, respectively (Table 11). A high proportion of captures were observed off the east coast of the South Island, including the Chatham Rise (60%), off the west coast of the South Island (12%) or on the Stewart-Snares shelf (14 %). These numbers should be regarded as only a general guide on the distribution of captures because observer coverage is not uniform across areas and may not be representative.

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the hoki trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (MFish 2006). The 2006 notice mandated that all trawlers > 28 m in length use a seabird scaring device while trawling (being “paired streamer lines”, “bird baffler” or “warp deflector” as defined in the notice). In the four complete fishing years after mitigation was made mandatory, the average rates of capture for Salvin’s and white-capped albatross (71% of albatross captures in this fishery) were 0.20 and 0.21 birds per 100 tows, respectively, compared with 0.61 and 0.26 per 100 tows in the three complete years before mitigation was made mandatory. This trend is masked in Table 10 by continued captures of smaller birds, especially sooty shearwater, in trawl nets (as opposed to on trawl warps where mitigation is applied).

Table 9: Number of tows by fishing year and observed NZ sea lion captures in hoki trawl fisheries, 1998–99 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. No estimates of total captures are presented here because the data are so sparse. Estimates are based on methods described in Thompson *et al.* (2013) and will soon be available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002-03 to 2010-11 are based on data version 20120531 and preliminary estimates for 2011-12 are based on data version 20130304.

	Fishing effort			Observed captures		Estsimated captures		
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% included
1998-99	32 242	3 558	11.0	0	0.00	-	-	-
1999-00	33 061	3 273	9.9	1	0.03	-	-	-
2000-01	32 018	3 549	11.1	1	0.03	-	-	-
2001-02	27 224	3 274	12.0	0	0.00	-	-	-
2002–03	27 786	2 593	9.3	1	0.04	2	0-7	35.9
2003–04	22 535	2 346	10.4	0	0.00	2	0-5	28.7
2004–05	14 540	2 132	14.7	0	0.00	1	0-4	24.7
2005–06	11 589	1 775	15.3	0	0.00	0	0-2	15.5
2006–07	10 604	1 758	16.6	0	0.00	0	0-2	23.4
2007–08	8 785	1 877	21.4	1	0.05	1	1-2	22.1
2008–09	8 174	1 660	20.3	0	0.00	0	0-1	23.9
2009–10	9 966	2 066	20.7	0	0.00	0	0-2	26.6
2010-11	10 403	1 724	16.6	0	0.00	1	0-2	26.3
2011-12†	11 332	2 475	21.8	0	0.00	-	-	-

† Model estimates for 2011-12 were not available at the time of publication.

Table 10: Number of tows by fishing year and observed and model-estimated total seabird captures in hoki trawl fisheries, 1998–99 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. * Estimates 1998–99 to 2001–02 from McKenzie & Fletcher (2006). Estimates are based on methods described in Abraham *et al.* (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002-03 to 2010-11 are based on data version 20120531 and preliminary estimates for 2011-12 are based on data version 20130304.

		Observed				Estimated		
	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.	% inc.
1998-99	32 242	3 558	11.0	133	3.74	1 144 *	950-1374	100.0
1999-00	33 061	3 273	9.9	91	2.78	993 *	821-1199	100.0
2000-01	32 018	3 549	11.1	296	8.34	2 055 *	1803-2348	100.0
2001-02	27 224	3 274	12.0	50	1.53	1 133 *	941-1358	100.0
2002–03	27 786	2 594	9.3	85	3.28	656	489-906	100.0
2003–04	22 535	2 346	10.4	33	1.41	340	258-442	100.0
2004–05	14 540	2 132	14.7	46	2.16	368	277-479	100.0
2005–06	11 590	1 775	15.3	54	3.04	345	238-532	100.0
2006–07	10 610	1 758	16.6	23	1.31	168	119-238	100.0
2007–08	8 782	1 873	21.3	28	1.49	151	109-202	100.0
2008–09	8 175	1 661	20.3	37	2.23	195	144-261	100.0
2009–10	9 965	2 066	20.7	53	2.57	221	170-287	100.0
2010–11	10 402	1 724	16.6	53	3.07	307	226-419	100.0
2011–12†	11 332	2 475	21.8	64	2.59	-	-	-

† Provisional data, model estimates for 2011-12 were not available at the time of publication.

Basking shark interactions

The basking shark was classified in 2005 as "Vulnerable" by IUCN and as in "Gradual Decline" under the NZ Threat Classification System, and are listed in CITES (Appendix II). Basking shark has been a protected species in New Zealand since 2010

Table 11: Number of observed seabird captures in hoki trawl fisheries, 2002–03 to 2011–12, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard *et al.* 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for hoki. Other data, version 20130304.

Albatross species	Risk Ratio	Cook Strait	ECSI	Chatham Rise	Stewart Snares Shelf	Auckland Islands	Sub-Antarctic	Fiordland	WCSI	Total
Salvin's	Very high	10	34	36	1	0	1	0	0	82
Southern Buller's	Very high	0	5	4	4	0	0	9	26	48
Chatham Island	Very high	0	0	0	1	0	0	0	0	1
NZ white capped	Very high	2	6	4	14	0	1	3	22	52
Southern royal	Medium	0	1	0	0	0	0	0	0	1
Campbell black-browed	Medium	0	1	0	0	0	0	0	5	6
Unidentified	N/A	2	6	2	1	0	1	0	1	11
Total albatrosses	**N/A**	**14**	**53**	**46**	**21**	**0**	**3**	**12**	**54**	**201**
Other bird species										
Flesh footed shearwater	Very high	0	1	0	0	0	0	0	0	1
Cape petrels	High	10	4	3	2	0	0	6	13	38
Westland petrel	Medium	1	1	1	0	0	0	0	9	12
Northern giant petrel	Medium	0	1	0	0	0	0	0	3	4
White-chinned petrel	Medium	3	14	9	9	1	1	2	0	39
Grey petrel	Medium	0	0	0	1	0	1	0	0	2
Sooty shearwater	Very low	1	121	6	23	0	0	6	0	157
Black-bellied storm petrel	-	0	0	0	1	0	0	0	0	1
Common diving petrel	-	2	0	0	1	0	0	3	0	6
Fairy prion	-	0	1	0	0	0	0	0	2	3
Grey-backed storm petrel	-	0	0	0	1	0	0	0	0	1
Unidentified seabird	N/A	1	2	0	0	0	0	0	6	9
Total other birds	**N/A**	**18**	**145**	**19**	**38**	**1**	**2**	**17**	**33**	**273**

Basking sharks are caught occasionally in hoki trawls (Francis & Duffy 2002, Francis & Smith 2010, Ballara *et al*. 2010a). Standardised capture rates from observer data showed the highest rates and catches occurred in 1989 off the WCSI, and in 1987-92 off the ECSI. Smaller peaks in both areas were observed in the late 1990s and early 2000s, but captures have been few since (Table 12). Most basking sharks have been captured in spring and summer and nearly all came from FMAs 3, 5, 6 and 7. Much of the recent decline in basking shark captures is probably attributable to a decline in fishing effort (Francis & Smith 2010). Of a range of fisheries and environmental factors considered, vessel nationality stood out as a key factor in high catches in the late 1980s and early 1990s (Francis & Sutton, 2012). Research is in progress to improve the understanding the interactions between basking sharks and fisheries (DOC project PRO2011/03).

5.4 Benthic interactions

The only target method of capture in the hoki fishery is trawling using either bottom (demersal) or midwater gear. Baird & Wood (2010) estimated that trawl for hoki accounted for 20–40% of all tows on or near the sea floor reported on TCEPR forms up to 2005–06, and Black et al. (2013) estimated that hoki has accounted for 30% of all tows reported on TCEPR forms since 1989–90. Between 2006–07 and 2010–11, 93% of hoki catch was reported on TCEPR forms. In the early years of the hoki fishery, vessels predominantly used midwater trawl as most of the catch was taken from spawning aggregations off the WCSI. Outside of the spawning season, bottom trawling is used on the Chatham Rise and Sub-Antarctic fishing grounds (Table 8). Twin trawls were used to catch almost half of the TACC in some years. This gear is substantially wider than single trawl gear and catches more fish per tow than single trawl gear. The relationship between total catch and bottom impact of twin trawls has, however, not been analysed. As the incidence of year round fishing increased, vessels increased fishing effort on the Chatham Rise and in the Sub-Antarctic, and the bottom trawl effort increased to a peak between 1997-98 and 2003-04. Effort has declined substantially in all areas since 2005-06, largely as a result of TACC reductions. Midwater trawling peaked in 1995-96 to 1996-97 in Cook Strait and on the Chatham Rise 1996-97 to 1997-98, but declined in all areas from 1997-98. Overall, midwater trawling has declined by ~90% since the peak in 1997 and bottom trawling by ~70% since the peak in 2000 (Table 13).

Table 12: Number of tows (data version 20130304), and number of captures (1994-95 to 2007-08 from Francis & Smith 2010; 2008-09 to 2011-12 from the central observer database) of basking shark in hoki trawls.

Year	Tows*	No. observed	% observed	No. Captures
1994–05	21 583	–	–	2
1995–06	24 610	–	–	0
1996–07	28 756	–	–	5
1997–08	30 354	–	–	14
1998–09	32 242	3 558	11.0	8
1999–00	33 061	3 273	9.9	2
2000–01	32 018	3 549	11.1	3
2001–02	27 224	3 274	12.0	0
2002–03	27 786	2 594	9.3	5
2004–04	22 535	2 344	10.4	2
2004–05	14 540	2 132	14.7	8
2005–06	11 589	1 775	15.3	0
2006–07	10 604	1 758	16.6	0
2007–08	8 785	1 875	21.3	1
2008–09	8 174	1 662	20.3	0
2009–10	9 966	2 066	20.7	0
2010–11	10 403	1 724	16.6	0
2011–12	11 332	2 475	21.8	1

Table 13: Summary of number of hoki target trawl tows (TCEPR only) in the hoki fishery from fishing years (FY) 1989-90 to 2011-12. (MW, mid-water trawl; BT, bottom trawl).

Fishery	WCSI/Puys		Cook Strait/ECSI		Sub-Antarctic		Chatham Rise/ECSI				
Season	Spawning		Spawning		Non-spawn		Non-spawn		All areas combined		%
Method	MW	BT	MW	BT	MW	BT	MW	BT	MW	BT	BT
FY											
1990	7 849	1 188	1 087	21	36	2 111	30	2 027	9 002	5 347	37
1991	7 354	1 679	2 229	21	81	3 927	954	3 490	10 618	9 117	46
1992	5 628	1 579	1 776	14	115	5 441	441	5 556	7 960	12 590	61
1993	5 490	1 861	1 583	22	442	4 913	1 057	5 269	8 572	12 065	58
1994	8 012	1 638	1 867	153	562	2 039	1 338	3 449	11 779	7 279	38
1995	7 225	1 505	2 030	255	419	2 328	2 175	6 262	11 849	10 350	47
1996	5 715	2 017	3 198	1 368	415	2 504	2 302	7 920	11 630	13 809	54
1997	7 563	1 890	3 561	1 335	334	3 421	2 342	9 303	13 800	15 949	54
1998	6 968	1 541	2 402	666	165	4 372	3 782	11 448	13 317	18 027	58
1999	5 477	2 118	2 033	635	419	3 659	2 424	11 439	10 353	17 851	63
2000	5 470	2 275	1 944	380	511	5 944	2 696	9 493	10 621	18 092	63
2001	6 228	2 577	1 968	170	667	5 448	912	9 862	9 775	18 057	65
2002	4 988	3 095	1 136	138	132	6 449	858	7 820	7 114	17 502	71
2003	4 615	2 977	2 117	167	96	4 407	496	9 278	7 324	16 829	70
2004	4 274	1 887	1 812	267	78	3 023	385	7 225	6 549	12 402	65
2005	2 534	1 308	1 457	74	68	1 428	340	4 996	4 399	7 806	64
2006	1 783	1 508	1 020	88	74	721	140	4 822	3 017	7 139	70
2007	1 147	752	919	35	25	1 194	57	4 769	2 148	6 750	76
2008	813	492	393	281	36	925	75	4 203	1 317	5 901	82
2009	689	354	747	267	38	927	11	3 914	1 485	5 462	79
2010	1 182	612	797	70	56	1 251	116	4 361	2 151	6 294	75
2011	1 581	912	489	63	62	1 245	52	4 075	2 184	6 295	74
2012	1 660	1 188	836	81	70	1 202	74	4 397	2 640	6 868	72

NOTE: Spawning fisheries include WCSI (Jul-Sep), Cook Strait (Jul-Sep), Puysegur (Jul-Dec), ECSI (Jul-Sep). Non-spawning fisheries include ECSI (Aug-Jun), Chatham Rise (Aug-Jun), Sub-Antarctic (Aug-Jun). TCER, CELR and North Island tows are excluded.

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

5.5 Other considerations

5.5.1 Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Although there has been no research on the disruption of spawning hoki by fishing in New Zealand, the hoki quota owners voluntarily closed ceased fishing some defined spawning grounds for certain periods on the WCSI, Pegasus Canyon (ECSI) and Cook Strait off the WCSI as a precautionary measure from 2004 to 2009 with the intention of assisting stock rebuilding. This closure was lifted in 2010 because the biomass of the western stock was estimated to have rebuilt to within the management target range.

5.5.2 Habitat of particular significance to fisheries management

Habitats of particular significance to fisheries management have not been defined for hoki or any other New Zealand fish. Studies of potential relevance have identified areas of importance for spawning and juveniles (O'Driscoll *et al*. 2003). Areas on Puysegur Bank, Canterbury Bight, Mernoo Bank, and Cook Strait have been subject to non-regulatory measures to reduce fishing mortality on juvenile hoki (Deepwater Group 2009).

6. STOCK ASSESSMENT

A new stock assessment was carried out in 2013 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, an acoustic survey, and updated catch at age data. The general-purpose stock assessment program, CASAL (Bull *et al*. 2012), was used and the approach, which used Bayesian estimation, was similar to that in the 2012 assessment (McKenzie 2013a).

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 for most model runs (i.e., all fish spawn in the area in which they were spawned). Sensitivity model runs were done in which natal fidelity is not assumed (but all fish once they have spawned in a given area return there for future spawnings, i.e., adult fidelity). There is little direct evidence of natal fidelity for hoki, though its life history characteristics would indicate that 100% natal fidelity is unlikely (Horn 2011).

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 14). 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.

Table 14: 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.

					Observations	
Step	Approx. months	Processes	*M* fraction	Age fraction	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 15). New data were available from a trawl survey on the Chatham Rise in January 2013 (Stevens *et al.* 2013b), a trawl survey on the Southern Plateau in December 2012 (Bagley & O'Driscoll 2013b), and a combined acoustic and trawl survey of spawning hoki on the west coast South Island in winter 2012 (O'Driscoll & Bagley 2013).

The 2012 WCSI survey was the first of this area since 2000 and using a modified design (Francis & O'Driscoll 2004), with an acoustic survey over the entire hoki spawning area and a random trawl survey north of Hokitika Canyon. Hoki abundance was estimated from the 2012 acoustic survey using the same methodology that was used for the eight previous surveys in the acoustic time-series (1988-2000) and the 2012 acoustic index was included in the 2013 assessment (Table 15). Trawl estimates of hoki were not included in the assessment pending the evaluation of the reliability of the trawl-based indices.

Table 15: 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 Southern Plateau, December SAsumbio	Trawl survey Southern Plateau, April SAautbio	Trawl survey Chatham Rise, January CRsumbio	Acoustic survey Cook Strait, winter CSacous
1988	417	-	-	-	-
1989	249	-	-	-	-
1990	255	-	-	-	-
1991	341*	-	-	-	191*
1992	345	80	68	120	-
1993	549*	87	-	186	613*
1994	-	100	-	146	597*
1995	-	-	-	120	411*
1996	-	-	89	153	196*
1997	655*	-	-	158	302*
1998	-	-	68	87	170*
1999	-	-	-	109	245*
2000	397*	-	-	72	-
2001	-	56	-	60	217*
2002	-	38	-	74	307*
2003	-	40	-	53	222*
2004	-	14	-	53	-
2005	-	18	-	85	124*
2006	-	21	-	99	128*
2007	-	14	-	70	218*
2008	-	46	-	77	179*
2009	-	47	-	144	334*
2010	-	65	-	98	-
2011	-	-	-	94	269*
2012	412*	46*	-	88*	-
2013	-	56*	-	124*	-

The age data used in the assessment (Table 16) are similar to those used in 2012, but with an additional years' data.

The error distributions assumed were multinomial (Bull *et al*. 2012) for the at-age data, and lognormal for all other data. The weight assigned to each data set was controlled by the effective sample size for each observation, calculated from the observation error, and a reweighting procedure for the data sets (McKenzie 2013, Francis 2011). An arbitrary CV of 0.25 (as used by Cordue 2001) was assumed for the proportion spawning observations.

Table 16: 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	1988-12*	otoliths
SA	WnspOLF	Catch at age	1992-94, 96, 99-00	OLF
	Wnspage	Catch at age	2001-04, 06-12*	otoliths
	SAsumage	Trawl survey	1992-94, 2001-10, 2012-13*	otoliths
	SAautage	Trawl survey	1992, 96, 98	otoliths
	pspawn	Proportion spawning	1992, 93, 98	otoliths
CS	Espage	Catch at age	1988-12*	otoliths
CR	EnspOLF	Catch at age	1992, 94, 96, 98	OLF
	Enspage	Catch at age	1999-12*	otoliths
	CRsumage	Trawl survey	1992-13*	otoliths

Two alternative sets of CVs were used for the biomass indices (Table 17). The "total" CVs represent the best estimates of the uncertainty associated with these data, and were used in final 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 initial model 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 17: 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

CRsumbio	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total	0.23	0.23	0.22	0.23	0.23	0.25	0.24	0.22	0.25
Observation	0.12	0.11	0.08	0.11	0.11	0.15	0.14	0.10	0.15

SAsumbio	1992	1993	1994	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013
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	0.26	0.25	0.25
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	0.16	0.15	0.15

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
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
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

CSacous	2007	2008	2009	2011
Total	0.46	0.30	0.39	0.39
Observation	0.26	0.06	0.15	0.18

WCacous	1988	1989	1990	1991	1992	1993	1997	2000	2012
Total	0.60	0.38	0.40	0.73	0.49	0.38	0.60	0.60	0.51
Observation	0.22	.015	0.06	0.14	0.14	0.07	0.10	0.14	0.15

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 used to derive some, which were forced to be higher than those from the spawning fisheries (Francis 2004).

The age ranges used in the model varied amongst data sets (Table 18). In all cases, the last age for these data sets was treated as a plus group.

Table 18: Age ranges used for at-age data sets.

	Age range	
Data set	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 19 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 19) is the same as that used in the 2012 assessment, so the catches used in the model (Table 20) are unchanged, except for minor revisions to years 2001 to 2012 (including removing catches taken outside the New Zealand EEZ).

For 2012-13 year, the TACC is 130 000 t with a catch limit arrangement for 60 000 t to be taken from the eastern fisheries and 70 000 t from the western fisheries. For the western stock the catch was split: 20 000 t (non-spawning), 50 000 t (spawning). In the stock assessment model the non-spawning fishery is split into two parts, separated by the migration of fish from the Chatham Rise to the Southern Plateau. The same proportions as in 2012 were used to split the western non-spawning catch into two parts. For the eastern stock the catch was split 41 000 t (non-spawning), 19 000 t (spawning) based on advice from industry representatives. As with the western stock, the non-spawning catch was split into two parts, using the same proportions as in 2012.

Table 19: 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
Southern Plateau	Wnsp1	Wnsp2	Wnsp2
Cook Strait; Pegasus	Ensp1	Ensp2	Esp
Chatham Rise; east coasts of South Island & North Island; null[1]	Ensp1	Ensp2	Ensp2

[1] no area stated

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 2011) 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 2008, 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 the initial biomass before fishing (B_{INIT}) is set equal to B_0. The steepness of the stock-recruitment relationship is set at 0.75 (Francis 2009).

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 the trawl surveys in areas CR and SA) and three migration ogives (Whome, Espmg, and Wspmg - see Table 20).

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 21. 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.

Table 20: 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).

					Fishery		
Year	Ensp1	Ensp2	Wnsp1	Wnsp2	Esp	Wsp	Total
1972	1 500	2 500	0	0	0	5 000	9 000
1973	1 500	2 500	0	0	0	5 000	9 000
1974	2 200	3 800	0	0	0	5 000	11 000
1975	13 100	22 900	0	0	0	10 000	46 000
1976	13 500	23 500	0	0	0	30 000	67 000
1977	13 900	24 100	0	0	0	60 000	98 000
1978	1 100	1 900	0	0	0	5 000	8 000
1979	2 200	3 800	0	0	0	18 000	24 000
1980	2 900	5 100	0	0	0	20 000	28 000
1981	2 900	5 100	0	0	0	25 000	33 000
1982	2 600	4 400	0	0	0	25 000	32 000
1983	1 500	8 500	3 200	3 500	0	23 300	40 000
1984	3 200	6 800	6 700	5 400	0	27 900	50 000
1985	6 200	3 800	3 000	6 100	0	24 900	44 000
1986	3 700	13 300	7 200	3 300	0	71 500	99 000
1987	8 800	8 200	5 900	5 400	0	146 700	175 000
1988	9 000	6 000	5 400	7 600	600	227 000	255 600
1989	2 300	2 700	700	4 900	7 000	185 900	203 500
1990	3 300	9 700	900	9 100	14 000	173 000	210 000
1991	17 400	14 900	4 400	12 700	29 700	135 900	215 000
1992	33 400	17 500	14 000	17 400	25 600	107 200	215 100
1993	27 400	19 700	14 700	10 900	22 200	100 100	195 000
1994	16 000	10 600	5 800	5 500	35 900	117 200	191 000
1995	29 600	16 500	5 900	7 500	34 400	80 100	174 000
1996	37 900	23 900	5 700	6 800	59 700	75 900	209 900
1997	42 400	28 200	6 900	15 100	56 500	96 900	246 000
1998	55 600	34 200	10 900	14 600	46 700	107 100	269 100
1999	59 200	23 600	8 800	14 900	40 500	97 500	244 500
2000	43 100	20 500	14300	19 500	39 000	105 600	242 000
2001	36 200	19 700	13200	16900	34 800	109 000	229 800
2002	24 600	18 100	16 800	13 400	24 600	98 000	195 500
2003	24 200	18 700	12 400	7 800	41 700	79 800	184 600
2004	17 900	19 000	6 300	5 300	41 000	46 300	135 800
2005	19 000	13 800	4 200	2 100	27 000	38 100	104 200
2006	22 000	14 700	2 000	4 700	20 500	40 400	104 300
2007	22 400	18 400	4 200	3 500	18 800	33 700	101 000
2008	22 100	19 400	6 500	2 200	17 900	21 200	89 300
2009	29 300	13 100	6 000	3 800	15 900	20 800	88 900
2010	28 500	13 500	6 700	5 600	16 400	36 600	107 300
2011	30 500	12 800	7 500	5 200	13 300	49 500	118 800
2012	28 500	14 700	9 100	6 600	15 400	55 800	130 100
2013	27 000	14 000	11 600	8 400	19 000	50 000	130 000

Calculation of fishing intensity and B_{MSY}

The fishing intensity for a given stock and model run was calculated as an annual exploitation rate, $U_y = \max_{as}\left(\sum_f C_{asfy} / N_{asy}\right)$, where the subscripts *a*, *s*, *f*, and *y* index age, sex, fishery, and year, respectively, *C* is the catch in numbers, and *N* is the number of fish in the population immediately before the first fishery of the year. This measure is deemed to be more useful than the spawning fisheries exploitation rates that have been presented in previous assessments, because it does not ignore the effect of the non-spawning fisheries, and thus represents the total fishing intensity for each stock.

Table 21: 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)[1]	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 *et al.* (2002)
q[CRsum].q	catchability, CRsumbio	lognormal	0.15	0.65	O'Driscoll *et al.* (2002)
q[SAsum].q	catchability, SAsumbio	lognormal	0.17	0.61	O'Driscoll *et al.* (2002)
q[SAaut].q	catchability, SAautbio	lognormal	0.17	0.61	O'Driscoll *et al.* (2002)
selectivity[Wspsl].shift_a	allows annual shifting of Wspsl	normal	0	0.25	Francis (2006)
natural_mortality.all[2]	*M*	lognormal	0.298	0.153	Smith (2004)
natural_mortality[3]	M_{male} & M_{female}, ages 5-9 only	lognormal	0.182	0.509	Cordue (2006)

[1] This is a beta distribution, transformed to have its range from 0.1 to 0.6, rather than the usual 0 to 1.
[2] Used only in runs where *M* was independent of age and sex
[3] Used only in runs where *M* varied with age and sex

For a given stock and run, the reference fishing intensities, $U_{35\%Bo}$ and $U_{50\%Bo}$, are defined as the levels of *U* that would cause the spawning biomass for that stock to tend to 35%B_0 or 50%B_0, respectively, assuming deterministic recruitment and individual fishery exploitation rates that are multiples of those in the current year. These reference fishing intensities were calculated by simulating fishing using a harvest strategy in which the exploitation rate for fishery *f* was $mU_{f,\text{current}}$, where $U_{f,\text{current}}$ is the estimated exploitation rate for that fishery in the current year, 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 a given stock, $U_{x\%Bo}$ was set equal to $m_{x\%}U_{\text{current}}$, where the multiplier, $m_{x\%}$ (calculated by interpolation) was that which caused the equilibrium biomass of that stock to be x%B_0.

The same sets of simulations were used to calculate B_{MSY} for each stock for the final model runs. B_{MSY} was defined as the equilibrium biomass (expressed as %B_0) for the value of *m* which maximised the equilibrium catch from that stock.

Caution about the interpretation of B_{MSY} estimates

There are several reasons why B_{MSY}, as calculated in this way, is not a suitable target for management of the hoki fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known (Francis 2009). Third, it makes no allowance for extended periods of low recruitment, such as was 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.

6.2 Results

The assessment was conducted in two steps. First, a set of initial exploratory model runs was carried out generating 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

An initial set of analyses was carried out after the new data became available (McKenzie 2013b). 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 Southern Plateau series (see SAsumbio in Table 15). This biomass increase was sustained in the four subsequent surveys (2009, 2010, 2012 and 2013). Furthermore, the SAsumbio data shows large annual changes in numbers-at-age which cannot be explained by changes in abundance, and are suggestive of a change in catchability for the survey. Because of this, and to improve the fit to the SAsumbio series, two model runs were done in which it was assumed that the catchability has changed over time.

In some sensitivity model runs, natal fidelity was not assumed, in contrast to the other model runs.

Three final runs

Three final runs were chosen by the Plenary: one with constant catchability in the SAsumbio series (1.7), and two where the catchability was assumed to have changed over time (1.16 and 1.19). Some results from four sensitivity runs are also presented.

For the previous assessment's base run the problem of the lack of old fish in both fishery-based and survey-based observations was dealt with by allowing M (natural mortality) to be dependent on age. Furthermore, the trawl survey biomass indices were upweighted to improve the fit to them. In the 2013 assessment, the same model was used and updated with the new data, but the trawl survey data were not upweighted as they had been in 2012 (Model 1.7; Table 22).

In the other two final runs for the current assessment two catchabilities are fitted for the SAsumbio series instead of one (Table 22). In run 1.16, the catchability for 2004–2007 inclusive is estimated separately from the other years in the series, whereas for run 1.19 the catchability from 2008–2013 inclusive is estimated separately. The trawl surveys are not upweighted for these runs (or for the sensitivities to them).

Table 22: Distinguishing characteristics for all model runs. The three final runs are marked with an asterisk. Aspects of a model run that distinguish it from other runs are shown in *bold italics*. Run 1.7 is a final run similar to the 2012 base case model except that the trawl survey indices were not upweighted. Run 1.16 is a final run with sensitivities 1.17 and 1.18. Run 1.19 is a final run with sensitivities 1.20 and 1.21.

Label	Two catchabilities for SAsumbio?	Response to lack of old fish in the observations	Trawl surveys up-weighted?	Sex in model and selectivities length-based?	Natal fidelity?
1.7*	No	M dependent on age	No	Yes	Yes
1.16*	04–07q different	M dependent on age	No	Yes	Yes
1.17	04–07q different	***Domed spawning selectivity***	No	***No***	Yes
1.18	04–07q different	M dependent on age	No	Yes	***No***
1.19*	08–13q different	M dependent on age	No	Yes	Yes
1.20	08–13q different	***Domed spawning selectivity***	No	***No***	Yes
1.21	08–13q different	M dependent on age	No	Yes	***No***

Bayesian posterior distributions were estimated for each of these runs using a Markov Chain Monte Carlo (MCMC) approach (McKenzie 2013c,d). 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 23 (estimates of spawning biomass), Figure 2 (biomass trajectories and year-class strengths) and Figure 3 (current biomass distributions). Compared to the constant catchability run (1.7), run 1.16 shows a higher current status of the stock (%B_0) for both stocks, whereas for run 1.19 the E stock is higher and the W stock lower. All model runs show that the biomasses of both stocks were at their lowest points in about 2004-06 and are now increasing, and that the W stock experienced seven consecutive years of poor recruitment from 1995 to 2001 inclusive. Recruitment for the W stock is estimated to have been well below average in 2010 and well above average in 2011. There is good agreement on estimates of year-class strengths, except that runs with domed selectivities (1.17 and 1.20) tend to estimate relatively stronger year classes in the early years.

The current status of the W stock is similar to that in the 2012 assessment. In that assessment, for the base case model, there was a 0.92 probability that the stock was above 35% B_0, whereas the probability for 2013 is 1.00 (run 1.7), 1.00 (run 1.16) or 0.91 (run 1.19). According to the Harvest Strategy Standard this means that the western stock has been considered to be fully rebuilt (at least a 70% probability that the (lower bound of the) target has been achieved) for at least the last three years.

Other runs

Sensitivities were conducted for two of the final runs (Table 22). In the first of the sensitivities the problem of the lack of old fish in both fishery-based and survey-based observations is dealt with by the alternative solution of allowing the spawning fishery selectivities (Espl, Wspsl) to be domed. In past assessments when domed selectivities were used, it was found that it was better to combine sexes in the model and make the selectivities age-based (Francis 2005). In the second sensitivity the assumption of natal fidelity is dropped (but adult fidelity is assumed).

In the sensitivity runs, the current biomass estimates (%B_0) for the E stock are at least as high as the associated final run when domed selectivity is assumed, but lower when natal fidelity is not assumed (Table 23). For the W stock, current biomass is higher for all sensitivity runs, and more uncertain when natal fidelity is not assumed (Table 23).

Table 23: Estimates of spawning biomass for the final runs* and sensitivities (median of marginal posteriors, with 95% confidence intervals in parentheses). $B_{current}$ is the spawning biomass in mid-season 2012-13.

	B_0 (‘000 t)		$B_{current}$ (‘000 t)		$B_{current}$ (%B_0)		
Run	E	W	E	W	E	W	E+W
1.7*	518(421,672)	967(791,1346)	263(164,389)	550(339,967)	50(36,69)	56(41,77)	54(44,70)
1.16*	553(445,696)	1105(871,1485)	313(198,473)	721(446,1163)	57(40,76)	65(48,84)	62(50,76)
1.19*	525(417,693)	945(778,1286)	288(180,436)	434(257,757)	55(39,74)	45(31,63)	49(37,62)
1.17	675(465,1007)	1203(933,1601)	395(232,668)	871(578,1302)	58(41,81)	73(57,91)	68(55,81)
1.18	627(465,838)	1314(1056,1621)	277(161,468)	1128(707,2126)	44(30,64)	85(62,150)	72(56,118)
1.20	651(453,996)	1079(840,1440)	398(236,671)	603(352,956)	60(42,83)	55(39,75)	58(45,71)
1.21	768(558,1122)	1106(894,1487)	368(207,636)	780(396,1833)	48(33,69)	70(41,146)	62(43,108)

Fishing intensity on both stocks was estimated to be at or near all-time highs in about 2003 and is now substantially lower (Figure 4).

For all the three final runs (Runs 1.7, 1.16 and 1.19) estimates of B_{MSY} were 25% for the E stock. For the W stock they were 27% (Run 1.7) and 26% (Runs 1.16 and 1.19).

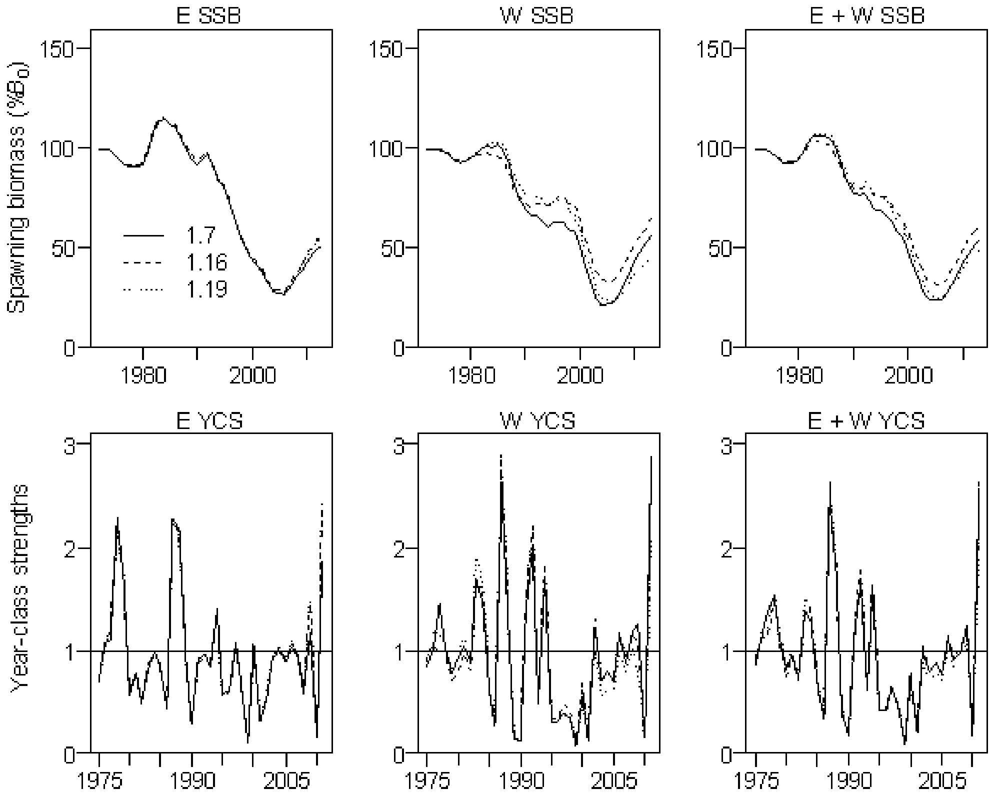


Figure 2: Estimated spawning biomass trajectories (SSB, upper panels) and year-class strengths (YCS, lower panels) for the E (left panels), W (middle panels) and E + W stocks (right panels) from the three final runs (Runs 1.7, 1.16, and 1.19). Plotted values are medians of marginal posterior distributions. Years are fishing years (1990 = 1989-90).

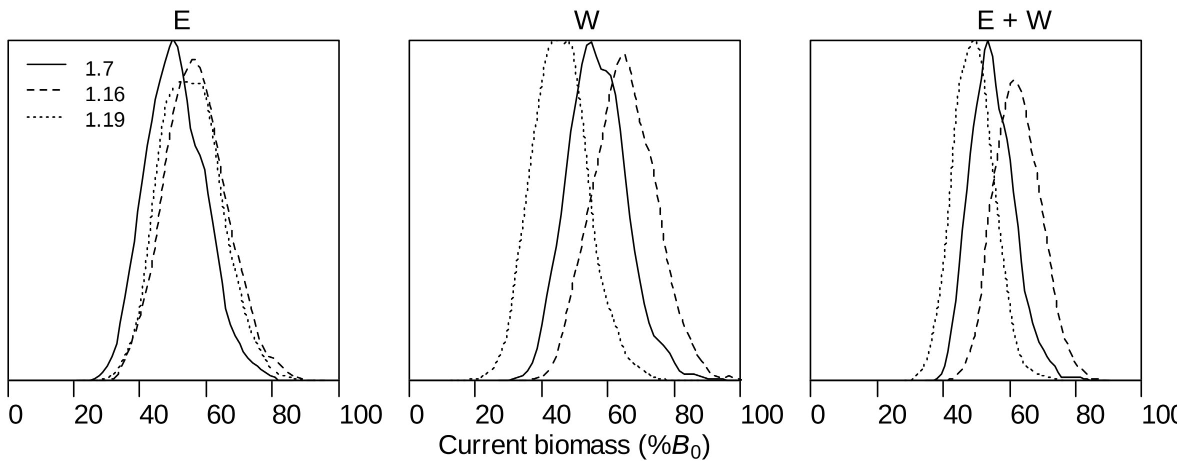


Figure 3: Estimated posterior distributions of current (spawning) biomass ($B_{2012\text{-}13}$) expressed as %B_0 for the E (left panel), W (middle panel), and E + W (right panel) from the three final model runs (1.7, 1.16 and 1.19).

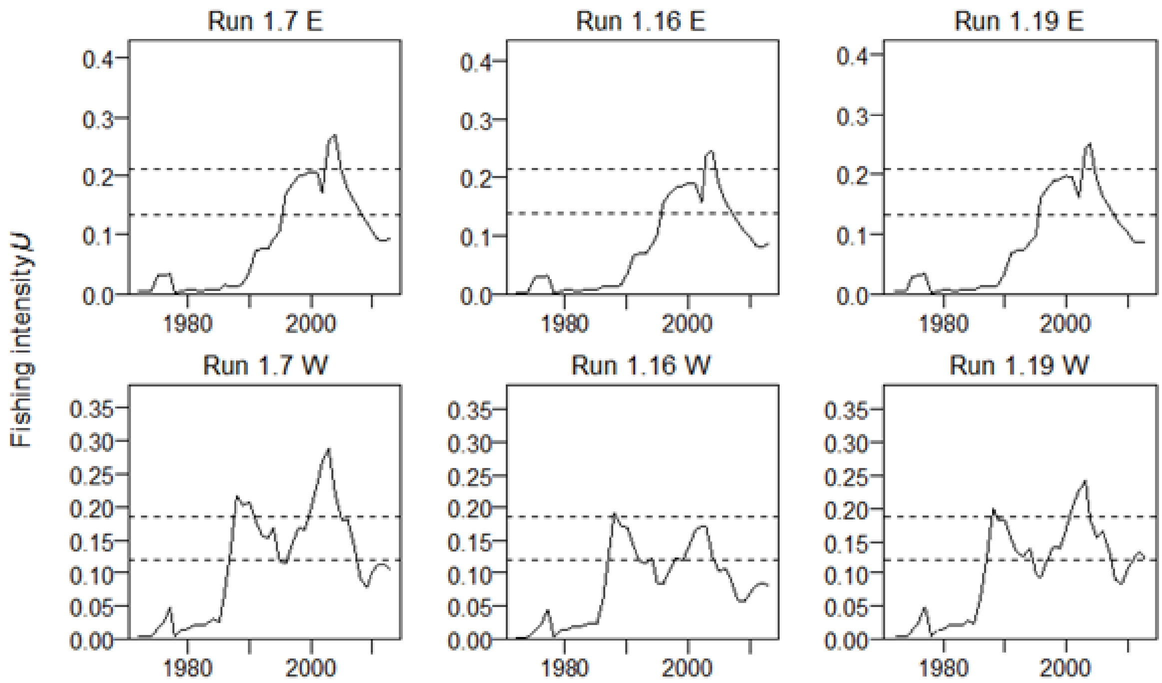


Figure 4: Fishing intensity, U (from MPDs), plotted by run and stock. Also shown (as broken lines) are the reference levels $U_{35\%Bo}$ (upper line) and $U_{50\%Bo}$ (lower line), which are the fishing intensities that would cause the spawning biomass to tend to 35% B_0 and 50% B_0, respectively. The y-axes are scaled so that the $U_{35\%}$ reference lines align horizontally (within and across the stocks).

6.3 Projections

Five-year projections were carried out, for each of the three final runs (1.7, 1.16, 1.19), under each of two alternative assumptions about future recruitment: 'ten-year' (in which future recruitments were selected at random from those estimated for 2001-2011) and 'drop 2011' (future recruitments selected from 2001-2010). The drop 2011 recruitment option was considered because of the poorly estimated 2011 years class strength which may not persist in the future. In all projections, future catches in each fishery were assumed to be the same as for 2013 (i.e. as in the last line of Table 20). The projections indicate that with these assumed catches, the E and W biomasses are likely to rise in the next 5 years under 'ten-year' recruitment and to stay much the same when the large 2011 recruitment is omitted (Figures 5).

The probabilities of the current (2013) 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 Tables 24-25 for the case where future catches remain at 2013 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.

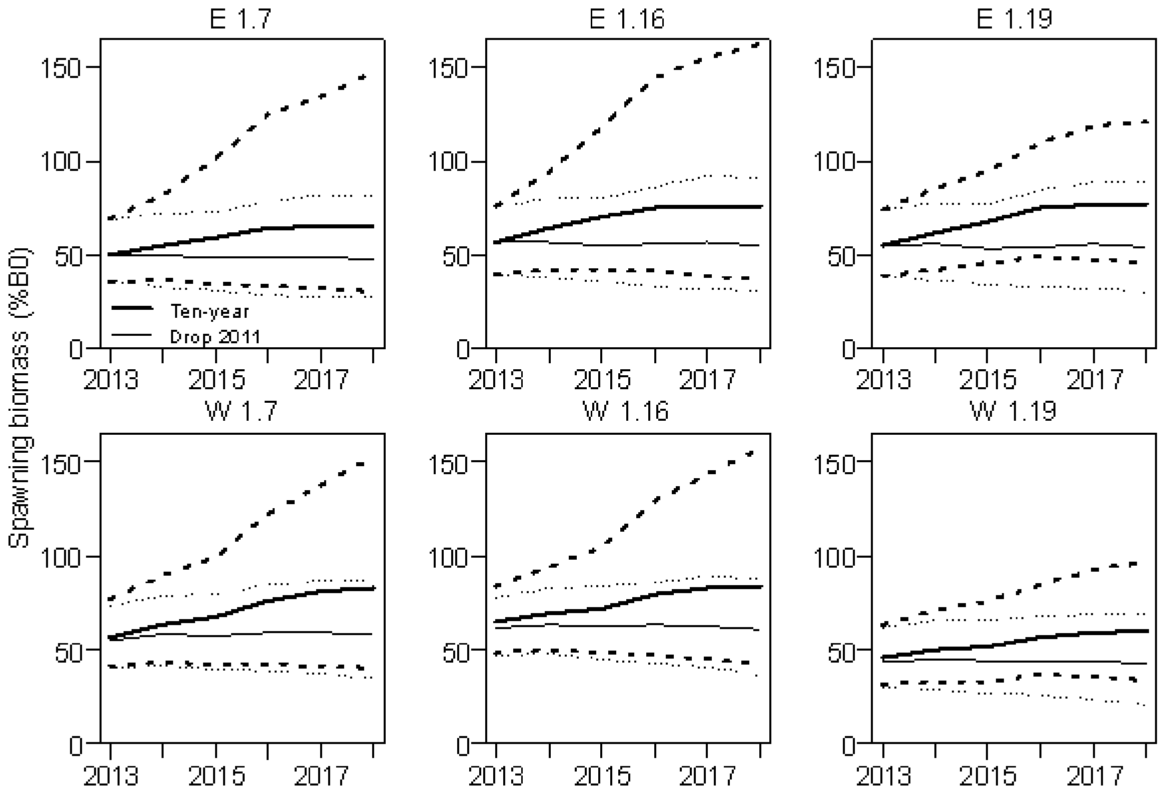


Figure 5: Projected spawning biomass (as %B_0) assuming randomised recruitment from 2012 onwards (thick lines) or 2011 onwards (thin lines) recruitment: median (solid lines) and 95% confidence intervals (broken lines) for the three final runs (Runs 1.7, 1.16 and 1.19).

Table 24: Probabilities (rounded to two decimal places) associated with projections for SSB (%B_0) for the three final runs (1.7, 1.16 and 1.19) for the ten-year recruitment option (recruitments selected from 2001-11).

			2013			2018: drop 2011
	1.7	1.16	1.19	1.7	1.16	1.19
EAST						
P(SSB<10%B_0)	0	0	0	0	0	0
P(SSB<20%B_0)	0	0	0	0	0	0
P(SSB<35%B_0)	0.02	0	0.01	0.06	0.01	0
P(SSB<50%B_0)	0.48	0.23	0.30	0.26	0.13	0.05
WEST						
P(SSB<10%B_0)	0	0	0	0	0	0
P(SSB<20%B_0)	0	0	0	0	0	0
P(SSB<35%B_0)	0	0	0.09	0.01	0	0.03
P(SSB<50%B_0)	0.21	0.05	0.7	0.1	0.06	0.22

Table 25: Probabilities (rounded to two decimal places) associated with projections for SSB (%B_0) for the three final runs (1.7, 1.16 and 1.19) with the drop 2011 recruitment option (recruitments selected from 2001-2010).

	2013			2018: drop 2011		
	1.7	1.16	1.19	1.7	1.16	1.19
EAST						
P(SSB<10%B_0)	0	0	0	0	0	0
P(SSB<20%B_0)	0	0	0	0	0	0
P(SSB<35%B_0)	0.02	0	0.01	0.14	0.05	0.08
P(SSB<50%B_0)	0.48	0.23	0.30	0.56	0.35	0.40
WEST						
P(SSB<10%B_0)	0	0	0	0	0	0
P(SSB<20%B_0)	0	0	0	0	0	0.02
P(SSB<35%B_0)	0	0	0.09	0.02	0.01	0.25
P(SSB<50%B_0)	0.21	0.05	0.70	0.26	0.19	0.73

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:

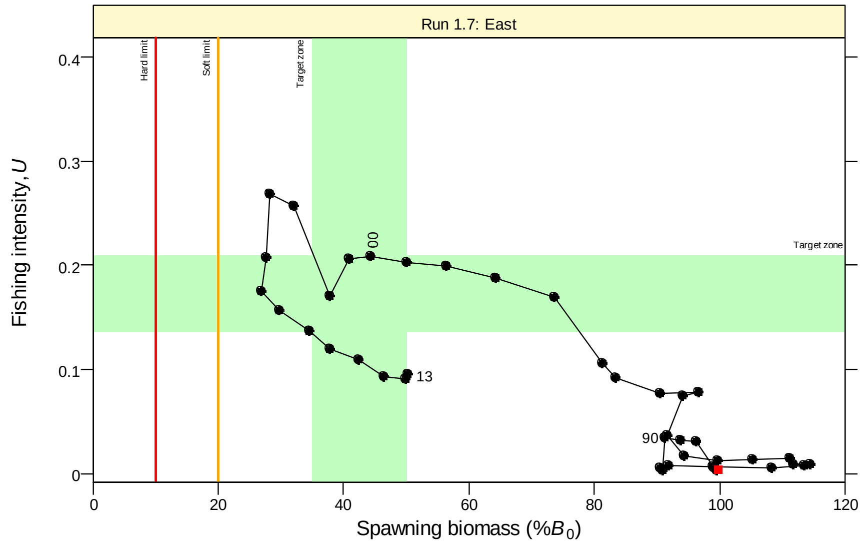
- Adults of the western stock occur on the west coast of the North and South Islands and the area south of New Zealand including Puysegur, Snares and the Southern Plateau;
- Adults of the eastern stock occur on the east coast of the South Island, Cook Strait and the ECNI up to North Cape;
- Juveniles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

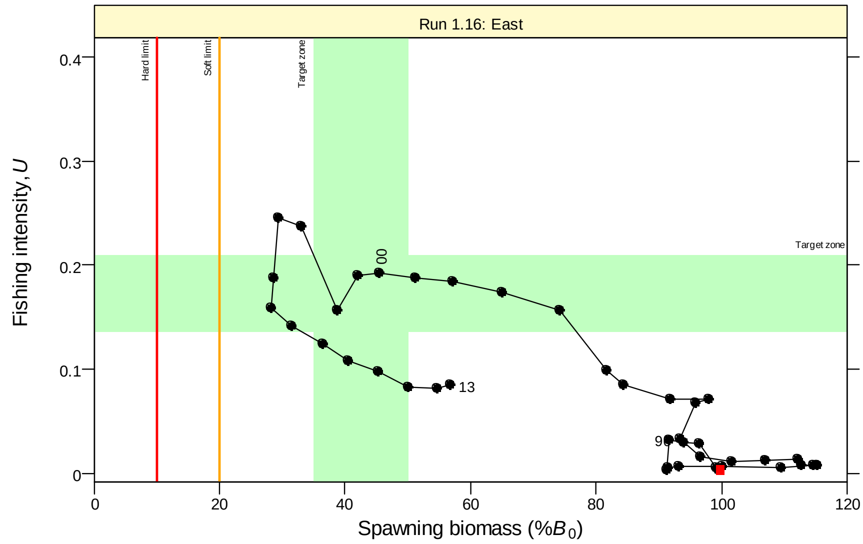
Both of these biological stocks lie within the HOK 1 Fishstock boundaries.

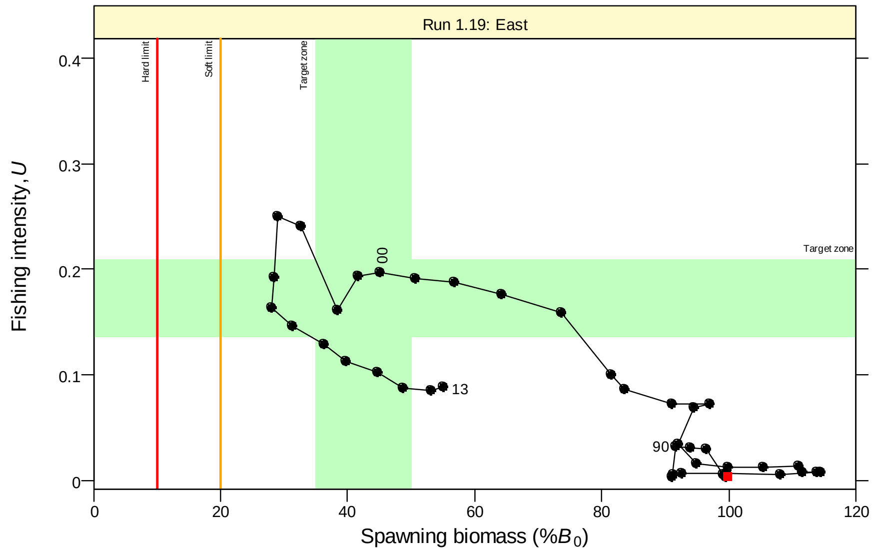
- **Eastern Hoki Stock**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Three final runs were used to evaluate hoki stock status: runs 1.7, 1.16 and 1.19
Reference Points	Target: 35-50% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{35\%B0}$
Status in relation to Target	B_{2013} was estimated to be 50-57% B_0; Very Likely (> 90%) to be at or above the lower end of the target range and About as Likely as Not (40-60%) to be at or above the upper end of the target range
Status in relation to Limits	B_{2013} is Exceptionally Unlikely (< 1%) to be below either the Soft or Hard Limit
Status in relation to Overfishing	Overfishing is Very Unlikely (<10%) to be occurring

Historical Stock Status Trajectory and Current Status







Trajectory over time of fishing intensity (*U*) and spawning biomass (% B_0), for the eastern hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2013. 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 ranges in biomass and fishing intensity. Biomass estimates are based on MCMC results, while fishing intensity is based on corresponding MPD results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The minimum estimate of biomass was 27-28% B_0 in 2006. Biomass has subsequently been increasing.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is estimated to have continuously decreased from 2004 to 2012, with a slight increase in 2013.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recent recruitment (2003-2009) is estimated to be near the long-term average for this stock, but 2010 was well below average and 2011 is well above average; the split between the eastern and western stocks of the latter is uncertain.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the eastern hoki stock is expected to increase over the next 5 years at assumed 2012-13 eastern fishery catch levels if the 2011 year class recruits to the eastern stock as estimated by the model, but to remain more or less constant if the 2011 recruitment to the eastern stock is average.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2013	Next assessment: 2014
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series of abundance indices (trawl and acoustic surveys) - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of fixed biological parameters	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	One run with a single catchability and two runs with two catchabilities are fitted to the Sub-Antarctic trawl survey series (SAsumbio) for the final runs. Trawl surveys are not upweighted.	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2011 year class between eastern and western stocks with respect to projections	

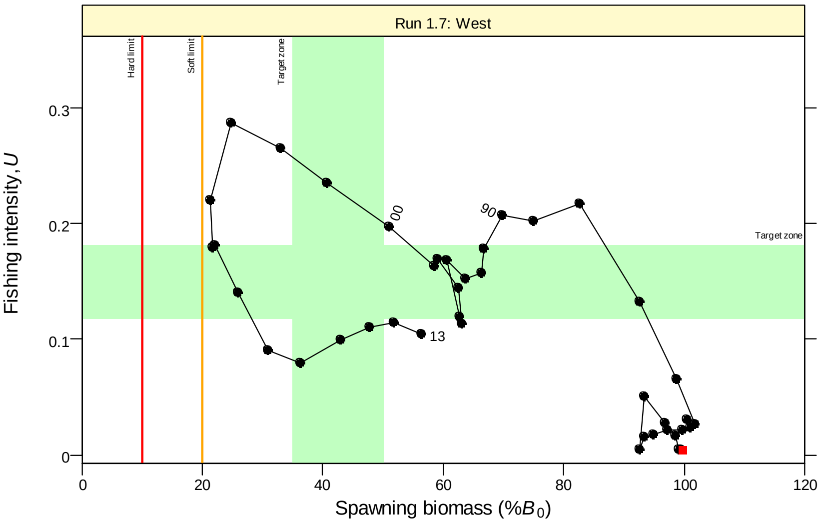
Qualifying Comments
The impact of the current young age structure of the population on spawning success is unknown.

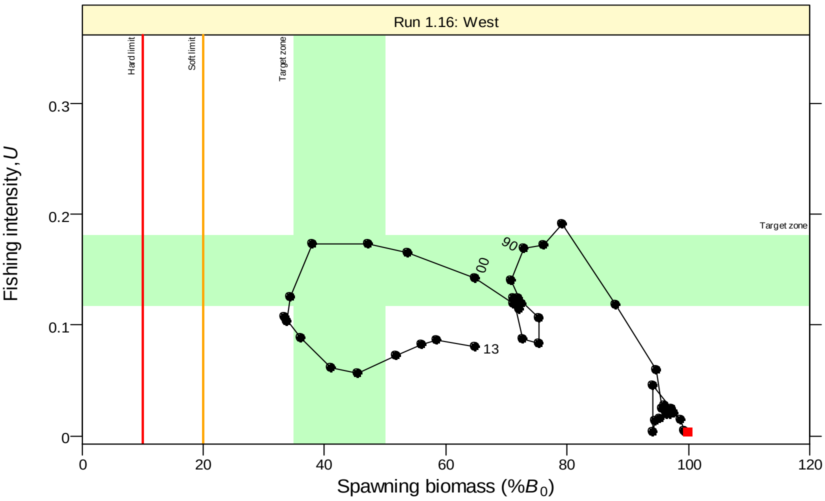
Fishery Interactions
In Cook Strait the main bycatch species are ling and spiny dogfish while on the Chatham Rise the main bycatch species are hake, ling, silver warehou, javelinfish, rattails and spiny dogfish, with lesser bycatches of ghost sharks, white warehou, sea perch and stargazers. Low productivity species taken in the hoki fisheries include basking sharks, deepsea skates and some other elasmobranchs. Incidental interactions with protected species and associated mortalities are noted for New Zealand fur seals and seabirds.

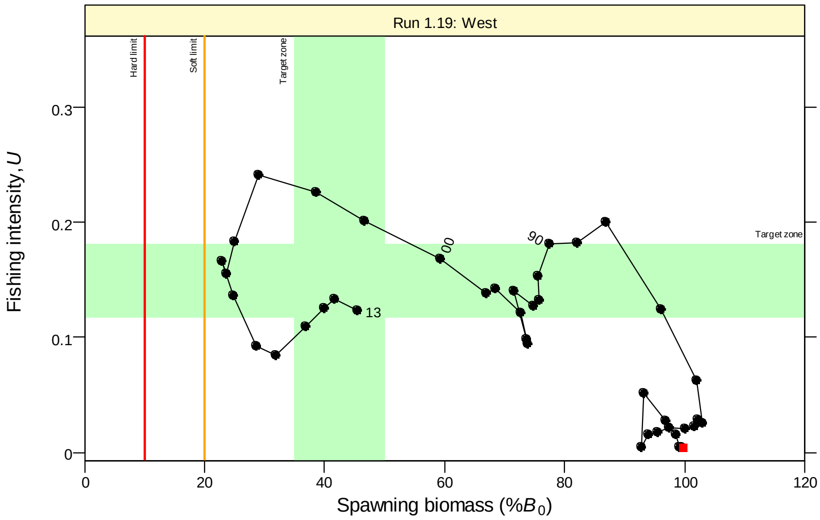
Western Hoki Stock

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Three final runs were used to evaluate hoki stock status: runs 1.7, 1.16 and 1.19
Reference Points	Target: 35-50% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{35\%B0}$
Status in relation to Target	B_{2013} was estimated to be 45-65% B_0; Very Likely (> 90%) to be above the lower end of the target range
Status in relation to Limits	B_{2013} is Exceptionally Unlikely (< 1%) to be below either the Soft or Hard Limit
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (<1%) to be occurring

Historical Stock Status Trajectory and Current Status







Trajectory over time of fishing intensity (*U*) and spawning biomass (% B_0), for the western hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2013. 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 ranges in biomass and fishing intensity. Biomass estimates are based on MCMC results, while fishing intensity is based on corresponding MPD results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The minimum estimate of biomass was 21-33% B_0 in the mid 2000s. Current biomass is estimated to be about double these values. According to the Harvest Strategy Standard the western stock is considered to have been fully rebuilt (at least a 70% probability that the target has been achieved).
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is estimated to have decreased since 2003, started increasing in 2010, and declined slightly in 2013.
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 five to six years in which recruitment is estimated to be near or above the long-term average, but the 2010 recruitment was well below average and 2011 was well above average.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the western hoki stock is expected to increase slowly over the next 5 years at assumed 2012-13 western fishery catch levels.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation	
Assessment Type	Level 1 - Full quantitative stock assessment
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions

Assessment Dates	Latest assessment: 2013	Next assessment: 2014
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series of abundance indices (trawl and acoustic surveys) - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of fixed biological parameters	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	Commercial CPUE WCSI trawl survey biomass estimate	3 – Low Quality: does not track stock biomass 3 – Low Quality: currently not included in the assessment pending an evaluation of their reliability for hoki
Changes to Model Structure and Assumptions	One run with a single catchability and two runs each with two catchabilities are fitted to the Sub-Antarctic trawl survey series (SAsumbio) for the final runs. Trawl surveys are not upweighted.	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2011 year class between eastern and western stocks with respect to projections - Probable catchability changes in Southern Plateau trawl surveys	

Qualifying Comments
The impact of the current young age structure of the population on spawning success is unknown.

Fishery Interactions
On the west coast South Island and in the Southern Plateau fisheries the main bycatch species are hake, ling, silver warehou, jack mackerel and spiny dogfish. Low productivity species taken in the hoki fisheries include basking sharks, deepsea skates and some other elasmobranchs. Incidental interactions with protected species and associated mortalities are noted for New Zealand fur seals and seabirds.

8. FOR FURTHER INFORMATION

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