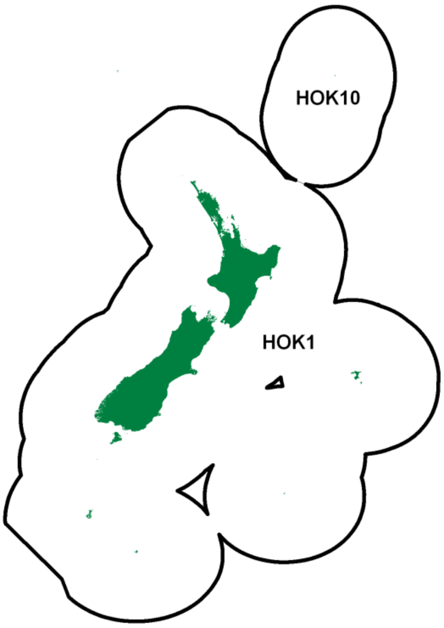
HOKI (HOK)

(*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.

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.

Table 2: Reported catch (t) from QMS, estimated catch (t) data, and TACC (t) for HOK 1 from 1986–97 to 2013–14. 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
2012–2013	131 500	128 000	130 000
2013–2014	146 500	144 000	150 000

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.

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 four years as stock status has improved (Table 2). The reported catch in 2013–14 of 146 500 t was about 3500 t less than the TACC of 150 000 t (Table 2).

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 five years to 69 400 t in 2013–14. This was about 47% of the total catch, making the WCSI the largest hoki fishery for the fourth consecutive year. In Cook Strait, catches peaked at 67 000 t in 1995–96, declined to 14 900 in 2010–11, but have increased over the past two years to 19 400 t in 2002–13 and 18 400 t in 2013–14. Non-spawning catches on the Chatham Rise peaked at about 75 000 t in 1997–98 and 1998–99, decreased to a low of 30 700 t in 2004–05, before increasing again to about 39 000 t from 2008–09 to 2011–12, decreasing to 36 500 t in 2012–13 and 33 800 t in 2013–14. The Chatham Rise was the largest hoki fishery from 2006–07 to 2009–10, but contributed only about 23% of the total catch in 2013–14. 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 19 900 t in 2013–14 (Table 3).

Table 3: Estimated total catch (t) (scaled to reported QMR or MHR) of hoki by area 1988–89 to 2013–14 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 2013–14 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
2012–2013	56 200	1 000	19 400	3 300	14 100	36 500	1 100	-	131 600
2013–2014	69 400	800	18 400	2 800	19 900	33 800	1 300	-	146 300

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), 70 000 t in 2011–12 and 2012–13 (overall TACC of 130 000 t), and 90 000 t in 2013–14 (overall TACC of 150 000 t). The split between eastern and western catches has been within 2000 t of the management targets since 2010–11. 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 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%
2012–2013	43%	17%	11%	29%
2013–2014	48%	12%	14%	27%

Total Allowable Commercial Catch (TACC) and area restrictions

In the 2013–14 fishing year, the TACC for HOK1 was 150 000 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 90 000 t of the TACC should be taken from western stock areas. With the allowance for other mortality at 1 300 t and 20 t allowances for customary and recreational catch, the 2013–14 TAC was 151 340 t. The TACC was increased to 160 000 t from 1 October 2014, with an agreement that 100 000 t should be taken from western areas

Chartered vessels may not fish inside the 12-mile Territorial Sea and there are various vessel size restrictions around some parts of the coast. On the WCSI, a 25-mile line closes much of the hoki spawning area in the Hokitika Canyon and most of the area south to the Cook Canyon to vessels larger than 46 m overall length. In Cook Strait, the whole spawning area is closed to vessels over 46 m overall length. 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 over 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 less than 55 cm total length) comprise more than 20% of the hoki catch by number.

2013–14 Hoki fishery

The overall estimated total catch in 2013–14 of 146 500 t was 20 000 t higher than that in 2012–13 and about 3500 t lower than the TACC (Table 3). Relative to 2012–13, catches from the main western areas (WCSI and Sub-Antarctic) increased in 2013–14, while those from the main eastern areas (Cook Strait and the Chatham Rise) decreased slightly.

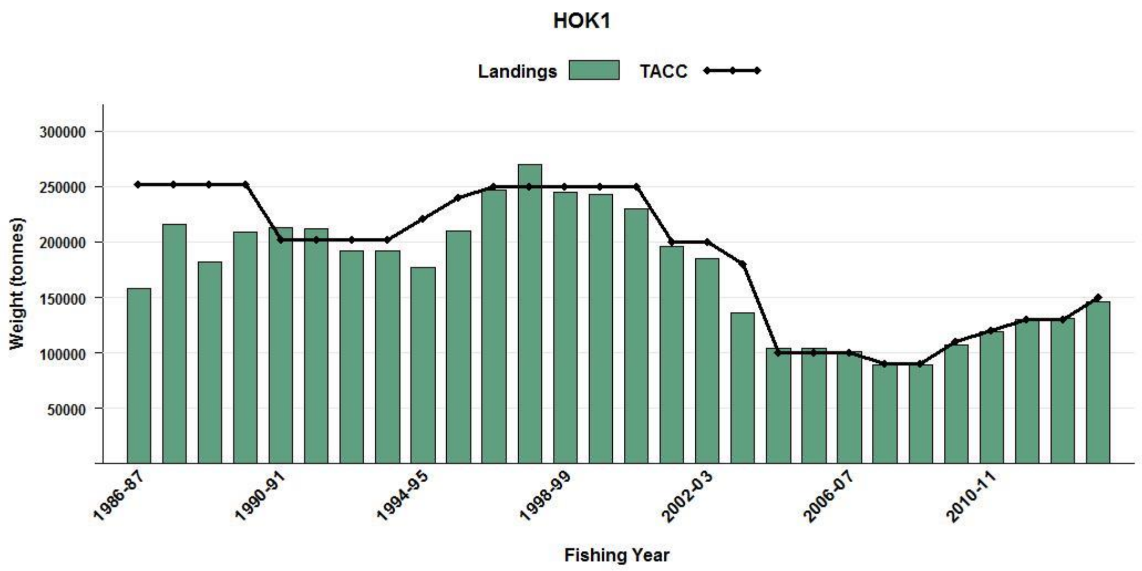
The WCSI catch increased by 13 000 t to 69 400 t in 2013–14. Catches from inside the 25 n. mile line made up 13% of the total WCSI catch in 2013–14, an increase in proportion from 2012–13, but still down from a peak of 41% of the catch in 2003–04. The WCSI fishing is season now longer – with fishing in May (although most pre-June catch is from inside the 25 n. mile line), and the 2014 season had higher catches through mid-August compared to the previous four seasons. Unstandardised catch rates on the WCSI in 2013–14 decreased slightly from 2012–13, but were the fourth highest in the series, with a median catch rate in all midwater tows targeting hoki of 5.9 t per hour. The WCSI catch in 2014 was dominated by fish from 60 to 100 cm from the 2005–09 year-classes (ages 5–9), with a smaller length mode from the 2011 year class (age 3). 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 increased again to 49% in 2013–14. Conversely, the percentage of small fish (under 65 cm) by number in the catch decreased from 31% in 2008–09 to 8% in 2012–13, but increased to 14% in 2013–14. From 1999–00 to 2003–04, the sex ratio of the WCSI catch was highly skewed, with many more females caught than males. In 2004–05 to 2010–11, as the catch of younger fish increased, the sex ratio reversed with more males than females caught. The sex ratio of the WCSI catch has been about even since 2011–12, with 53% females in 2012–13 and 2013–14. 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 has been decreasing recently.

The Chatham Rise fishery took 33 800 t in 2013–14. Over 97% of the Chatham Rise catch was taken in bottom trawls, with the median unstandardised catch rate in bottom trawls targeting hoki of 1.1 t per hour in 2013–14. The catch was bimodal and dominated by hoki of 50–90 cm, with the left hand mode from the 2011 year-class (age 2), with the right hand mode from the 2007–09 year-classes (ages 4–6), and few larger, older fish. The 2010 year-class was poorly represented at age 3+. The modal age was 2+. The Chatham Rise fishery caught more young fish than the WCSI fishery, with only 23% of hoki aged 7 years and older. About 45% of the catch by number was less than 65 cm in 2013–14, due to the high numbers of 2+ hoki caught. The sex ratio was even.

The catch from Cook Strait in 2013–14 (18 000 t) decreased by about 1000 t from that in 2012–13. Peak catches were from mid-July to mid-September, with about 3800 t caught outside the spawning season. Unstandardised catch rates in Cook Strait continued to be high, but the median catch rate in midwater tows targeting hoki decreased from 17.5 t per hour in 2012–13 to 12.3 t per hour in 2013–14. There was a broad age distribution of females from ages 3 to 14, while most males were ages 3–10. The modal age was 5 (2009 year-class), with another mode at age 3 (2011 year class). Only 16% of the catch was fish less than 65 cm. The sex ratio of the Cook Strait catch has fluctuated over time, but was female-dominated from 2001–05, and has been generally male-dominated since, with 63% males in the catch in 2013–14. Apparent changes in sex ratio in the last four years may be related to biases in sampling. As on the WCSI, the mean length at age showed a period of increase in the Cook Strait fishery, but appears to have decreased recently.

The catch from the Southern Plateau of 19 900 t in 2013–14 was about 5800 t higher than that in 2012–13. The percentage of the catch from hoki target tows in 2013–14 was 87%, having fallen as low as 70% in 2006–07. Unstandardised catch rates in bottom trawls targeting hoki were 1.6 t per hour in 2013–14. The length distribution of hoki from the Sub-Antarctic in 2013–14 was bimodal with the smaller mode consisting of fish from the 2011 year-class (age 2), and the larger mode from the 2007–09 year-classes (ages 4–6). The modal age of females and males was 2+ (2011 year-class). The percentage of fish in the catch less than 65 cm was 42% in 2013–14, and about 54% of the fish caught in the Sub-Antarctic in 2013–14 were females.

Catches from ECNI increased by 280 t to 1300 t, whereas catches from Puysegur and ECSI decreased by 170 t to 780 t, and by 560 t to 2 800 t, respectively.



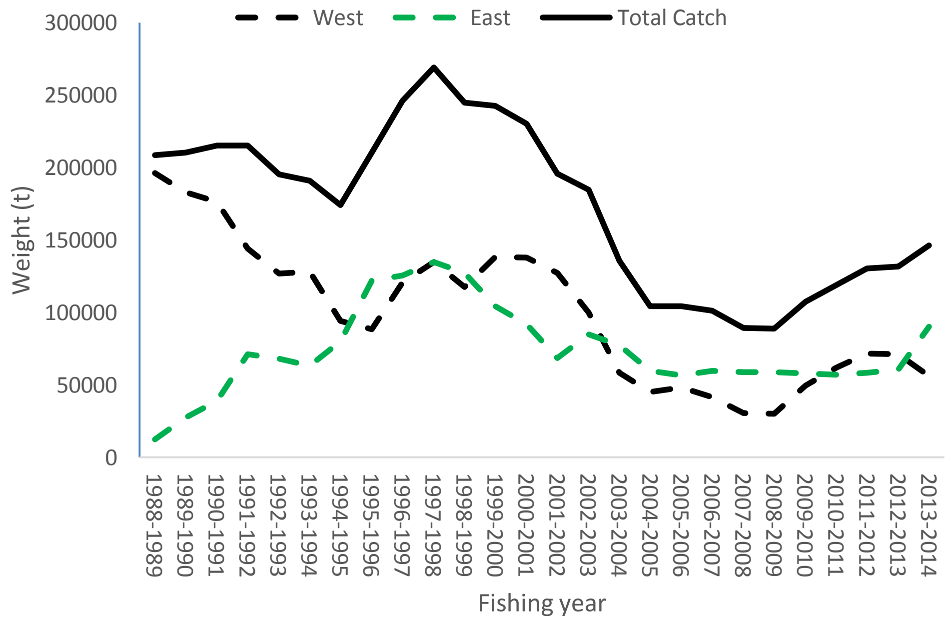


Figure 1: Upper: Reported commercial landings and TACCs for HOK 1 since 1986–87. Lower: The eastern and western components of the total HOK 1 landings since 1988–89. Note that these figures do not show data prior to entry into the QMS.

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 et al. (2010) 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° S to 54° 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 larger hoki have been targeted over other hill complexes outside the survey areas of both the Chatham Rise and Southern Plateau (Dunn & Livingston 2004), and have also been 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, developed to estimate proportion spawning from summer samples of post-spawner hoki on the Southern Plateau, indicated that approximately 85% of the hoki aged 4 years and older from 2003–2004 had spawned (Grimes & O'Driscoll 2006, Parker et al 2009).

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 fewer 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 2009b). 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 2012).

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last reviewed by the Aquatic Environment Working Group for the May 2012 Fishery Assessment Plenary. The tables have been updated and minor corrections made for this report by the DWFAWG. This summary is from the perspective of the hoki fishery; a more comprehensive review from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review 2103 (MPI 2013).

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 2009a, Connell et al 2010, Stevens et al 2011). Hoki show ontogenetic shifts in their feeding preferences, and larger hoki (over 80 cm) consume proportionately more fish and squid than do smaller hoki (Dunn et al 2009a, Connell et al 2010). The diet of hoki overlaps with those of alfonsino, arrow squid, hake, javelinfish, Ray’s bream, and shovelnose dogfish (Dunn et al 2009a). Hoki are prey to several piscivores, particularly hake but also stargazers, smooth skates, several deep water shark species, and ling; (Dunn et al 2009a). 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)

The main commercial bycatch species in hoki target fisheries off the west coast South Island, 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 90%, 1%, and 2%, respectively, of the catch in target hoki trawls between 2008–09 and 2012–13 (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 by fishing year. Data from the Central Observer Database.

Species	2008–09		2009–10		2010–11		2011–12		2012–13	
	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%
Hoki	19 522	87.2	24 696	87.	20 600	86.5	32 360	89.1	27 309	94.5
Ling	548	2.5	624	2.2	555	2.3	975	2.7	348	1.2
Javelinfish	494	2.2	734	2.6	469	2.0	425	1.2	93	0.3
Rattails	334	1.5	572	2.0	403	1.7	441	1.2	91	0.3
Silver warehou	191	0.9	337	1.2	380	1.6	352	1.0	139	0.5
Hake	227	1.0	235	0.8	319	1.3	396	1.1	379	1.3
Spiny dogfish	187	0.8	233	0.8	226	0.9	439	1.2	137	0.5
White warehou	58	0.3	64	0.2	89	0.4	65	0.2	5	0.02
Pale ghost shark	81	0.4	101	0.4	82	0.3	95	0.3	4	0.01
Sea perch	16	0.1	55	0.2	81	0.3	56	0.2	11	0.04
Barracouta	6	0.0	4	0.0	44	0.2	4	0.01	<1	<0.01
Southern blue whiting	37	0.2	7	0.0	40	0.2	12	0.03	2	0.01
Shovelnose dogfish	35	0.2	29	0.1	38	0.2	26	0.1	2	0.01
Lookdown dory	24	0.1	33	0.1	40	0.2	49	0.1	19	0.1
Ribaldo	27	0.1	39	0.1	33	0.1	26	0.1	8	0.03
Arrow squid	16	0.1	26	0.1	31	0.1	35	0.1	24	0.1
Gemfish	9	0.0	6	0.0	27	0.1	6	0.02	10	0.03
Smooth skate	11	0.1	22	0.1	26	0.1	21	0.1	18	0.1
Stargazer	14	0.1	23	0.1	25	0.1	15	0.04	5	0.02
Others	555	2.5	485	1.7	305	1.3	510	1.4	285	1.0

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 2005b, Smith & Baird 2009, Thompson & Abraham 2010a, Baird 2011). The numbers captured have been declining since 1998–99 and the capture rate has also been declining, with the lowest capture rates over the last four years (Table 7). Captures occur mostly in Cook Strait (54%), off the west coast South Island (24%), and east coast South Island, including the western Chatham Rise (15%) (Table 8). Estimated captures of New Zealand fur seals in the hoki fishery have accounted for about half of all fur seals estimated to have been 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 targeting species other than hoki could not be included in the models.

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 2012–13. 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 available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and preliminary data for 2012–13 are based on data version 20140131.

		Observed					Estimated		
	Tows	No. obs	% obs	Captures	Rate		Mean	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		636	352–1 142	100.0
2003–04	22 523	2 346	10.4	49	2.09		750	398–1 376	100.0
2004–05	14 545	2 131	14.7	120	5.63		797	422–1 504	100.0
2005–06	11 590	1 775	15.3	62	3.49		452	217–938	100.0
2006–07	10 602	1 758	16.6	29	1.65		269	121–567	100.0
2007–08	8 788	1 879	21.4	58	3.09		323	163–677	100.0
2008–09	8 174	1 660	20.3	37	2.23		217	99–470	100.0
2009–10	9 965	2 066	20.7	30	1.45		179	88–366	100.0
2010–11	10 404	1 724	16.6	24	1.39		180	84–375	100.0
2011–12	11 333	2 579	22.8	33	1.28		213	101–448	100.0
2012–13	11 682	4 515	38.7	58	1.28		242	114-534	100.0

Table 8: Model estimates (means) of the number of NZ fur seal captures in hoki trawl fisheries by area, 2002–03 to 2011–12. Data version 20130304. Model estimates for 2012–13 were not available at the time of publication.

	Cook	WCSI	ECSI	Fiordland	Stewart-Snares	Chatham Rise	Sub-Antarctic	Total
2002–03	263	162	91	23	19	12	27	597
2003–04	354	191	109	10	17	11	8	700
2004–05	384	203	94	30	26	11	8	756
2005–06	230	108	55	10	12	5	0	420
2006–07	155	33	42	1	17	3	0	251
2007–08	190	45	58	0	7	3	2	305
2008–09	139	24	27	0	9	1	0	200
2009–10	103	29	28	0	11	2	1	174
2010–11	95	43	23	1	6	1	1	170
2011–12	114	52	25	1	5	2	0	199

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, the highest recorded rate in the last 15 years being 0.05 sea lions per 100 tows and with a total of only five animals observed captured since 1998–99 (Table 9, MPI 2103). All observed captures have been close to the Auckland Islands or nearby on the Stewart-Snares shelf.

Table 9: Number of tows by fishing year and observed NZ sea lion captures in hoki trawl fisheries, 1998–99 to 2012–13. 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 available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and preliminary data for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated 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	0–6	100.0
2003–04	22 521	2 346	10.4	0	0.00	2	0–5	100.0
2004–05	14 540	2 131	14.7	0	0.00	1	0–4	100.0
2005–06	11 590	1 775	15.3	0	0.00	0	0–2	100.0
2006–07	10 607	1 758	16.6	0	0.00	0	0–2	100.0
2007–08	8 787	1 877	21.4	1	0.05	1	1–2	100.0
2008–09	8 176	1 662	20.3	0	0.00	0	0–2	100.0
2009–10	9 967	2 066	20.7	0	0.00	0	0–2	100.0
2010–11	10 402	1 724	16.6	0	0.00	0	0–2	100.0
2011–12	11 332	2 579	22.8	0	0.00	0	0–2	100.0
2012–13†	11 678	4 515	38.7	1	0.02	1	1–3	100.0

† Model estimates were not available for the most recent year at the time of publication.

Seabird interactions

Vessels targeting hoki incidentally catch seabirds, with information on observed captures summarised for 1998–99 to 2002–03 by Baird (2005a), for 2003–04 to 2005–06 by Baird & Smith (2007, 2008) and for 1989–90 to 2008–09 by Abraham & Thompson (2011).

In the 2011–12 fishing year there were 61 observed captures of birds in hoki trawl fisheries. In the same year it was estimated by a statistical model that there were a total of 265 (95% c.i. 207–347) captures in hoki trawl fisheries (Table 10). Annual observed seabird capture rates have ranged between 1.31 and 8.34 per 100 tows in the hoki fishery over the time period 1998–99 and 2012–13, with a slight downward trend over time. 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 2.16 birds per 100 tows, a low rate relative to other New Zealand trawl fisheries, e.g. for scampi (5.57 birds per 100 tows) and squid (13.78 birds per 100 tows) over the same years. The hoki fishery accounted for about 13% of seabird captures in the trawl fisheries modelled by Abraham et al (2013) from v20130304.

Table 10: Number of tows by fishing year and observed and model-estimated total seabird captures in hoki trawl fisheries, 1998–99 to 2012–13. 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 2011–12 are based on data version 20130304 and preliminary estimates for 2012–13 are based on data version 20140131.

		Observed				Estimated	
	Tows	No. obs	% obs	Captures	Rate	95% c.i.	% inc.
1998–99	32 242	3 558	11.0	133	3.74	950–1374	100.0
1999–00	33 061	3 273	9.9	91	2.78	821–1199	100.0
2000–01	32 018	3 549	11.1	296	8.34	1803–2348	100.0
2001–02	27 224	3 274	12.0	50	1.53	941–1358	100.0
2002–03	27 786	2 593	9.3	85	3.28	478–892	100.0
2003–04	22 523	2 346	10.4	33	1.41	254–433	100.0
2004–05	14 545	2 131	14.7	46	2.16	282–505	100.0
2005–06	11 590	1 775	15.3	54	3.04	232–580	100.0
2006–07	10 602	1 758	16.6	23	1.31	120–238	100.0
2007–08	8 788	1 879	21.4	28	1.49	105–191	100.0
2008–09	8 174	1 660	20.3	37	2.23	140–247	100.0
2009–10	9 965	2 066	20.7	53	2.57	158–247	100.0
2010–11	10 404	1 724	16.6	54	2.90	207-371	100.0
2011–12	11 333	2 579	22.8	61	2.29	194-307	100.0
2012–13†	11 682	4 515	38.6	96	2.13	215-333	100.0

† Provisional data, model estimates for the most recent year were not available at the time of publication.

Observed seabird captures since 2002–03 have been dominated by six species: Salvin's, southern Buller's, and NZ white-capped albatrosses make up 39%, 28%, and 25% of the albatrosses captured, respectively; and sooty shearwaters, white-chinned petrels, and cape petrels make up 58%, 16%, and 12% of other birds, respectively (Table 11). The highest proportions of captures have been observed off the east coast of the South Island (39%), off the west coast of the South Island (19%), on the Chatham Rise (16%), and on the Stewart-Snares shelf (15%). 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 (Department of Internal Affairs, 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being "paired streamer lines", "bird baffler" or "warp deflector" as defined in the notice). 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 11: Number of observed seabird captures in hoki trawl fisheries, 2002–03 to 2012–13, 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 20140131.

Albatrosses	Risk Ratio	Auckland Islands	Chatham Rise	Cook Strait	ECSI	Fiordland	Stewart Snares Shelf	Sub-Antarctic	WCSI	Total
Salvin's	V. high	0	50	8	40	0	3	1	0	102
Southern Buller's	V. high	0	5	0	7	9	14	0	38	73
NZ white capped	V. high	0	4	3	6	4	22	1	25	65
Southern royal	Medium	0	0	0	1	0	0	0	0	1
Campbell black-browed	Medium	0	0	0	2	0	0	0	7	9
Unidentified	N/A	0	1	1	6	0	2	1	0	11
Total albatrosses	**N/A**	**0**	**60**	**12**	**62**	**13**	**41**	**3**	**70**	**261**
Other birds										
Flesh footed shearwater	V. high	0	0	0	1	0	0	0	0	1
Cape petrel	High	0	3	8	4	6	3	0	15	39
Westland petrel	Medium	0	2	1	0	0	0	0	12	15
Northern giant petrel	Medium	0	0	0	1	0	0	0	2	3
White-chinned petrel	Medium	1	13	3	17	2	12	1	0	49
Grey petrel	Medium	0	0	0	0	0	1	1	0	2
Sooty shearwater	V. low	0	8	1	133	6	27	0	0	175
Black-bellied storm petrel	-	0	0	0	0	0	1	0	0	1
Common diving petrel	-	0	0	0	0	3	1	0	0	4
Fairy prion	-	0	0	0	1	0	0	0	3	4
Grey-backed storm petrel	-	0	0	0	0	0	1	0	0	1
Unidentified seabird	N/A	0	2	0	1	0	0	0	6	9
Total other birds	**N/A**	**1**	**28**	**13**	**158**	**17**	**46**	**2**	**38**	**303**
All birds total	**N/A**	**1**	**88**	**25**	**220**	**30**	**87**	**5**	**108**	**564**

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

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 that 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 of 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 trawling 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 trawls 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 13). 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 but is now likely to increase again with increases in TACCs in recent years. 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 about 90% since the peak in 1997 and bottom trawling by about 70% since the peak in 2000 (Table 13).

Table 12: Number of tows (data version 20140131), 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. Data for 2012–13 is provisional and is from v20140131.

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	27 785	2 593	9.3	5
2004–04	22 535	2 346	10.4	2
2004–05	14 543	2 131	14.7	8
2005–06	11 590	1 775	15.3	0
2006–07	10 607	1 758	16.6	0
2007–08	8 786	1 877	21.3	1
2008–09	8 176	1 662	20.3	0
2009–10	9 966	2 066	20.7	0
2010–11	10 405	1 724	16.6	0
2011–12	11 332	2 579	22.8	1
2012–13	11 680	4 517	38.7	3

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/Puysegur**		**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											
1989–90	7 849	1 188	1 087	21	36	2 111	30	2 027	9 002	5 347	37
1990–91	7 354	1 679	2 229	21	81	3 927	954	3 490	10 618	9 117	46
1991–92	5 628	1 579	1 776	14	115	5 441	441	5 556	7 960	12 590	61
1992–93	5 490	1 861	1 583	22	442	4 913	1 057	5 269	8 572	12 065	58
1993–94	8 012	1 638	1 867	153	562	2 039	1 338	3 449	11 779	7 279	38
1994–95	7 225	1 505	2 030	255	419	2 328	2 175	6 262	11 849	10 350	47
1995–96	5 715	2 017	3 198	1 368	415	2 504	2 302	7 920	11 630	13 809	54
1996–97	7 563	1 890	3 561	1 335	334	3 421	2 342	9 303	13 800	15 949	54
1997–98	6 968	1 541	2 402	666	165	4 372	3 782	11 448	13 317	18 027	58
1998–99	5 477	2 118	2 033	635	419	3 659	2 424	11 439	10 353	17 851	63
1999–00	5 470	2 275	1 944	380	511	5 944	2 696	9 493	10 621	18 092	63
2000–01	6 228	2 577	1 968	170	667	5 448	912	9 862	9 775	18 057	65
2001–02	4 988	3 095	1 136	138	132	6 449	858	7 820	7 114	17 502	71
2002–03	4 615	2 977	2 117	167	96	4 407	496	9 278	7 324	16 829	70
2003–04	4 274	1 887	1 812	267	78	3 023	385	7 225	6 549	12 402	65
2004–05	2 534	1 308	1 457	74	68	1 428	340	4 996	4 399	7 806	64
2005–06	1 783	1 508	1 020	88	74	721	140	4 822	3 017	7 139	70
2006–07	1 147	752	919	35	25	1 194	57	4 769	2 148	6 750	76
2007–08	813	492	393	281	36	925	75	4 203	1 317	5 901	82
2008–09	689	354	747	267	38	927	11	3 914	1 485	5 462	79
2009–10	1 182	612	797	70	56	1 251	116	4 361	2 151	6 294	75
2010–11	1 581	912	489	63	62	1 245	52	4 075	2 184	6 295	74
2011–12	1 660	1 188	836	81	70	1 202	74	4 397	2 640	6 868	72
2012–13	2 662	1 032	1 045	71	6	1 373	169	4 175	3 882	6 651	60
2013–14	2 327	1 110	1 029	40	12	1 872	133	4 016	3 501	7 038	67

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 et al 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 2013 (MPI 2013).

5.5 Other factors

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 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 2011).

6. STOCK ASSESSMENT

A new stock assessment was carried out in 2015 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 a trawl 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 2014 assessment (McKenzie 2015b).

6.1 Methods

Model structure

The model partitioned the population into two sexes, 17 age groups (1 to 16 and a plus group, 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)]. It is assumed that the adult fish of the two stocks do not mix: those from the W stock spawn off the 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 there are no direct observations of maturity to use in the model but information about proportion spawning is available (there are two April/May observations on SA of proportions of females that will spawn that year).

The model's annual cycle divided the fishing year into five time steps and includes four types of migration (Table 14). The first type of migration 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 (and given the labels in the model of Ensp1, Ensp2, Wnsp1, Wnsp2).

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 occurred 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 was treated as being of age 2.25 in that time step. etc. The last column ("Prop. mort.") shows the proportion of that time step's total mortality that was assumed to have taken place when each observation is made.

					Observations	
Step	Approx. months	Processes	*M* fraction	Age fraction	Label	Prop. 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 Southern Plateau in December 2014 (Bagley et al 2015). The age data used in the assessment (Table 16) are similar to those used in 2014, but with an additional year's 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 2015a, Francis 2011). An arbitrary CV of 0.25 (as used by Cordue 2001) was assumed for the proportion spawning observations.

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	225
2008	-	46	-	77	179
2009	-	47	-	144	359
2010	-	65	-	98	-
2011	-	-	-	94	298
2012	412	46	-	88	-
2013	357	56	-	124	353
2014	-	-	-	102	-
2015	-	31*	-	-	-

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). Espage for 2011, 2012, 2013 were omitted for model runs.

Area	Label	Data type	Years	Source of age data
WC	Wspage	Catch at age	1988–14*	Otoliths
SA	WnspOLF	Catch at age	1992–94, 96, 99–00	OLF
	Wnspage	Catch at age	2001–04, 06–14*	Otoliths
	SAsumage	Trawl survey	1992–94, 2001–10, 2012–13, 15*	Otoliths
	SAautage	Trawl survey	1992, 96, 98	Otoliths
	pspawn	Proportion spawning	1992, 93, 98	Otoliths
CS	Espage	Catch at age	1988–14*	Otoliths
CR	EnspOLF	Catch at age	1992, 94, 96, 98	OLF
	Enspage	Catch at age	1999–14*	Otoliths
	CRsumage	Trawl survey	1992–14	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 added 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 included only the uncertainty associated with between-transect (and within-stratum) variation in total backscatter. In some model runs only the observation-error rather than the total CVs for all trawl survey biomass indices was used 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	2014			
Total	0.23	0.23	0.22	0.23	0.23	0.25	0.24	0.22	0.25	0.22			
Observation	0.12	0.11	0.08	0.11	0.11	0.15	0.14	0.10	0.15	0.10			
SAsumbio	1992	1993	1994	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
SAsumbio	2012	2013	2015										
Total	0.25	0.25	0.24										
Observation	0.15	0.15	0.13										
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	2013								
Total	0.46	0.30	0.39	0.35	0.30								
Observation	0.26	0.06	0.13	0.14	0.15								
WCacous	1988	1989	1990	1991	1992	1993	1997	2000	2012	2013			
Total	0.60	0.38	0.40	0.73	0.49	0.38	0.60	0.28	0.34	0.35			
Observation	0.22	0.15	0.06	0.14	0.14	0.07	0.10	0.14	0.15	0.13			

The observation CVs for the otolith-based, at-age data were calculated by a bootstrap procedure, which included an 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 observation-errors, which were forced to be higher than those from the spawning fisheries (Francis 2004b).

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 in the model according to area and month (Table 19). 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) was the same as that used in the 2014 assessment, so the catches used in the model (Table 20) are unchanged, except for minor revisions to years 2001 to 2014 (including removing catches taken outside the New Zealand EEZ).

Table 19: The division of annual catches by area and months into the six model fisheries (Esp, Wsp, Ensp1, Ensp2, Wnsp1, and Wnsp1). The small amount of catch reported in the areas west coast North Island and Challenger, typically about 100 t per year, has been distributed pro-rata across all fisheries).

Fishery	Model fishery	Areas	Months
Western spawning fishery	Wsp	West Coast South Island & Puysegur	October–September
Western non-spawning fishery 1	Wnsp 1	Southern Plateau	October–March
Western non-spawning fishery 2	Wnsp 2	Southern Plateau	April–September
Eastern spawning fishery	Esp	Cook Strait & Pegasus Canyon	June–September
Eastern non-spawning fishery 1	Ensp 1	Cook Strait & Pegasus Canyon Chatham Rise, East Coast South Island, East Coast North Island & null[1]	October–March
Eastern non-spawning fishery 2	Ensp 2	Cook Strait & Pegasus Canyon Chatham Rise East Coast South Island East Coast North Island null[1]	April–May April–September

[1] catch reported to no area.

For the 2013–14 year, the TACC was 150 000 t with a catch limit arrangement for 60 000 t to be taken from the eastern fisheries and 90 000 t from the western fisheries (this limit was not met by 3 800 t for the eastern fisheries, and exceeded by 100 t for the western fisheries). For 2014–15 year, the TACC was 160 000 t with a catch limit arrangement for 60 000 t to be taken from the eastern fisheries and 100 000 t from the western fisheries. It was estimated by industry representatives that the 100 000 t catch limit for the 2014–2015 western fishery would be split: 22 000 t (non-spawning), 78 000 t (spawning). In the stock assessment model the non-spawning fishery was split into two parts, separated by the migration of fish from the Chatham Rise to the Southern Plateau. The same proportions as in 2014 were used to split the western non-spawning catch into two parts. For the eastern stock, the catch split for 2014–15 was estimated as 41 500 t (non-spawning), 18 500 t (spawning). As with the western stock, the non-spawning catch was split into two parts, using the same proportions as in 2014.

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). For example, the YCS for 1970, was for fish spawned in the winter of 1970, that first arrived in the model in area CR, at age 1.6 y, in about December 1971, which was in model year 1972. Associated with B_0 was an estimated mean recruitment, R_0, which was used, together with a Beverton-Holt stock-recruit function and the YCSs, to calculate the recruitment in each year. The first five YCSs (for years 1970 to 1974) were set equal to 1 (because of the lack of at-age data for the early years), but all remaining YCSs (for 1975 to 2013) were estimated. The model corrects for bias in estimated YCSs arising from ageing error. YCSs were constrained to average to 1 over the years 1975 to 2010, so that R_0 may be thought of as the average recruitment over that period. R_0 and a set of YCSs were estimated separately for each stock. The B_0 for each stock was calculated as the spawning biomass that would occur given no fishing and constant recruitment, R_0, and the initial biomass before fishing (B_{INIT}) was set equal to B_0. The steepness of the stock-recruitment relationship was assumed fixed at 0.75 (Francis 2009).

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

The model used six selectivity ogives (four for the eastern and western spawning and non-spawning fisheries and one each for the trawl surveys in areas CR and SA) and three migration ogives (Whome, Espmg, and Wspmg).

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

Prior distributions were assumed for all parameters. The main priors used are shown in Table 21. In addition, bounds were imposed for parameters with non-uniform distributions. For the catchability parameters, these were calculated by O'Driscoll et al (2002) (who called them overall bounds); for other parameters, they were set at the 0.001 and 0.999 quantiles of their distributions. Prior distributions for all other parameters were 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

	Fishery						
Year	Ensp1	Ensp2	Wnsp1	Wnsp2	Esp	Wsp	Total
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	14 300	19 500	39 000	105 600	242 000
2001	36 200	19 700	13 200	16 900	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

Table 20 [continued]

	Fishery						
Year	Ensp1	Ensp2	Wnsp1	Wnsp2	Esp	Wsp	Total
2006	23 100	14 400	2 300	4 700	20 100	39 700	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	28 400	14 700	9 100	6 600	15 400	55 800	130 000
2013	29 900	11 800	6 500	7 600	18 600	57 200	131 600
2014	27 200	11 700	10 600	9 300	17 300	70 200	146 300
2015	29 000	12 500	10 000	12 000	18 500	78 000	160 000

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_B0_total	log($B_{0,E}$ + $B_{0,W}$)	uniform	11.6	16.2	
pE (= B0_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	Francis (2004a)
recruitment[W].YCS	year-class strengths (W)	lognormal	1	0.95	Francis (2004a)
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 $mU_{f,\mathrm{current}}$, where $U_{f,\mathrm{current}}$ 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 $m_{x\%}U_{\mathrm{current}}$, 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, the closeness of B_{MSY} to the soft limit permits the limit to be breached too easily and too frequently, given, for example, a limited period of low recruitment. 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 2015c). In the 2008 assessment, the model was unable to fit the threefold increase in estimated biomass between the 2007 and 2008 trawl 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), but the biomass declined substantially in 2015. Furthermore, the SAsumbio survey 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 conducted in which it was assumed that the catchability has changed over time.

In an alternative approach to try to improve the fit to the SAsumbio series, the trawl survey data was upweighted in a sensitivity run.

Final runs

The DWFAWG chose four model runs to investigate, which were similar to the three final runs of 2014 assessment. The four runs consisted of a constant catchability (single *q*) model for the SAsumbio series (1.1), a variation on this with the trawl surveys upweighted (1.2), and two runs with *q*s that varied over different periods: a 2004–07 variable-q model (1.3) and a 2008–15 variable-q model (1.4). The models where the trawl surveys were not upweighted (1.1, 1.3, and 1.4) showed acceptably good fits to the data and broadly similar trends in biomass and stock status. Compared to the other models, the model with the trawl surveys upweighted gave a much reduced estimate of current western biomass.

Following exploration of these four models, the DWFAWG selected the single-*q* model (1.1) as the base case. This choice was based largely on the fit to the data, and the expectation that a run of four low biomass estimates from a survey time-series is not unexpected statistically (Cordue 2014). Results of both of the variable-*q* models are presented as sensitivities to the base case, as is the upweighted trawl survey model. Results from other sensitivities to the base case are described and presented below.

For the 2014 base model 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. Also, natal fidelity was assumed, and the trawl survey data were not upweighted. In the base model of the 2015 assessment, these model features were kept, and the model updated with the new data. There are some differences between the 2014 and 2015 assessments in the way the Bayesian runs are conducted. For the 2014 assessment, the migration and selectivity parameters that hit bounds in the MPD fits were set at these bounds for the Bayesian runs; whereas for the 2015 assessment they are not set at the bounds. In the 2014 assessment catchability parameters were estimated as nuisance parameters, but are estimated as free parameters for the 2015 assessment.

Other sensitivity model runs were carried out to the base model run (Table 22). These tested the sensitivity of model 1.1 to assumptions about natal fidelity but still assuming adult fidelity (1.5), and domed spawning selectivity (1.6).

Table 22: Distinguishing characteristics for all model runs, including all sensitivities to the base run 1.1.

Run	Main assumptions
1.1 - base case	natal fidelity *M* is age-dependent single q for Southern Plateau trawl series trawl surveys are not upweighted
1.2	as 1.1 but the trawl surveys are upweighted
1.3 - 2004–07 two-*q*	as 1.1 but with a different q for 2004-07
1.4 - 2008–15 two-*q*	as 1.1 but with a different q for 2008-15
1.5	as 1.1 but natal fidelity is not assumed
1.6	as 1.1 but domed spawning selectivity (instead of *M* age-dependent)

Bayesian posterior distributions were estimated for each of these runs using a Markov Chain Monte Carlo (MCMC) approach (McKenzie 2015d & e). For each run, three chains of length four million were completed, the initial 500 000 samples of each chain was discarded, and the remaining samples were concatenated and thinned to produce a posterior sample of size 2000.

Model estimates are presented for the spawning stock biomass (Table 23), biomass trajectories and year-class strengths (Figure 2), and current biomass distributions (Figure 3). Compared to the base case (1.1), upweighting the trawl surveys results in the same current biomass for the E stock (%B_0), whereas for the W stock the %B_0 is much lower. Allowing two catchabilities results in the same current status of the E stock (%B_0), whereas for the W stock, the %B_0 is either higher (1.3) or lower (1.4). The other sensitivities give higher %B_0 for the stock estimates, except for the E stock when natal fidelity is not assumed (1.5).

Table 23: Estimates of spawning biomass for the base case* and sensitivities (median of marginal posteriors, with 95% confidence intervals in parentheses). $B_{current}$ is the spawning biomass in mid-season 2014–15. The base case 1.1 estimates a single catchability for SAsumbio, runs 1.3 and 1.4 estimate two catchabilities. All other sensitivities are conducted against the base case 1.1– see table 22.

	B_0(‘000 t)		$B_{current}$(‘000 t)		$B_{current}$(%B_0)		
Run	E	W	E	W	E	W	E+W
1.1*	540(446,674)	897(758,1126)	322(213,476)	459(286,735)	59(43,78)	51(36,69)	55(43,67)
1.2	517(425,636)	773(686,887)	313(221,426)	230(150,337)	60(48,74)	30(20,40)	42(35,50)
1.3	563(461,707)	978(804,1258)	343(225,519)	537(319,838)	60(45,80)	55(38,71)	57(45,70)
1.4	556(450,693)	890(746,1133)	336(226,515)	372(197,646)	61(45,81)	42(25,61)	49(38,63)
1.5	711(539,943)	1011(844,1268)	364(207,599)	584(360,956)	51(33,71)	58(40,82)	55(44,71)
1.6	629(443,882)	976(767,1293)	383(239,607)	618(393,963)	61(45,82)	63(47,81)	63(51,76)

In the base case model (Run1.1), where constant catchability is assumed for all years, the observation of low biomass in the November 2014 Southern Plateau trawl survey was interpreted as observation error (i.e. the survey underestimated the biomass by chance). If the low biomass is real, the implication is that the western stock status is much lower (30%). In run 1.2 the trawl survey indices are upweighted relative to other data by removing the process error of 20%. The lower stock status also resulted in more pessimistic projections shown in Table 24, with the probability of the western stock going below 20% B_0 reaching 0.34 in 2020. The WG noted that the next scheduled Southern Plateau trawl survey is in November 2016, although the hoki stock assessment will be updated with other sources of data in 2016.

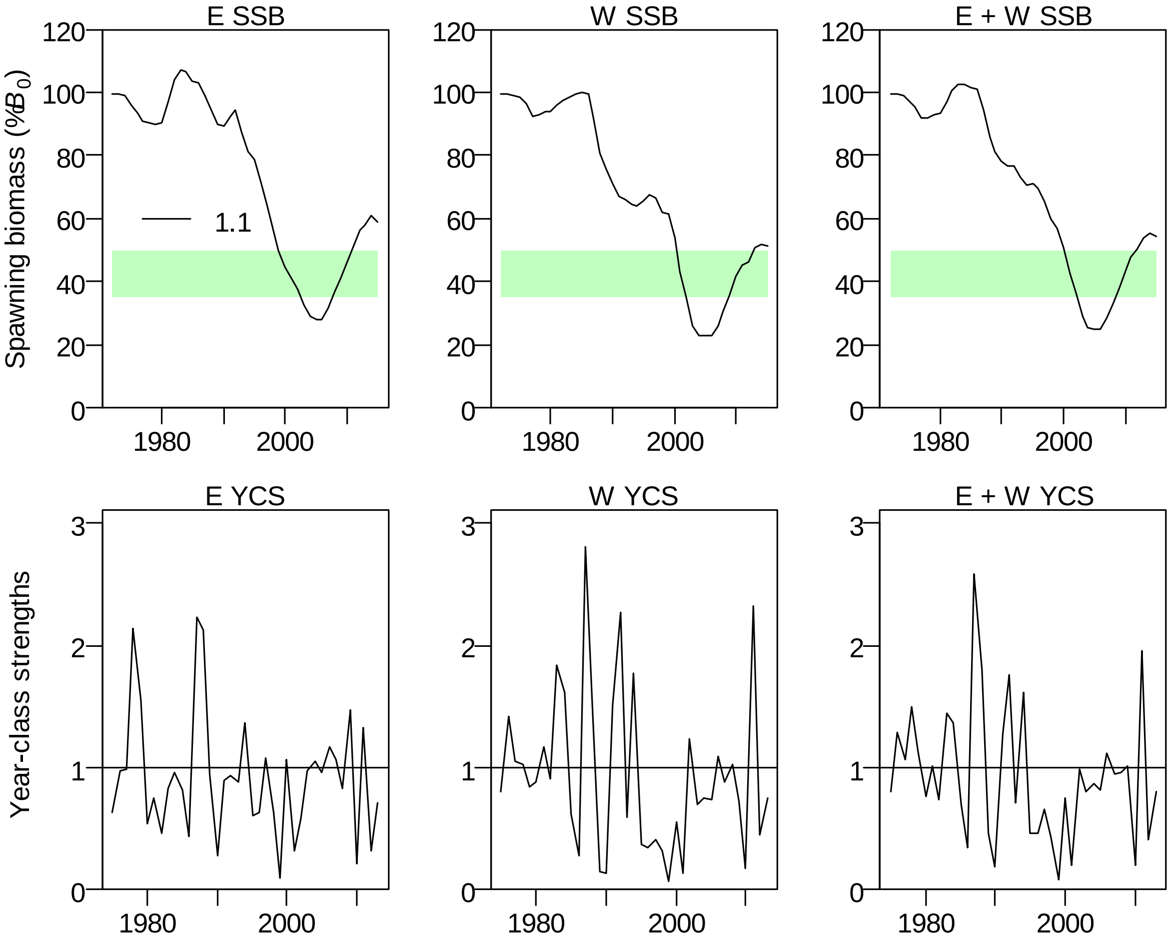


Figure 2: Estimated spawning biomass trajectories (SSB, upper panels) and year-class strengths (YCS, lower panels) for the E (left panels), W (middle panels) and E + W stocks (right panels) from the base case run 1.1. Plotted values are medians of marginal posterior distributions. Years are fishing years (1990 = 1989–90). The shaded green region represents the target zone of 35–50% B_0.

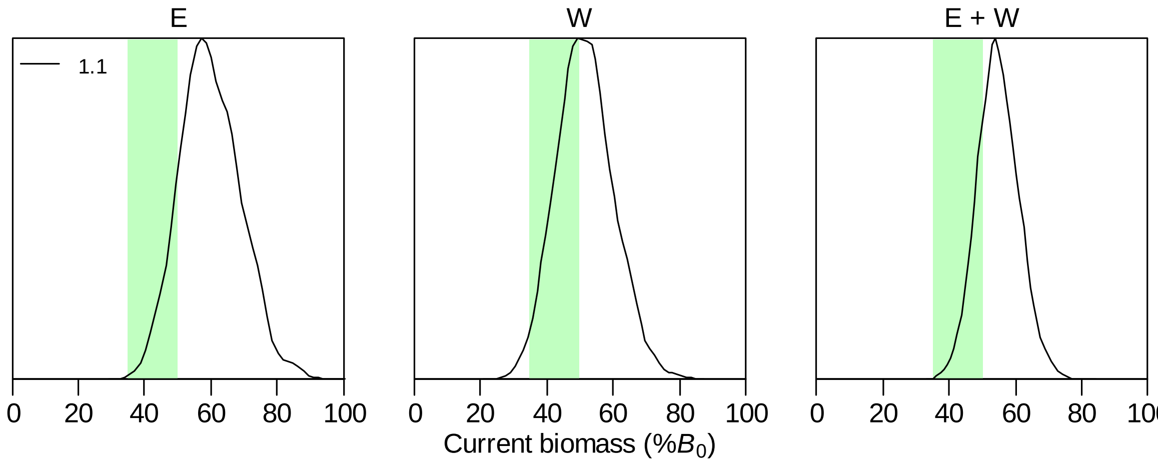


Figure 3: Estimated posterior distributions of current (spawning) biomass ($B_{2013\text{-}14}$) expressed as %B_0 for the E (left panel), W (middle panel), and E + W (right panel) from the base case run 1.1. The shaded green region represents the target zone of 35–50% B_0.

The base run (1.1) shows that the biomasses of both stocks were at their lowest points in about 2004–06 (at about 30% B_0 for the E stock and 25% B_0 for the W stock), are continuing to increase, and that the W stock experienced seven consecutive years of poor recruitment from 1995 to 2001 inclusive (Figure 2). During the period of poor recruitment to the W stock, the E stock showed below average recruitment but not as poor as that seen for the W stock (Figure 2). Recruitment to the W stock following the 1995–2001 period of poor recruitment was estimated to have been just below average for 2002–2009, below average in 2010 and 2012 and 2013, and well above average in 2011.

In the 2014 assessment base case there was a 1.00 probability that the stock was above 35% B_0, whereas the probability for 2015 is 0.98 for the base case (1.1). Based on the 2015 assessment, the Harvest Strategy Standard defines that the western stock has been fully rebuilt (i.e. at least a 70% probability of being above the lower bound of the management target of 35% B_0) for at least three years.

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 the base run (1.1) estimates of deterministic B_{MSY} were 25% for the E stock and 26% for the W stock.

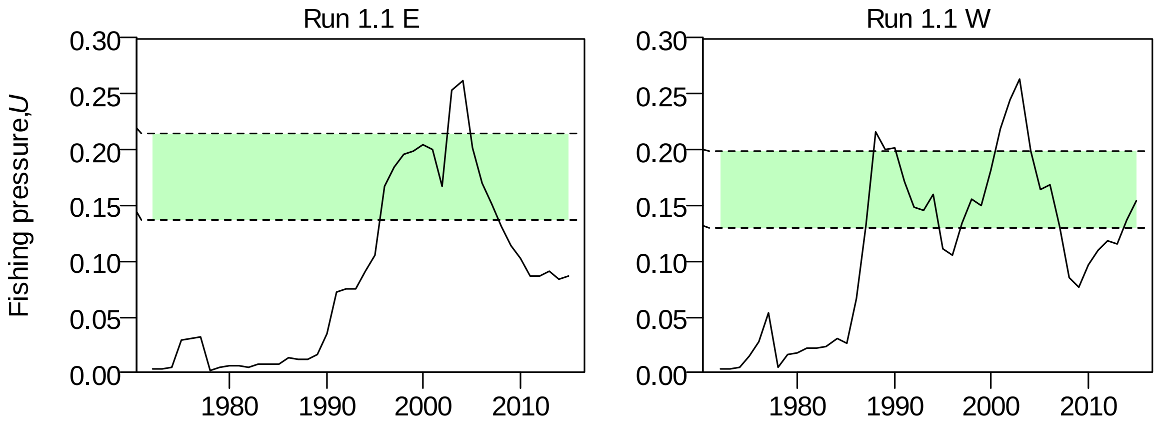


Figure 4: Base case fishing intensity, U (from MPDs), plotted by stock. Also shown (as broken lines) are the reference levels $U_{35\%Bo}$ (upper line) and $U_{50\%Bo}$ (lower line), which are the fishing intensities that would cause the spawning biomass to tend to 35% B_0 and 50% B_0, respectively (with the associated management range shaded in green).

6.3 Projections

Five-year projections were carried out for two models: the base model with a single catchability for the SAsumbio series (1.1), and the model where the trawl surveys are upweighted (1.2).

In all projections, future recruitments were selected at random from those estimated for 2004–2013, and the future catches in each fishery were assumed to be the same as for 2015 (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 remain flat or decline slightly over the next 5 years (Figure 5).

The probabilities of the current (2015) and projected spawning stock biomass being below the hard limit of 10% B_0, the soft limit of 20% B_0, and the lower and upper ends of the interim management target range of 35–50% B_0 are presented in Table 24 for the case where future catches remain at 2015 levels. The probability of either stock being less than either the soft or the hard limit over the five year projection period is negligible for the E stock, but 0.34 or less for the W stock when trawl surveys are upweighted (run 1.2). Both stocks are projected to be within or above the 35–50% B_0 target range at the end of the projection period, except for the W stock when trawl surveys are upweighted.

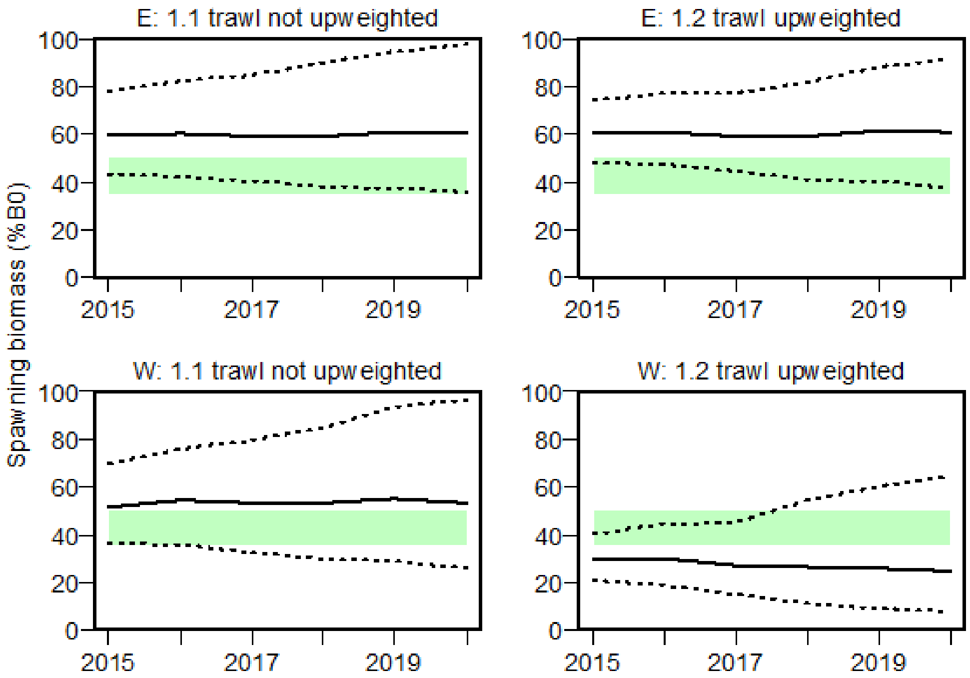


Figure 5: Projected spawning biomass (as %B_0): median (solid lines) and 95% confidence intervals (broken lines) for the base case (1.1) and a sensitivity with the trawl surveys upweighted (1.2). The shaded green region represents the target management range of 35–50% B_0.

Table 24: Probabilities (to two decimal places) associated with projections for SSB (%B_0) for the base case (1.1) and a sensitivity with the trawl surveys upweighted (1.2) for 2015 through to 2020.

	2015	2016	2017	2018	2019	2020
EAST 1.1						
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	0.01	0.01	0.01	0.02
P (SSB<50%B_0)	0.13	0.15	0.20	0.23	0.22	0.24
EAST 1.2						
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	0	0	0.01
P (SSB<50%B_0)	0.04	0.06	0.12	0.18	0.16	0.20
WEST 1.1						
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	0.02	0.04	0.06	0.07	0.11
P (SSB<50%B_0)	0.44	0.34	0.39	0.41	0.38	0.43
WEST 1.2						
P (SSB<10%B_0)	0	0	0	0.01	0.04	0.07
P (SSB<20%B_0)	0.02	0.05	0.15	0.24	0.29	0.34
P (SSB<35%B_0)	0.84	0.78	0.83	0.8	0.77	0.77
P (SSB<50%B_0)	1.00	1.00	0.99	0.96	0.94	0.92

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 simultaneously spawning takes place (Cook Strait and the WCSI), and observed and inferred migration patterns of adults and juveniles:

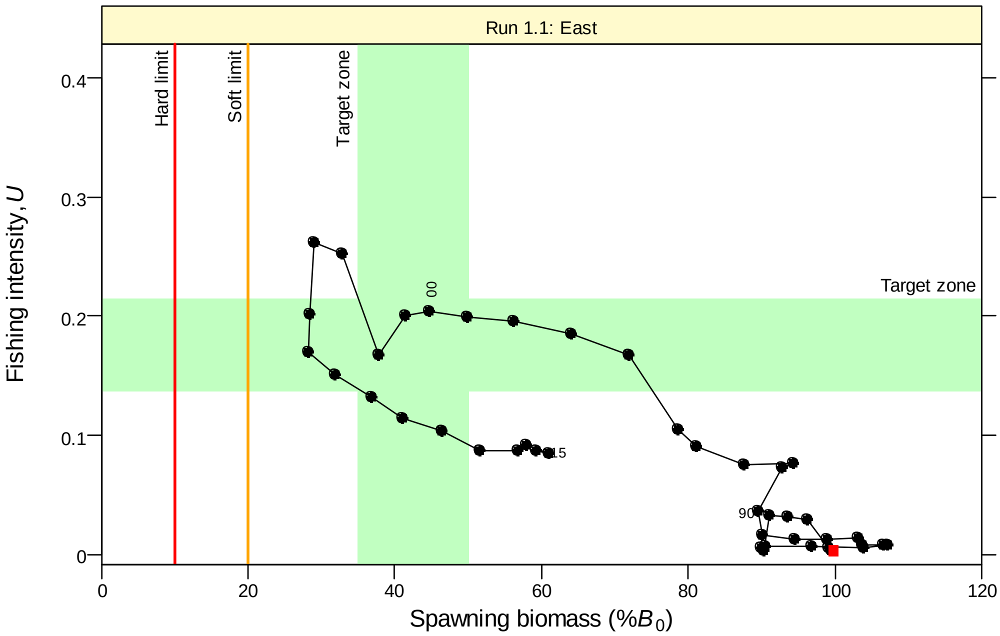
- Adults of the western stock occur on the west coast of the North and South Islands and the area south of New Zealand including Puysegur, Snares and the Southern Plateau;
- Adults of the eastern stock occur on the east coast of the South Island, Cook Strait and the ECNI up to North Cape;
- Juveniles 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	2015
Assessment Runs Presented	A base run used to evaluate hoki stock status: run 1.1
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_{2015} was estimated to be 59% B_0; Virtually Certain (> 99%) to be at or above the lower end of the target range and Likely (> 60%) to be at or above the upper end of the target range
Status in relation to Limits	B_{2015} 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 (% *B₀*), for the eastern hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2015 (15). The red vertical line at 10% B_0 represents the hard limit, the yellow line at 20% B_0 is the soft limit, and the shaded area represents the 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	Biomass has been stable for the last 4 years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been flat for the last 5 years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recent recruitment (2003–2009) is estimated by the model to be near the long-term average for this stock, but 2010 was well below average, 2011 about average and 2012 below average. The actual split of recruitment between the eastern and western stocks for these three year classes is uncertain.

Projections and Prognosis	
Stock Projections or Prognosis	If the year classes recruit to the eastern stock as estimated by the model, the biomass of the eastern hoki stock is expected to remain more or less constant over the next five years at assumed 2014–15 eastern 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: 2015	Next assessment: 2016
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	Catchabilities estimated as free instead of nuisance, MPD parameters not set at bounds (when they hit them) for Bayesian runs	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2011 year class between eastern and western stocks with respect to projections	

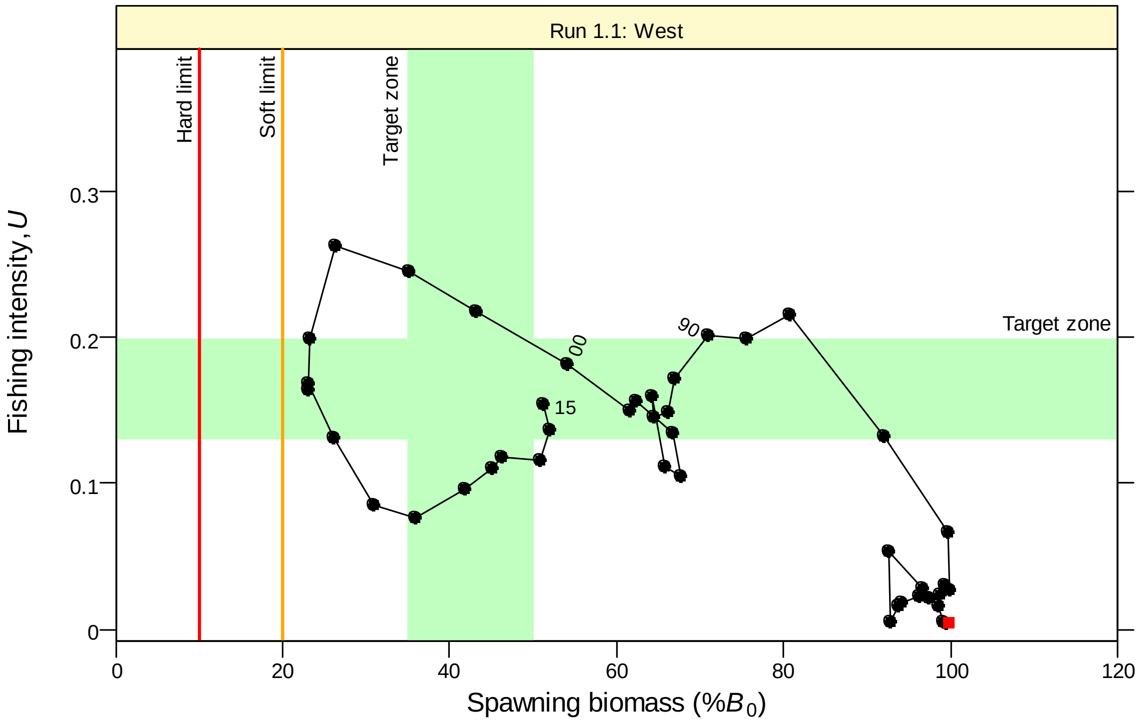
Qualifying Comments
-

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 captures or protected species are noted for New Zealand fur seals and seabirds.

Western Hoki Stock

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	A base run used to evaluate hoki stock status: run 1.1
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_{2015} was estimated to be 51% 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_{2015} is Exceptionally Unlikely (< 1%) to be below the Hard Limit and Very Unlikely (< 10%) to be below the Soft Limit
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity (*U*) and spawning biomass (% *B₀*), for the western hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2015 (15). The red vertical line at 10% B_0 represents the hard limit, that the yellow line at 20% B_0 is the soft limit, and the shaded area represents the 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	Biomass has been stable at about 50% B_0 for the last 3 years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is estimated to have decreased from 2003 to 2009, and to have increased since.
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 by the model 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, 2011 was well above average, and 2012 below average The actual split of recruitment between the eastern and western stocks for these three year classes is uncertain.

Projections and Prognosis	
Stock Projections or Prognosis	If the year classes recruit to the western stock as estimated by the model, the biomass of the western hoki stock is expected to to remain more or less constant over the next five years at assumed 2014–15 western fishery catch levels.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

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: 2015	Next assessment: 2016
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	- Catchabilities estimated as free instead of nuisance, MPD parameters not set at bounds (when they hit them) for Bayesian runs	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2011 year class between eastern and western stocks with respect to projections - Possible catchability changes in Southern Plateau trawl surveys	

Qualifying Comments
The low abundance index from the 2014 southern trawl survey is interpreted by the model as observation error. Run 1.2 shows the implications (low stock status) if the trawl survey index is reflecting an actual change in biomass.

Fishery Interactions
In the west coast South Island and 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 captures of protected species are noted for New Zealand fur seals and seabirds.

8. FOR FURTHER INFORMATION

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