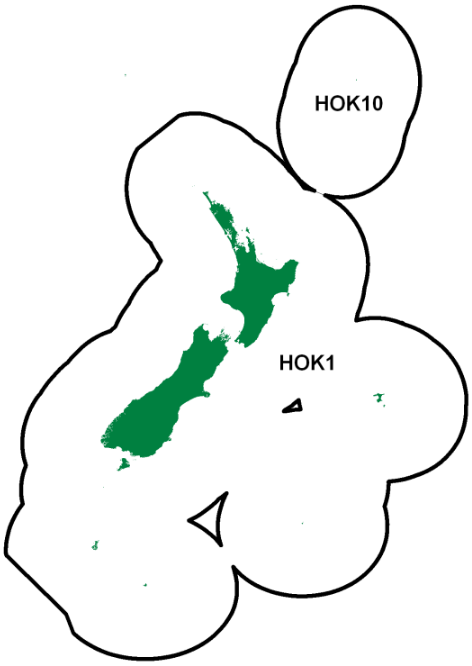
HOKI (HOK)

(*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 in the Sub-Antarctic. These fisheries usually operate in depths of 300–800 m. The Chatham Rise fishery generally has similar catches over all months except in July-September, when catches are lower due to the fishery moving to the spawning grounds. In the Sub-Antarctic, catches have typically peaked in April-June. Out-of-season catches are also taken from Cook Strait and the east coast of the North Island, but these are small by comparison.

The hoki fishery was developed by Japanese and Soviet vessels in the early 1970s. Catches peaked at 100 000 t in 1977, but dropped to less than 20 000 t in 1978 when the EEZ was declared and quota limits were introduced (Table 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, after 1991, the surimi component of catches decreased and processing to head and gut, or to fillet product increased, as did “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. No surimi has been produced from hoki since 2002. Since 1998 twin-trawl rigs have operated in some hoki fisheries, and trawls made of spectra twine (a high strength twine with reduced diameter resulting in reduced drag and improved fuel efficiencies) were introduced to some vessels in 2007–08. Since 2012–13, precision seafood harvest (PSH) technology has been tested in the hoki fishery. This is a prototype trawl system that aims to target specific species and fish size, as well as enabling fish to be landed in much better condition than traditional trawls. The use of PSH in the hoki fishery is moving towards becoming "routine" although use in high volume spawning aggregations is currently not viable.

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 2015–16. Reported catches are from the QMR and MHR systems. Estimated catches include TCEPR and CELR 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

Table 2: [Continued]

2011–2012	130 000	126 000	130 000
2012–2013	131 500	128 000	130 000
2013–2014	146 500	144 000	150 000
2014–2015	161 500	156 500	160 000
2015–2016	136 719	136 087	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 in five steps following increases in the TACC over the past five years as stock status has improved (Table 2). The TACC for 2015–16 was 150 000 t, reduced from the 160 000 t TACC in 2014–15 (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. This has been due to a combination of TAC changes and redistribution of fishing effort. The WCSI fishery accounted for about 50% of the total hoki catch in 2015–16, and has been the largest fishery in New Zealand for the six most recent years (Table 3). Cook Strait catches peaked at 67 000 t in 1995–96, but have been relatively stable in the range from 15 000 to 20 000 t in the past 10 years. The Chatham Rise was the largest hoki fishery from 2006–07 to 2009–10, but contributed only about 27% of the total catch in 2015–16. Catches from the Sub-Antarctic peaked at over 30 000 t from 1999–2000 to 2001–02, declined to a low of 6200 t in 2004–05 before increasing to 19 900 t in 2013–14, then decreasing again to 6600 t in 2015–16. Catches from other areas have remained at relatively low levels (Table 3).

Table 3: Estimated total catch (t) (scaled to reported QMR or MHR) of hoki by area 1988–89 to 2015–16 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 2015–16 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	Sub Antarctic	Chatham 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
2014–2015	78 700	1 900	20 100	3 600	16 400	40 100	800	-	161 500
2015–2016	68 900	1 100	18 400	4 100	6 600	36 700	900	-	136 700

From 1999–00 to 2001–02, there was a redistribution in catch from eastern stock areas (Chatham Rise, ECSI, ECNI, and Cook Strait) to western stock areas (WCSI, Puysegur, and Sub-Antarctic) (Table 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 western catch was further increased to 60 000 t in 2010–11 (within the overall TACC of 120 000 t), to 70 000 t in 2011–12 and 2012–13 (overall TACC of 130 000 t), to 90 000 t in 2013–14 and 2015–16 (overall TACC 150 000 t), and to 100 000 t in 2014–15 (overall TACC 160 000 t). The split between eastern and western catches has been within 2000 t of the management targets since 2011–12, except in 2014–15 where the eastern catch was 4600 t over the target, and in 2015–16 where the western catch was lower than the target total by 13 400 t. Figure 1 shows the reported landings and TACC for HOK 1, 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%
2014–2015	50%	15%	10%	25%
2015–2016	51%	16%	5%	28%

Total Allowable Commercial Catch (TACC) and area restrictions
In the 2015–16 fishing year, the TACC for HOK 1 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 1300 t and 20 t allowances for customary and recreational catch, the 2015–16 TAC was 151 529 t.

Vessels larger than 46 m in overall length may not fish inside the 12-mile Territorial Sea, and there are other 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 Benthic Protection Areas (BPAs) to bottom trawling and dredging, representing about 30% of the EEZ and including depths that are outside the depth range of hoki.

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.

2015–16 Hoki fishery
The overall catch of 136 719 t was 25 000 t lower than the catch in 2014–15 and about 13 000 t lower than the TACC (Table 3). Relative to 2014–15, catches in 2015–16 decreased in all areas except for the ECSI and ECNI.

The WCSI catch decreased by 10 000 t to 68 900 t in 2015–16. Catches from inside the 25 n. mile line made up 23% of the total WCSI catch in 2015–16, an increase in proportion from 2014–15, but still lower than the peak of 41% of the catch taken inside-the-line in 2003–04. The WCSI fishing season is now longer – with fishing in May (although most pre-June catch is from inside the 25 n. mile line). Unstandardised catch rates on the WCSI in 2015–16 decreased from 2014–15, with a median catch rate in all midwater tows targeting hoki of 5.0 t per hour. The WCSI catch in 2016 was dominated by fish from 60 to 110 cm from the 2006–12 year-classes (ages 4–10). The female hoki had two broad length modes, while males were strongly unimodal. The 2011 year class (age 5) made up the smaller female length mode and dominated the male length frequency. Few hoki less than 65 cm were caught on the WCSI. 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 was about even in 2016, with 57% females. 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 36 700 t in 2015–16, a decrease of 3400 t from 2014–15. Over 92% of the 2015–16 Chatham Rise catch was taken in bottom trawls, with the median unstandardised catch rate in bottom trawls targeting hoki of 1.2 t per hour. The length frequencies for both males and female hoki were bimodal and dominated by fish of 50–90 cm, with the small left-hand mode from 45–55 cm from the 2014 year-class (age 2+), and the stronger right-hand mode from the 2010 and 2011 year-classes (ages 4+ and 5+), with a few larger, older fish. About 27% of the catch by number was less than 65 cm in 2015–16. Females comprised 61% of the catch.

The catch from Cook Strait of 18 400 t was down by about 1900 t from that in 2014–15, and at a level similar to that in 2013–14. Peak catches were from mid-July to mid-September, with about 4100 t caught outside the spawning season, and PSH trawls accounting for 3000 t. Unstandardised catch rates in Cook Strait continued to be high - the median catch rate in midwater tows targeting hoki was 26.2 t per hour in 2015–16. The modal age was 5 (2011 year-class), and this year-class dominated the length and age frequencies, especially for males. Only 10% 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 then, with 57% males in the catch in 2015–16. 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 Sub-Antarctic of 6600 t in 2015–16 was about 10 000 t lower than in 2014–15 and the lowest since 2004–05. Most (86%) of the 2015–16 catch came from hoki target tows. Unstandardised catch rates in bottom trawls targeting hoki were only 0.3 t per hour in 2015–16. The length distribution of hoki from the Sub-Antarctic in 2015–16 was bimodal and similar for males and females. The catch was dominated by hoki of 40–55 cm from the 2014 year-class (age 1+), and fish from 58–90 cm from a broad range of ages primarily from ages 2–10. The proportion of the catch of fish less than 65 cm was similar to that on the Chatham Rise, at 28%. About 60% of the fish caught in the Sub-Antarctic in 2015–16 were females. Observer sampling in the Sub-Antarctic in 2015–16 was not well representative of the overall spatial and temporal distribution of the catch. Deeper tows were under-sampled and there was little coverage in Statistical Area 603.

Catches from Puysegur decreased by to 800 t from 2014–15 to 2015–16, whereas catches from ECNI and ECSI increased by 100 and 500 t respectively.

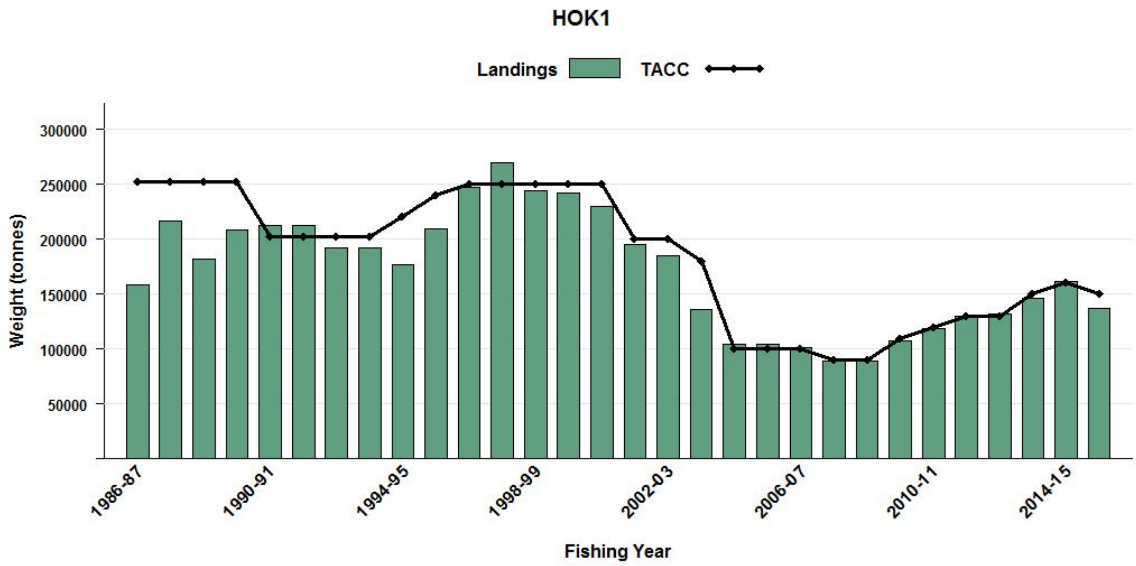


Figure 1a: Reported commercial landings and TACCs for HOK 1 since 1986–87. Note that these figures do not show data prior to entry into the QMS.

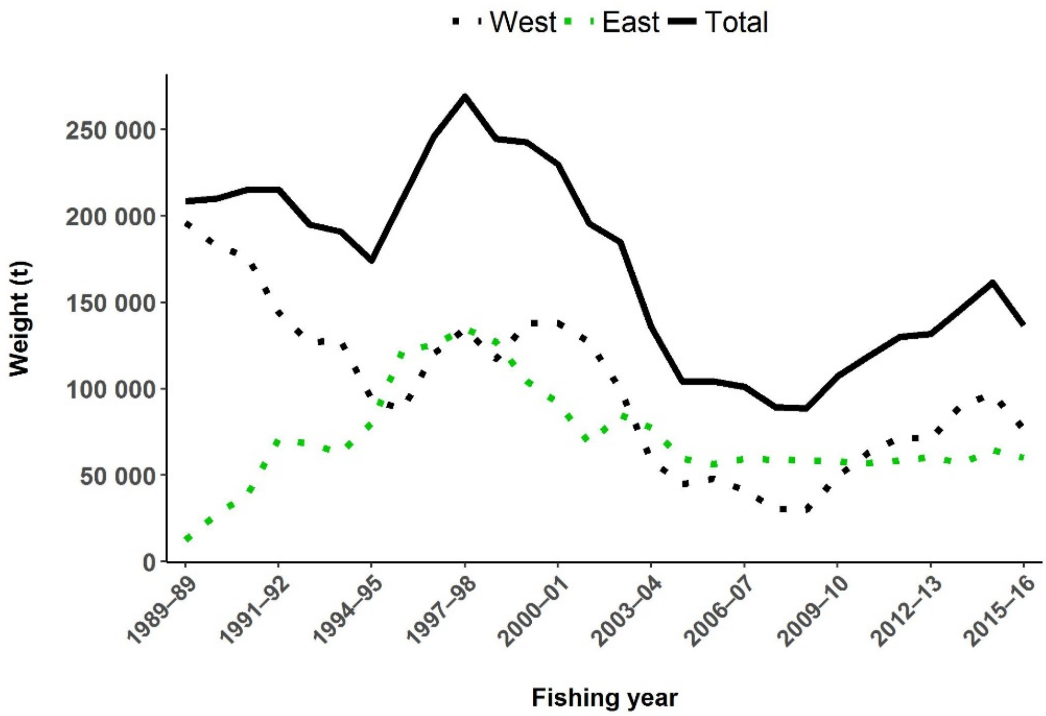


Figure 1b: The eastern and western components of the total HOK 1 landings since 1988–89. Note that these figures do not show data prior to entry into the QMS.

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^o S to 54^o S, from depths of 10 m to over 900 m, with greatest abundance between 200 and 600 m. Large adult hoki are generally found deeper than 400 m, while juveniles are more abundant in shallower water. In the January 2003 Chatham Rise trawl survey, exploratory tows with mid-water gear over a hill complex east of the survey area found low density concentrations of hoki in mid-water at 650 m over depths of 900 m or greater (Livingston et al 2004). The proportion of larger hoki outside the survey grounds is unknown. Commercial data also indicate that larger hoki have been targeted over other hill complexes outside the survey areas of both the Chatham Rise and Sub-Antarctic (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 Sub-Antarctic and Chatham Rise, and to a lesser extent around the North Island. Juvenile fish (2–4 yrs) are found on the Chatham Rise throughout the year.

Hoki spawn from late June to mid-September, releasing multiple batches of eggs. They have moderately high fecundity with a female of 90 cm TL spawning over 1 million eggs in a season (Schofield & Livingston 1998). Not all hoki within the adult size range spawn in a given year. Winter surveys of both the Chatham Rise and Sub-Antarctic have found significant numbers of large hoki with no gonad development, at times when spawning is occurring in other areas. Histological studies of female hoki from the Sub-Antarctic in May 1992 and 1993 estimated that 67% of hoki aged 7 years and older on the Sub-Antarctic would spawn in winter 1992, and 82% in winter 1993 (Livingston et al 1997). A similar study repeated in April 1998 found that a much lower proportion (40%) of fish aged 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 in the Sub-Antarctic, 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 in both the Sub-Antarctic and Chatham Rise. Analyses of trawl survey (1991–02) and commercial data suggests that a significant proportion of hoki move from the Chatham Rise to the Sub-Antarctic as they approach maturity, with most movement between ages 3 and 7 years (Bull & Livingston 2000, Livingston et al 2002). Based on a comparison of 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 Sub-Antarctic. A study of the observed sex ratios of hoki in the two spawning and two non-spawning fisheries found that in all areas, the proportion of male hoki declines with age (Livingston et al 2000). There is little information at present to determine the season of movement, the exact route followed, or the length of time required, for fish to move from the Chatham Rise to the Sub-Antarctic. Bycatch of hoki from tuna vessels following tuna migrations from the Sub-Antarctic showed a northward shift in the incidence of hoki towards the WCSI in May-June (Bull & Livingston 2000). The capture of net-damaged fish on Pukaki Rise following the WCSI spawning season where there had been intense fishing effort in 1989 also provides circumstantial evidence that hoki migrate from the WCSI back to the Sub-Antarctic post-spawning (Jones 1993).

Growth is fairly rapid with juveniles reaching about 27–35 cm TL at the end of the first year. 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	
HOK 1	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 Sub-Antarctic), and from the two main spawning grounds in Cook Strait and WCSI (Livingston et al 1992, Livingston & Schofield 1996b, Horn & Sullivan 1996). These differences clearly demonstrate that there are two sub-populations of hoki. Whether or not they reflect genetic differences between the two sub-populations, or they are just the result of environmental differences between the Chatham Rise and Sub-Antarctic, is not known. No genetic differences have been detected with selectively neutral markers (Smith et al 1981, 1996) but a low exchange rate between stocks could reduce genetic differentiation.

Two pilot studies appeared to provide support for the hypothesis of spawning stock fidelity for the Cook Strait and WCSI spawning areas. Smith et al (2001) found significant differences in gill raker counts, and Hicks & Gilbert (2002) found significant differences in measurements of otolith rings, between samples of 3 year-old hoki from the 1997 year-class caught on the WCSI and in Cook Strait. However, when additional year-classes were sampled, differences were not always detected (Hicks et al 2003). It appears that there are differences in the mean number of gill rakers and otolith measurements between stocks, but, due to high variation, large sample sizes would be needed to detect these (Hicks et al 2003). 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 DWWG 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 Sub-Antarctic 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. Analyses by 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 fully reviewed by the Aquatic Environment Working Group for the May 2012 Fishery Assessment Plenary. However, the tables have been updated with more recent data, where available, and minor corrections made for the 2017 report. This summary is from the perspective of the hoki fishery; a more comprehensive review from an issue-by-issue perspective is available in the 2016 Aquatic Environment & Biodiversity Annual Review (MPI 2016, http://www.mpi.govt.nz/document-vault/16339).

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 Bycatch (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 1990–91 to 2012–13, hoki, hake, and ling accounted for 91% 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 & O’Driscoll, 2015b).

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	2010–11		2011–12		2012–13		2013–14		2014–15	
	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%
Hoki	20 600	86.5	32 360	89.1	53 271	84.7	49 998	85.9	50 431	88
Ling	555	2.3	975	2.7	1922	3.1	1605	3.0	1357	2.4
Javelinfish	469	2.0	425	1.2	1090	1.7	767	1.3	822	1.4
Rattails	403	1.7	441	1.2	1086	1.7	686	1.2	644	1.1
Silver warehou	380	1.6	352	1.0	867	1.4	612	1.1	529	0.9
Hake	319	1.3	396	1.1	1703	2.7	1232	2.1	1006	1.8
Spiny dogfish	226	0.9	439	1.2	503	0.8	652	1.1	465	0.8
White warehou	89	0.4	65	0.2	115	0.2	189	0.3	37	0.1
Pale ghost shark	82	0.3	95	0.3	184	0.3	165	0.3	108	0.2
Sea perch	81	0.3	56	0.2	172	0.3	79	0.1	127	0.2
Barracouta	44	0.2	4	0.01	11	0.0	14	0.0	187	0.3
Southern blue whiting	40	0.2	12	0.03	10	0.02	86	0.2	37	0.1
Shovelnose dogfish	38	0.2	26	0.1	87	0.1	68	0.1	20	0.0
Lookdown dory	40	0.2	49	0.1	152	0.2	136	0.2	105	0.2
Ribaldo	33	0.1	26	0.1	87	0.1	93	0.2	52	0.1
Arrow squid	31	0.1	35	0.1	82	0.1	124	0.2	85	0.2
Gemfish	27	0.1	6	0.02	37	0.1	105	0.2	56	0.1
Smooth skate	26	0.1	21	0.1	78	0.1	49	0.1	62	0.1
Stargazer	25	0.1	15	0.04	71	0.1	47	0.1	60	0.1
Others	305	1.3	510	1.4	1334	2.1	1499	2.6	1149	2.3

5.3 Incidental capture of Protected Species (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 on board 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 2016).

Vessels targeting hoki incidentally catch fur seals (Baird 2005b, Smith & Baird 2009, Thompson & Abraham 2010a, Baird 2011, Abraham et al 2016). The numbers captured have been below 62 since 2005-06 and the lowest capture rates have been over the last five years (Table 7). Captures occur mostly off the west coast South Island (45%) in the Cook Strait (34%), and east coast South Island, including the western Chatham Rise (14%) (Table 8). Estimated captures of New Zealand fur seals in the hoki fishery have accounted for 44% of all fur seals estimated to have been caught by trawling in the EEZ between 2002–03 and 2014-15 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 2014–15. 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. Other estimates are based on methods described in Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2014–15 are based on data version 20160001.

	Fishing effort			Observed		Estimated		
	Tows	No. obs	%	Capture	Rate	Mean	95% c.i.	% inc.
1998–99	32 293	3561	11	84	2.4	919	*	95.6
1999–00	33 078	3275	9.9	102	3.1	764	*	95.8
2000–01	32 019	3548	11.1	66	1.9	804	*	97.6
2001–02	27 233	3277	12	110	3.4	844	*	96.3
2002–03	27 787	2593	9.3	45	1.7	622	346–1 110	100
2003–04	22 523	2347	10.4	56	2.4	734	395–1 321	100
2004–05	14 540	2133	14.7	120	5.6	746	411–1 356	100
2005–06	11 590	1775	15.3	62	3.5	428	213–857	100
2006–07	10 609	1758	16.6	29	1.6	259	123–538	100
2007–08	8 787	1878	21.4	58	3.1	310	153–630	100
2008–09	8 176	1662	20.3	37	2.2	197	95–414	100
2009–10	9 964	2066	20.7	30	1.5	172	87–351	100
2010–11	10 403	1724	16.6	24	1.4	178	85–359	100
2011–12	11 330	2703	23.9	34	1.3	198	97–393	100
2012–13	11 680	4515	38.7	61	1.4	244	123–517	100
2013–14	12 948	3977	30.7	32	0.8	167	84–325	100
2014–15	13 585	3613	26.6	42	1.2	295	139–649	100

Table 8: Model estimates (means) of the number of NZ fur seal captures in hoki trawl fisheries by area, 2002–03 to 2013–14. Data version 2015001. Model estimates for 2014–15 were not available at the time of publication.

	Cook	WCSI	ECSI	Fiordland	Stewart-Snares	Chatham Rise	Sub-Antarctic	Total
2002–03	266	182	85	19	17	12	33	620
2003–04	353	218	102	10	15	10	9	723
2004–05	387	220	89	26	22	11	8	776
2005–06	231	117	56	10	9	5	0	435
2006–07	162	38	41	0	15	3	0	261
2007–08	195	47	55	0	6	3	2	315
2008–09	138	25	26	0	8	1	0	200
2009–10	101	32	28	0	10	2	1	174
2010–11	98	49	22	1	5	1	1	179
2011–12	113	59	24	1	4	2	0	205
2012–13	159	60	22	0	2	1	0	246
2013–14	72	62	15	0	3	1	1	156

NZ sea lion interactions

The New Zealand (or Hooker's) sea lion was classified in 2008 as "Vulnerable" by IUCN and in 2016 as "Nationally Critical" under the NZ Threat Classification System (Baker et al 2016). 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.

Table 9: Number of tows by fishing year and observed NZ sea lion captures in hoki trawl fisheries, 2002-03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2014–15 are based on data version 2016v1.

			Fishing effort		Observed			Estimated
	Tows	No.	% obs	Captures	Rate	Mean	95%	%
2002-03	27 787	2 593	9.3	1	0	2	0–6	18
2003-04	22 523	2 347	10.4	0	0	1	0–5	14.3
2004-05	14 540	2 133	14.7	0	0	1	0–3	12.4
2005-06	11 590	1 775	15.3	0	0	0	0–2	7.8
2006-07	10 609	1 758	16.6	0	0	0	0–2	11.7
2007-08	8 787	1 878	21.4	1	0.1	1	1–2	11.1
2008-09	8 176	1 662	20.3	0	0	0	0–1	12
2009-10	9 964	2 066	20.7	0	0	0	0–2	13.1
2010-11	10 403	1 724	16.6	0	0	0	0–2	13.3
2011-12	11 330	2 703	23.9	0	0	0	0–2	12.1
2012-13	11 680	4 515	38.7	1	0	1	1–3	12.4
2013-14	12 948	3 977	30.7	0	0	1	0–2	14.9
2014-15	13 585	3 613	26.6	0	0	1	0–3	13.2

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), for 1989–90 to 2008–09 by Abraham & Thompson (2011) and for Abraham et al 2016.

In the 2014–15 fishing year there were 81 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 416 (95% c.i. 335–518) captures in hoki trawl fisheries (Table 10). Annual observed seabird capture rates have ranged between 1.3 and 3.9 per 100 tows in the hoki fishery over the time period 2002–03 and 2014–15, with little apparent trend. These estimates include all bird species and all methods of capture and should be interpreted with caution. The average capture rate in hoki trawl fisheries for the period from 2002–03 to 2014–15 is about 2.36 birds per 100 tows, a low rate relative to other New Zealand trawl fisheries, e.g. for scampi (4.27 birds per 100 tows) and squid (13.75 birds per 100 tows) over the same years.

Table 10: Number of tows by fishing year and observed and model-estimated total seabird captures in hoki trawl fisheries, 1998–99 to 2014–15. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2014–15 are based on data version 2016v01.

					Observed			Estimated
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% inc.
2002–03	27 787	2593	9.3	82	3.2	721	571--923	100.0
2003–04	22 523	2347	10.4	32	1.4	409	316--522	100.0
2004–05	14 540	2133	14.7	43	2	429	321--581	100.0
2005–06	11 590	1775	15.3	53	3	314	237--417	100.0
2006–07	10 609	1758	16.6	23	1.3	201	146--273	100.0
2007–08	8 787	1878	21.4	28	1.5	181	133--246	100.0
2008–09	8 176	1662	20.3	37	2.2	245	182--329	100.0
2009–10	9 964	2066	20.7	53	2.6	281	217--363	100.0
2010–11	10 403	1724	16.6	52	3	320	250--415	100.0
2011–12	11 330	2703	23.9	58	2.1	253	199--322	100.0
2012–13	11 680	4515	38.7	102	2.3	285	235--357	100.0
2013–14	12 948	3977	30.7	156	3.9	397	335--483	100.0
2014–15	13 585	3613	26.6	81	2.2	416	335--518	100.0

Observed seabird captures since 2002–03 have been dominated by six species: Salvin’s, southern Buller’s, and NZ white-capped albatrosses make up 42%, 27%, and 23% of the albatrosses captured, respectively; and sooty shearwaters, white-chinned petrels, and cape petrels make up 48%, 16%, and 11% of other birds, respectively (Table 11). The highest proportions of captures have been observed off the east coast of the South Island (33%), off the west coast of the South Island (23%), on the Stewart-Snares shelf (18%), and on the Chatham Rise (16%). 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.

The hoki target fishery contributes to the total risk posed by New Zealand commercial fishing to seabirds (see Table 11). The two species to which the fishery poses the most risk are Southen Buller's albatross and Salvin's albatross, with this target fishery poses 0.608 and 0.325 of PST (Table 12). Southern Buller's albatross and Salvin's albatross were both assessed at very high risk (Richard & Abraham 2013, 2015).

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 2014–15, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard & Abraham 2015 and Richard et al 2017, where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for hoki. Data based on version 2016v01.

	Risk ratio	East Coast South Island	West Coast South Island	Stewart Snares Shelf	Chatham Rise	Cook Strait	Fiordland	Subantarctic	Auckland Islands	Bay of Plenty	Total
Salvin's albatross	High	57	0	3	82	10	0	1	0	0	153
Southern Buller's albatross	High	8	61	19	6	0	8	1	0	0	103
Chatham Island albatross	High	0	0	0	1	0	0	1	0	0	2
New Zealand white-capped albatross	High	8	33	29	4	6	4	0	0	0	84
Northern Buller's albatross	Medium	0	1	0	0	0	0	0	0	0	1
Campbell black-browed albatross	Low	0	6	2	0	0	0	0	0	0	8
Southern royal albatross	Negligible	1	0	0	0	0	0	0	0	0	1
Albatrosses	-	2	0	0	0	1	0	1	0	0	4
Great albatrosses	-	1	0	0	0	0	0	0	0	0	1
Smaller albatrosses	-	0	0	0	2	0	0	0	0	0	2
Southern black-browed albatross	-	1	0	0	0	0	0	0	0	0	1
Total albatrosses	-	**78**	**101**	**53**	**95**	**17**	**12**	**4**	**0**	**0**	**360**
Flesh-footed shearwater	High	1	0	0	0	0	0	0	0	2	3
Westland petrel	High	0	18	0	2	1	0	0	0	0	21
Northern giant petrel	Medium	1	2	0	3	0	0	0	0	0	6
White-chinned petrel	Negligible	22	0	33	19	3	2	3	4	0	86
Grey petrel	Negligible	1	0	1	1	0	1	1	0	0	5
Snares Cape petrel	Negligible	0	1	0	1	0	4	0	0	0	6
Sooty shearwater	Negligible	188	2	47	11	1	6	0	4	0	259
Common diving petrel	Negligible	0	0	4	0	0	1	0	0	0	5
Fairy prion	Negligible	0	6	0	0	0	0	0	0	0	6
Black-bellied storm petrel	Negligible	0	0	1	0	0	0	0	0	0	1
Cape petrel	-	4	10	2	2	8	3	0	0	0	29
Cape petrels	-	0	3	1	0	0	0	0	0	0	4
Grey-backed storm petrel	-	0	0	2	0	0	0	0	0	0	2
Petrels	-	0	0	0	1	0	0	0	0	0	1
Prions	-	0	0	1	0	0	0	0	0	0	1
Storm petrels	-	0	1	0	0	0	0	0	0	0	1
Petrels, prions and shearwaters	-	1	0	0	0	0	0	0	0	0	1
Total other birds	-	**218**	**43**	**92**	**40**	**13**	**17**	**4**	**8**	**2**	**437**

Table 12: Risk ratio of seabirds predicted by the level two risk assessment for the hoki fishery and all fisheries included in the level two risk assessment, 2006–07 to 2014–15, showing seabird species with a risk ratio of at least 0.001 of PST. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard & Abraham 2015 and Richard et al 2017, where full details of the risk assessment approach can be found). The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

		Risk ratio			
Species name	**PST (mean)**	**JMA target bottom longline**	**TOTAL**	**Risk category**	**DOC Threat Classification**
Black petrel	437.1	0.01	1.153	Very high	Threatened: Nationally Vulnerable
Salvin's albatross	3 597.9	0.12	0.78	High	Threatened: Nationally Critical
Flesh-footed shearwater	1 451.2	0.01	0.669	High	Threatened: Nationally Vulnerable
Westland petrel	349.8	0.07	0.476	High	At Risk: Naturally Uncommon
Southern Buller's albatross	1369	0.14	0.392	High	At Risk: Naturally Uncommon
Chatham Island albatross	425.2	0.02	0.362	High	At Risk: Naturally Uncommon
New Zealand white-capped albatross	10 914.5	0.04	0.353	High	At Risk: Declining
Gibson's albatross	496.3	0.00	0.337	High	Threatened: Nationally Critical
Northern Buller's albatross	1 628.2	0.03	0.253	Medium	At Risk: Naturally Uncommon
Antipodean albatross	364.2	0.00	0.203	Medium	Threatened: Nationally Critical
Otago shag	284.6	0.00	0.144	Medium	At Risk: Recovering
Northern giant petrel	335.9	0.03	0.138	Medium	At Risk: Recovering
Campbell black-browed albatross	1 980.4	0.01	0.077	Low	Threatened: Nationally Vulnerable
White-chinned petrel	25 626.3	0.01	0.055	Negligible	Not Threatened
Northern royal albatross	716.3	0.00	0.043	Low	At Risk: Naturally Uncommon
Grey petrel	5 526.3	0.00	0.037	Negligible	At Risk: Naturally Uncommon
Grey-faced petrel	29 933.3	0.00	0.005	Negligible	Not Threatened
Sooty shearwater	617 452.6	0.00	0.002	Negligible	At Risk: Declining
Common diving petrel	135 247.8	0.00	0.002	Negligible	At Risk: Relict
Hutton's shearwater	15 047.5	0.00	0.001	Negligible	Threatened: Nationally Vulnerable

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 13). 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 to improve the understanding of the interactions between basking sharks and fisheries was reported in Francis & Sutton (2012).

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 14). 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 14).

Table 13: 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
2003–04	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 14: Summary of number of hoki target trawl tows (TCEPR only) in the hoki fishery from fishing years (FY) 1989–90 to 2015–16. (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	1 826	1 019	1 045	98	6	1 373	169	4 175	3 046	6 665	69
2013–14	2 330	1 111	1 029	65	12	1 872	133	4 016	3 504	7 064	67
2014–15	2 716	1 244	952	53	89	1 620	209	4 319	3 966	7 236	61
2015–16	2 696	1 526	814	10	10	834	100	3 907	3 620	6 277	63

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 2017 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 to perform a Bayesian stock assessment similar to the 2016 assessment (McKenzie 2017a).

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 divides the fishing year into five time steps and includes four types of migration (Table 15). 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) are 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 15: 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		
					CSacous	0.5
5	Jul–Sep	increment ages	0.25	0	WCacous	0.5
		spawning fisheries (Esp, Wsp)				

Data and error assumptions

Five series of abundance indices were used in the assessment (Table 16). New data were available from a trawl survey on the Sub-Antarctic in November/December 2016 (MacGibbon et al 2017). The age data used in the assessment (Table 17) are similar to those used in 2016, 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 16: Abundance indices ('000 t) used in the stock assessment (* data new to this assessment). Years are fishing years (1990 = 1989–90). - no data.

	Acoustic survey	Trawl survey	Trawl survey	Trawl survey	Acoustic survey
1988	266	-	-	-	-
1989	165	-	-	-	-
1990	169	-	-	-	-
1991	227	-	-	-	88
1992	229	80	68	120	-
1993	380	87	-	186	283
1994	-	100	-	146	278
1995	-	-	-	120	194
1996	-	-	89	153	92
1997	445	-	-	158	141
1998	-	-	68	87	80
1999	-	-	-	109	114
2000	263	-	-	72	-
2001	-	56	-	60	102
2002	-	38	-	74	145
2003	-	40	-	53	104
2004	-	14	-	53	-
2005	-	18	-	85	59
2006	-	21	-	99	60
2007	-	14	-	70	104
2008	-	46	-	77	82
2009	-	47	-	144	166
2010	-	65	-	98	-
2011	-	-	-	94	141
2012	283	46	-	88	-
2013	233	56	-	124	168
2014	-	-	-	102	-
2015	-	31	-	-	204
2016	-	-	-	115	-
2017	-	38*	-	-	-

Table 17: Age data used in the assessment (* data new to this assessment). Data are from otoliths or from the length-frequency analysis program OLF (Hicks et al 2002). Years are fishing years (1990 = 1989–90).

Area	Label	Data type	Years	Source of age data
WC	Wspage	Catch at age	1988–2016*	Otoliths
SA	WnspOLF	Catch at age	1992–94, 96, 99–00	OLF
	Wnspage	Catch at age	2001–04, 06–14, 16*	Otoliths
	SAsumage	Trawl survey	1992–94, 2001–10, 2012–13, 15, 17*	Otoliths
	SAautage	Trawl survey	1992, 96, 98	Otoliths
	pspawn	Proportion spawning	1992, 93, 98	Otoliths
CS	Espage	Catch at age	1988–2010, 2014–16*	Otoliths
CR	EnspOLF	Catch at age	1992, 94, 96, 98	OLF
	Enspage	Catch at age	1999–2016*	Otoliths
	CRsumage	Trawl survey	1992–2014, 2016	Otoliths

Two alternative sets of CVs were used for the biomass indices. The "total" CVs represent an estimate of the total uncertainty associated with these data, and were used in initial model runs. For the trawl-survey indices, these were calculated as the sum of an observation-error CV (which was calculated using the standard formulae for stratified random surveys, e.g., Livingston & Stevens (2002) and a process-error CV, which was set at 0.2, following Francis et al (2001) (note that CVs added as squares: $CV_{total}^2 = CV_{process}^2 + CV_{observation}^2$). For final model runs the process-error CV for the Chatham Rise and Sub-Antarctic trawl surveys were estimated in the MPD model run, and set at their MPD estimated values for the MCMC model runs (base case: 0.146 for Chatham Rise and 0.379 for Sub-Antarctic). The base case CVs are shown in Table 18.

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.

Table 18: Coefficients of variation (CVs) used with biomass indices in the assessment. Total CVs include both observation error CVs and process error CVs. Process errors for CRsumbio and SAsumbio are estimated for each model in an MPD run, with total CVs shown here for the base model (1.1). Years are fishing years (1990 = 1989–90).

CRsumbio	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total	0.17	0.18	0.18	0.17	0.18	0.17	0.18	0.19	0.19	0.18	0.18	0.17	0.20
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	2016		
Total	0.19	0.18	0.17	0.18	0.18	0.21	0.20	0.18	0.21	0.18	0.20		
Observation	0.12	0.11	0.08	0.11	0.11	0.15	0.14	0.10	0.15	0.10	0.14		
SAsumbio	1992	1993	1994	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total	0.39	0.38	0.39	0.40	0.41	0.40	0.40	0.40	0.40	0.39	0.41	0.40	0.41
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	2017									
Total	0.41	0.41	0.40	0.42									
Observation	0.15	0.15	0.13	0.17									
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	2015							
Total	0.46	0.30	0.39	0.35	0.30	0.33							
Observation	0.26	0.06	0.13	0.14	0.15	0.17							
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 19). In all cases, the last age for these data sets was treated as a plus group.

Table 19: 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 among the six fisheries in the model according to area and month (Table 20). 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 20) was the same as that used in the 2016 assessment, so the catches used in the model (Table 21) are unchanged, except for revisions to the assumed catch for 2016.

Table 20: 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	Sub-Antarctic	October–March
Western non-spawning fishery 2	Wnsp 2	Sub-Antarctic	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	April–May
		Chatham Rise East Coast South Island East Coast North Island null[1]	April–September

[1] catch reported to no area.

For the 2016–17 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. The quota in 2015-16 was not fully caught, and it was assumed that 10 000 t of catch would be carried over into the 2016-17 year, to give a total commercial catch of 160 000 t. Industry representatives indicated that this would likely be taken from the western stock, with eastern stock catches remaining the same. In the stock assessment model the non-spawning fisheries were split into two parts, separated by the migration of fish from the Chatham Rise to the Sub-Antarctic (Table 21).

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 the time series of 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 2015) were estimated, with an equality constraint for the 2015 east and west YCSs (due to insufficient information to estimate the east and west YCSs separately). The model corrects for bias in estimated YCSs arising from ageing error. YCSs were constrained to average to 1 over the years 1975 to 2012, 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 most model runs it was assumed to vary with age (following a double-exponential curve) and separately for each sex; in one model run (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 (Table 22). In addition, bounds were imposed for parameters with non-uniform distributions. For the catchability parameters, these were calculated by O'Driscoll et al (2002, 2016) (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 21: Catches (t) by fishery and fishing year (1972 means fishing year 1971–72), as used in this assessment. Years are fishing years (1990 = 1989–90).

							Fishery
Year	Ensp1	Ensp2	Wnsp1	Wnsp2	Esp	Wsp	Total
1972	1 500	2 500	0	0	0	5 000	9 000
1973	1 500	2 500	0	0	0	5 000	9 000
1974	2 200	3 800	0	0	0	5 000	11 000
1975	13 100	22 900	0	0	0	10 000	46 000
1976	13 500	23 500	0	0	0	30 000	67 000
1977	13 900	24 100	0	0	0	60 000	98 000
1978	1 100	1 900	0	0	0	5 000	8 000
1979	2 200	3 800	0	0	0	18 000	24 000
1980	2 900	5 100	0	0	0	20 000	28 000
1981	2 900	5 100	0	0	0	25 000	33 000
1982	2 600	4 400	0	0	0	25 000	32 000
1983	1 500	8 500	3 200	3 500	0	23 300	40 000
1984	3 200	6 800	6 700	5 400	0	27 900	50 000
1985	6 200	3 800	3 000	6 100	0	24 900	44 000
1986	3 700	13 300	7 200	3 300	0	71 500	99 000
1987	8 800	8 200	5 900	5 400	0	146 700	175 000
1988	9 000	6 000	5 400	7 600	600	227 000	255 600
1989	2 300	2 700	700	4 900	7 000	185 900	203 500
1990	3 300	9 700	900	9 100	14 000	173 000	210 000
1991	17 400	14 900	4 400	12 700	29 700	135 900	215 000
1992	33 400	17 500	14 000	17 400	25 600	107 200	215 100
1993	27 400	19 700	14 700	10 900	22 200	100 100	195 000
1994	16 000	10 600	5 800	5 500	35 900	117 200	191 000
1995	29 600	16 500	5 900	7 500	34 400	80 100	174 000
1996	37 900	23 900	5 700	6 800	59 700	75 900	209 900
1997	42 400	28 200	6 900	15 100	56 500	96 900	246 000
2017	28 900	11 600	8 500	8 200	19 600	83 200	160 000
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
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

Table 21: [Continued]

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	32 300	12 500	9 100	7 300	19 800	80 600	161 600
2016	28 900	11 600	3 400	3 300	19 600	69 900	136 700

Table 22: 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	Values		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	0.55	0.90	O’
q[WCacous].q	catchability, WCacous	lognormal	0.39	0.77	O’Driscoll et al (2016)
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

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.

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.

Calculations of fishing intensity and B_{MSY} were done for each sample from the MCMC, and results summarised as medians and credible intervals. The reference fishing intensities, $U_{35\%Bo}$ and $U_{50\%Bo}$ are summarised as medians.

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.

An initial set of analyses was carried out after the new data became available (McKenzie 2017b, 2017c, 2017d, 2017e). A model run with 0.2 process error assumed for the Chatham Rise and Sub-Antarctic trawl survey series, and a single catchability (q), did not fit the most recent Sub-Antarctic biomass estimates very well and the residuals from this run were unacceptable. To give acceptable residual patterns for the Chatham Rise and Sub-Antarctic trawl survey series, a run was conducted in which the process error for these were estimated (instead of fixed at the value of 0.20). This run resulted in a lower process error for the Chatham Rise surveys (0.146) but a higher process error for the Sub-Antarctic trawl survey series (0.379). The impact of the higher process error is to increase the uncertainty in the biomass estimates for the western stock. The DWWG agreed that this run would be the base case for 2017.

The SAsumbio survey data shows large annual changes in numbers-at-age that cannot be explained entirely by changes in abundance, and which are suggestive of changes in survey catchability. Because of this, and to improve the fit to the SAsumbio series, model runs have previously been conducted where the catchability has changed over time (two q values were fitted to the survey time series). In the previous assessment, and in 2017, one catchability was assumed for the whole time series but a higher process error was allowed to account for the annual variation in observations; this effectively down weights the Sub-Antarctic trawl survey data relative to other data sources in the model.

For the previous assessment (2016) 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 weighting of CRsumbio and SAsumbio trawl data determined by their estimated process error. In the base model of the 2017 assessment, these model features were kept and the model updated with the new data. The model with process error estimated (1.1) was preferred to that with process error fixed at 0.20 (Run 1.15) because of the lower residuals for the fits to CRsumbio and SAsumbio. In both models a run of four low biomass estimates from SAsumbio for 2004–2007 is not unexpected statistically (Cordue 2014). In the base case model (Run 1.1) the observation of low biomass in the November-December 2014 and November-December 2016 Sub-Antarctic trawl surveys was interpreted as being due to observation error (i.e. the survey underestimated the biomass by chance).

Sensitivity model runs were carried out to the base model run (Table 23). These tested the sensitivity of model 1.1 to the process errors for CRsumbio and SAsumbio (1.15), and the western stock biomass indices (1.16 and 1.17). Other sensitivity runs conducted included assumptions about natal fidelity but still assuming adult fidelity, and domed spawning selectivity.

Table 23: Characteristics for model runs, including sensitivities to the base run 1.1.

Run	Main assumptions
1.1 - base case	natal fidelity
	M is age-dependent
	single q for Sub-Antarctic trawl series
	process error of CRsumbio and SAsumbio estimated
1.15	as 1.1 but process error fixed at 0.20 for CRsumbio and SAsumbio
1.16	as 1.1 but drop SAsumbio
1.17	as 1.1 but drop WCacous

Bayesian posterior distributions were estimated for each of these runs using a Markov Chain Monte Carlo (MCMC) approach. For each run, three chains of length four million were completed, with adaptive step size allowed during the first 100 000 samples. 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 24), biomass trajectories and year-class strengths (Figure 2), and current biomass distributions (Figure 3). Compared to the base case (1.1), a process error of 0.20 resulted in essentially the same current biomass for the E stock (%B_0), whereas for the W stock the %B_0 was lower (Run 1.15). Dropping SAsumbio or WCacous resulted in essentially the same current biomass for the E stock (%B_0), whereas for the W stock the %B_0 was higher or lower respectively (Runs 1.16 and 1.17). Other sensitivity runs conducted included assumptions about natal fidelity but still assuming adult fidelity, and domed spawning selectivity. For these other sensitivity runs median values of current biomass (%B_0) were greater than the upper target zone value of 50%B_0 for both stocks.

Table 24: 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 2016–17. The base case 1.1 estimates the process error for CRsumbio and SAsumbio, whereas run 1.15 sets these at 0.20. All other sensitivities are conducted against the base case 1.1– see Table 23.

	B_0(‘000 t)		$B_{current}$(‘000 t)		$B_{current}$(%B_0)		
Run	E	W	E	W	E	W	E+W
1.1 (Base)	547(455,684)	1031(824,1594)	328(223,492)	611(338,1263)	60(44,79)	59(40,84)	60(46,77)
1.15	522(428,643)	923(782,1223)	322(205,479)	431(249,783)	62(44,81)	47(31,66)	53(40,66)
1.16	573(453,735)	1453(1037,2220)	360(232,562)	1140(638,2042)	63(46,84)	79(58,100)	75(59,92)
1.17	535(429,674)	922(778,1216)	323(212,483)	434(239,792)	60(44,81)	47(29,70)	52(41,68)

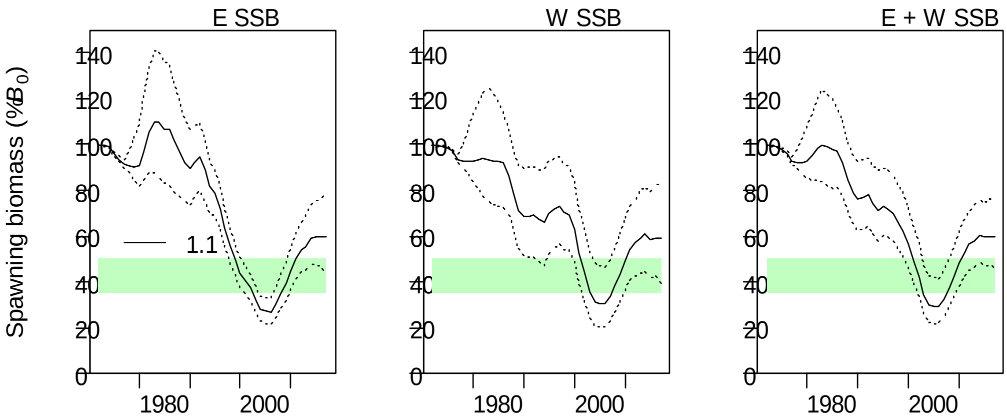


Figure 2 [upper]: Estimated spawning biomass trajectories (SSB, upper panels) for the E (left panels), W (middle panels) and E + W stocks (right panels) from the base case run 1.1. Plotted values are medians (solid black line) with 95% confidence intervals (dotted lines). Years are fishing years (1990 = 1989–90). The shaded green region represents the target zone of 35–50% B_0.

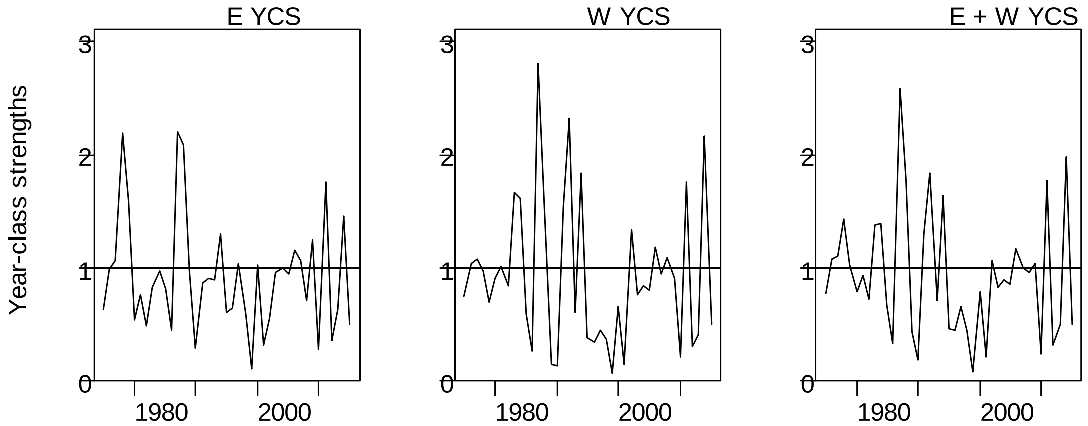


Figure 2 [Lower]: Year-class strengths (YCS, lower panels) for the E (left panels), W (middle panels) and E + W stocks (right panels) from the base case run 1.1. Plotted values are medians of marginal posterior distributions. Years are fishing years (1990 = 1989–90).

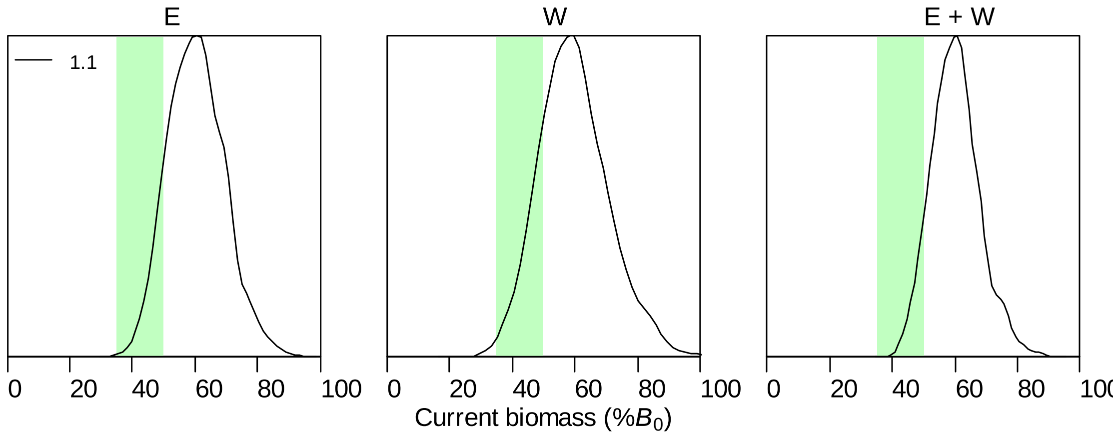


Figure 3: Estimated posterior distributions of current (spawning) biomass ($B_{2016\text{-}17}$) expressed as %B_0 for the E (left panel), W (middle panel), and E + W (right panel) from the base case run 1.1. The shaded green region represents the target zone of 35–50% B_0.

The base run (1.1) shows that the biomasses of both stocks were at their lowest points from about 2004 to 2006 (at about 27% B_0 for the E stock and 31% B_0 for the W stock). after the W stock experienced seven consecutive years of poor recruitment from 1995 to 2001 inclusive and the E stock had below average recruitment over the same period (Figure 2). Both the E and W stocks have since increased to levels which exceed the target zone. 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 2015, and well above average in 2011 and 2014.

In the 2016 assessment base case there was a 1.00 probability that the western stock was above 35% B_0, whereas the probability for the 2017 base case (1.1.) is 0.99. Based on the 2017 assessment, the Harvest Strategy Standard defines the western stock to have 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 26.5% (25.0–28.0) for the E stock and 26.9% (25.6–28.0) for the W stock, with 95% confidence intervals shown in brackets.

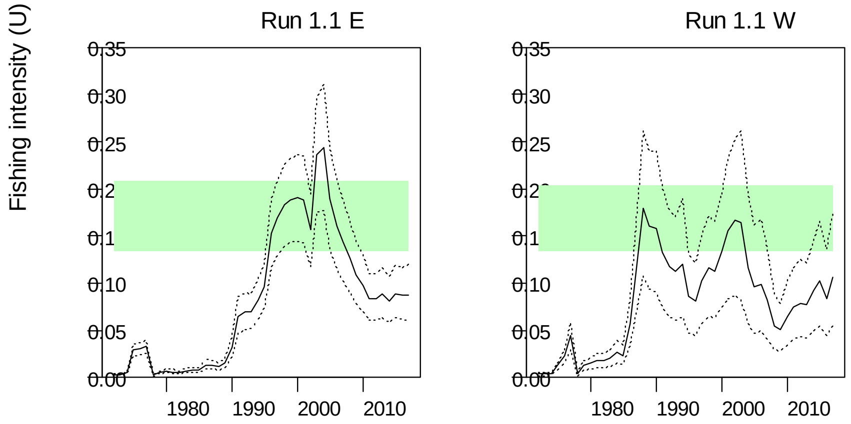


Figure 4: Base case fishing intensity, U (from MCMCs), plotted by stock. Shown are medians (solid black line) with 95% confidence intervals (dotted lines). Also shown shaded in green is the management range where the upper bound is the reference level $U_{35\%B_0}$ and the lower bound $U_{50\%B_0}$ which are the fishing intensities that would cause the spawning biomass to tend to 35% B_0 and 50% B_0, respectively.

6.3 Projections

Five-year projections were carried out for the base model (1.1) and the most pessimistic model for the western stock (1.17), by selecting future recruitments at random from those estimated for 2006–2015. Total catch was assumed to equal the current TACC of 150 000 t with 60 000 t catch for the east stock and 90 000 t for the west stock. The projections indicate that the E and W biomasses are likely to increase slightly over the next 5 years (Figure 5).

The estimated probability of either stock being less than the soft or the hard limit at the end of the five year projection period is negligible (Table 25). Both stocks are projected to remain within or above the 35–50% B_0 target range at the end of the projection period.

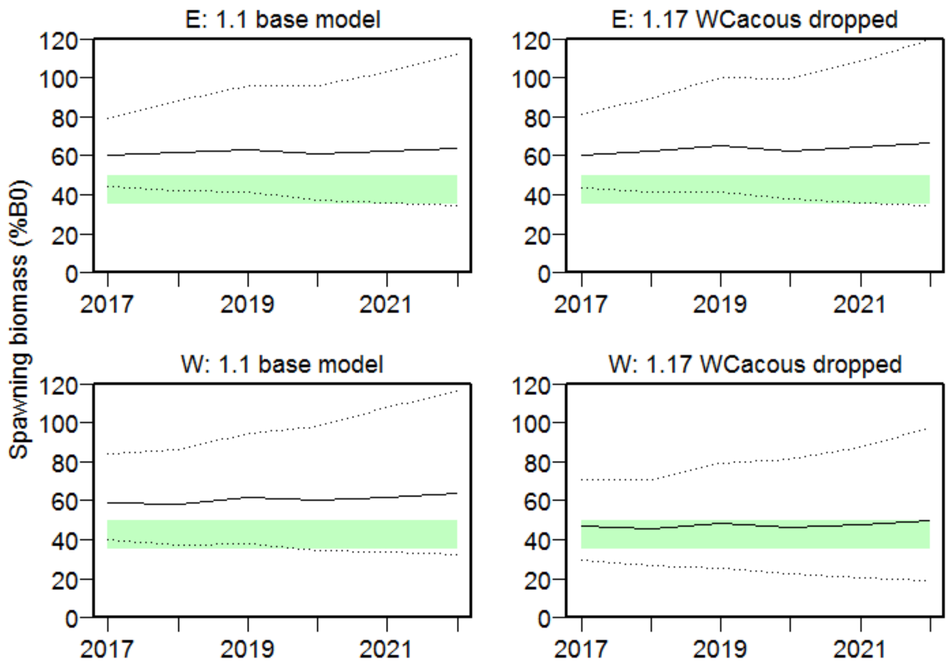


Figure 5: Projected spawning biomass (as %B_0): median (solid lines) and 95% confidence intervals (broken lines) for the base case (1.1) and a sensitivity with the west coast South Island acoustic biomass series dropped (1.17). The shaded green region represents the target management range of 35–50% B_0.

Table 25: Probabilities (to two decimal places) associated with projections for SSB (%B0) for the base case (1.1) for 2017 through to 2022, and for a sensitivity with the west coast South Island acoustic biomass series dropped (1.17).

	2017	2018	2019	2020	2021	2022
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	0.01	0.02	0.03
P (SSB<50%B_0)	0.11	0.14	0.14	0.20	0.20	0.20
EAST 1.17						
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	0.01	0.02	0.03
P (SSB<50%B_0)	0.11	0.13	0.13	0.19	0.18	0.17
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)	0.01	0.01	0.02	0.03	0.03	0.04
P (SSB<50%B_0)	0.18	0.23	0.17	0.24	0.23	0.21
WEST 1.17						
P (SSB<10%B_0)	0	0	0	0	0	0
P (SSB<20%B_0)	0	0	0.01	0.02	0.02	0.03
P (SSB<35%B_0)	0.10	0.15	0.14	0.19	0.20	0.20
P (SSB<50%B_0)	0.62	0.64	0.55	0.58	0.55	0.51

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 Sub-Antarctic;
- 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.

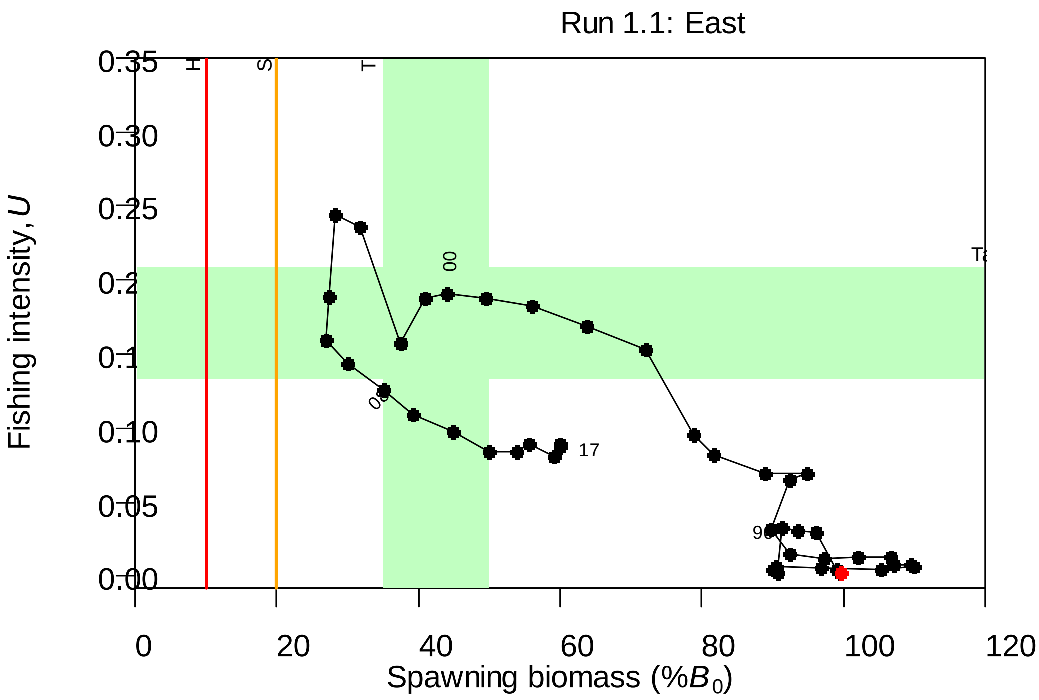
Both of these biological stocks lie within the HOK 1 Fishstock boundaries.

- **Eastern Hoki Stock**

Stock Status	
Year of Most Recent Assessment	2017
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_{2017} was estimated to be 60% 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_{2017} 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 2017 (17). The red vertical line at 10% *B₀* represents the hard limit, the yellow line at 20% *B₀* is the soft limit, and the shaded area represents the management target ranges in biomass and fishing intensity. Biomass and fishing intensity estimates are medians from MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The 2017 base case suggests that biomass has been increasing or stable for the last 6 years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been flat for the last 7 years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	A strong year class is apparent for 2011. The 2016 Chatham Rise trawl survey estimated the 2014 year class to be the second highest on record from this time series. The actual split of recruitment between the eastern and western stocks for the three most recent 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 future 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: 2017	Next assessment: 2018
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	-	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2014 and 2015 year classes between eastern and western stocks with respect to projections	

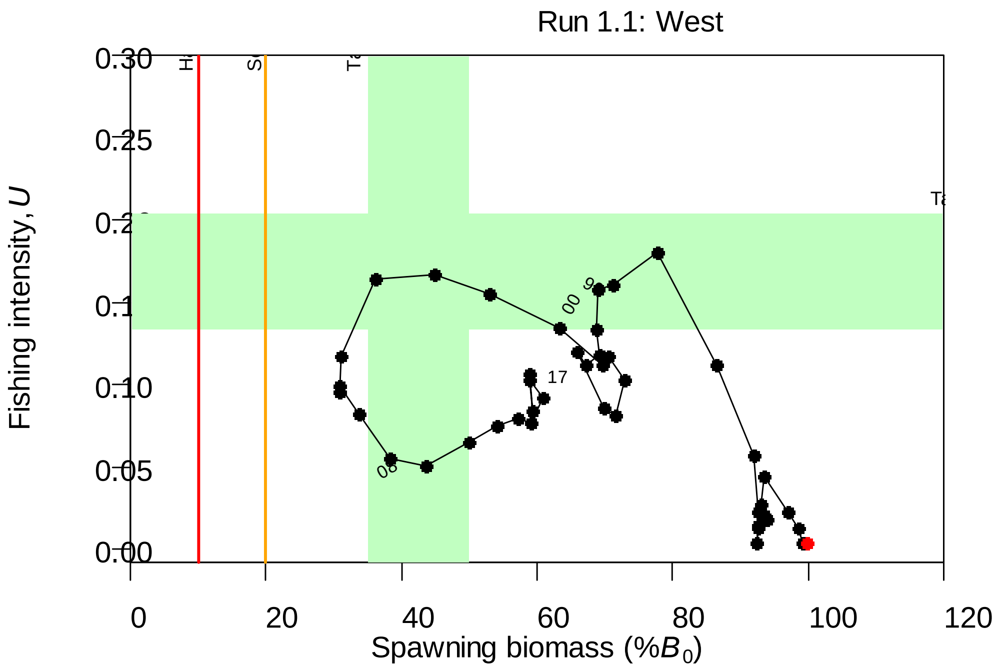
Qualifying Comments
-

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	2017
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_{2017} was estimated to be 59% B_0; Very Likely (> 90%) 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_{2017} is Exceptionally Unlikely (< 1%) to be below the Hard Limit and Exceptionally Unlikely (< 1%) to be below the Soft Limit
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity (*U*) and spawning biomass (% B_0), for the western hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2017 (17). 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 and fishing intensity estimates are medians from MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The 2017 base case suggests that biomass has been stable at about 59% B_0 for the last 5 years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been stable at about 0.10 for the last 4 years
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Strong year classes are apparent for 2011 and 2014. The 2017 Sub-Antarctic trawl survey estimated the 2015 year class to be below average. The actual split of recruitment between the eastern and western stocks for the three most recent year class strengths 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 increase over the next five years at assumed future 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: 2017	Next assessment: 2018
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 - Some years of age data, as described in Table 17	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 3- Low quality: Currently not used as it was thought not to be representative of the fishery
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2014 and 2015 year classes between eastern and western stocks with respect to projections - Possible catchability changes in Sub-Antarctic trawl surveys	

Qualifying Comments
In the 2017 base case where process error is estimated for the two trawl surveys, there is increased uncertainty in the western stock assessment. In this run the low abundance index from the November-December 2014 and 2016 Sub-Antarctic trawl surveys are interpreted by the model as being low due to observation and process error. The risk is that if the Sub-Antarctic trawl survey is reflecting an actual change in biomass, then the western stock status would be lower than estimated in the base case. Another trawl survey of the Sub-Antarctic is scheduled for November-December 2018.

Fishery Interactions
In the west coast South Island and Sub-Antarctic 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

Abraham, E R; Berkenbusch, K; Richard, Y; Thompson, F (2016) Summary of the capture of seabirds, mammals, and turtles in New Zealand commercial fisheries, 2002–03 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No.169*. 205 p.

Abraham, E R; Thompson, F N (2011) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report* No. 79. 74 p.

Abraham, E R; Thompson, F N; Berkenbusch, K (2013) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Ministry for Primary Industries, Wellington).

Abraham, E R; Thompson, F N; Oliver, M D (2010) Summary of the capture of seabirds, mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report* No.45. 149 p.

Anderson, O F; Gilbert, D J; Clark, M R (2001) Fish discards and non-target catch in the trawl fisheries for orange roughy and hoki in New Zealand waters for the fishing years 1990–91 to 1998–99. *New Zealand Fisheries Assessment Report 2001/16*. 57 p.

Anderson, O F; Smith, M H (2005) Fish discards and non-target fish catch in the New Zealand hoki trawl fishery, 1999–2000 to 2002–03. *New Zealand Fisheries Assessment Report 2005/3*. 37 p.

Bagley N W; Ballara S L; O'Driscoll, R L; Fu, D; Lyon W (2013a) A review of hoki and middle depth summer trawl surveys of the Sub-Antarctic, November December 1991–1993 and 2000–2009. *New Zealand Fisheries Assessment Report 2013/41*. 63 p.

Bagley, N W; O'Driscoll, R L; Oeffner, J (2013b) Trawl survey of hoki and middle-depth species in the Southland and Sub-Antarctic areas, November–December 2011 (TAN1117). *New Zealand Fisheries Assessment Report 2013/23*. 70 p.

Bagley, N W; O'Driscoll, R L; Oeffner, J (2014) Trawl survey of hoki and middle-depth species in the Southland and Sub-Antarctic areas, November–December 2012 (TAN1215). *New Zealand Fisheries Assessment Report 2014/12*. 70 p.

Baird, S J (2005a) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Baird, S J (2005b) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/12*. 35 p.

Baird, S J (2011) New Zealand fur seals – summary of current knowledge *New Zealand Aquatic Environment and Biodiversity Report No. 72.* 51 p.

Baird, S J; Bagley, N W; Wood, B A; Dunn, A; Beentjes, M (2002) The spatial extent and nature of mobile bottom fishing methods within the New Zealand EEZ 1989–90 to 1998–99. Final Research Report for MFish Project ENV2000/05. 36 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J; Smith, M H (2007) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2003–04 and 2004–05. *New Zealand Aquatic Environment and Biodiversity Report* No. 9. 108 p.

Baird, S J; Smith, M H (2008) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2005–06. *New Zealand Aquatic Environment and Biodiversity Report* No. 18. 125 p.

Baird, S J (2005) Incidental capture of *Phocarctos hookeri (New* Zealand sea lions) in New Zealand commercial fisheries, 2002–03. *New Zealand Fisheries Assessment Report 2005/9.* 13 p.

Baird, S J; Wood, B (2010) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. Final Research Report prepared as part completion of Objective 5 of BEN200601 for the Ministry of Fisheries. 33 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J; Wood, B A; Bagley, N W (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report* No. 73. 143 p.

Baker, C S; Chilvers, B L; Childerhouse, S; Constantine, R; Currey, R; Mattlin, R; van Helden, A; Hitchmough, R; Rolfe, J (2016) Conservation status of New Zealand marine mammals, 2013. *New Zealand Threat Classification Series 14.* Department of Conservation, Wellington. 18 p.

Ballara, S L; Hurst, R J; Cordue, P L (1999) Estimates of natural mortality for hoki. Final Research Report for Ministry of Fisheries Project HOK9801 Objective 10. 11 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Ballara, S L; O'Driscoll, R L (2014) Catches, size, and age structure of the 2012–13 hoki fishery, and a summary of input data used for the 2014 stock assessment. *New Zealand Fisheries Assessment Report 2014/41.* 123 p.

Ballara, S L; O'Driscoll, R L (2015a) Catches, size, and age structure of the 2013–14 hoki fishery, and a summary of input data used for the 2015 stock assessment. *New Zealand Fisheries Assessment Report 2015/57.*

Ballara, S L; O'Driscoll, R L (2015b) Fish and invertebrate bycatch and discards in New Zealand hoki, hake, and ling fisheries from 1990–91 until 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 158.*

Ballara, S L; O'Driscoll, R L; Anderson, O F (2010) Fish discards and non-target fish catch in the trawl fisheries for hoki, hake, and ling in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 48*. 100 p.

Ballara, S L; O'Driscoll, R L; Bagley, N W; Stevens, D W; Fu, D (2008) Hoki data collation: a report to the 2008 Hoki Working Group on the hoki trawl and acoustic surveys, catches, CPUE, size, and age structure of the hoki fishery, including the 2005–06 data update. WG HOK 2008/03. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Ballara, S L; Phillips, N L; Smith, M H; Dunn, A (2006) Descriptive analysis of hoki (*Macruronus novaezelandiae*) fisheries on the west coast South Island, Cook Strait, Chatham Rise, and sub-Antarctic, and catch-per-unit-effort analysis of the Chatham Rise hoki fishery for the years 1990–2003. *New Zealand Fisheries Assessment Report 2006/19*. 57 p.

Black, J; Wood, R; Berthelsen, T; Tilney, R (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010. *New Zealand Aquatic Environment and Biodiversity Report* No. 110. 57 p.

Booth, J D; Baird, S J; Stevenson, M L; Bagley, N W; Wood, B A (2002) Review of technologies and practices to reduce bottom trawl bycatch and seafloor disturbance in New Zealand. Final Research Report for MFish Project ENV2000/06. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford, E (2002) Estimation of the variance of mean catch rates and total catches of non-target species in New Zealand fisheries. *New Zealand Fisheries Assessment Report 2002/54*. 60 p.

Bradford-Grieve, J M; Livingston, M E (Eds.) (2011) Spawning fisheries and the productivity of the marine environment off the west coast of the South Island, New Zealand. *New Zealand Aquatic Environment and Biodiversity Report* No. 84. 136 p.

Bradford-Grieve, J; Livingston, M E; Sutton, P; Hadfield, M (2007) Ocean variability and declining hoki stocks: an hypothesis as yet untested. *New Zealand Science Review* Vol. 63 (3–4): 76–80.

Bradford-Grieve, J M; Probert, P K; Baker, A N; Best, H A; Boyd; Broekhuizen, N; Childerhouse, S; Clark, M; Hadfield, M; Hall, J A; Hanchet, S; Nodder, S D; Safi, K; Thompson, D; Wilkinson, I; Zeldis, J (2003) Pilot trophic model for subantarctic water over the Southern Plateau, New Zealand: a low biomass, high transfer efficiency system. *Journal of Experimental Marine Biology* 289: 223–262.

Brander, K M (2005) Cod recruitment is strongly affected by climate when stock biomass is low. *ICES Journal of marine science* 62: 339–343.

Brothers, N; Duckworth, A R; Safina, C; Gilman, E L (2010) Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. PLoS ONE 5(8): e12491.

Bull, B (2000) An acoustic study of the vertical distribution of hoki on the Chatham Rise. *New Zealand Fisheries Assessment Report 2000/05*. 60 p.

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30-2012/03/21. *NIWA Technical Report* 135. 280 p.

Bull, B; Livingston, M E (2000) Hoki migration patterns: an analysis of commercial catches in New Zealand waters 1985–99. NIWA Client Report 2000/63. 49 p.

Bull, B; Livingston, M E (2001) Links between climate variation and the year class strength of New Zealand hoki (*Macruronus novaezelandiae)*: an update. *New Zealand Journal of Marine and Freshwater Research* 35(5). 871–880.

Bull, B; Livingston, M E; Hurst, R J; Bagley, N (2001) Upper-slope fish communities on the Chatham Rise, New Zealand, 1992–99. *New Zealand Journal of Marine and Freshwater Research* 35 (3): 795–815.

Butterworth, D; Hillary, R; Ianelli, J (2014) Report on the review of the New Zealand hoki stock assessment model. Unpublished report to MPI 4th March 2014 18p.

Clark, M R (1985a) The food and feeding of seven fish species from the Campbell Plateau, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 33: 339–363.

Clark, M R (1985b) Feeding relationships of seven fish species from the Campbell Plateau, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 19: 365–374.

Collie, J S; Hall, S J; Kaiser, M J; Poiner, I R (2000) A quantitative analysis of fishing impacts on shelf-sea benthos. *Journal of Animal Ecology* 69: 785–798.

Connell, A M; Dunn, M R; Forman, J (2010) Diet and dietary variation of New Zealand hoki *Macruronus novaezelandiae*. *New Zealand Journal of Marine and Freshwater Research* 44: 289–308.

Conservation Services Programme (2008) Summary of autopsy reports for seabirds killed and returned from observed New Zealand fisheries, 1 October 1996 - 30 September 2005, with specific reference to 2002/03, 2003/04, 2004/05. *DOC Research & Development Series* 291. Department of Conservation, Wellington. 110 p.

Coombs, R F; Cordue, P L (1995) Evolution of a stock assessment tool: acoustic surveys of spawning hoki (*Macruronus novaezelandiae*) off the west coast of South Island, New Zealand, 1985–91. *New Zealand Journal of Marine and Freshwater Research* 29: 175–194.

Cordue, P L (2001) MIAEL estimation of biomass and fishery indicators for the 2001 assessment of hoki stocks. *New Zealand Fisheries Assessment Report* 2001/65. 59 p.

Cordue, P L (2006) Report on the 13 November 2006 M-prior HWG sub-group meeting. Unpublished report to the Hoki Working Group, dated 17 November 2006. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cordue, P L (2014) ORH assessments: ESCR reference points and projections MEC further work and reference points DWWG 2014-69. Unpublished report to the Deepwater Working Group, dated 11 April 2014. (Unpublished report held by Ministry for Primary Industries, Wellington.)

De Juan, S; Thrush, S F; Demestre, M (2007) Functional changes as indicators of trawling disturbance on a benthic community located in a fishing ground (NW Mediterranean Sea*). Marine Ecology Progress Series* 334: 117–129.

Deepwater Group (2011) Operational Procedures: Hoki Fishery, v. 13 October 2011. http://deepwater.hosting.outwide.net/wp-content/uploads/2013/03/Operational-Procedures-Hoki-2013-14.pdf

Department of Internal Affairs. (2006) Seabird Scaring Devices – Circular Issued Under Authority of the Fisheries (Commercial Fishing) Amendment Regulations 2006 (No. F361). New Zealand Gazette 6 April 2006 : 842–846.

Dunford, A J; O'Driscoll, R L; Oeffner, J (2015) Improvements in estimating an acoustic target strength–length relationship for hoki (*Macruronus novaezeladiae*). *Fisheries Research 162*: 12–19.

Dunn, A; Livingston, M E (2004) Update catch-per-unit-effort indices and descriptive analyses for hoki (*Macruronus novaezelandiae*) fisheries on the west coast South Island, Cook Strait, Chatham Rise, and Sub-Antarctic, 1990 to 2002. *New Zealand Fisheries Assessment Report* 2004/35. 55 p.

Dunn, M; Connell, A; Stevens, D (2007) Preliminary results from Chatham Rise Trophic Study presented at Marine Science Conference, Nelson 2006.

Dunn, M; Horn, P (2010) Trophic relationships of hoki, hake, and ling on the Chatham Rise. Final Research Report for Ministry of Fisheries Project ENV2006-07. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Dunn, M; Horn, P; Connell, A; Stevens, D; Forman, J; Pinkerton, M; Griggs, L; Notman, P; Wood, B (2009a) Ecosystem-scale trophic relationships: diet composition and guild structure of middle-depth fish on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project ZBD2004-02, Objectives 1–5. 351 p.

Dunn, M; Hurst, R; Renwick, J; Francis, R I C C; Devine, J; McKenzie, A (2009b) Fish abundance and climate trends in New Zealand. *New Zealand Aquatic Environment and Biodiversity Report* No. 31.

Francis, M P; Duffy, C (2002) Distribution, seasonal abundance and bycatch of basking sharks (*Cetorhinus maximus*) in New Zealand, with observations on their winter habitat. *Marine Biology* 140(4): 831–842.

Francis, M P; Hurst, R J; McArdle, B; Bagley, N W; Anderson, O F (2002) New Zealand demersal fish assemblages. *Environmental Biology of Fishes* 62(2): 215–234.

Francis, M P; Smith, M H (2010) Basking shark (*Cetorhinus maximus*) bycatch in New Zealand fisheries, 1994–95 to 2007–08 *New Zealand Aquatic Environment and Biodiversity Report* 2010/49. 57 p.

Francis, M P; Sutton, P (2012) Possible factors affecting bycatch of basking sharks (*Cetorhinus maximus*) in NewZealand trawl fisheries. NIWA Client Report WLG2012-48 to The Department of Conservation. 38 p.

Francis, R I C C (2001) Improving the consistency of hoki age estimation. *New Zealand Fisheries Assessment Report 2001/12*. 18 p.

Francis, R I C C (2003) Analyses supporting the 2002 stock assessment of hoki. *New Zealand Fisheries Assessment Report 2003/5*. 34 p.

Francis, R I C C (2004a) Assessment of hoki (*Macruronus novaezelandiae*) in 2003. *New Zealand Fisheries Assessment Report 2004/15*. 95 p.

Francis, R I C C (2004b) Preliminary analyses for the 2004 hoki assessment. WG-Hoki-2004/9. 28p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Francis, R I C C (2005) Assessment of hoki (*Macruronus novaezelandiae*) in 2004. *New Zealand Fisheries Assessment Report 2005/35*. 97 p.

Francis, R I C C (2006) Assessment of hoki (*Macruronus novaezelandiae*) in 2005. *New Zealand Fisheries Assessment Report 2006/3*. 96 p.

Francis, R I C C (2007) Assessment of hoki (*Macruronus novaezelandiae*) in 2006. *New Zealand Fisheries Assessment Report 2007/15*. 99 p.

Francis, R I C C (2008a) Assessment of hoki (*Macruronus novaezelandiae*) in 2007. *New Zealand Fisheries Assessment Report 2008/4*. 109 p.

Francis, R I C C (2009) Assessment of hoki (*Macruronus novaezelandiae*) in 2008. *New Zealand Fisheries Assessment Report 2009/7*. 80 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences*. 68: 1124–1138.

Francis, R I C C; Hadfield, M G; Bradford-Grieve, J M; Sutton, P J H (2006) Links between climate and recruitment of New Zealand hoki (*Macruronus novaezelandiae*) now unclear. *New Zealand Journal of Marine and Freshwater Research* 40: 547–560.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Francis, R I C C; Neil, H L; Horn, P L; Gillanders, B; Marriott, P; Vorster, J (2011) A pilot study to evaluate the utility of otolith microchemistry for determining natal fidelity in New Zealand hoki Final Research Report for Ministry of Fisheries Research Project HOK2006/05 Objective 1. 24 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Grange, K (1993) Hoki offal dumping on the continental shelf: a preliminary benthic assessment. *NewZealand Marine Sciences Society Review* 35: 15.

Grimes, P J; O'Driscoll, R L (2006) Estimating the proportion of female hoki on the Southern Plateau which spawn each year by microscopic examination of gonad samples. Final Research Report for Ministry of Fisheries Project MDT2003/01 Objective 6. 40 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Haist, V; Hurst, R J; O'Driscoll, R L; Middleton, D A J (2007) Hoki codend retention study. Final report for Deepwater Group Ltd. Seafood Industry Council, October 2007. 26 p.

Helson, J; Leslie, S; Clement, G; Wells, R; Wood, R (2010) Private rights, public benefits: Industry driven seabed protection. *Marine Policy 34(3*): 557–566.

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series*, *260*, 97–108.

Hewitt, J; Floer, O; Bowden, D (2010) Challenger Plateau and Chatham Rise communities and habitats. Presentation to the Biodiversity research Advisory group April 2010 as part of Ministry of Fisheries project ZBD2007-01, Objectives 9, 10. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Hicks, A C; Cordue, P L; Bull, B (2002) Estimating proportion at age and sex in the commercial catch of hoki (*Macruronus novaezelandiae*) using length frequency data. *New Zealand Fisheries Assessment Report 2002/43*. 51 p.

Hicks, A C; Gilbert, D J (2002) Stock discrimination of hoki (*Macruronus novaezelandiae*) based on otolith ring measurements. *New Zealand Fisheries Assessment Report 2002/2*. 31 p.

Hicks, A C; Smith, P J; Horn, P L; Gilbert, D J (2003) Differences in otolith measurements and gill raker counts between the two major spawning stocks of hoki (*Macruronus novaezelandiae*) in New Zealand. *New Zealand Fisheries Assessment Report 2003/7*. 23 p.

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Science*s 63:721–36.

Hitchmough, R; Bull, L; Cromarty, P (Comps.) (2007) New Zealand Threat Classification System lists 2005. Wellington, Science & Technical Publishing, Department of Conservation. 194 p.

Horn, P L (2011) Natal fidelity: a literature review in relation to the management of the New Zealand hoki (*Macruronus novaezelandiae*) stocks. *New Zealand Fisheries Assessment Report 2011/34*. 18 p.

Horn, P L; Sullivan, K J (1996) Validated aging methodology using otoliths, and growth parameters for hoki (*Macruronus novaezelandiae*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research* 30: 161–174.

Hurst, R J; Bagley, N,W; Anderson, O F; Francis, M P; Griggs, L H; Clark, M R; Paul, L J; Taylor, P R (2000) Atlas of juvenile and adult fish and squid distributions from bottom and mid-water trawls and tuna longlines in New Zealand waters. *NIWA Technical Report* 84. 162 p.

Hurst, R J; Renwick, J A; Sutton, P J H; Uddstrom, M J; Kennan, S C; Law, C S; Rickard, G J; Korpela, A; Stewart, C; Evans, J (2012) Climate and ocean trends of potential relevance to fisheries in the New Zealand region. *New Zealand Aquatic Environment and Biodiversity Report No. 90*. 202 p.

Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology*, 70: 459–475.

Jones, J B (1993) Net damage injuries to New Zealand hoki, *Macruronus novaezelandiae*. *New Zealand Journal of Marine and Freshwater Research* 27: 23–30.

Kaiser, M J; Clarke, K R; Hinz, H; Austen, M C V; Somerfield, P J; Karakassis, I (2006) Global analysis of response and recovery of benthic biota to fishing. *Marine Ecology Progress Series* 311: 1–14.

Kaiser, M J; Collie, J S; Hall, S J; Jennings, S; Poiner, I R (2002) Modification of marine habitats by trawling activities: prognosis and solutions. *Fish and Fisheries* 3: 114–136.

Kalish, J M; Livingston, M E; Schofield, K A (1996) Trace elements in the otoliths of New Zealand blue grenadier (*Macruronus novaezelandiae*) as an aid to stock discrimination. *Marine and Freshwater Research* 47: 537–542.

Langley, A D (2001) Summary report of biological data collected from the hoki fishery by the Hoki Management Company Limited during the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2001/77*. 34 p.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J ;Hadfield, M; Currie, K; Goh, A (2009) Development of a benthic-optimised marine environment classification for waters within the New Zealand EEZ. Final Research Report prepared as part completion of Objective 5 of BEN200601 for the Ministry of Fisheries. 52 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Livingston, M E (1990a) Stock structure of New Zealand hoki, *Macruronus novaezelandiae*. New Zealand Fisheries Assessment Research Document 90/8. 21 p. (Unpublished report held by NIWA library, Wellington.)

Livingston, M E (1990b) Spawning hoki (*Macruronus novaezelandiae* Hector) concentrations in Cook Strait and off the east coast of the South Island, New Zealand, August–September 1987. *New Zealand Journal of Marine and Freshwater Research* 24: 503–517.

Livingston, M E (2000) Links between climate variation and the year class strength of New Zealand hoki (*Macruronus novazealandiae*) Hector. *New Zealand Journal of Marine and Freshwater Research* 34: 55–69.

Livingston, M E (2002) Potential interactions between New Zealand's hoki fishery and key components of the marine ecosystem and associated processes. NIWA Client Report WGTN 2002/53: 41 p.

Livingston, M E; Bull, B (2000) The proportion of female hoki developing to spawn on the Southern Plateau, April 1998. *New Zealand Fisheries Assessment Report 2000/13*. 20 p.

Livingston, M E; Bull, B; Gilbert, D J (2000) The observed sex ratios of hoki (*Macruronus novaezelandiae*) in New Zealand, 1983–99. *New Zealand Fisheries Assessment Report 2000/24*. 40 p.

Livingston, M E; Bull, B; Stevens, D W (2002) Migration patterns during the life-cycle of hoki (*Macruronus novaezelandiae*): an analysis of trawl survey data in New Zealand waters 1991–2002. Final Research Report for Ministry of Fisheries Research Project HOK2000/01 Objective 6. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Livingston, M E; Clark, M; Baird, S J (2003) Trends in incidental catch of major fisheries on the Chatham Rise for fishing years 1989–90 to 1998–99. *New Zealand Fisheries Assessment Report 2003/52*. 74 p

Livingston, M E; Pinkerton, M (2004) Sampling programme to construct and quantify food webs supporting important fish and invertebrate species in New Zealand waters. Final Research Report for Ministry of Fisheries Research Project ENV2002/07 Obj.1. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Livingston, M E; Renwick, J (2003) Climate change and implication for fisheries. *Seafood New Zealand* 11(11): 40–41.

Livingston, M E; Rutherford, K (1988) Hoki wastes on west coast fishing grounds. *Catch*, March 1988: 16–17.

Livingston, M E; Schofield, K A (1996a) Annual changes in the abundance of hoki and other species on the Chatham Rise, Jan 1992–Jan 1995 and the Southern Plateau, Dec 1991–Dec 1993. New Zealand Fisheries Assessment Research Document 1996/14. 35 p. (Unpublished report held by NIWA library, Wellington.)

Livingston, M E; Schofield, K A (1996b) Stock discrimination of hoki (*Macruronus novaezelandiae* Merlucciidae) in New Zealand waters, using morphometrics. *New Zealand Journal of Marine and Freshwater Research* 30: 197–208.

Livingston, M E; Schofield, K A; Sullivan, K J (1992) The discrimination of hoki groups in New Zealand waters using morphometrics and age-growth parameters. New Zealand Fisheries Assessment Research Document 1992/18. 30 p. (Unpublished report held by NIWA library, Wellington.)

Livingston, M E; Stevens, D W (2002) Review of trawl survey abundance data available as inputs to the hoki stock assessment. *New Zealand Fisheries Assessment Report 2002/48*. 69 p.

Livingston, M E; Stevens, D W; O'Driscoll, R L; Francis, R I C C (2004) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2003 (TAN0301). *New Zealand Fisheries Assessment Report 2004/16*. 71 p.

Livingston, M E; Vignaux, M; Schofield, K A (1997) Estimating the annual proportion of non-spawning adults in the New Zealand hoki, *Macruronus novaezelandiae* Hector. *Fishery Bulletin* 95: 99–113.

Lohrer, D A M; Trush, S F; Gibbs, M (2004) Bioturbators enhance ecosystem function through complex biogeochemical interactions. *Nature* 431: 1092–1095.
Macaulay, G J (2006) Target strength estimates of hoki. Final Research Report for Ministry of Fisheries Project HOK2004/03 Objective 3. 13 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)
MacDiarmid, A M; Thompson, D; Oliver, M (2005) Ecosystem Effects of the Hoki Trawl Fishery. NIWA Client Report: WLG2005- 77.
MacGibbon, D; O'Driscoll, R.; Ballara, S.; Doonan, I.; Bagley, N. (2017). Sub-Antarctic trawl survey of hoki & middle depth species Nov-Dec 2016 (TAN1614) DWWG2017-21. 31 p. (Unpublished report held by the Ministry for Primary Industries, Wellington).
MacKenzie, D; Fletcher, D (2006) Characterisation of seabird captures in commercial trawl and longline fisheries in New Zealand 1997/98 to 2003/04. Final Research Report for ENV2004/04, held by the Ministry for Primary Industries, New Zealand. 102 p.
Massey, B R; Hore, A J (1987) A preliminary trawl mesh selection study of barracouta (*Thyrsites atun*). Central Fisheries Region Internal Report No. 6. 28 p. (Unpublished report, held by Ministry for Primary Industries, Napier.)
McClatchie, S; Millar, R B; Webster, F; Lester, P J; Hurst, R; Bagley, N (1997) Demersal fish community diversity off New Zealand: Is it related to depth, latitude and regional surface phytoplankton? *Deep-Sea Research* I 44 (4): 647–667.
McClatchie, S; Pinkerton, M; Livingston, M E (2005) Relating the distribution of a semi-demersal fish, *Macruronus novaezelandiae*, to their pelagic food supply. *Deep- Sea Research* Part I 52: 1489–1501.
McKenzie, A (2011) Assessment of hoki (Macruronus novaezelandiae) in 2011. New Zealand Fisheries Assessment Report 2011/64. 52 p.
McKenzie, A (2013) Assessment of hoki (Macruronus novaezelandiae) in 2012. New Zealand Fisheries Assessment Report 2013/27. 65 p.
McKenzie, A (2015a) Assessment of hoki (Macruronus novaezelandiae) in 2013. New Zealand Fisheries Assessment Report 2015/08. 73 p.
McKenzie, A (2015c) Initial assessment results for hoki in 2015. DWWG2015-17. 20 p. (Unpublished report held by the Ministry for Primary Industries, Wellington).
McKenzie, A (2017a) Assessment of hoki (*Macruronus novaezelandiae*) in 2016. *New Zealand Fisheries Assessment Report 2017/11*. 84 p.
McKenzie, A. (2017b). Estimating the Sub-Antarctic trawl survey process error: some further explorations. Word document DWWG-2017-02.
McKenzie, A. (2017c). Initial MPD assessment results for hoki in 2017. Word document DWWG-2017-27.
McKenzie, A. (2017d). Follow-up on initial MPD assessment results for hoki in 2017. Word document DWWG-2017-37.
McKenzie, A. (2017e). Follow-up on initial MPD assessment results for hoki in 2017: supplement. PowerPoint presentation DWWG-2017-37c.
McKenzie, A; Francis, R I C C (2009) Assessment of hoki (*Macruronus novaezelandiae*) in 2009. *New Zealand Fisheries Assessment Report 2009/63.* 43 p.
McKnight, D G; Probert, P K (1997) Epibenthic communities on the Chatham Rise, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 31:505–513.
Middleton, D A J; Abraham, E R (2007) The efficacy of warp strike mitigation devices: Trials in the 2006 squid fishery. Final Research Report for research project IPA2006/02. (Unpublished report held by Ministry for Primary Industries, Wellington).
MPI (2013) Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand. 538 p.
MPI (2016) Aquatic Environment and Biodiversity Annual Review 2015. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand. 682 p.
Murdoch, R C (1990) Diet of hoki larvae (*Macruronus novaezelandiae*) off Westland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24: 519–527.
Murdoch, R C (1992) A review of the ecology of hoki *Macruronus novaezelandiae* (Hector), larvae in New Zealand waters. *Bureau of Rural Resources Proceedings* 15: 3–16.
Murdoch, R C; Guo, R; McCrone, A (1990) Distribution of hoki (*Macruronus novaezelandiae*) eggs and larvae in relation to hydrography in eastern Cook Strait, September 1987. *New Zealand Journal of Marine and Freshwater Research* 24: 533–543.
Norse, E A; Watling, L (1999) Impacts of mobile fishing gear: the biodiversity perspective. *American Fisheries Society Symposium* 22: 31–40.
O'Driscoll, R L (2002) Review of acoustic data inputs for the 2002 hoki stock assessment. *New Zealand Fisheries Assessment Report 2002/36*. 67 p.
O'Driscoll, R L (2004) Estimating uncertainty associated with acoustic surveys of spawning hoki *(Macruronus novaezelandiae*) in Cook Strait, New Zealand. *ICES Journal of Marine Science* 61: 84–97.
O'Driscoll, R L (2012) Acoustic survey of spawning hoki in Cook Strait during winter 2011. *New Zealand Fisheries Assessment Report 2012/17*. 50 p.
O'Driscoll, R L; Bagley, N W (2001) Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic area 1991–98. *NIWA Technical Report 102*. 115 p.
O'Driscoll, R L; Bagley, N W; Ballara, S L; Oeffner, J (2014) Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2012 (TAN1210). *New Zealand Fisheries Assessment Report 2014/9*. 102 p.
O'Driscoll, R L; Bagley, N W; Ballara, S L; Ladroit, Y (2015) Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2013 (TAN1308). *New Zealand Fisheries Assessment Report 2015/20*. 104 p.
O'Driscoll, R L; Bagley, N W; Macaulay, G J; Dunford, A J (2004) Acoustic surveys of spawning hoki off South Island on FV *Independent 1*in winter 2003. *New Zealand Fisheries Assessment Report 2004/29*. 48 p.
O'Driscoll, R L; Booth, J D; Bagley, N W; Anderson, O F; Griggs, L H; Stevenson, M L; Francis, M P (2003) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. *NIWA Technical Report* 119. 377 p.
O'Driscoll, R L; Hurst, R J; Dunn, M R; Gauthier, S; Ballara, S L (2011a) Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys. *New Zealand Aquatic Environment and Biodiversity Report 2011/76*. 99 p.
O'Driscoll, R; Hurst, R; Livingston, M; Cordue, P; Starr, P (2002) Report of Hoki Working Group technical meeting 8 March 2002. WG-HOK-2002/27. (Unpublished report held by the Ministry for Primary Industries, Wellington.)
O'Driscoll, R L; Ladroit, Y; Dunford, A J; MacGibbon, D J (2016) Acoustic survey of spawning hoki in Cook Strait during winter 2015 and update of acoustic q priors for hoki assessment modelling. *New Zealand Fisheries Assessment Report 2016/44*. 55 p.
O'Driscoll, R L; Macaulay, G J (2005) Using fish processing time to carry out acoustic surveys from commercial vessels. *ICES Journal of Marine Science* 62: 295–305.
O'Driscoll, R L; MacGibbon, D; Fu, D; Lyon, W; Stevens, D W (2011b) A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992–2010. *New Zealand Fisheries Assessment Report 2011/47*. 814 p.
Parker, S J; Grimes, P J; Smith, M H (2009) Reproductive status determination for hoki ovary samples using classification analysis. Final Research Report for Ministry of Fisheries Research Project SAP2008/08. 27 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)
Probert, P K; Grove, S L (1998) Macrobenthic assemblages of the continental shelf and upper slope off the west coast of South Island, New Zealand. *Journal of the Royal Society of New Zealand* 28:259–280.
Probert, P K; McKnight, D G (1993) Biomass of bathyal macrobenthos in the region of the Subtropical Convergence, Chatham Rise, New Zealand. *Deep-Sea Research* I 40: 1003–1007.

Probert, P K; McKnight, D G; Grove, S L (1997) Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. Aquatic Conservation: In, *Trophic Relationships in the Marine Environment*. Aberdeen University Press, Aberdeen, 439–452.

Reiss, H; Greenstreet, SPR; Seibe, K; Ehrich S; Piet GJ; Quirijns F; Robinson L; Wolff WK; Kronke I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. *Marine Ecology Progress Series* 394:201–213.

Rice, J (2006) Impacts of mobile bottom gears on seafloor habitats, species, and communities: a review and synthesis of selected international reviews. *CSAS Research Document* 2006/57. 35 p.

Richard, Y; Abraham, E R (2013) Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report* No. 109. 58 p.

Richard, Y.; Abraham, E.R. (2015). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report* No. 162. 85 p

Richard, Y.; E. R. Abraham; K. Berkenbusch (2017). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report.* 133 p.

Roberts, J M; Harvey, S M; Lamont, P A; Gage, J D; Humphery, J D (2000) Seabed photography, environmental assessment and evidence of deep-water trawling on the continental margin west of the Hebrides. *Hydrobiologia* 441: 173–183

Rutherford, J C; Roper, D S; Nagels, J W (1988) A preliminary study of the dispersion of hoki wastes and potential oxygen depletion off the west coast South Island. Unpublished Report prepared for Fisheries Research Division, MAFFISH, Wellington, by the Ministry of Works Water Quality Centre, Hamilton. 36 p.

Schofield, K A; Livingston, M E (1998) Ovarian development and the potential annual fecundity of western stock hoki (*Macruronus novaezelandiae)*. *New Zealand Journal of Marine and Freshwater Research* 32(1): 147–159.

Smith, M H (2004) Fitting priors for natural mortality and proportion of virgin hoki biomass in eastern stock. WG-HOK-2004/14. 7p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Smith, M H; Baird, S J (2009) Model-based estimation of New Zealand fur seal (*Arctocephalus forsteri*) incidental captures and strike rates for trawl fishing in New Zealand waters for the years 1994–95 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 40*. 90 p.

Smith, P J; Bull, B; McVeagh, S M (2001) Evaluation of meristic characters for determining hoki relationships. Final Research Report for Ministry of Fisheries Research Project HOK1999/05 Objective 1. 10 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Smith, P J; McVeagh, S M; Ede, A (1996) Genetically isolated stocks of orange roughy (*Hoplostethus atlanticus*), but not of hoki (*Macruronus novaezelandiae*), in the Tasman sea and southwest Pacific ocean around New Zealand*. Marine Biology* 125: 783–793.

Smith, P J; Patchell, G; Benson, P G (1981) Genetic tags in the New Zealand hoki *Macruronus novaezelandiae*. *Animal Blood Groups and Biochemical Genetics* 12: 37–45.

Snelder, T H; Leathwick, J R; Dey, K L; Rowden, A A; Weatherhead, M A; Fenwick, G D; Francis, M P; Gorman, R M; Grieve, J M; Hadfield, M G; Hewitt, J E; Richardson, K M; Uddstrom, M J; Zeldis, J R (2006) Development of an ecological marine classification in the New Zealand region. *Environmental Management, 39*: 12–29.

Stevens, D W; Hurst, R J; Bagley, N W (2011) Feeding habits of New Zealand fishes: a literature review and summary of research trawl database records 1960 to 2000. *New Zealand Aquatic Environment and Biodiversity Report* No. 85. 218 p.

Stevens, D W; O'Driscoll, R L; Ladroit, Y; Ballara, S L; MacGibbon, D J; Horn, P L (2015) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2014 (TAN1401). *New Zealand Fisheries Assessment Report 2015/19*. 119 p.

Sullivan, K J; Coombs, R F (1989) Hoki stock assessment 1989. *New Zealand Fisheries Assessment Research Document 1989/4*. 26 p.

Thompson, F N; Abraham, E. R (2009) Dolphin bycatch in New Zealand trawl fisheries, 1995–96 to 2006–07. *New Zealand Aquatic Environment and Biodiversity Report* No.36. 24 p.

Thompson, F N; Abraham, E R (2010a) Estimation of fur seal (*Arctocephalus forsteri*) bycatch in New Zealand trawl fisheries, 2002–03 to 2008–09 *New Zealand Aquatic Environment and Biodiversity Report No. 61*. 34 p.

Thompson, F N; Oliver, M D; Abraham, E R (2010b) Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995–96 to 2007–08 *New Zealand Aquatic Environment and Biodiversity Report No. 52*. 25 p.

Thompson, F N; Abraham, E R (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report* No. 80. 172 p.

Thompson, F N; Berkenbusch, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73 p.

Tuck, I; Cole, R; Devine, J (2009) Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report* No 42. 188 p.

Vignaux, M (1994) Catch per unit of effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. New Zealand Fisheries Assessment Research Document 1994/11. 29 p. (Unpublished report held by NIWA library, Wellington.)

Zeldis, J R; Murdoch, R C; Cordue, P L; Page, M J (1998) Distribution of hoki (*Macruronus novaezelandiae*) eggs, larvae and adults off Westland, New Zealand, and the design of an egg production survey to estimate hoki biomass. *Canadian Journal of Fisheries and Aquatic Science* 55: 1682–1694.