ORANGE ROUGHY, CHATHAM RISE AND SOUTHERN NEW ZEALAND (ORH 3B)

1. FISHERY SUMMARY

1.1 Commercial fisheries

Orange roughy are found in waters deeper than 750 m throughout Quota Management Area 3B. Historically, the main fishery has been concentrated on the Chatham Rise. Annual reported orange roughy catches in ORH 3B ranged between 24 000–33 000 t in the 1980s, progressively decreased from 1989–90 to 1995–96 because of a series of TACC reductions, were stable over the mid-1990s–mid-2000s and decreased further from 2005–2006 as TACCs were further reduced (Table 1 and Figure 1).

Table 1: Annual reported catches and TACCs of orange roughy from ORH 3B. (Catches from 1978–79 to 1985–86 are from Robertson & Mace 1988) and from 1986–87 to 2016–17 from Fisheries Statistics Unit and Quota Monitoring System data). ‡

Fishing year	Reported catch (t)	TACC (t)	Agreed catch limit (t) β
1979–80†	11 800	-	-
1980–81†	31 100	-	-
1981–82†	28 200	23 000	-
1982–83*	32 605	23 000	-
1983–84*	32 535	30 000	-
1984–85	29 340	30 000	-
1985–86	30 075	29 865	-
1986–87	30 689	38 065	-
1987–88	24 214	38 065	-
1988–89	32 785	38 300	-
1989–90	31 669	32 787	-
1990–91	21 521	23 787	-
1991–92	23 269	23 787	-
1992–93	20 048	21 300	-
1993–94	16 960	21 300	-
1994–95	11 891	14 000	-
1995–96	12 501	12 700	-
1996–97	9 278	12 700	-
1997–98	9 638	12 700	-
1998–99	9 372	12 700	-
1999–00	8 663	12 700	-
2000–01	9 274	12 700	-
2001–02	11 325	12 700	-
2002–03	12 333	12 700	-
2003–04	11 254	12 700	-
2004–05	12 370	12 700	-
2005–06	12 554	12 700	-
2006–07	11 271	11 500	-
2007–08	10 291	10 500	-
2008–09	8 758	9 420	-
2009–10	6 662	7 950	-
2010–11	3 486	4 610	3 860
2011–12	2 765	3 600	2 850
2012–13	2 515	3 600	2 850
2013–14	4 492	4 500	-
2014–15	4 747	5 000	-
2015–16	4 529	5 000	-
2016–17	4 486	5 197	-

† Catches for 1979–80 to 1981–82 are for an April–March fishing year.
* Catches for 1982–83 and 1983–84 are 15 month totals to accommodate the change over from an April–March fishing year to an October–September fishing year. The TACC for the interim season, March to September 1983, was 16 125 t.
‡ Catches from 1984–85 onwards are for a 1 October–30 September fishing year.
β Agreed, non-regulatory catch limits between industry and MPI, which includes 'shelving' (an agreement that transfers ACE to a third party to effectively reduce the catch without adjusting the TACC).

There have been major changes in the distribution of catch and effort over the history of this fishery (Table 2). Initially, it was confined to the Chatham Rise and, until 1982, most of the catch was taken from areas of relatively flat bottom on the northern slopes of the Rise (in the Spawning Box), between mid-June and mid-August, when the fish form large aggregations for spawning (Figure 2).

ORANGE ROUGHY (ORH 3B)

From 1983 to 1989 about one third of the catch was taken from the south and east Chatham Rise, where new fishing grounds developed on and around knolls and hill features. Much of the catch from these areas was taken outside the spawning season as the fishery extended to most months of the year.
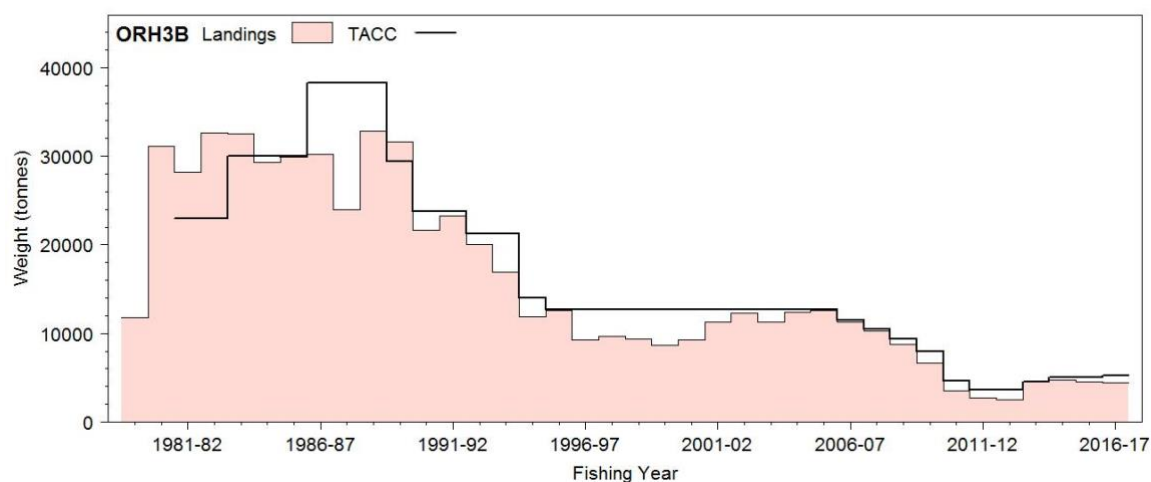

Figure 1: Reported commercial landings and TACCs for ORH 3B.

Table 2: **ORH 3B catches by area, to the nearest 10 t or 100 t, and by percentage (to the nearest percent) of the total ORH 3B reported catch. Catches are equivalent to those shown in Table 1, but allocated to area using the ratio of estimated catches, and revised such that all years are from 1 October–30 September. Note that catches for the East Rise are given by the sum of Spawning Box and Rest of East Rise.**

Year	Northwest Rise		South Rise		Spawning box		Rest of East Rise		Non-Chatham	
	t	%	t	%	t	%	t	%	t	%
1978–79	0	0	0	0	11 500	98	300	2	0	0
1979–80	1 200	4	800	3	27 900	90	1 200	4	0	0
1980–81	8 400	30	3 700	13	16 000	57	100	0	0	0
1981–82	7 000	28	500	2	16 600	67	800	3	0	0
1982–83	5 400	35	4 800	31	4 600	30	600	4	0	0
1983–84	3 300	13	5 100	21	15 000	61	1 500	6	0	0
1984–85	1 800	6	7 900	27	18 400	63	1 100	4	0	0
1985–86	3 700	12	5 300	18	17 000	56	4 100	13	0	0
1986–87	3 200	10	4 900	16	20 200	66	2 400	8	0	0
1987–88	1 600	7	6 800	28	13 500	56	2 300	10	0	0
1988–89	3 800	12	9 200	28	16 700	51	3 100	9	0	0
1989–90	3 300	10	11 000	35	16 200	51	1 100	3	200	1
1990–91	1 500	7	6 900	32	6 100	28	6 100	29	900	4
1991–92	300	1	2 200	9	1 000	4	12 000	51	7 800	34
1992–93	3 800	19	5 400	27	100	0	4 700	23	6 100	30
1993–94	3 500	21	5 100	30	0	0	4 900	29	3 500	20
1994–95	2 400	20	1 600	13	500	5	3 500	30	3 800	32
1995–96	2 400	19	1 300	10	1 600	13	2 200	17	5 000	40
1996–97	2 200	24	1 400	15	1 700	19	1 900	21	1 900	21
1997–98	2 300	23	1 700	17	2 400	24	2 200	22	1 600	16
1998–99	2 700	28	1 200	13	1 100	11	2 500	27	1 900	21
1999–00	2 100	24	1 100	13	1 500	17	3 100	36	800	9
2000–01	2 600	27	1 700	18	1 200	13	2 300	24	1 500	17
2001–02	2 200	19	1 100	10	3 100	28	3 600	31	1 300	12
2002–03	2 200	19	1 500	13	3 200	27	3 900	33	1 500	7
2003–04	2 000	18	1 400	12	4 300	38	2 600	23	1 000	9
2004–05	1 600	13	1 700	14	4 100	33	3 000	24	2 000	16
2005–06	1 400	11	1 300	10	3 900	31	3 900	31	2 100	16
2006–07	700	7	1 200	11	4 200	37	3 700	32	1 500	16
2007–08	800	8	1 300	13	3 800	37	2 700	26	1 600	16
2008–09	750	8	1 170	14	3 400	39	2 150	25	1 290	15
2009–10	720	11	940	14	3 120	47	1 260	19	620	9
2010–11	40	1	460	13	1 860	53	740	21	380	11
2011–12	70	3	300	11	1 520	55	770	28	100	3
2012–13	110	4	290	12	1 450	58	590	24	70	3
2013–14	800	18	500	12	1 420	33	1 240	29	540	12
2014–15	800	17	370	8	1 990	43	700	15	630	14
2015–16	700	16	360	8	1 220	28	1 800	42	460	11
2016–17	730	16	530	12	1 310	29	1 150	26	590	13

In the early 1990s, effort within the Chatham Rise further shifted from the Spawning Box to eastern and northwestern parts of the Rise. The Spawning Box was closed to fishing from 1992–93 to 1994–

95. In more recent years, catches from the main fishing grounds on the Chatham Rise have declined due to TACC reductions.

The early 1990s also saw the Puysegur fishery develop, followed by other fishing grounds near the Auckland Islands and on the Pukaki Rise, which was also a focus for the fishery south of the Chatham Rise.

Since 1992–93, the distribution of the catch within ORH 3B has been affected by a series of catch-limit agreements between the fishing industry and the Minister responsible for fisheries. Initially, the agreement was that at least 5 000 t be caught south of 46° S. Subsequently, the catch limits, and the designated sub-areas to which they apply, have changed from year to year.

The TACC was reduced to 3 600 t in 2011–12 (Table 1). The agreed catch limit for the East and South Chatham Rise is currently 3 100 t (Table 3). A three-year staged process to reduce F to F_{MSY} was initiated on 1 October 2008. Under this approach, the catch limit was to be set at 4.5% ($F_{MSY} = M$) of the estimated current biomass in each year from 1 October 2010. However, for 2013–14 the TACC was increased to 4500 t (Table 1) in response to the increased biomass estimates following the discovery of the Rekohu plume.

The catch limit for the Sub-Antarctic has been substantially undercaught since 2009–10. However, the combined East and South Rise sub-area catch limits were exceeded by 450 t in 2005–06 and by 350 t in 2006–07 (100 t were taken against the allowance for research surveys). Taking the research allowance into account, catch limits for the combined east and south Rise sub-area have not been exceeded in subsequent years. Since 2004–05, 250 t of the ORH 3B TACC has been set aside for industry research surveys (Table 3), although this has sometimes been used in areas outside the East and South Chatham Rise.
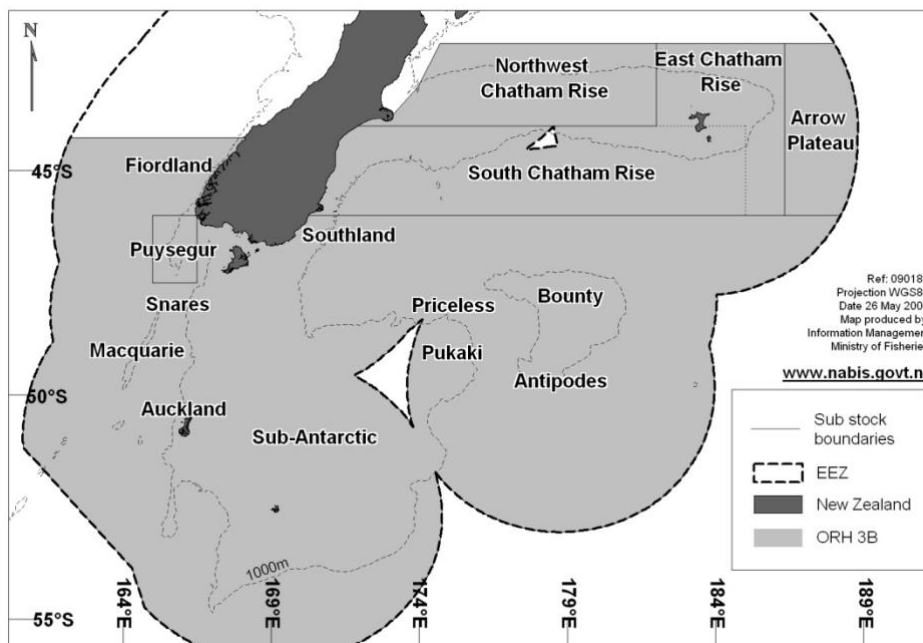

Figure 2: ORH 3B sub-areas and the approximate position of other named fisheries outside of the Chatham Rise. The Spawning Box is in the western part of the East Rise (to the west of the vertical broken line at 175°W). The East and South Rise are currently managed as a single unit. The Arrow Plateau has been designated a Benthic Protected Area. The Sub-Antarctic is all areas below 46°S on the east coast, and 44°16'S on the west coast, except Puysegur.

Table 3: Catch limits (t) by designated sub-area within ORH 3B, as agreed between the industry and the Ministers responsible for fisheries since 1992–93. Note that East Rise includes the Spawning Box, closed between 1992–93 and 1994–95. Sub-area boundaries have varied somewhat between years. * South Rise included in East Rise catch limit. ** Arrow Plateau included in Sub-Antarctic.

Year	Northwest Chatham Rise	East Chatham Rise	South Chatham Rise	Puysegur	Arrow Plateau	Sub-Antarctic
1992–93	3 500	4 500	6 300	5 000	-	2 000
1993–94	3 500	4 500	6 300	5 000	-	2 000
1994–95	2 500	3 500	2 000	2 000	3 000	1 000
1995–96	2 250	4 950	*	1 000	**	4 500
1996–97	2 250	4 950	*	500	**	5 000
1997–98	2 250	4 950	*	0	1 500	4 000
1998–99	2 250	4 950	*	0	1 500	4 000
1999–00	2 250	4 950	*	0	1 500	4 000
2000–01	2 250	4 950	*	0	1 500	4 000
2001–02	2 000	7 000	1 400	0	1 000	1 300
2002–03	2 000	7 000	1 400	0	1 000	1 300
2003–04	2 000	7 000	1 400	0	1 000	1 300
2004–05†	1 500	7 250	1 400	0	1 000	1 300
2005–06†	1 500	7 250	1 400	0†	1 000	1 300
2006–07	750	8 650‡	*	0	0	1 850
2007–08†	750	7 650#	*	0	0	1 850
2008–09†	750	6 570§	*	0	0	1 850
2009–10†	750	5 100	*	0	0	1 850
2010–11	750β	2 960†	*	150	0	500
2011–12	750β	1 950†	*	150	0	500
2012–13	750 β	1 950†	*	150	0	500
2013–14	750	3 100	*	150	0	500
2014–15	1 250 δ	3 100	*	150	0	500
2015–16	1 250 δ	3 100	*	150	0	500
2016–17	1 250 δ	3 100	*	347	0	500

† an additional 250 t set aside for industry research surveys.

‡ 8650 t allocated to the East and South Chatham Rise combined, with no more than 2000 t from the South Rise, and no more than 7250 t from the East Rise.

Combined East and South Rise catch not to exceed 7650 t; East Rise not to exceed 6500 t; South Rise catch not to exceed 1750 t.

§ In 2008–09, the catch from the spawning plume was not to exceed 3285 t.

β From 2010–11 to 2012–13, quota owners agreed to avoid fishing the Northwest Rise.

δ Quota owners agreed to shelve 207 tonnes of Northwest Chatham Rise ACE for 2014–15 to 2017–18. This left 1043 tonnes available to catch.

Outside the Spawning Box, catches increased in the 1990s and catch rates have been highly variable, sustained largely by the discovery of new fishing areas. Flat areas on the Northwest Rise and several major hills on the South Rise were important in the late 1980s, but currently do not support their previous levels of catch, now accounting for less than 5% of the estimated catch (Table 4). High catch rates can still occur, but these are less frequent than observed in the early years of the fishery. Catches from the Northwest Rise fell to near zero in 2010–11 as a result of an agreement among quota owners to avoid fishing in this area (Table 2). This agreement was extended to the 2011–12 and 2012–13 fishing years. Quota owners then agreed to shelve 207 tonnes of Northwest Chatham Rise ACE for 2014–15 to 2017–18.

Between 1991–92 and 2000–01, more than half of the Chatham Rise catch came from four hill complexes: the Andes, Smith City and neighbours, Graveyard, and Big Chief and neighbours (Table 4). All of these have shown a decline in unstandardised catch rate since the early years of the fishery, and in recent years, catch rates in these hill complexes have remained relatively low. After 2000–01, the proportion of the catch from these hill complexes decreased, as a greater proportion of the catch came from the Spawning Box (about 39% in 2008–09). In addition, large catches have been made in recent years outside of the spawning season, in recently developed areas of the southeast Rise. Catches from the Spawning Box taken during the spawning season (which peaks in July) have been relatively high since 2001–02, although unstandardised catch rates have been variable (Table 4).

Table 4: Orange roughy estimated catches (to nearest 10 t) and unstandardised median catch rates (to nearest 0.1 t/tow) for four important hill complexes and the Spawning Box In season (spawning plume area, May-August) and Out season (September-April) on the Chatham Rise (letters indicating subareas, as in Table 3, in parentheses), using catch and effort data held by NIWA. Only tows targeted at orange roughy are included. (Approximate positions are: Big Chief, 44.7 S, 175.2 W; Smiths City and near-neighbours, 43.1 S, 174.2 W; Andes, 44.2 S, 174.6 W; Graveyard, 42.8 S, 180 W). -, catch < 10 t (2016–17 data are provisional, and catch totals are possibly incomplete). - means catch < 10 t. NA means catch >10 t but there were fewer than 3 vessels in the fishery.

	Andes (E)			Smith's City NE Hills (E)			Spawning Box In (E)			Spawning Box Out (E)		
Year	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow
1979–80	-	-	-	110	36	3.1	9 800	968	10.7	7 400	795	6.1
1980–81	-	-	-	-	2	-	11 100	890	11.5	6 240	462	11.5
1981–82	-	-	-	40	11	3.6	4 750	470	4.5	4 450	604	4.9
1982–83	-	-	-	40	2	17.8	3 980	227	13.4	3 840	386	8.1
1983–84	-	-	-	60	7	6.3	6 590	378	13.4	8 630	836	7.7
1984–85	-	-	-	10	3	3.2	9 320	676	10.4	7 460	537	10.0
1985–86	-	-	-	670	52	11.4	8 521	659	10.0	7 650	859	6.1
1986–87	-	-	-	210	34	3.9	8 090	597	8.9	12 010	1 036	6.2
1987–88	-	-	-	160	33	4.5	7 870	622	8.0	5 820	701	5.1
1988–89	30	18	0.3	310	48	3.9	7 070	598	9.6	6 500	811	5.0
1989–90	90	13	1.5	40	9	4.0	6 830	403	12.5	4 960	602	5.3
1990–91	80	12	3.2	4 890	633	3.5	2 820	238	8.0	2 810	206	8.0
1991–92	7 080	724	5.0	1 270	222	2.0	650	85	6.0	300	54	5.7
1992–93	2 940	345	5.0	600	84	2.0	50	2	27.0	-	-	-
1993–94	3 320	605	1.8	560	109	2.8	-	-	-	-	-	-
1994–95	1 650	573	1.0	1 140	345	1.0	490	86	0.3	10	25	0.1
1995–96	1 120	418	0.5	410	145	1.0	1 360	127	5.0	140	27	0.8
1996–97	730	260	1.0	720	164	1.0	930	101	3.0	620	130	2.3
1997–98	1 140	476	0.5	400	146	0.4	1 580	118	6.0	630	148	1.1.65
1998–99	1 260	448	1.0	810	272	1.0	510	73	2.7	490	139	2.0
1999–00	1 990	529	1.0	680	210	0.8	910	34	25.0	510	111	2.0
2000–01	980	354	1.1	650	191	1.0	810	59	5.5	430	123	2.0
2001–02	2 040	546	1.5	490	167	0.9	2 120	159	4.0	980	222	1.8
2002–03	2 230	872	1.0	400	124	0.5	2 150	166	8.0	1 000	216	2.3
2003–04	1 170	677	0.5	360	160	0.8	1 880	163	6.0	1 050	278	2.5
2004–05	1 090	518	0.6	310	127	0.9	1 910	214	4.4	850	230	3.8
2005–06	1 340	727	0.5	370	119	0.7	1 630	117	9.0	1 740	257	2.6
2006–07	1 160	583	0.5	570	201	0.7	1 980	121	11.2	1720	356	2.5
2007–08	N/A	N/A	N/A	N/A	N/A	N/A	2 550	200	5.0	750	192	3.0
2008–09	N/A	N/A	N/A	N/A	N/A	N/A	2 020	121	18.0	1 010	209	2.4
2009–10	440	243	0.5	160	84	0.5	1 980	136	8.5	850	248	1.7
2010–11	460	151	1.2	90	27	0.4	1 230	75	15.0	70	28	2.0
2011–12	450	164	1.0	130	26	0.5	660	39	22.5	80	24	3.8
2012–13	N/A	N/A	N/A	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A
2013–14	790	218	1.0	140	39	0.9	390	40	4.9	30	18	2.0
2014–15	460	162	1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2015–16	1 180	437	0.4	130	75	0.2	N/A	N/A	N/A	390	96	3.0
2016–17	700	407	0.3	68	36	0.4	0	0	0	320	104	1.7

	Rest of East (E)			Graveyard (NW)			Rest of Northwest (NW)			Hegerville (S)		
Year	Catc	Tow	t/to	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow
1979–80	560	206	2.2	-	-	-	840	81	7.7	20	2	8.1
1980–81	30	10	3.5	50	7	4.0	7 960	2 074	2.3	980	235	3.3
1981–82	360	77	4.0	90	12	6.4	3 830	616	4.4	40	9	4.3
1982–83	1 030	63	8.5	90	11	5.0	8 500	1 484	3.6	7 440	856	7.1
1983–84	1 190	139	6.4	-	-	-	2 780	657	2.9	3 370	493	4.5
1984–85	990	80	9.5	-	-	-	1 640	314	3.3	5 660	824	4.5
1985–86	3 030	306	8.1	30	11	2.5	3 400	564	2.8	3 660	840	1.8
1986–87	1 950	296	4.6	30	11	2.0	2 920	660	2.3	2 470	601	1.6
1987–88	2 100	324	5.3	130	19	4.7	1 360	386	2.4	2 020	673	0.8
1988–89	2 080	299	4.5	130	25	3.2	2 780	782	1.8	1 170	568	0.6
1989–90	360	86	3.0	160	28	5.5	2 100	602	2.0	470	237	0.6
1990–91	480	87	1.0	10	2	4.2	1 230	261	2.6	170	75	0.3
1991–92	3 050	366	5.0	70	25	1.3	180	60	2.0	30	52	< 0.1
1992–93	570	75	2.0	3 300	297	5.1	170	69	1.4	290	83	1.5
1993–94	510	122	1.9	2 180	363	1.9	1 120	213	1.0	220	129	0.5
1994–95	440	195	1.0	1 510	363	1.0	720	268	1.0	100	95	< 0.1
1995–96	450	120	0.5	1 790	355	1.0	430	212	0.8	80	104	< 0.1
1996–97	370	117	1.0	870	243	0.5	1 210	400	2.0	170	75	0.2
1997–98	450	259	0.3	830	305	0.4	1 290	487	1.0	60	52	0.1
1998–99	350	214	0.3	930	186	0.5	1 510	550	1.0	50	1	0.5
1999–00	390	162	0.3	630	239	0.5	1 280	353	1.0	50	10	0.3
2000–01	580	155	1.0	1 010	301	0.5	1 310	613	1.0	100	21	3.0
2001–02	900	240	1.1	730	206	0.9	1 260	645	0.8	30	18	0.6
2002–03	1 280	397	0.8	1 080	253	0.8	1 050	593	0.8	150	42	1.4
2003–04	840	394	0.6	740	126	0.7	1 030	586	1.0	100	48	0.4
2004–05	1 330	405	0.9	920	170	1.1	560	331	0.7	100	23	2.2
2005–06	1 810	533	0.8	960	188	0.6	380	238	0.7	90	53	0.5
2006–07	1 540	573	0.9	590	78	1.8	80	29	0.2	160	38	0.6
2007–08	N/A	N/A	N/A	390	176	0.6	320	109	0.8	280	107	0.6
2008–09	1 170	443	1.0	390	75	1.3	280	110	0.5	500	182	0.5

Table 4 [continued]

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Year	Catch	Tow	t/tow	Catch	Tow	t/tow	Catch	Tow	t/tow	Catch	Tow	t/tow
2009–10	560	217	1.2	290	90	0.8	360	193	1.2	470	120	1.0
2010–11	130	43	0.6	N/A	N/A	N/A	30	5	1.0	150	32	2.0
2011–12	120	61	0.7	-	-	-	30	4	1.5	N/A	N/A	N/A
2012–13	N/A	N/A	N/A	-	-	-	30	7	1.6	N/A	N/A	N/A
2013–14	260	82	1.0	570	102	1.1	110	67	0.7	N/A	N/A	N/A
2014–15	200	52	1.4	550	164	0.5	180	106	0.7	-	-	-
2015–16	360	263	0.3	400	165	0.5	180	215	0.5	-	-	-
2016–17	269	154	0.4	187	137	0.5	473	329	0.7	21	34	0.1

	Big Chief (S)			Rest of South (S)			Rekohu		
Year	Catc	Tow	t/to	Catc	Tow	t/to	Catch	Tow	t/to
1979–80	-	-	-	20	12	< 0.1	30	8	3.1
1980–81	-	-	-	110	25	3.4	60	4	14.1
1981–82	-	-	-	30	28	1.1	-	-	-
1982–83	-	-	-	180	31	< 0.1	30	4	3.9
1983–84	-	-	-	120	86	0.1	-	-	-
1984–85	-	-	-	870	289	0.6	-	-	-
1985–86	-	-	-	530	198	0.6	40	2	2.3
1986–87	-	-	-	1 440	433	1.1	N\A	N/A	N/A
1987–88	-	-	-	3 180	924	0.7	40	5	0.4
1988–89	1 010	199	1.7	4 650	1	0.3	60	5	0.6
1989–90	2 830	529	1.5	4 090	1	1.0	N/A	N/A	N/A
1990–91	3 150	453	2.1	1 620	500	0.3	N/A	N/A	N/A
1991–92	820	138	2.5	780	308	0.3	-	-	-
1992–93	3 310	703	2.0	1 190	462	< 0.1	-	-	-
1993–94	2 350	698	0.6	2 060	1	0.1	-	-	-
1994–95	510	242	0.8	880	937	< 0.1	-	-	-
1995–96	580	151	1.0	460	553	< 0.1	-	-	-
1996–97	560	195	0.5	440	304	< 0.1	-	-	-
1997–98	950	285	0.4	410	503	0.1	-	-	-
1998–99	560	215	0.5	390	258	0.3	-	-	-
1999–00	380	123	0.5	430	173	0.5	-	-	-
2000–01	1 020	213	0.8	400	203	0.5	-	-	-
2001–02	660	234	0.9	280	186	0.5	-	-	-
2002–03	660	276	0.5	480	204	0.5	-	-	-
2003–04	570	300	0.5	460	266	0.4	1 030	151	4.0
2004–05	790	308	0.5	490	231	0.6	1 030	200	2.9
2005–06	500	303	0.4	400	281	0.4	160	65	1.1
2006–07	510	282	0.4	200	187	0.3	80	43	0.7
2007–08	690	335	0.5	170	189	0.3	N/A	N/A	N/A
2008–09	330	307	0.2	120	158	0.1	N/A	N/A	N/A
2009–10	180	121	0.3	40	68	0.2	60	28	1.3
2010–11	210	60	0.5	30	34	< 0.1	400	31	6.5
2011–12	180	72	0.5	10	20	0.5	670	36	19.5
2012–13	N\A	N\A	N\A	50	19	0.3	710	39	25.0
2013–14	350	77	1.0	90	40	0.9	950	40	24.2
2014–15	250	56	0.9	40	11	0.5	1 780	89	21.7
2015–16	190	159	0.1	110	61	0.1	700	54	10.8
2016–17	393	139	0.2	69	74	0.1	868	115	5.0

Table 5: **Estimated ORH 3B catches (to the nearest 10 t) and unstandardised median catch rates (to nearest 0.1 t/tow) for areas outside the Chatham Rise, using estimated catch and effort data held by NIWA. Only tows targeted at orange roughy are included. For this table the areas were defined by the following rectangles: Arrow - 42.17-46°S, 173.67°W; Auckland - 49-52 °S, 165-167 °E; Bounty - 46-47.5°S, 177.5-180°E; Priceless - 48-48.44°S, 174.7-175.2°E; Other Pukaki - 47-50.4°S, 174-176.4°E (and not in Priceless); Puysegur - 46-47.5 °S, 165-166.5 °E. The area described as Antipodes in previous reports is now included in Other Pukaki. All years are from 1 October-30 September (2016-17 data are provisional and catch totals may be incomplete). - means catch < 10 t. N/A means catch greater than 10 t, but there were fewer than 3 vessels in the fishery.**

	Arrow		Auckland		Bounty		Priceless		Other Pukaki		Puysegur		Other	
Year	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow	Catch	t/tow
1985–86	120	18.5	-	-	-	-	-	-	-	-	-	-	-	-
1986–87	110	10.6	-	-	-	-	-	-	-	-	-	-	-	-
1987–88	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1988–89	-	-	-	-	-	-	-	-	-	-	-	-	30	<0.1
1989–90	-	-	-	-	-	-	-	-	-	-	100	1.4	50	6.0
1990–91	150	4.5	-	-	-	-	-	-	-	-	600	4.6	20	<0.1
1991–92	100	10.0	-	-	-	-	-	-	-	-	6 320	10.6	170	0.6
1992–93	10	6.5	30	< 0.1	-	-	-	-	-	-	4 280	6.7	330	< 0.1
1993–94	470	1.0	180	< 0.1	-	-	-	-	-	-	2 410	1.9	80	< 0.1
1994–95	750	0.3	880	0.2	-	-	-	-	-	-	1 260	7.9	20	< 0.1
1995–96	170	0.1	370	0.1	-	-	-	-	3 060	5.0	730	2.4	520	< 0.1
1996–97	280	0.1	120	< 0.1	20	< 0.1	-	-	670	< 0.1	490	2.6	400	< 0.1
1997–98	330	0.1	360	0.1	240	< 0.1	10	< 0.1	130	< 0.1	-	-	1 050	< 0.1
1998–99	730	0.3	440	0.1	130	0.1	-	-	120	< 0.1	-	-	1 820	0.5

Table 5 [continued]

1999–00	280	0.1	150	< 0.1	170	< 0.1	-	-	-	-	-	-	60	< 0.1
2000–01	190	0.1	60	< 0.1	150	0.3	-	-	20	< 0.1	-	-	1 030	0.3
2001–02	70	0.2	130	0.1	40	0.1	550	22.3	-	-	-	-	460	0.4
2002–03	220	0.2	-	-	220	1.5	480	7.0	-	-	-	-	400	0.4
2003–04	140	0.1	-	-	90	0.2	450	0.3	-	-	-	-	440	< 0.1
2004–05	60	0.1	-	-	100	0.4	540	0.3	520	9.8	N/A	N/A	550	< 0.1
2005–06	100	0.1	-	-	40	0.2	540	0.9	740	4.0	N/A	N/A	250	< 0.1
2006–07	-	-	-	-	-	-	470	0.5	N/A	N/A	-	-	-	-
2007–08	-	-	N/A	N/A	-	-	N/A	N/A	N/A	N/A	-	-	-	-
2008–09	-	-	N/A	N/A	-	-	N/A	N/A	N/A	N/A	-	-	150	0.5
2009–10	-	-	N/A	N/A	N/A	N/A	210	< 0.1	320	0.3	-	-	60	< 0.1
2010–11	-	-	N/A	N/A	N/A	N/A	-	-	N/A	N/A	-	-	20	0.4
2011–12	-	-	N/A	N/A	-	-	-	-	-	-	-	-	-	-
2012–13	-	-	N/A	N/A	-	-	-	-	N/A	N/A	-	-	-	-
2013–14	-	-	N/A	N/A	-	-	-	-	-	-	-	-	-	-
2014–15	-	-	350	< 0.1	-	-	-	-	-	-	-	-	-	-
2015–16	-	-	380	0.6	-	-	-	-	-	-	N/A	N/A	-	-
2016–17	-	-	184	0.3	N/A	N/A	-	-	N/A	N/A	N/A	N/A	N/A	N/A

The first fishery to be developed south of the Chatham Rise was on Puysegur Bank, where spawning aggregations of orange roughy were found during a joint Industry-Ministry exploratory fishing survey in 1990–91. The fishery developed rapidly, but from 1993–94 catch limits were substantially under-caught. Catch limits were subsequently reduced from the initial level of 5 000 t, and the industry implemented a catch limit of 0 t beginning in the 1997–98 fishing year (reported catches in 2004–05 and 2005–06 were taken during industry surveys). A catch limit of 150 t was provided for research purposes in Puysegur from 2010-11 (Table 3). Following a stock assessment of Puysegur in 2017, a commercial catch limit was set at 347 t from 1 October 2017.

Exploratory fishing on the Macquarie Ridge south of Puysegur in 1993 led to the development of a fishery off the Auckland Islands. Total catch rose to around 900 t in 1994–95, but then dropped to less than 200 t by 1999–00, and catches remained low until an increase in 2013–14. In 1993–94, catches were taken on the 'Arrow Plateau', and became the first major fishery to develop on the easternmost section of the Chatham Rise. A catch limit of 3 000 t was put in place for 1994–95, with an additional limit of 500 t for each hill. Only a few hills in this area have been fished successfully, and the catch has never reached the catch limit, which was reduced to 1 000 t by the early 2000s (Table 3). The Arrow Plateau was closed to orange roughy fishing when it was designated a Benthic Protected Area in 2007 Table 5).

In 1995–96, large catches were reported on the southeast Pukaki Rise, with a catch total of over 3 000 t. However, the catches dropped rapidly and the fishery effectively ceased within a few years. From 2001–02, a fishery developed on the northeast Pukaki Rise, including the area known as Priceless, where catches were mostly taken at the start of the fishing year. Catches at Priceless reached the feature limit of 500 t for each of the six years up to 2006–07, but catches and catch rates declined substantially from 2007–08, and have remained low since. Areas of the northeast Pukaki Rise outside of Priceless were developed in 2004–05 and also showed a rapid decline in catches and catch rates. By 2007–08, the fishery in the sub-Antarctic was limited to the Auckland Islands and northeast Pukaki Rise areas. From 2008–09 the fishery extended over a relatively wide area, but catches and catch rates were low, and the fishery effectively ceased from 2010–11 (Table 5).

Catches of orange roughy have also been taken off the Bounty Islands (around 100–200 t per year from 1997–98 to 2004–05, but infrequently since then, and none since 2011–12) (Table 5), off the Snares Islands (up to around 500 t per year, but infrequently in recent years), areas of the Macquarie Ridge (100–500 t per year from 2000–01 to 2004–05, and in 2008–09), and off Fiordland (around 500 t in 2000–01, but subsequent catches rapidly decreased).

1.2   Recreational fisheries
No recreational fishing for orange roughy is known in this quota management area.

1.3   Customary non-commercial fisheries
No customary non-commercial fishing for orange roughy is known in this quota management area.
1.4   Illegal catch

No information is available on illegal catch in this quota management area.

1.5 Other sources of mortality

There has been a history of catch overruns on the Chatham Rise because of lost fish and discards, and discrepancies in tray weights and conversion factors. In assessments, total removals from each part of the Chatham Rise were assumed to exceed reported catches by the overrun percentages in Table 6. For Puysegur and other southern fisheries there is no reason to believe that, if there was an overrun in catches, this shows any trend over time. For this reason, it was assumed that there was no overrun for this area.

Table 6: Chatham Rise catch overruns (%) by year.

Year	1978–79	1979–80	1980–81	1981–82	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88
Overrun	30	30	30	30	30	30	30	28	26	24
Year	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95 and subsequently			
Overrun	22	20	15	10	10	10	5			

Within the TAC an allowance of 5% of the TACC is allocated for other sources of mortality (currently 225 t).

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy section.

3. STOCKS AND AREAS

For the purposes of this report the term "stock" refers to a biological unit with a single major spawning ground, in contrast to a "Fishstock" which refers to a management unit.

Genetically two main stocks are recognised within ORH 3B (Chatham Rise and Puysegur; Smith & Benson 1997) and these are considered to be distinct from stocks in adjacent areas (Cook Canyon and Ritchie Bank). However, it is likely, because of their geographical separation and discontinuities in the distribution of orange roughy, that concentrations of spawning fish on the Arrow Plateau, near the Auckland Islands, and west of the Antipodes Islands also form separate stocks.

Genetic data have been applied to define stock boundaries, both within ORH 3B, and between it and adjacent areas. Mitochondrial DNA shows that there are considerable differences between Puysegur fish and fish from the geographically adjacent areas Cook Canyon and Chatham Rise. Allozyme frequency studies suggest that Chatham Rise fish are distinct from those on the Ritchie Bank (ORH 2A). These data also suggest multiple stocks within the Chatham Rise, but do not indicate clear stock boundaries. Although there is significant heterogeneity amongst allozyme frequencies from different areas of the Rise, these frequencies varied as much in time (samples from the same location at different times) as in space (samples from different locations at the same time).

Chatham Rise

The stock structure of orange roughy on the Chatham Rise was comprehensively reviewed in 2008 (Dunn & Devine 2010). This review evaluated all available data as no single dataset seemed to provide definitive information about likely stock boundaries. The data analysed included: catch distribution and CPUE patterns; location of spawning and nursery grounds; inferred migrations; size, maturity and condition data; genetic studies, and habitat and natural boundaries.

There is evidence that a separate stock exists on the Northwest Rise. The Northwest Rise contains a large spawning ground on the Graveyard Hills, and also nursery grounds around, and primarily to the west of, the Graveyard Hills. There is a gap in the distribution of early juveniles (under 15 cm SL) between the Graveyard area and the Spawning Box at approximately 178°W. A research trawl survey

found post-spawning adult fish to the west, but not to the east, of the Graveyard Hills, and a westerly post-spawning migration was inferred. Analyses of median length from commercial and research trawls found that orange roughy on the Northwest Chatham Rise and Graveyard Hills were smaller than those on the East Rise. A substantial decline in the size of 50% maturity after 1992 was found for both the Graveyard Hills and the Northwest Rise, but not for other areas. The only information that does not support the Northwest Rise being a separate stock is an indication from patterns in commercial catch rates that some fish arriving to spawn in the Spawning Box may come from the west (Coburn & Doonan 1994, 1997). Catch data and genetic studies do not shed any further light on stock structure. Oceanographic models suggest that a gyre to the east of the Graveyard may provide a mechanism for a separation between the Northwest Chatham Rise and the East Rise. Based on the available data, the Northwest Chatham Rise is considered to be a separate stock.

The separation of the Northeast Hills and Andes as separate stocks from the Spawning Box and Eastern Flats was based on observations of simultaneous spawning aggregations occurring on these hills, and because stock assessment models indicated a mismatch between the standardised CPUE trends. On the other hand, the occurrence of a continuous nursery ground throughout the area; similar trends in size of 50% maturity in each area; the essentially continuous habitat with similar environmental conditions and inferred post-spawning migrations from the Spawning Box towards the east Rise all suggest that all of these areas are a single stock. Analyses of median lengths from commercial catches showed no obvious differences between areas. In addition, the spawning aggregations found on the Northeast Hills and Andes appear to have been minor compared to that in the Spawning Box. The spawning aggregation on the Northeast Hills is also associated with an increase in mean length and catch rates, suggesting that fish spawning on these hills are not resident, and thus are not separate from the surrounding area. Based on the available data the Northeast Hills and Andes are therefore considered to be from the same stock as the Spawning Box and Eastern Flats.

The only evidence to separate the eastern area of the South Rise (Big Chief and surrounds) from the East Rise is the lack of spawning migrations inferred from an absence of a seasonal effect in standardised CPUE analyses. The evidence that the Big Chief area is the same stock as the East Rise includes the fact that the nursery grounds and habitat are continuous; there were no splits between the areas identified from analyses of median length; and the fisheries are similar. The reports of spawning fish around Big Chief have been infrequent, and so are considered equivocal on stock structure. The Big Chief area is therefore considered part of the East Rise stock.

There is weak evidence that the area of the South Rise west of and including Hegerville is a separate stock. The evidence includes median length analyses which indicated a split in this area, and an oceanographic front at 177°W. However, very few catches of spawning orange roughy have been reported in this area, and there appears to be no substantial nursery ground. Both of these factors support the idea that this area does not have a separate stock. In the area to the west of the suggested split the fish are relatively small during spawning, and relatively large during non-spawning. Combined with a standardised CPUE which shows a decline in abundance around July (peak spawning), and a somatic condition factor which declines during September–November (post-spawning), this supports a hypothesis of adult fish leaving the area to spawn elsewhere.

The South Rise could provide feeding habitat for the stock, which is estimated to have had an initial biomass of over 300 000 t, an amount that was probably too large to inhabit only the East Rise. There is more evidence to support orange roughy in this area being part of the East Rise stock than there is to the contrary. The current hypothesis is that the area to the west of the current convergence may be relatively marginal habitat, where larger juvenile, maturing and adult orange roughy were once predominant, and there is little spawning and few juveniles because the water is relatively cold.

Based on these analyses, the Chatham Rise has been divided into two areas: the Northwest, and the East and South Rise combined (Figure 2). The centre of the Northwest stock is the Graveyard Hills. The centre of the East and South Rise stock is the Spawning Box during spawning, and the southeast corner of the Rise during non-spawning.

4.   STOCK ASSESSMENT

No model-based stock assessments were conducted for ORH 3B stocks from 2007 to 2013 inclusive. This was primarily because the 2006 stock assessment, which assumed deterministic recruitment, showed an increasing trend in biomass which was not supported by recent biomass indices. Deterministic recruitment was assumed because ageing data were considered to be unreliable. With the successful assessment of the MEC stock in 2013, which used age data from the new ageing methodology (Tracey et al 2007; Horn et al 2016), there was a return to model-based assessment in 2014. Recruitment in all of these assessments has been derived from limited age data.

4.1   Northwest Chatham Rise

A Bayesian stock assessment was conducted for the Northwest Chatham Rise (NWCR) stock in 2018, using data up to 2016–17. This used an age-structured population model fitted to acoustic-survey estimates of spawning biomass, proportion-at-age from a trawl survey and targeted trawling on a spawning aggregation, proportion-spawning-at-age from a trawl survey, and length frequencies from the commercial fishery.

4.1.1   Model structure

The model was single-sex and age-structured (1–100 years with a plus group), with maturity estimated separately (i.e., fish were classified by age and as mature or immature). A single-time step was used and the single fishery was assumed to be year-round on mature fish. Spawning was taken to occur after 75% of the mortality and 100% of mature fish were assumed to spawn each year. The catch history was constructed from the Northwest catches in Table 2 using the catch over-run percentages in Table 6. Natural mortality was assumed to be fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in table 2 of the Orange Roughy Introduction section.

4.1.2   Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: acoustic-survey spawning biomass estimates from the main spawning hills (Graveyard and Morgue); an age frequency and an estimate of proportion-spawning-at-age taken from a 1994 wide-area trawl survey; an age-frequency taken from targeted trawls above Morgue, and length frequencies collected from the commercial fishery covering 1989–2005.

Acoustic estimates

Three types of acoustic-survey estimates were available for use in the assessment: AOS estimates (from a multi-frequency towed system, e.g., see Kloser et al 2011); 38 kHz estimates from a towed-body system; and 38 kHz estimates from a hull-mounted system. The reliability of the data from the different systems in each year was considered and estimates from the AOS and towed-body systems were used in the base model (Table 7). An alternative treatment of the available acoustic data was to include additional survey estimates from 2002 and 2004 (Table 7). All of the data in Table 7 were used in the sensitivity run labelled "Extra acoustics".

Table 7:   **Acoustic survey estimates of spawning biomass used in the base model (excludes 2002 and 2004) and the sensitivity run "Extra acoustics" (uses all data). "GY" = Graveyard, "M" = Morgue, "O" = other hills. The CVs are those used in the model and do not include any process error.**

Year	System	Frequency	Areas	Snapshots	Estimate (t)	CV (%)
1999	Towed-body	38 kHz	GY+M+O	1	8 126	22
2002	Towed-body	38 kHz	GY+O	2	9 414	20
2004	Hill-mounted	38 kHz	GY	6	2 717	16
2012	AOS	38 kHz	GY	3	5 550	17
	AOS	38 kHz	M	4	9 087	11
2013	AOS	120 kHz	GY	1	6 656	31
2016	AOS	38 kHz	GY	1	0	N/A
	AOS	38 kHz	M	3	14 051	13

The acoustic estimates in 1999, 2012 (total = 14 637 t, CV 17%), and 2016, were assumed to represent "most" of the spawning biomass in each year. This was modelled by treating the acoustic estimates as relative biomass and estimating the proportionality constant (q) with an informed prior. The prior was normally distributed with a mean of 0.8 (i.e., "most" = 80%) and a CV of 19% (see Orange Roughy Introduction). The 2013 Graveyard estimate was modelled as relative biomass with an informed prior on the q with a mean of 0.3 (derived from the relative proportions of the Graveyard and Morgue estimates in 2012 with the 80% assumption).

Trawl survey data

A wide-area trawl survey of the northwest flats was conducted in late May and early June of 1994 (72 stations; Tracey & Fenaughty 1997). An age-frequency for the trawl-selected biomass was estimated using 300 otoliths selected using the method of Doonan et al (2014). The female proportion spawning-at-age was also estimated. These data were fitted in the model: age frequency (multinomial with an effective sample size of 60); proportion-spawning-at-age (binomial with effective sample size at each age equal to the number of female otoliths at age).

Length frequencies

The length frequencies from the previous assessment in 2006 were used: nine years of length-frequency data from the period 1989–97 were combined into a single length-frequency that was centred on the 1993 fishing year. Eight years of length-frequency data from the period 1998–2005 were combined into a single length-frequency that was centred on the 2002 fishing year. The effective sample size was set at one sixth of the number of tows for each period: 19 for the "1993" period and 35 for the "2002" period (A. Hicks pers. comm.). The data were assumed to be multinomial.

Age frequencies

In addition to the age frequencies from the 1994 trawl survey, an age frequency was developed from samples taken above Morgue during the spawning season in 2016. Approximately 300 otoliths were randomly selected from three tows. The age frequency was fitted as multinomial with effective sample sizes of 60. The 2016 age frequency from Morgue was derived from the use of a demersal trawl fished a few metres off the bottom, and this in part led to concerns about the representativeness of this sampling.

4.1.3 Model runs and results

In the base model, the acoustic estimates from 1999, 2012, 2013, and 2016 were used, and the age-frequency from 2016 was excluded. There were four main sensitivity runs: add the extra acoustic data; the *LowM-Highq* and *HighM-Lowq* "standard" runs (see Orange Roughy Introduction); and including the 2016 age-frequency with its own (logistic) selectivity.

In the base model, the main parameters estimated were: virgin (unfished, equilibrium) biomass (B_0), maturity ogive, trawl-survey (logistic) selectivity, CV of length-at-mean-length-at-age for ages 1 and 100 years (linear interpolation assumed for intermediate ages), and year class strengths (YCS) from 1940 to 1979 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). In the sensitivity run including the 2016 age-frequency the YCS were estimated from 1940 to 1992.

Model diagnostics

The model provided good MPD fits to the data (Figures 3 and 4). The acoustic indices, free to "move" somewhat as they are relative, were fitted well (Figure 3). The posterior estimates for the acoustic qs were not very different from the priors, but there was some movement in the Graveyard and Morgue q, with the posterior slightly lower (and therefore SSB slightly higher) than expected (Figure 5).

Numerous MPD sensitivity runs were performed. These showed that the main drivers of the estimated stock status were natural mortality (M) and the means of the acoustic q priors (lower M and higher mean q give lower stock status; higher M and lower mean q give higher stock status).
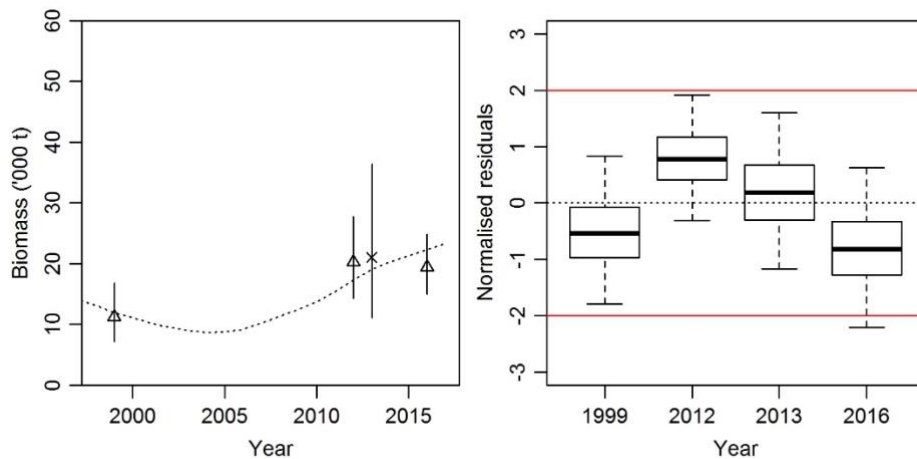
Figure 3: NWCR, base, (left) MPD fits to the acoustic biomass indices; broken line, spawning biomass trajectory; scaled acoustic indices for x, Graveyard survey, and Δ, Graveyard and Morgue surveys; (right) MCMC normalised residuals for the acoustic biomass indices. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.
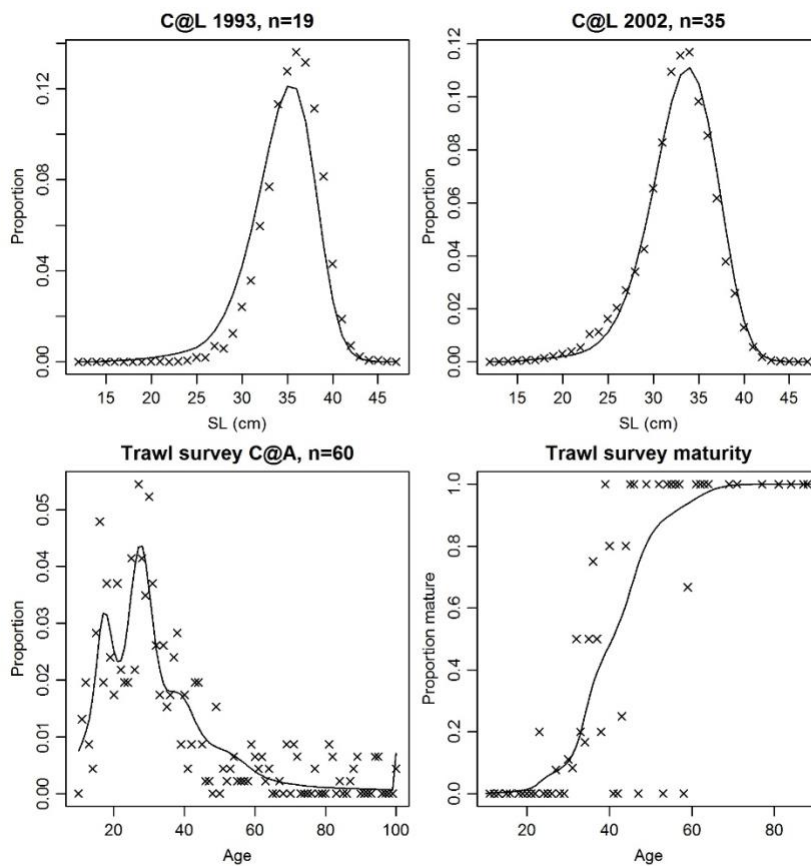
Figure 4: NWCR, base, MPD fits: (x, observations; lines, predictions): (top) commercial catch-at-length samples (n is the effective sample size); (bottom) trawl survey catch-at-age and proportion mature at age.
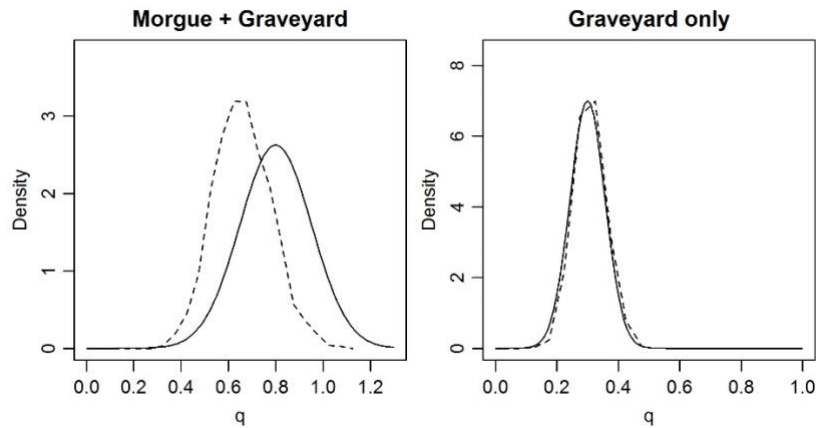
Figure 5: NWCR base, MCMC diagnostics: prior (solid line) and posterior (broken line) distributions for the two acoustic *q*s (left, mean *q*-prior = 0.8; right, mean q-prior = 0.3).

When the Morgue age-frequency was fitted assuming that the selectivity on Morgue was equal to maturity the fit was poor, particularly to the left-hand side of the age frequency distribution. When the Morgue age frequency was fitted assuming a separate logistic selectivity ogive the fit was acceptable (Figure 6). The Morgue age frequency had an unexpectedly high proportion of older fish, and the sampling methodology was also unusual. As a result, it was agreed to exclude the Morgue age frequency data from the base model.
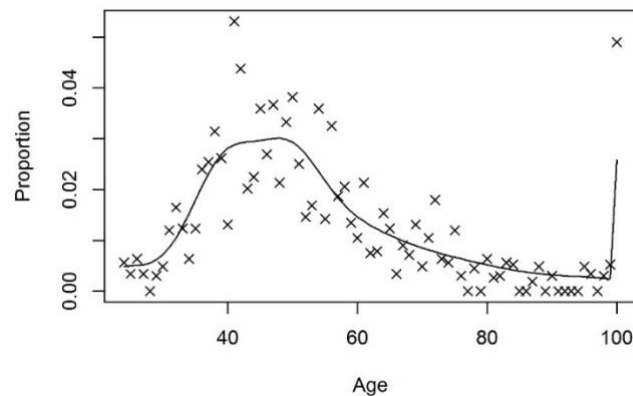
Figure 6: NWCR, base, MPD fits: (x, observations; lines, predictions) to the Morgue age frequency (effective sample size n = 60).

MCMC Results

For the base model, and the sensitivity runs, MCMC convergence diagnostics indicated no lack of convergence. Virgin biomass, B_0, was estimated to be between 64 000–67 300 t for all runs (Table 8). Current stock status was similar across the base and the first two sensitivity runs (Table 8). For the two "bounding" runs, where M and the mean of the acoustic q priors were shifted by 20%, median current stock status was estimated to be close to the lower bound, or upper bound, of the target range of 30–50% B_0 (Table 8).

Table 8: NWCR, MCMC estimates of virgin biomass (B_0) and stock status (B_{2017} as %B_0) for the base model and four sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2017} (%B_0)	95% CI
Base	0.045	65.2	59.9–75.0	38	31–48
Extra acoustics	0.045	64.0	60.0–76.7	36	31–43
Include Morgue AF	0.045	65.1	58.6–76.5	38	30–48
Low *M*-High q	0.036	67.3	63.0–73.9	29	23–36
High *M*-Low q	0.054	65.5	58.2–77.7	48	40–58

For the base model, there was a 98% probability that the stock was above 30% B_0 in 2017. For the sensitivity runs, the probability of being above 30% B_0 in 2017 was 98% (Extra acoustics), 97% (Include Morgue AF), 36% (Low M-High q), and 100% (High M-low q).

The estimated YCS showed little variation across cohorts, but recruitment was relatively high in 1940–52, 1965–68, and 1975–79 (Figure 7).
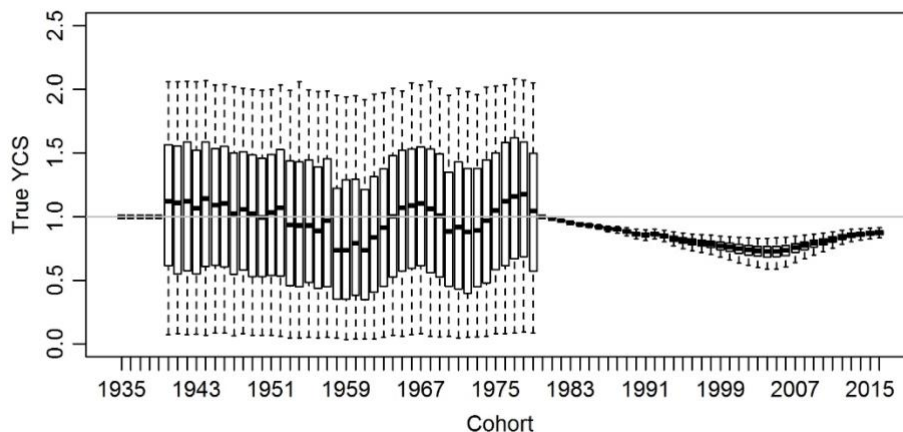
Figure 7: NWCR base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated spawning-stock biomass (SSB) trajectory showed a declining trend from 1980 (when the fishery started) through to 2004 when the biomass was About as Likely as Not (40–60%) to be below the soft limit (Figure 8). Since 2005 the estimated biomass has increased steadily.
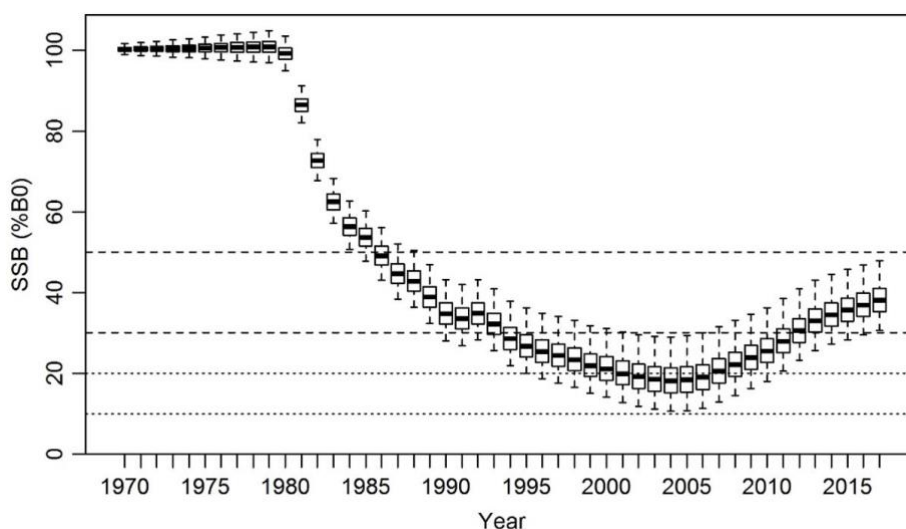
Figure 8: NWCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Dotted lines indicate the hard limit (10% B_0) and soft limit (20% B_0), dashed lines the management target range (30–50% B_0).

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity by year. Fishing intensity is represented in term of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity (at that rate, not tonnage) will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ forces the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was above $U_{20\%B0}$ for most of the history of the fishery; it was briefly in the target range ($U_{30\%B0}$–$U_{40\%B0}$) from 2009–2010 before dropping substantially when the industry agreed

to curtail fishing the NWCR in 2011, and has been in or just below the target range since 2014 (Figure 9). There was less than a 1% probability that the exploitation rate in 2017 was below $U_{30\%B0}$.
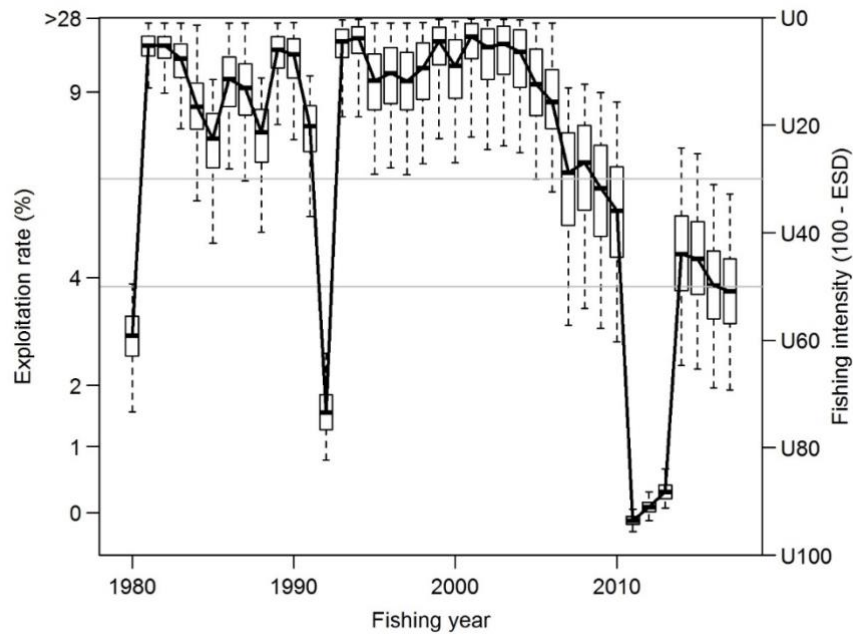
Figure 9: NWCR base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–50% B_0 is marked by horizontal lines.

Projections

Five-year biomass projections were made for the Base model run assuming future catches to be the TACC (1 250 t), or the current agreed catch limit (1 043 t; 207 t has been shelved). For each projection scenario, future recruitment variability was sampled from actual estimates between 1940 and 1979.

At the TACC (1 250 t) and the current agreed catch limit (1 043 t), SSB is predicted to remain stable or slowly increase over the next five years, and the probability of the SSB going below the soft or hard limits is zero (Table 9).

Table 9: ORH 3B NWCR Bayesian median and 95% credible intervals (in parentheses) of projected B_{2022}, B_{2022} as a percentage of B_0, and B_{2022}/B_{2017} (%) for the model runs.

Model run	Catch	B_{2022}	B_{2022} (%B_0)	B_{2022}/B_{2017} (%)	p($B_{2022} < 0.2\ B_0$)	p($B_{2022} < 0.1\ B_0$)
Base	1 043	26 500 (20 000–38 100)	41 (33–51)	107 (104–111)	0	0
	1 250	25 600 (19 100–37 200)	39 (31–50)	104 (101–107)	0	0

Biological reference points, management targets and yield

Orange roughy stocks with model based stock assessments are managed according to the Harvest Control Rule (HCR) that was developed in 2014 using a Management Strategy Evaluation (MSE) (Cordue 2014b). The HCR has a target management range of 30–50% B_0.

Yield estimates are not reported for this stock.

4.2   East and South Chatham Rise

A Bayesian stock assessment was conducted for the East and South Chatham Rise (ESCR) stock in 2018, using data up to 2016–17. The model was an age-structured population model fitted to acoustic-survey estimates of spawning biomass, trawl-survey biomass indices, age frequencies from spawning aggregations, and length frequencies from trawl surveys and commercial fisheries.

4.2.1 Model structure

The model was single-sex and age-structured (1–100 years with a plus group), with maturity estimated separately (i.e., fish were classified by age and as mature or immature). A single-time step was used and four year-round fisheries, with logistic selectivities, were modelled: Box & flats, Eastern hills, Andes, and South Rise. These fisheries were chosen following Dunn (2007) who assessed the Box & flats, Eastern hills, and Andes as separate stocks and hence had already prepared length frequency data for those fisheries. No length frequencies were available from the South Rise fishery and its selectivity was assumed to be the same as the Andes (so effectively there were three fisheries in the model). Spawning was taken to occur after 75% of the mortality and 100% of mature fish were assumed to spawn each year.

The catch history was constructed by apportioning the total ORH 3B reported catch across areas using catch proportions from estimated catch on TCEPR forms (Table 4). The over-run percentages in Table 6 were applied. Natural mortality was assumed fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in table 2 of the Orange Roughy Introduction section.

4.2.2 Input data and statistical assumptions

There were four main data sources for observations fitted in the assessment: acoustic-survey spawning biomass estimates from the Old-plume (2002–2014, 2016), Rekohu (2011–2014, 2016) and the Crack (2011, 2013, 2016); age frequencies from the spawning areas (2012, 2013, and 2016); trawl survey biomass indices and length frequencies; and length frequencies collected from the commercial fisheries.

Acoustic estimates

The Old plume was acoustically surveyed as early as 1996, but the survey estimates are only considered to represent a consistent time series from 2002–2012 (see Cordue 2008; Hampton et al 2008, 2009, 2010; Doonan et al 2012). Like the Rekohu plume, which was first noted in 2010 and first surveyed in 2011, the Old plume occurs on an area of flat bottom and can be adequately surveyed using a hull-mounted transducer. In 2011, 2013 and 2016, an additional (but known historically) spawning area was surveyed; known as the Crack (also known as Mt. Muck), it is an area of rough terrain which requires a towed-body or trawl-mounted system to be used to reduce the height of the shadow or dead zone (i.e., with the transducer at a depth of about 500–700 m).

The estimates selected by the DWFAWG for use in the stock assessment are shown in Table 10. In order to make the estimates as comparable as possible across years, only biomass estimates from 38 kHz transducers were used and those from the hull-mounted system were weather-adjusted in the same way as earlier estimates (see presentations from Kloser and Ryan to the DWFAWG meetings in 2013 and 2014).

A key question evaluated in the 2014 assessment was how long has the Rekohu plume been in existence (Cordue, 2014a). If the Rekohu plume had always existed (and was not discovered until 2010) then it would be one of three major spawning sites and could be modelled as such along with the Old plume and the Crack. This would imply that the Old-plume time series was tracking a consistent part of the spawning biomass (and its decline over time was therefore an important indicator of stock status). If, on the other hand, the Rekohu plume had very recently formed, this would imply that the Old-plume time series was a biomass index only up until the year before the Rekohu plume came into existence.

Table 10: Acoustic estimates of average pluming spawning biomass in the three main spawning areas as used in the assessment. All estimates were obtained from surveys on *FV San Wataki* from 38 kHz transducers. Each estimate is the average of a number of snapshots as reflected by the estimated CVs. Some estimates have been revised since the 2014 assessment (Dunn & Doonan, in prep.).

	Old plume		Rekohu		Crack	
	Estimate (t)	CV (%)	Estimate (t)	CV (%)	Estimate (t)	CV (%)
2002	63 950	6	–	–	–	–
2003	44 316	6	–	–	–	–
2004	44 968	8	–	–	–	–
2005	43 923	4	–	–	–	–
2006	47 450	10	–	–	–	–
2007	34 427	5	–	–	–	–
2008	31 668	8	–	–	–	–
2009	28 199	5	–	–	–	–
2010	21 205	7	–	–	–	–
2011	16 422	8	28 113	18	6 794	21
2012	19 392	7	27 121	10	–	–
2013	15 554	14	33 348	10	5 471	16
2014	19 360	18	44 421	25	–	–
2015	–	–	–	–	–	–
2016	11 192	13	27 027	13	5 341	10

Following Cordue (2014a), in the base model it is assumed that the Old-plume time series cannot be relied on to provide a consistent index for any part of the spawning biomass. In 2011, 2013 and 2016, the estimates of average spawning biomass across the three areas were summed to form comparable indices for each year. The 2012 and 2014 estimates from Rekohu and the Old-plume were summed to provide a 2012 and 2014 index with a different proportionality constant or q. The Old-plume indices from 2002–2010 were used, but each point in the time series was given its own q. Informed priors were used for all of the qs in the Old-plume series, for the 2012 and 2014 biomass indices, and the indices comprising 2011, 2013, and 2016 observations.

For 2011, 2013, and 2016, it was assumed that "most" of the biomass was being indexed so the "standard" acoustic q prior was used: lognormal (mean = 0.8, CV = 19%) (see Orange Roughy Introduction). The mean of the q prior for 2012 and 2014 was derived from the observed biomass proportions across the three areas and the assumption that 80% of the spawning biomass was indexed in 2011, 2013 and 2016, which gave a mean of 0.7 for the 2012 and 2014 indices, a reflection that this index did not include an estimate for the Crack. For 2002 to 2010 the means of the q priors were assumed to decrease linearly from 0.7 (2002) down to 0.30 (2010), reflecting the gradual increase in the relative importance of the Rekohu plume. The linear sequence was derived by assuming 0.7 in 2002 (i.e., assuming that the Rekohu plume did not exist and only the Crack was missing from the survey estimate) and using the observed biomass proportions in 2011 with the 80% assumption (which gave the Old-plume being about 25% of the total spawning biomass). To reflect the increased uncertainty in the acoustic qs in years other than 2011 and 2013, the priors were given an increased CV of 30%.

A sensitivity run was conducted that, similar to the base run, assumed for 2011, 2013, and 2016, the "standard" acoustic q prior: lognormal (mean = 0.8, CV = 19%). However, the q for the 2012 and 2014 surveys was estimated with a uniform prior, but with a penalty on the ratio between the q estimated for the 2011, 2013, and 2016 surveys (which covered all three areas), and the q estimated for the 2012 and 2014 surveys (which covered only two). The penalty was lognormal (mean = 0.88, CV = 1.4%), and estimated from the distribution of biomass between areas observed in 2011, 2013, and 2016. This means that the 2012 and 2014 surveys were assumed to cover 88% of the area (relative biomass) covered in 2011, 2013, and 2016, which high precision (low CV). Similarly, the q for the Old plume survey in 2010 was uniform, with a penalty on the ratio on the q between the 2011, 2013, and 2016 surveys and that on the 2010 survey (which covered just one area): lognormal (mean = 0.3, CV = 0.075). Subsequent Old plume survey qs for 2009–2002 were all uniform, but with penalties on their sequential q ratios, where the mean of the penalty changed linearly such that the q for the 2002 Old plume survey would be 0.7; all penalties were lognormal, with assumed CVs of 0.1 (CVs for these penalties could not be estimated). Compared to the base run, this "ratio-q" sensitivity run placed greater emphasis on maintaining the relativity between sequential acoustic biomass estimates.

Trawl survey data

Research trawl surveys of the Spawning Box during July were completed from 1984 to 1994, using three different vessels: FV *Otago Buccaneer*, FV *Cordella*, and RV *Tangaroa* (Figure 10). A consistent area was surveyed using fixed station positions (with some random second phase stations each year).
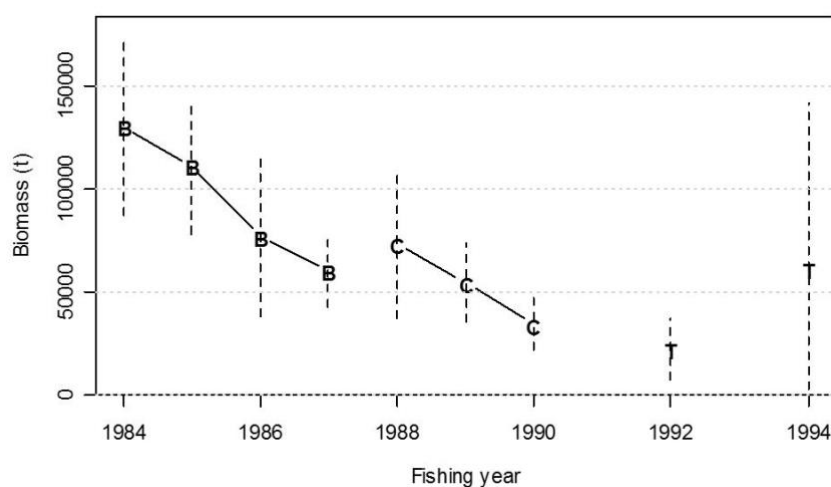

Figure 10: **The Spawning Box trawl survey biomass indices (assuming a catchability of 1 for each vessel), with 95% confidence intervals shown as vertical lines. Vessels indicated as B, FV *Otago Buccaneer*; C, FV *Cordella*; T, RV *Tangaroa*.**

The biomass indices were fitted as relative indices with a separate time series for each vessel (with uninformed priors on the qs). The second point in the *Tangaroa* time series, although very large (driven by a single high catch), has a large CV and so is unlikely to have had much effect on the assessment results.

Data from two wide-area surveys by *Tangaroa* in 2004 and 2007 were also used. These surveys covered the area which extends from the western edge of the Spawning Box around to the northern edge of the Andes. The area surveyed did not include the Old-plume, the Northeast Hills, or the Andes. The survey used a random design over sixteen strata grouped into five sub-areas. The trawl net used was the full-wing and relatively fine mesh 'ratcatcher' net. The surveys covered the same survey area as the Spawning Box trawl surveys from 1984 to 1994 as well as additional strata to the east. In 2007, the survey ran from 4–27 July and 62 trawl tows were completed. In 2004, the survey ran from 7–29 July and 57 trawl tows were completed.

The surveys had almost identical estimates of total biomass in each year (17 000 t) with low CVs (10% and 13% respectively). They were fitted as relative biomass with an uninformed prior on the q.

Length frequencies

The length frequencies from all of the trawl surveys were fitted in the model as multinomial random variables. Effective sample sizes (N) were taken from Dunn (2007) for the Spawning Box surveys and were assumed equal to the number of tows for the wide-area surveys (across all surveys the effective Ns ranged from about 20–80). Trawl survey length frequencies were fitted assuming that all mature fish were selected, but immature fish were selected assuming capped-logistic ogives. One selectivity ogive for immature fish was shared by the *Buccaneer, Cordella*, and *Tangaroa* Spawning Box surveys, with a second ogive for the immature fish caught in the *Tangaroa* wide-area survey.

Length frequencies from the commercial fisheries were developed by Hicks (2006) and also fitted in the model. For the Spawning Box and associated flat ground fishery, three years of length-frequency data from the period 1989–91 were combined into a single length-frequency that was centred on 1990, and four years 2002–05 were combined and centred on 2004. In a similar way, for Andes four years 1992–95 were combined and centred on 1993, three years 1997–99 combined and centred on 1998, and five years combined 2001–05 and centred on 2003. For the eastern hills, seven years 1991–97 were combined and centred on 1995, and five years 2001–05 combined and centred on 2003. These were fitted as multinomial with effective sample sizes ranging from 8–38.

Age frequencies

Age frequencies were developed for the Old-plume and Rekohu plume in 2012, and for the Old-plume, Rekohu, and the Crack in 2013 and 2016 (Doonan et al 2014a, b; 2017). Approximately 300 otoliths were randomly selected from each area in 2012 and 2016, and 250 from each area in 2013. The fish in the Old-plume were noted to be generally older than those in the Rekohu plume. The fish from the Crack, showed a mixture of ages from new spawners (20–30 years) through to much older fish (80–100 years). In the base model, the age frequencies were combined across areas and fitted as multinomial with effective sample sizes of 50 (2012) and 60 (2013 and 2016) respectively, reflecting the low number of trawls from which samples were taken.

4.2.3 Model runs and results

In the base model, the Old-plume time series was assumed to be unreliable in terms of trend and therefore each point from 2002 to 2010 was given its own q; also, natural mortality (M) was fixed at 0.045. There were several important sensitivity runs: assume that the Rekohu plume first occurred in 2007; adjust M and the mean of the priors by 20% (the standard *LowM-Highq* and *HighM-Lowq* runs, see Orange Roughy Introduction); and assume penalties on acoustic q-ratios.

In the base model, the main parameters estimated were: virgin (unfished, equilibrium) biomass (B_0), maturity ogive, trawl-survey selectivities, fisheries selectivities, CV of length-at-mean-length-at-age for ages 1 and 100 years (linear relationship assumed for intermediate ages), and year class strengths (YCS) from 1930 to 1990 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). There were also the numerous acoustic and trawl-survey qs.

Model diagnostics

The base model provided good MPD fits to the data. The MPD fits to the acoustic indices were good, except the biomass observed in 2016 was lower than predicted (Figure 11). The normalised residuals of the acoustic indices for the base MCMC model were similarly good, and showed no apparent trend, although the 2016 biomass estimate was substantially lower than predicted (Figure 12).

The posteriors for the acoustic qs were shifted to the left of the priors for the surveys covering all three spawning aggregations (2011, 2013, and 2016), indicating that the predicted biomass was higher than expected (Figure 13). For the Old-plume time series, posteriors were sometimes shifted towards the left of the priors, but more often to the right, indicating the predicted biomass was more often lower than expected (Figure 13).

The MPD fits to the trawl indices were good but the model-predicted biomass had a shallower decline than that estimated from the indices from the *Buccaneer* and *Cordella* surveys (Figure 11). Also, the model did not fit the very large increase in the *Tangaroa* Spawning Box survey (Figure 11).

The fits to the age frequencies were as good as can be expected given the inconsistent shape of the age frequencies in the consecutive years, for example relatively more fish aged 30–40 years in 2013 (Figure 14).

The MPD fits to the commercial length frequencies were excellent except the 1990 Spawning Box and eastern flats commercial fishery length frequency (Figure 15). Likewise the fits to the trawl survey length frequencies were excellent (Figure 15). The capped-logistic selectivities assumed for immature fish estimated that a small proportion of immature fish were caught, and therefore were able to fit the long tails observed on the left-hand side of the Spawning Box survey length frequencies.
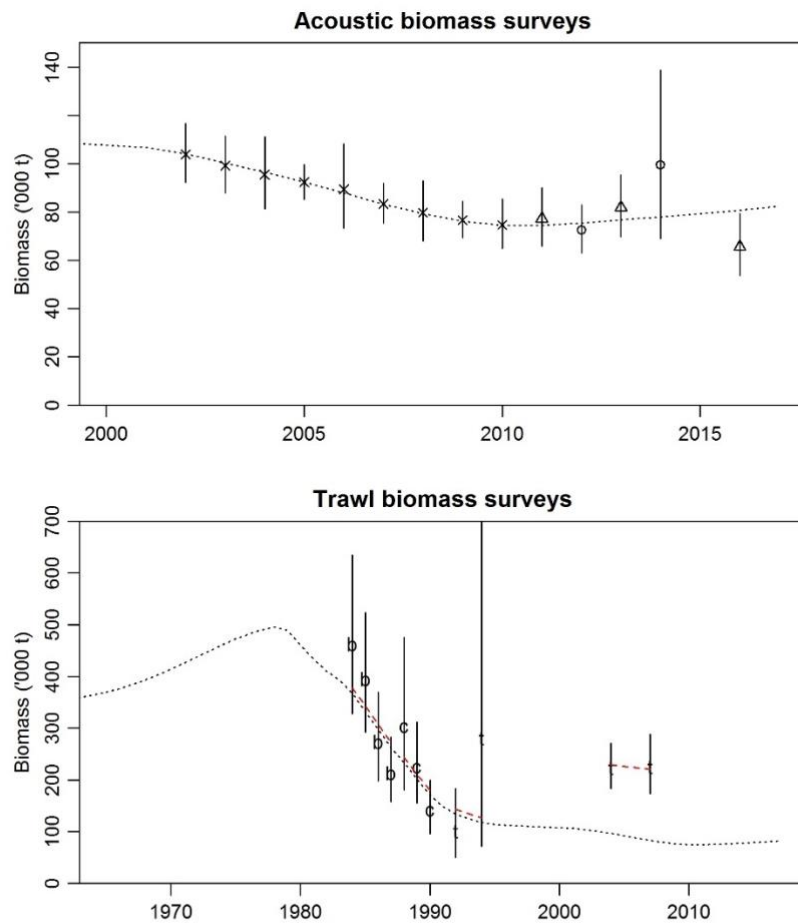
Figure 11: ESCR, MPD, base: fit to the acoustic indices: (top) spawning biomass trajectory and scaled acoustic indices; x, Old plume surveys; Δ, three-area 2011, 2013 and 2016 surveys; o, two-area 2012 and 2014 surveys; (bottom) the spawning biomass trajectory (dotted line) and fits of the trawl surveys to their respective vulnerable biomass (red dashed lines), for b, *Buccaneer*; c, *Cordella*; t (1992 and 1994), *Tangaroa* Spawning Box; t (2004 and 2007), *Tangaroa* wide-area. Vertical lines indicate 95% confidence intervals.
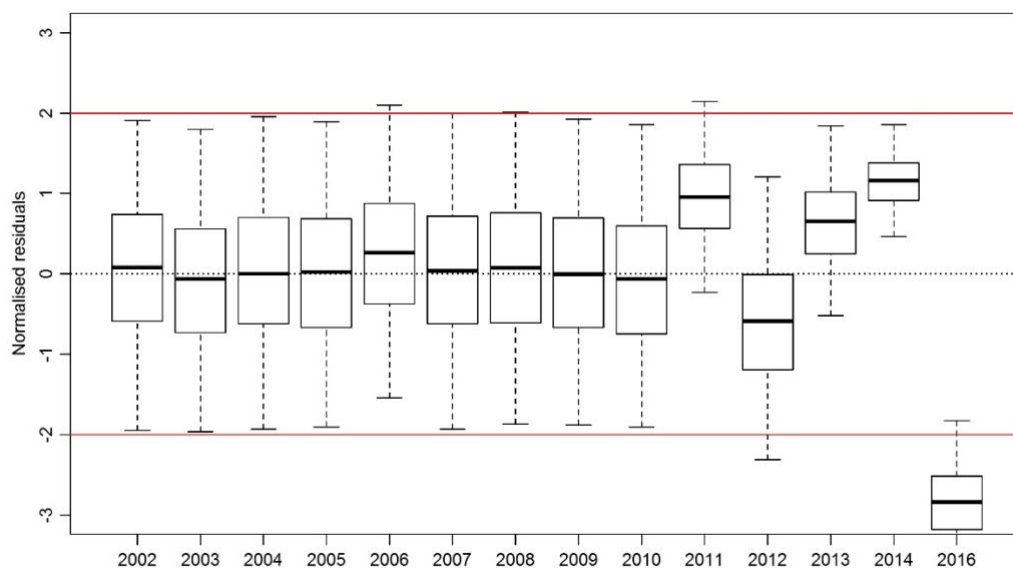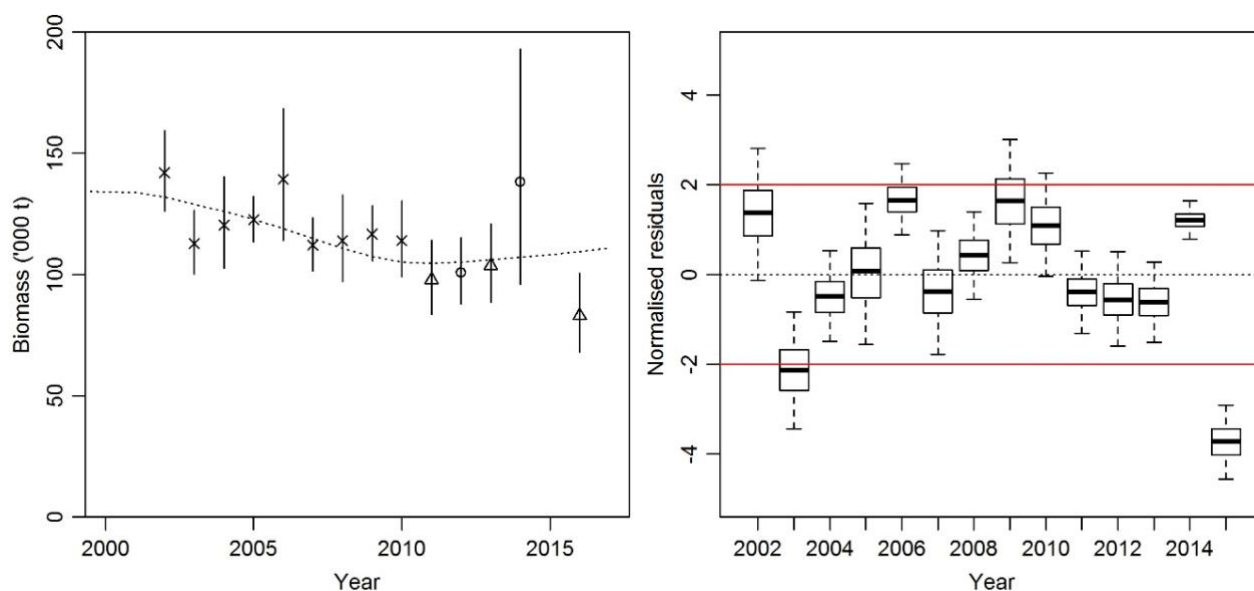

Figure 12: ESCR, MCMC base: normalized residual for the acoustic indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution.
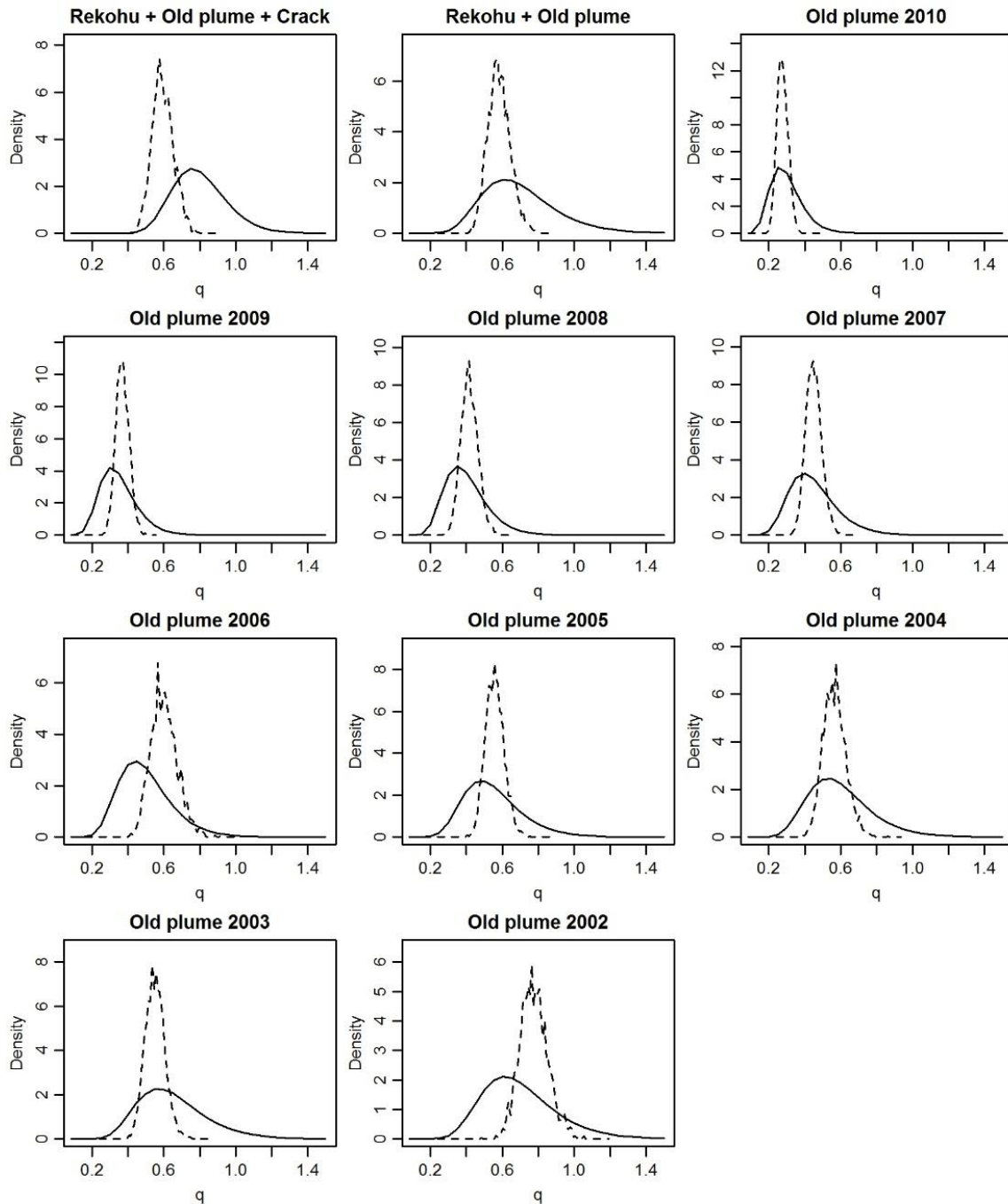
Figure 13: ESCR, MCMC base: prior (solid lines) and posterior distributions (broken lines) for acoustic _q_s.

Numerous sensitivity runs were conducted at the MPD stage (see also Cordue 2014a). The sensitivity runs included in management advice from the 2014 assessment were maintained in the 2017 assessment (Table 11). These runs included evaluating the effect of estimating M, assuming the Rekohu plume was not formed until 2007, the two "bounding" runs, where M and the mean of the acoustic q priors were shifted by 20% (High M-low q; low-M high q). Additional sensitivity runs included the ratio-q run, and runs assuming lognormal priors for YCS.

In the ratio-q sensitivity run, the fits to most acoustic indices were good, but the 2003 and 2016 biomass estimates were lower than predicted (Figure 16). The MCMC normalised residuals for the acoustic indices had a similar pattern, with the 2016 biomass estimate substantially lower than predicted. The median estimates of stock size and status were very similar to those from the base run (<1% difference); however, the 95% credible intervals from the ratio-q run were about 30% broader.

With a lognormal YCS prior, the estimated stock size and status was sensitive to the assumed σ_R (variability in YCS). Estimates from the nearly-uniform YCS prior (assumed in the base model) were roughly equivalent to a lognormal YCS prior with $\sigma_R = 0.6$.

The residuals of the base model indicated that additional process error of around 20% was needed to adequately fit the 2011–16 acoustic biomass index, notably the low estimate for 2016; however, adding the process error made no material difference to the outcome (%B_0 was still 33%). The Deepwater Fisheries Assessment Working Group concluded that additional process error should only be added when there was a clear rationale for this to take place, and after further observations had been added to the series.
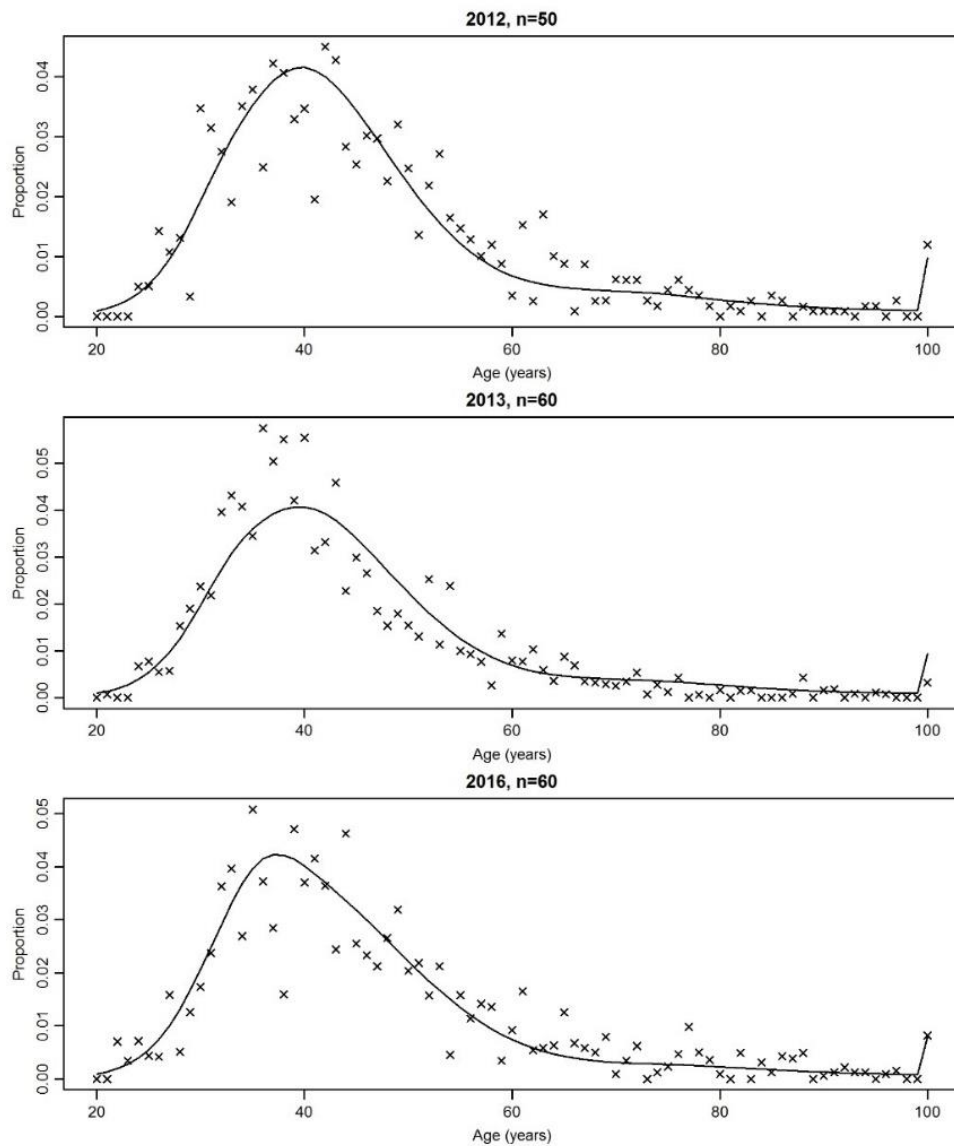
Figure 14: ESCR, MPD base: fits (lines) to the spawning season age frequencies (points); n is the effective sample size.
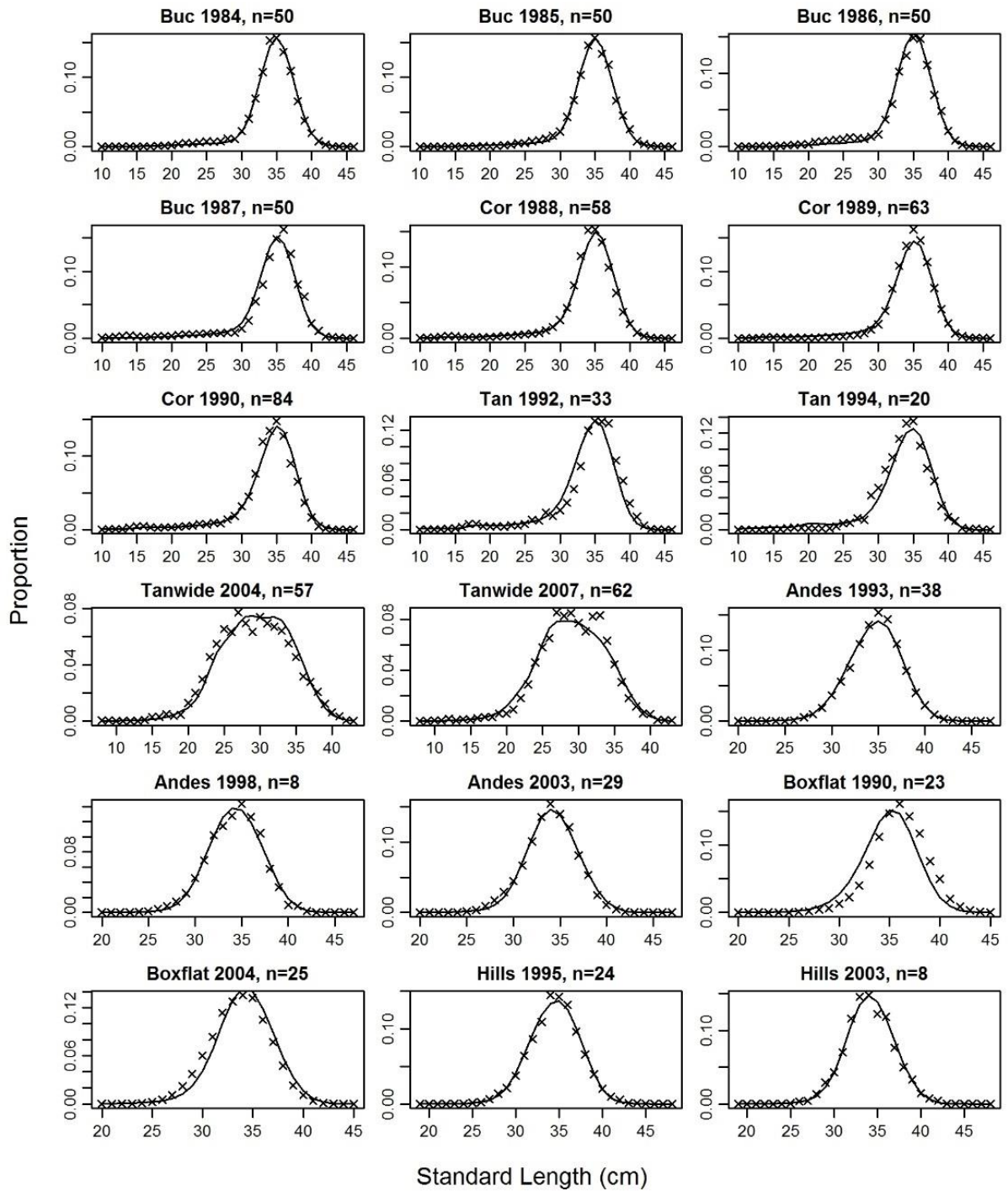
Figure 15: ESCR, MPD base: fits (lines) to the length frequencies (x) for the *Buccaneer* **surveys (Buc),** *Cordella* **surveys (Cor),** *Tangaroa* **Spawning Box surveys (Tan),** *Tangaroa* **wide-area surveys (Tanwide), commercial Andes fishery (Andes), commercial Spawning Box and eastern flats fishery (Boxflat), and eastern hills fishery (Hills); n is the effective sample size.**

Figure 16: ESCR, MPD, ratio-q: fit to the acoustic indices: (left) spawning biomass trajectory and scaled acoustic indices; x, Old plume surveys; Δ, three-area 2011, 2013 and 2016 surveys; o, two-area 2012 and 2014 surveys; (right) MCMC normalized residual for the acoustic indices (note 2016 is below -3 sd). The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution.

MCMC results

For the base model, MCMC convergence diagnostics were good once the three chains (with random starting values near the MPD estimate) had been run for 15 million iterations. Some technical changes were made to improve chain convergence, including re-estimation of the covariance matrix; these improved diagnostics whilst giving results very similar to the model without the changes.

Virgin biomass, B_0, was estimated to be about 313 000 t for the base model with median estimates ranging from 300 600–363 100 t for the four sensitivity runs presented (Table 11). Current stock status was similar across the base and the first two sensitivity runs (Table 11). The lower stock status when M was estimated reflects the lower estimates of M (0.034 rather than 0.045). For the two "bounding" runs, where M and the mean of the acoustic q priors were shifted by 20%, current stock status was estimated below the biomass target range of 30–50% B_0 for the pessimistic *LowM-Highq* run and within the target range for the optimistic *HighM-Lowq* run (Table 11).

Table 11: ESCR, MCMC estimates of virgin biomass (B_0) and stock status (B_{2017} as %B_0) for the base model and four sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2017} (%B_0)	95% CI
Base	0.045	313.3	281.2–346.9	33	28–37
Estimate M	0.034	363.1	304.3–416.1	27	21–34
Rekohu 2007	0.045	300.6	270.8–332.4	31	26–35
Low M-High q	0.036	335.5	308.3–362.8	25	20–29
High M-Low q	0.054	306.3	272.8–342.7	42	36–47

The estimated YCS show little variation across cohorts but do exhibit a long-term trend (Figure 17). The stock status trajectory shows a steady decline from the start of fishery until the mid-1990s, where it remained in the 20–30% range until an upturn in about 2010 (Figure 18).

For the base model, there was an 86% probability that the stock was above 30% B_0 in 2017. Therefore, for the base model, the stock is considered to be fully rebuilt according to the Harvest Strategy Standard (at least a 70% probability that the lower end of the management target range of 30–50% B_0 has been achieved).
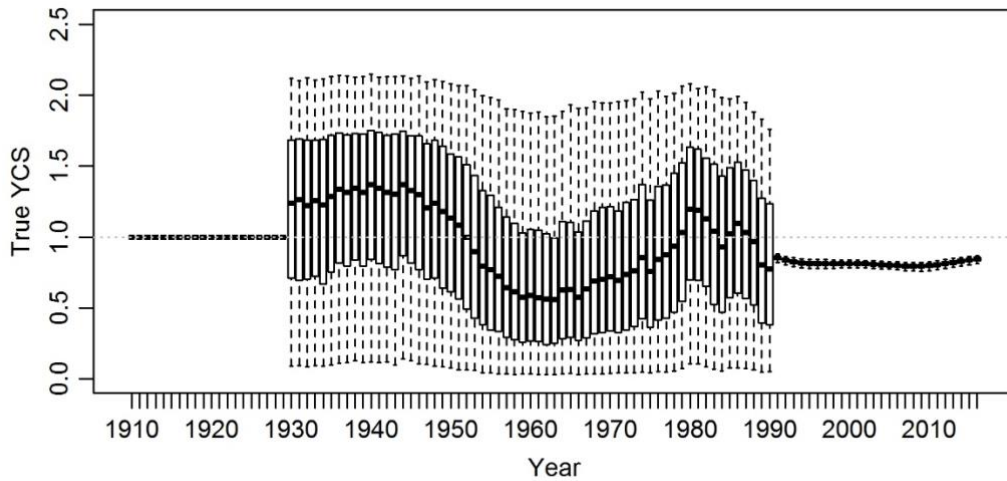
Figure 17: ESCR base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.
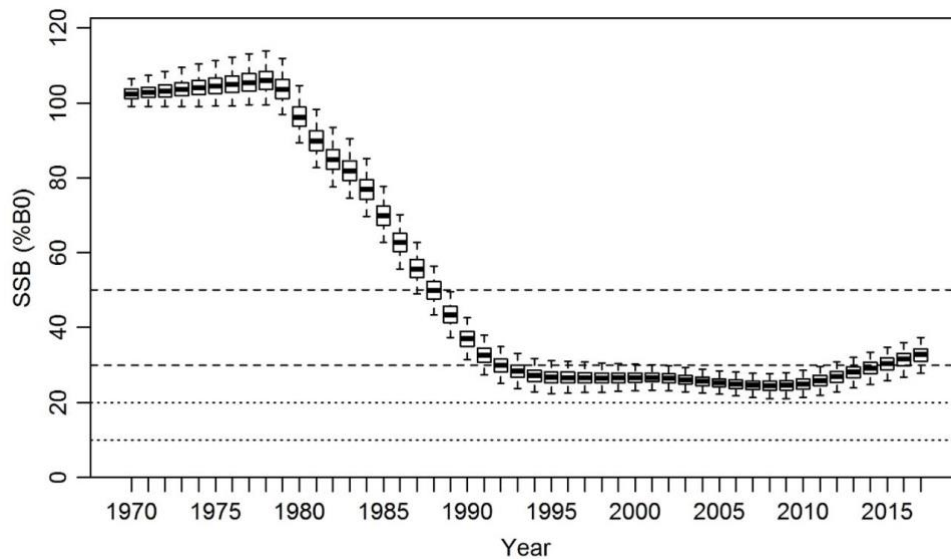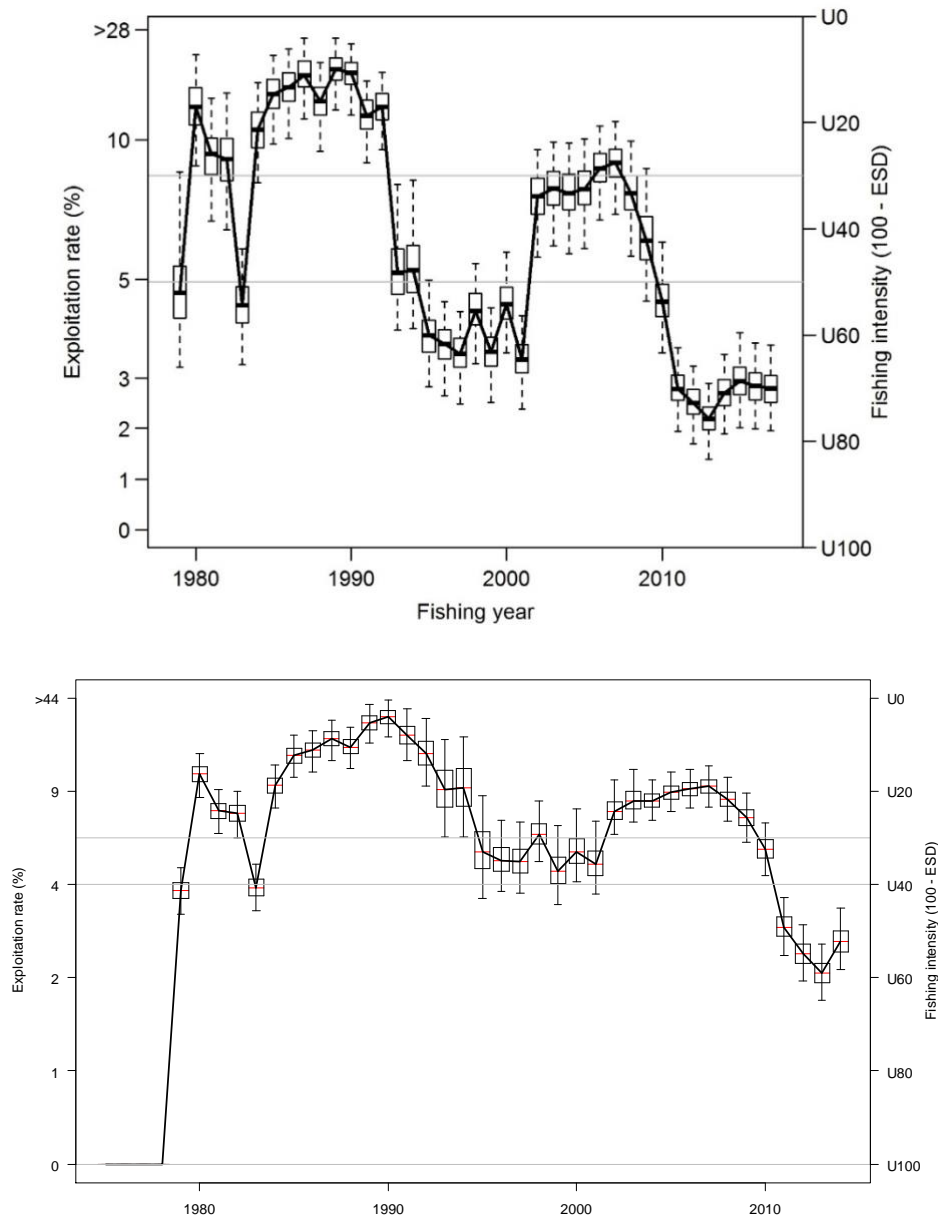

Figure 18: ESCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Dotted lines indicate the hard limit (10% B_0) and soft limit (20% B_0), dashed lines the biomass target range (30–50% B_0).

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity by year. Fishing intensity is represented in terms of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ forces the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was within or above the target range ($U_{30\%B0}$–$U_{50\%B0}$) for most years of the fishery except 1994–95 to 2000–01 and after 2009–10, after 2009–10 fishing intensity was below the target range (Figure 19).

Figure 19: ESCR base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–50% B_0 is marked by horizontal lines.

Projections

Five-year biomass projections were made for the Base model run assuming future catches to be the TACC (3 100 t). For each projection scenario, future recruitment variability was sampled from actual estimates between 1940 and 1979.

At the TACC, the SSB is predicted to slowly increase over the next five years, and the probability of the SSB going below the soft or hard limits is zero (Table 12).

Table 12: ORH 3B ESCR Bayesian median and 95% credible intervals (in parentheses) of projected B_{2022}, B_{2022} as a percentage of B_0, and B_{2022}/B_{2017} (%) for the model runs.

Model run	Catch	B_{2022}	B_{2022} (%B_0)	B_{2022}/B_{2017} (%)	p($B_{2022} < 0.2\,B_0$)	p($B_{2022} < 0.1\,B_0$)
Base	3 100	120 300 (100 200–147 600)	39 (34–45)	119 (114–127)	0	0

Biological reference points, management targets and yield

Orange roughy stocks with model based stock assessments are managed according to the Harvest Control Rule (HCR) that was developed in 2014 using a Management Strategy Evaluation (MSE) (Cordue 2014b). The HCR has a target management range of 30–50% B_0.

Yield estimates are not reported for this stock.

4.3 Puysegur

A Bayesian stock assessment was conducted for the Puysegur stock in 2017 using very similar methods to those used in the 2014 orange roughy stock assessments of ESCR, NWCR, MEC, and ORH7A (Cordue 2014a). An age-structured population model was fitted to an acoustic-survey estimate of spawning biomass, two trawl-survey indices and associated length frequencies, two spawning-season age frequencies, and a small number of length frequencies from the commercial fishery.

4.3.1 Model structure

The model was single-sex and age-structured (1–120 years with a plus group), with maturity estimated separately (i.e., fish were classified by age and as mature or immature). Two time steps were used to model a non-spawning season fishery and a spawning season fishery. Spawning was taken to occur after 50% of the spawning-season mortality and 100% of mature fish were assumed to spawn each year.

The catch history as reported in Table 5 (see above) was split into a spawning (June-August) and a non-spawning season (October-May and September) using the ratio of estimated catches, with the addition of catches during 2005, 2006, and 2015 when fish were caught during acoustic surveys. The catch for 2016–17 was assumed to be zero. Natural mortality was fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in table 2 of the Orange Roughy Introduction section (ESCR growth parameters were assumed).

4.3.2 Input data and statistical assumptions

There were four main data sources used in the assessment: an acoustic-survey spawning biomass estimate in 2015 from the main spawning hill (Goomzy); two age frequencies during the spawning seasons in 1992 and 2015; biomass indices and length frequencies from trawl surveys in 1992 and 1994; and scaled length frequencies developed from Scientific Observer data collected from the commercial fishery in 1994 and 1997.

Acoustic estimate

Two types of acoustic-survey estimates were available for use in the assessment: an estimate from a 38 kHz hull-mounted system during an AOS survey (AOS is a multi-frequency towed system, e.g., see Kloser et al 2011) and 38 kHz estimates from a hull-mounted system. The reliability of the data from the different surveys and the two main hills was considered and only the estimate from the 2015 survey on Goomzy was used in the base model (Table 13). The estimates from Godiva were unreliable because the surveyed marks contained a mix of species (Hampton et al 2005, 2006). In 2005 and 2006 it was not clear that the marks on Goomzy were exclusively orange roughy but in 2015 there was strong evidence from both trawling and the multi-frequency system that the surveyed marks were almost exclusively orange roughy (Ryan & Tilney 2016).

Table 13: Acoustic survey estimates of spawning biomass available to the stock assessment. Only the 2015 estimate from Goomzy was used in the base model.

Year	Area	Snapshots	Estimate (t)	CV (%)
2005	Godiva	3	2 600	23
	Goomzy	4	4 000	22
2006	Godiva	4	900	51
	Goomzy	3	3 200	50
2015	Godiva	2	180	Not calculated
	Goomzy	2	4 200	26

The acoustic estimate in 2015 from Goomzy was assumed to represent "most" of the spawning biomass in that year. This was modelled by treating the acoustic estimate as relative biomass and estimating the proportionality constant (q) with an informed prior. The prior was lognormally distributed with a mean of 0.8 (i.e., "most" = 80%) and a CV of 19% (see Orange Roughy Introduction section).

Age frequencies

Age frequencies were developed for the *Giljanes* spawning-season trawl survey in 1992 (Clark & Tracey 1993) and the targeted trawling on spawning marks during the 2015 acoustic survey (Ryan & Tilney 2016)(Ian Doonan, NIWA, pers. comm.). Approximately 400 otoliths were used for each age frequency and CVs were calculated for each proportion at age from bootstrapping. In 2015, the mode (for the smoothed distribution) is at about 40 years whereas in 1992 the mode is closer to 60 years (Figure 20). It is notable that in both years the ages extend out to at least 130 years (Figure 20). In the base model, the age frequencies were fitted as multinomial with effective sample sizes of 80 and 60 respectively. The sample size of 80 is the approximate number of trawl stations during the survey in 1992 and the value of 60 was derived from the between year ratio of equivalent multinomial sample sizes derived from the bootstrap CVs.
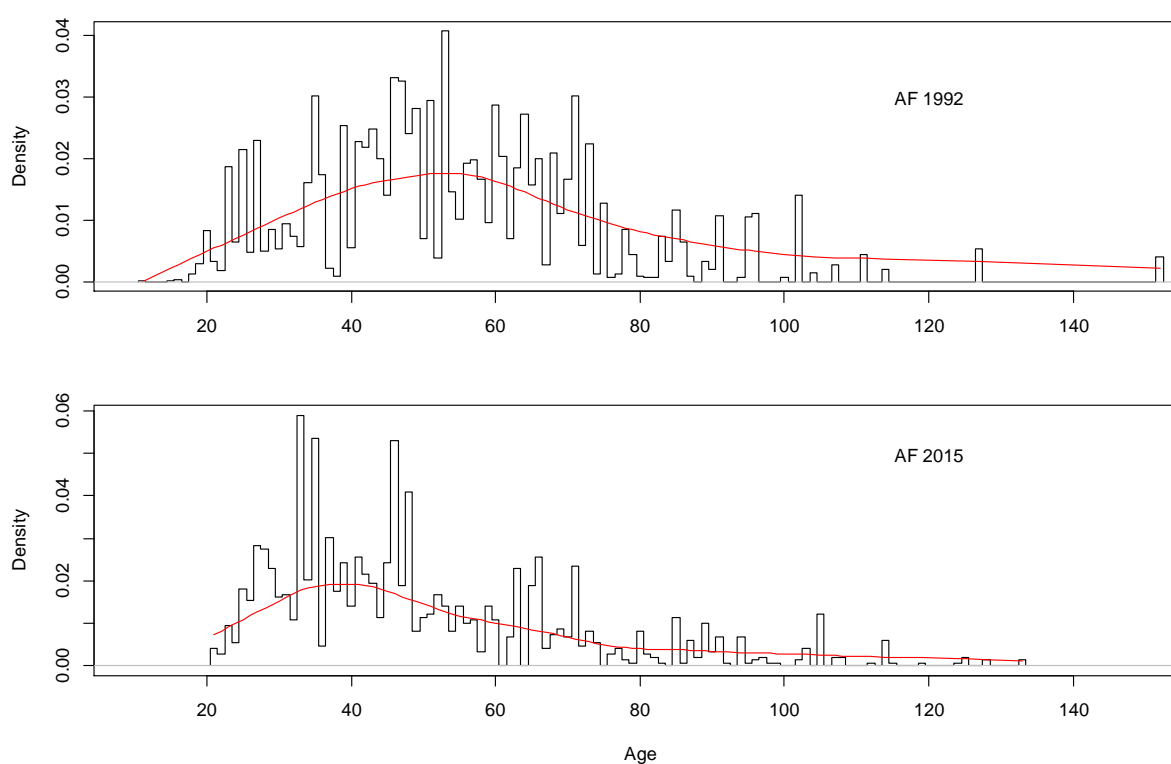
Figure 20: Puysegur: age frequencies from 1992 and 2015 used in the base model. The red lines were produced using the lowess smoother in R.

Trawl survey data

Trawl surveys of the Puysegur area were undertaken on *Tangaroa* in 1992 and 1994 (Clark & Tracey 1994, Clark et al 1996). However, the timing of the surveys was not ideal with the second survey being more than a month later than the first (Puysegur strata occupied in 1992: 8 August–11 September, and in 1994: 24 September–23 October). An analysis of seasonal CPUE suggested that catch rates in the later period could be expected to be 50% of those in the earlier period. Also, an analysis of fish length data suggested that larger fish were caught in the June-August period – the period taken to be the "spawning season" in the model (although spawning occurs in July). It appears that during the June-August period larger fish are more available to the fishing fleet and could have been more available to the trawl survey. There was a very large reduction in the biomass indices for such a short period (Table 14).

Table 14: Trawl survey biomass indices for all fish from the *Tangaroa* trawl surveys of the Puysegur area in 1992 and 1994. The CVs given are those used in the modelling and include no process error.

	Biomass index (t)	CV (%)
1992	6630	28
1994	1160	24

To allow for a possible reduction in availability between the 1992 and 1994 surveys, due to the change in timing, the selectivity for the trawl survey was modelled separately for mature and immature fish and an availability parameter for mature fish was estimated for the 1994 survey. The length frequencies from the trawl surveys are bimodal which could be partly explained by two groups of fish distinguished by maturity (Figure 21).
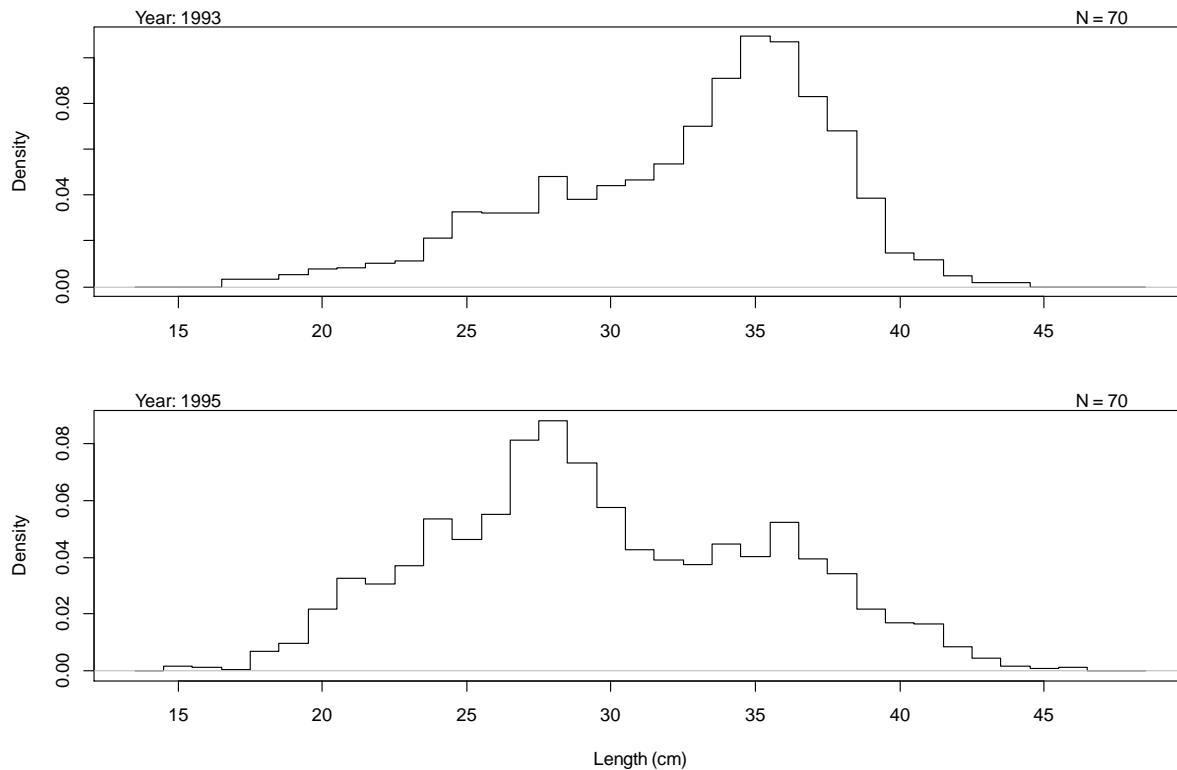
Figure 21: Puysegur: length frequencies for the *Tangaroa* trawl surveys in 1992 and 1994 (fitted in the model as beginning of year in 1993 and 1995). The effective samples sizes of N = 70 were the approximate number of stations in each survey.

Length frequencies (commercial fishery)

Scientific observer coverage of the Puysegur fishery was very patchy over the small number of years when the fishery operated. The best coverage was in the 1993–94 fishing year when there were 15 samples in the non-spawning season and 44 samples in the spawning season. The next best year, when more than one month was sampled in the non-spawning season, was 1996–97 when there were 6 non-spawning season samples and 3 spawning season samples. Scaled length frequencies were produced in those two years for the spawning and non-spawning seasons. The data were assumed to be multinomial with effective sample sizes equal to the number of samples.

4.3.3   Model runs and results

In the base model, the acoustic estimate from Goomzy in 2015 was used, with the *Tangaroa* trawl survey data, and natural mortality (*M*) was fixed at 0.045. There were six main sensitivity runs: exclude the *Tangaroa* trawl survey data; low weight on the age frequencies; high weight on the age frequencies; estimate *M*; and the *LowM-Highq* and *HighM-Lowq* "standard" runs (see Orange Roughy Introduction section). There were additional sensitivities: treating the trawl surveys as strictly comparable; using lognormal priors on the free year class strength parameters; alternative fixed non-spawning season fishing selectivities; adding a 5% overrun to the catch history; and using a higher CV on the acoustic *q* prior.

In the base model, the main parameters estimated were: virgin (unfished, equilibrium) spawning biomass (B_0), maturity ogive, trawl-survey selectivity, CV of length-at-mean-length-at-age for ages 1 and 120 years (linear relationship assumed for intermediate ages), and year class strengths (YCS) from 1917 to 1990 (with the Haist parameterisation and "nearly uniform" priors on the free parameters).

Model diagnostics

The model provided good MPD fits to the data. Residuals were examined mainly at the MCMC level and these were all acceptable suggesting that the data weightings (CVs and effective sample sizes) were reasonable.

The marginal posterior distribution of the acoustic q shifted somewhat to the left of the prior but remains well within the distribution of the prior (Figure 22).

The MPD sensitivity runs where the trawl surveys were assumed strictly comparable, despite the difference in timing, were unable to fit the decline in the trawl indices and showed poorer fits to the trawl survey length frequencies than the base model. The objective function decreased by 7 likelihood units when the availability parameter for 1994 was estimated (which supports the inclusion of the single additional parameter).

When lognormal priors were used for the free YCS parameters the trawl survey indices were fitted adequately (as the availability parameter was estimated) but the fits to the composition data (length and age frequencies) were degraded compared to the base model (which used nearly uniform priors on the free YCS parameters). The worst example of the poor fits was for the *Tangaroa* trawl survey length frequency in 1994. The reason for the poorer fits to the composition data was because the use of a lognormal prior severely constrained the estimated YCS. The near uniform prior allows much more freedom in the pattern of estimated YCS. Behaviour in the MCMC runs is much improved for the lognormal priors but there is the issue that the choice of sigmaR is arbitrary (see the Orange Roughy Introduction section).
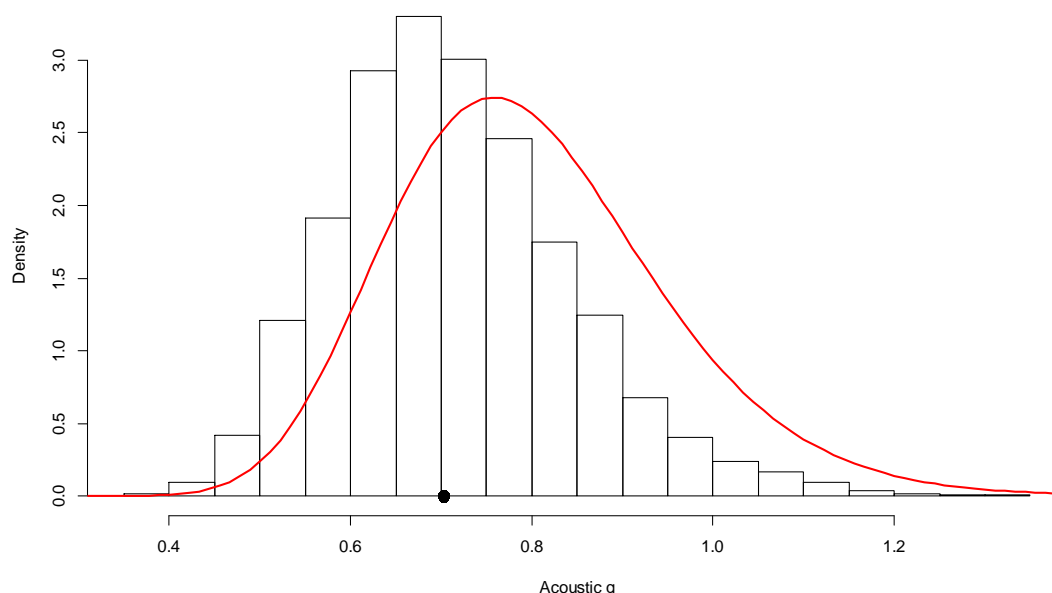

Figure 22: Puysegur: the marginal posterior distribution of the acoustic *q* (histogram) compared to its prior (red line). The black dot marks the median of the marginal posterior.

MCMC Results

For the base model, and the sensitivity runs, MCMC convergence diagnostics for virgin biomass (B_0) and stock status were very good. B_0 was estimated to be between 12 000–26 000 t for all runs (Table 15). Current stock status was similar across the base and the first four sensitivity runs (Table 15). The slightly lower stock status when M was estimated reflects the lower estimates of M (0.040 rather than 0.045). For the two "bounding" runs, where M and the mean of the acoustic q prior were shifted by 20%, median current stock status was within or above the biomass target range of 30–50% B_0 for both runs (Table 15). The sensitivity with a higher CV on the acoustic q prior gave similar results to the base model with a slighter higher B_0 and stock status. The 5% overrun model gave almost identical results to the base model. All other sensitivity runs gave stock status estimates within the range covered by the *LowM-Highq* and *HighM-Lowq* models.

Table 15: Puysegur: MCMC estimates of virgin biomass (B_0) and stock status (B_{2017} as %B_0) for the base model and six sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2017} (%B_0)	95% CI
Base	0.045	17	13–23	49	36–62
No trawl	0.045	17	13–24	51	39–64
Low AF	0.045	15	12–21	46	34–61
High AF	0.045	18	14–26	51	39–63
Estimate M	0.040	18	13–25	47	34–61
LowM-Highq	0.036	18	14–23	42	30–55
HighM-Lowq	0.054	17	12–25	57	44–69

For the base model, (and all sensitivities) the stock is considered to be fully rebuilt according to the Harvest Strategy Standard (at least a 70% probability that the lower end of the management target range of 30–50% B_0 has been achieved).

The estimated YCS show a trend across cohorts with above average recruitment prior to 1950 with below average recruitment up until about 1980 (Figure 23). The variation in the more recent (true) YCS is due to variation in depletion levels across the MCMC samples (and hence different levels of recruitment were generated from the stock-recruitment relationship).
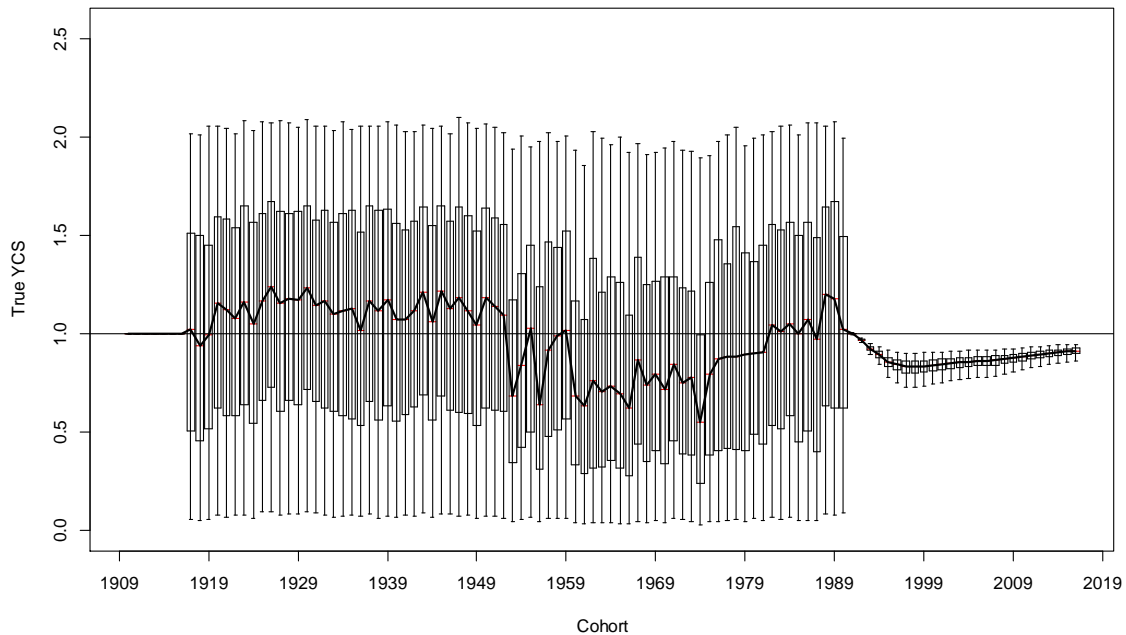

Figure 23: Puysegur base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated spawning-stock biomass (SSB) trajectory showed a declining trend from 1990 (when the fishery started) through to 1998 when the fishery was closed (Figure 24). Since 1998 the estimated biomass has increased steadily and has been well within the target range for the last decade (Figure 24).
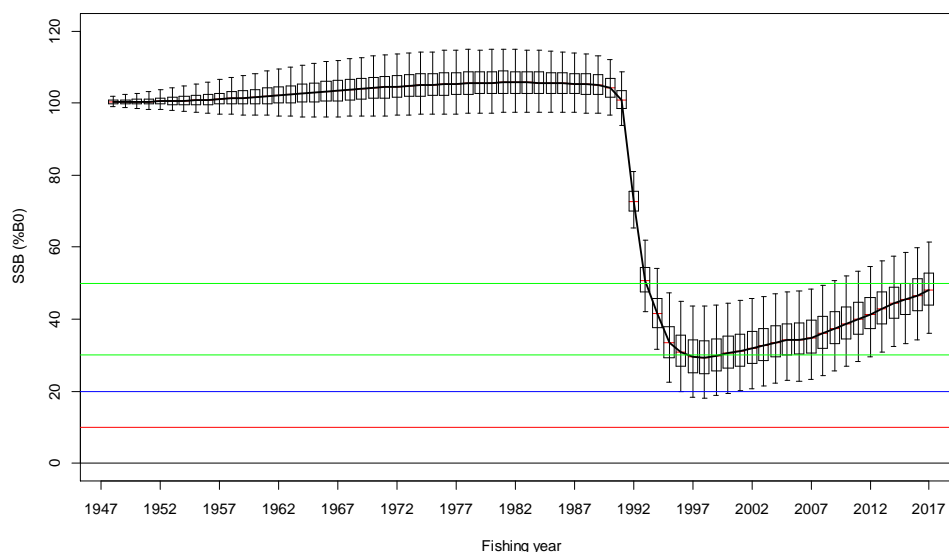
Figure 24: Puysegur base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity by year. Fishing intensity is represented in terms of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ forces the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was above $U_{20\%B0}$ for most of the history of the fishery before it was closed in 1998; it was briefly in the target range ($U_{30\%B0}$–$U_{50\%B0}$) in 2006 when there was a combined acoustic and trawl survey (Figure 25).
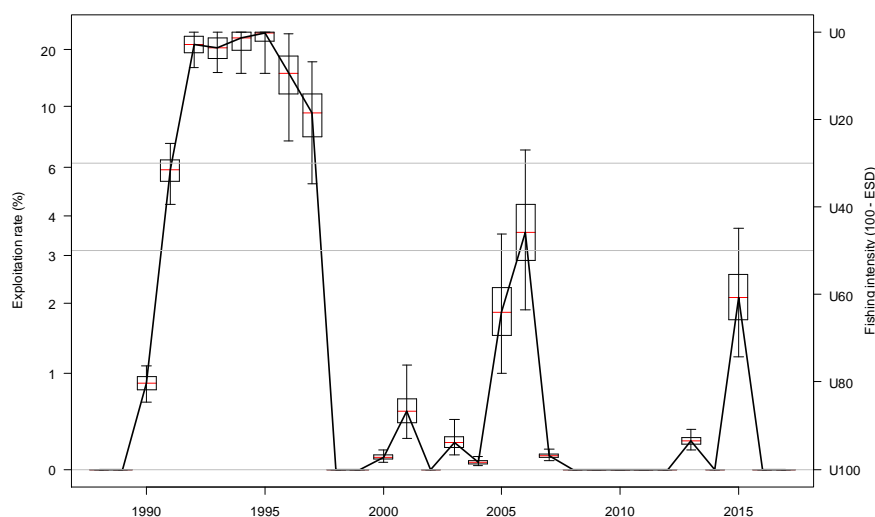

Figure 25: Puysegur base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–50% B_0 is marked by horizontal lines.

Biological reference points, management targets and yield

Orange roughy stocks with model based stock assessments are managed according to the Harvest Control Rule (HCR) that was developed in 2014 using a Management Strategy Evaluation (MSE) (Cordue 2014b). The HCR has a target biomass range of 30–50% B_0.

Yield estimates are not reported for this stock.

4.4 Research needs

- Ongoing monitoring of the stock will be required if the fishery is reopened (Update: the Puysegur orange roughy fishery was reopened in 2017).
- This is best done with acoustic survey estimates conducted during the spawning season.
- Additional representative age frequencies from the commercial catch and from spawning aggregations will also be required.
- It would also be useful to estimate von Bertalanffy growth parameters specifically for Puysegur orange roughy, rather than using the estimates from the Chatham Rise.

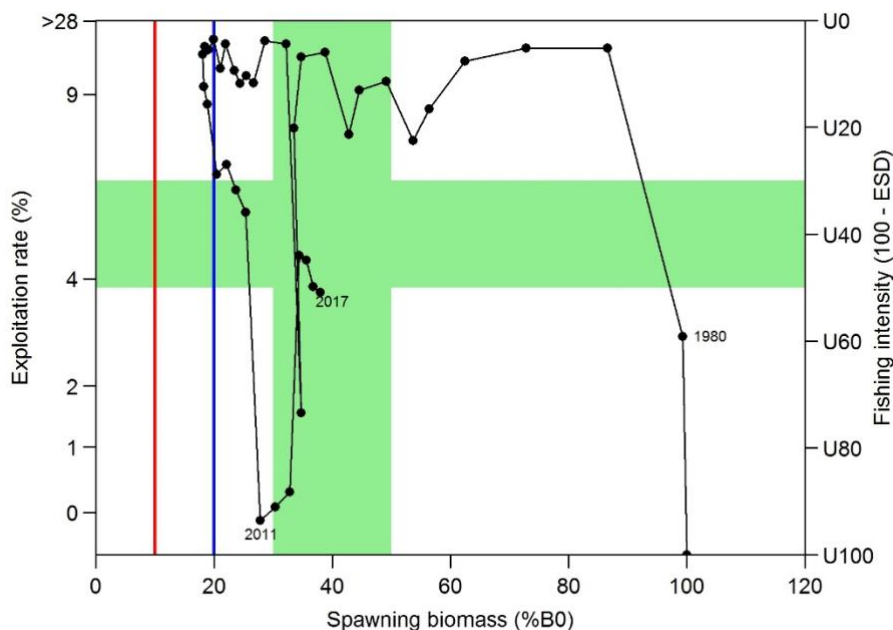# 5.   STATUS OF THE STOCKS

5.1   Chatham Rise

Stock Structure Assumptions

Chatham Rise orange roughy are believed to comprise two biological stocks; these are assessed and managed separately: one on the Northwest of the Chatham Rise and the other ranging throughout the East and South Rise. This assumed stock structure is based on the presence of two main areas where spawning takes place simultaneously, and observed and inferred migration patterns of adults and juveniles. These two biological stocks form the bulk of the ORH 3B Fishstock. They are geographically separated from all other ORH 3B biological stocks.

- **Northwest Chatham Rise**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–50% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B0}$–$U_{50\%B0}$
Status in relation to Target	B_{2017} was estimated at 38% B_0. Very Likely (> 90%) to be at or above the lower end of the management target range
Status in relation to Limits	B_{2017} is Exceptionally Unlikely (< 1%) to be below the Soft Limit. B_{2017} is Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status

Historical trajectory of spawning biomass (%B_0), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30–50 % B_0 and the corresponding exploitation rate range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red. Note that the Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass reached its lowest point in 2004 and has increased consistently since then. According to the Harvest Strategy Standard, the stock is considered to be fully rebuilt (at least a 70% probability that the lower end of the management target range of 30–50% B_0 has been achieved).
Recent Trend in Fishing Intensity or Proxy	Fishing intensity decreased sharply from 2010 to 2011 and has remained below the overfishing threshold since then.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	At both the TACC (1 250 t) and current agreed catch (1 043 t), the biomass is expected to stay steady or increase over the next 5 years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	At both TACC and current agreed catch limit: 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%) at both TACC and current agreed catch limit.

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: 2018	Next assessment: 2021

Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Acoustic estimates of spawning biomass on Graveyard (1999, 2012–13) and Morgue (1999, 2012, 2016).	1 – High Quality
	- Trawl survey age frequency and proportion-spawning-at-age (1994).	1 – High Quality
	- 17 years of length frequency data.	1 – High Quality
	- Morgue age frequency (2016); only as a sensitivity	2 – Medium or Mixed Quality: potential non-representative sampling
Data not used (rank)	- CPUE	3 – Low Quality: unlikely to be indexing stock-wide abundance
	- Trawl surveys of hills (1990–2002)	3 – Low Quality: unlikely to be indexing stock-wide abundance
	- Wide-area acoustic survey estimates	2 – Medium or Mixed Quality: large potential bias due to mixed-species
	- Chatham Rise trawl survey deepwater stations (2010–2016)	2 – Medium or Mixed Quality: variable indices
	- Egg survey estimate	3 – Low Quality: survey design assumptions not met
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- The largest source of uncertainty is the proportion of the NWCR spawning stock that is indexed by the acoustic survey in each year. - In the base case, patterns in year class strengths are based on only one year of age composition data. - The time series of abundance indices is short and restricted to the period of lower stock status.	

Qualifying Comments
Estimates of stock biomass are sensitive to the means of the q priors.

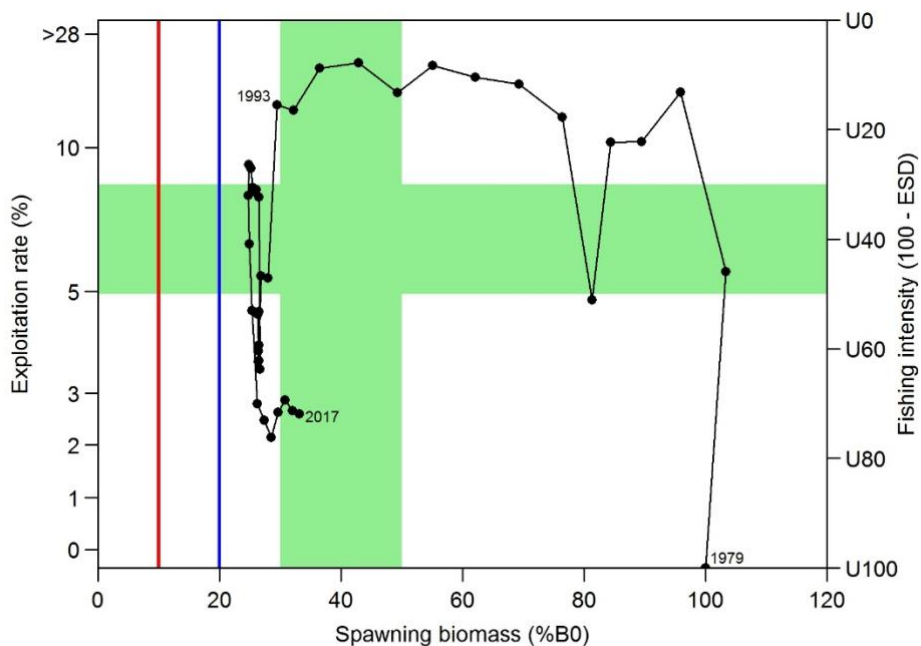| **Fishery Interactions** |
|---|
| Main bycatch species are smooth oreo, black oreo, rattails, deepwater dogfish and hoki, with lesser bycatches of Johnson's cod and ribaldo. Low productivity bycatch species include deepwater sharks, skates and corals. Observed incidental captures of protected species include corals, low numbers of seabirds and occasional New Zealand fur seals. |

- **East and South Chatham Rise**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–50% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B_0}$–$U_{50\%B_0}$
Status in relation to Target	B_{2017} was estimated to be 33% B_0

ORANGE ROUGHY (ORH 3B)

	Likely (> 60%) to be at or above the lower end of the management target range
Status in relation to Limits	B_{2017} is Very Unlikely (< 10%) to be below the Soft Limit B_{2017} is Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status

Historical trajectory of spawning biomass (%B_0), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30–50 % B_0 and the corresponding exploitation rate range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red. Note that the Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The spawning biomass is estimated to have been slowly increasing over the last six years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity (exploitation rate) is estimated to have been below the lower end of the target range in the last seven years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Biomass is expected to increase slowly at catches equal to the TACC.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	At the catch limit (3 100 t): Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: 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: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Four short time series of biomass indices from research trawl surveys	1 – High Quality
	- Acoustic indices from research surveys of spawning plumes (Old-plume, Rekohu plume, Crack)	1 – High Quality
	- Age frequencies from the spawning plumes in 2012, 2013, and 2016	1 – High Quality
	- Length frequencies from commercial fisheries	1 – High Quality
Data not used (rank)	- CPUE	3 – Low Quality: unlikely to be indexing stock-wide abundance
	- Acoustic surveys of hills (hull-mounted transducers)	3 – Low Quality: major species identification and dead zone issues
	- Wide-area acoustic survey estimates	2 – Medium or Mixed Quality: large potential bias due to mixed-species
	- Chatham Rise deepwater trawl survey stations (2010–2016)	2 – Medium or Mixed Quality: variable indices
Changes to Model Structure and Assumptions	None.	
Major Sources of Uncertainty	- The largest source of uncertainty is the proportion of the ESCR spawning stock that is indexed by the acoustic survey in each year. - Stock status is dependent on the timing of the appearance of the Rekohu spawning plume, which is unknown. - Patterns in year class strengths are based on only 3 years of age composition data.	

Qualifying Comments
Estimates of stock biomass are sensitive to the means of the *q* priors.

Fishery Interactions
Main bycatch species are smooth oreo, black oreo, deepwater dogfish, hoki and rattails, with lesser bycatches of slickhead, Johnson's cod and morids. Low productivity bycatch species include deepwater sharks and dogfish and also corals. Observed incidental captures of protected species include corals, low numbers of seabirds and occasional New Zealand fur seals.

- **5.2   Southern ORH 3B fisheries**

There are several other small fisheries in ORH 3B in the southern waters of which Puysegur appears to be the largest stock.

Puysegur

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–50% B_0 Soft Limit: 20% B_0

	Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B0}$
Status in relation to Target	B_{2017} was estimated at 49% B_0. Very Likely (> 90%) to be at or above the lower end of the management target range
Status in relation to Limits	B_{2017} is Exceptionally Unlikely (< 1%) to be below the Soft or Hard Limits
Status in relation to Overfishing	An agreed closure of the fishery was in place until 2017. Overfishing in 2017 is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status
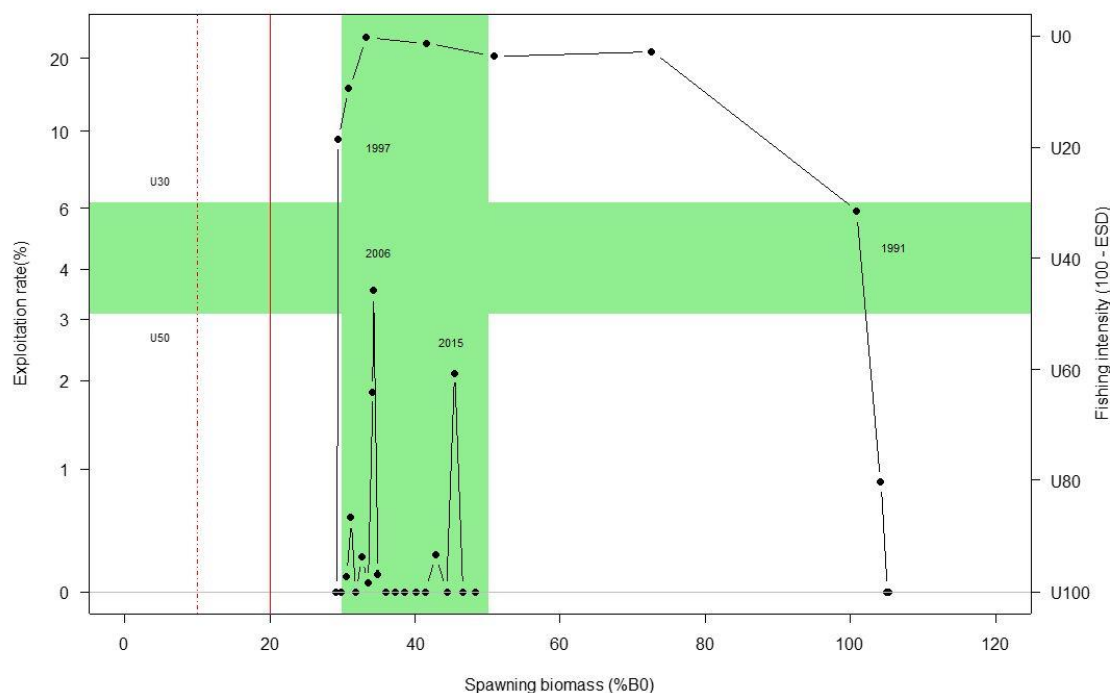
Historical trajectory of spawning biomass (%B_0), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30–50% B_0 and the corresponding exploitation rate range are marked in green. The soft limit (20% B_0) and the hard limit (10% B_0) are marked in red. Note that the left-hand Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass reached its lowest point in 1998 and has increased steadily since then. According to the Harvest Strategy Standard, the stock is now considered to be fully rebuilt (at least a 70% probability that the lower end of the management target range of 30–50% B_0 has been achieved).
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been close to zero since the fishery was closed in 1997-98 with the exception of 2005, 2006, and 2015 when surveys were conducted.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	No projections were conducted
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catch is zero

Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current catch is zero	

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: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Acoustic estimate of spawning biomass on Goomzy (2015) - Trawl survey indices and length frequencies (1992, 1994) - Age frequencies (1992, 2015) - 2 years of length frequency data	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- CPUE - Winter trawl surveys (1991, 1992, 2006) - Acoustic survey estimates (2005, 2006) - Additional commercial length frequencies	3 – Low Quality: unlikely to be indexing stock-wide abundance 2 – Medium or Mixed Quality: unlikely to be indexing stock-wide abundance 2 – Medium or Mixed Quality: large potential bias due to mixed species 2 – Medium or Mixed Quality: not enough months sampled within each year
Changes to Model Structure and Assumptions	- The previous assessment was in 1998. - Model now based on spawning biomass rather than transition-zone mature biomass. - Age data included to enable estimation of year class strengths rather than assuming deterministic recruitment. - Trawl survey indices better modelled to allow for difference in timing - A more stringent data quality threshold was imposed on data inputs (e.g., CPUE indices not used)	
Major Sources of Uncertainty	-The largest source of uncertainty is the proportion of the Puysegur spawning stock that is indexed by the acoustic survey in 2015. - The single acoustic estimate is the only recent biomass index. - Patterns in year class strengths are based on only two years of age frequencies.	

Qualifying Comments

-	

Fishery Interactions

Historically the Puysegur orange roughy fishery included black and smooth oreos, deepwater dogfish, black cardinal fish, slickheads and rattails as significant bycatch. Interactions with other species are currently being characterised.

- **Auckland Islands (Pukaki South)**

The Deepwater Working Group examined the data on orange roughy catch and effort from the Auckland Islands area in 2006, and found that there had been relatively little fishing activity in this area in the previous few years. There were insufficient data to conduct a standardised CPUE analysis, and it was believed that unstandardised CPUE did not provide a suitable index of relative abundance. Therefore, a stock assessment could not be carried out.

- **Other fisheries**

In 2006 the Deepwater Working Group examined the data on orange roughy catch and effort from other parts of ORH 3B – the Bounty Islands, Pukaki Rise, Snares Island and the Arrow Plateau – and agreed that there were insufficient data to carry out standardised CPUE analyses for any of these areas.

6.   FOR FURTHER INFORMATION

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Bull, R; Doonan, I J; Tracey, D M; Coombs, R F (2000) An acoustic estimate of orange roughy abundance on the Northwest Hills, Chatham Rise, June–July 1999. New Zealand. Fisheries Assessment Research Document 2000/20. 36 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

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