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 to mid-2000s, and decreased further from 2005–2006 as TACCs were further reduced, and then increased after 2012–13, as TACCs were increased(Table 1 and Figure 1).

Table 1: Annual reported catches and TACCs of orange roughy from ORH 3B. Catches from 1979–80 to 1985–86 are from Robertson & Mace (1988) and from 1986–87 to present from Fisheries Statistics Unit and Quota Monitoring System data.

Fishing year	Reported catch (t)	TACC (t)	Agreed catch limit (t) §
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	–
2017–18	4 942	5 197	–
2018–19	5 157	6 091	–
2019–20	5 624	6 772	–
2020–21	6 524	7 967	
2021–22	6 781	7 967	

† 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.
§ 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).

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.

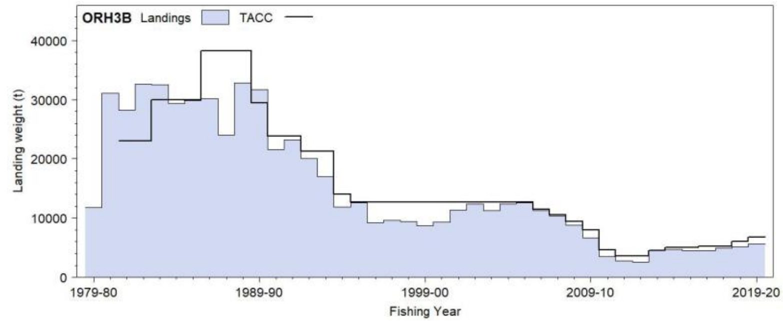

Figure 1: Reported commercial landings and TACCs for ORH 3B.

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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 are allocated to an 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
2017–18	840	17	445	9	1 285	26	1 532	31	840	17
2018–19	304	7	455	10	2 556	55	651	14	684	15
2019–20	342	5	307	6	3 233	59	1 144	21	596	11

2020–21	391	6	235	4	4 241	65	1 311	20	346	5
2021–22	203	3	61	1	5 099	75	963	14	454	7

In the early 1990s, effort within Chatham Rise shifted further 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. Since it was reopened, the annual catch mostly came from the Spawning Box and the Rest ofthe East Rise (Table 2).

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 5000 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 3600 t in 2011–12 but has since been increased (Table 1). The agreed catchlimit for the East and South Chatham Rise has increased in most years since 2017–18 (Table 3).

The catch limits by subarea are given in Tables 3. On five occasions, 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.

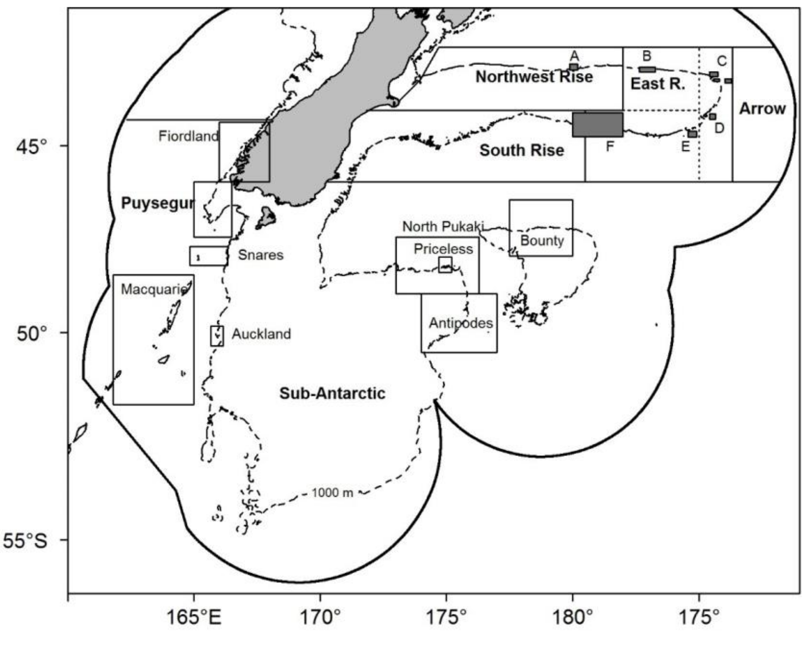


Figure 2: ORH 3B fishery sub-areas and the approximate position of other named fisheries. The recognised stocks are indicated by bold text. The rectangles mark the main fishing grounds, with those on Chatham Rise shaded: A, Graveyard (180) hills; B, Spawning Box; C, Smith's City NE hills; D, Andes; E, Chiefs; F, South Rise (Mt. Kiso & Hegerville).

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 no longer produce their previous levels of catch (Table 4). High catchrates 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 to2017–18. The catch limit was set at 1150 t from 1 October 2018.

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
2017–18	1 250 δ	3 100	*	347	0	500
2018–19	1 150	4 095	*	347	0	500
2019–20	1 150	4 775	*	347	0	500
2020–21	1 150	5 970	*	347	0	500
2021–22	1 150	5 970	*	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.

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 75% in 2021–22). Catches from the Old Spawning Plume during the spawning season (which peaks in July) decreased to <100 t between 2015–16 and 2019–20 as fishing was focused on Rekohu, but then increased in 2020–21 and 2021-22 (Table 4).

Table 4: Orange roughy estimated catches (to nearest 10 t), effort as number of tows, and unstandardised catch rates (total catch divided by total number of tows; to nearest 0.1 t/tow) for orange roughy target fishing on Chatham Rise. Spawning Box In season is spawning plume area May-August), and Out season is September-April Letters in parentheses indicate subareas, as in Table 3. Approximate positions are: Big Chief, 44.7° S, 175.2° W; Smiths City and neighbours, 43.1° S, 174.2° W; Andes, 44.2° S, 174.6° W; Graveyard, 42.8° S, 180° W). NA is shown when there were fewer than three vessels in the fishery within the last five years reported. –, zero targeted catch and effort. CPUE is not an accepted index of stock abundance but may inform local abundance. **[Continued on next page]**

	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**
1978–79	–	–	–	–	–	–	7 100	446	15.9	2 240	172	13.0
1979–80	–	–	–	110	36	3.1	9 800	967	10.1	7 400	791	9.4
1980–81	–	–	–	2	2	1.0	11 100	889	12.5	6 240	461	13.5
1981–82	–	–	–	40	11	3.6	4 750	470	10.1	4 450	604	7.4
1982–83	–	–	–	40	2	20.0	3 980	227	17.5	3 840	386	9.9
1983–84	–	–	–	60	7	8.6	6 590	378	17.4	8 630	836	10.3
1984–85	–	–	–	10	3	3.3	9 320	676	13.8	7 460	537	13.9
1985–86	–	–	–	670	52	12.9	8 521	659	12.9	7 650	859	8.9
1986–87	–	–	–	210	34	6.2	8 090	597	13.6	12 010	1 035	11.6
1987–88	–	–	–	160	33	4.8	7 870	622	12.7	5 820	701	8.3
1988–89	30	18	1.7	310	48	6.5	6 970	595	11.7	6 730	817	8.2
1989–90	90	13	6.9	40	9	4.4	6 830	403	16.9	5 020	609	8.2
1990–91	80	12	6.7	4 890	633	7.7	2 820	238	11.8	2 900	212	13.7
1991–92	7 080	724	9.8	1 270	222	5.7	650	85	7.6	380	59	6.4
1992–93	2 940	345	8.5	600	84	7.1	50	2	25.0	60	11	5.5
1993–94	3 320	605	5.5	560	109	5.1	–	–	–	20	3	6.7
1994–95	1 650	573	2.9	1 140	345	3.3	490	86	5.7	20	31	0.6
1995–96	1 120	418	2.7	410	145	2.8	1 360	127	10.7	150	42	3.6
1996–97	730	260	2.8	720	164	4.4	930	101	9.2	610	107	5.7
1997–98	1 140	476	2.4	400	146	2.7	1 580	118	13.4	660	154	4.3
1998–99	1 260	448	2.8	810	272	3.0	510	73	7.0	530	151	3.5
1999–00	1 990	529	3.8	680	210	3.2	910	34	26.8	520	112	4.6
2000–01	980	354	2.8	650	191	3.4	810	59	13.7	440	124	3.5
2001–02	2 040	546	3.7	490	167	2.9	2 120	159	13.3	960	219	4.4
2002–03	2 230	872	2.6	400	124	3.2	2 150	166	13.0	1 000	216	4.6
2003–04	1 170	677	1.7	360	160	2.3	1 880	163	11.5	1 030	276	3.7
2004–05	1 090	518	2.1	310	127	2.4	1 910	214	8.9	860	230	3.7
2005–06	1 340	727	1.8	370	119	3.1	1 630	117	13.9	1 730	256	6.8
2006–07	1 160	583	2.0	570	201	2.8	1 980	121	16.4	1 720	355	4.8
2007–08	900	418	2.2	286	77	3.7	2 550	200	12.8	780	195	4.0
2008–09	350	327	1.1	473	174	2.7	2 020	121	16.7	1 030	214	4.8
2009–10	440	243	1.8	160	84	1.9	1 980	136	14.6	850	246	3.5
2010–11	460	151	3.0	90	27	3.3	1 230	75	16.4	70	28	2.5
2011–12	450	164	2.7	130	26	5.0	660	39	16.9	80	24	3.3
2012–13	450	163	2.8	10	7	1.4	580	30	19.3	70	18	3.9
2013–14	790	218	3.6	140	39	3.6	390	40	9.8	30	18	1.7
2014–15	460	162	2.8	42	16	2.6	210	27	7.8	50	9	5.6
2015–16	1 180	438	2.7	130	75	1.7	43	5	8.6	390	96	4.1
2016–17	700	438	1.6	70	37	1.9	–	–	–	320	104	3.1
2017–18	760	505	1.5	200	76	2.6	10	1	10.0	400	114	3.5
2018–19	470	423	1.1	190	81	2.3	40	10	4.0	260	95	2.7
2019–20	440	345	1.3	220	106	2.1	20	21	1.0	550	152	3.6
2020–21	180	281	0.6	140	85	1.6	1 220	167	7.3	1 530	303	5.0
2021–22	90	92	1.0	290	89	3.3	2 170	210	10.3	960	205	4.7

	Rest of East (E)			Graveyard (NW)			Rest of Northwest (NW)			Hegerville (S)		
Year	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**
1979–80	560	206	2.7	–	–	–	840	81	10.4	20	2	10.0
1980–81	30	10	3.0	80	8	10.0	7 960	2 072	3.8	980	235	4.2
1981–82	360	77	4.7	90	12	7.5	3 830	613	6.2	40	9	4.4
1982–83	1 030	63	16.3	90	11	8.2	8 500	1 482	5.7	7 440	856	8.7
1983–84	1 190	139	8.6	–	–	–	2 780	657	4.2	3 370	493	6.8
1984–85	990	80	12.4	–	–	–	1 640	314	5.2	5 660	824	6.9
1985–86	3 030	306	9.9	60	15	4.0	3 400	560	6.1	3 660	840	4.4
1986–87	1 950	296	6.6	30	12	2.5	2 920	659	4.4	2 470	601	4.1
1987–88	2 100	324	6.5	130	19	6.8	1 360	387	3.5	2 020	673	3.0
1988–89	2 090	299	7.0	130	28	4.6	3 280	846	3.9	1 160	563	2.1
1989–90	360	86	4.2	180	33	5.5	2 100	599	3.5	480	237	2.0
1990–91	540	92	5.9	10	4	2.5	1 230	268	4.6	230	80	2.9
1991–92	3 020	362	8.3	60	23	2.6	190	65	2.9	50	57	0.9
1992–93	610	85	7.2	3 240	298	10.9	210	80	2.6	400	91	4.4
1993–94	530	124	4.3	2 150	362	5.9	1 110	227	4.9	250	135	1.9
1994–95	500	199	2.5	1 590	362	4.4	800	293	2.7	120	107	1.1
1995–96	520	132	3.9	1 790	347	5.2	370	179	2.1	80	102	0.8
1996–97	310	102	3.0	840	205	4.1	1 070	345	3.1	120	92	1.3
1997–98	470	259	1.8	810	306	2.6	1 300	498	2.6	60	56	1.1
1998–99	350	210	1.7	930	187	5.0	1 520	553	2.7	120	23	5.2
1999–00	390	157	2.5	620	236	2.6	1 360	369	3.7	10	9	1.1
2000–01	380	139	2.7	1 010	299	3.4	1 310	614	2.1	110	22	5.0
2001–02	800	215	3.7	730	206	3.5	1 270	652	1.9	30	20	1.5
2002–03	980	339	2.9	1 080	254	4.3	1 060	596	1.8	180	45	4.0
2003–04	440	267	1.6	750	127	5.9	1 090	595	1.8	100	48	2.1
2004–05	410	200	2.1	920	176	5.2	570	332	1.7	100	23	4.3

2005–06	1 210	404	3.0	960	191	5.0	440	253	1.7	110	59	1.9
2006–07	970	431	2.3	590	76	7.8	140	42	3.3	160	38	4.2

Table 4: [Continued]

	Rest of East (E)			Graveyard (NW)			Rest of Northwest (NW)			Hegerville (S)		
Year	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow
2007–08	1 030	331	3.1	390	176	2.2	330	114	2.9	280	109	2.6
2008–09	970	372	2.6	390	75	5.2	300	113	2.7	530	184	2.9
2009–10	510	195	2.6	290	89	3.3	360	193	1.9	470	131	3.6
2010–11	120	39	3.1	10	5	2.0	30	5	6.0	130	32	4.1
2011–12	120	56	2.1	30	6	5.0	30	4	7.5	60	25	2.4
2012–13	60	38	1.6	70	9	7.8	20	5	4.0	30	10	3.0
2013–14	190	64	3.0	570	102	5.6	220	121	1.8	10	8	1.3
2014–15	160	36	4.4	550	164	3.4	200	120	1.7	10	8	1.3
2015–16	250	189	1.3	400	166	2.4	210	245	0.9	10	11	0.9
2016–17	180	131	1.4	190	143	1.3	430	323	1.3	21	30	0.7
2017–18	330	144	2.3	400	183	2.2	340	218	1.6	NA	NA	NA
2018–19	330	170	1.9	140	81	1.7	180	147	1.2	NA	NA	NA
2019–20	420	216	1.9	130	69	1.9	140	114	1.2	NA	NA	NA
2020–21	820	204	4.0	120	69	1.7	240	141	1.7	NA	NA	NA
2021–22	510	164	3.1	100	63	1.6	90	94	1.0	NA	NA	NA

	Big Chief (S)			Rest of South (S)			Rekohu		
Year	Catch	Tows	t/tow	Catch	Tows	t/tow	Catch	Tows	t/tow
1978–79	–	–	–	–	–	–	140	9	15.6
1979–80	–	–	–	20	12	1.7	30	7	4.3
1980–81	–	–	–	110	25	4.4	60	4	15.0
1981–82	–	–	–	30	28	1.1	20	3	6.7
1982–83	–	–	–	180	31	5.8	30	4	7.5
1983–84	–	–	–	120	86	1.4	1	1	1.0
1984–85	–	–	–	870	289	3.0	0	0	–
1985–86	–	–	–	530	198	2.7	10	2	5.0
1986–87	–	–	–	1 440	433	3.3	40	4	10.0
1987–88	–	–	–	3 180	923	3.4	10	5	2.0
1988–89	1 010	198	5.1	4 810	1 810	2.7	40	5	8.0
1989–90	2 860	529	5.4	4 240	1 114	3.8	60	7	15.0
1990–91	3 150	457	6.9	1 710	508	3.4	–	–	–
1991–92	820	136	6.0	1 230	425	2.9	10	2	5.0
1992–93	3 300	690	4.8	1 260	476	2.6	–	–	–
1993–94	2 370	695	3.4	2 240	1 181	1.9	–	–	–
1994–95	530	262	2.0	930	960	1.0	1	4	0.3
1995–96	580	142	4.1	410	411	1.0	20	1	20.0
1996–97	420	138	3.0	360	209	1.7	2	3	0.7
1997–98	950	294	3.2	460	541	0.9	1	3	0.3
1998–99	560	212	2.6	420	265	1.6	–	–	–
1999–00	380	123	3.1	510	193	2.6	–	–	–
2000–01	1 020	213	4.8	440	222	2.0	–	–	–
2001–02	660	233	2.8	340	211	1.6	10	2	5.0
2002–03	650	275	2.4	480	205	2.3	–	–	–
2003–04	570	299	1.9	470	276	1.7	1 030	151	6.8
2004–05	790	308	2.6	520	240	2.2	1 030	200	5.2
2005–06	500	302	1.7	410	283	1.4	160	65	2.5
2006–07	510	282	1.8	200	191	1.0	80	43	1.9
2007–08	690	335	2.1	170	189	0.9	180	55	3.3
2008–09	330	308	1.1	100	155	0.6	100	39	2.6
2009–10	180	125	1.4	40	63	0.6	60	28	2.1
2010–11	210	59	3.6	30	35	0.9	400	31	12.9
2011–12	180	72	2.5	10	18	0.6	670	36	18.6
2012–13	100	36	2.8	20	17	1.2	710	39	18.2
2013–14	350	77	4.5	140	85	1.6	950	40	23.8
2014–15	250	57	4.4	150	109	1.4	1 780	89	20.0
2015–16	190	159	1.2	110	66	1.7	700	54	13.0
2016–17	390	160	2.4	80	60	1.3	870	115	7.6
2017–18	340	180	1.9	50	57	0.9	800	83	9.6
2018–19	310	219	1.4	40	74	0.5	2 010	162	12.4
2019–20	160	156	1.0	60	71	0.8	2 560	269	9.5
2020–21	90	103	0.9	NA	NA	NA	1 200	202	5.9
2021–22	40	31	1.3	10	12	0.5	1 600	192	8.3

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 5000 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 at 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 1999–2000, and catches remained low until an increase in 2013–14.

In 1993–94, catcheswere taken on the 'Arrow Plateau', which became the first major fishery to develop on the easternmost section of the Chatham Rise. A catch limit of 3000 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 1000 t by the early 2000s (Table 3). The Arrow Plateau was closed to orange roughy fishing when it was designated a Benthic Protection Area in 2007 (Table 5). In 1995–96, large catches were reported on the southeast Pukaki Rise, with a catch total of over 3000 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 limitof 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. After 2008–09, the fishery extended over a relatively wide area, but catches and catch rates were low, and the fishery was effectively reduced to the Auckland Islands between 2011–12 and 2017–18 (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), 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 catches rapidly decreased).

Table 5: Orange roughy estimated catches (to nearest 10 t, or for smaller catches 5 t of <1 t), tows, and unstandardised catch rates (total catch divided by total number of tows; to nearest 0.1 t/tow) for orange roughy target fishing in areas outside Chatham Rise. For this table, the areas were defined by the following rectangles: Arrow, 42.17° to 46° S, east of 173° W; Auckland, 49° to 52° S, 165° to 167° E; Bounty, 46° to 47.5° S, 177.5° E to 180°; Priceless, 48° to 48.44° S, 174.7° to 175.2° E; Other Pukaki, 47° to 50.4° S, 174° to 176.4° E (and not in Priceless); Puysegur, 46° to 47.5° S, 165° to 166.5° E. The area described as Antipodes in previous reportsis now included in Other Pukaki. All years are from 1 October–30 September. NA is shown when there were fewer than three vessels in the fishery within the last five years reported. –, zero targeted catch and effort. CPUE is not an accepted index of stock abundance but may inform local abundance

	Arrow			Auckland			Bounty			Priceless		
Year	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**
1985–86	120	9	13.8	–	–	–	–	–	–	–	–	–
1986–87	110	10	10.8	–	–	–	–	–	–	–	–	–
1987–88	5	3	1.6	–	–	–	–	–	–	–	–	–
1988–89	10	3	3.3	–	–	–	–	–	–	–	–	–
1989–90	–	–	–	–	–	–	–	–	–	5	2	1.0
1990–91	200	16	11.1	–	–	–	–	–	–	–	–	–
1991–92	110	8	8.7	–	–	–	< 1	8	< 0.1	–	–	–
1992–93	20	3	2.8	30	30	1.5	–	–	–	5	6	0.3
1993–94	460	113	7.7	180	168	1.2	< 1	2	< 0.1	< 1	1	0.2
1994–95	760	249	3.0	840	206	4.7	< 1	5	< 0.1	–	–	–
1995–96	170	50	3.4	370	213	1.6	< 1	35	< 0.1	–	–	–
1996–97	250	152	1.7	120	92	1.1	20	13	1.5	< 1	3	< 0.1
1997–98	330	183	1.8	360	186	1.9	160	113	1.4	10	12	1.1
1998–99	760	273	2.7	440	219	2.0	130	167	0.8	10	2	3.0
1999–00	290	155	1.8	150	132	1.1	170	71	2.4	5	2	2.0
2000–01	190	83	2.3	60	68	0.9	150	55	2.7	< 1	1	< 0.1
2001–02	70	48	1.5	130	58	2.3	40	26	1.4	550	18	30.5
2002–03	220	80	2.7	10	30	0.3	220	53	4.1	480	36	13.2
2003–04	140	79	1.8	5	25	0.2	90	53	1.8	450	98	4.6
2004–05	60	86	0.7	5	6	0.8	100	38	2.6	540	175	3.1
2005–06	100	69	1.3	–	–	–	40	34	1.0	540	62	8.7
2006–07	–	–	–	–	–	–	5	14	< 0.1	470	92	5.1
2007–08	–	–	–	150	29	5.1	1	2	0.5	540	101	5.3
2008–09	–	–	–	110	17	6.3	< 1	1	< 0.1	180	42	4.3
2009–10	–	–	–	20	26	0.7	10	9	0.7	5	28	0.1
2010–11	–	–	–	40	26	1.5	100	28	3.5	5	8	0.3
2011–12	–	–	–	20	6	3.0	< 1	3	< 0.1	< 1	3	0.3
2012–13	–	–	–	40	12	3.1	–	–	–	–	–	–
2013–14	–	–	–	300	45	6.6	–	–	–	–	–	–

2014–15	–	–	–	350	88	3.9	–	–	–	–	–	–
2015–16	–	–	–	380	54	7.0	–	–	–	–	–	–
2016–17	–	–	–	150	58	2.6	50	6	7.7	<1	1	<0.1
2017–18	–	–	–	105	31	3.4	NA	NA	NA	NA	NA	NA
2018–19	–	–	–	NA	NA	NA	NA	NA	NA	NA	NA	NA
2019–20	–	–	–	NA	NA	NA	NA	NA	NA	NA	NA	NA
2020–21	–	–	–	NA	NA	NA	NA	NA	NA	NA	NA	NA
2021–22	–	–	–	–	–	–	–	–	–	–	–	–

	Other Pukaki			Puysegur			Other		
Year	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**	**Catch**	**Tows**	**t/tow**
1985–86	–	–	–	–	–	–	–	–	–
1986–87	–	–	–	–	–	–	–	–	–
1987–88	–	–	–	–	–	–	–	–	–
1988–89	–	–	–	–	–	–	30	10	3.3
1989–90	10	6	1.8	110	75	1.5	50	8	10.2
1990–91	10	1	6.0	600	124	4.8	20	36	0.6
1991–92	< 1	2	< 0.1	6 380	671	9.5	220	51	5.7
1992–93	5	13	0.3	4 190	630	6.6	360	226	1.9
1993–94	20	9	2.2	2 430	1 312	1.8	100	427	0.3
1994–95	50	20	2.2	1 250	156	8.0	90	80	1.5
1995–96	3 010	306	5.0	580	241	2.4	550	229	2.9
1996–97	670	595	< 0.1	430	160	2.7	400	152	2.8
1997–98	130	194	< 0.1	–	–	–	1 100	512	2.3
1998–99	130	82	< 0.1	10	6	1.9	1 780	492	3.8
1999–00	< 1	46	< 0.1	–	–	–	110	309	0.4
2000–01	40	25	1.6	–	–	–	190	556	1.9
2001–02	< 1	1	< 0.1	10	10	0.9	180	199	2.3
2002–03	10	3	3.2	–	–	–	310	120	6.6
2003–04	< 1	9	< 0.1	10	3	4.1	280	221	1.8
2004–05	520	43	11.7	100	17	5.6	460	153	3.7
2005–06	740	91	8.1	220	80	2.7	230	115	2.2
2006–07	730	119	6.2	–	–	–	1	6	< 1
2007–08	700	160	4.4	–	–	–	< 1	14	< 0.1
2008–09	630	127	4.9	–	–	–	< 1	10	< 0.1
2009–10	320	114	2.8	–	–	–	1	29	0.1
2010–11	90	50	1.7	–	–	–	40	41	1.1
2011–12	40	10	3.5	–	–	–	50	41	2.0
2012–13	–	–	–	–	–	–	200	45	4.7
2013–14	–	–	–	–	–	–	50	57	2.0
2014–15	–	–	–	140	29	5.0	110	44	4.2
2015–16	–	–	–	–	–	–	< 1	2	< 0.1
2016–17	<1	2	0.3	–	–	–	90	67	3.4
2017–18	NA	NA	NA	NA	NA	NA	NA	NA	NA
2018–19	NA	NA	NA	NA	NA	NA	NA	NA	NA
2019–20	NA	NA	NA	NA	NA	NA	NA	NA	NA
2020–21	NA	NA	NA	NA	NA	NA	NA	NA	NA
2021–22	NA	NA	NA	NA	NA	NA	–	–	–

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 fishing 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 in the Orange Roughy Introduction.

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 because no single dataset seemed to provide definitive information about likely stock boundaries. The analysed data 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 standard length) 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. However, the following suggest that all these areas are a single stock: 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. 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 with those in the Spawning Box. The spawning aggregation on the Northeast Hills has also exhibited 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 an 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 the idea of 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 zone 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. 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. The assessment of the MEC stock in 2013 used age data from the new ageing methodology (Traceyet al 2007, Horn et al 2016) and estimated recruitment. A similar assessment approach has been used for Northwest Chatham Rise and East & South Chatham Rise stocks since 2014, and Puysegur stock since 2017 (Cordue, 2014).

Stock assessment research for 2023

Research in 2023 raised some concerns about the results of the most recent stock assessment models of the Northwest Chatham Rise (2018) and East & South Chatham Rise (2020) which estimated both stocks to be in the target zone of 30–50% B_0. The concerns stemmed from inconsistencies between the stock biomass and trends estimated by the models, and observational data such as local estimates of CPUE and acoustic time series.

The 2018 accepted stock assessment estimated the Northwest Chatham Rise Spawning Stock Biomass (SSB) declined until about 2003–04, followed by a steady biomass rebuild. The biomass was estimated to have roughly doubled between the low point, 2003–04, and 2016–17, and was at 38% B0 in 2016–17 (see Table 9).

The Northwest Chatham Rise fishery took 17% of the agreed catch limit in 2021–22. About 20% of the recent catch was taken during the spawning season, compared to 60–85% historically (Anderson & Dunn 2012). This may be because the main spawning aggregation now occurs on the Morgue hill which was closed to bottom fishing in 2001, rather than the Graveyard hill which remains open to fishing. The recent fishery used more long tows on flat ground, rather than short tows on features; about 50% catch was taken in tows >4 hours duration after 2015–16, compared historically to about 50–90% from tows <1 hour (Figure 3). Unstandardised CPUE have been flat or declining, and was at historical lows in 2016–17 and 2021–22 (Table 4; Figure 4).

The 2020 East & South Chatham Rise assessment estimated the SSB trend was roughly flat from about 1994–95, with a steady rebuild after 2009–10. The biomass was estimated to have increased by about 45% between the low point, 2007–08, and 2019–20, and was at 36% B_0 in 2019–20 (see Table 12).

The East & South Chatham Rise fishery took 103% of the agreed catch limit in 2021–22. Since about 2015–16, the fishery changed from 65–90% caught in short tows of <1 hour duration on features and outside of the spawning season (June and July), to 50–60% caught in long tows of >2 hours duration (Figure 3), and about 90% taken during the spawning season. Three vessels have dominated the catch since about 2000–01, with four more vessels contributing since 2019–20. Unstandardised CPUE have generally been flat or slowly declining since 2010–11, and were at historical lows within the last two years for non-spawning fisheries at Andes complex, Big Chief & neighbours, Hegerville & neighbours, and Rest of South, but generally flat or variable for Smith City & neighbours and the spawning fisheries (Table 4; Figure 4).

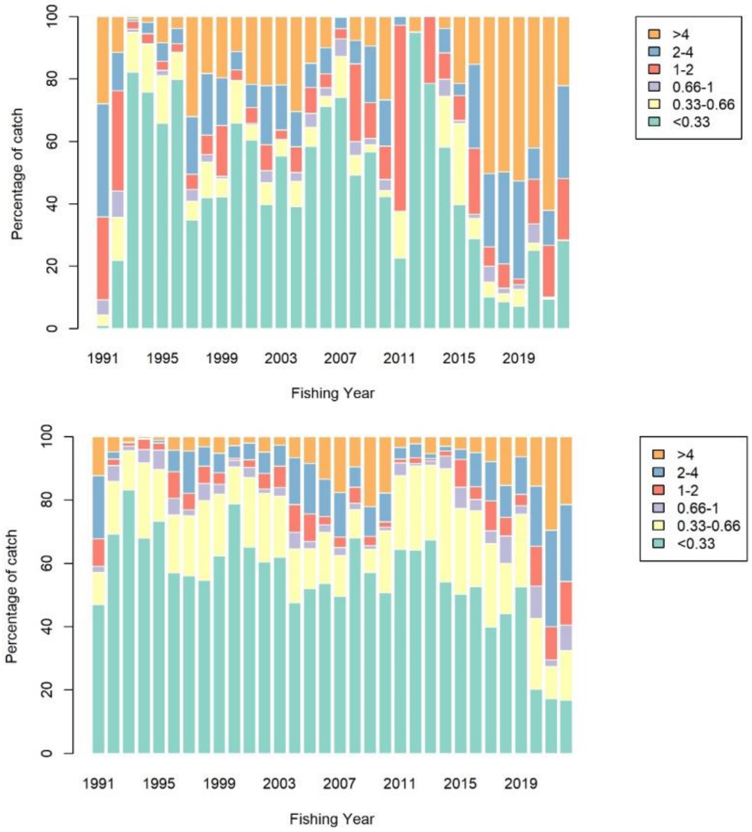


Figure 3: Northwest Chatham Rise (top panel) and East & South Chatham Rise (bottom panel) percentage of tows by duration (hours) and fishing year.

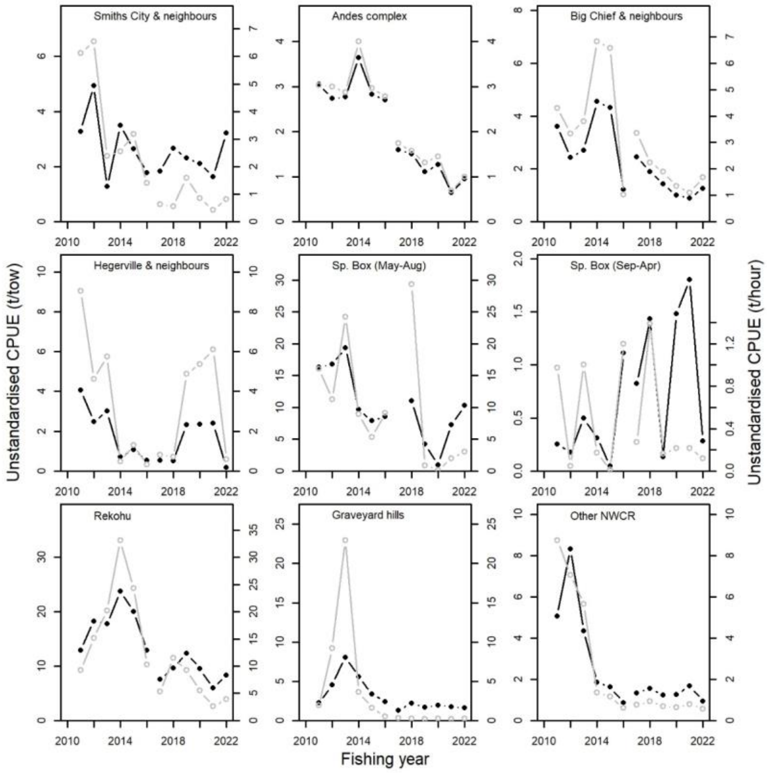


Figure 4: ORH 3B fishery sub-areas and annual unstandardized CPUE for the periods 2009–10 to 2015–16 (period of lower catches and TAC); 2016–17 to 2021–22 (recent years within which fishery characteristic have changed: see text). Black lines and points, t/tow (left y-axis); Grey lines and points, t/hour (right y-axis). CPUE is not an accepted index of stock abundance but may inform local abundance

The acoustic estimates of the Northwest Chatham Rise SSB have been low and variable for the Graveyard hill and increasing for the Morgue hill (Figure 5; Table 7). The combined area series shows an increasing SSB. The 2018 assessment model estimated SSB to be about 40% higher than was observed. It is unknown whether the orange roughy SSB on the closed hill Morgue move away from the hill to areas open for fishing outside of the spawning season.

The acoustic estimates of the East & South Chatham Rise SSB have declined and then been flat for the Old Spawning Plume, have been flat then lower for Rekohu, and flat then higher for Mt. Muck (Figure 5; Table 7). The combined area series is flat. The 2020 assessment model estimated SSB to be just over double the observed SSB for Old Spawning Plume, Rekohu, and Mt.Muck combined.

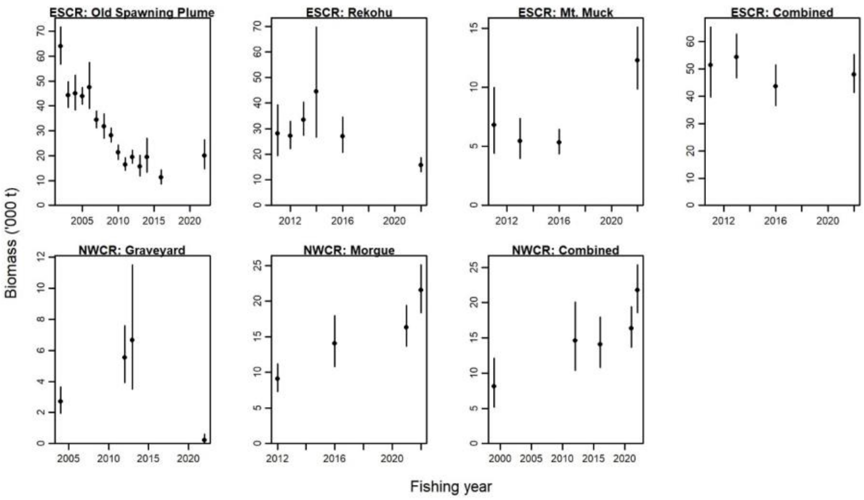


Figure 5: ORH 3B sub-areas and Spawning Stock Biomass estimates from acoustic surveys. ESCR, East & South Chatham Rise; NWCR, Northwest Chatham Rise. Vertical lines indicate 95% CI.

Table 7: Acoustic survey spawning stock biomass estimates (t) for the Northwest Chatham Rise stock and East & South Chatham Rise stock. CV in parentheses.

Fishing Year	Graveyard	Morgue	Combined
1989–99	NA	NA	8 126 (0.22)
2003–04	2 717 (0.16)	–	–
2011–12	5 550 (0.17)	9 087 (0.11)	14 637 (0.17)
2012–13	6 656 (0.31)	–	–
2015–16	–[1]	14 051 (0.17)	14 051 (0.17)
2020–21	–[1]	16 332 (0.09)	16 332 (0.09)
2021–22	225 (0.66)	21 747 (0.08)	21 972 (0.08)

1. Marks deemed insufficient to motivate a full AOS survey.

Fishing year	Old spawning plume	Rekohu	Mt. Muck	Combined
2001–02	63 950 (0.06)	–	–	–
2002–03	44 316 (0.06)	–	–	–
2003–04	44 968 (0.08)	–	–	–
2004–05	43 923 (0.04)	–	–	–
2005–06	47 450 (0.10)	–	–	–
2006–07	34 427 (0.05)	–	–	–
2007–08	31 668 (0.08)	–	–	–
2008–09	28 199 (0.05)	–	–	–
2009–10	21 205 (0.07)	–	–	–
2010–11	16 422 (0.08)	28 113 (0.18)	6 794 (0.21)	51 329 (0.13)
2011–12	19 392 (0.07)	27 121 (0.16)	–	–
2012–13	15 554 (0.14)	33 348 (0.10)	5 471 (0.16)	54 373 (0.07)
2013–14	19 360 (0.18)	44 421 (0.25)	–	–
2015–16	11 192 (0.13)	27 027 (0.13)	5 341 (0.10)	43 560 (0.09)
2021–22	19 906 (0.15)	15 786 (0.09)	12 289 (0.11)	48 981 (0.07)

For the Northwest Chatham Rise, age frequencies from Morgue in 2016 were found to include a greater proportion of old fish than expected. These data could not be fitted with the 2018 model assumptions (Dunn & Doonan 2017), and the 2016 age data were therefore excluded from the 2018 assessment. Samples from 2021 provided a similar age structure to 2018. However, samples from 2022 were different, with a large mode of fish around age 40 (Figure 6).

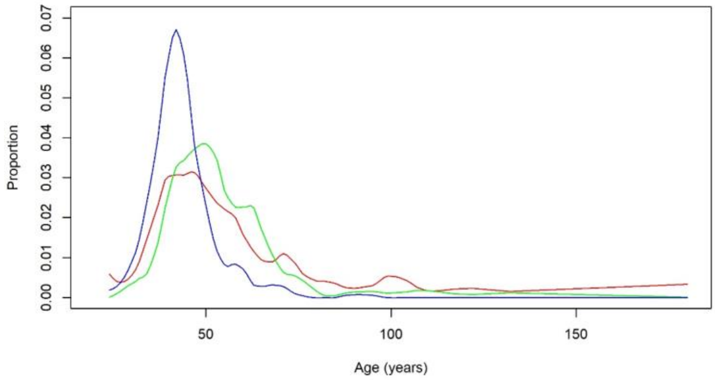


Figure 6: Northwest Chatham Rise, Morgue hill smoothed age frequency distributions: red line, 2016; green line, 2021; blue line, 2022.

For the East & South Chatham Rise, age frequencies for the combined areas (age frequencies weighted by acoustic biomass estimates) were similar in 2012 and 2016, but 2013 included a greater proportion of fish under about 40 years of age, whereas 2022 had very few fish less than about 45 years (Figure 7).

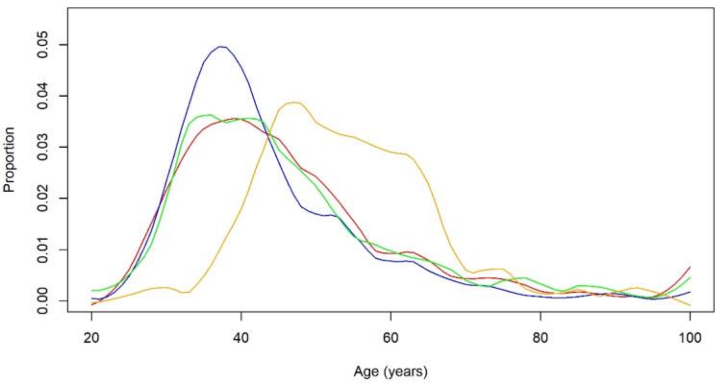


Figure 7: East & South Chatham Rise, combined area (Old Spawning plume, Rekohu, Mt.Muck) smoothed age frequency distributions: red line, 2012; blue lines, 2013, green line 2016, orange line, 2022.

The plausibility of the large observed changes in age frequencies was not resolved. The changes might be explained by selectivity or recruitment patterns, but perhaps more likely by sampling variability (due to the aggregating nature of orange roughy). Similarly pronounced changes in age structure have previously been seen in Chatham Rise orange roughy, and the age data were rejected from assessment models (Francis 2006).

Investigations using the CASAL assessment model in 2023 focused on the larger and more problematic East & South Chatham Rise stock. Emerging issues include:

- The recent increase in SSB predicted by the previous 2018 and 2020 assessments is not seen in the observational data and could be an artifact of model assumptions.

- Stock productivity appears to be lower than expected given the estimates of biological parameters used in the 2018 and 2020 models. All observations were inconsistent with the hypothesis that recruitment had remained constant. Recruitment was estimated to decline and then remain low once the fishery started. However, inconsistencies in age frequency data, and relatively high ageing error, meant recruitment was poorly informed.

- Length frequencies from research trawl surveys did provide some information on recruitment in the model, but the surveys were not representative (they were not designed for year class strength estimation), and this influence was misleading.

- Length frequencies from the commercial fishery and research trawl surveys had a predominant influence on model biomass estimates. Because of the slow growth of orange roughy, length frequencies are not expected to provide reliable information on stock status.

- The acoustic Old Spawning Plume series provided information only through the *q* priors, and favored a larger B_0 (around 350–380 kt). The subsequent combined area acoustic series provided information through the both the *q* prior and the series trend, with both favoring a lower B_0 (< 320 kt). This conflict suggests the assumptions used to interpret these series may be incorrect.

- The longevity of orange roughy, and potential for extended gaps in recruitment, made estimation of B_0 problematic. This is because the fishery, and scientific monitoring, may not have existed long enough to have experienced average productivity.

- The decline in the Spawning Box trawl survey biomass series was too steep to be fitted by the model. This lack of fit influenced estimates of biomass and age at maturity (assumed equal to selectivity). Disturbance of spawning aggregations by fishing may have influenced trawl survey results, and an additional SSB outside of the survey coverage might explain the observed steep biomass decline. The largest SSB outside of the trawl survey coverage has been found at Rekohu.

- The longevity and extended age structure of orange roughy populations means recruitment estimation has to cover a wide range of year classes. Simulation studies have shown this can cause model over-parameterization, and inaccurate estimates of stock size and status (Stephenson et al., 2022). Given the data and number of estimated parameters the 2020 model is likely to be overparameterized.

-The working group also questioned model assumptions including separate qs for each survey from 2002-2010 on the Old Spawning Plume

- A hypothesis used in the accepted assessment model was that the Old Spawning Plume acoustic biomass series between 2002 and 2010 was not representative of the SSB, and the series decline was caused by fish moving from the Old Spawning Plume to Rekohu. This assumption may be incorrect.

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 tables 1 and 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 8). An alternative treatment of the available acoustic data was to include additional survey estimates from 2002 and 2004 (Table 8). All of the data in Table 8 were used in the sensitivity run labelled 'Extra acoustics'.

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).

Table 8: 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

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 8 and 9). The acoustic indices, free to 'move' somewhat as they are relative, were fitted well (Figure 8). The posterior estimates for the acoustic *q*s 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 10).
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).

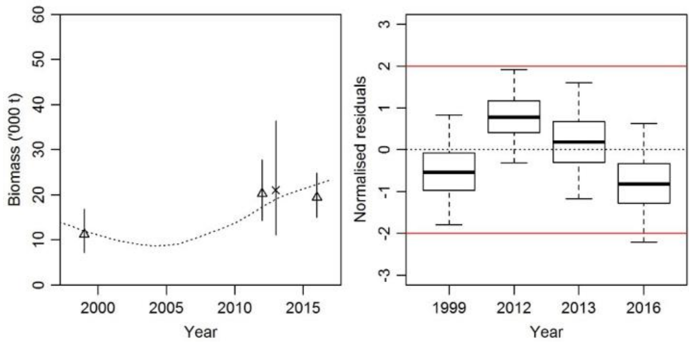


Figure 8: NWCR, base, (left) MPD fits to the acoustic biomass indices; broken line, spawning biomass trajectory; scaled acoustic indices for x, Graveyard survey, and Δ, Graveyard and Morgue surveys; (right) MCMC normalised residuals for the acoustic biomass indices. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

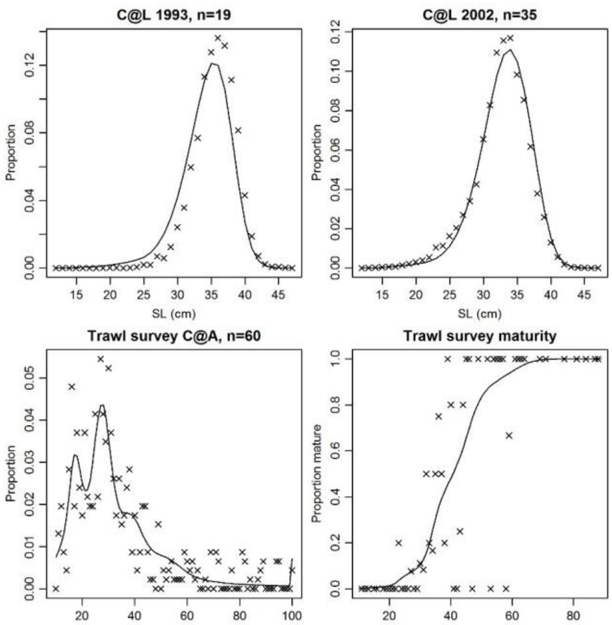


Figure 9: NWCR, base, MPD fits: (x, observations; lines, predictions): (top) commercial catch-at-length samples (n is the effective sample size); (bottom) trawl survey catch-at-age and proportion mature at age.

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 11). 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.

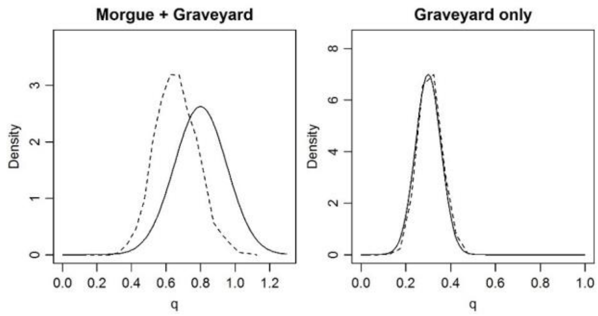


Figure 10: NWCR base, MCMC diagnostics: prior (solid line) and posterior (broken line) distributions for the two acoustic *q*s (left, mean *q*-prior = 0.8; right, mean q-prior = 0.3).

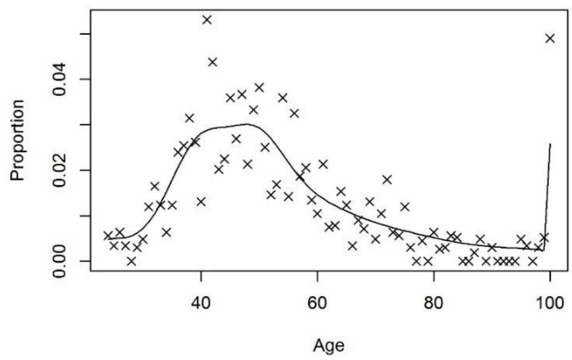


Figure 11: NWCR, base, MPD fits: (x, observations; lines, predictions) to the Morgue age frequency (effective sample size n = 60).

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 9). Current stock status was similar across the base and the first two sensitivity runs (Table 9). 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 9).

Table 9: 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 12).

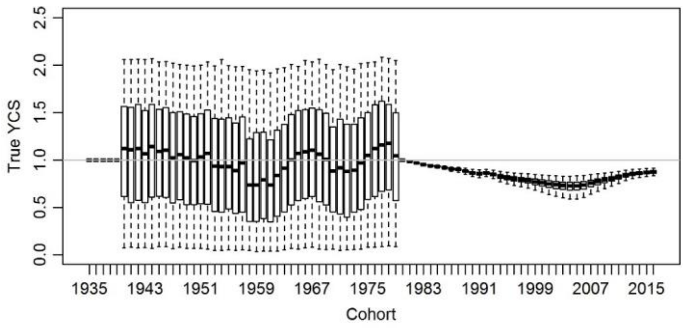


Figure 12: NWCR base, MCMC estimated 'true' YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

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 13). Since 2005 the estimated biomass has increased steadily.

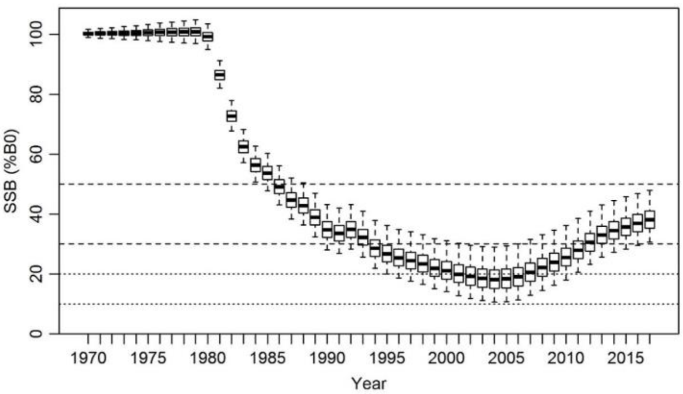


Figure 13: NWCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Dotted lines indicate the hard limit (10% B_0) and soft limit (20% B_0), and dashed lines the management target range (30–50% 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 14). There was less than a 1% probability that the exploitation rate in 2017 was below $U_{30\%B0}$.

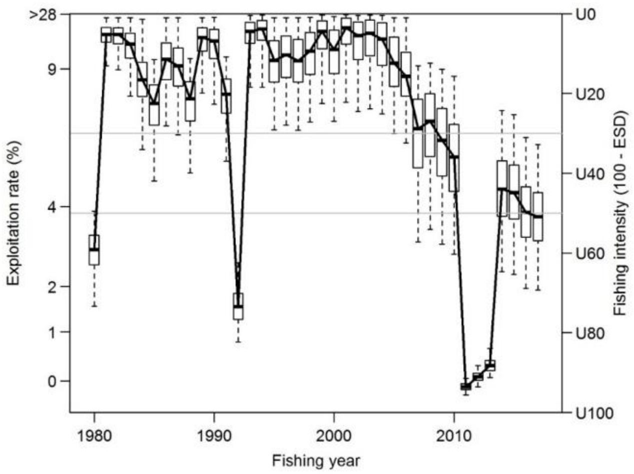


Figure 14: NWCR base, MCMC estimated fishing intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing intensity range associated with the biomass target of 30–50% B_0 is marked by horizontal lines.

Projections

Five-year biomass projections were made for the Base model run assuming future catches to be the TACC (1250 t), or the current agreed catch limit (1043 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 (1250 t) and the current agreed catch limit (1043 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 10).

Table 10: 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 (t)	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

The East and South Chatham Rise (ESCR) stock was assessed in 2014 (Cordue 2014a). The assessment was updated in 2018 using data up to 2016–17 (Dunn & Doonan 2018). That assessment was then updated to the end of 2017–18 to allow application of the orange roughy Harvest Control Rule (HCR) (Cordue 2014b, 2018). The assessment has been updated in 2020 to apply the HCR to calculate a catch recommendation for 2020–21. In each assessment 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, in the updated base model, 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 2). 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 Tables 1 and 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 DWWG for use in the stock assessment are shown in Table 11. 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.

A key question evaluated in the 2014 assessment was how long the Rekohu plume has 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 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.

Following Cordue (2014a), 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 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 for this proportionality constant (q_1): 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. This gave a mean of 0.7 for the proportionality constant (q_2) of 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 *q*s in years other than 2011 and 2013, the priors were given an increased CV of 30%.

Table 11: 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 Waitaki* 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 2018).

	Old plume		Rekohu		Crack	
Year	**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

As well as updating the base model, two additional runs were made which had different assumptions with regard to the acoustic *q*s. In the standard *LowMhighq* sensitivity run, the means of the acoustic *q* priors were all increased by 20% (and the value of *M* was decreased by 20%). In the 'q-ratio model' a prior was placed on the ratio q_1/q_2. The standard lognormal prior was used for q_1 and a uniform prior for q_2. A lognormal prior was used for the ratio with the mean equal to 1.14 (0.8/0.7) and a CV of 7.5% which strongly encouraged the ratio to be greater than 1 (reflecting that three areas had been surveyed for the first time series but only two of those areas for the second time series).

There was no agreement in the DWWG as to whether the updated base model or the q-ratio model was to be preferred. The *LowMhighq* model was run relative to the updated base model because that had the lowest estimated stock status and therefore the *LowMhighq* model would be a 'worst case' scenario as intended. The updated base model is denoted as the 'current model' rather than the base model.

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 15). A consistent area was surveyed using fixed station positions (with some random second phase stations each year).

The biomass indices were fitted as relative indices with a separate time series for each vessel (with uninformed priors on the *q*s). 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 to 27 July and 62 trawl tows were completed. In 2004, the survey ran from 7 to 29 July and 57 trawl tows were completed.

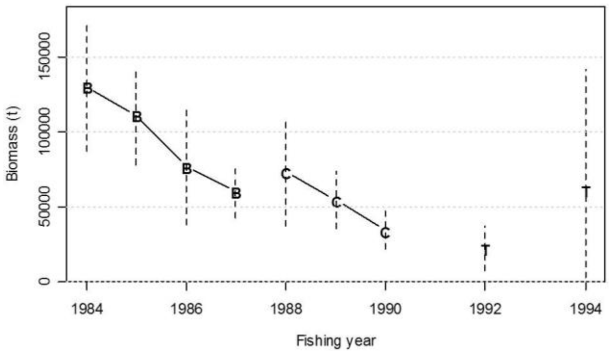


Figure 15: The Spawning Box trawl survey biomass indices (assuming a catchability of 1 for each vessel), with 95% confidence intervals shown as vertical lines. Vessels indicated as B, FV *Otago Buccaneer*; C, FV *Cordella*; T, RV *Tangaroa*.

The 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 to 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; 2018). 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) 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

As well as the updated base model (denoted as the ‘current model’) there were two additional models: the q-ratio model which assumed a single fishery on mature fish, had a prior on q_1/q_2, and added 20%

process error to the associated acoustic biomass indices; and the standard *LowMhighq* model (see Orange Roughy Introduction)

In all three models, the main parameters estimated were: virgin (unfished, equilibrium) biomass (B_0), the 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 *q*s.

MCMC chain diagnostics

For each model, three chains of fifteen million iterations were run. One sample in each one thousand iterations were stored and the first one thousand samples were discarded as a 'burn-in' (the chains start near the MPD estimate and early samples may be unrepresentative of the posterior distribution). The traces of the main free parameters were checked to make sure that they did not exhibit any long-term trends, and the estimates of B_0 and current stock status ($SS_{2020} = B_{2020}/B_0$) from each chain were checked to see that they were the same to two significant figures. Point estimates (median) and 95% credibility intervals (95% CIs) were constructed using all three chains combined after the burn-in (a total of 42 000 samples).

Model diagnostics

MPD fits and MCMC fits and residuals and marginal posterior distributions for the *q*s were examined for the current model and the q-ratio model. In general, the fits were excellent and the *q* posterior distributions and standardised residuals were acceptable (see Figures 16–18). The main exception was for the current model where the normalised residuals for the 2016 acoustic estimate are well outside the expected range (Figure 19). In the q-ratio model the residuals are much improved because of the addition of 20% process error (the CV is only 10% in the current model which is just a measure of observation error).

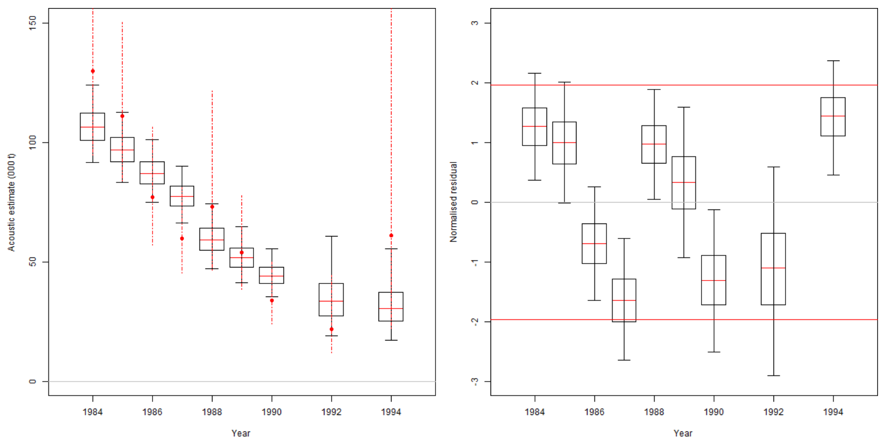


Figure 16: Current model: the MCMC fits and normalised residuals for the trawl survey biomass estimates in the spawning box. The observations are plotted with 95% confidence intervals (left plot, red vertical lines). The MCMC predictions (left plot) and normalised residuals (right plot) are plotted as a 'box and whiskers'. The middle 50% of the distribution is in the box with the whiskers extending to a 95% C.I.

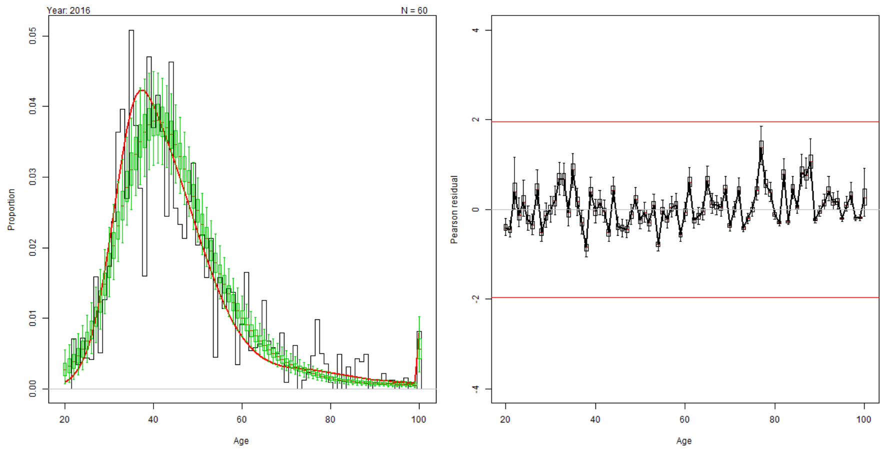


Figure 17: Current model: the MCMC fits and normalised residuals for the 2016 spawning population age frequency (left plot, histogram in black). The MPD fit is shown as the red line in the left plot. The MCMC predictions (left plot) and Pearson residuals (right plot) are plotted as a "box and whiskers". The middle 50% of the distribution is in the box with the whiskers extending to a 95% C.I.

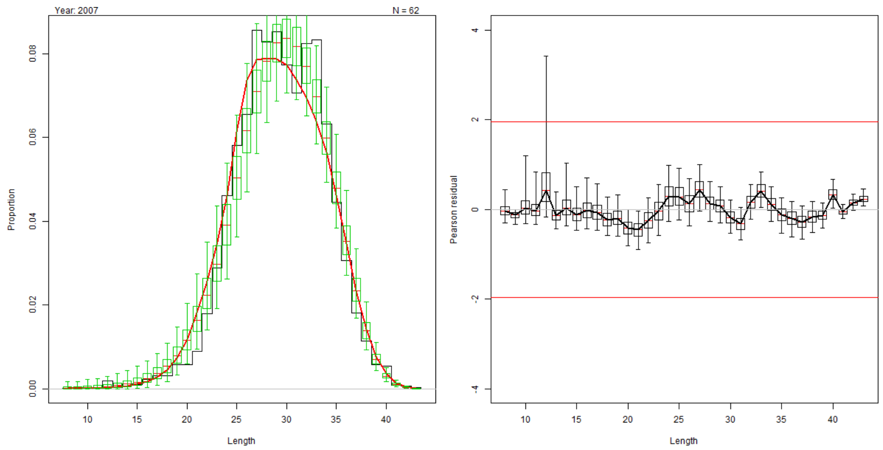


Figure 18: Current model: the MCMC fits and normalised residuals for the 2007 wide-area trawl survey length frequency (left plot, histogram in black). The MPD fit is shown as the red line in the left plot. The MCMC predictions (left plot) and Pearson residuals (right plot) are plotted as a 'box and whiskers'. The middle 50% of the distribution is in the box with the whiskers extending to a 95% C.I.

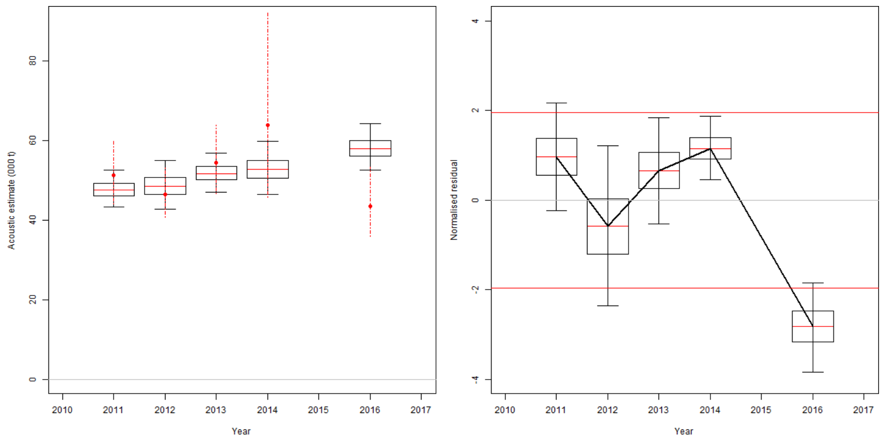


Figure 19: Current model: the MCMC fits and normalised residuals for the acoustic survey biomass estimates since 2011. The observations are plotted with 95% confidence intervals (left plot, red vertical lines). The MCMC predictions (left plot) and normalised residuals (right plot) are plotted as a 'box and whiskers'. The middle 50% of the distribution is in the box with the whiskers extending to a 95% C.I.

The marginal posterior distributions for the two main acoustic *q*s are well within their prior distributions (Figure 20). However, in the current model the ratio of the two *q*s has a probability of being less than 1 of 39%. A value less than 1 must be considered very unlikely because an extra area is surveyed for the q_1 time series. This is the main reason for the q-ratio model which corrects this diagnostic through the informed prior (and has a marginal posterior distribution with only a 5% probability of being less than 1).

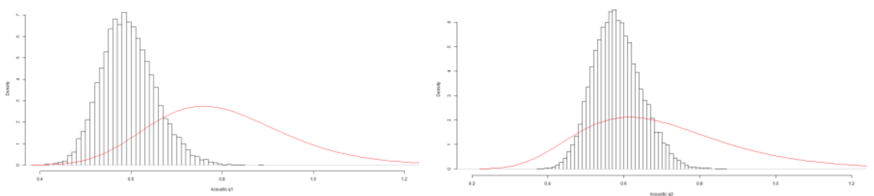


Figure 20: Current model: the prior distributions (red lines) and marginal posterior distributions (histograms) for the two main acoustic *q*s.

MCMC results

Virgin biomass, B_0, was estimated to be about 300 000–350 000 t for the three models (Table 12). Current stock status was similar for the current and q-ratio models, both having the 95% CIs above 30% B_0 (Table 12). The pessimistic *LowMhighq* run has stock status estimated just below 30% B_0 (Table 12).

Table 12: ESCR, MCMC estimates of virgin biomass (B_0), current biomass (B_{2020}), and stock status (B_{2020} as % B_0) for the three models.

	B_0 (000 t)		B_{2020} (000 t)		Stock status (% B_0)	
	Median	95% CI	Median	95% CI	Median	95% CI
Current model	312	281–346	111	91–135	36	30–41
q-ratio model	354	331–380	135	109–164	38	32–44
LowMhighq	337	308–363	90	71–111	27	22–32

The estimated YCS show little variation across cohorts but do exhibit a long-term trend (Figure 21). 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 22).

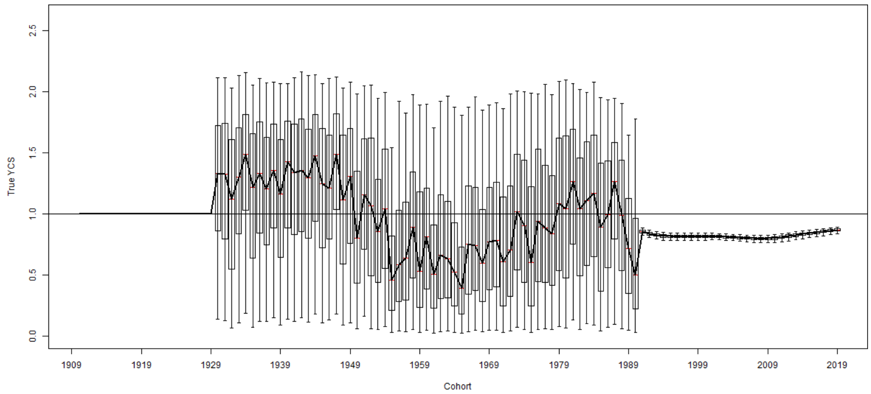


Figure 21: ESCR current model, MCMC estimated 'true' YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Year classes between 1930 and 1990 were estimated.

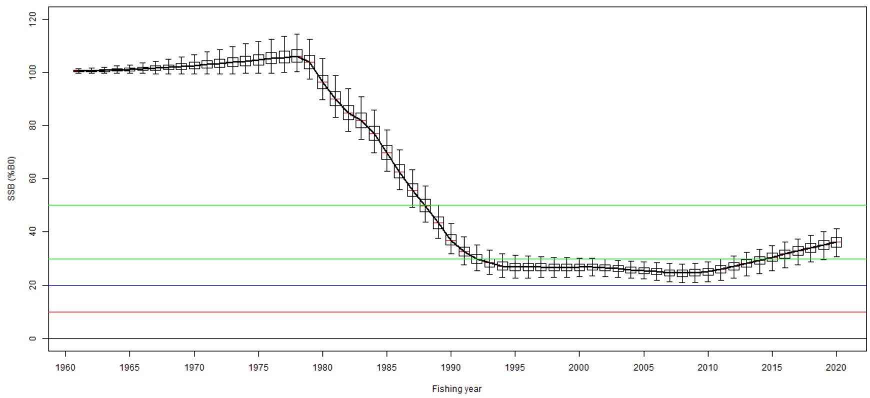


Figure 22: ESCR current model, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Horizontal lines are plotted at the hard limit (10% B_0), the soft limit (20% B_0), and the biomass target range (30–50% B_0).

Fishing intensity was approximated using an average exploitation rate (total catch divided by catch-weighted beginning-of-year vulnerable biomass). Estimated exploitation rates were within or above the target range ($U_{30\%B0}$–$U_{50\%B0}$) up to 2009–10. Since 2010–11 they have generally been below the target range (Figure 23).

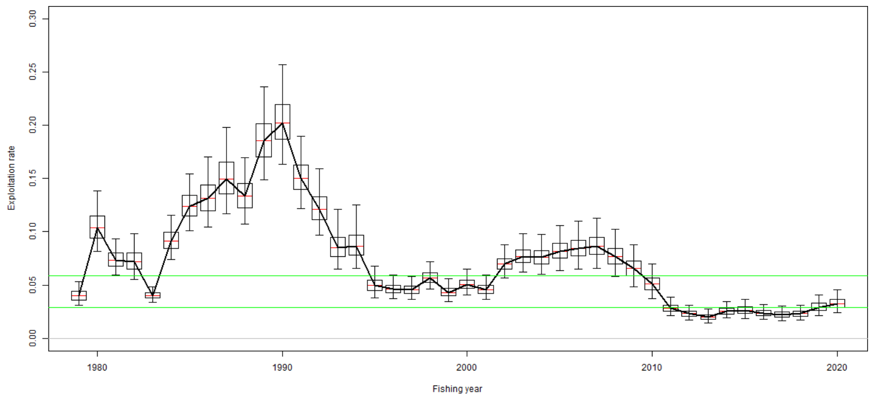


Figure 23: ESCR current model, MCMC estimated exploitation rates. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The exploitation rates associated with the biomass target of 30–50% B_0 are marked by horizontal lines at $U_{30\%B0}$ and $U_{50\%B0}$.

Biological reference points, management targets and yield

Catch limits for the ESCR stock are recommended from 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. Within that range there is a linear relationship between current estimated stock status and the instantaneous fishing mortality (exploitation rate) that is applied to next year's beginning-of-year vulnerable biomass to obtain the recommended catch limit (Figure 24).

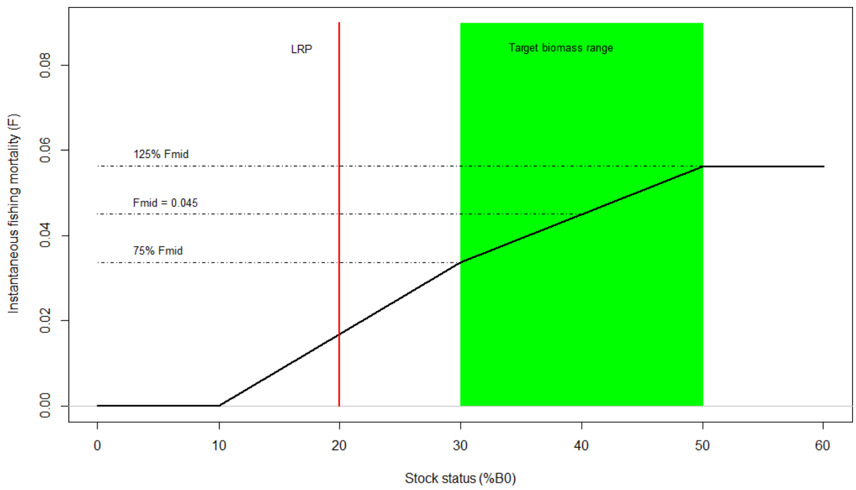


Figure 24: The orange roughy HCR showing the relationship between current estimated stock status and the instantaneous fishing mortality rate (or exploitation rate) applied to next year's beginning-of-year vulnerable biomass to derive the recommended catch limit. The target biomass range is 30–50% B_0 and the limit reference point (LRP) is 20% B_0 (see Cordue 2014b).

The HCR was applied to the current model and the q-ratio model. The medians of the marginal posterior distributions are used in the calculation. Because estimated stock status is less than 40% B_0 in both runs the exploitation rates are less than F_{mid} = 0.045 (Figure 24, Table 13). The slightly higher stock status for the q-ratio model gives a higher exploitation rate than the current model but, because of the lower vulnerable biomass, the recommended catch limit from both models is similar (Table 13).

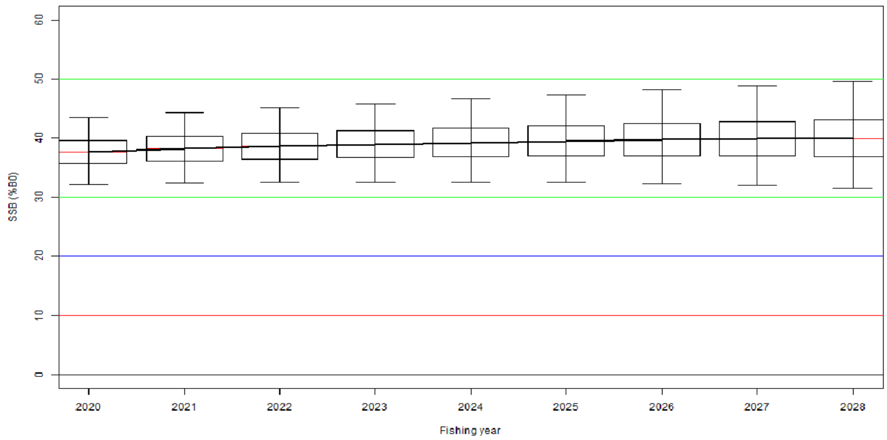
Table 13: The estimated stock status in 2019–20, the catch-weighted vulnerable biomass at the beginning of 2020–21, and the associated exploitation rate and recommended catch limit from the HCR for the current model and the q-ratio model.

Model	Stock status (% B_0)	Exploitation rate	Vulnerable biomass (t)	Catch limit (t)
Current model	36	0.04050	156 735	6 348
q-ratio model	38	0.04275	146 977	6 283

Projections

Projections at the recommended catch limits (plus 5% to allow for incidental mortality) were performed for the current model and the q-ratio model. The highest of the two catch limits was used in a projection for the *LowMhighq* model. This was to check that the highest HCR recommended catch limit was still safe even if the pessimistic scenario represented by the *LowMhighq* model was true. Projections were done over 8 years because the HCR is meant to be applied every four years. Random recruitment was brought in from 1991 by resampling from the last ten years of estimated YCS (1981–1990).

In each case, stock status was projected to rise slowly from the current estimated stock status and there was close to zero probability of the stock status being below 20% B_0 over the next 8 years (Figure 25).



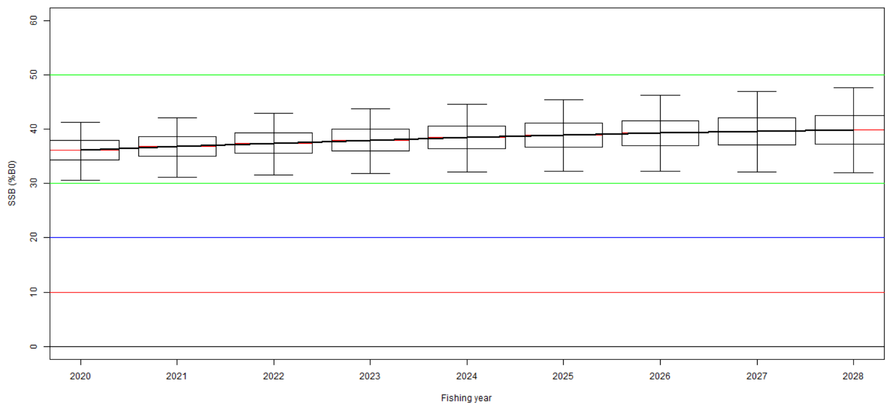


Figure 25: Projected stock status for catches at the HCR recommended catch limits plus 5% to allow for incidental mortality. Top: q-ratio model projected at 6283 t (plus 5%). Bottom: current model projected at 6348 t (plus 5%). Each box covers the middle 50% of the distribution and the whiskers extend to 95% CIs. **[Continued on next page]**

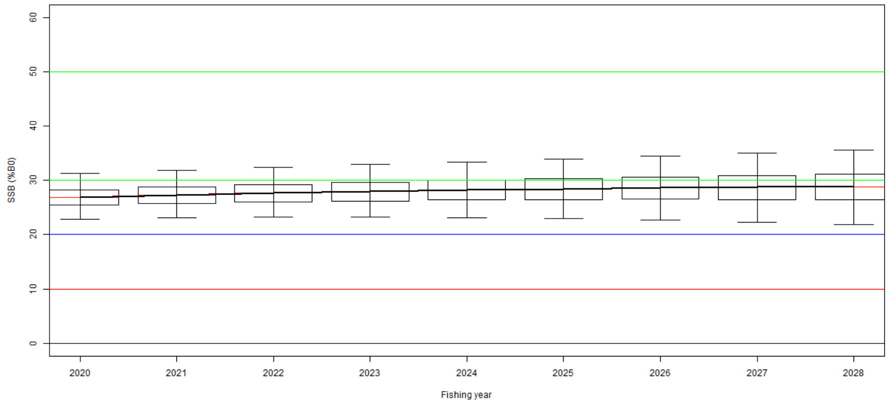


Figure 25 [Continued]: Projected stock status for catches at the HCR recommended catch limits plus 5% to allow for incidental mortality. *LowMhighq* model projected at 6348 t (plus 5%). Each box covers the middle 50% of the distribution and the whiskers extend to 95% CIs.

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 ORH 7A (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 (September–May) 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 a38 kHz hull-mounted system during an AOS survey (AOS is a multi-frequency towed system, see for example 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 14). 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 14: 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 26). It is notable that in both years the ages extend out to at least 130 years (Figure 21). 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.

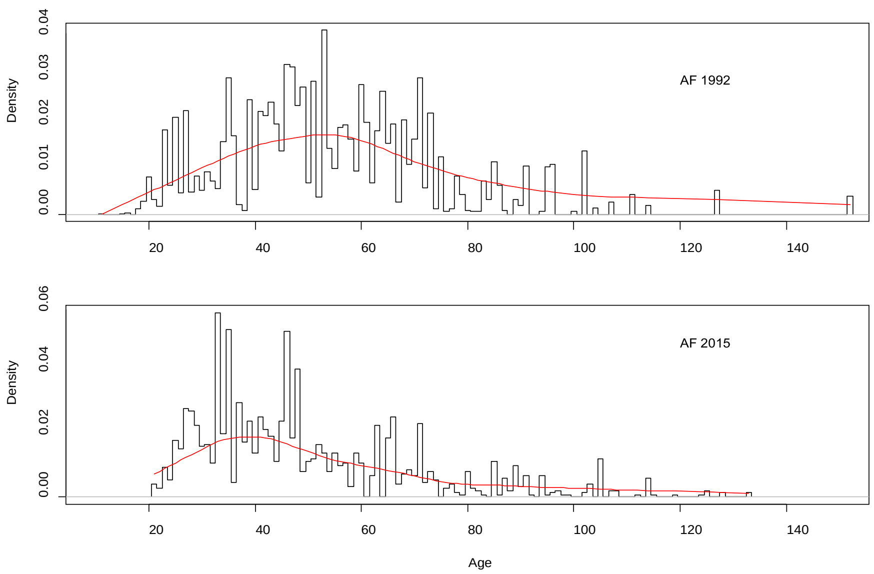


Figure 26: Puysegur: age frequencies from 1992 and 2015 used in the base model. The red lines were produced using the lowess smoother in R.

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 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 15).

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 27).

Table 15: 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	6 630	28
1994	1 160	24

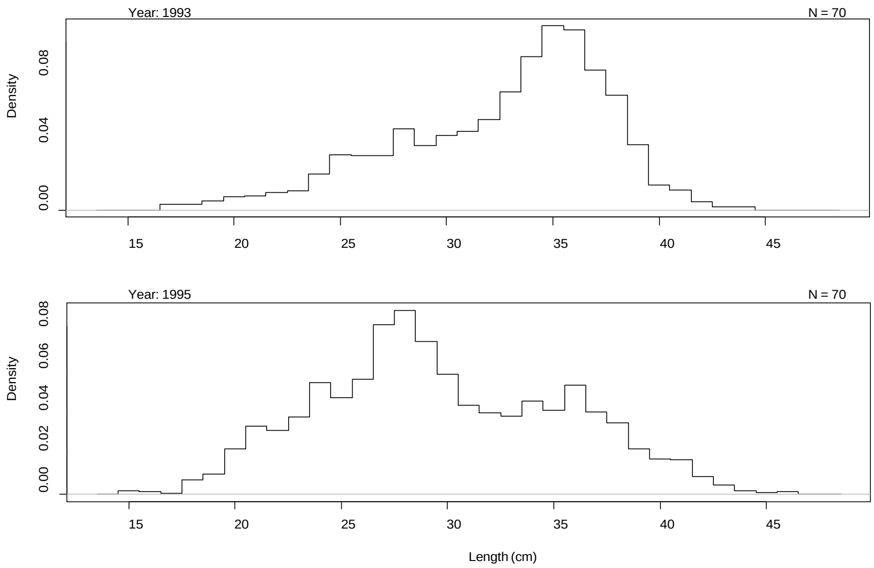


Figure 27: Puysegur: length frequencies for the *Tangaroa* trawl surveys in 1992 and 1994 (fitted in the model as beginning of year in 1993 and 1995). The effective samples sizes of N = 70 were the approximate number of stations in each survey.

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 28).

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 (because the availability parameter was estimated) but the fits to the composition data (length and age frequencies) were degraded compared with 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).

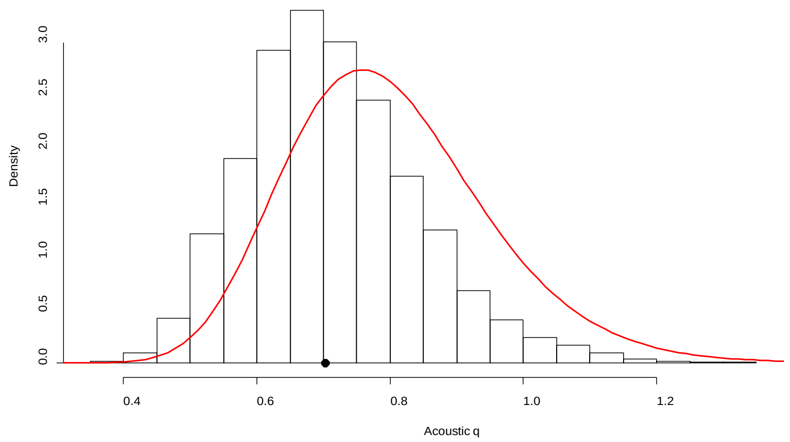


Figure 28: Puysegur: the marginal posterior distribution of the acoustic *q* (histogram) compared to its prior (red line). The black dot marks the median of the marginal posterior.

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 16). Current stock status was similar across the base and the first four sensitivity runs (Table 16). 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 16). 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 16: 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 29). 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).

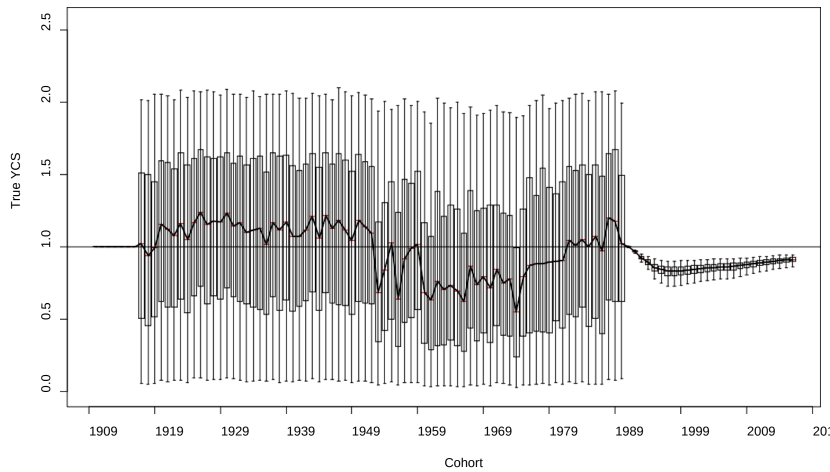


Figure 29: Puysegur base, MCMC estimated 'true' YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

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 30). Since 1998 the estimated biomass has increased steadily and has been well within the target range for the last decade (Figure 30).

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 31).

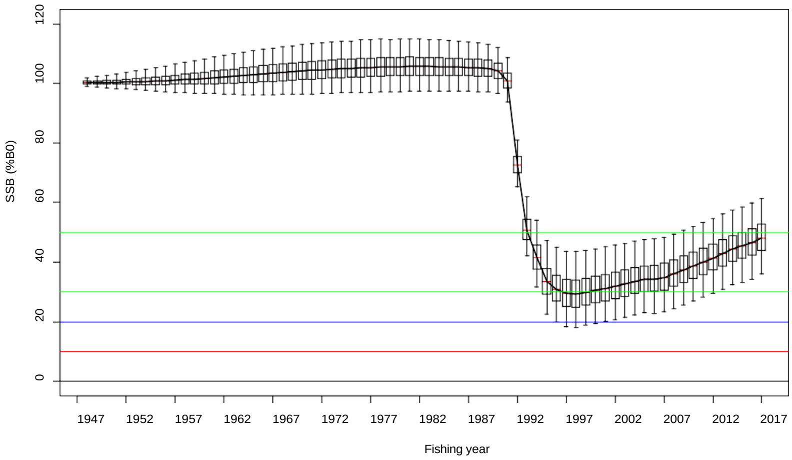


Figure 30: Puysegur base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.

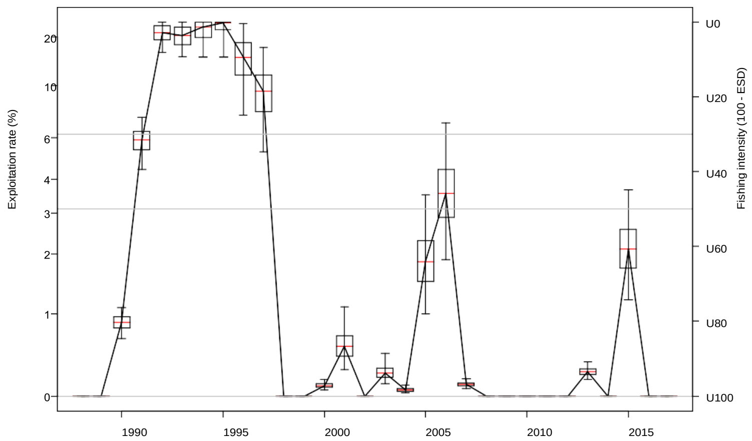


Figure 31: Puysegur base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–50% B_0 is marked by horizontal lines.

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.

5. FUTURE RESEARCH CONSIDERATIONS

- Stock assessment models should be developed to evaluate different hypotheses of spatial stock structure.
- Investigate reinstating previously discarded data including historical wide area trawl surveys.
- Investigate alternative uses of the acoustic time series and their priors.
- For the near future, consider more frequent acoustic biomass estimates be conducted for East & South Chatham Rise, and Northwest Chatham Rise that cover all of the main spawning areas for each stock
- Acoustic biomass surveys of the Morgue seamount outside of the spawning season could determine whether the SSB is absent and therefore likely to be vulnerable to fishing.
- Estimates of ageing error should be made to ensure an appropriate signal is taken from age frequency data.
- Investigate representativeness of age frequencies derived from mark identification trawls including comparison with age frequencies from the spawning fishery.
- Estimate age frequency for the non-spawning fishery.
- Additional age frequency data (including collection of otoliths from more tows and increasing sample size of otoliths read) would increase the information available for estimation of trends in recruitment, and for evaluating the causes of variability in age samples.
- Stock assessment models should evaluate methods for reducing the number of parameters being estimated, particularly in the estimation of recruitment.

6. STATUS OF THE STOCKS

6.1 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 and East and South Chatham Rise

The consensus of the Working Group was the previously accepted assessment models for the (2018) NWCR and (2020) ESCR can no longer be considered to accurately reflect stock status and the Status of the Stocks tables have been removed.

The acoustic estimates of the Northwest Chatham Rise SSB have been low and variable for the Graveyard hill and increasing for the Morgue hill. The combined area series shows an increasing SSB from 1999-2022 at current catch levels. The acoustic estimates of the East & South Chatham Rise SSB have declined and then been flat for the Old Spawning Plume, have been flat then lower for Rekohu, and flat then higher for Mt. Muck (Figure 5). The combined area series is flat from 2011-2022 at current catch levels.

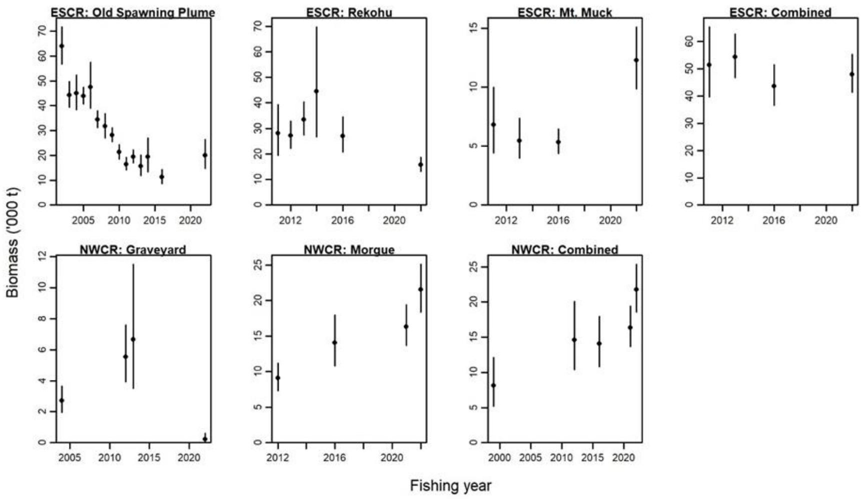


Figure 5: ORH 3B sub-areas and Spawning Stock Biomass estimates from acoustic surveys. ESCR, East & South Chatham Rise; NWCR, Northwest Chatham Rise. Vertical lines indicate 95% CI.

There has been insufficient time to develop credible new assessments, so current stock status is unable to be determined. There is a plan to undertake further research (as per future research section) to enable new assessments to be completed by 2025 at which time the Status of the Stocks tables can be updated.

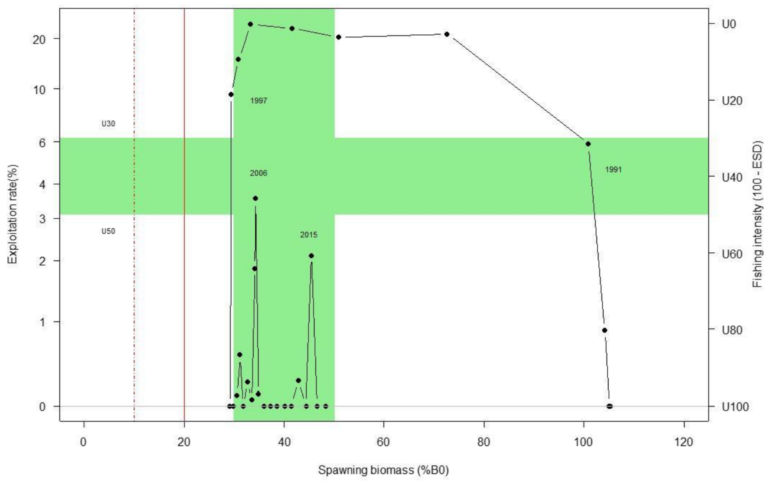
- **5.2 Southern ORH 3B fisheries**

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: 2022
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. Orange roughy are caught using bottom trawl gear. Bottom trawling interacts with benthic habitats.

- **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.

Commented [MD2]: Does some commentary need to be added to this (dated) information - the subantartic fisheries outside of puysegur? Although I guess these fisheries have largely been and gone. They have contributed as much, sometimes more, to the 3B catches than the NWCR.

7. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C J; Iball, S D (Comps) (1998) Report from the Fishery Assessment Plenary, May 1998: stock assessments and yield estimates. 409 p. (Unpublished report held by NIWA library, Wellington.)

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.)

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2003) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.01-2003/08/01. *NIWA Technical Report 124*. 223 p.

Clark, M R; Anderson, O F; Dunn, M (2003) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/60.* 51p.

Clark, M R; Anderson, O F; Francis, R I C C; Tracey, D M (2000) The effects of commercial exploitation on orange roughy (*Hoplostethus atlanticus*) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. *Fisheries Research* 45(3): 217–238.

Clark, M R; Tracey, D M (1993) Orange roughy off the southeast coast of the South Island and Puysegur Bank: exploratory and research fishing, June-August l992. *New Zealand Fisheries Technical Report No. 35*. 30 p.

Clark, M R; Tracey, D M (1994) Trawl survey of orange roughy, black oreo, and smooth oreo in southern New Zealand waters August-September l992 (TAN9208). *New Zealand Fisheries Data Report No. 40*. 37 p.

Clark, M R; Anderson, O F; Tracey, D M (1996) Trawl survey of orange roughy, black oreo, and smooth oreo in southern New Zealand waters September-October 1994 (TAN9409). *New Zealand Fisheries Data Report No. 72*. 39 p.

Coburn, R P; Doonan, I J (1994) Orange roughy fishing on the North East Chatham Rise: a description of the commercial fishery, 1979–1988. *New Zealand Fisheries Technical Report* 38.

Coburn, R P; Doonan, I J (1997) The fishery for orange roughy on the northeast Chatham Rise, 1988–99 to 1993–94. *New Zealand Fisheries Technical Report 48*. 28 p.

Coombs, R F; Barr, R (2007) *In situ* measurements of orange roughy (*Hoplostethus atlanticus*) target strength. *ICES Journal of Marine Science 64*: 1220–1234.

Cordue, P L (2008) Review of estimates of Chatham Rise orange roughy biomass from plume surveys. Report prepared for the New Zealand Ministry of Fisheries. 39 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Cordue, P L (2010) Linear-model derived bottom-referenced weather corrections for the CR ORH plume time series (2002–2009). Report to the DWWG, DWWG2010-30, New Zealand Ministry of Fisheries. 71 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Cordue, P L (2014a) The 2014 orange roughy stock assessments. *New Zealand Fisheries Assessment Report 2014/50.* 135 p.

Cordue, P L (2014b) A Management Strategy Evaluation for orange roughy. ISL Client Report for Deepwater Group. (Unpublished report held by Fisheries New Zealand, Wellington.)

Cordue, P L (2018) A brief update of the ORH3B ESCR and NWCR stock assessments to the end of the 2016–17 and 2017–18 fishing years with application of the Harvest Control Rule in both years. ISL Client Report for Deepwater Group Ltd. 59 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Doonan, I J (1991) Orange roughy fishery assessment, CPUE analysis - linear regression, NE Chatham Rise 1991. New Zealand Fisheries Assessment Research Document 1991/9. 48 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Doonan, I J (1994) Life history parameters of orange roughy; estimates for 1994. New Zealand Fisheries Assessment Research Document 1994/19. 13 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Doonan, I (2009) Re-analysis of the spawning plume biomass, towbody acoustics surveys 1998 & 2000. Deepwater Working Group document 2009/16. (Unpublished report held by Fisheries New Zealand, Wellington.)

Doonan, I; Bull, B (2001) Absolute biomass for 1999, NE and East Chatham Rise. WG-Deepwater-01/27. (Unpublished report held by Fisheries New Zealand, Wellington.)

Doonan, I; Bull, B; Dunford, A; Coombs, R; Tracey, D; Hart, A (2001) Acoustic estimates of the biomass of aggregations of orange roughy in the Spawning Box and on the Northeastern and Eastern Hills, Chatham Rise, July 2000. *New Zealand Fisheries Assessment Report 2001/70*. 31 p.

Doonan, I J; Dunn, M; Dunford, A; Hart, A C; Tracey, D (2006) Acoustic estimates of orange roughy abundance on the Northeastern and Eastern Chatham Rise, July 2004: wide-area survey and hill survey. *New Zealand Fisheries Assessment Report 2006/58*. 45 p.

Doonan, I J; Dunn, M; Hart, A C (2009) Abundance estimates of orange roughy on the Northeastern and Eastern Chatham Rise, July 2007: wide-area trawl survey and hill acoustic survey (TAN0709). *New Zealand Fisheries Assessment Report 2009/20*. 38 p.

Doonan, I; Hart, A C (2003) Notes on the abundance of mature orange roughy on the NW Chatham Rise and Graveyard Hills, ORH 3B, 20 June - 7 July 2002. WG-Deepwater- 03/01. (Unpublished report held by Fisheries New Zealand, Wellington.)

Doonan, I J; Hart, A C; Bagley, N; Dunford, A (2012) Orange roughy abundance estimates of the north Chatham Rise Spawning Plumes (ORH3B), *San Waitaki* acoustic survey, June-July 2011. *New Zealand Fisheries Assessment Report 2012/28*. 35 p.

Doonan, I J; Horn, P L; Ó Maolagáin, C (2014a) Orange roughy age estimates: Chatham Rise (ORH 3B) spawning plumes in 2012, and mid-east coast North Island (ORH 2A) fishery from 1989–91 and 2010. *New Zealand Fisheries Assessment Report 2014/24*. 19 p.

Doonan, I J; Horn, P L; Ó Maolagáin, C (2014b) Age composition of orange roughy from ORH 3B (Chatham Rise: northwest ,1994, and northeast,2013), and from ORH 7A (Challenger Plateau in 1987, 2006 and 2009). *New Zealand Fisheries Assessment Report 2014/59*. 33 p.

Doonan, I J; Horn, P L; Ó Maolagáin, C; Datta, S (2018) Age composition of orange roughy from ORH 3B, Chatham Rise, 2016: Mount Muck, Old Plume, Rekohu Plume, and Morgue. *New Zealand Fisheries Assessment Report 2018/48*. 17 p.

Dunn, M R (2007) CPUE analysis and assessment of the Northeast Chatham Rise orange roughy stock (part of ORH 3B) to the end of 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2007/8*. 75 p.

Dunn, M R; Anderson, O F; Doonan, I J (2008) Evaluation of stock status for orange roughy on the east and south Chatham Rise for 2008. *New Zealand Fisheries Assessment Report 2008/65*. 30 p.

Dunn, M R; Devine, J A (2010) An holistic approach to determining stock structure of orange roughy on the Chatham Rise. *New Zealand Fisheries Assessment Report 2010/17*. 65 p.

Dunn, M R; Doonan, I J (2018) Assessment of the Chatham Rise orange roughy stocks for 2017. *New Zealand Fisheries Assessment Report 2018/59*. 60 p.

Dunn, M R; Rickard, G J; Sutton, P J H; Doonan, I J (2009) Nursery grounds of orange roughy around New Zealand. *ICES Journal of Marine Science 66*: 871–885.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 26 p. (Unpublished report held by NIWA library, Wellington.)

Francis, R I C C (1995) The longevity of orange roughy: a reinterpretation of the radiometric data. New Zealand Fisheries Assessment Research Document 1995/2. 13 p. (Unpublished report held by NIWA library, Wellington.)

Francis, R I C C (1996) Orange roughy sex ratios and catch rate distributions in the Chatham Rise Spawning Box. New Zealand Fisheries Assessment Research Document 1996/13. 27 p. (Unpublished document held by NIWA library.)

Francis, R I C C (2006) Some recent problems in New Zealand orange roughy assessments. *New Zealand Fisheries Assessment Report 2006/43*. 65 p.

Francis, R I C C (2001a) Orange roughy CPUE on the South and east Chatham Rise. *New Zealand Fisheries Assessment Report 2001/26*. 30 p.

Francis, R I C C (2001b) Stock Assessment of orange roughy on the South Chatham Rise. *New Zealand Fisheries Assessment Report 2001/27*. 25 p.

Francis, R I C C (2001c) Stock assessment for 2001 of orange roughy on the northeast Chatham Rise. *New Zealand Fisheries Assessment Report 2001/41*. 32 p.

Francis, R.I.C.C. (2006). Some recent problems in New Zealand orange roughy assessments. New Zealand Fisheries Assessment Report 2006/43. 65 p.

Francis, R I C C; Bull, B (2000) Assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). *New Zealand Fisheries Assessment Report 2000/21*. 17 p.

Francis, R I C C; Clark, M R; Coburn, R P; Field, K D; Grimes, P J (1995) Assessment of the ORH 3B orange roughy fishery for the 1994–95 fishing year. New Zealand Fisheries Assessment Research Document 1995/4. 43 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Francis, R I C C; Clark, M R; Grimes, P J (1997) Calculation of the recruited biomass of orange roughy on the northwest Chatham Rise using the 1996 Graveyard Hill egg survey (TAN9608). New Zealand Fisheries Assessment Research Document 1997/29. 18 p. (Unpublished report held by NIWA library, Wellington.)

Francis, R I C C; Horn, P L (1997) Transition zone in otoliths of orange roughy (*Hoplostethus atlanticus*) and its relationship to the onset of maturity. *Marine Biology 129*: 681–687.

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

Hampton, I; Soule, M A; Nelson, J C (2005) Acoustic survey of orange roughy on Graveyard hill and in the spawning plume, North Chatham Rise, and on Puysegur Bank, New Zealand, June/July 2005. 98 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hampton, I; Soule, M A; Nelson, J C (2006) Acoustic and trawl survey of orange roughy on Puysegur Bank, and in the spawning plume and northeast hills on the North Chatham Rise, New Zealand, July 2006. 91 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hampton, I; Soule, M; Nelson, J (2008) Standardisation of acoustic estimates of orange roughy biomass in the North Chatham Rise Spawning Plume between 1996 and 2007, made with vessel-mounted transducers. 26 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hampton, I; Soule, M; Nelson, J (2009) Corrections to time series of acoustic estimates of orange roughy spawning biomass in the Spawning Plume in area ORH3B from vessel-mounted transducers, 1996 to 2008. 29 p. WG-Deepwater-09/14. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hampton, I; Soule, M A; Nelson, J C (2010) Standardised acoustic estimates of orange roughy biomass in the Spawning Plume in area ORH 3B from vessel-mounted and towed transducers, 1996–2009. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hicks, A C (2006) Changes in lengths from the commercial catch in the Spawning Box. WG-Deepwater-06/ (Unpublished report held by Fisheries New Zealand, Wellington.)

Hilborn, R; Walters, C J (1992) *Quantitative fisheries stock assessment: choice, dynamics, and uncertainty*. Chapman and Hall, New York, 570 p.

Horn, P L; Tracey, D M; Clark, M R (1998) Between-area differences in age and length at first maturity of the orange roughy *Hoplostethus atlanticus*. *Marine Biology 132 (2)*: 187–194.

Horn, P L; Tracey, D M; Doonan, I J; Krusic-Golub, K (2016) Age determination protocol for orange roughy (*Hoplostethus atlanticus*). *New Zealand Fisheries Assessment Report 2016/03*. 30 p

Kloser, R J; Horne, J K (2003) Characterizing uncertainty in target-strength measurements of a deepwater fish: orange roughy (*Hoplostethus atlanticus*). *ICES Journal of Marine Science 60*: 516–523.

Kloser, R J; Macaulay, G; Ryan, T; Lewis, M (2011) Improving acoustic species identification and target strength using frequency difference and visual verification: example for a deep-sea fish orange roughy. DWWG 2011-52. (Unpublished report held by Fisheries New Zealand, Wellington.)

Macaulay, G; Kloser, R J; Ryan, T (2009) Visually verified *in situ* target strength measurements of orange roughy from the Chatham Rise, July 2007. Final Research Report for Ministry of Fisheries Research Project ORH2006-01A, Objective 2. (Unpublished report held by Fisheries New Zealand, Wellington.) 45 p.

Mace, P M; Fenaughty, J M; Coburn, R P; Doonan, I J (1990) Growth and productivity of orange roughy (*Hoplostethus atlanticus*) on the north Chatham Rise. *New Zealand Journal of Marine and Freshwater Research 24*: 105–119.

McKenzie, A (2003) Standardised CPUE analysis and stock assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). *New Zealand Fisheries Assessment Report 2003/61*. 24 p.

McKenzie, A (2005) Standardised CPUE analysis and stock assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). Final Research Report for Ministry of Fisheries Project (ORH2003-02). 42 p (Unpublished report held by Fisheries New Zealand, Wellington.)

Robertson, D A; Mace, P M (1988) Assessment of the Chatham Rise orange roughy fishery for 1987/88. New Zealand Fisheries Assessment Research Document 1988/37. 5 p. (Unpublished report held by NIWA library, Wellington.)

Ryan, T E; Tilney, R L (2016) Biomass surveys of orange roughy and oreo species using a net-attached acoustic optical system for New Zealand ORH7B and ORH3B Puysegur management zones in June, July 2015. 67 p. (Copy held at CSIRO Marine and Atmospheric Research, Hobart.)

Smith, M H (2006) Northwest Chatham Rise mature biomass estimate for the stock assessment. WG-Deepwater-06/17. (Unpublished report held by Fisheries New Zealand, Wellington.)

Smith, P J; Benson, P G (1997) Genetic diversity in orange roughy from the east of New Zealand. *Fisheries Research 31(3)*: 197–213.

Soule, M A; Hampton, I; Nelson, J C; Tilney, R L (2010) Acoustic survey of orange roughy on the North Chatham Rise (ORH 3B), New Zealand. June/July 2010. Report prepared for New Zealand Deepwater Group Ltd.

Soule, M A; Nelson, J C; Hampton, I (2007) Acoustic survey of orange roughy in the spawning plume on the North Chatham Rise, New Zealand. DWWG-2008/83. (Unpublished report held by Fisheries New Zealand, Wellington.)

Stephenson, F.; Biggerstaff, A.; Dunn, M.; A'mar, T.; Doonan, I.; Rowden, A.; Geange, S. (2022). A 2022 orange roughy stock assessment for Louisville Ridge, West Norfolk Ridge, Lord Howe Rise, and Northwest Challenger Plateau. South Pacific Regional Fisheries Management Organisation, 10th Meeting of the Scientific Committee, Seoul, Korea, 26-30 September 2022. SC10-DW01_rev1. 37 p.

Taylor, P (2001) Assessment of orange roughy fisheries in southern New Zealand for 2000. *New Zealand Fisheries Assessment Report 2001/24*. 30 p.

Tracey, D M; Fenaughty, J M (1997) Distribution and relative abundance of orange roughy on the Chatham Rise, May–July 1994. *New Zealand Fisheries Technical Report No. 44*. 43 p.

Tracey, D; Horn, P; Marriott, P; Krusic-Golub, K; Gren, C; Gili, R; Mieres, L C (2007) Orange Roughy Ageing Workshop: otolith preparation and interpretation. (Unpublished report to the Deepwater Fisheries Assessment Working Group; held by Fisheries New Zealand, Wellington.)