# 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 (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 | 6 525 | 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.

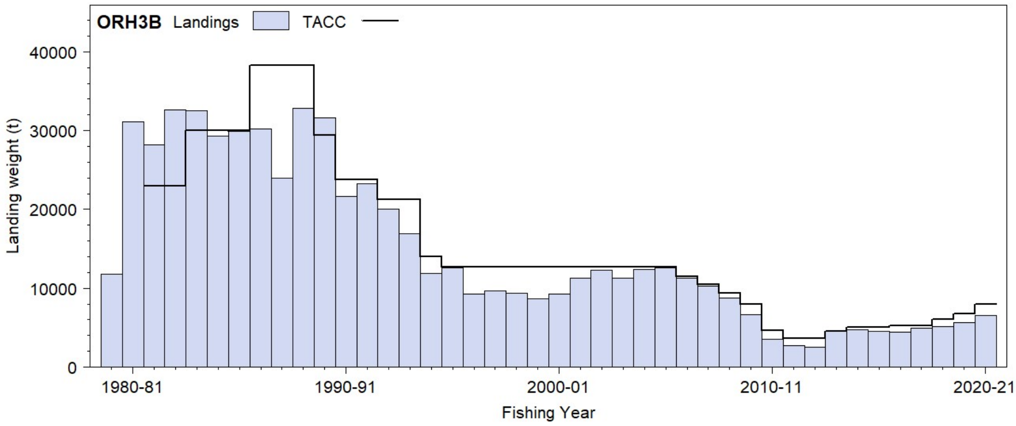



**Figure 1: Reported commercial landings and TACCs for ORH 3B.**

**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. [Continued on next page]**

| 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 |

**Table 2 [continued]**

| Year | Northwest Rise | | South Rise | | Spawning box | | Rest of East Rise | | Non-Chatham | |
|---|---|---|---|---|---|---|---|---|---|---|
| | t | % | t | % | t | | t | % | t | % |
| 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 | 6 | 307 | 6 | 3 233 | 59 | 1 144 | 21 | 596 | 11 |
| 2020–21 | 385 | 5.9 | 235 | 3.6 | 4 241 | 65.0 | 1 311 | 20.1 | 346 | 5.3 |

In the early 1990s, effort within the 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 has mostly come from the Spawning Box and the Rest of the 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 catch limit for the East and South Chatham Rise has increased in each year since 2017–18 (Table 3).

The catch limit for the Sub-Antarctic has been substantially under-caught since 2009–10. However, the combined East and South Rise sub-area catch limits were exceeded by 450 t in 2005–06 and by 350 t in 2006–07 (100 t were taken against the allowance for research surveys). Taking the research allowance into account, catch limits for the combined East and South Rise sub-area have not been exceeded in subsequent years. 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.

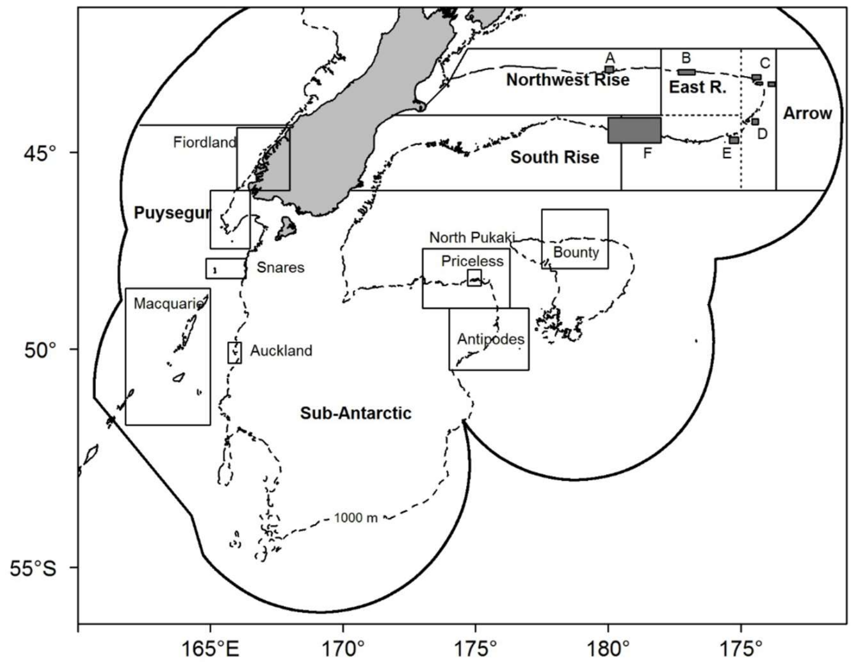



**Figure 2: ORH 3B fishery sub-areas and the approximate position of other named fisheries. The recognised stocks are indicated by bold text. The rectangles mark the main fishing grounds, with those on Chatham Rise shaded: A, Graveyard (180) hills; B, Spawning Box; C, Smith's City NE hills; D, Andes; 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 currently do not support their previous levels of catch, now accounting for less than 5% of the estimated catch (Table 4). High catch rates can still occur, but these are less frequent than observed in the early years of the fishery. Catches from the Northwest Rise fell to near zero in 2010–11 as a result of an agreement among quota owners to avoid fishing in this area (Table 2). This agreement was extended to the 2011–12 and 2012–13 fishing years. Quota owners then agreed to shelve 207 tonnes of Northwest Chatham Rise ACE for 2014–15 to 2017–18. 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 | 750*β* | 2 960† | * | 150 | 0 | 500 |
| 2011–12 | 750*β* | 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 | 5 670 | * | 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 39% in 2008–09). In addition, in recent years large catches have been made outside the spawning season, in recently developed areas of the southeast Rise. Catches from the Spawning Box taken during the spawning season (which peaks in July) have been relatively high since 2001–02, although unstandardised catch rates have been variable (Table 4).

**Table 4: Orange roughy estimated catches (to nearest 10 t) and unstandardised median catch rates (to nearest 0.1 t/tow) for four important hill complexes and the Spawning Box In season (spawning plume area, May-August) and Out season (September-April) on the Chatham Rise (letters indicating subareas, as in Table 3, in parentheses), using catch and effort data held by NIWA. Only tows targeted at orange roughy are included. (Approximate positions are: Big Chief, 44.7° S, 175.2° W; Smiths City and near-neighbours, 43.1° S, 174.2° W; Andes, 44.2° S, 174.6° W; Graveyard, 42.8° S, 180° W). –, catch < 10 t. NA means catch >10 t but there were fewer than 3 vessels in the fishery.** **[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 |
| 1979–80 | – | – | – | 110 | 36 | 3.1 | 9 800 | 968 | 10.7 | 7 400 | 795 | 6.1 |
| 1980–81 | – | – | – | – | 2 | – | 11 100 | 890 | 11.5 | 6 240 | 462 | 11.5 |
| 1981–82 | – | – | – | 40 | 11 | 3.6 | 4 750 | 470 | 4.5 | 4 450 | 604 | 4.9 |
| 1982–83 | – | – | – | 40 | 2 | 17.8 | 3 980 | 227 | 13.4 | 3 840 | 386 | 8.1 |
| 1983–84 | – | – | – | 60 | 7 | 6.3 | 6 590 | 378 | 13.4 | 8 630 | 836 | 7.7 |
| 1984–85 | – | – | – | 10 | 3 | 3.2 | 9 320 | 676 | 10.4 | 7 460 | 537 | 10.0 |
| 1985–86 | – | – | – | 670 | 52 | 11.4 | 8 521 | 659 | 10.0 | 7 650 | 859 | 6.1 |
| 1986–87 | – | – | – | 210 | 34 | 3.9 | 8 090 | 597 | 8.9 | 12 010 | 1 036 | 6.2 |
| 1987–88 | – | – | – | 160 | 33 | 4.5 | 7 870 | 622 | 8.0 | 5 820 | 701 | 5.1 |
| 1988–89 | 30 | 18 | 0.3 | 310 | 48 | 3.9 | 7 070 | 598 | 9.6 | 6 500 | 811 | 5.0 |
| 1989–90 | 90 | 13 | 1.5 | 40 | 9 | 4.0 | 6 830 | 403 | 12.5 | 4 960 | 602 | 5.3 |
| 1990–91 | 80 | 12 | 3.2 | 4 890 | 633 | 3.5 | 2 820 | 238 | 8.0 | 2 810 | 206 | 8.0 |
| 1991–92 | 7 080 | 724 | 5.0 | 1 270 | 222 | 2.0 | 650 | 85 | 6.0 | 300 | 54 | 5.7 |
| 1992–93 | 2 940 | 345 | 5.0 | 600 | 84 | 2.0 | 50 | 2 | 27.0 | – | – | – |
| 1993–94 | 3 320 | 605 | 1.8 | 560 | 109 | 2.8 | – | – | – | – | – | – |
| 1994–95 | 1 650 | 573 | 1.0 | 1 140 | 345 | 1.0 | 490 | 86 | 0.3 | 10 | 25 | 0.1 |
| 1995–96 | 1 120 | 418 | 0.5 | 410 | 145 | 1.0 | 1 360 | 127 | 5.0 | 140 | 27 | 0.8 |
| 1996–97 | 730 | 260 | 1.0 | 720 | 164 | 1.0 | 930 | 101 | 3.0 | 620 | 130 | 2.3 |
| 1997–98 | 1 140 | 476 | 0.5 | 400 | 146 | 0.4 | 1 580 | 118 | 6.0 | 630 | 148 | 1.6 |
| 1998–99 | 1 260 | 448 | 1.0 | 810 | 272 | 1.0 | 510 | 73 | 2.7 | 490 | 139 | 2.0 |
| 1999–00 | 1 990 | 529 | 1.0 | 680 | 210 | 0.8 | 910 | 34 | 25.0 | 510 | 111 | 2.0 |
| 2000–01 | 980 | 354 | 1.1 | 650 | 191 | 1.0 | 810 | 59 | 5.5 | 430 | 123 | 2.0 |
| 2001–02 | 2 040 | 546 | 1.5 | 490 | 167 | 0.9 | 2 120 | 159 | 4.0 | 980 | 222 | 1.8 |
| 2002–03 | 2 230 | 872 | 1.0 | 400 | 124 | 0.5 | 2 150 | 166 | 8.0 | 1 000 | 216 | 2.3 |
| 2003–04 | 1 170 | 677 | 0.5 | 360 | 160 | 0.8 | 1 880 | 163 | 6.0 | 1 050 | 278 | 2.5 |
| 2004–05 | 1 090 | 518 | 0.6 | 310 | 127 | 0.9 | 1 910 | 214 | 4.4 | 850 | 230 | 3.8 |
| 2005–06 | 1 340 | 727 | 0.5 | 370 | 119 | 0.7 | 1 630 | 117 | 9.0 | 1 740 | 257 | 2.6 |
| 2006–07 | 1 160 | 583 | 0.5 | 570 | 201 | 0.7 | 1 980 | 121 | 11.2 | 1 720 | 356 | 2.5 |
| 2007–08 | NA | NA | NA | NA | NA | NA | 2 550 | 200 | 5.0 | 750 | 192 | 3.0 |
| 2008–09 | NA | NA | NA | NA | NA | NA | 2 020 | 121 | 18.0 | 1 010 | 209 | 2.4 |
| 2009–10 | 440 | 243 | 0.5 | 160 | 84 | 0.5 | 1 980 | 136 | 8.5 | 850 | 248 | 1.7 |
| 2010–11 | 460 | 151 | 1.2 | 90 | 27 | 0.4 | 1 230 | 75 | 15.0 | 70 | 28 | 2.0 |
| 2011–12 | 450 | 164 | 1.0 | 130 | 26 | 0.5 | 660 | 39 | 22.5 | 80 | 24 | 3.8 |
| 2012–13 | NA | NA | NA | – | – | – | NA | NA | NA | NA | NA | NA |
| 2013–14 | 790 | 218 | 1.0 | 140 | 39 | 0.9 | 390 | 40 | 4.9 | 30 | 18 | 2.0 |
| 2014–15 | 460 | 162 | 1.0 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2015–16 | 1 180 | 438 | 0.4 | 130 | 75 | 0.2 | NA | NA | NA | 390 | 96 | 3.0 |
| 2016–17 | 700 | 438 | 0.2 | 68 | 37 | 0.4 | – | 0 | – | 320 | 104 | 1.7 |
| 2017–18 | 761 | 505 | 0.2 | 202 | 76 | 0.9 | – | 0 | – | 396 | 113 | 2.0 |
| 2018–19 | 465 | 423 | 0.2 | 188 | 81 | 0.4 | 42 | 10 | 1.0 | 258 | 95 | 2.0 |
| 2019–20 | 437 | 346 | 0.3 | 224 | 106 | 0.4 | 21 | 21 | 0.6 | 554 | 152 | 2.0 |
| 2020–21 | 180 | 281 | 0.2 | 139 | 85 | 0.5 | 1 216 | 167 | 4.2 | 1 526 | 303 | 3.0 |

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

**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 |
| 2008–09 | 1 170 | 443 | 1.0 | 390 | 75 | 1.3 | 280 | 110 | 0.5 | 500 | 182 | 0.5 |
| 2009–10 | 560 | 217 | 1.2 | 290 | 90 | 0.8 | 360 | 193 | 1.2 | 470 | 120 | 1.0 |
| 2010–11 | 130 | 43 | 0.6 | NA | NA | NA | 30 | 5 | 1.0 | 150 | 32 | 2.0 |
| 2011–12 | 120 | 61 | 0.7 | – | – | – | 30 | 4 | 1.5 | NA | NA | NA |
| 2012–13 | NA | NA | NA | – | – | – | 30 | 7 | 1.6 | NA | NA | NA |
| 2013–14 | 260 | 82 | 1.0 | 570 | 102 | 1.1 | 110 | 67 | 0.7 | NA | NA | NA |
| 2014–15 | 200 | 52 | 1.4 | 550 | 164 | 0.5 | 180 | 106 | 0.7 | – | – | – |
| 2015–16 | 360 | 263 | 0.3 | 400 | 165 | 0.5 | 180 | 215 | 0.5 | – | – | – |
| 2016–17 | 269 | 154 | 0.4 | 187 | 137 | 0.5 | 473 | 329 | 0.7 | 21 | 34 | 0.1 |
| 2017–18 | 450 | 166 | 0.8 | 402 | 185 | 0.5 | 3338 | 216 | 0.6 | NA | NA | NA |
| 2018–19 | 391 | 187 | 0.8 | 136 | 81 | 0.8 | 179 | 146 | 0.4 | NA | NA | NA |
| 2019–20 | 451 | 227 | 1.0 | 133 | 69 | 0.5 | 144 | 114 | 0.5 | NA | NA | NA |
| 2020–21 | 899 | 235 | 1.0 | 121 | 69 | 0.6 | 238 | 141 | 1.1 | NA | NA | NA |

| | Big Chief (S) | | | Rest of South (S) | | | Rekohu | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Catch | Tows | t/tow | Catch | Tows | t/tow | Catch | Tows | t/tow |
| 1979–80 | – | – | – | 20 | 12 | < 0.1 | 30 | 8 | 3.1 |
| 1980–81 | – | – | – | 110 | 25 | 3.4 | 60 | 4 | 14.1 |
| 1981–82 | – | – | – | 30 | 28 | 1.1 | – | – | – |
| 1982–83 | – | – | – | 180 | 31 | < 0.1 | 30 | 4 | 3.9 |
| 1983–84 | – | – | – | 120 | 86 | 0.1 | – | – | – |
| 1984–85 | – | – | – | 870 | 289 | 0.6 | – | – | – |
| 1985–86 | – | – | – | 530 | 198 | 0.6 | 40 | 2 | 2.3 |
| 1986–87 | – | – | – | 1 440 | 433 | 1.1 | NA | NA | NA |
| 1987–88 | – | – | – | 3 180 | 924 | 0.7 | 40 | 5 | 0.4 |
| 1988–89 | 1 010 | 199 | 1.7 | 4 650 | 1 768 | 0.3 | 60 | 5 | 0.6 |
| 1989–90 | 2 830 | 529 | 1.5 | 4 090 | 1 121 | 1.0 | NA | NA | NA |
| 1990–91 | 3 150 | 453 | 2.1 | 1 620 | 500 | 0.3 | NA | NA | NA |
| 1991–92 | 820 | 138 | 2.5 | 780 | 308 | 0.3 | – | – | – |
| 1992–93 | 3 310 | 703 | 2.0 | 1 190 | 462 | < 0.1 | – | – | – |
| 1993–94 | 2 350 | 698 | 0.6 | 2 060 | 1 129 | 0.1 | – | – | – |
| 1994–95 | 510 | 242 | 0.8 | 880 | 937 | < 0.1 | – | – | – |
| 1995–96 | 580 | 151 | 1.0 | 460 | 553 | < 0.1 | – | – | – |
| 1996–97 | 560 | 195 | 0.5 | 440 | 304 | < 0.1 | – | – | – |
| 1997–98 | 950 | 285 | 0.4 | 410 | 503 | 0.1 | – | – | – |
| 1998–99 | 560 | 215 | 0.5 | 390 | 258 | 0.3 | – | – | – |
| 1999–00 | 380 | 123 | 0.5 | 430 | 173 | 0.5 | – | – | – |
| 2000–01 | 1 020 | 213 | 0.8 | 400 | 203 | 0.5 | – | – | – |
| 2001–02 | 660 | 234 | 0.9 | 280 | 186 | 0.5 | – | – | – |
| 2002–03 | 660 | 276 | 0.5 | 480 | 204 | 0.5 | – | – | – |
| 2003–04 | 570 | 300 | 0.5 | 460 | 266 | 0.4 | 1 030 | 151 | 4.0 |
| 2004–05 | 790 | 308 | 0.5 | 490 | 231 | 0.6 | 1 030 | 200 | 2.9 |
| 2005–06 | 500 | 303 | 0.4 | 400 | 281 | 0.4 | 160 | 65 | 1.1 |
| 2006–07 | 510 | 282 | 0.4 | 200 | 187 | 0.3 | 80 | 43 | 0.7 |
| 2007–08 | 690 | 335 | 0.5 | 170 | 189 | 0.3 | NA | NA | NA |
| 2008–09 | 330 | 307 | 0.2 | 120 | 158 | 0.1 | NA | NA | NA |
| 2009–10 | 180 | 121 | 0.3 | 40 | 68 | 0.2 | 60 | 28 | 1.3 |
| 2010–11 | 210 | 60 | 0.5 | 30 | 34 | < 0.1 | 400 | 31 | 6.5 |
| 2011–12 | 180 | 72 | 0.5 | 10 | 20 | 0.5 | 670 | 36 | 19.5 |
| 2012–13 | NA | NA | NA | 50 | 19 | 0.3 | 710 | 39 | 25.0 |
| 2013–14 | 350 | 77 | 1.0 | 90 | 40 | 0.9 | 950 | 40 | 24.2 |
| 2014–15 | 250 | 56 | 0.9 | 40 | 11 | 0.5 | 1 780 | 89 | 21.7 |
| 2015–16 | 190 | 159 | 0.1 | 110 | 61 | 0.1 | 700 | 54 | 10.8 |
| 2016–17 | 393 | 139 | 0.2 | 69 | 74 | 0.1 | 868 | 115 | 5.0 |
| 2017–18 | 340 | 1 802 | 0.2 | 20 | 33 | 0.4 | 801 | 83 | 5.5 |
| 2018–19 | 312 | 219 | 0.1 | 43 | 72 | 0.3 | 2005 | 162 | 7.5 |
| 2019–20 | 156 | 156 | 0.2 | 56 | 70 | 0.2 | 2563 | 269 | 5.0 |
| 2020–21 | 103 | 92 | 0.2 | NA | NA | NA | 1 201 | 202 | 2.2 |

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, catches were 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 limit of 500 t for each of the six years up to 2006–07, but catches and catch rates declined substantially from 2007–08, and have remained low since. Areas of the northeast Pukaki Rise outside of Priceless were developed in 2004–05 and also showed a rapid decline in catches and catch rates. By 2007–08, the fishery in the sub-Antarctic was limited to the Auckland Islands and northeast Pukaki Rise areas. From 2008–09 the fishery extended over a relatively wide area, but catches and catch rates were low, and the fishery effectively ceased from 2010–11 (Table 5).

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

**Table 5: Estimated ORH 3B catches (to the nearest 10 t) and unstandardised median catch rates (to nearest 0.1 t/tow) for areas outside the Chatham Rise, using estimated catch and effort data held by NIWA. Only tows that targeted orange roughy are included. 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 reports is now included in Other Pukaki. All years are from 1 October–30 September. – means catch < 10 t. NA means catch greater than 10 t, but there were fewer than 3 vessels in the fishery.**

| | Arrow | | Auckland | | Bounty | | Priceless | | Other Pukaki | | Puysegur | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Catch | t/tow | Catch | t/tow | Catch | t/tow | Catch | t/tow | Catch | t/tow | Catch | t/tow | Catch | t/tow |
| 1985–86 | 120 | 18.5 | – | – | – | – | – | – | – | – | – | – | – | – |
| 1986–87 | 110 | 10.6 | – | – | – | – | – | – | – | – | – | – | – | – |
| 1987–88 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 1988–89 | – | – | – | – | – | – | – | – | – | – | – | – | 30 | <0.1 |
| 1989–90 | – | – | – | – | – | – | – | – | – | – | 100 | 1.4 | 50 | 6.0 |
| 1990–91 | 150 | 4.5 | – | – | – | – | – | – | – | – | 600 | 4.6 | 20 | <0.1 |
| 1991–92 | 100 | 10.0 | – | – | – | – | – | – | – | – | 6 320 | 10.6 | 170 | 0.6 |
| 1992–93 | 10 | 6.5 | 30 | < 0.1 | – | – | – | – | – | – | 4 280 | 6.7 | 330 | < 0.1 |
| 1993–94 | 470 | 1.0 | 180 | < 0.1 | – | – | – | – | – | – | 2 410 | 1.9 | 80 | < 0.1 |
| 1994–95 | 750 | 0.3 | 880 | 0.2 | – | – | – | – | – | – | 1 260 | 7.9 | 20 | < 0.1 |
| 1995–96 | 170 | 0.1 | 370 | 0.1 | – | – | – | – | 3 060 | 5.0 | 730 | 2.4 | 520 | < 0.1 |
| 1996–97 | 280 | 0.1 | 120 | < 0.1 | 20 | < 0.1 | – | – | 670 | < 0.1 | 490 | 2.6 | 400 | < 0.1 |
| 1997–98 | 330 | 0.1 | 360 | 0.1 | 240 | < 0.1 | 10 | < 0.1 | 130 | < 0.1 | – | – | 1 050 | < 0.1 |
| 1998–99 | 730 | 0.3 | 440 | 0.1 | 130 | 0.1 | – | – | 120 | < 0.1 | – | – | 1 820 | 0.5 |
| 1999–00 | 280 | 0.1 | 150 | < 0.1 | 170 | < 0.1 | – | – | – | – | – | – | 60 | < 0.1 |
| 2000–01 | 190 | 0.1 | 60 | < 0.1 | 150 | 0.3 | – | – | 20 | < 0.1 | – | – | 1 030 | 0.3 |
| 2001–02 | 70 | 0.2 | 130 | 0.1 | 40 | 0.1 | 550 | 22.3 | – | – | – | – | 460 | 0.4 |
| 2002–03 | 220 | 0.2 | – | – | 220 | 1.5 | 480 | 7.0 | – | – | – | – | 400 | 0.4 |
| 2003–04 | 140 | 0.1 | – | – | 90 | 0.2 | 450 | 0.3 | – | – | – | – | 440 | < 0.1 |
| 2004–05 | 60 | 0.1 | – | – | 100 | 0.4 | 540 | 0.3 | 520 | 9.8 | NA | NA | 550 | < 0.1 |
| 2005–06 | 100 | 0.1 | – | – | 40 | 0.2 | 540 | 0.9 | 740 | 4.0 | NA | NA | 250 | < 0.1 |
| 2006–07 | – | – | – | – | – | – | 470 | 0.5 | NA | NA | – | – | – | – |
| 2007–08 | – | – | NA | NA | – | – | NA | NA | NA | NA | – | – | – | – |
| 2008–09 | – | – | NA | NA | – | – | NA | NA | NA | NA | – | – | 150 | 0.5 |
| 2009–10 | – | – | NA | NA | NA | NA | 210 | < 0.1 | 320 | 0.3 | – | – | 60 | < 0.1 |
| 2010–11 | – | – | NA | NA | NA | NA | – | – | NA | NA | – | – | 20 | 0.4 |
| 2011–12 | – | – | NA | NA | – | – | – | – | – | – | – | – | – | – |
| 2012–13 | – | – | NA | NA | – | – | – | – | NA | NA | – | – | – | – |
| 2013–14 | – | – | NA | NA | – | – | – | – | – | – | – | – | – | – |
| 2014–15 | – | – | 350 | < 0.1 | – | – | – | – | – | – | – | – | 38 | 0.6 |
| 2015–16 | – | – | 380 | 0.6 | – | – | – | – | – | – | NA | NA | – | – |
| 2016–17 | – | – | 184 | 0.3 | NA | NA | – | – | NA | NA | NA | NA | 49 | 0.8 |
| 2017–18 | – | – | 105 | 0.1 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2018–19 | – | – | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2019–20 | – | – | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2020–21 | – | – | NA | NA | NA | NA | NA | NA | 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 Introduction – Orange roughy chapter.

## 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. With the successful assessment of the MEC stock in 2013, which used age data from the new ageing methodology (Tracey et al 2007, Horn et al 2016), there was a return to model-based assessment in 2014. Recruitment in all of these assessments has been derived from limited age data.

## 4.1 Northwest Chatham Rise

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

### 4.1.1 Model structure

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

### 4.1.2 Input data and statistical assumptions

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

**Acoustic estimates**

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

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

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

### 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 Introduction – Orange roughy chapter); and including the 2016 age frequency with its own (logistic) selectivity.

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

## Model diagnostics

The model provided good MPD fits to the data (Figures 3 and 4). The acoustic indices, free to 'move' somewhat as they are relative, were fitted well (Figure 3). The posterior estimates for the acoustic *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 5). Numerous MPD sensitivity runs were performed. These showed that the main drivers of the estimated stock status were natural mortality (*M*) and the means of the acoustic *q* priors (lower *M* and higher mean *q* give lower stock status; higher *M* and lower mean *q* give higher stock status).

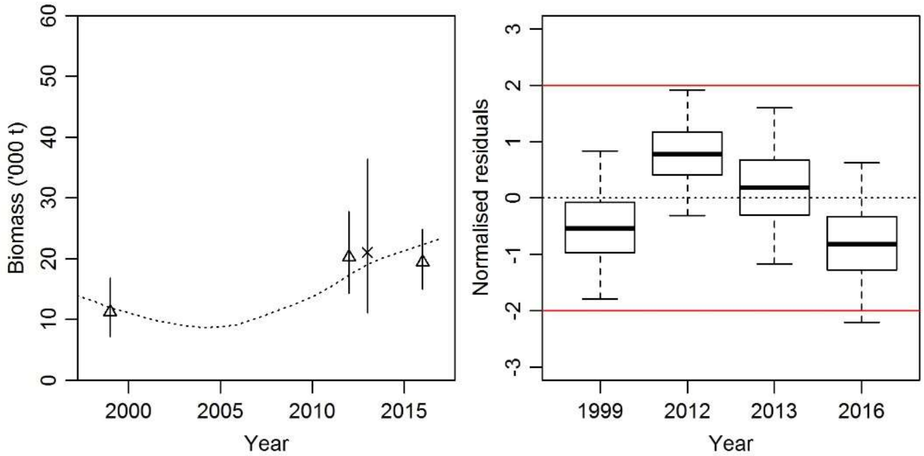



**Figure 3: NWCR, base, (left) MPD fits to the acoustic biomass indices; broken line, spawning biomass trajectory; scaled acoustic indices for x, Graveyard survey, and Δ, Graveyard and Morgue surveys; (right) MCMC normalised residuals for the acoustic biomass indices. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.**

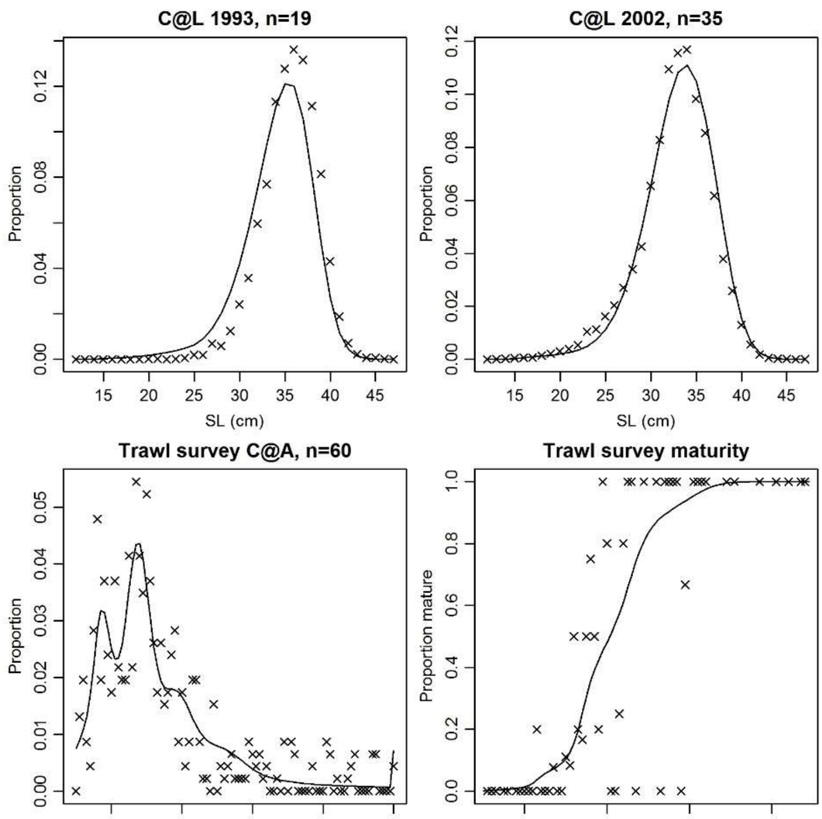



**Figure 4: NWCR, base, MPD fits: (x, observations; lines, predictions): (top) commercial catch-at-length samples (n is the effective sample size); (bottom) trawl survey catch-at-age and proportion mature at age.**

When the Morgue age frequency was fitted assuming that the selectivity on Morgue was equal to maturity the fit was poor, particularly to the left-hand side of the age frequency distribution. When the Morgue age frequency was fitted assuming a separate logistic selectivity ogive, the fit was acceptable (Figure 6). The Morgue age frequency had an unexpectedly high proportion of older fish, and the sampling methodology was also unusual. As a result, it was agreed to exclude the Morgue age frequency data from the base model.

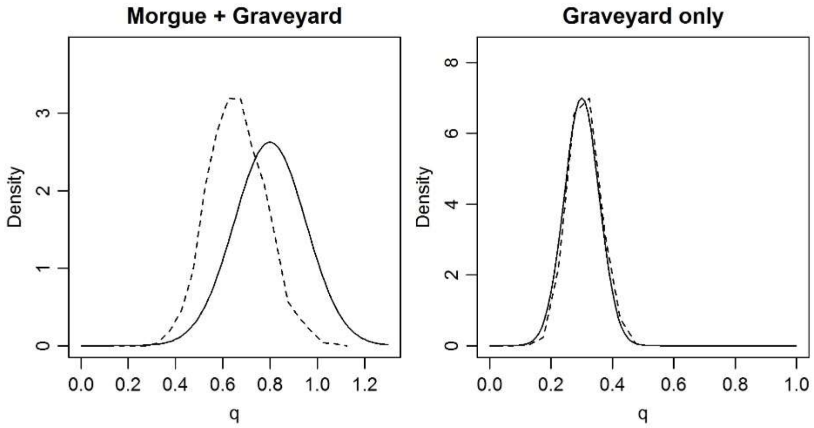



**Figure 5: NWCR base, MCMC diagnostics: prior (solid line) and posterior (broken line) distributions for the two acoustic *q*s (left, mean *q*-prior = 0.8; right, mean q-prior = 0.3).**

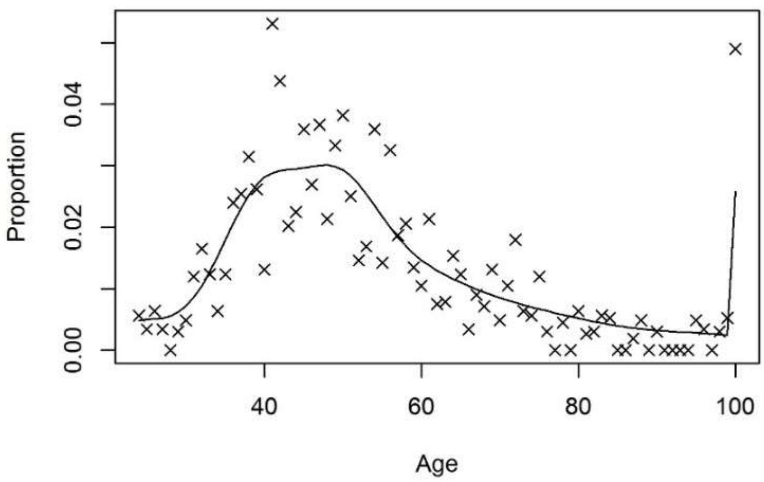



**Figure 6: NWCR, base, MPD fits: (x, observations; lines, predictions) to the Morgue age frequency (effective sample size n = 60).**

## MCMC Results

For the base model, and the sensitivity runs, MCMC convergence diagnostics indicated no lack of convergence. Virgin biomass, $B_0$, was estimated to be between 64 000–67 300 t for all runs (Table 8). Current stock status was similar across the base and the first two sensitivity runs (Table 8). For the two 'bounding' runs, where *M* and the mean of the acoustic *q* priors were shifted by 20%, median current stock status was estimated to be close to the lower bound, or upper bound, of the target range of 30–50% $B_0$ (Table 8).

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

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

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

The estimated YCS showed little variation across cohorts, but recruitment was relatively high in 1940–52, 1965–68, and 1975–79 (Figure 7).

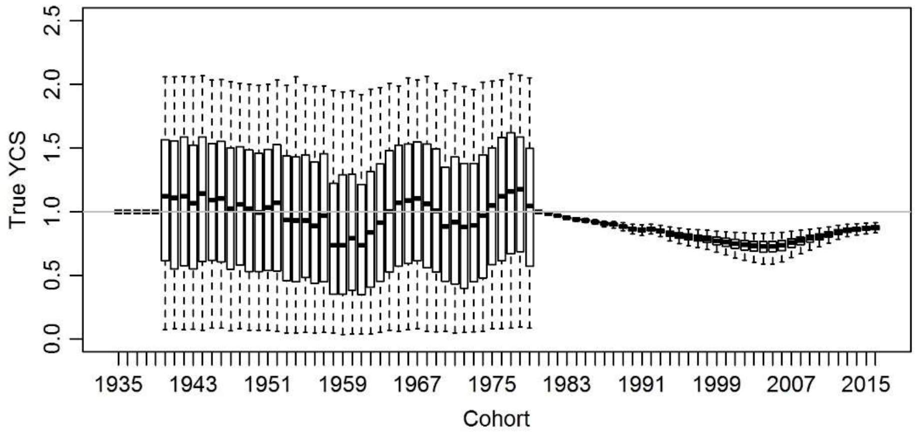



**Figure 7: NWCR base, MCMC estimated 'true' YCS ($R_y/R_0$). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.**

The estimated spawning stock biomass (*SSB*) trajectory showed a declining trend from 1980 (when the fishery started) through to 2004 when the biomass was About as Likely as Not (40–60%) to be below the soft limit (Figure 8). Since 2005 the estimated biomass has increased steadily.

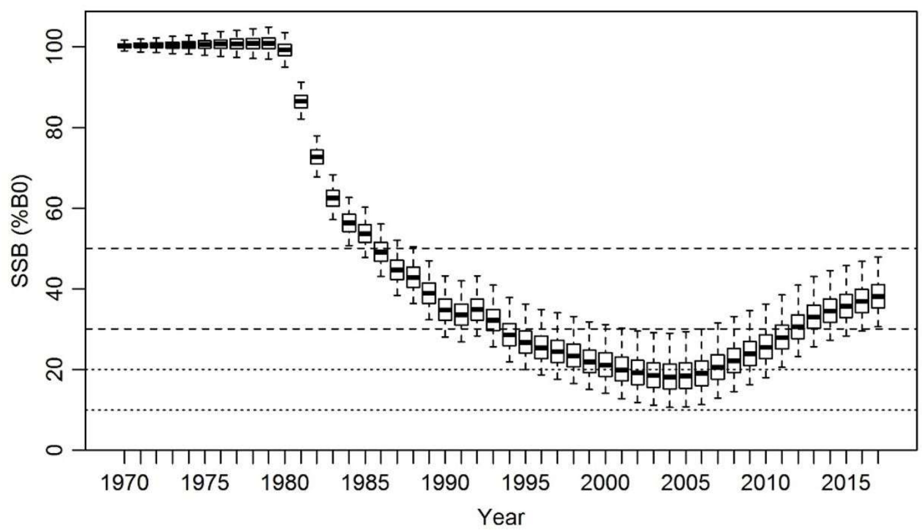



**Figure 8: NWCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Dotted lines indicate the hard limit (10% $B_0$) and soft limit (20% $B_0$), and dashed lines the management target range (30–50% $B_0$).**

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 9). There was less than a 1% probability that the exploitation rate in 2017 was below $U_{30\%B0}$.

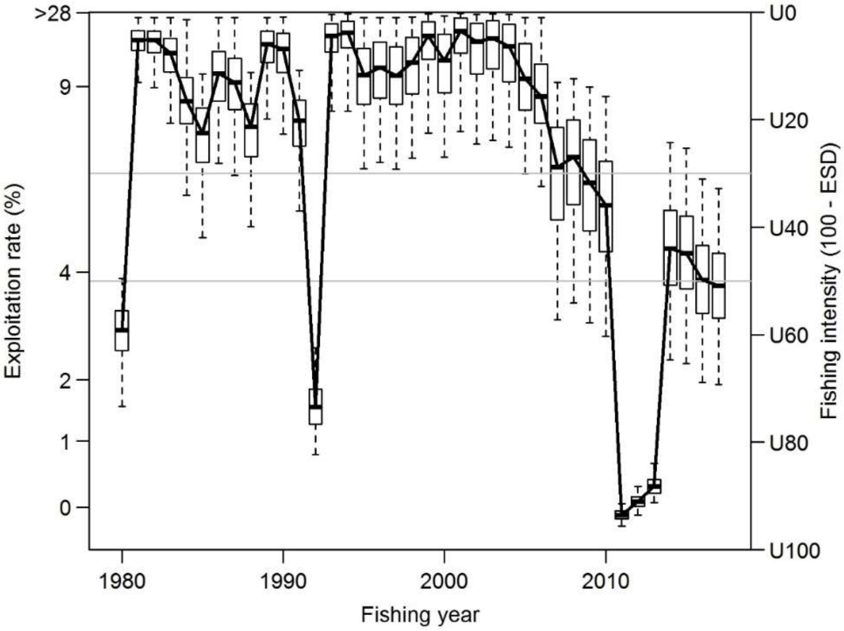



**Figure 9: NWCR base, MCMC estimated fishing intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing intensity range associated with the biomass target of 30–50% $B_0$ is marked by horizontal lines.**

## Projections

Five-year biomass projections were made for the Base model run assuming future catches to be the TACC (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 9).

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

| Model run | Catch (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 Introduction – Orange roughy chapter.

#### 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 10. 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 *q*s 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 Introduction – Orange roughy chapter). 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 10: Acoustic estimates of average pluming spawning biomass in the three main spawning areas as used in the assessment. All estimates were obtained from surveys on FV *San 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 10). 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.

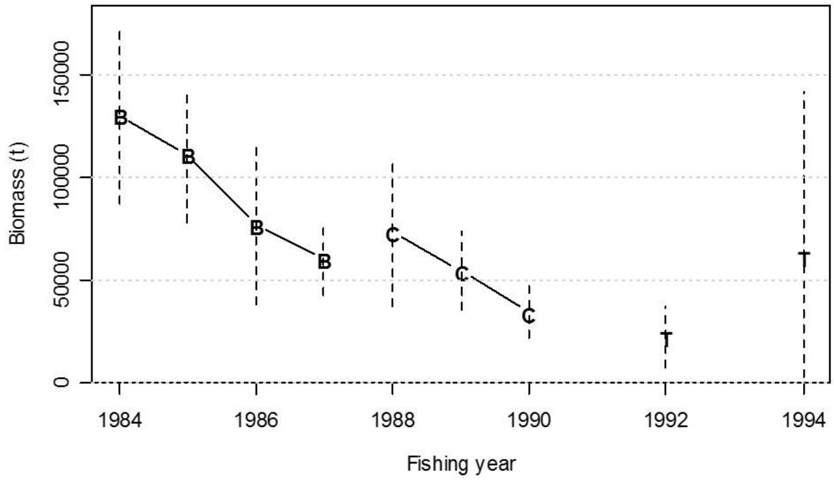



**Figure 10: The Spawning Box trawl survey biomass indices (assuming a catchability of 1 for each vessel), with 95% confidence intervals shown as vertical lines. Vessels indicated as B, FV *Otago Buccaneer*; C, FV *Cordella*; T, RV *Tangaroa*.**

The 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 Introduction – Orange roughy chapter).

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 11–13). The main exception was for the current model where the normalised residuals for the 2016 acoustic estimate are well outside the expected range (Figure 14). 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).

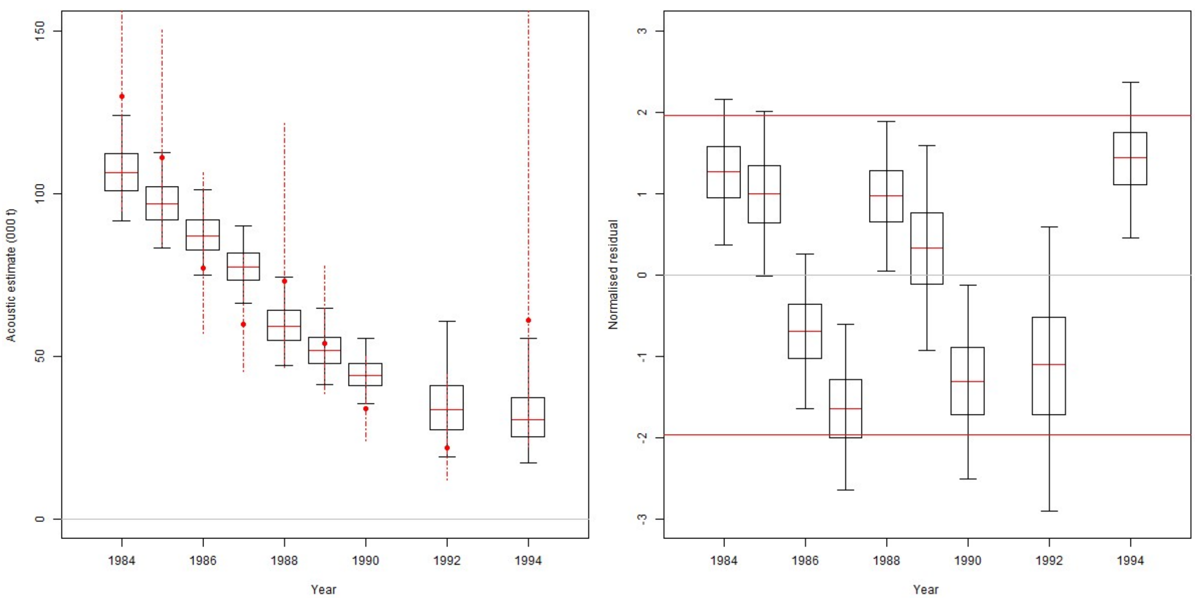



**Figure 11: Current model: the MCMC fits and normalised residuals for the trawl survey biomass estimates in the spawning box. The observations are plotted with 95% confidence intervals (left plot, red vertical lines). The MCMC predictions (left plot) and normalised residuals (right plot) are plotted as a 'box and whiskers'. The middle 50% of the distribution is in the box with the whiskers extending to a 95% C.I.**

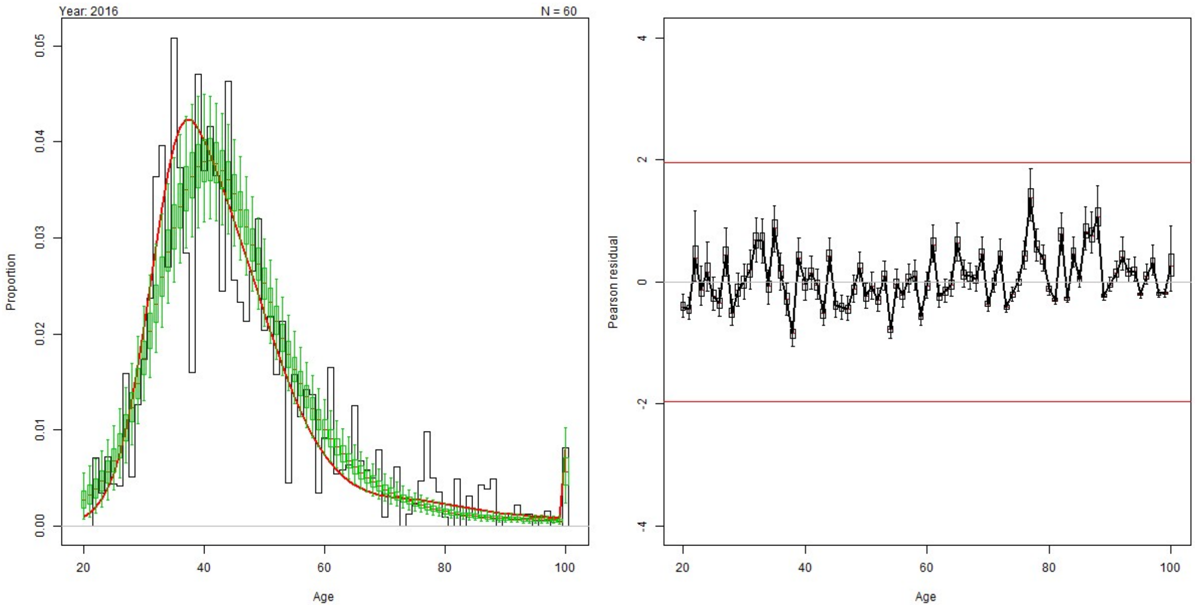



**Figure 12: Current model: the MCMC fits and normalised residuals for the 2016 spawning population age frequency (left plot, histogram in black). The MPD fit is shown as the red line in the left plot. The MCMC predictions (left plot) and Pearson residuals (right plot) are plotted as a "box and whiskers". The middle 50% of the distribution is in the box with the whiskers extending to a 95% C.I.**

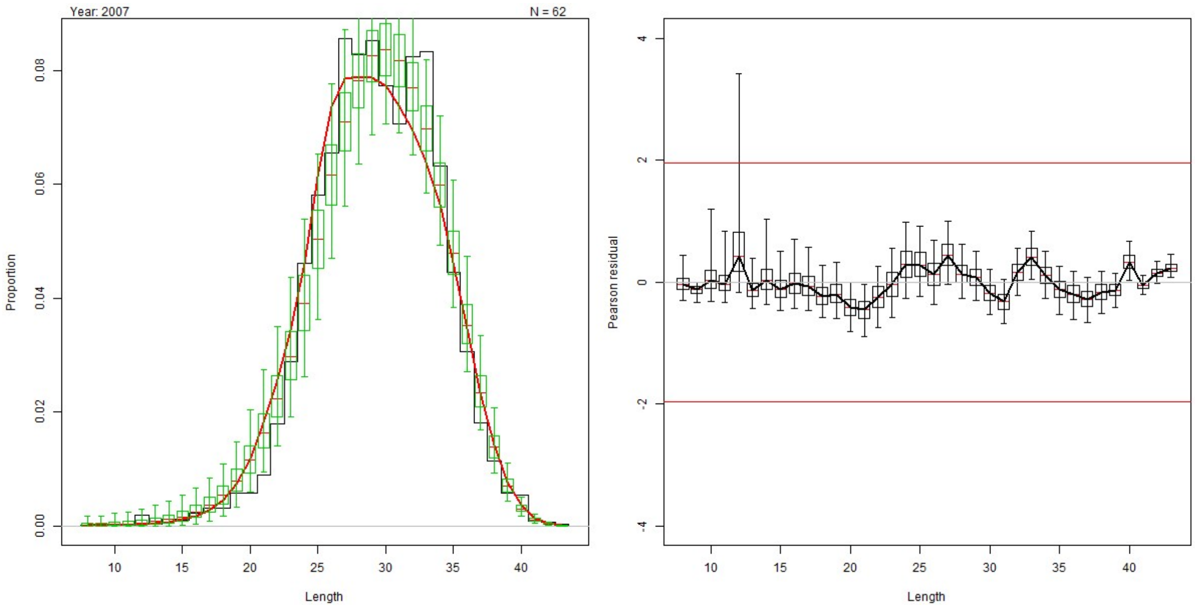



**Figure 13: Current model: the MCMC fits and normalised residuals for the 2007 wide-area trawl survey length frequency (left plot, histogram in black). The MPD fit is shown as the red line in the left plot. The MCMC predictions (left plot) and Pearson residuals (right plot) are plotted as a 'box and whiskers'. The middle 50% of the distribution is in the box with the whiskers extending to a 95% C.I.**

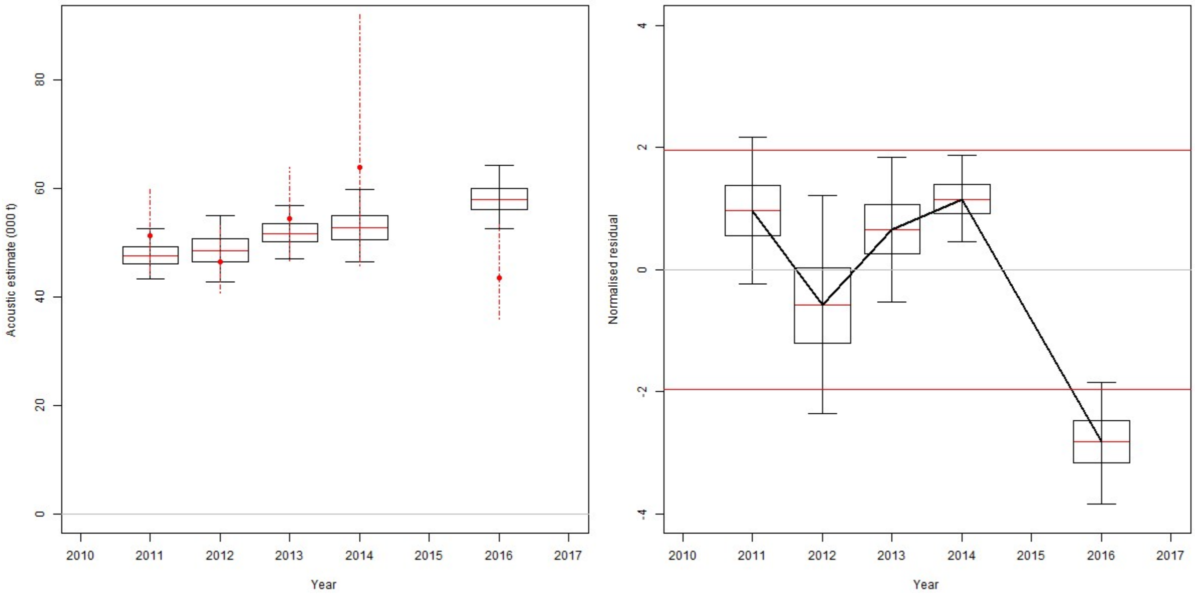



**Figure 14: Current model: the MCMC fits and normalised residuals for the acoustic survey biomass estimates since 2011. The observations are plotted with 95% confidence intervals (left plot, red vertical lines). The MCMC predictions (left plot) and normalised residuals (right plot) are plotted as a '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 15). 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).

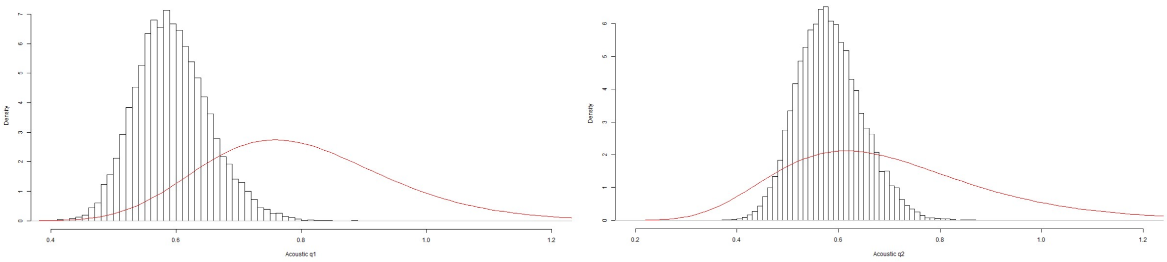


**Figure 15: Current model: the prior distributions (red lines) and marginal posterior distributions (histograms) for the two main acoustic *q*s.**

## MCMC results

Virgin biomass, $B_0$, was estimated to be about 300 000–350 000 t for the three models (Table 11). Current stock status was similar for the current and q-ratio models, both having the 95% CIs above 30% $B_0$ (Table 11). The pessimistic *LowMhighq* run has stock status estimated just below 30% $B_0$ (Table 11).

**Table 11: 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 16). 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 17).

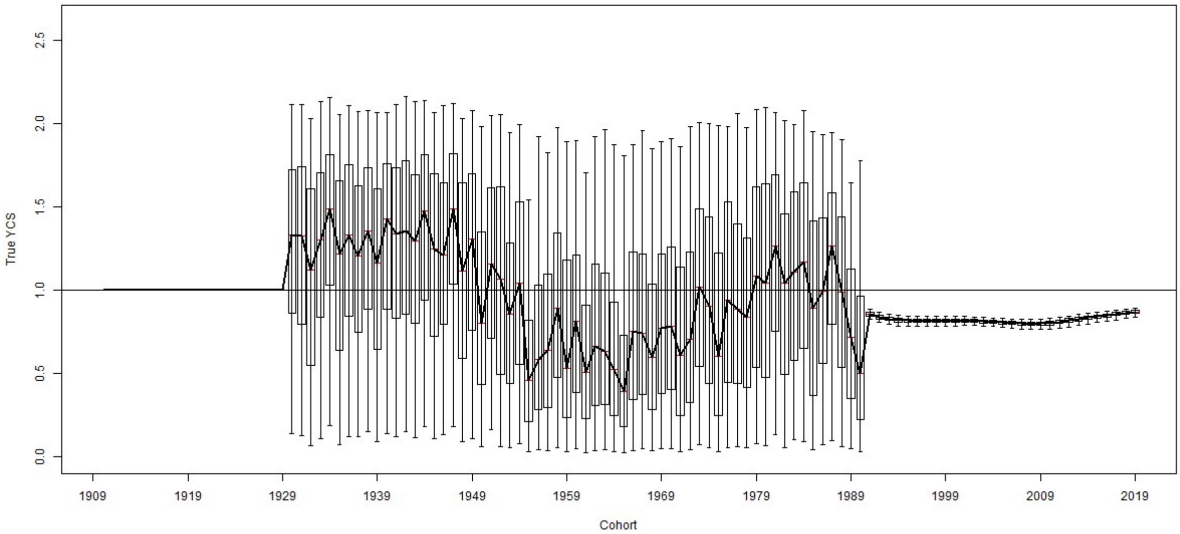



**Figure 16: ESCR current model, MCMC estimated 'true' YCS ($R_y/R_0$). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Year classes between 1930 and 1990 were estimated.**

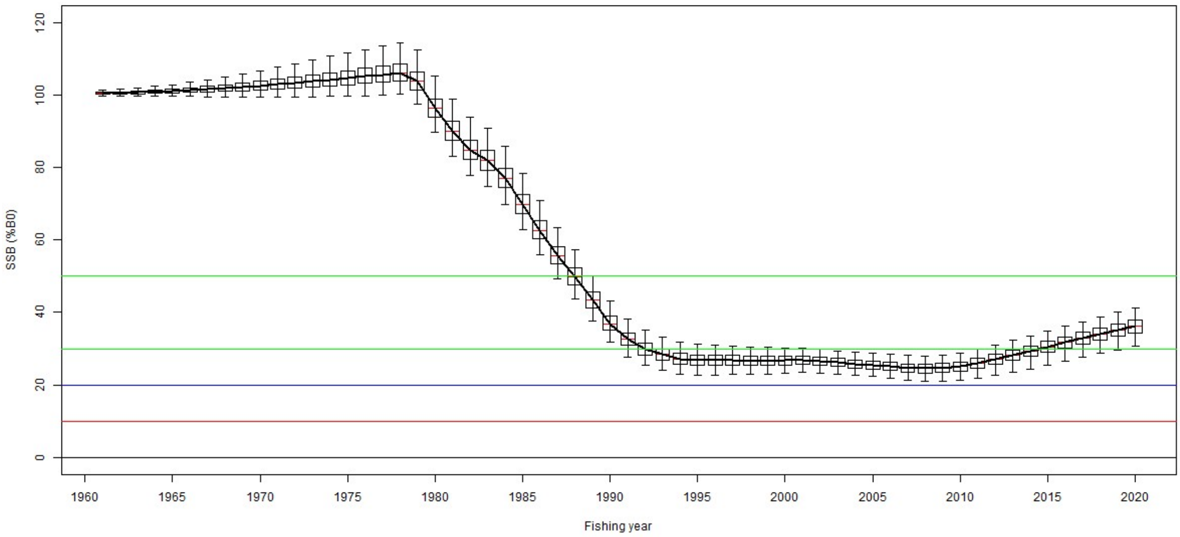



**Figure 17: ESCR current model, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. Horizontal lines are plotted at the hard limit (10% $B_0$), the soft limit (20% $B_0$), and the biomass target range (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 18).

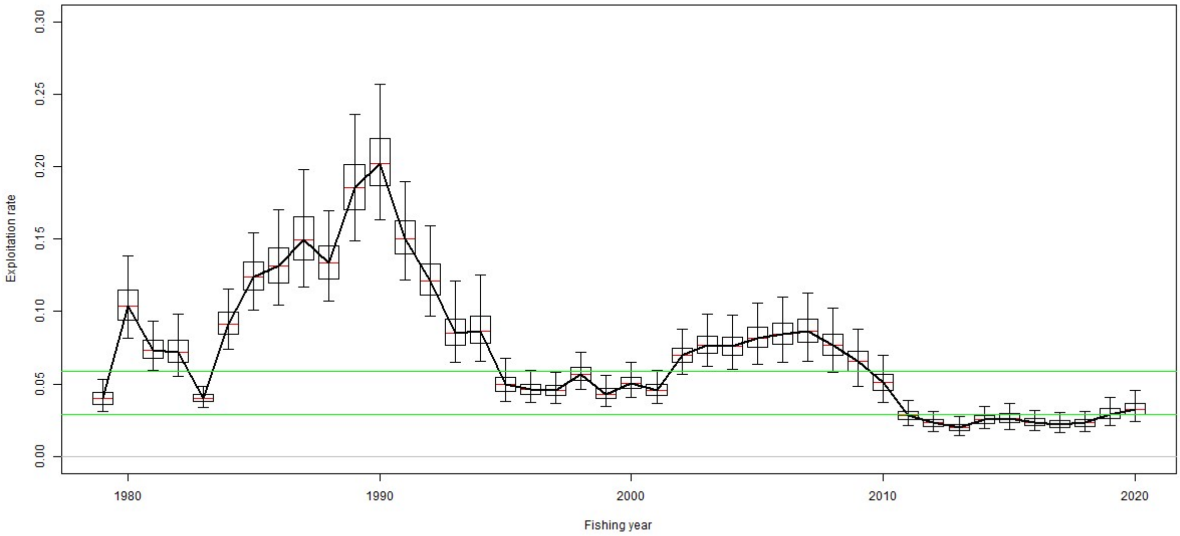



**Figure 18: ESCR current model, MCMC estimated exploitation rates. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The exploitation rates associated with the biomass target of 30–50% $B_0$ are marked by horizontal lines at $U_{30\%B0}$ and $U_{50\%B0}$.**

## 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 19).

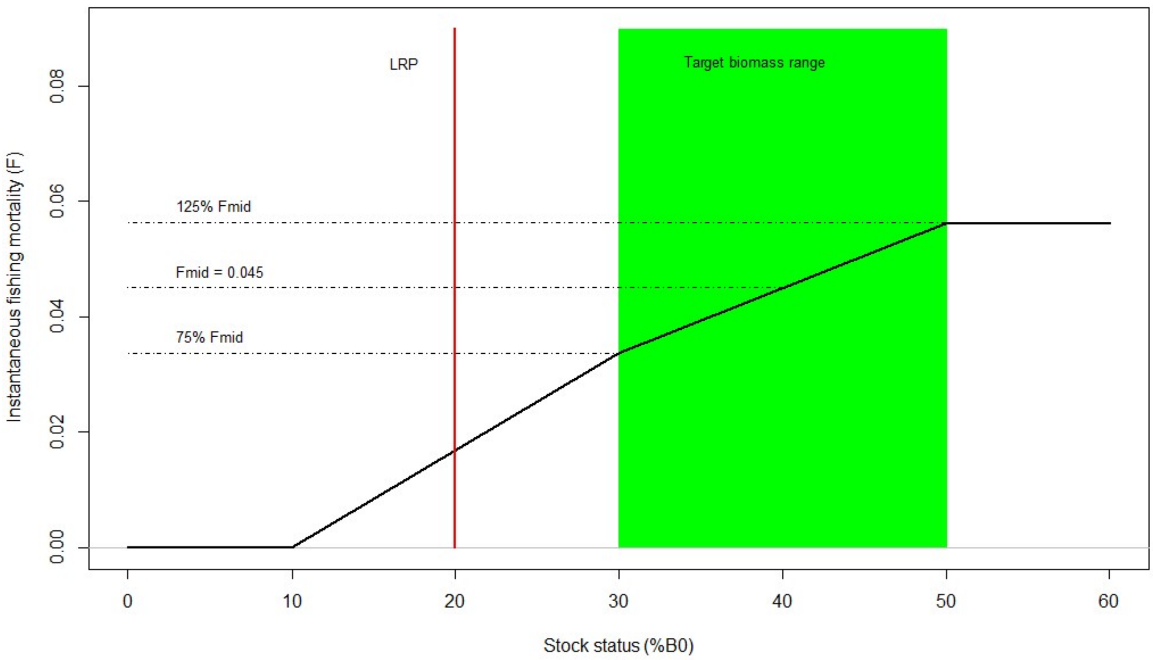



**Figure 19: The orange roughy HCR showing the relationship between current estimated stock status and the instantaneous fishing mortality rate (or exploitation rate) applied to next year's beginning-of-year vulnerable biomass to derive the recommended catch limit. The target biomass range is 30–50% $B_0$ 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 19, Table 12). 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 12).

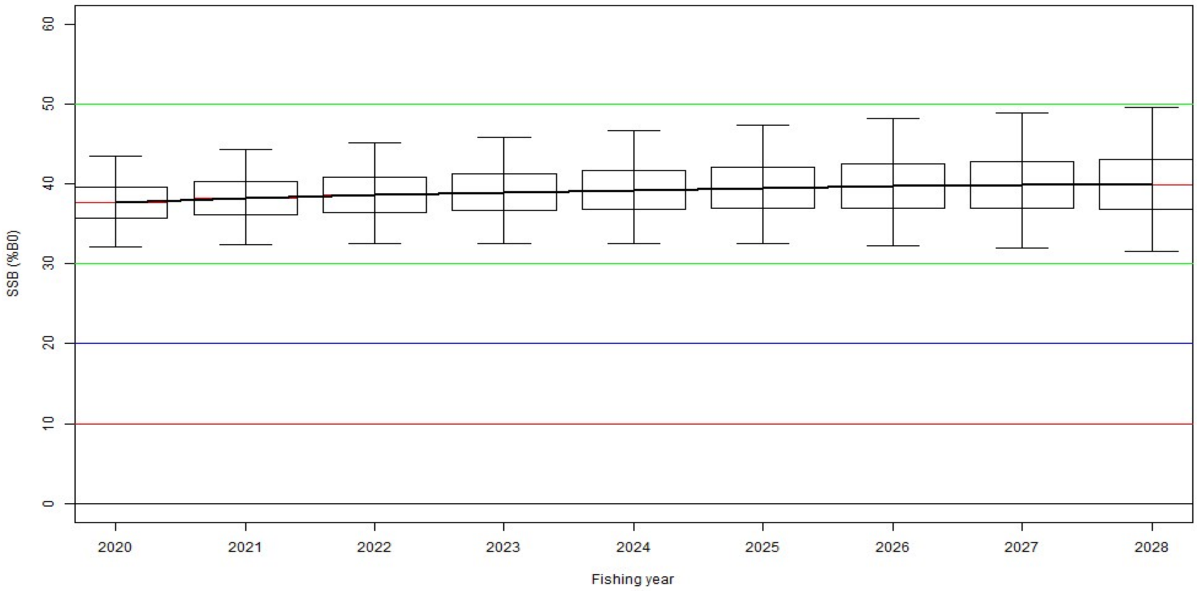
**Table 12: The estimated stock status in 2019–20, the catch-weighted vulnerable biomass at the beginning of 2020–21, and the associated exploitation rate and recommended catch limit from the HCR for the current model and the q-ratio model.**

| 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 20).



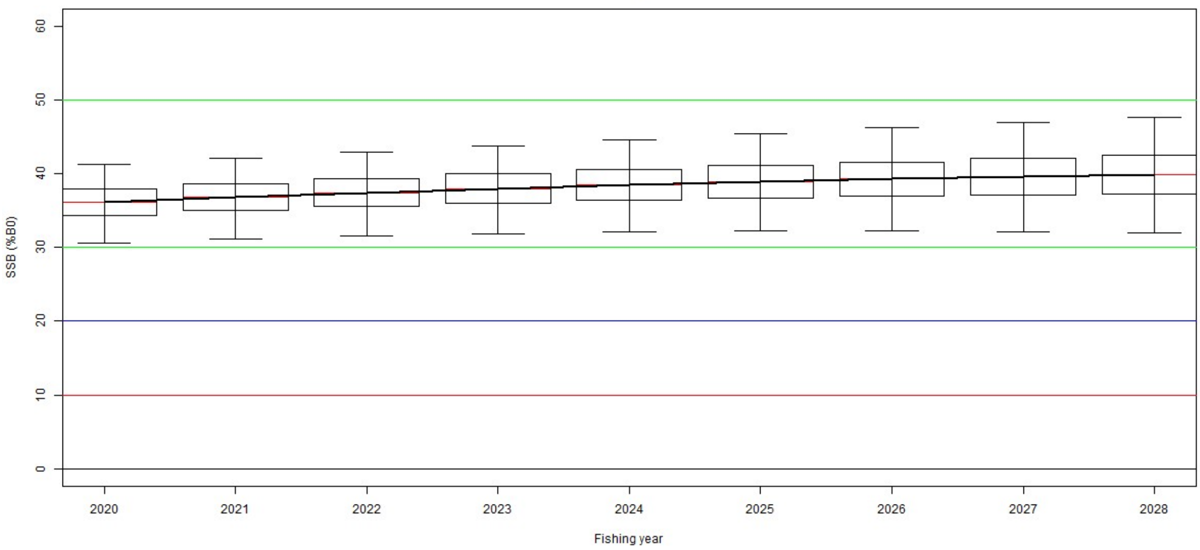




**Figure 20: Projected stock status for catches at the HCR recommended catch limits plus 5% to allow for incidental mortality. Top: q-ratio model projected at 6283 t (plus 5%). Bottom: current model projected at 6348 t (plus 5%). Each box covers the middle 50% of the distribution and the whiskers extend to 95% CIs. [Continued on next page]**

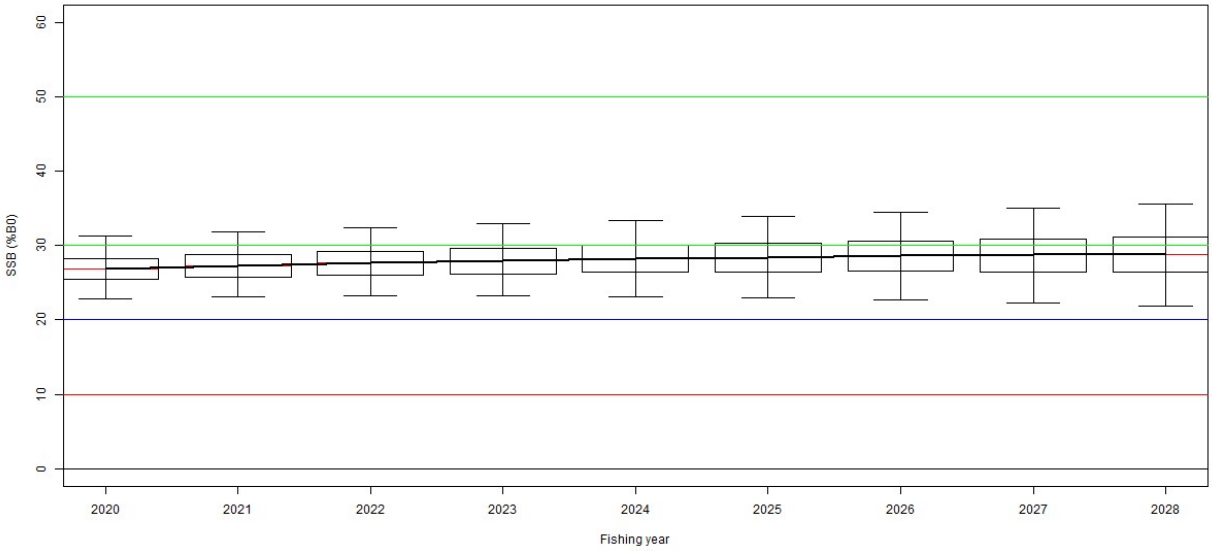



**Figure 20 [Continued]: Projected stock status for catches at the HCR recommended catch limits plus 5% to allow for incidental mortality. *LowMhighq* model projected at 6348 t (plus 5%). Each box covers the middle 50% of the distribution and the whiskers extend to 95% CIs.**

## 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 Introduction – Orange roughy chapter (ESCR growth parameters were assumed).

### 4.3.2 Input data and statistical assumptions

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

**Acoustic estimate**

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

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

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

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

## 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 21). 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.

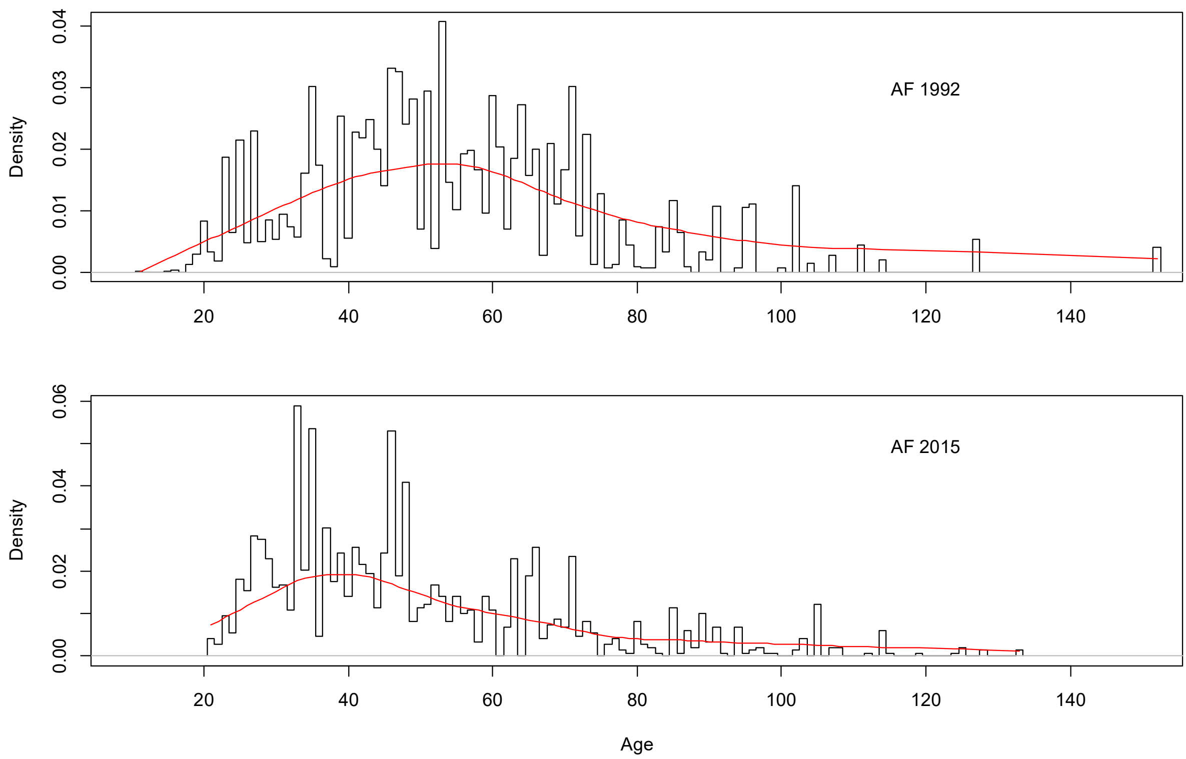



**Figure 21: Puysegur: age frequencies from 1992 and 2015 used in the base model. The red lines were produced using the lowess smoother in R.**

## 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 14).

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 22).

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

| | Biomass index (t) | CV (%) |
|---|---|---|
| 1992 | 6 630 | 28 |
| 1994 | 1 160 | 24 |

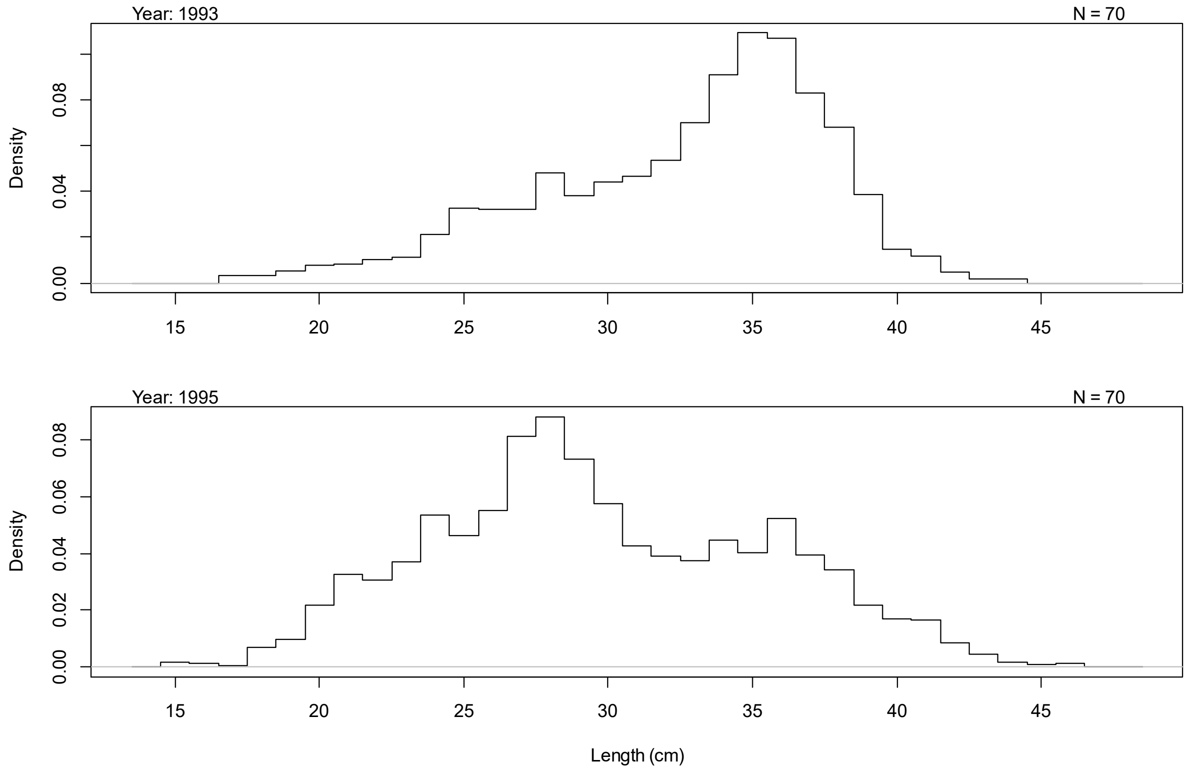



**Figure 22: Puysegur: length frequencies for the *Tangaroa* trawl surveys in 1992 and 1994 (fitted in the model as beginning of year in 1993 and 1995). The effective samples sizes of N = 70 were the approximate number of stations in each survey.**

## 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 Introduction – Orange roughy chapter). 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 23).

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 Introduction – Orange roughy chapter).

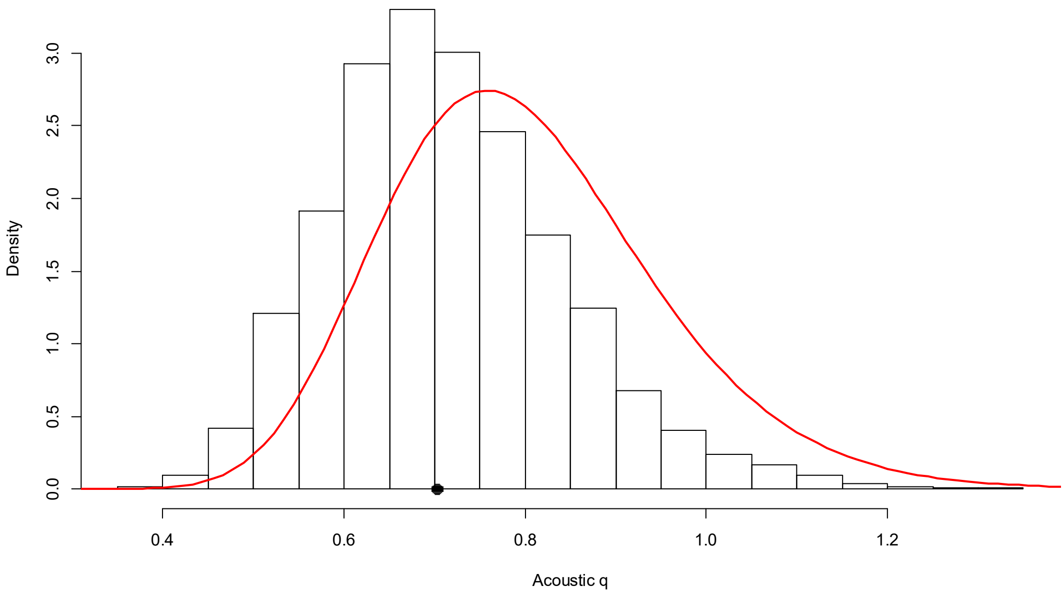



**Figure 23: Puysegur: the marginal posterior distribution of the acoustic *q* (histogram) compared to its prior (red line). The black dot marks the median of the marginal posterior.**

**MCMC Results**

For the base model, and the sensitivity runs, MCMC convergence diagnostics for virgin biomass ($B_0$) and stock status were very good. $B_0$ was estimated to be between 12 000–26 000 t for all runs (Table 15). Current stock status was similar across the base and the first four sensitivity runs (Table 15). The slightly lower stock status when *M* was estimated reflects the lower estimates of *M* (0.040 rather than 0.045). For the two 'bounding' runs, where *M* and the mean of the acoustic *q* prior were shifted by 20%, median current stock status was within or above the biomass target range of 30–50% $B_0$ for both runs (Table 15). The sensitivity with a higher CV on the acoustic *q* prior gave similar results to the base model with a slighter higher $B_0$ and stock status. The 5% overrun model gave almost identical results to the base model. All other sensitivity runs gave stock status estimates within the range covered by the *LowM-Highq* and *HighM-Lowq* models.

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

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

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

The estimated YCS show a trend across cohorts with above average recruitment prior to 1950 with below average recruitment up until about 1980 (Figure 24). 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).

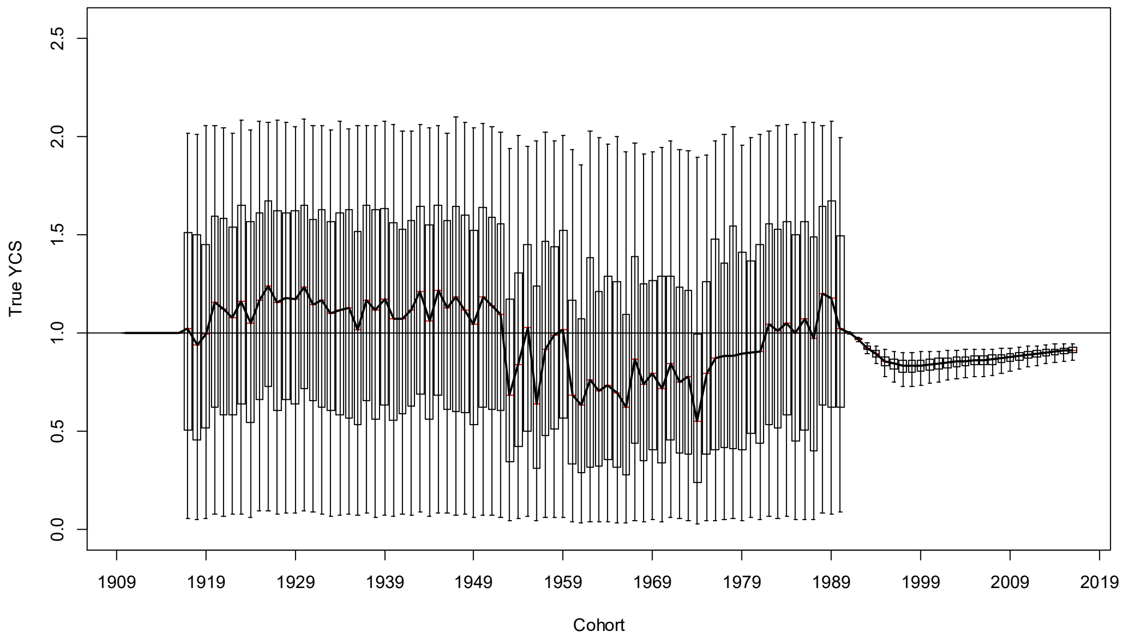



**Figure 24: Puysegur base, MCMC estimated 'true' YCS ($R_y/R_0$). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.**

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 25). Since 1998 the estimated biomass has increased steadily and has been well within the target range for the last decade (Figure 25).

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 26).

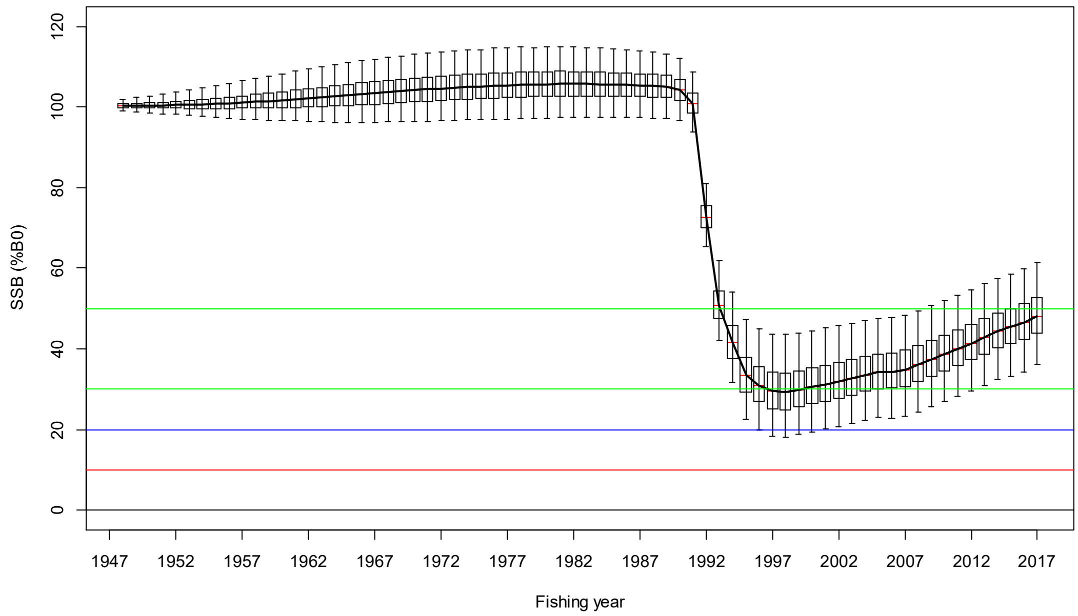



**Figure 25: Puysegur base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.**

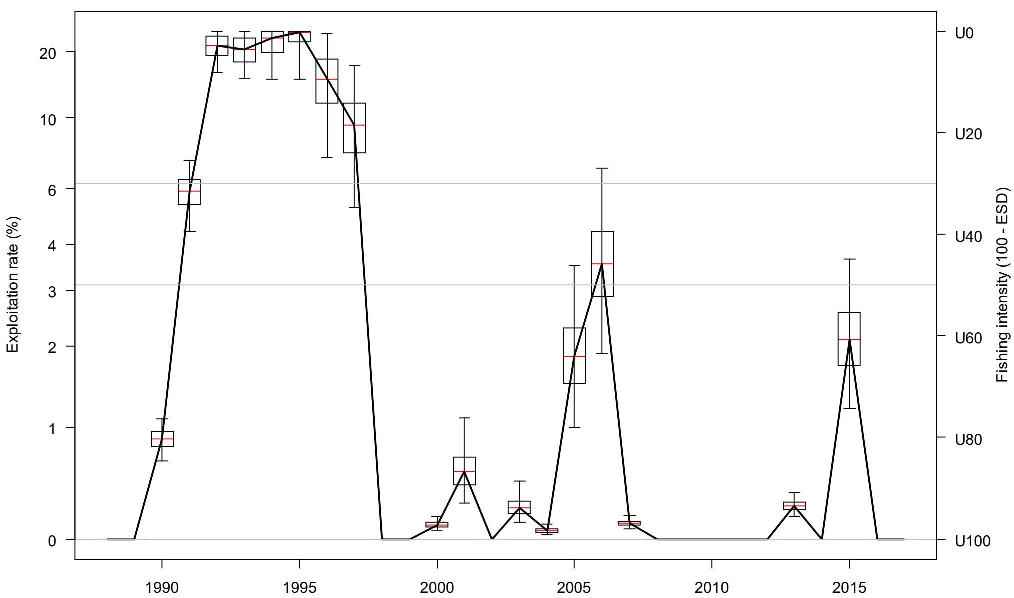



**Figure 26: Puysegur base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–50% $B_0$ is marked by horizontal lines.**

**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. STATUS OF THE STOCKS

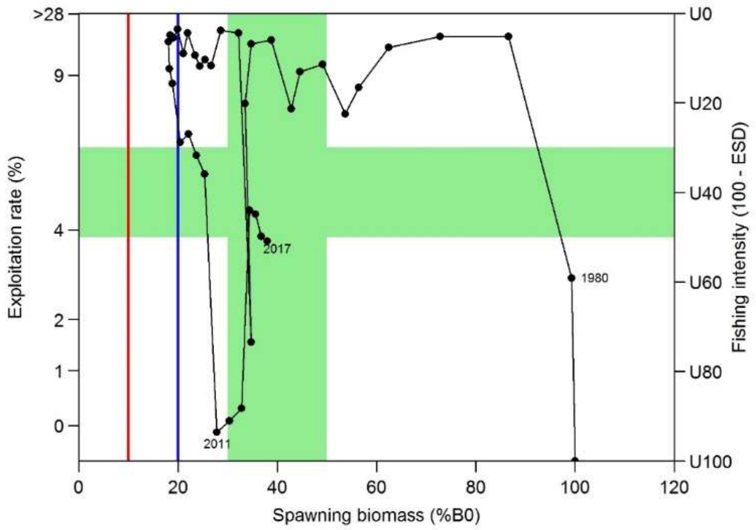
### 5.1 Chatham Rise

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

- **Northwest Chatham Rise**

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

**Historical Stock Status Trajectory and Current Status**




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

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

| **Projections and Prognosis** | |
|---|---|
| Stock Projections or Prognosis | At both the TACC (1250 t) and current agreed catch (1043 t), the biomass is expected to stay steady or increase over the next 5 years. |
| Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits | At both TACC and current agreed catch limit:<br>Soft Limit: Exceptionally Unlikely (< 1%)<br>Hard Limit: Exceptionally Unlikely (< 1%) |
| Probability of Current Catch or TACC causing Overfishing to continue or to commence | Exceptionally Unlikely (< 1%) at both TACC and current agreed catch limit. |

| **Assessment Methodology and Evaluation** | | |
|---|---|---|
| Assessment Type | Level 1 - Full Quantitative Stock Assessment | |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of posterior distributions | |
| Assessment Dates | Latest assessment: 2018 | Next assessment: 2021 |
| Overall assessment quality rank | 1 – High Quality | |
| Main data inputs (rank) | - Acoustic estimates of spawning biomass on Graveyard (1999, 2012–13) and Morgue (1999, 2012, 2016). | 1 – High Quality |
| | - Trawl survey age frequency and proportion-spawning-at-age (1994). | 1 – High Quality |
| | - 17 years of length frequency data. | 1 – High Quality |
| | - Morgue age frequency (2016); only as a sensitivity | 2 – Medium or Mixed Quality: potential non-representative sampling |
| Data not used (rank) | - CPUE | 3 – Low Quality: unlikely to be indexing stock-wide abundance |
| | - Trawl surveys of hills (1990–2002) | 3 – Low Quality: unlikely to be indexing stock-wide abundance |
| | - Wide-area acoustic survey estimates | 2 – Medium or Mixed Quality: large potential bias due to mixed-species |
| | - Chatham Rise trawl survey deepwater stations (2010–2016) | 2 – Medium or Mixed Quality: variable indices |
| | - Egg survey estimate | 3 – Low Quality: survey design assumptions not met |

| | |
|---|---|
| Changes to Model Structure and Assumptions | - |
| Major Sources of Uncertainty | - The largest source of uncertainty is the proportion of the NWCR spawning stock that is indexed by the acoustic survey in each year.<br>- In the base case, patterns in year class strengths are based on only one year of age composition data.<br>- The time series of abundance indices is short and restricted to the period of lower stock status. |

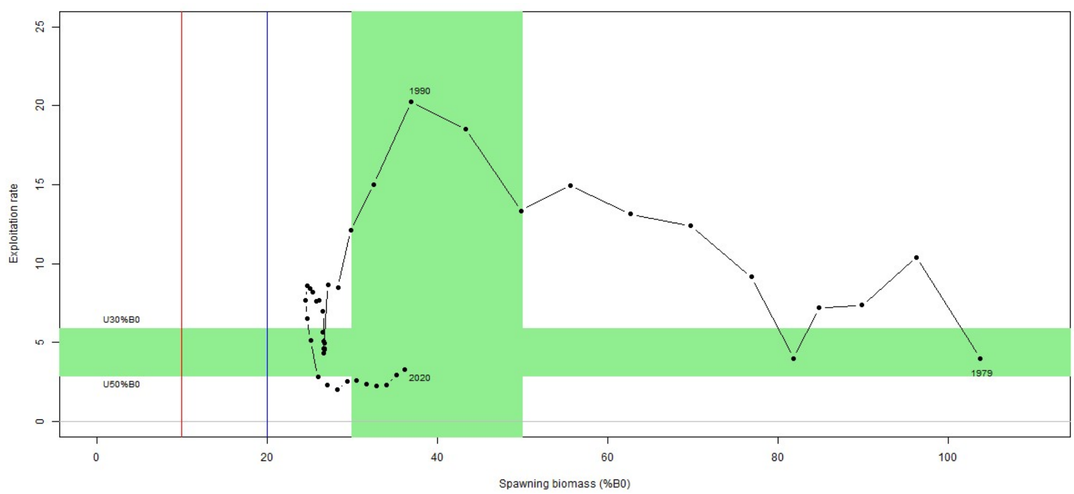
| **Qualifying Comments** |
|---|
| Estimates of stock biomass are sensitive to the means of the *q* priors. |

| **Fishery Interactions** |
|---|
| Main bycatch species are smooth oreo, black oreo, rattails, deepwater dogfish, and hoki, with lesser bycatches of Johnson's cod and ribaldo. Low productivity bycatch species include deepwater sharks, skates, and corals. Observed incidental captures of protected species include corals, low numbers of seabirds, and occasional New Zealand fur seals. Orange roughy are caught using bottom trawl gear. Bottom trawling interacts with benthic habitats. |

- **East and South Chatham Rise**

| **Stock Status** | |
|---|---|
| Year of Most Recent Assessment | 2020 |
| Assessment Runs Presented | Updated 2018 base model |
| Reference Points | Management Target: Biomass range 30–50% $B_0$<br>Soft Limit: 20% $B_0$<br>Hard Limit: 10% $B_0$<br>Overfishing threshold: Fishing intensity range $U_{30\%B0}$–$U_{50\%B0}$ |
| Status in relation to Target | $B_{2020}$ was estimated to be 36% $B_0$<br>Likely (> 60%) to be at or above the lower end of the management target range |
| Status in relation to Limits | $B_{2020}$ is Very Unlikely (< 10%) to be below the Soft Limit<br>$B_{2020}$ is Exceptionally Unlikely (< 1%) to be below the Hard Limit |
| Status in relation to Overfishing | Overfishing is Exceptionally Unlikely (< 1%) to be occurring |

**Historical Stock Status Trajectory and Current Status**




**Historical trajectory of spawning biomass (% $B_0$) and exploitation rate (%) (current model, medians of the marginal posteriors). The biomass target range of 30–50 % $B_0$ and the corresponding exploitation rate range are marked in green. The soft limit (20% $B_0$) is marked in blue and the hard limit (10% $B_0$) in red.**

| **Fishery and Stock Trends** | |
|---|---|
| Recent Trend in Biomass or Proxy | The spawning biomass is estimated to have been slowly increasing since 2009–10. |
| Recent Trend in Fishing Intensity or Proxy | Fishing intensity (exploitation rate) is estimated to have been near or below the lower end of the target range since 2010–11. |
| Other Abundance Indices | - |
| Trends in Other Relevant Indicators or Variables | - |

| **Projections and Prognosis** | |
|---|---|
| Stock Projections or Prognosis | Biomass is expected to increase slowly at catches equal to the current catch limit (4775 t) or the HCR recommended catch limit (6348 t). |
| Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits | At the current catch limit (4775 t) or the HCR recommended catch limit (6348 t):<br>Soft Limit: Very Unlikely (< 10%)<br>Hard Limit: Exceptionally Unlikely (< 1%) |

| **Assessment Methodology and Evaluation** | | |
|---|---|---|
| Assessment Type | Level 1 - Full Quantitative Stock Assessment | |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of posterior distributions | |
| Assessment Dates | Latest assessment: 2020 | Next assessment: 2022 |
| Overall assessment quality rank | 1 – High Quality | |
| Main data inputs (rank) | - Four short time series of biomass indices from research trawl surveys | 1 – High Quality |
| | - Acoustic indices from research surveys of spawning plumes (Old plume, Rekohu plume, Crack) | 1 – High Quality |
| | - Age frequencies from the spawning plumes in 2012, 2013, and 2016 | 1 – High Quality |
| | - Length frequencies from commercial fisheries | 1 – High Quality |
| Data not used (rank) | - CPUE | 3 – Low Quality: unlikely to be indexing stock-wide abundance |
| | - Acoustic surveys of hills (hull-mounted transducers) | 3 – Low Quality: major species identification and dead zone issues |
| | - Wide-area acoustic survey estimates | 2 – Medium or Mixed Quality: large potential bias due to mixed-species |
| | - Chatham Rise deepwater trawl survey stations (2010–2020) | 2 – Medium or Mixed Quality: variable indices |
| Changes to Model Structure and Assumptions | None | |
| Major Sources of Uncertainty | - The largest source of uncertainty is the proportion of the ESCR spawning stock that is indexed by the acoustic survey in each year.<br>- Stock status is dependent on the timing of the appearance of the Rekohu spawning plume, which is unknown.<br>- Patterns in year class strengths are based on only 3 years of age composition data. | |

| Qualifying Comments |
|---|
| - Estimates of stock biomass are sensitive to the means of the *q* priors.<br>- Lack of fit to the 2016 acoustic biomass estimate. |

| Fishery Interactions |
|---|
| Main bycatch species are smooth oreo, black oreo, deepwater dogfish, hoki, and rattails, with lesser bycatches of slickhead, Johnson's cod, and morids. Low productivity bycatch species include deepwater sharks and dogfish and also corals. Observed incidental captures of protected species include corals, low numbers of seabirds, and occasional New Zealand fur seals. Orange roughy are caught using bottom trawl gear. Bottom trawling interacts with benthic habitats. |

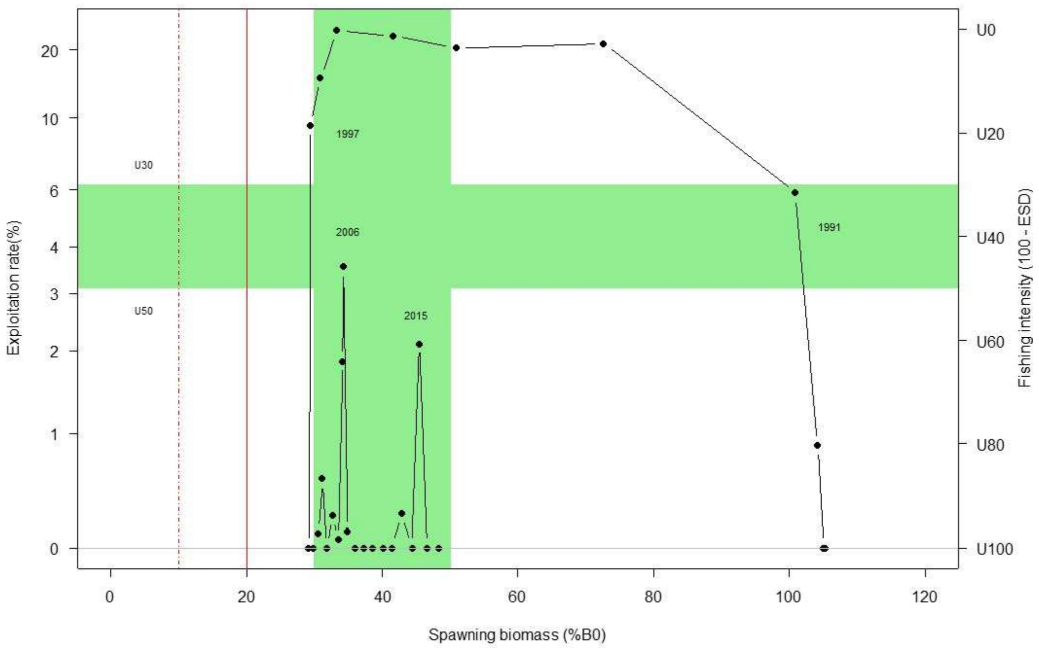
- **5.2 Southern ORH 3B fisheries**

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% $B_0$<br>Soft Limit: 20% $B_0$<br>Hard Limit: 10% $B_0$<br>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)<br>- Trawl survey indices and length frequencies (1992, 1994)<br>- Age frequencies (1992, 2015)<br>- 2 years of length frequency data | 1 – High Quality<br><br>1 – High Quality<br>1 – High Quality<br>1 – High Quality |
| Data not used (rank) | - CPUE<br><br>- Winter trawl surveys (1991, 1992, 2006)<br><br>- Acoustic survey estimates (2005, 2006)<br><br>- Additional commercial length frequencies | 3 – Low Quality: unlikely to be indexing stock-wide abundance<br>2 – Medium or Mixed Quality: unlikely to be indexing stock-wide abundance<br>2 – Medium or Mixed Quality: large potential bias due to mixed species<br>2 – Medium or Mixed Quality: not enough months sampled within each year |

| | |
|---|---|
| Changes to Model Structure and Assumptions | - The previous assessment was in 1998.<br>- Model now based on spawning biomass rather than transition-zone mature biomass.<br>- Age data included to enable estimation of year class strengths rather than assuming deterministic recruitment.<br>- Trawl survey indices better modelled to allow for difference in timing<br>- 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.<br>- The single acoustic estimate is the only recent biomass index.<br>- 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.

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