



Fisheries New Zealand

Tini a Tangaroa

Orange roughy fisheries on Chatham Rise and Campbell Plateau (ORH 3B)

New Zealand Fisheries Assessment Report 2018/52

M.R. Dunn

ISSN 1179-5352 (online)

ISBN 978-1-98-857127-0 (online)

November 2018



Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
<http://www.mpi.govt.nz/news-and-resources/publications>
<http://fs.fish.govt.nz> go to Document library/Research reports

© Crown Copyright – Fisheries New Zealand

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
1. INTRODUCTION	2
2. DESCRIPTION OF THE FISHERY	3
2.1 Catch and Effort data sources and methods	3
2.2 Data grooming	5
2.3 Description of the ORH 3B fishery	5
3. OBSERVER DATA	32
4. DISCUSSION	53
5. ACKNOWLEDGMENTS	54
6. REFERENCES	54

EXECUTIVE SUMMARY

Dunn, M.R. (2018). Orange roughy fisheries on Chatham Rise and Campbell Plateau (ORH 3B).

New Zealand Fisheries Assessment Report 2018/52. 54 p.

This report updates descriptive analyses of commercial catch and effort data for the orange roughy fishery on Chatham Rise and Campbell Plateau (sub-Antarctic) (ORH 3B), using data to the end of the 2015–16 fishing year. Data are summarised back to the start of most of the fisheries, and are analysed in detail for the most recent fishing years. This report also analyses samples of orange roughy catch composition for Chatham Rise provided by the Ministry for Primary Industries Observer Programme.

No substantive new areas have been developed on the Northwest Chatham Rise. On the East & South Chatham Rise, a new non-spawning fishery in the Spawning Box has developed. Most of the subareas of the sub-Antarctic fishery have been abandoned in recent years, with the fishery becoming focused solely around the Auckland Islands. There were some recent changes to the seasonality of the fisheries. The fishery on the East & South Chatham Rise has recently experienced a gap in fishing between about March and June, whereas the fishery on the Northwest Chatham Rise has extended to operate all year. Unstandardised catch rates in several areas have a similar pattern, and were relatively high between about 2008–09 and 2014–15, but then declined in 2015–16.

Substantial data on catch composition were collected by Ministry for Primary Industries observers. The mean length of orange roughy in catches was highly variable between locations, and between years. The smallest fish were caught on flat grounds of the Northwest Chatham Rise, and the largest on hill and other areas of the East & South Chatham Rise. Spawning fish were sampled at numerous locations throughout Chatham Rise, with simultaneous spawning in late June and early July. The sex ratio favoured males in spawning locations on the northern Chatham Rise, and favoured females on parts of the east and south Chatham Rise.

1. INTRODUCTION

The New Zealand orange roughy Quota Management Area 3B (ORH 3B) includes Chatham Rise, the Campbell Plateau (sub-Antarctic), and the lower part of the South Island (Figure 1).

The work described in this report was carried out under Ministry for Primary Industries project DEE2016/21 Specific Objective 1, “*To carry out a descriptive analysis of the commercial catch and effort data, survey data, and observer data for orange roughy on the Northwest Chatham Rise and East & South Chatham Rise*”. The survey data are not described in this report, but appear in the separate report of the stock assessment for Specific Objective 2, “*To carry out stock assessments of the Northwest Chatham Rise and East & South Chatham Rise*”.

This report updates the descriptive analysis of the fishery to the end of the 2015–16 fishing year (New Zealand fishing years start 1 October), and updates the descriptive analysis of catch and effort data, last reported by Anderson & Dunn (2012) up to the end of the 2008–09 fishing year. The management of the ORH 3B fishery is described by Ministry for Primary Industries (2016).

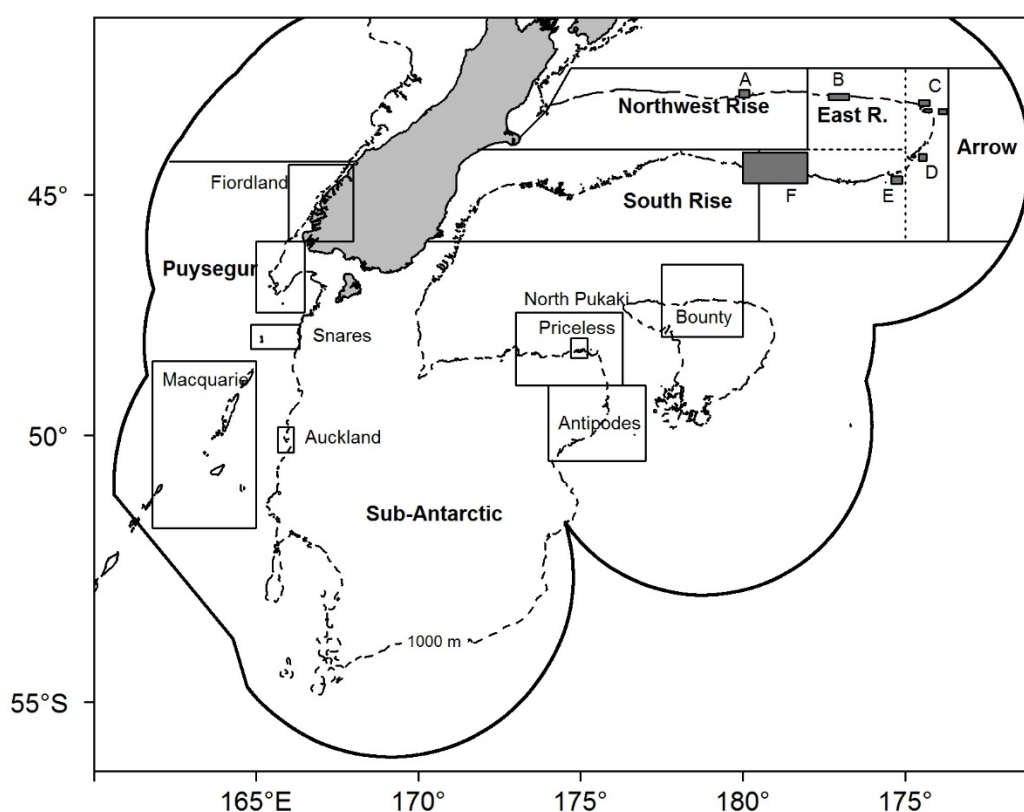


Figure 1: The ORH 3B fishery area. The recognised stocks are indicated by bold text. The rectangles mark the main fishing grounds, with those on Chatham Rise shaded: A, Graveyard (180) hills; B, Spawning Box; C, northeast hills; D, Andes; E, Chiefs; F, south Rise (Mt. Kiso & Hegerville).

2. DESCRIPTION OF THE FISHERY

2.1 Catch and Effort data sources and methods

Estimated catch and effort data for the orange roughy fishery have mostly been recorded on either Trawl Catch Effort Processing Return (TCEPR) or Catch, Effort and Landing Return (CELR) forms. The TCEPR forms give tow-by-tow information, with location and estimated catch for each trawl. The CELR forms provided daily estimated catch records with effort as the number and total duration of tows in the day. CELR forms have mostly been used by smaller inshore vessels. Larger deepwater vessels (over 28 m in length) are required to complete TCEPR forms. There are also “high-seas” versions of both form types for use by vessels fishing outside the New Zealand EEZ. A new form, the Trawl Catch Effort Return (TCER), was introduced on 1 October 2007 and records similar catch and effort data to the TCEPR forms, and effectively replaces the CELR forms previously used. Up-to-date data from each form type until the end of the 2015–16 fishing year were requested from the Ministry for Primary Industries catch-effort database. TCEPR/TCER data were combined with data from previous extracts to provide a full tow-by-tow data for the entire history of the fishery. CELR data were stored in a spreadsheet file. This report focuses on data from the more detailed TCEPR/TCER forms. Although CELR forms were widely used in earlier years their use in most fisheries has declined over time, representing less than 10% of the total estimated catch since 1993–94, and they were not used in any orange roughy fishing after 2007–08 (Anderson & Dunn 2012).

Data were selected from all trawls where orange roughy were either the declared target species, or were caught. TCEPR/TCER data were error-checked using routines developed in the statistical software package R. Error checks were performed for recorded bottom depth, fishing depth, location, trawl speed and duration, and time of day. Missing or erroneous values were replaced with imputed average values. For example: where depth was missing it was replaced with the median depth from all other tows recorded within 1 n.mile of that tow position. Obvious errors in the recording of target species, or location (due to confusion of the western with the eastern hemisphere), were also corrected. All tows were then assigned to a QMA and fishery or subarea. Following Anderson & Dunn (2012), various subareas have been defined for descriptive analyses of the fisheries:

- **Graveyard Hills.** Also known as the 180 hills. The area of hills within the limits 179.88°E–178.80°W and 42.67–42.83° S. The 180 hills are close together, and it is therefore difficult to allocate tows to specific hills.
- **Northwest Chatham Rise flat.** The northwest Chatham Rise subarea, but excluding the Graveyard hills. Within this region is an area known as ‘the hole’, at around 176°E.
- **Spawning Box.** The area of largely flat seabed within the limits 42.17°–44° S and 178°–175° W. A number of fisheries have been described, most notably the fishery on spawning plumes in winter, and pre-spawning fisheries at the eastern and western ends of the Spawning Box (Anderson & Dunn 2012). The following subdivisions are used here:
 - **Spawning Plume.** The sub-area of the Spawning Box within the limits 42.75–42.9° S and 176.72–177.36° W, for tows fished in June, July and August.
 - **Spawning Box background.** The area within the Spawning Box but not in the Spawning Plume.
 - **Rekohu.** The Rekohu feature has not previously been described. For analyses in this report, catches and effort were selected between 177.65–178° W, and 42.6–43°S.
- **Smith’s City & neighbours.** This area contains the fishing hills Smith’s City, Camerons, and Erebus, and is defined as the area inside three boxes having the limits: 174.25–174.59°W and 43.02–42.89°S; 173.70–173.98°W and 43.09–43.22°S; 174.18–174.41°W and 43.10–43.17°S.

- **Eastern Flats.** The area is the East Chatham Rise excluding the Spawning Box, Smith's City & neighbours, and Andes. The area includes a number of specific fisheries, notably the hill fisheries Not Till Sunday and Kenwood, and the Middle-ground fishery (Anderson & Dunn 2012). The following subdivisions are used here:
 - **Kenwood.** The area around the hills known as Kenwood, Harrisville, and Dickman, to the north and west of the Andes, within the limits 174.44–174.70°W and 43.88–44.02°S.
 - **Middle ground.** The area to the west and south of the Andes within the limits 174.6–175°W and 44.35–44.63°S.
- **Andes.** The area of hills within the limits 174.33–174.58°W and 44.1–44.25° S. Hills in the Andes complex are close together, and it is difficult to allocate tows to specific hills.
- **Big Chief & neighbours.** The area of hills within the limits 175.08–175.42°W and 44.58–44.75° S. Hills in the Chiefs area are close together, and it is difficult to allocate tows to specific hills.
- **Hegerville & surrounds.** The Hegerville hill and surrounding area within the limits 180°–178°W and 43.74–46.00° S.
- **Antipodes.** An area of small seamounts (e.g., Barbaras, Bob's Knob) within the boundary of 49° 00' – 50° 30' S and 174° 00' – 177° 00' E. Although the fishery has been termed "Antipodes" by the fishing industry, the position of the fishery is on the eastern margin of the Pukaki Rise.
- **North Pukaki.** An area of the northern edge of the Pukaki Rise, within the boundary of 47° 30' – 49° S and 173° – 176° 18' E, but not including the area known as Priceless.
- **Priceless.** An area within North Pukaki, with the boundaries 48° 5.5' – 48° 26.5' S and 174° 42' – 175° 13' E.
- **Auckland Islands.** A complex of small seamounts (e.g., Barbara Thomas, DSW, Jenny Shipley) northwest of the Auckland Islands within the boundary of 49° 50' – 50° 20' S and 165° 40' – 166° 10' E.
- **Bounty Platform.** An area of undulating bottom with numerous peaks and drop-offs on the slopes north of the Bounty Islands within the boundary of 46° 30' – 48° 00' S and 177° 30' E – 180° 00'. It has mainly been a target oreo fishery, with the occasional large catch of orange roughy.
- **Macquarie Ridge.** A long ridge southwest of Puysegur Bank lying south of 48° 30' S and west of 165° 00' E. Macquarie Ridge is mainly an oreo fishery.
- **Snares.** A large elongated seamount (Bob's Gun) off the Snares Islands with two smaller features to the west, lying within the boundaries of 47° 45' – 48° 15' S and 164° 50' – 166° 20' E. Snares has been mainly an oreo fishery.
- **Fiordland.** An area of the west coast of the South Island, lying between the boundaries 44° 20' – 46° S and 166° – 168° E.
- **Puysegur Box.** An area of small hills (e.g., Goomzy, Godiva, Malcolm's Monument, Acne) and drop-offs (e.g., Alistair's) within the boundary of 46° 00' – 47° 30' S and 165° 00' – 166° 30' E.
- **Arrow.** A small plateau to the northeast of the Chatham Rise, lying between latitudes 42° 10' S and 46° S and bounded in the west at 173° 40' W and in the east by the perimeter of the EEZ.

To estimate the catch history used in stock assessments, the official annual catch statistics were pro-rated between areas using the estimated catch data. The assessment of the Northwest Chatham Rise assumes only one fishery (Graveyard plus Northwest Chatham Rise flat), whereas that for the East & South Chatham Rise required the catch to be pro-rated between four fisheries; the Spawning Box and Eastern Flats; Northeast Hills (Smith's City & neighbours); Andes; and South Chatham Rise (Big Chief & neighbours plus Hegerville & surrounds).

2.2 Data grooming

The orange roughy catch and effort data (all data to the end of 2015–16) were groomed simultaneously for this project and for another study, the descriptive analyses of orange roughy fisheries around the northern North Island (Dunn, 2017). The impact of grooming is therefore the same as reported in Dunn (2017). Data grooming had only a small effect on the data set, with 4% of the data groomed for tow location, and less than 1% groomed for depth, tow speed, and tow distance. Tows in the data set were centred around 900 m depth, a speed of 3 knots (5.6 km h⁻¹), a length of 2.6 km or just over half an hour, an average of 6.5 km from a seamount summit, and spread evenly throughout the day and night.

2.3 Description of the ORH 3B fishery

The official boundary to the Northwest Chatham Rise passes through the fishery at the western edge of the Mernoo Gap (Figure 2). Revising the boundary location, such that the catches on the boundary were assigned with their nearest neighbours, meant that these catches were excluded from the Northwest Chatham Rise stock and allocated to the Mid-East Coast stock.

There has generally been good agreement between pro-rated estimated catches, and those analysed and supplied by MPI (T. Bock, MPI, pers. comm.); in recent years less than 5% difference (Table 1). Although there is inconsistency between the catches from this report and Ministry for Primary Industries (2016) in the earlier years (pre-1990 in particular), the catch totals were very similar (within 3% for 1979–80 to 1988–89), and therefore these alternative catch histories would be likely to make little difference in the stock assessment. Annual catches for both stocks both peaked in the 1980s, and then declined to a low point around 2010–11 to 2012–13.

McMillan & Clark (2015) reviewed catch data for the early years of the ORH 3B fishery (1979–80 to 1985–86 inclusive), and noted that totals for 1987–88 and 1988–89 were much lower than reported by Ministry for Primary Industries (2016), and much lower than data held in the NIWA database *DW_CDB* (this database contains previously groomed historical data, and also includes some catch and effort records believed to be missing from the MPI database). McMillan & Clark (2015) could not resolve which dataset was “best”, or find any detailed documentation of how the early catch history was calculated (despite talking to people involved in the analyses at the time). McMillan & Clark (2015) also noted that some Soviet catches of orange roughy during the 1970s were possible (perhaps a few thousand tonnes).

The main fishing areas of the Chatham Rise, with trawl positions and catch sizes, are shown in Figure 3. No new substantial fishing areas have been developed since the last characterisation (2008–09). The last two fishing years saw more catches on the non-hill parts of the Northwest Chatham Rise. Areas of the northeast Chatham Rise to the east of the main spawning plumes were fished in 2015–16, for the first time since 2009–10. The sub-Antarctic fishery has been largely abandoned, except for the western regions (Snarres, Macquarie Ridge, and Auckland Islands).

Figure 4 shows the seasonal pattern of catch and effort for the main fishery regions. On the East Chatham Rise (Spawning Box and Eastern Flats), the catches have historically been taken steadily through the year, but the last three fishing years saw a break in fishing between early March and the end of June. In 2014–15, about 70% of the catch was taken during the spawning season (from late June), but this decreased to around 30% in 2015–16.

On the South Chatham Rise, the fishery used to extend throughout the year until the start of the spawning season on the north rise (June), but in the last three years the catches were completed by April.

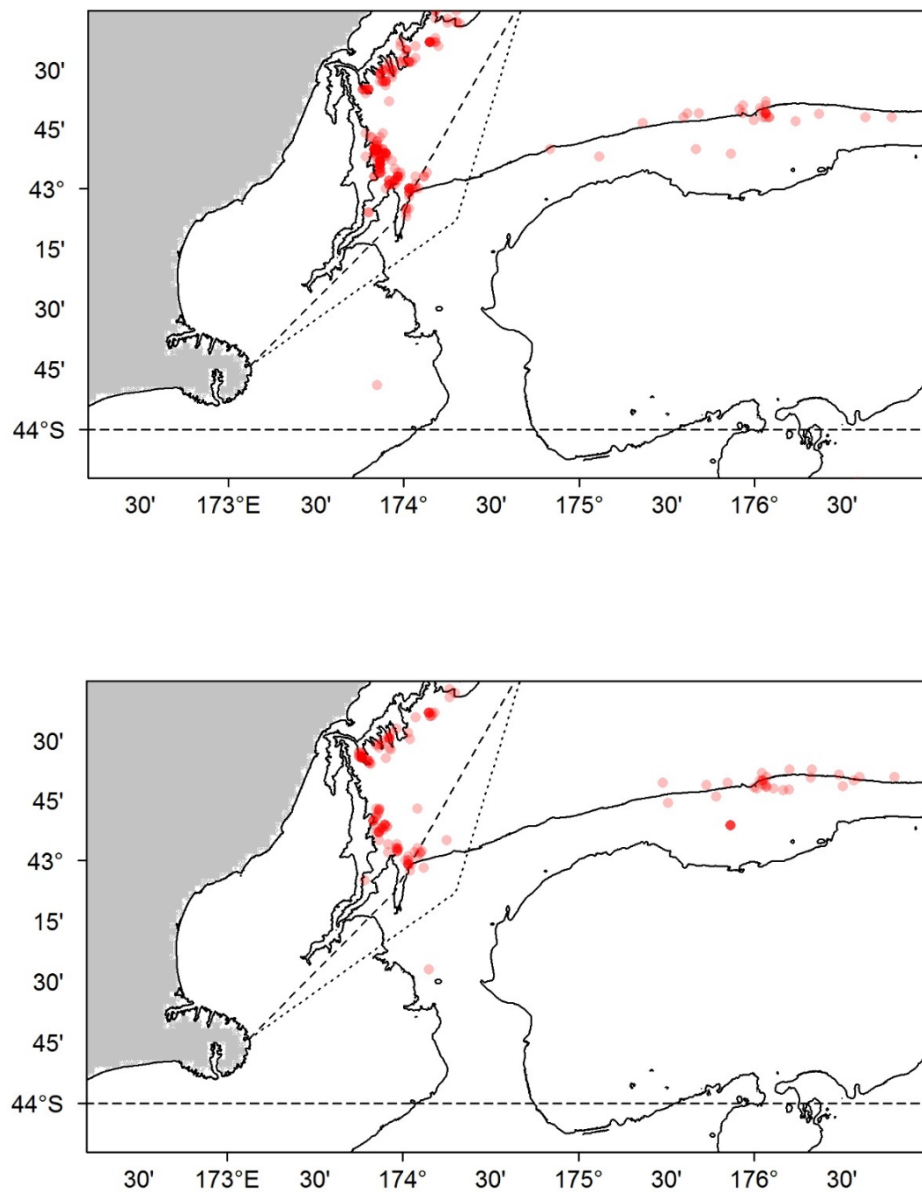


Figure 2: Location of non-zero catches of orange roughy (red dots; dots are transparent so a darker red colour indicates more points) in the Northwest Chatham Rise – Mid East Coast stock boundary region. Dashed line, the official stock boundary (Clement & Associates Ltd., 2015); dotted line, the revised boundary (inflection point moved from 173.95° to 174.3°W). Example years shown are upper panel, 2013–14; lower panel, 2014–15. Solid lines, the 500 m and 1000 m isobaths.

Table 1: Estimates of orange roughy catch (t) for the East and South Chatham Rise, and Northwest Chatham Rise, stock regions. MPI¹, Ministry for Primary Industries “industry reported” (MHR) estimates, with noted research catches in square parentheses (T. Bock, MPI, pers. comm.). MPI (2016) are those used in historical stock assessment, where they are then inflated by the assumed catch over-runs. Estimates from “this report” are reported catch for ORH 3B (MPI, 2016) scaled to subarea using groomed tow-by-tow trawl estimated catch data. Fishing years only consistent from 1984–85 onwards (MPI, 2016).

Fishing year	East & South Chatham Rise			Northwest Chatham Rise			Assumed over-runs (%)
	MPI ¹ [Research]	MPI (2016)	This report	MPI ¹ [Research]	MPI (2016)	This Report	
1978–79	–	11 800	–	–	0	0	30
1979–80	–	29 900	11 300	–	1 200	500	30
1980–81	–	19 800	21 921	–	8 400	9 179	30
1981–82	–	17 900	20 123	–	7 000	8 065	30
1982–83	–	10 000	21 836	–	5 400	10 761	30
1983–84	–	21 600	28 750	–	3 300	3 780	30
1984–85	–	27 400	27 559	–	1 800	1 781	30
1985–86	–	26 400	26 553	–	3 700	3 519	28
1986–87	–	27 500	27 758	–	3 200	2 931	26
1987–88	–	22 600	22 697	–	1 600	1 517	24
1988–89	–	29 000	29 125	–	3 800	3 615	22
1989–90	–	28 300	28 200	–	3 300	3 249	20
1990–91	–	19 100	19 127	–	1 500	1 486	15
1991–92	–	15 200	15 788	–	300	271	10
1992–93	–	10 200	10 195	–	3 800	3 833	10
1993–94	–	10 000	10 222	–	3 500	3 732	10
1994–95	–	5 600	6 085	–	2 400	2 591	5
1995–96	–	5 100	5 089	–	2 400	2 430	5
1996–97	–	5 000	5 210	–	2 200	2 345	5
1997–98	–	6 300	6 008	–	2 300	2 320	5
1998–99	–	4 800	5 306	–	2 700	2 910	5
1999–00	–	5 700	6 024	–	2 100	2 144	5
2000–01	–	5 200	5 332	–	2 600	2 549	5
2001–02	–	7 800	8 027	–	2 200	2 057	5
2002–03	–	8 600	8 803	–	2 200	2 347	5
2003–04	–	8 300	8 374	–	2 000	2 040	5
2004–05	–	8 800	8 805	–	1 600	1 600	5
2005–06	–	9 100	9 152	–	1 400	1 393	5
2006–07	–	9 100	9 079	–	700	743	5
2007–08	–	7 800	7 991	–	800	650	5
2008–09	–	6 720	6 882	–	750	560	5
2009–10	–	5 320	5 384	–	720	671	5
2010–11	3 072 [96]	3 060	3 105	38 [–]	40	33	5
2011–12	2 597 [259]	2 590	2 611	65 [–]	70	74	5
2012–13	2 355 [326]	2 330	2 335	109 [–]	110	110	5
2013–14	3 185 [–]	–	3 197	801 [–]	–	752	5
2014–15	3 269 [–]	–	3 306	824 [–]	–	795	5
2015–16	3 368 [–]	–	3 398	702 [–]	–	714	5

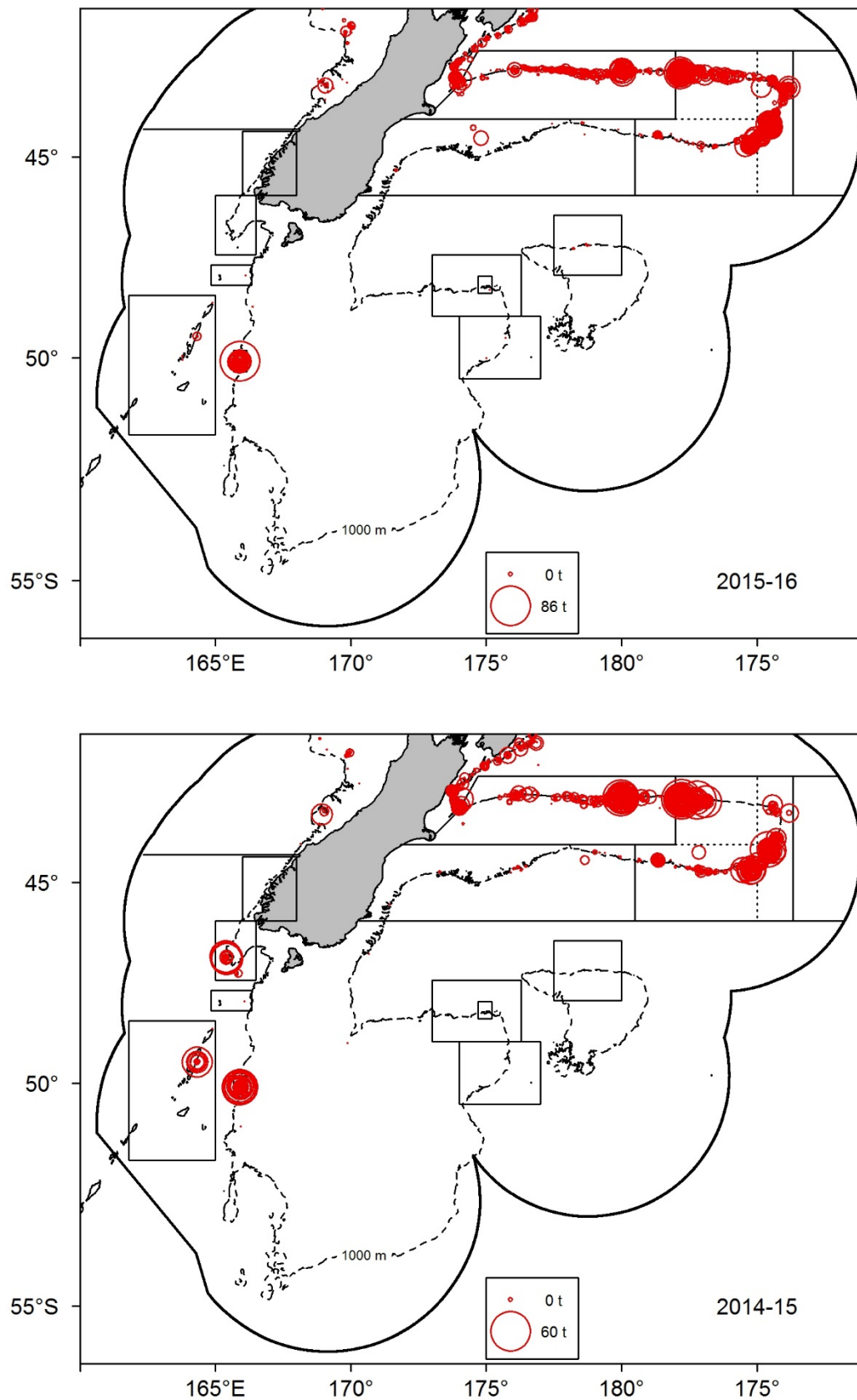


Figure 3: Distribution of trawls and orange roughy catch rate (t/tow) by fishing year. Circle area proportional to catch rate. Rectangles show the descriptive report fishery subareas.

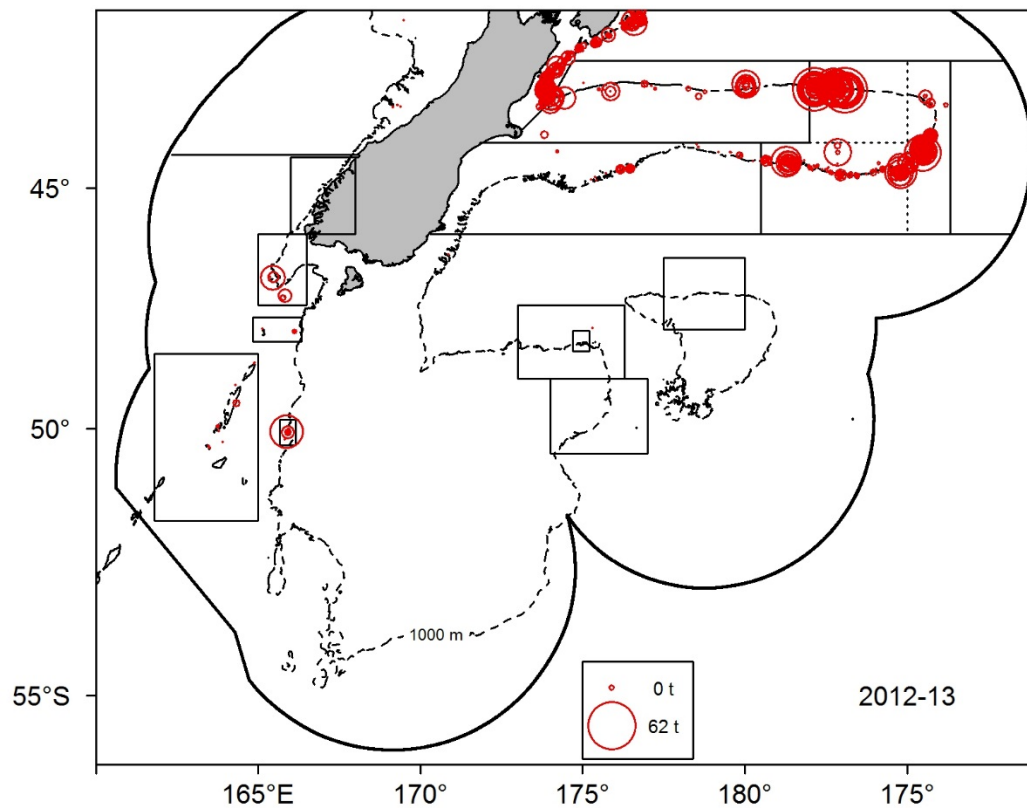
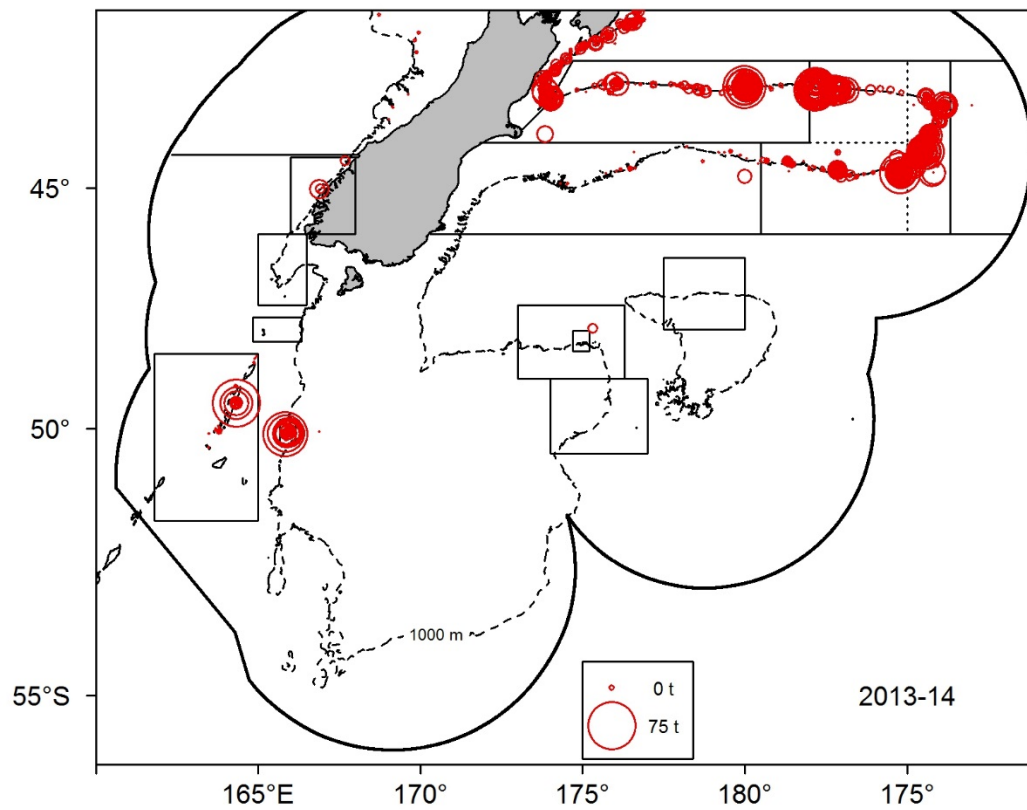


Figure 3 (cont.): Distribution of trawls and orange roughy catch rate (t/tow) by fishing year. Circle area proportional to catch rate. Rectangles show the descriptive report fishery subareas.

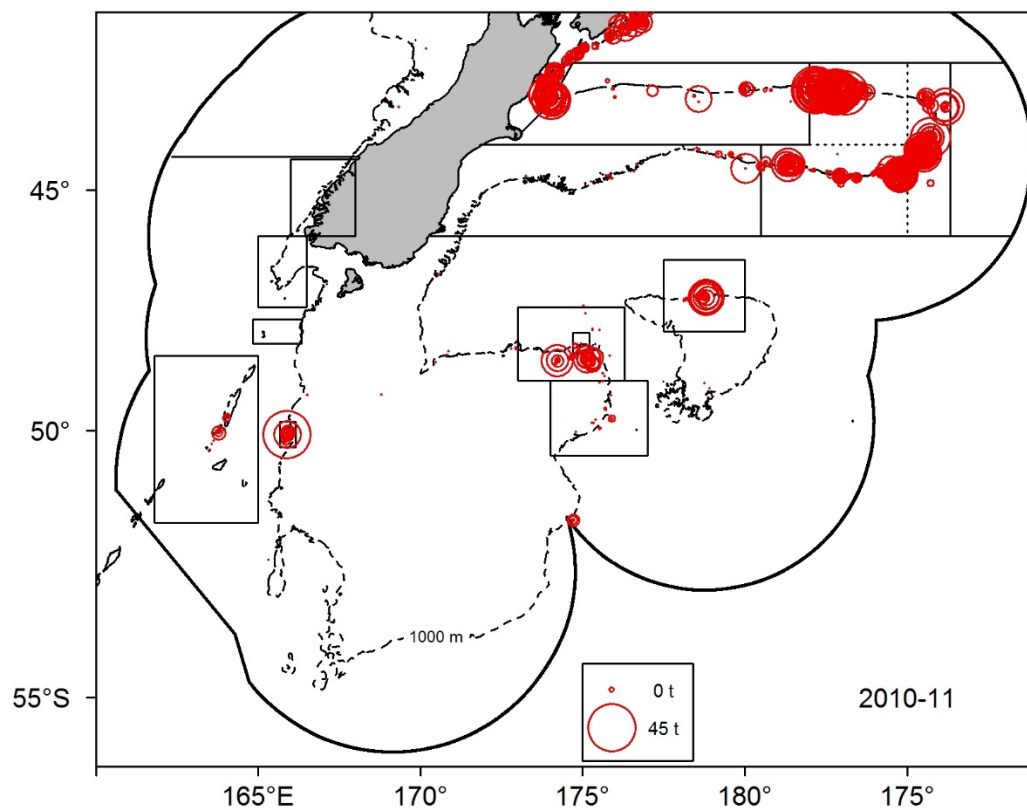
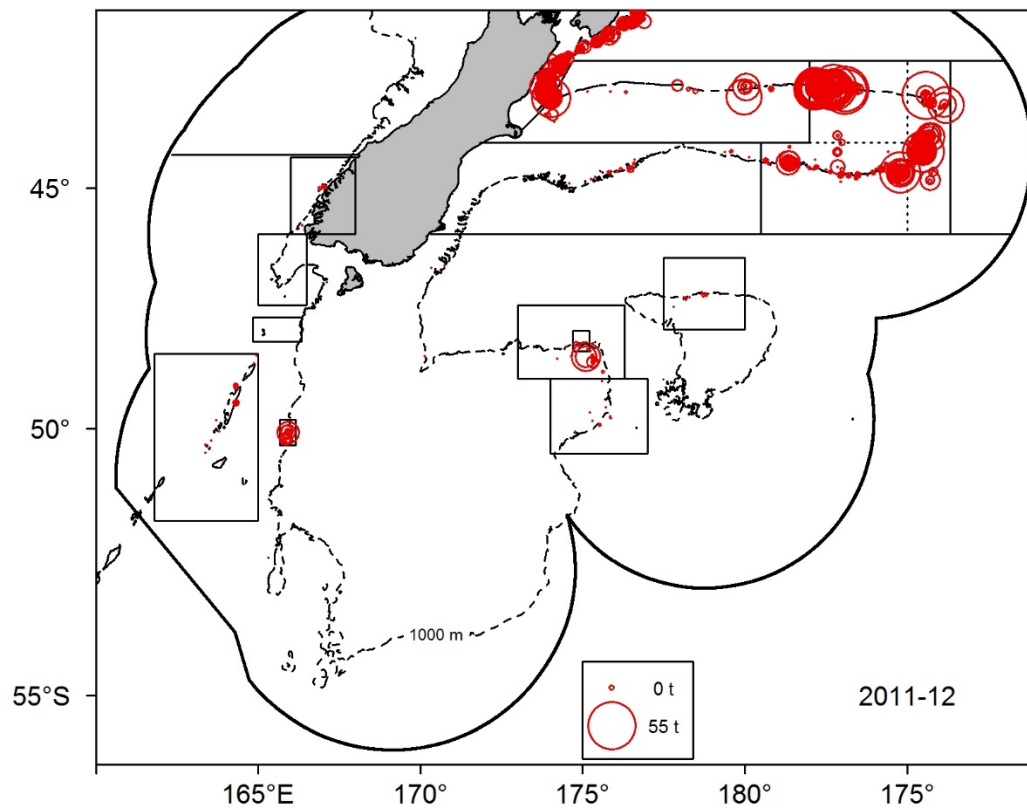


Figure 3 (cont.): Distribution of trawls and orange roughy catch rate (t/tow) by fishing year. Circle area proportional to catch rate. Rectangles show the descriptive report fishery subareas.

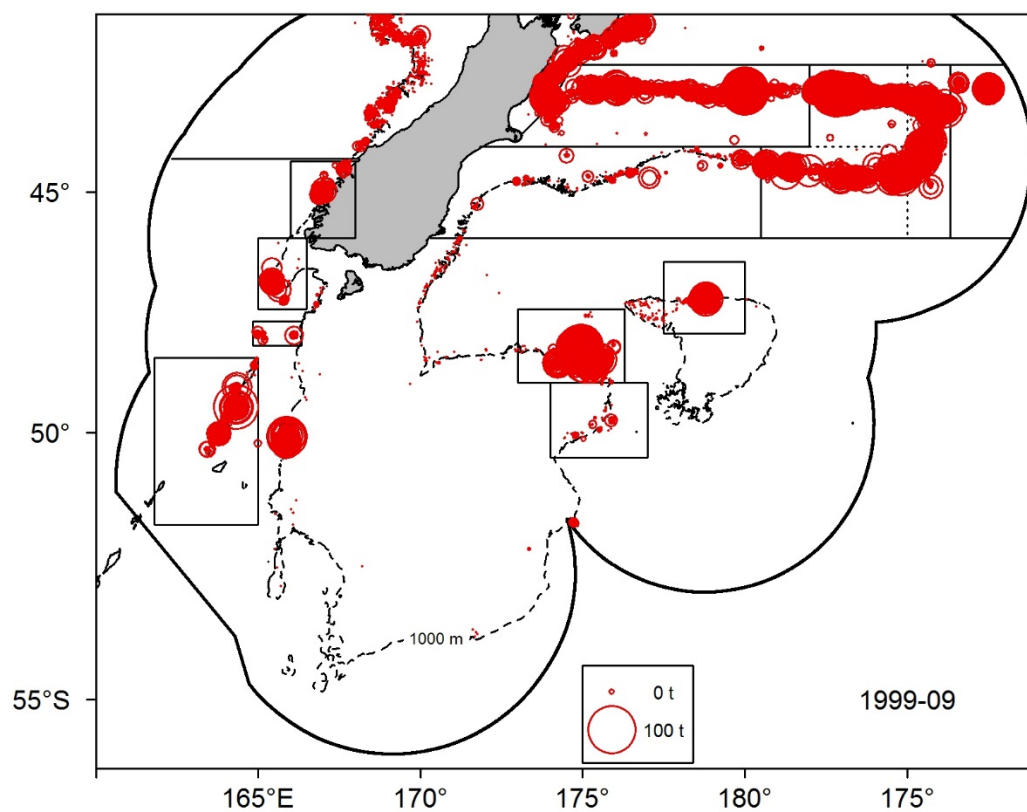
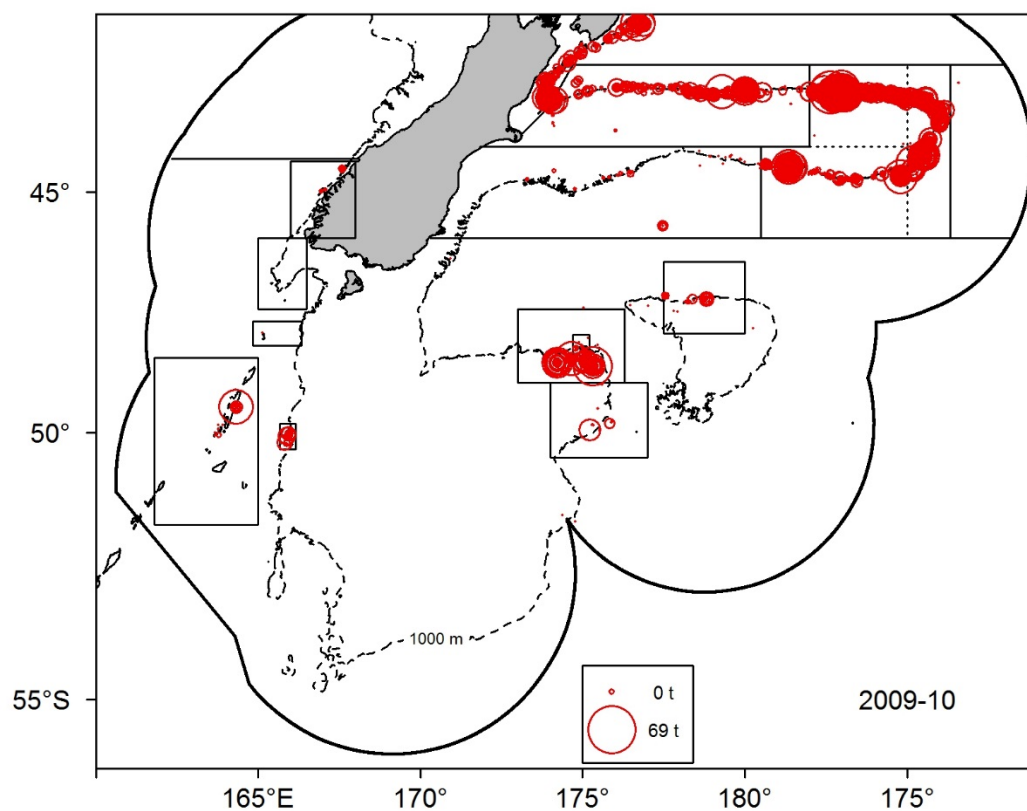


Figure 3 (cont.): Distribution of trawls and orange roughy catch rate (t/tow) by fishing year. Circle area proportional to catch rate. Rectangles show the descriptive report fishery subareas.

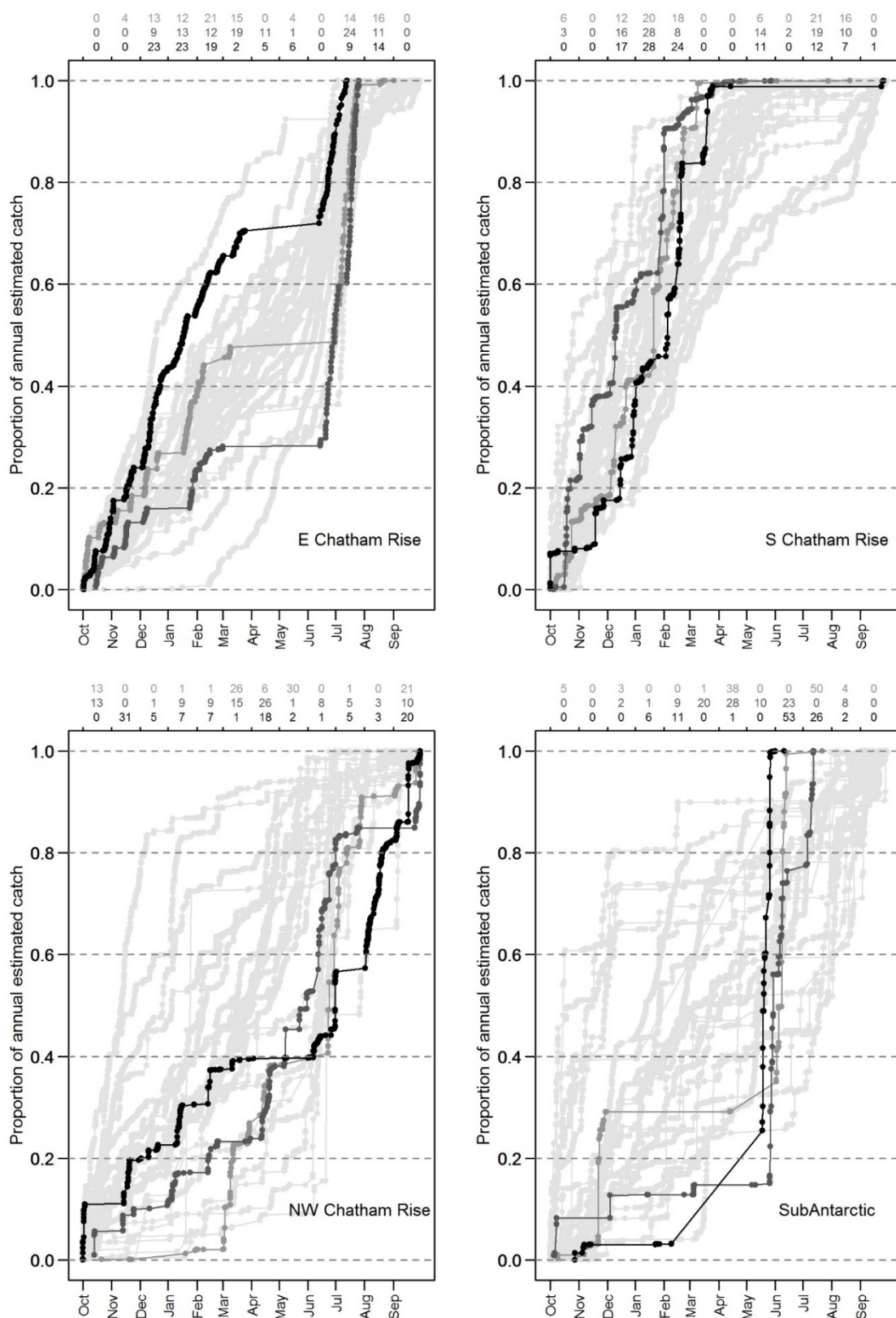


Figure 4: Cumulative catches and effort in ORH 3B. Catches are summed in chronological order through the fishing year, and scaled to the total estimated catch for the year. Each point represents the relative accumulated catch after the addition of the catch from each new trawl. The 2013–14, 2014–15, and 2015–16 fishing years are shown individually in grey, dark grey, and black, respectively. The percentage of trawls by month is shown above each panel, using the same shading to represent years. Cumulative catches for all previous years are shown in light grey.

On the Northwest Chatham Rise, catches have been made throughout the year during the last three years, in contrast to the period detailed by the last characterisation (2006–07 to 2008–09) when about 70% (or more) of the catch was taken during spawning (June) (Figure 4).

In the sub-Antarctic, the timing of the fishery has been variable as the focus of the fishery has moved between subareas (Figure 4). In last three years, most of the catch was taken over a relatively short period during June. Catches before then were sporadic, often with a gap of a month or more between catches.

The seasonal patterns of fishing are shown for Chatham Rise subareas in Figure 5. For the Graveyard (180 Hills), although in some earlier years more than 90% of the catch was taken during the spawning season (May to July), this has not been the case in recent years. During the last three years, as much as 50% of the catch from Graveyard was made before May, and up to 30% after July.

Most historical catches at Rekohu have been made just before and during spawning (May–July). Between 1980–81 and 1995–96, the greatest catches were during May–July, although catches were only a few tens of tonnes (maximum 60 t) suggesting that spawning fish were present in the area but a substantial plume was not fished (see also Table 3). Between 2003–04 and 2009–10, catches from Rekohu were much larger, and although a few catches continued to be made during June in all years, there was no fishing during July, and most effort and catches were outside of the spawning season. For example, in 2004–05 the greatest effort (25–36 tows month⁻¹) and catches (120–220 t month⁻¹) were taken in November and December, and April and May. Since 2011–12, the catches have been larger again, and taken almost entirely between mid-June and early-July (peak spawning). In 2015–16, some catches were also made at the start of the fishing year, although catches then (63 t) were not as good as in some years (e.g., 100 t or more were caught during October in 2005–06 and 2007–08).

Catches from the spawning box have historically been taken during the spawning season, with the large aggregations absent in this area outside of that time. The 2013–14 and 2014–15 years were typical in this respect, but 2015–16 was different, with relatively successful fishing throughout the year and about half of the catch taken between October and March. Most of this fishing took place at the eastern end of the Spawning Box, to the east of Rekohu and northwest of Mt. Muck (“the crack”), although there was also a little fishing on Mt. Muck and to the east (see Figure 3). Historically, there has never been a substantive fishery in this area at this time, suggesting that this is an attempt to develop these grounds.

On Smith’s City & neighbours, in recent years there were a few good catches relatively early in the fishing year. Fishing on Smith’s City & neighbours appeared to be rather hit and miss (a large proportion of the total annual catch taken in a few tows), as is typical for some hill fisheries. The timing of the fishery on Andes was similar to the historical pattern, with fishing starting in October, but in the last three years the fishing was complete by March, whereas earlier it had typically extended to May. A similar pattern was apparent for Big Chief & neighbours.

On the Northwest Chatham Rise, the fishery changed in the early 1990s from tows over a relatively wide area of flat grounds to tows on the 180 Hills, as seen in Figure 6 with the abrupt shift to a concentration of effort and catch into a few new areas. Since 1992–93, catch and effort has been focused on and around the 180 Hills, and since 2001–02 also at the western end of the Northwest Chatham Rise (on and around Mernoo Gap Hill). The spatial extent of the fishery was reduced when catches were reduced during 2010–11 to 2012–13, but the previous fishing pattern resumed once catches increased again from 2013–14. No new areas have been developed in recent years.

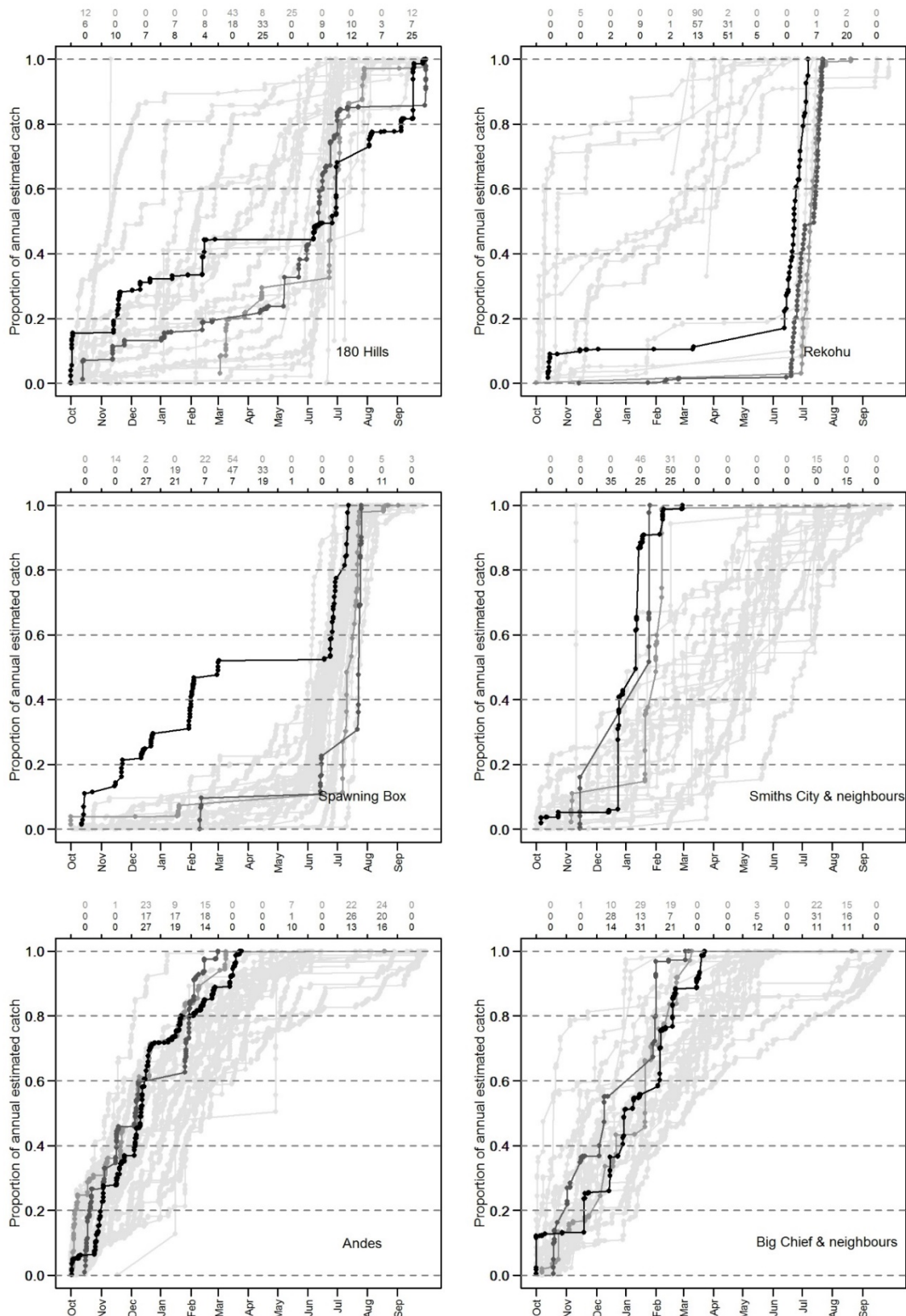


Figure 5: Cumulative catches and effort in Chatham Rise subareas. Catches are summed in chronological order through the fishing year, and scaled to the total estimated catch for the year. Each point represents the relative accumulated catch after the addition of the catch from each new trawl. The 2013–14, 2014–15, and 2015–16 fishing years are shown individually in grey, dark grey, and black, respectively. The percentage of trawls by month is shown above each panel, using the same shading to represent years. Cumulative catches for all previous years are shown in light grey.

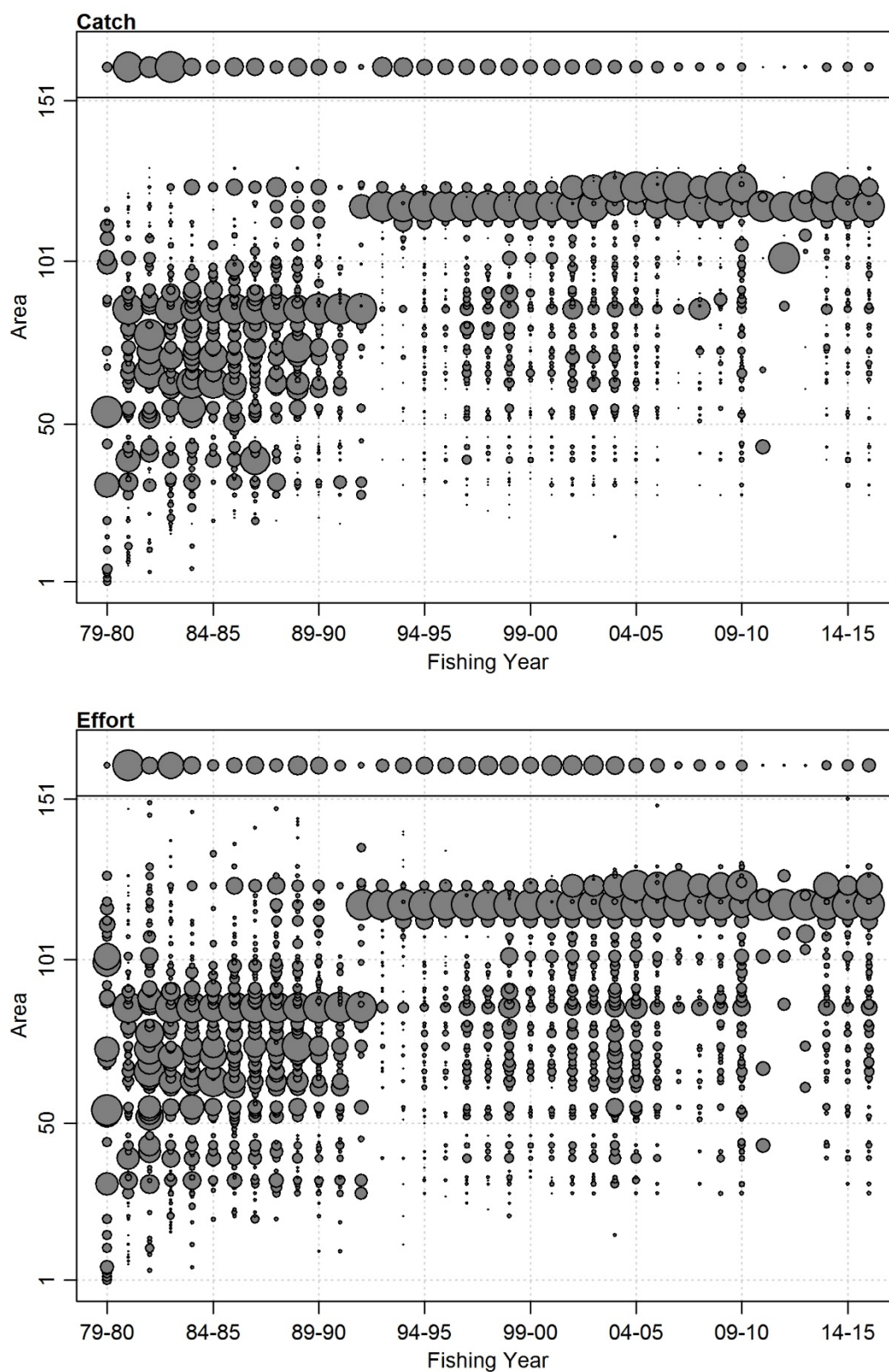


Figure 6: The distribution of orange roughy estimated catch (top panel) and effort (number of tows, bottom panel) by fishing year and area (where area is a square of 1/10th of a degree latitude and longitude) for Northwest Chatham Rise fishery. Catch and effort are proportional to circle size. The top panel in each plot shows the (relative) total catch (upper) and total effort (lower) by year. The maximum circle size in each year is set to be equal. Areas were ordered, in both plots, by the mean year in which the catch was taken.

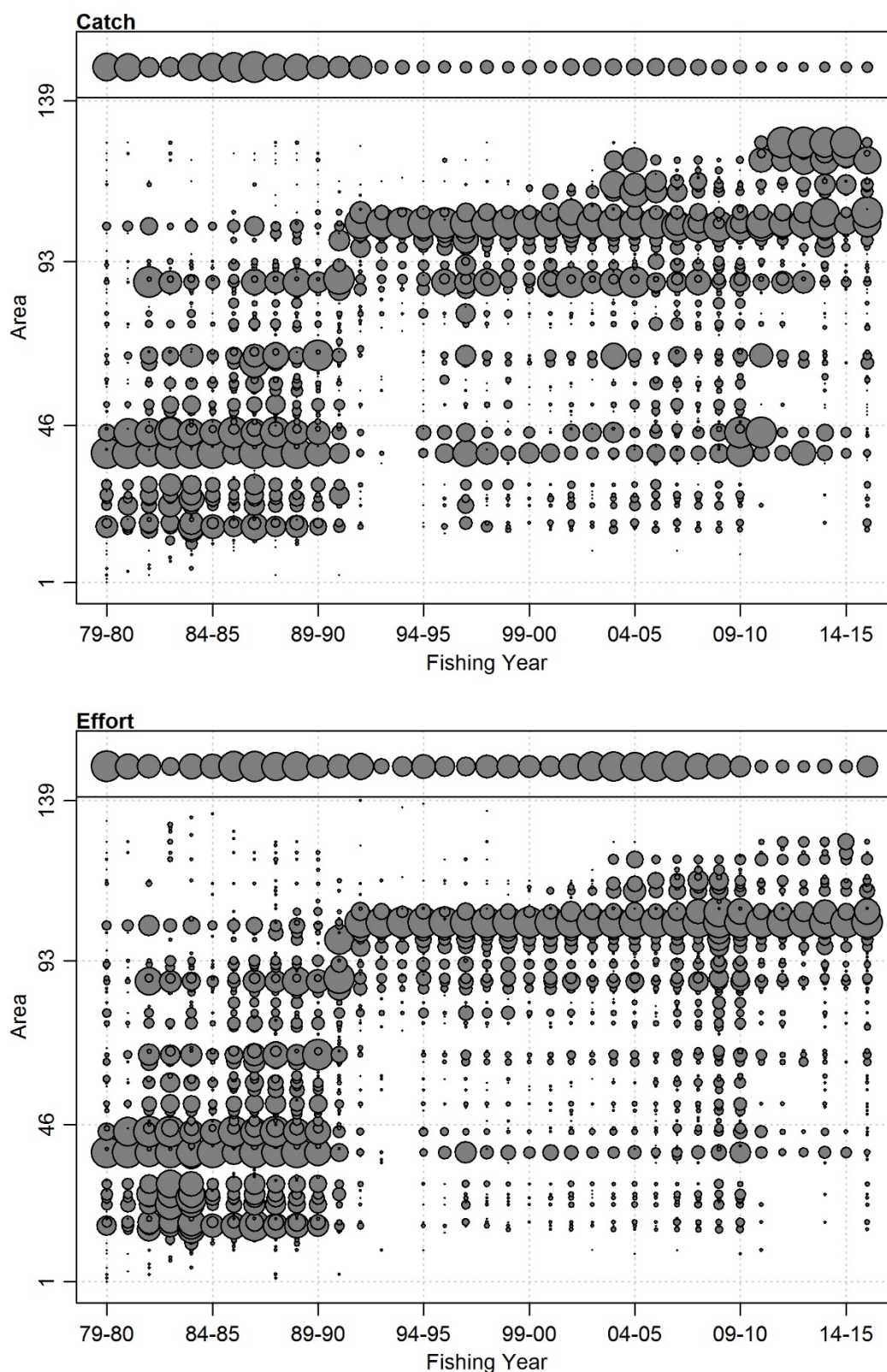


Figure 7: The distribution of orange roughy estimated catch (top panel) and effort (number of tows, bottom panel) by fishing year and area for East Chatham Rise fishery. Other details as for Figure 6.

On the East Chatham Rise, the fishery switched from predominantly fishing in the Spawning Box and eastern flats, to fishing on hill features, when the Spawning Box was closed in the early 1990s (Figure 7). The new areas added to the fishery since 2000–01 have almost entirely been associated with

the development of the fishery at and around Rekohu; the most recent substantive area added in 2010–11. The footprint was relatively broad in 2015–16, and included areas of the Spawning Box that had not been fished since 2009–10.

On the South Chatham Rise, effort was relatively high until the early 1990s. During the 1980s there was a progression of catches and effort, from east to west, but culminating in a fishery focused on the Chiefs area at the eastern end of the South Rise which has persistently dominated the fishery (Figure 8). The region to the east (Hegerville & Surrounds) was more actively fished between 2008–09 and 2014–15, and yielded good catches from 2008–09 to 2012–13. No new areas have been developed in recent years.

In the Sub-Antarctic, about one third of the areas fished (nominally targeting orange roughy) have never yielded catches of orange roughy (Figure 9). There was a steady sequential fishing of locations from the early 1990s, with large catches rarely persisting in any area for more than 4 or 5 years, and the most persistent fishery area starting in 2001–02 and lasting until 2014–15 (Priceless and north Pukaki). In 2015–16 the fishing footprint was at an historically low level, with notable fishing and catches from just one area (Auckland Islands).

On Chatham Rise, the catches, effort, and number of vessels markedly declined in the period after 2006–07, concomitant with catch quota reductions (Tables 2 and 3). Most orange roughy were caught in targeted tows, with a greater proportion as bycatch in the Sub-Antarctic, and on south and northwest Chatham Rise. Short tow duration (under 1 hour) is consistent with more hill fishing or targeting of acoustic fish marks.

The catches on the Northwest Chatham during the last three years were dominated by the 180 Hills, but effort was more evenly split between the Graveyard and the Northwest Chatham Rise Flat (Table 4). On both the Graveyard hills and the Northwest Chatham Rise Flat in 2015–16, the catch rates were relatively low, and the proportion of tows yielding large catches were at an historical low.

For many years the targeted orange roughy fishing effort on Chatham Rise has been highest within the Andes area, and this has persisted to 2015–16 (Table 4). The Andes is a complex of hills within an area of about 10 nautical square miles, within which a total of 11 102 tows were completed between 1988–89 and 2015–16. During 2007–08 and 2008–09, catches from the Andes declined dramatically (by 72%), and then remained at around this lower level until 2014–15. In 2015–16 catches increased back to a level similar to that seen in 2006–07. Catch rates increased during the period of relatively low effort and catches. Effort and catches from the Smith's City & neighbours reached an historical low in 2012–13. In 2015–16 catches and effort increased somewhat, to levels similar to 2007–08, but catch rates and the proportion of tows yielding large catches were both at historical low levels.

In recent years, effort and catch rates on the Spawning Plume declined substantially, with the proportion of tows taking large catches in 2014–15 reduced to about a third of that of 2012–13, and catches in 2015–16 less than 10% of those taken in 2012–13 (not shown in Table 4 - see caption). Catches and effort from Rekohu remained relatively high in recent years, although catch rates in 2015–16 were reduced substantially from the previous year. A broadly similar temporal pattern of catches and effort was seen for Middle Ground (just to the southwest of Andes), and the Eastern Flats. Effort and catches from Kenwood (just to the northwest of Andes), which were important during 2005–06 to 2007–08, remained at low levels (data not shown) (Anderson & Dunn, 2012). In the Spawning Box, but outside of the plume, effort and catches dropped substantially in 2010–11, then reached a low in 2013–14. Catches and effort increased in 2015–16, to a level around one third of that before 2010–11, with relatively good catch rates achieved.

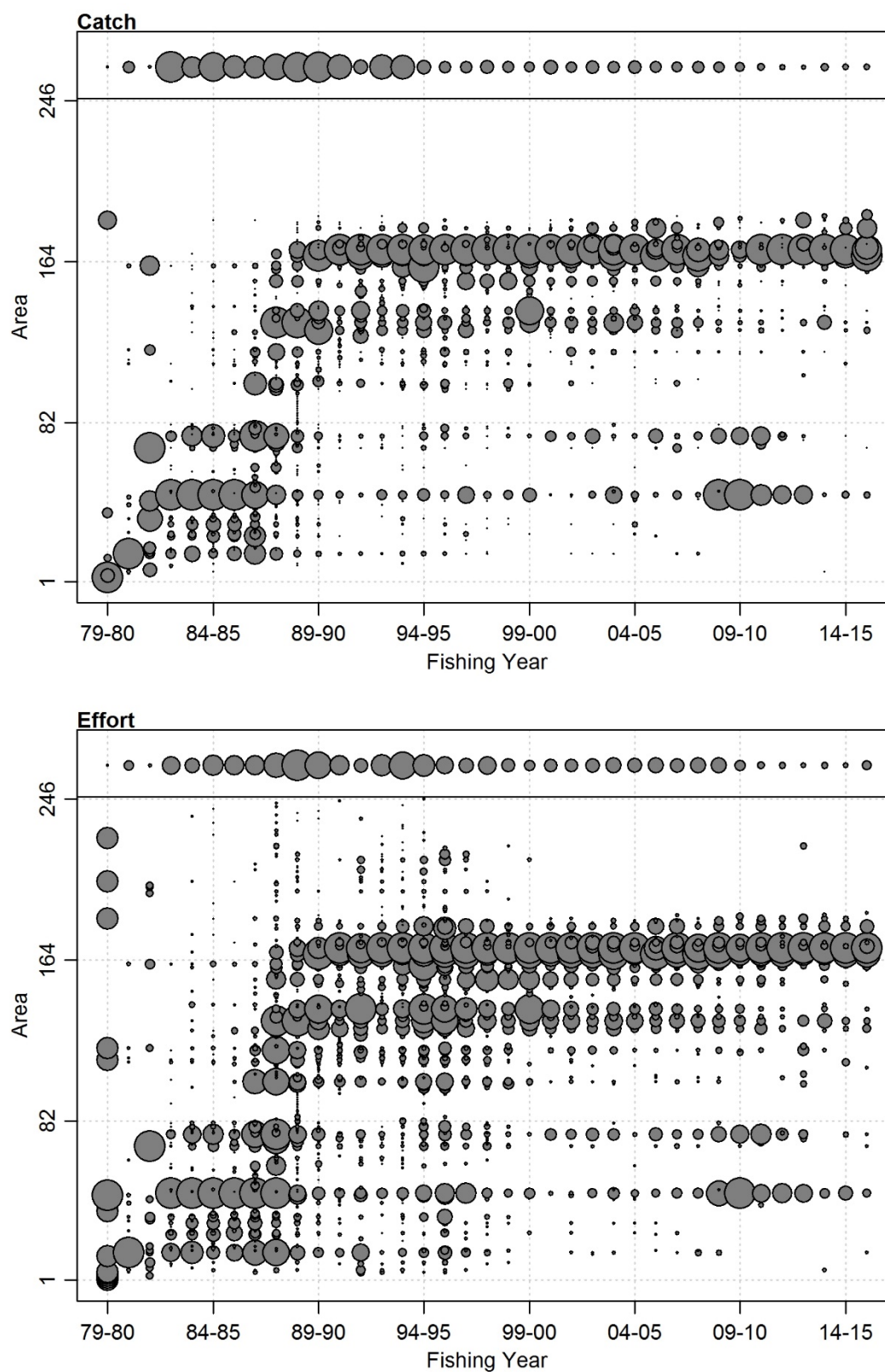


Figure 8: The distribution of orange roughy estimated catch (top panel) and effort (number of tows, bottom panel) by fishing year and area for South Chatham Rise fishery. Other details as for Figure 6.

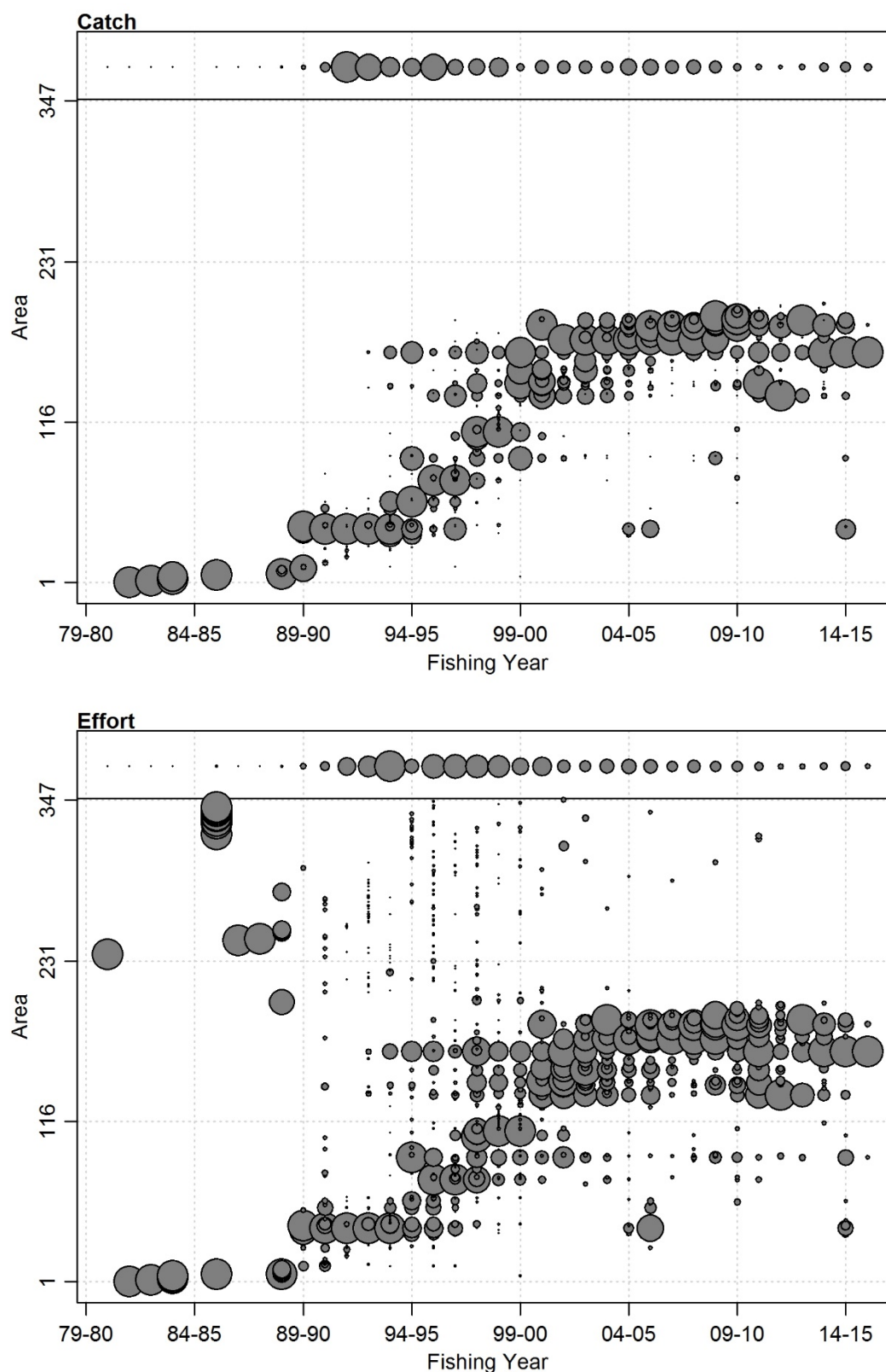


Figure 9: The distribution of orange roughy estimated catch (top panel) and effort (number of tows, bottom panel) by fishing year and area for the Sub-Antarctic fishery. Other details as for Figure 6.

Unlike most other areas of the East & South Chatham Rise, effort in Hegerville & surrounds decreased substantially in 2010–11, and then decreased further to 2015–16 (Table 4). Catches and catch rates in 2015–16 were at a historical low. For Big Chief & neighbours, fishing effort was low between 2010–

11 to 2014–15, and increased in 2015–16 to a level about half that seen in years before 2009–10. Catch rates in 2015–16 (not shown in Table 4 - see caption) were at an historical low, and the proportion of tows yielding large catches was close to the historical low.

Table 2: ORH 3B. Summary of effort, catch (t), catch rates, tow duration, and frequency of large catches for the fishing years 1979–80 to 2015–16, using tow-by-tow data. Catch rates and tow duration are calculated only for years in which there were ten or more tows. Tow duration data for 2015–16 were incomplete and statistics therefore not presented. In accordance with MPI rules, statistics are not presented when there were fewer than 3 vessels in a year.

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
Northwest Chatham Rise								
1979–80	12	100	81	864	4.16	2.23	2.00	0.34
1980–81	34	2 416	86	9 075	2.26	0.79	3.00	0.08
1981–82	20	663	95	3 976	3.69	1.21	3.00	0.19
1982–83	27	1 512	99	8 674	3.61	1.06	3.42	0.17
1983–84	20	694	95	2 885	2.68	0.72	3.50	0.09
1984–85	21	379	84	1 717	2.53	0.72	3.67	0.15
1985–86	27	622	92	3 641	2.62	0.80	3.00	0.19
1986–87	26	718	93	2 962	2.04	0.71	3.00	0.09
1987–88	24	533	76	1 544	1.37	0.47	3.00	0.06
1988–89	23	834	97	2 926	1.75	0.54	3.00	0.08
1989–90	18	735	86	2 337	1.50	0.50	3.00	0.07
1990–91	21	459	57	1 361	1.00	0.24	4.00	0.07
1991–92	15	107	79	256	1.19	0.57	1.67	0.05
1992–93	17	390	94	3 475	3.80	16.30	0.19	0.29
1993–94	23	606	95	3 347	1.17	3.80	0.23	0.17
1994–95	16	645	98	2 241	1.00	1.84	0.25	0.07
1995–96	18	586	97	2 222	0.81	1.50	0.23	0.10
1996–97	19	688	93	2 103	1.20	0.68	2.85	0.05
1997–98	22	830	95	2 230	0.72	0.67	0.83	0.05
1998–99	25	788	93	2 543	1.00	0.45	2.00	0.07
1999–00	25	744	80	2 019	0.60	0.55	0.33	0.08
2000–01	26	1 092	84	2 490	0.78	0.44	1.32	0.04
2001–02	22	939	91	2 031	0.68	0.39	2.32	0.04
2002–03	27	996	85	2 266	0.70	0.40	2.58	0.04
2003–04	22	892	80	1 952	0.80	0.24	4.00	0.04
2004–05	18	567	88	1 557	0.78	0.36	2.40	0.06
2005–06	13	448	95	1 342	0.60	0.46	0.50	0.06
2006–07	10	126	85	698	1.00	1.67	0.32	0.20
2007–08	9	307	93	711	0.60	1.09	0.30	0.05
2008–09	7	215	86	690	0.54	0.51	1.17	0.09
2009–10	8	308	91	696	0.90	0.40	2.03	0.05
2010–11	9	20	50	52	0.36	0.40	0.92	0.10
2011–12	8	26	38	68	0.27	0.31	0.28	0.08
2012–13	9	29	59	123	1.40	4.20	1.00	0.14
2013–14	13	204	95	759	0.96	1.48	0.32	0.10
2014–15	13	297	97	763	0.50	0.66	0.42	0.06
2015–16	11	441	93	672	0.50	–	–	0.02
East Chatham Rise								
1979–80	23	2 076	97	18 971	6.76	3.84	2.00	0.41
1980–81	31	1 376	99	17 478	11.39	7.87	1.50	0.61
1981–82	17	1 168	100	9 615	4.55	1.78	2.50	0.26
1982–83	16	684	100	8 916	9.61	3.60	3.00	0.48
1983–84	19	1 374	99	16 503	9.00	2.69	3.00	0.45
1984–85	20	1 307	99	17 870	10.16	3.52	3.00	0.51
1985–86	26	1 889	99	19 876	8.06	2.15	3.50	0.40

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
1986–87	23	1 967	100	22 293	6.45	1.60	3.75	0.38
1987–88	26	1 693	100	16 002	5.79	1.41	3.58	0.30
1988–89	24	1 780	100	16 030	5.88	1.75	3.58	0.31
1989–90	20	1 117	100	12 329	7.00	2.00	3.50	0.36
1990–91	18	1 186	99	11 108	5.00	6.73	0.25	0.29
1991–92	9	1 469	99	12 453	4.50	15.00	0.18	0.26
1992–93	7	516	98	4 321	4.00	18.00	0.22	0.26
1993–94	11	850	98	4 475	2.00	8.00	0.22	0.14
1994–95	11	1 239	99	3 725	1.00	3.75	0.22	0.07
1995–96	12	841	100	3 489	1.00	2.50	0.25	0.11
1996–97	10	785	99	3 388	1.00	3.39	0.23	0.11
1997–98	13	1 153	100	4 191	0.50	1.50	0.25	0.09
1998–99	14	1 159	99	3 436	1.00	2.40	0.25	0.07
1999–00	12	1 056	99	4 496	1.00	3.24	0.20	0.11
2000–01	11	887	99	3 454	1.29	4.28	0.23	0.09
2001–02	7	1 336	100	6 529	1.50	3.90	0.25	0.13
2002–03	11	1 781	100	7 074	1.00	2.80	0.27	0.11
2003–04	12	1 836	99	6 346	1.00	1.89	0.32	0.09
2004–05	13	1 712	99	6 532	1.29	1.90	0.32	0.10
2005–06	9	1 827	100	7 041	0.98	2.03	0.27	0.11
2006–07	11	1 885	100	7 048	1.00	1.50	0.32	0.09
2007–08	4	1 384	99	5 986	1.07	1.46	0.27	0.12
2008–09	6	1 314	100	5 115	1.00	1.16	0.23	0.10
2009–10	6	965	99	4 054	1.60	1.20	0.38	0.10
2010–11	5	355	100	2 370	2.00	6.27	0.32	0.20
2011–12	5	354	99	2 119	1.50	4.29	0.30	0.16
2012–13	4	304	100	1 913	2.00	6.00	0.30	0.17
2013–14	7	441	99	2 558	1.50	5.00	0.28	0.18
2014–15	4	362	98	2 768	2.40	7.26	0.33	0.25
2015–16	5	931	100	2 804	0.50	–	–	0.09

South Chatham Rise

1979–80	17	206	7	561	1.88	1.82	1.00	0.03
1980–81	23	996	26	4 194	3.16	6.02	0.50	0.08
1981–82	8	218	17	306	0.27	0.19	1.50	0.02
1982–83	18	1 027	86	8 686	6.49	5.50	1.17	0.34
1983–84	17	1 021	57	5 384	2.50	2.48	1.17	0.17
1984–85	21	1 438	77	7 449	2.77	1.87	1.42	0.17
1985–86	24	1 443	72	5 097	1.08	0.98	1.17	0.09
1986–87	27	1 521	68	4 593	0.82	0.71	1.00	0.07
1987–88	24	2 330	69	6 946	0.73	0.60	1.00	0.08
1988–89	20	2 862	89	7 536	0.46	0.45	0.85	0.07
1989–90	18	2 181	87	7 949	1.00	1.58	0.47	0.09
1990–91	18	1 337	77	6 357	1.00	3.42	0.33	0.13
1991–92	16	743	67	2 482	1.00	2.28	0.27	0.09
1992–93	16	1 349	93	4 922	1.00	4.21	0.20	0.11
1993–94	18	2 035	96	4 657	0.25	0.91	0.23	0.06
1994–95	19	1 349	94	1 538	0.04	0.04	0.28	0.02
1995–96	16	897	90	1 159	0.03	0.05	0.33	0.02
1996–97	14	709	81	1 280	0.20	0.45	0.25	0.05
1997–98	17	991	85	1 561	0.15	0.30	0.30	0.03
1998–99	20	825	59	1 196	0.20	0.42	0.33	0.03
1999–00	17	534	57	1 114	0.20	0.56	0.30	0.05
2000–01	12	636	69	1 665	0.40	1.26	0.25	0.07
2001–02	11	500	88	1 070	0.50	2.22	0.20	0.05
2002–03	16	626	83	1 401	0.50	1.80	0.21	0.05
2003–04	15	774	79	1 245	0.30	1.11	0.23	0.03

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
2004–05	11	719	78	1 535	0.48	2.00	0.23	0.05
2005–06	13	797	80	1 148	0.34	1.40	0.22	0.02
2006–07	10	702	72	1 091	0.30	1.20	0.22	0.03
2007–08	7	760	83	1 221	0.43	1.58	0.23	0.03
2008–09	4	801	81	1 074	0.20	0.78	0.23	0.03
2009–10	7	551	59	866	0.20	0.87	0.25	0.04
2010–11	7	261	50	439	0.10	0.97	0.25	0.05
2011–12	8	243	48	290	0.20	0.92	0.25	0.02
2012–13	10	274	23	293	0.11	0.60	0.25	0.03
2013–14	8	281	44	480	0.10	0.45	0.30	0.04
2014–15	11	301	25	378	0.10	0.27	0.33	0.03
2015–16	8	306	75	334	0.10	–	–	0.03
Sub-Antarctic								
1980–81	2	–	–	–	–	–	–	–
1981–82	2	–	–	–	–	–	–	–
1982–83	1	–	–	–	–	–	–	–
1983–84	4	14	21	4	0.05	0.02	2.96	0.00
1984–85	0	–	–	–	–	–	–	–
1985–86	5	33	30	3	0.05	0.02	3.00	0.00
1986–87	2	–	–	–	–	–	–	–
1987–88	1	–	–	–	–	–	–	–
1988–89	7	16	69	36	0.01	0.00	1.18	0.06
1989–90	6	94	82	158	0.25	0.93	0.38	0.02
1990–91	6	249	65	830	0.25	0.86	0.27	0.10
1991–92	21	694	90	6 821	5.00	13.13	0.33	0.33
1992–93	18	1 057	82	5 458	1.80	3.60	0.33	0.15
1993–94	14	1 864	98	2 689	0.00	0.00	0.44	0.03
1994–95	16	561	72	2 782	0.50	1.76	0.23	0.14
1995–96	19	1 225	92	5 060	0.30	0.60	0.23	0.12
1996–97	13	1 234	92	1 862	0.05	0.16	0.22	0.03
1997–98	20	1 135	90	2 272	0.00	0.00	0.22	0.05
1998–99	21	1 170	81	2 741	0.15	0.53	0.25	0.06
1999–2000	19	770	72	515	0.03	0.07	0.27	0.01
2000–01	16	927	76	1 514	0.20	0.40	0.37	0.04
2001–02	16	504	65	1 353	0.17	0.50	0.33	0.06
2002–03	15	488	49	1 449	0.15	0.46	0.33	0.08
2003–04	15	572	70	1 049	0.06	0.13	0.42	0.04
2004–05	19	623	70	2 266	0.15	0.30	0.33	0.10
2005–06	8	514	73	2 025	0.15	0.37	0.32	0.11
2006–07	7	356	65	1 302	0.17	0.59	0.40	0.11
2007–08	4	434	71	1 488	0.20	0.72	0.30	0.10
2008–09	4	369	60	1 184	0.05	0.14	0.37	0.09
2009–10	5	369	59	554	0.05	0.23	0.38	0.04
2010–11	3	254	45	315	0.02	0.09	0.37	0.03
2011–12	3	95	32	74	0.03	0.18	0.28	0.03
2012–13	3	38	37	66	0.04	0.26	0.31	0.05
2013–14	3	131	60	516	0.04	0.22	0.23	0.11
2014–15	4	144	96	615	0.09	0.22	0.34	0.12
2015–16	4	81	69	384	0.08	–	–	0.15

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

Year	Northwest Chatham Rise	East Chatham Rise	South Chatham Rise	Puysegur	Arrow Plateau	Sub- Antarctic
1992–93	3 500	4 500	6 300	5 000	-	2 000
1993–94	3 500	4 500	6 300	5 000	-	2 000
1994–95	2 500	3 500	2 000	2 000	3 000	1 000
1995–96	2 250	4 950	*	1 000	**	4 500
1996–97	2 250	4 950	*	500	**	5 000
1997–98	2 250	4 950	*	0	1 500	4 000
1998–99	2 250	4 950	*	0	1 500	4 000
1999–00	2 250	4 950	*	0	1 500	4 000
2000–01	2 250	4 950	*	0	1 500	4 000
2001–02	2 000	7 000	1 400	0	1 000	1 300
2002–03	2 000	7 000	1 400	0	1 000	1 300
2003–04	2 000	7 000	1 400	0	1 000	1 300
2004–05†	1 500	7 250	1 400	0	1 000	1 300
2005–06†	1 500	7 250	1 400	0†	1 000	1 300
2006–07	750	8 650‡	*	0	0	1 850
2007–08†	750	7 650#	*	0	0	1 850
2008–09†	750	6 570§	*	0	0	1 850
2009–10†	750	5 100	*	0	0	1 850
2010–11	750β	2 960†	*	150	0	500
2011–12	750β	1 950†	*	150	0	500
2012–13	750 β	1 950†	*	150	0	500
2013–14	750	3 100	*	150	0	500
2014–15	1 250 δ	3 100	*	150	0	500
2015–16	1 250	3 100	*	150	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. This left 1043 tonnes available to catch

Table 4: ORH 3B subareas. Summary of effort, catch (t), catch rates, tow duration, and frequency of large catches for the fishing years 1979–80 to 2015–16, using tow-by-tow data. Catch rates and tow duration are calculated only for years in which there were twenty or more tows. * tows were within the defined areas and therefore close to, but not on, the hills; tows on the hills have shorter tow duration. Tow duration data for 2015–16 were incomplete and statistics therefore not presented. In accordance with MPI rules, statistics are not presented when there were fewer than 3 vessels in a year.

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
180 Hills (Graveyard complex)								
1979–80	12	100	81	864	4.16	2.23	2.00	0.34
1980–81*	4	7	100	49	—	—	—	0.14
1981–82*	3	12	100	87	—	—	3.04	0.33
1982–83*	5	12	92	88	—	—	3.50	0.17
1983–84*	0	—	—	—	—	—	—	—
1984–85*	0	—	—	—	—	—	—	—
1985–86*	3	11	100	32	—	—	4.00	0.00
1986–87*	5	11	100	27	—	—	3.22	0.00
1987–88*	4	19	100	126	—	—	3.00	0.21
1988–89*	4	25	100	125	3.21	1.13	3.00	0.08

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
1989–90*	3	28	100	160	5.50	1.93	2.96	0.07
1990–91*	1	–	–	–	–	–	–	–
1991–92	2	–	–	–	–	–	–	–
1992–93	8	297	100	3 298	5.13	36.29	0.17	0.38
1993–94	11	367	99	2 209	1.90	10.00	0.18	0.19
1994–95	8	368	99	1 512	1.00	4.56	0.20	0.09
1995–96	10	356	100	1 790	1.00	4.62	0.17	0.15
1996–97	12	247	98	877	0.49	2.07	0.18	0.09
1997–98	10	305	100	829	0.40	2.05	0.18	0.07
1998–99	8	189	98	937	0.80	3.75	0.17	0.14
1999–00	9	245	98	634	0.50	3.00	0.17	0.06
2000–01	10	301	100	1 014	0.50	2.52	0.22	0.08
2001–02	9	206	100	729	0.87	3.20	0.25	0.09
2002–03	14	253	100	1 080	0.80	3.00	0.20	0.09
2003–04	11	129	98	748	0.75	2.09	0.23	0.13
2004–05	6	171	99	919	1.14	5.45	0.20	0.14
2005–06	8	188	100	958	0.57	2.00	0.20	0.11
2006–07	3	78	100	591	1.75	9.30	0.23	0.29
2007–08	5	176	100	386	0.63	2.52	0.25	0.05
2008–09	5	75	100	385	1.28	4.50	0.18	0.13
2009–10	4	90	100	286	0.84	4.80	0.17	0.10
2010–11	1	–	–	–	–	–	–	–
2011–12	1	–	–	–	–	–	–	–
2012–13	1	–	–	–	–	–	–	–
2013–14	6	102	100	567	1.13	5.79	0.23	0.17
2014–15	9	164	100	553	0.50	1.80	0.31	0.10
2015–16	10	165	100	396	0.50	–	–	0.04
Northwest Chatham Rise Flat								
1979–80	12	100	81	864	4.16	2.23	2.00	0.34
1980–81	34	2 409	86	9 026	2.26	0.79	3.00	0.08
1981–82	20	651	95	3 889	3.67	1.20	3.00	0.19
1982–83	27	1 500	99	8 586	3.61	1.05	3.42	0.17
1983–84	20	694	95	2 885	2.68	0.72	3.50	0.09
1984–85	21	379	84	1 717	2.53	0.72	3.67	0.15
1985–86	27	611	92	3 608	2.62	0.80	3.00	0.19
1986–87	26	707	93	2 934	2.04	0.71	3.00	0.09
1987–88	24	514	75	1 418	1.33	0.45	3.00	0.06
1988–89	23	809	97	2 802	1.70	0.51	3.00	0.08
1989–90	18	707	85	2 177	1.30	0.46	3.00	0.07
1990–91	21	457	57	1 353	1.00	0.23	4.00	0.07
1991–92	15	82	73	189	1.09	0.50	2.42	0.05
1992–93	15	93	74	177	0.75	0.29	2.50	0.02
1993–94	22	239	89	1 138	1.00	0.55	1.00	0.13
1994–95	16	277	97	729	1.00	0.79	1.28	0.04
1995–96	17	230	92	432	0.60	0.40	2.00	0.03
1996–97	18	441	91	1 226	1.70	0.52	3.97	0.02
1997–98	22	525	93	1 402	1.00	0.50	2.65	0.04
1998–99	25	599	92	1 606	1.00	0.33	3.00	0.05
1999–00	25	499	71	1 386	0.60	0.25	2.47	0.08
2000–01	26	791	77	1 476	0.80	0.32	3.83	0.03
2001–02	22	733	88	1 303	0.60	0.27	3.25	0.03
2002–03	27	743	80	1 185	0.70	0.26	3.92	0.02
2003–04	22	763	77	1 204	0.80	0.19	4.33	0.02
2004–05	18	396	84	638	0.60	0.17	4.00	0.03
2005–06	13	260	92	383	0.60	0.22	3.26	0.03
2006–07	10	48	60	107	0.44	0.28	2.10	0.04

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
2007–08	9	131	83	325	0.50	0.39	1.93	0.06
2008–09	6	140	79	305	0.40	0.20	2.52	0.06
2009–10	7	218	87	409	1.00	0.31	3.98	0.02
2010–11	9	15	33	40	0.12	0.12	1.53	0.13
2011–12	8	20	20	41	0.22	0.30	0.65	0.05
2012–13	8	20	40	51	0.45	0.17	2.55	0.10
2013–14	13	102	90	192	0.60	0.41	1.87	0.04
2014–15	13	133	93	210	0.59	0.32	2.57	0.02
2015–16	11	276	88	276	0.50	–	–	0.00
Rekohu								
1979–80	6	8	100	33	–	–	2.00	0.12
1980–81	4	4	100	56	–	–	1.04	0.50
1981–82	1	–	–	–	–	–	–	–
1982–83	3	4	100	28	–	–	1.75	0.25
1983–84	2	–	–	–	–	–	–	–
1984–85	0	–	–	–	–	–	–	–
1985–86	2	–	–	–	–	–	–	–
1986–87	3	4	100	39	–	–	2.96	0.50
1987–88	2	–	–	–	–	–	–	–
1988–89	3	5	100	43	–	–	1.00	0.20
1989–90	4	4	100	59	–	–	3.71	0.25
1990–91	0	–	–	–	–	–	–	–
1991–92	2	–	–	–	–	–	–	–
1992–93	0	–	–	–	–	–	–	–
1993–94	0	–	–	–	–	–	–	–
1994–95	0	–	–	–	–	–	–	–
1995–96	1	–	–	–	–	–	–	–
1996–97	1	–	–	–	–	–	–	–
1997–98	1	–	–	–	–	–	–	–
1998–99	1	–	–	–	–	–	–	–
1999–00	0	–	–	–	–	–	–	–
2000–01	0	–	–	–	–	–	–	–
2001–02	1	–	–	–	–	–	–	–
2002–03	0	–	–	–	–	–	–	–
2003–04	5	152	99	1 027	4.00	1.76	2.13	0.21
2004–05	3	200	100	1 034	2.87	1.21	2.53	0.16
2005–06	5	65	100	157	1.10	0.36	3.00	0.03
2006–07	5	43	100	78	0.72	0.28	2.90	0.00
2007–08	1	–	–	–	–	–	–	–
2008–09	2	–	–	–	–	–	–	–
2009–10	5	28	100	55	1.27	0.75	2.50	0.00
2010–11	4	31	100	400	6.50	2.48	1.90	0.45
2011–12	4	36	100	674	19.46	56.50	0.43	0.58
2012–13	3	39	100	712	25.00	98.57	0.25	0.67
2013–14	4	40	100	950	24.16	82.56	0.38	0.78
2014–15	4	89	100	1 784	21.70	62.07	0.38	0.76
2015–16	4	55	98	696	10.50	–	–	0.51
Spawning Plume								
1979–80	18	999	97	10 574	11.26	8.45	1.25	0.53
1980–81	24	898	99	11 148	11.52	8.19	1.50	0.65
1981–82	17	470	100	4 752	4.50	2.50	1.83	0.35
1982–83	9	227	100	3 980	13.44	7.07	2.00	0.60
1983–84	17	378	100	6 591	13.44	3.76	3.00	0.57
1984–85	20	676	100	9 316	10.44	3.71	3.00	0.54
1985–86	23	659	100	8 521	9.97	2.96	3.00	0.50
1986–87	21	597	100	8 089	8.91	2.26	3.32	0.47

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
1987–88	24	624	100	7 899	7.96	2.01	3.29	0.45
1988–89	22	598	100	7 067	9.63	3.23	2.50	0.43
1989–90	17	403	100	6 829	12.50	4.00	3.00	0.57
1990–91	9	238	100	2 819	8.00	2.83	3.00	0.36
1991–92	5	85	100	653	6.00	1.57	4.17	0.15
1992–93	1	–	–	–	–	–	–	–
1993–94	0	–	–	–	–	–	–	–
1994–95	1	–	–	–	–	–	–	–
1995–96	4	127	100	1 356	5.00	3.59	1.17	0.32
1996–97	6	101	100	934	3.00	2.11	1.17	0.23
1997–98	6	118	100	1 579	6.00	6.86	0.53	0.39
1998–99	4	73	100	505	2.70	4.36	0.50	0.22
1999–00	2	34	100	914	25.00	200.89	0.11	0.71
2000–01	3	59	100	814	5.50	21.36	0.30	0.37
2001–02	4	159	100	2 118	4.00	8.12	0.35	0.37
2002–03	6	166	100	2 154	8.00	15.00	0.30	0.47
2003–04	5	163	100	1 880	6.00	7.40	0.67	0.40
2004–05	9	214	100	1 912	4.36	3.91	0.93	0.30
2005–06	6	118	99	1 634	8.70	5.25	0.57	0.47
2006–07	7	121	100	1 975	11.20	6.00	0.68	0.51
2007–08	3	200	100	2 545	5.00	15.43	0.25	0.43
2008–09	3	121	100	2 019	18.00	49.97	0.23	0.58
2009–10	3	136	100	1 977	8.5	34.84	0.22	0.49
2010–11	3	75	100	1 226	15.00	59.90	0.23	0.59
2011–12	3	39	100	655	15.00	84.00	0.27	0.56
2012–13	2	–	–	–	–	–	–	–
2013–14	4	40	100	387	4.75	21.17	0.35	0.45
2014–15	2	–	–	–	–	–	–	–
2015–16	2	–	–	–	–	–	–	–
Spawning Box (not plume)								
1979–80	22	827	96	7 701	5.87	2.82	2.42	0.37
1980–81	25	462	100	6 244	11.52	7.12	1.50	0.56
1981–82	17	607	100	4 446	4.80	1.73	2.83	0.21
1982–83	16	388	99	3 847	8.06	2.62	3.21	0.42
1983–84	19	841	99	8 647	7.68	2.46	3.00	0.43
1984–85	19	548	98	7 550	9.94	3.42	3.00	0.49
1985–86	24	870	99	7 659	6.00	1.63	3.50	0.31
1986–87	21	1 036	100	12 006	6.16	1.54	3.83	0.38
1987–88	26	703	100	5 823	5.04	1.20	3.50	0.25
1988–89	23	811	100	6 500	5.00	1.43	3.42	0.27
1989–90	18	602	100	4 959	5.25	1.45	3.71	0.27
1990–91	12	206	100	2 806	8.00	2.60	3.00	0.43
1991–92	8	55	98	294	5.50	1.31	4.25	0.07
1992–93	0	–	–	–	–	–	–	–
1993–94	0	–	–	–	–	–	–	–
1994–95	3	25	100	5	0.10	0.19	0.52	0.00
1995–96	7	27	100	137	0.83	0.86	0.63	0.15
1996–97	4	130	100	615	2.25	1.51	2.00	0.14
1997–98	7	148	100	629	1.45	0.96	1.82	0.09
1998–99	8	139	100	486	1.60	0.75	2.67	0.07
1999–00	5	111	100	511	2.00	1.48	1.73	0.12
2000–01	8	124	99	434	2.00	1.01	2.00	0.10
2001–02	6	222	100	977	2.00	0.95	2.98	0.09
2002–03	8	216	100	995	1.80	1.11	2.50	0.11
2003–04	11	278	100	1 049	2.29	0.90	3.18	0.08
2004–05	11	230	100	852	2.50	0.87	3.00	0.07

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
2005–06	9	257	100	1 735	3.80	1.32	3.90	0.21
2006–07	11	356	100	1 717	2.61	0.86	4.00	0.10
2007–08	3	192	100	750	2.45	0.75	3.97	0.08
2008–09	3	209	100	1 012	3.04	0.89	4.00	0.10
2009–10	5	249	100	854	2.40	0.69	4.00	0.04
2010–11	4	28	100	66	1.70	0.71	3.23	0.00
2011–12	3	24	100	83	2.00	0.73	2.58	0.04
2012–13	1	–	–	–	–	–	–	–
2013–14	4	19	95	31	0.80	–	–	0.00
2014–15	2	–	–	–	–	–	–	–
2015–16	3	96	100	394	3.00	–	–	0.08
Northeast Hills								
1979–80*	5	36	100	108	3.06	0.67	4.54	0.00
1980–81*	2	–	–	–	–	–	–	–
1981–82*	4	11	100	42	–	–	0.75	0.00
1982–83*	2	–	–	–	–	–	–	–
1983–84*	3	7	100	58	–	–	–	0.29
1984–85*	2	–	–	–	–	–	–	–
1985–86*	6	52	100	665	11.44	3.59	3.50	0.58
1986–87*	9	34	100	210	3.94	0.94	3.96	0.18
1987–88*	13	33	100	163	4.52	1.08	4.00	0.06
1988–89*	9	48	100	309	3.92	0.85	4.82	0.21
1989–90*	4	9	100	42	–	–	–	0.11
1990–91	6	642	99	4 928	3.50	23.08	0.15	0.24
1991–92	5	222	100	1 272	2.00	12.50	0.15	0.16
1992–93	4	84	100	598	2.00	15.00	0.21	0.27
1993–94	5	110	99	621	2.85	13.51	0.18	0.15
1994–95	7	345	100	1 136	1.00	4.62	0.20	0.08
1995–96	7	145	100	405	1.00	5.60	0.22	0.05
1996–97	7	166	99	721	1.00	7.50	0.17	0.11
1997–98	9	146	100	396	0.40	1.99	0.17	0.05
1998–99	8	272	100	809	1.00	3.32	0.20	0.07
1999–00	8	210	100	675	0.78	3.75	0.17	0.10
2000–01	7	191	100	650	1.00	6.00	0.18	0.08
2001–02	5	167	100	492	0.90	4.50	0.18	0.09
2002–03	6	124	100	404	0.52	3.60	0.17	0.09
2003–04	6	160	100	364	0.80	3.00	0.20	0.04
2004–05	7	127	100	306	0.90	3.00	0.20	0.06
2005–06	6	119	100	366	0.72	4.18	0.18	0.11
2006–07	6	201	100	569	0.68	3.00	0.22	0.09
2007–08	1	–	–	–	–	–	–	–
2008–09	1	–	–	–	–	–	–	–
2009–10	5	84	100	162	0.49	1.85	0.20	0.04
2010–11	4	26	100	85	0.38	10.57	0.15	0.12
2011–12	3	26	100	128	0.45	3.09	0.23	0.12
2012–13	1	–	–	–	–	–	–	–
2013–14	3	39	100	136	0.90	4.44	0.20	0.40
2014–15	1	–	–	–	–	–	–	–
2015–16	3	75	100	131	0.20	–	–	0.04
Eastern Flats								
1979–80	9	206	100	555	2.23	0.55	4.32	0.02
1980–81	4	10	100	28	–	–	–	0.00
1981–82	7	77	100	359	3.99	1.68	2.58	0.09
1982–83	6	63	100	1 025	8.49	4.65	3.00	0.48
1983–84	9	146	95	1 202	6.36	1.74	3.33	0.32
1984–85	7	80	100	991	9.47	3.15	3.00	0.46

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
1985–86	12	306	100	3 027	8.12	2.36	3.50	0.39
1986–87	12	296	100	1 948	4.56	1.17	4.00	0.20
1987–88	17	328	99	2 105	5.27	1.27	4.00	0.17
1988–89	16	300	100	2 082	4.47	0.97	5.00	0.21
1989–90	12	86	100	356	3.00	0.76	4.00	0.07
1990–91	10	87	100	481	1.00	2.73	0.22	0.15
1991–92	6	366	100	3 045	5.00	17.56	0.19	0.27
1992–93	5	75	100	566	2.00	5.00	0.25	0.20
1993–94	11	126	97	506	1.90	6.00	0.25	0.11
1994–95	8	200	98	442	1.00	3.33	0.22	0.04
1995–96	9	122	98	452	0.50	2.09	0.27	0.11
1996–97	7	120	98	371	1.00	3.00	0.23	0.08
1997–98	11	260	100	446	0.27	1.09	0.25	0.03
1998–99	11	218	98	369	0.30	1.21	0.25	0.03
1999–00	11	165	98	390	0.30	2.29	0.17	0.05
2000–01	8	155	100	575	1.00	4.33	0.18	0.09
2001–02	6	240	100	895	1.14	6.00	0.18	0.10
2002–03	8	400	99	1 289	0.78	3.29	0.23	0.08
2003–04	9	398	99	843	0.60	2.45	0.22	0.06
2004–05	8	408	99	1 330	0.92	3.00	0.22	0.08
2005–06	8	538	99	1 811	0.72	2.90	0.20	0.10
2006–07	7	578	99	1 544	0.91	1.71	0.25	0.06
2007–08	2	–	–	–	–	–	–	–
2008–09	4	447	99	1 169	1.00	1.04	0.23	0.05
2009–10	4	221	100	561	1.20	0.90	0.37	0.03
2010–11	4	43	100	131	0.64	5.50	0.25	0.05
2011–12	5	62	98	122	0.66	3.10	0.24	0.03
2012–13	3	47	100	95	1.00	4.75	0.30	0.02
2013–14	5	82	100	260	1.00	1.66	0.27	0.07
2014–15	3	52	100	201	1.40	6.00	0.27	0.10
2015–16	3	263	100	358	0.32	–	–	0.03
Andes complex								
1988–89	2	–	–	–	–	–	–	–
1989–90	2	–	–	–	–	–	–	–
1990–91	3	13	92	75	–	–	0.17	0.15
1991–92	5	739	98	7 174	5.00	24.00	0.17	0.31
1992–93	6	355	97	3 103	5.00	21.82	0.22	0.26
1993–94	11	614	99	3 348	1.60	7.55	0.23	0.15
1994–95	10	583	98	1 655	1.00	4.05	0.23	0.06
1995–96	10	419	100	1 121	0.50	1.87	0.25	0.06
1996–97	9	265	98	746	1.00	3.65	0.22	0.06
1997–98	10	478	100	1 141	0.50	1.76	0.25	0.05
1998–99	10	456	98	1 267	1.00	3.00	0.25	0.07
1999–00	10	536	99	2 007	1.00	4.01	0.22	0.10
2000–01	9	358	99	981	1.05	4.53	0.25	0.06
2001–02	6	546	100	2 038	1.50	5.74	0.25	0.10
2002–03	7	875	100	2 233	0.95	3.00	0.28	0.06
2003–04	8	685	99	1 183	0.52	1.88	0.30	0.02
2004–05	5	533	97	1 097	0.60	2.20	0.25	0.04
2005–06	5	730	100	1 337	0.53	2.00	0.25	0.03
2006–07	6	586	99	1 164	0.50	1.87	0.27	0.04
2007–08	1	–	–	–	–	–	–	–
2008–09	1	–	–	–	–	–	–	–
2009–10	4	247	98	445	0.45	2.22	0.25	0.03
2010–11	3	152	99	462	1.20	5.47	0.35	0.05
2011–12	5	167	98	456	1.00	4.44	0.32	0.04

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
2012–13	2	–	–	–	–	–	–	–
2013–14	5	221	99	795	1.00	6.28	0.30	0.09
2014–15	4	169	96	480	1.00	4.08	0.33	0.05
2015–16	4	437	100	1 182	0.40	–	–	0.08
Middle Ground								
1997–98	1	–	–	–	–	–	–	–
1998–99	0	–	–	–	–	–	–	–
1999–00	1	–	–	–	–	–	–	–
2000–01	2	–	–	–	–	–	–	–
2001–02	2	–	–	–	–	–	–	–
2002–03	4	57	98	285	1.40	6.00	0.20	0.11
2003–04	4	126	100	380	0.65	4.65	0.17	0.10
2004–05	4	207	100	918	1.37	6.04	0.18	0.12
2005–06	6	128	100	602	1.94	10.46	0.17	0.18
2006–07	5	140	99	555	1.16	7.02	0.17	0.11
2007–08	1	–	–	–	–	–	–	–
2008–09	2	–	–	–	–	–	–	–
2009–10	4	20	100	48	0.18	2.50	0.18	0.10
2010–11	3	5	100	16	–	–	0.25	0.00
2011–12	2	–	–	–	–	–	–	–
2012–13	2	–	–	–	–	–	–	–
2013–14	3	18	100	64	–	–	0.23	0.11
2014–15	1	–	–	–	–	–	–	–
2015–16	2	–	–	–	–	–	–	–
Big Chief and Neighbours								
1988–89	4	199	100	1 014	1.70	3.37	0.62	0.13
1989–90	8	543	98	2 913	1.50	4.50	0.42	0.15
1990–91	10	469	97	3 244	2.20	10.27	0.18	0.20
1991–92	5	140	99	829	2.70	15.00	0.17	0.18
1992–93	5	703	100	3 308	2.00	8.79	0.17	0.14
1993–94	10	698	100	2 353	0.58	3.33	0.18	0.10
1994–95	8	243	100	518	0.80	3.55	0.20	0.05
1995–96	7	153	99	579	1.00	5.00	0.20	0.08
1996–97	6	196	99	558	0.50	2.86	0.17	0.09
1997–98	10	287	99	953	0.40	1.90	0.20	0.07
1998–99	7	217	99	564	0.50	3.00	0.18	0.08
1999–00	8	124	99	381	0.50	3.30	0.17	0.07
2000–01	7	214	100	1 018	0.78	5.45	0.17	0.14
2001–02	7	237	99	664	0.92	4.29	0.18	0.08
2002–03	9	280	99	669	0.50	2.14	0.18	0.06
2003–04	7	316	95	605	0.50	2.49	0.22	0.04
2004–05	5	323	95	841	0.53	2.82	0.20	0.07
2005–06	5	323	94	549	0.40	2.18	0.18	0.04
2006–07	4	301	94	590	0.38	2.06	0.18	0.04
2007–08	3	338	99	692	0.50	3.00	0.20	0.04
2008–09	3	323	95	379	0.23	1.15	0.20	0.03
2009–10	4	129	97	182	0.25	1.70	0.20	0.02
2010–11	3	60	98	217	0.50	3.60	0.22	0.13
2011–12	4	74	97	176	0.50	3.00	0.18	0.05
2012–13	2	–	–	–	–	–	–	–
2013–14	5	78	99	350	0.85	4.62	0.18	0.14
2014–15	4	61	92	247	0.60	6.00	0.17	0.13
2015–16	2	–	–	–	–	–	–	–
Hegerville and Surrounds								
1979–80	4	19	10	18	0.08	0.04	2.17	0.05
1980–81	5	606	39	2 545	3.47	7.29	0.50	0.05

Fishing year	Number of vessels	Total number of tows	% ORH target	Total estimated catch	Median catch rate (t/tow)	Median catch rate (t/h)	Median tow duration	Proportion of tows > 10 t
1981–82	5	14	64	64	3.13	2.54	1.46	0.07
1982–83	17	982	87	8 484	6.91	5.72	1.17	0.34
1983–84	13	740	67	4 640	4	3.37	1.33	0.22
1984–85	18	1 038	79	6 394	3.84	2.63	1.50	0.20
1985–86	17	1 115	75	4 461	1.49	1.27	1.17	0.11
1986–87	18	798	75	2 832	1.22	1.09	1.03	0.08
1987–88	15	938	72	2 478	0.82	0.57	1.08	0.07
1988–89	14	615	92	1 261	0.65	0.71	1.00	0.03
1989–90	11	311	76	586	0.70	1.00	0.58	0.04
1990–91	10	110	68	279	1.00	1.15	0.72	0.05
1991–92	5	67	78	57	0.00	0.00	0.65	0.00
1992–93	6	116	72	306	0.48	1.04	0.42	0.08
1993–94	9	133	97	223	0.50	0.81	0.58	0.02
1994–95	7	105	90	101	0.04	0.01	0.57	0.01
1995–96	9	132	79	84	0.00	0.00	0.62	0.01
1996–97	6	89	84	175	0.30	0.60	0.50	0.04
1997–98	8	94	55	85	0.19	0.22	0.75	0.01
1998–99	8	107	16	144	0.15	0.12	0.75	0.02
1999–00	9	77	13	146	0.15	0.27	0.72	0.05
2000–01	7	69	30	159	0.40	1.09	0.48	0.06
2001–02	7	36	50	56	0.17	0.22	0.72	0.03
2002–03	8	72	58	224	1.00	2.87	0.28	0.07
2003–04	10	87	55	137	0.33	0.59	0.33	0.02
2004–05	7	56	41	132	0.31	0.63	0.43	0.09
2005–06	10	96	55	144	0.48	1.01	0.34	0.01
2006–07	7	86	44	219	0.50	1.06	0.29	0.05
2007–08	5	139	77	301	0.50	1.43	0.27	0.06
2008–09	3	228	80	526	0.50	1.71	0.27	0.07
2009–10	6	238	54	599	0.45	1.70	0.27	0.08
2010–11	6	77	44	164	0.32	1.04	0.25	0.04
2011–12	5	67	37	85	0.25	0.95	0.30	0.01
2012–13	7	92	11	116	0.30	1.15	0.30	0.03
2013–14	7	60	12	21	0.10	0.21	0.45	0.00
2014–15	9	62	12	54	0.20	0.28	0.40	0.00
2015–16	7	41	22	20	0.10	–	–	0.00

The Rekohu fishery has not previously been described in any detail. The main fishery has taken place around spawning (July) within an area about 10 km across (Figure 10). In the years before 2003–04, the catches during the spawning season were more widespread and sporadic, and it seems the spawning aggregation had not been located (or was not present). Outside of the spawning season, the catches were in a similar area (perhaps centred slightly deeper (northward) than during spawning), and also extended to the east, both before and after 2003–04.

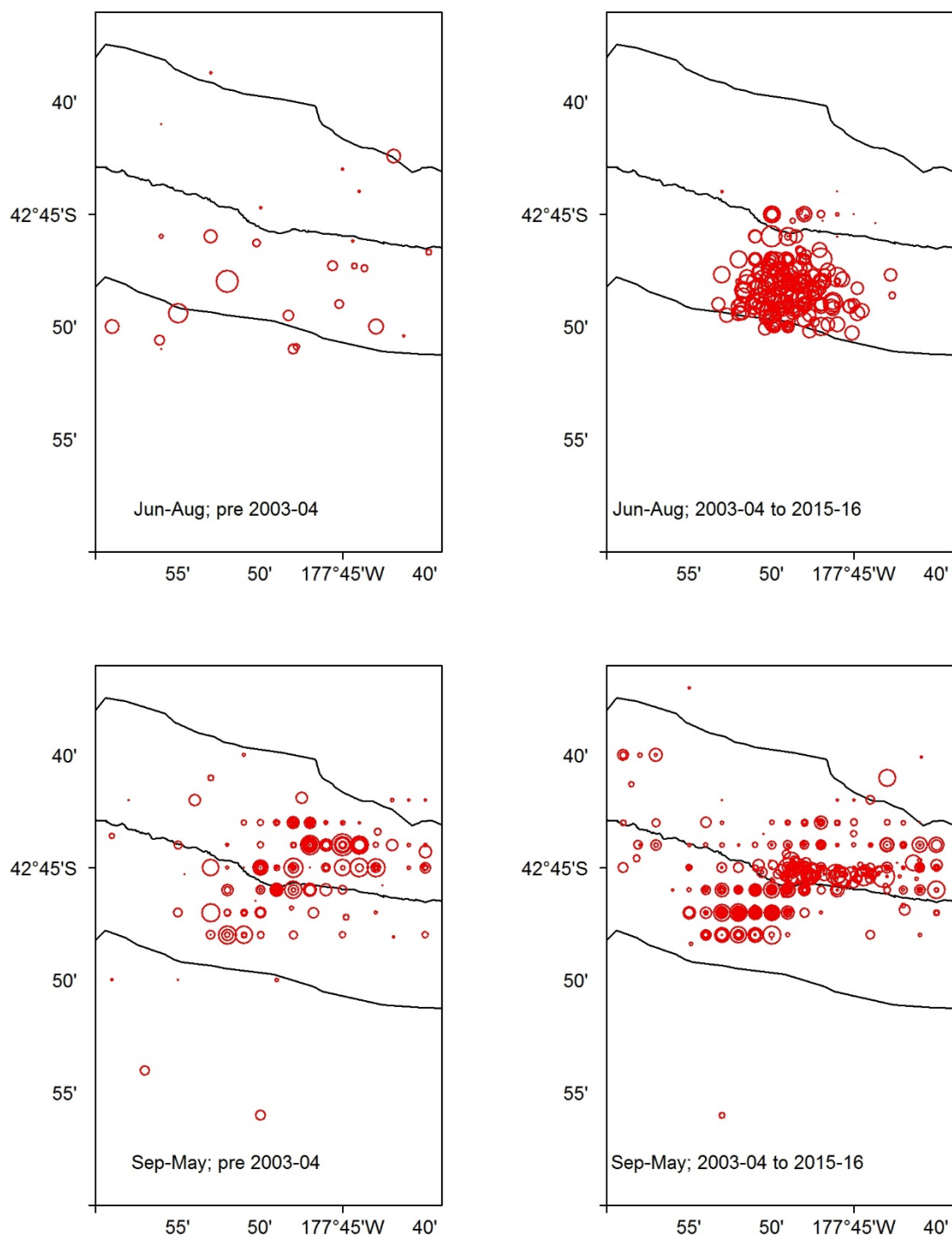


Figure 10: Estimated catches of orange roughy from tows that caught or targeted orange roughy, for the Rekohu region, by season across all years, and across all months by year groups. Circles proportional to catch size; left panels max. 60 t, top right panel 36 t, bottom right panel 49 t. Solids lines are the 750 m, 1000 m, and 1250 m isobaths.

The highest unstandardised catch rates have historically been achieved in the Spawning Plume, followed by the Graveyard and Rekohu, where spawning plumes, or pre- and post-spawning aggregations have been targeted (Figure 11). Unstandardised catch rates in all three areas have declined over the last three years.

Unstandardised catch rates for the Northwest Chatham Rise Flat fishery slowly declined and then remained relatively low but stable. Unstandardised catch rates from Eastern Flats, Andes, and Big Chief & Neighbours, all increased from 2009–10, but then decreased in 2015–16. Catch rates for Smith's City & neighbours increased or remained stable after 2009–10, and catch rates from Hegerville & surrounds decreased after 2012–13.

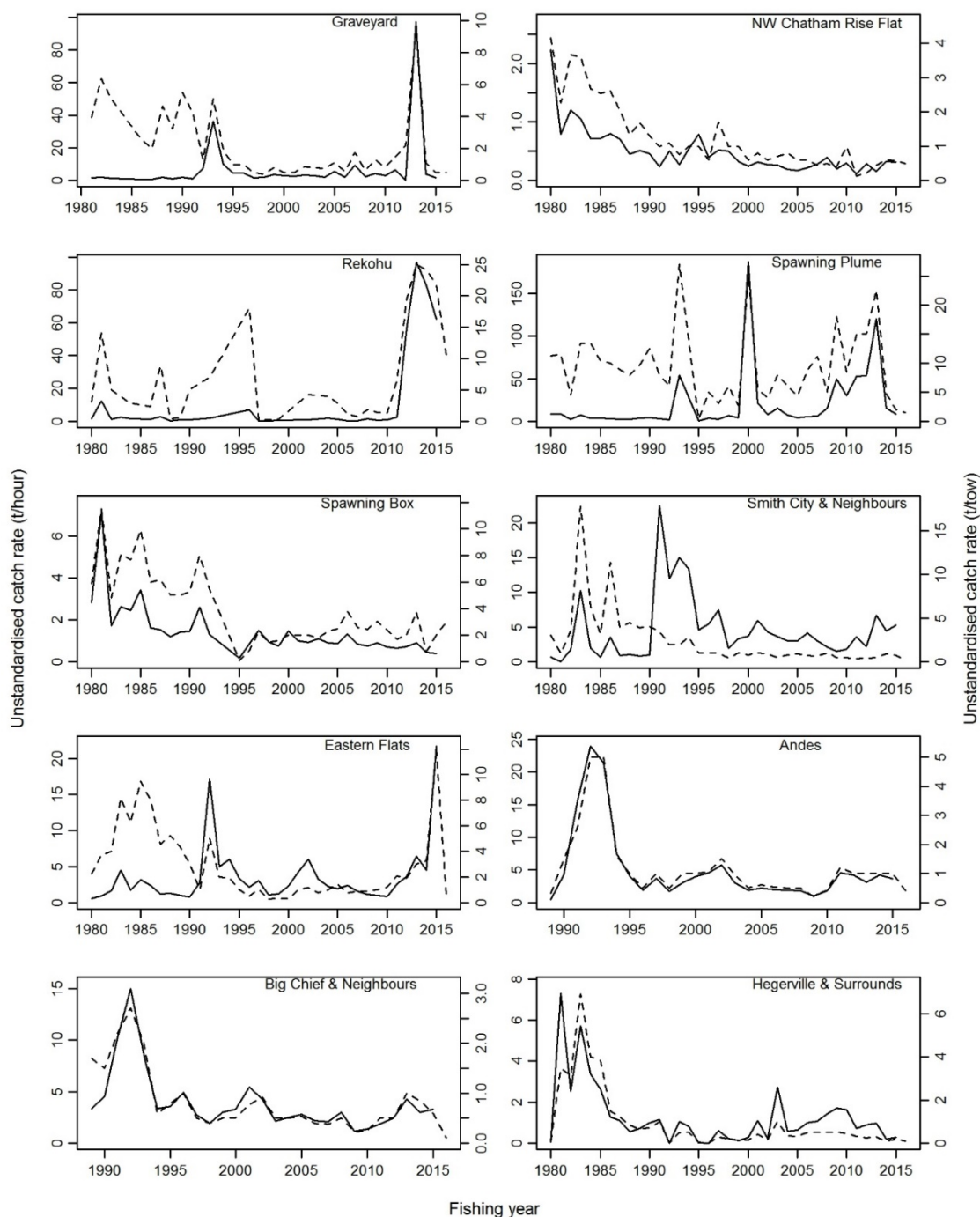


Figure 11: Unstandardised catch rates (solid line, t/tow; broken line, t/hr) for subareas of Chatham Rise. Tow duration data for 2015–16 were incomplete and catch rate was therefore not calculated.

3. OBSERVER DATA

The Ministry's Observer Programme (OP) has collected orange roughy sex, maturity stage, and length data in ORH 3B every year since 1991–92 (Table 5). The percentage of the fishery observed was

relatively low between 2010–11 and 2013–14; the reduced absolute coverage since 2010–11 is associated with the smaller size of the fishery. These data indicate that, on average, 43% of the trips were observed, 17% of the catch observed, 6% of the tows observed, and 0.2% of the catch actually sampled. A total of 328 943 fish have been measured (average 12 651 year⁻¹), and 169 521 females staged (average 6 520 yr⁻¹).

Table 5: Summary of Ministry observer samples taken of orange roughy from ORH 3B Chatham Rise, showing the number of tows, trips, and vessels (Ves) sampled, the weight of fish sampled, and the catch weight from which this sample was taken, the number of fish measured for length (Fish meas.) and number of females sampled for maturity stage (Fish staged), and the coverage of the fishery as the percentage of tows (Tows) and percentage of catches (Catch) observed, and the percentage of the catch that was actually measured (sample; noting that the observed catches are subsampled), and percentage of trips sampled.

Fishing year	Tows	Trips	Ves	Sample (t)	Catch (t)	Fish meas.	Fish staged	% of estimated catch			
								Tows	Catch	Sample	Trips
1990–91	123	9	9	11.5	2 057	11 186	5 784	4.1	10.9	0.06	90.0
1991–92	168	8	7	18.8	2 401	15 027	8 356	7.2	15.8	0.12	53.3
1992–93	85	5	3	10.4	1 163	8 005	4 105	3.8	9.1	0.08	50.0
1993–94	167	13	8	18.1	1 991	14 761	7 614	4.8	16.0	0.15	26.5
1994–95	119	13	8	13.0	1 023	10 403	5 129	3.7	13.6	0.17	52.0
1995–96	46	7	5	4.2	820	8 159	3 732	2.0	11.9	0.06	36.8
1996–97	92	4	3	10.8	762	8 184	4 367	4.2	11.3	0.16	28.6
1997–98	114	7	6	12.1	1 390	9 797	5 028	3.8	17.4	0.15	35.0
1998–99	51	9	8	5.3	340	4 724	2 456	1.8	4.7	0.07	40.9
1999–00	127	10	8	11.0	384	9 354	4 462	5.4	5.0	0.14	32.3
2000–01	210	12	7	15.9	888	13 250	6 689	8.0	11.7	0.21	66.7
2001–02	192	10	9	18.2	1 783	15 032	7 085	6.9	18.5	0.19	37.0
2002–03	265	10	7	25.6	2 173	19 931	10 566	7.8	20.2	0.24	50.0
2003–04	113	12	8	10.0	490	7 845	4 468	3.2	5.1	0.10	70.6
2004–05	300	10	6	40.3	2 842	30 882	15 261	10.0	29.5	0.42	52.6
2005–06	229	10	7	29.3	3 119	23 205	11 665	7.5	32.7	0.31	52.6
2006–07	204	9	5	24.5	3 040	18 485	9 600	7.5	34.4	0.28	29.0
2007–08	383	9	4	40.2	3 149	31 163	15 587	15.6	39.8	0.51	33.3
2008–09	378	10	4	42.0	3 376	31 422	16 946	16.2	49.1	0.61	47.6
2009–10	293	10	5	29.2	1 890	22 227	12 336	16.1	33.7	0.52	50.0
2010–11	28	4	3	2.2	75	1 780	922	4.4	2.6	0.08	21.1
2011–12	31	4	3	3.1	89	2 228	1 294	5.0	3.6	0.13	19.0
2012–13	7	2	2	0.2	5	139	102	1.2	0.2	0.01	22.2
2013–14	24	4	4	1.8	177	1 510	740	2.6	4.7	0.05	50.0
2014–15	62	5	3	5.7	1 025	4 272	1 962	6.5	26.2	0.15	26.3
2015–16	80	10	8	7.7	591	5 972	3 265	4.8	15.5	0.20	35.7

The representativeness of observer sampling of orange roughy trawls was evaluated by plotting the proportion of landed catch for each year by subarea and by month as circles, and overlaying this with the proportion of the observed catch for those same cells as crosses (Figure 12). If the proportions are the same, the cross dimensions equal the circle diameters; if over- or under-sampling has occurred, the crosses are either larger or smaller than the circles. Across all areas, sampling of the catch was relatively poor during 2010–11 to 2013–14. In recent years, the Northwest Chatham Rise was generally over-sampled during November, December, and June, and under-sampled during September and October, and between January and May. The fishing at the start of the fishing year (October to December) and around spawning (May to July) has generally been well sampled, but the winter fishery (January to

April), and fishing at the end of the fishing year (September), has often been poorly sampled. Sampling of the South Chatham Rise has generally been good, although individual months may have been over- or under-sampled in any one year. Similarly, coverage of the East Chatham Rise has been relatively good, with some months not sampled in any one year but with no consistent pattern.

The average lengths of the sampled orange roughy appear to have declined slightly for some areas, such as Andes, Graveyard, and the East Chatham Rise, although there is considerable inter-year variability (Figure 13). In most areas of the east and south Chatham Rise, (Andes, Smith's City & neighbours, Big Chief & neighbours, Hegerville & Surrounds, and South Chatham Rise (Flats)), average fish lengths seemed to decline until around 2007–08, and then increase. Smaller orange roughy lengths are notable on the Northwest Chatham Rise flats, South Chatham Rise flats, and Hegerville & surrounds, although in these areas lengths were also more variable. The fish in the Spawning Plume were larger than those seen in the wider Spawning Box, and also larger than those at Rekohu. The Hole, although historically known as a spawning location on the Northwest Chatham Rise (see subsequent analyses), has barely been sampled.

Catch-weighted length-frequency distributions for each subarea are shown in Figures 14–22. Most length frequency distributions were unimodal, with relatively little skew. On the Northwest Chatham Rise (largely flat ground; excludes Graveyard Hills), more smaller fish were seen than elsewhere, and there was a suggestion of relatively strong recruitment first seen in 1996–97, and extending perhaps to 2002–03; this would be consistent with good recruitment of cohorts spawned around 1980. On the South Chatham Rise hills, smaller fish were seen from the late 1990s into the early 2000s, similar to the pattern seen on the Northwest Chatham Rise. No recruitment events were suggested in other length frequency samples. On the South Chatham Rise flats smaller fish were often sampled, but it was unclear if there was any period of good recruitment. In 2006–07, a second mode of larger fish was seen, consistent with anecdotal reports of a single large catch of large fish in that region that year.

A classification tree analysis was used to investigate patterns in the length samples. The response term was the median length (Standard Length, SL) in each tow where at least twenty fish were measured. Potential predictors included the categorical predictors subarea, fishing year, month, and vessel key, and continuous predictors longitude, latitude, depth, proportion female, fishing year (offered as both a categorical and continuous variable), and distance between the start position of the tow and the summit of the nearest feature (seamount, hill or pinnacle) from the NIWA database *seamounts* (Rowden et al., 2008). The tree was pruned using 10-fold cross validation and complexity parameter *rp*, using the R library *rpart*. The estimated stratification was equally temporal and spatial (Figure 23). In the predominantly early and recent years (right hand branch), smaller fish were sampled on the Northwest Chatham Rise (flat) and the South Chatham Rise (flat). In the intermediate years (left hand branch), smaller fish were again found on the Northwest Chatham Rise (flat), but also the Hole, with larger fish in these two subareas sampled during 2005–06 to 2007–08, and outside of these years during March–May, July, and October. In the other areas (spawning areas of the northeast Chatham Rise, east Chatham Rise, plus various hill areas), larger fish were sampled in Big Chief & neighbours, East Chatham Rise (flat), Graveyard, and Spawning Plume. Other environmental predictors such as distance from hill and depth did not feature, nor did statistics such as proportion female, and vessel. The analysis of mean length suggested splitting the Northwest Chatham Rise into two strata; Graveyard, and other (Northwest Chatham Rise flat, and the Hole). For the east and south Chatham Rise, the analysis suggested splitting the South Chatham Rise from other subareas in some years, and in other years combining the South Chatham Rise with all subareas except the Spawning Plume, East Chatham Rise Flat, and Big Chief & neighbours.

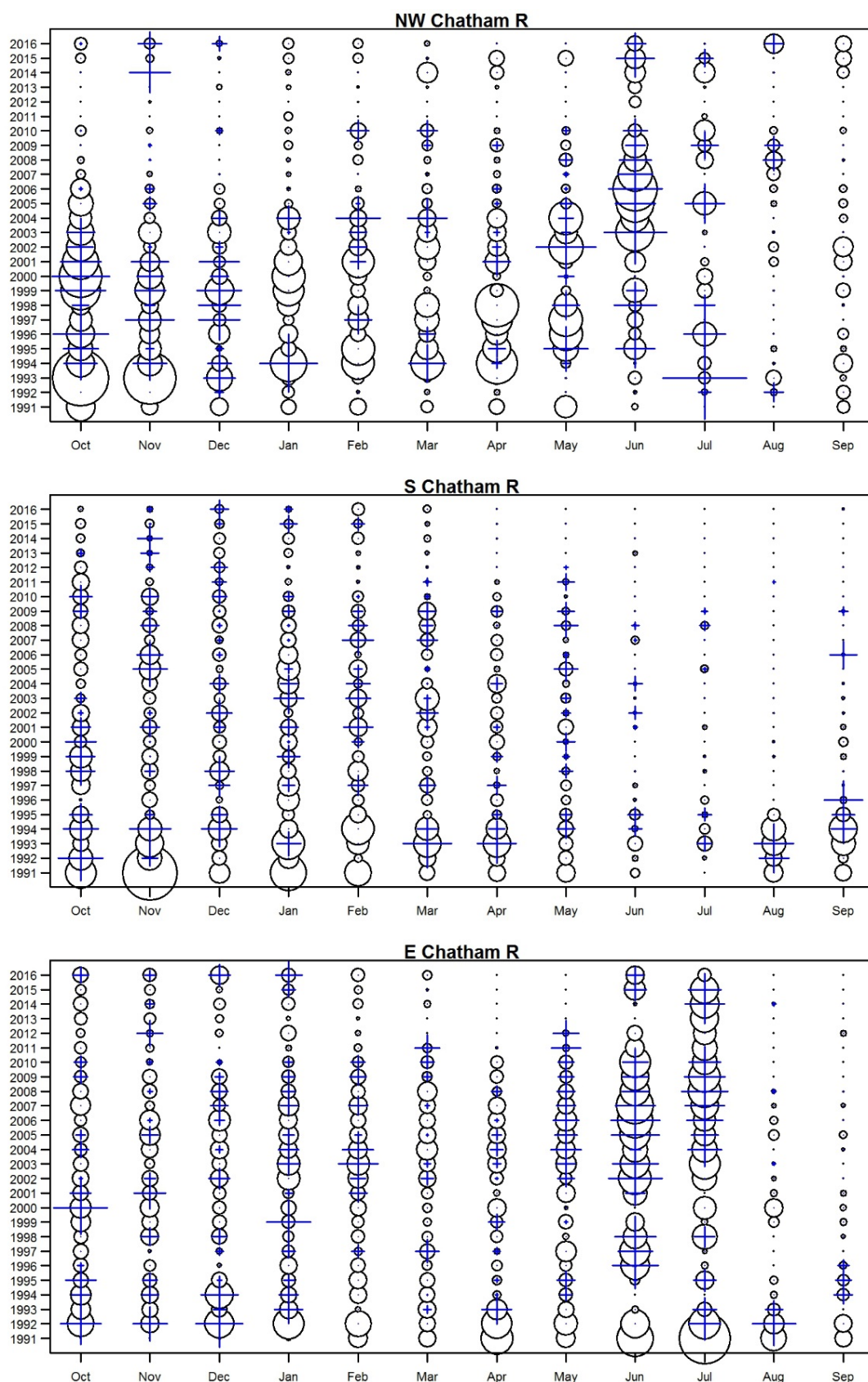


Figure 12: Representativeness of observer sampling of orange roughy catch by fishing year and month, by subarea of ORH 3B Chatham Rise. Circles show the proportion of target catch by month within a year, crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.

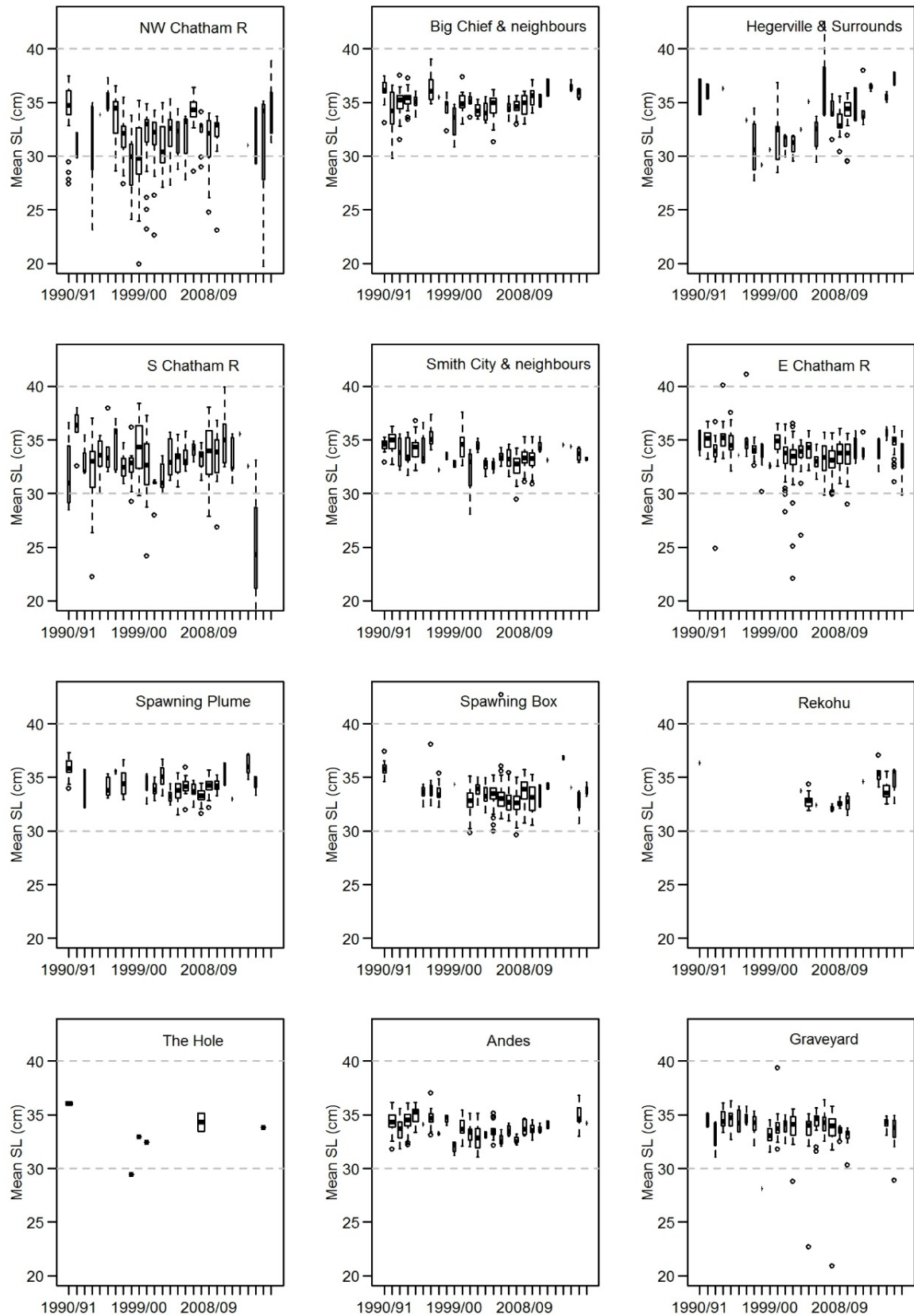


Figure 13: Box plot of annual mean lengths (SL) of orange roughy by tow (unweighted) by subarea in ORH 3B Chatham Rise. Horizontal broken lines mark 30 and 40 cm SL (arbitrary points for reference). Width of boxes is proportional to sample size.

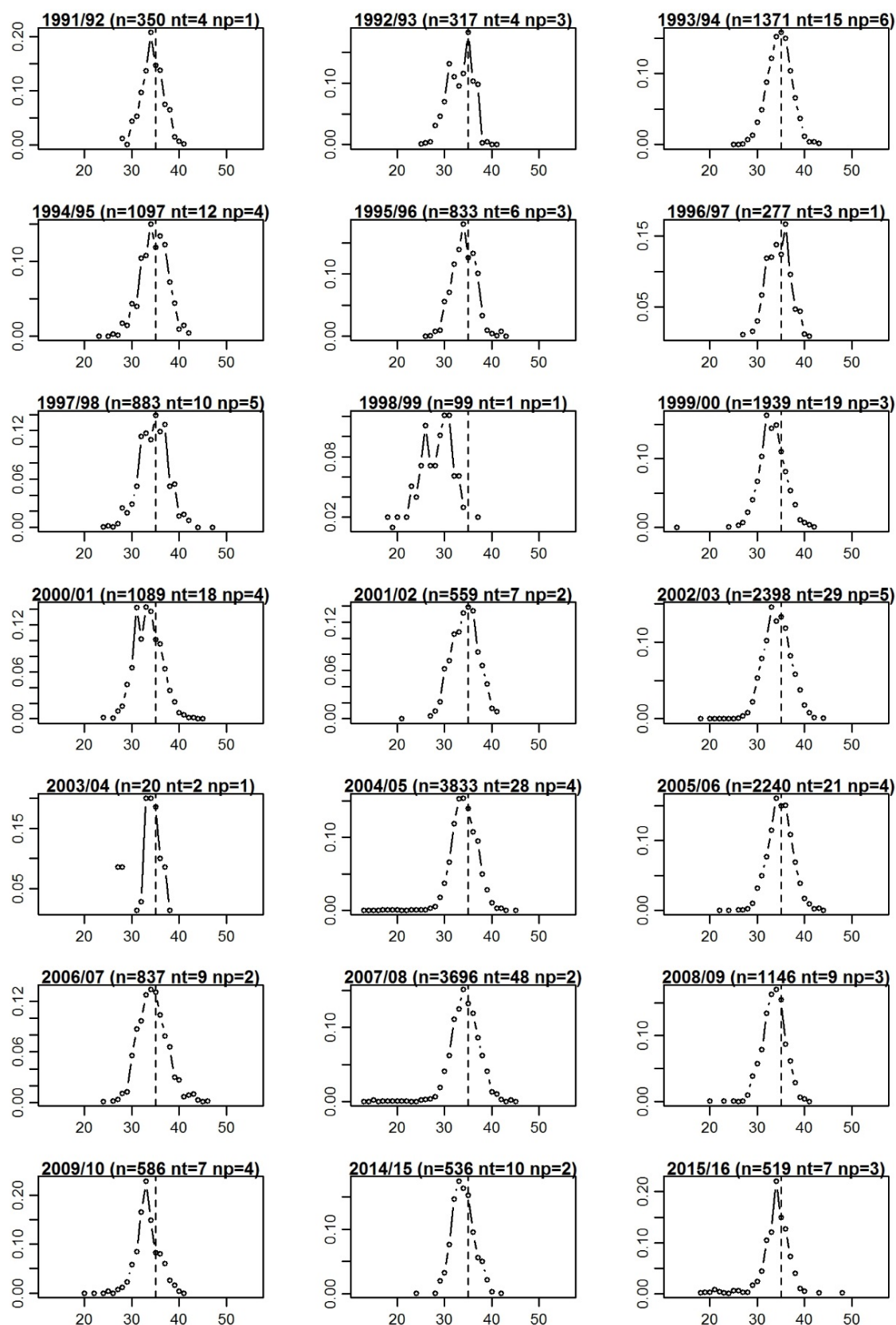


Figure 14: Catch-weighted length-frequency distributions for orange roughy in the Graveyard hills subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

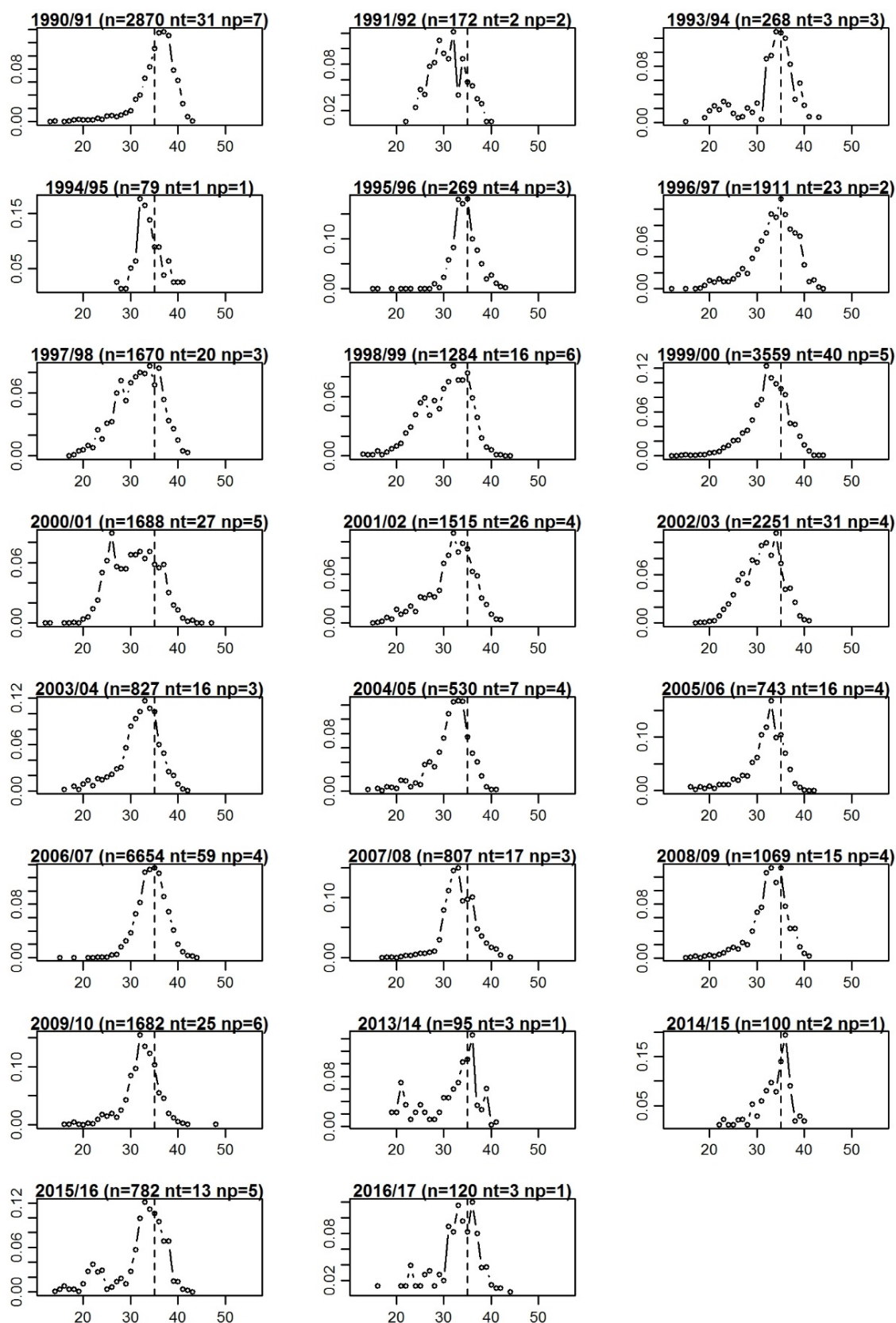


Figure 15: Catch-weighted length-frequency distributions for orange roughy in the Northwest Chatham rise (flat) subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

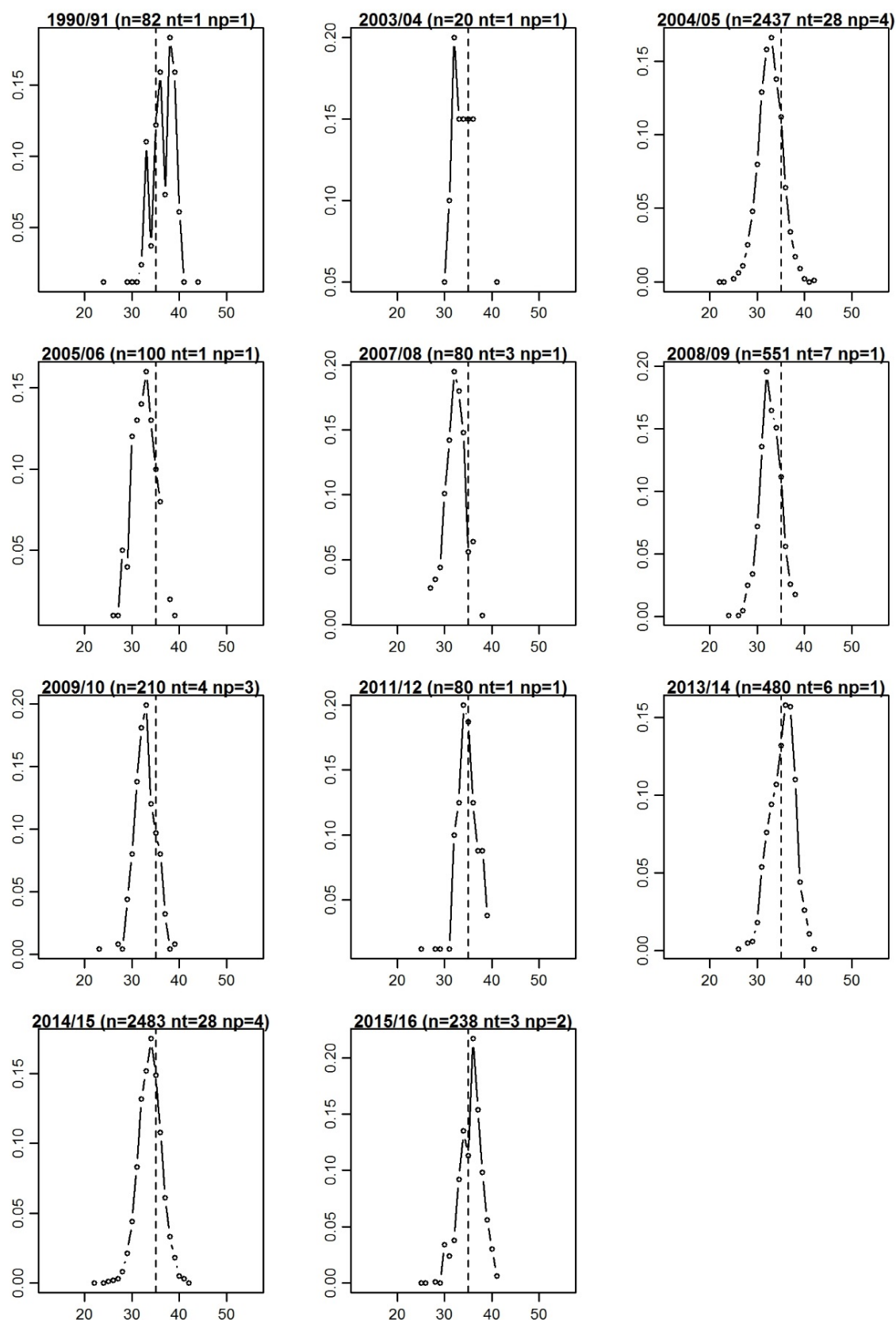


Figure 16: Catch-weighted length-frequency distributions for orange roughy in the Northwest Chatham Rise (flat) subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

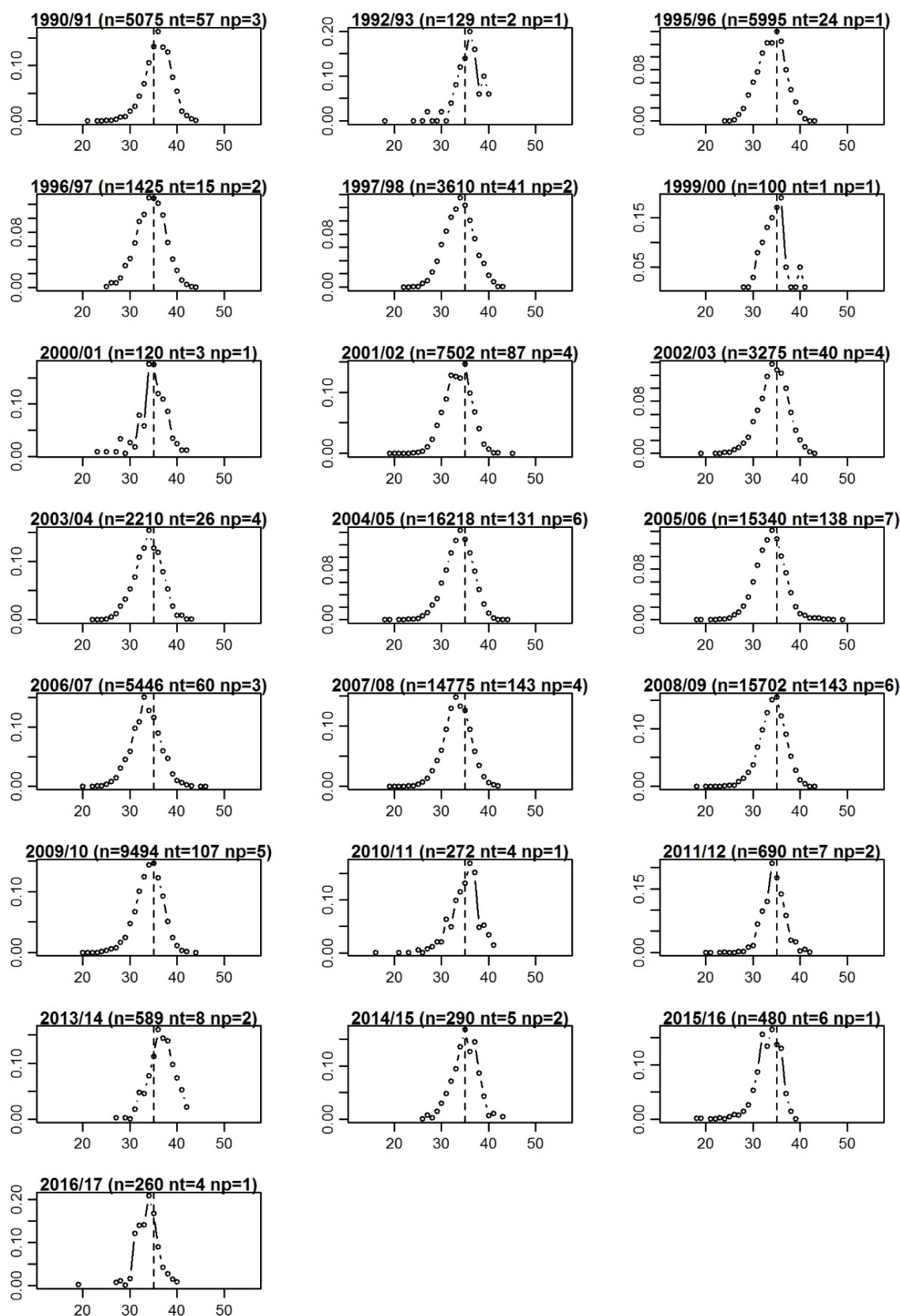


Figure 17: Catch-weighted length-frequency distributions for orange roughy in the Spawning Box (not Spawning Plume, nor Rekohu) subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

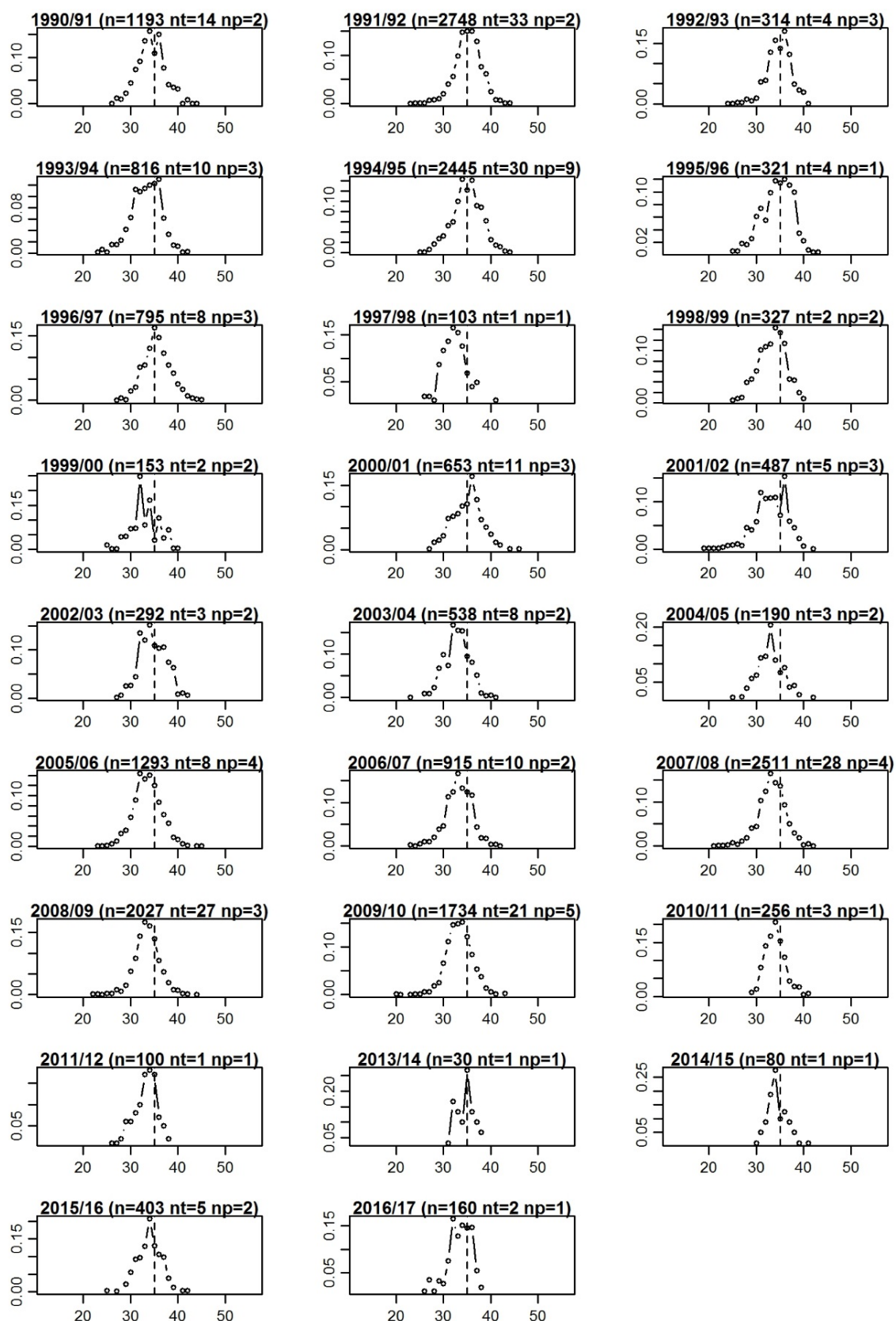


Figure 18: Catch-weighted length-frequency distributions for orange roughy in the Smith's City & neighbours subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

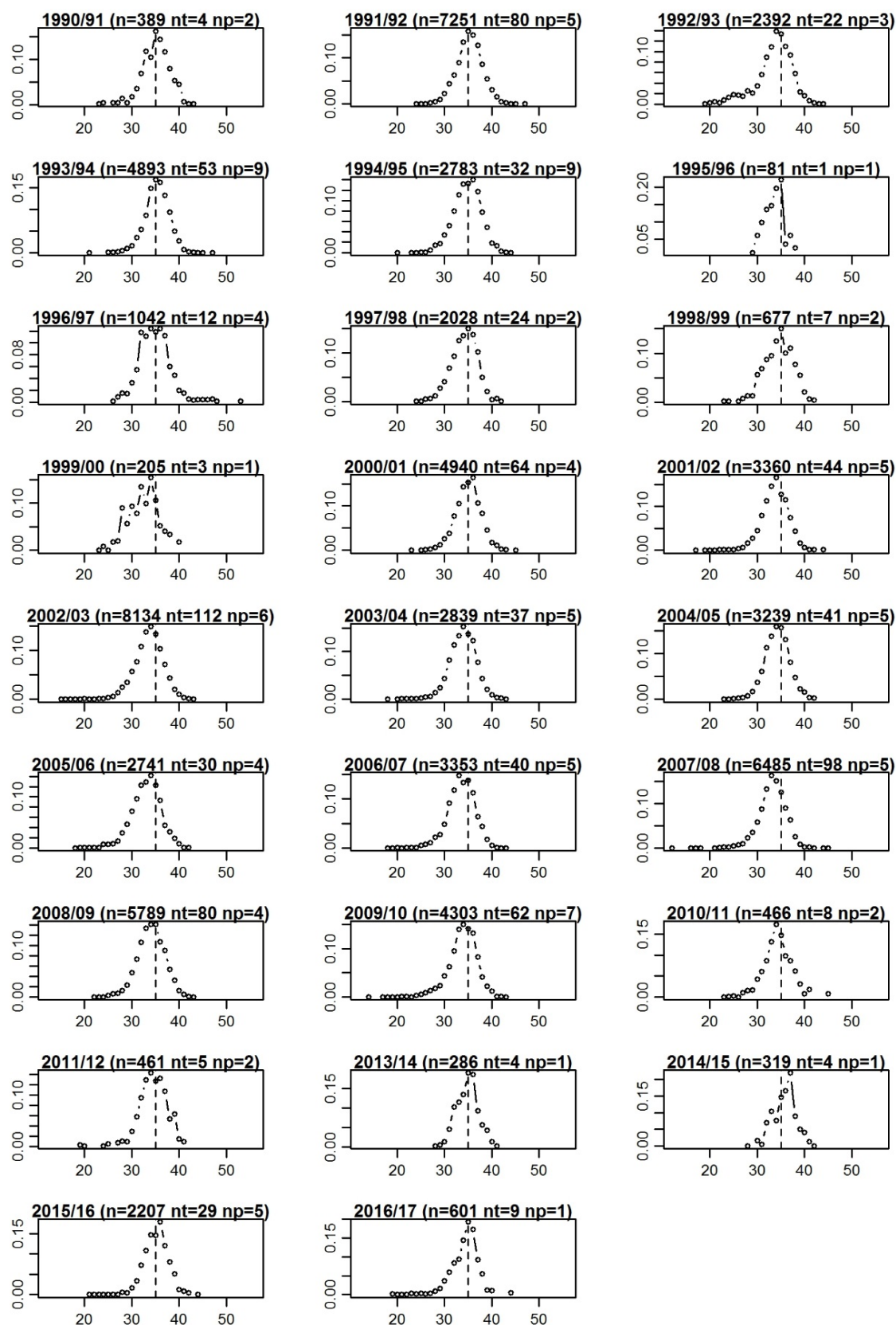


Figure 19: Catch-weighted length-frequency distributions for orange roughy in the East Chatham Rise Flats subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

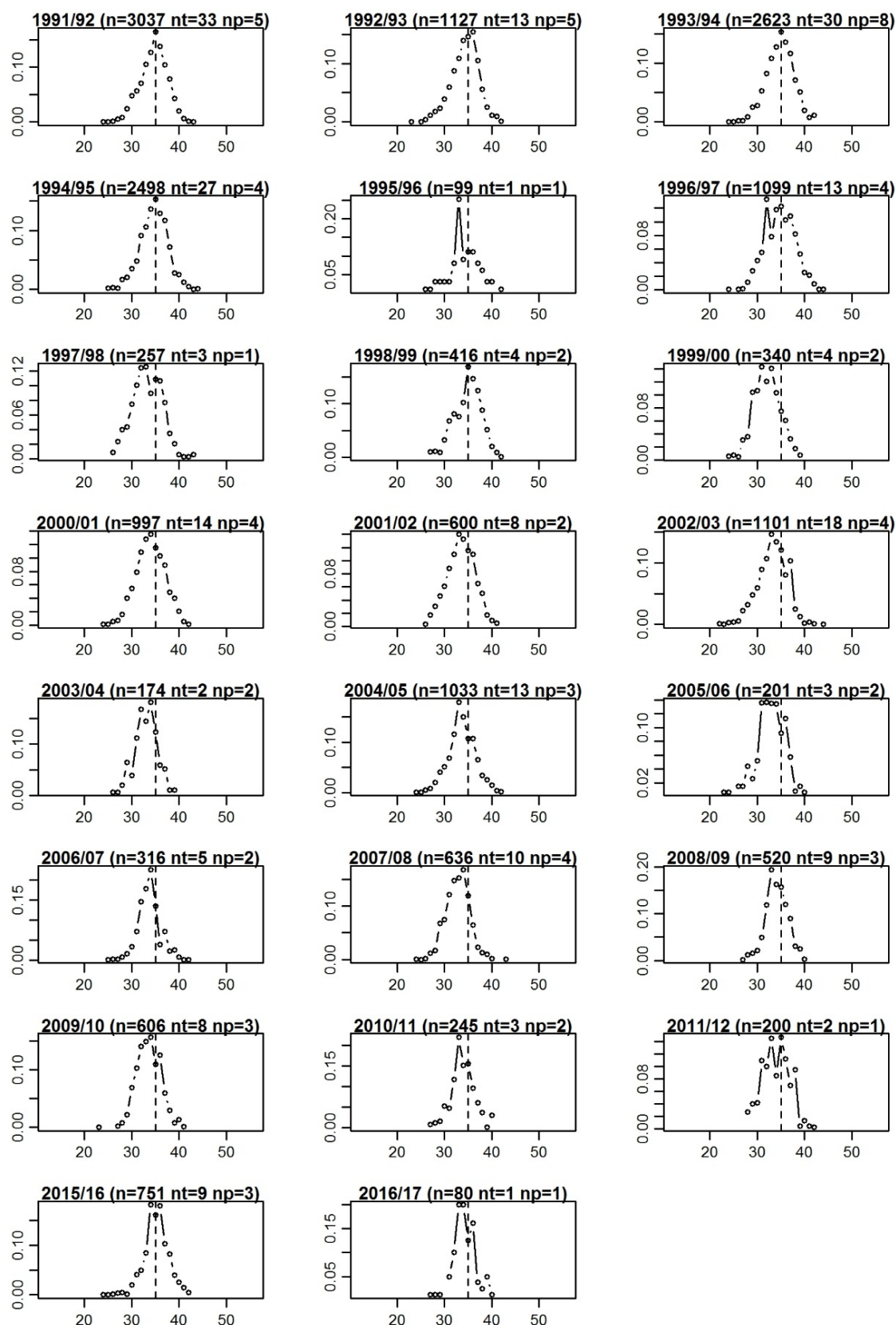


Figure 20: Catch-weighted length-frequency distributions for orange roughy in the Andes subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

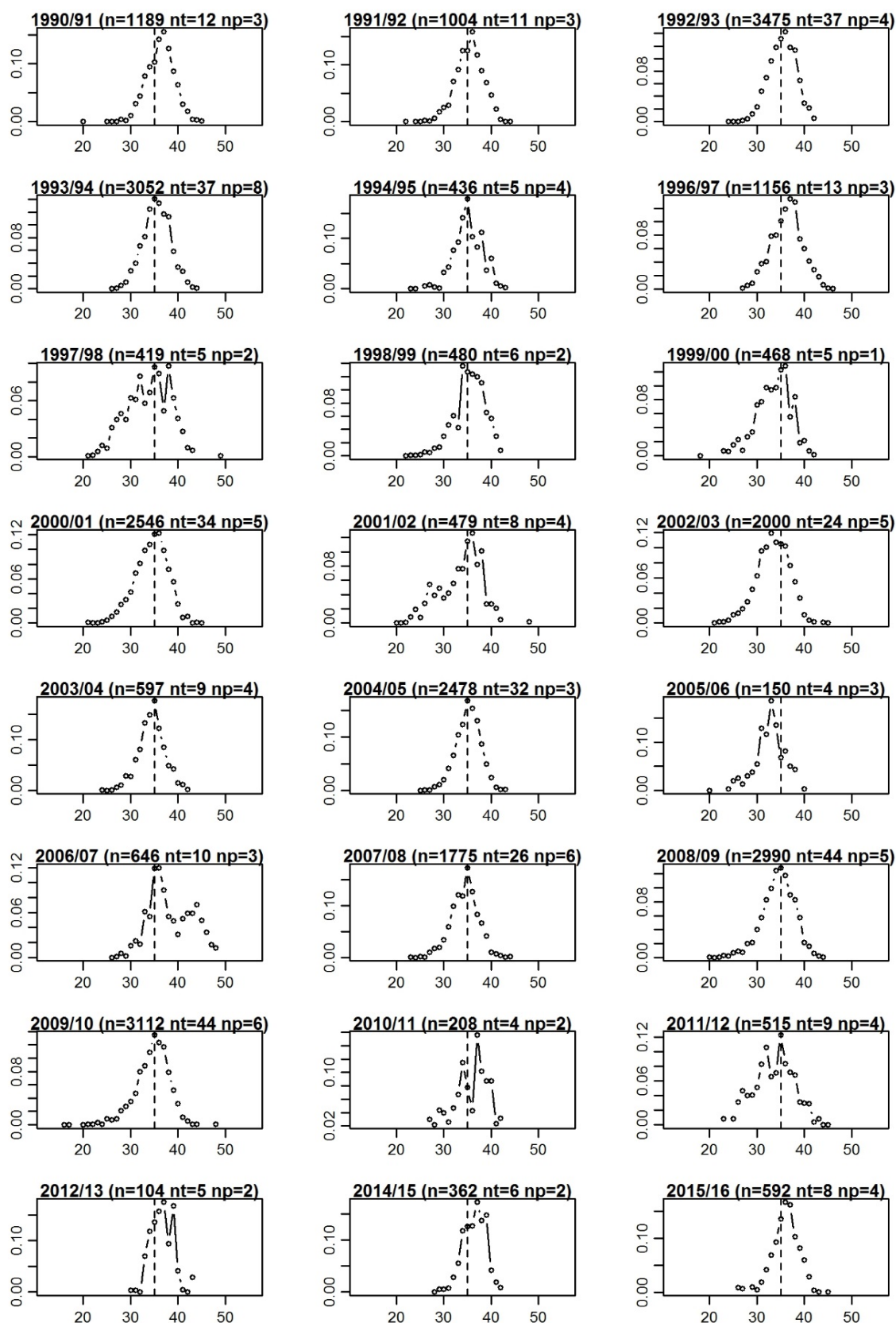


Figure 21: Catch-weighted length-frequency distributions for orange roughy in the South Chatham Rise Hills (Chiefs, Hegerville etc) subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

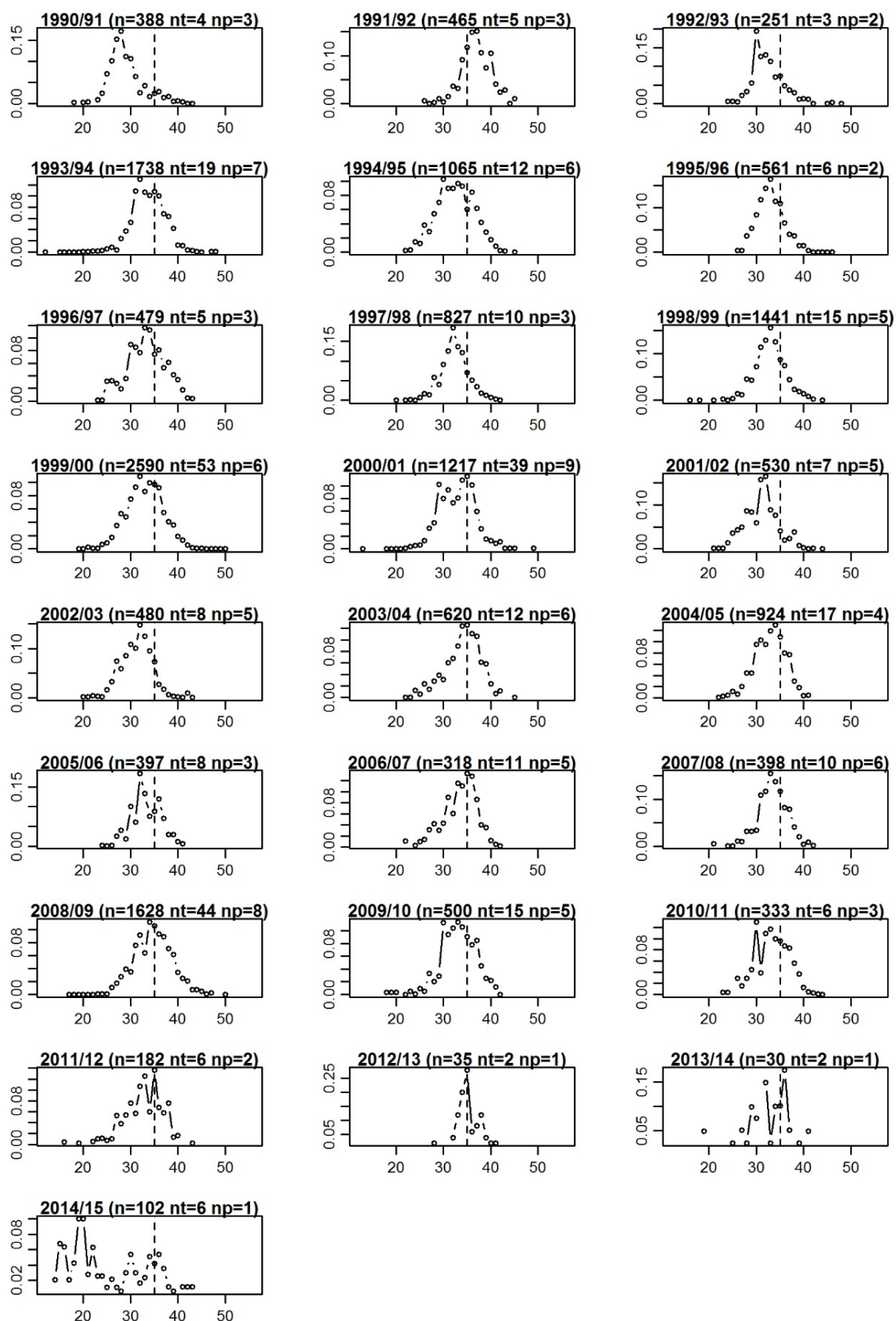


Figure 22: Catch-weighted length-frequency distributions for orange roughy in the South Chatham Rise Flats subarea of ORH 3B. Vertical broken line marks 35 cm SL (arbitrary point shown for reference). n, number of fish measured; nt, number of tows sampled; np, number of trips sampled.

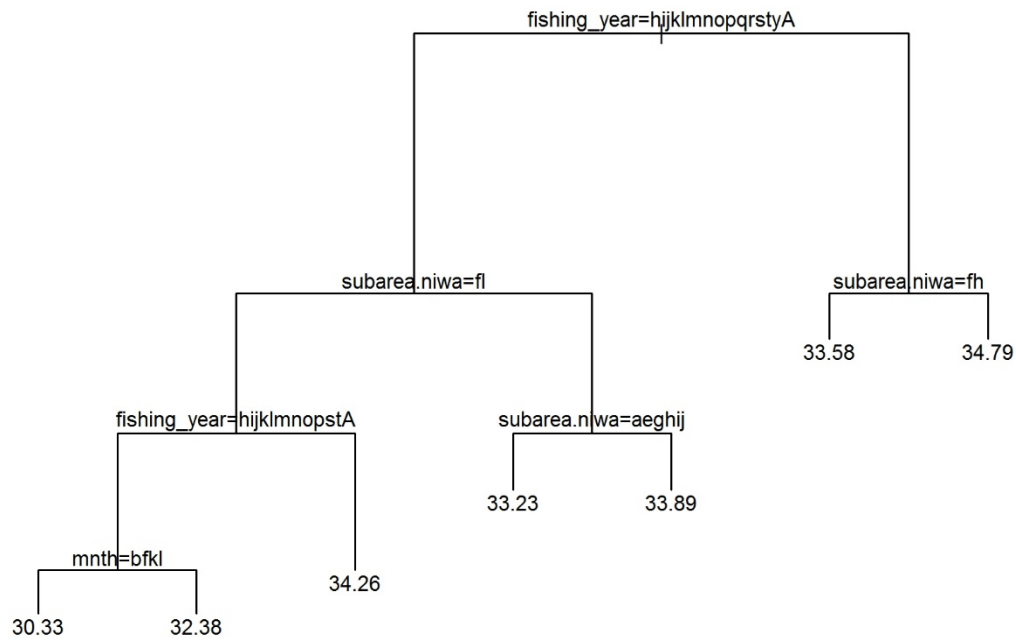


Figure 23: Classification tree for median orange roughy length by tow in ORH 3B Chatham Rise (n tows = 2951). At the first split, fishing years to the left-hand side are 1997–98 to 2009–10, 2014–15 and 2016–17 (mean length 33.4 cm); to the right-hand side are 1990–91 to 1996–7, 2010–11 to 2013–14, and 2015–16 (mean length 34.6 cm). Subarea.niwa f, Northwest Chatham Rise (flat); g, South Chatham Rise (flat); k, the Hole. Dist_hill, distance from summit of nearest hill (km). Subarea aeghij are South Chatham Rise, Hegerville & surrounds, Andes, Smiths City & neighbours, Spawning Box (not plume) and Rekohu (otherwise Big Chief & neighbours, East Chatham Rise (flat), Graveyard, and Spawning Plume). Fishing years at split on left hand branch; to the right, 2005–06 to 2007–08; to the left, 1997–98 2005–06, 2008–09, 2009–10, and 2016–17 (otherwise 2006–07, 2007–08, and 2014–15). Mnth bfkl are Feb, Jun, Nov and Dec (otherwise Mar–May, Jul, and Oct).

A suggested stratification of subareas is given in Table 6. The stratification for the Northwest Chatham Rise is straightforward. A stratification for the East & South Chatham Rise is less clear. Although the analysis of mean length could support separating the Spawning Plume and Rekohu, these two spawning areas are treated as components of a single spawning stock in the assessment model, and so are combined here; the suggested stratification puts samples from the spawning season and the Spawning Plume and Rekohu into the same stratum (Table 6). The most western reaches and most southern reaches of flat ground within the East & South Chatham Rise are separated and described as “surround”; being Rekohu (non-spawning), Spawning Box (non-spawning), and the flat areas of the south Chatham Rise (see Section 2.1). The other regions outside of these strata, where most catches have been taken from hill areas such as Chiefs, Andes, and northeast Hills (Section 2.1), are the “main” area.

The orange roughy in the Northwest Chatham Rise Flat were smaller than seen elsewhere on Chatham Rise, with those on the Northwest Chatham Rise Hills a similar size to those seen on the East & South Chatham Rise (Figure 24). The 1990–91 samples indicated relatively large fish, but the samples may be anomalous due to poor observer coverage (see Figure 12). The mean length in the East & South Chatham Rise Main appeared to decline slowly between the early 1990s and 2009–10, whereas the mean length in Surround and Plume appeared stable. The mean length for Main appeared to be greater than for Plume, suggesting fish on the hills may be larger than seen in the plumes (or smaller mature fish were not seen on the hills).

Table 6: Number of tows by subarea allocated to suggested strata for estimation of length frequency distributions.

	Northwest Chatham Rise Flat	Northwest Chatham Rise Hills	East & South Chatham Rise: Main	East & South Chatham Rise: Plumes	East & South Chatham Rise: Surround
Andes	0	0	233	0	0
Big Chief & neighbours	0	0	288	0	0
East Chatham Rise Flat	0	0	905	0	0
Graveyard	0	269	0	0	0
Hegerville & surrounds	0	0	110	0	0
NW Chatham Rise Flat	390	0	0	0	0
Rekohu (plume)	0	0	0	35	48
South Chatham Rise Flat	0	0	0	0	325
Smith City & neighbours	0	0	245	0	0
Spawning Box	0	0	0	0	740
Spawning Plume	0	0	0	312	0
The Hole	10	0	0	0	0

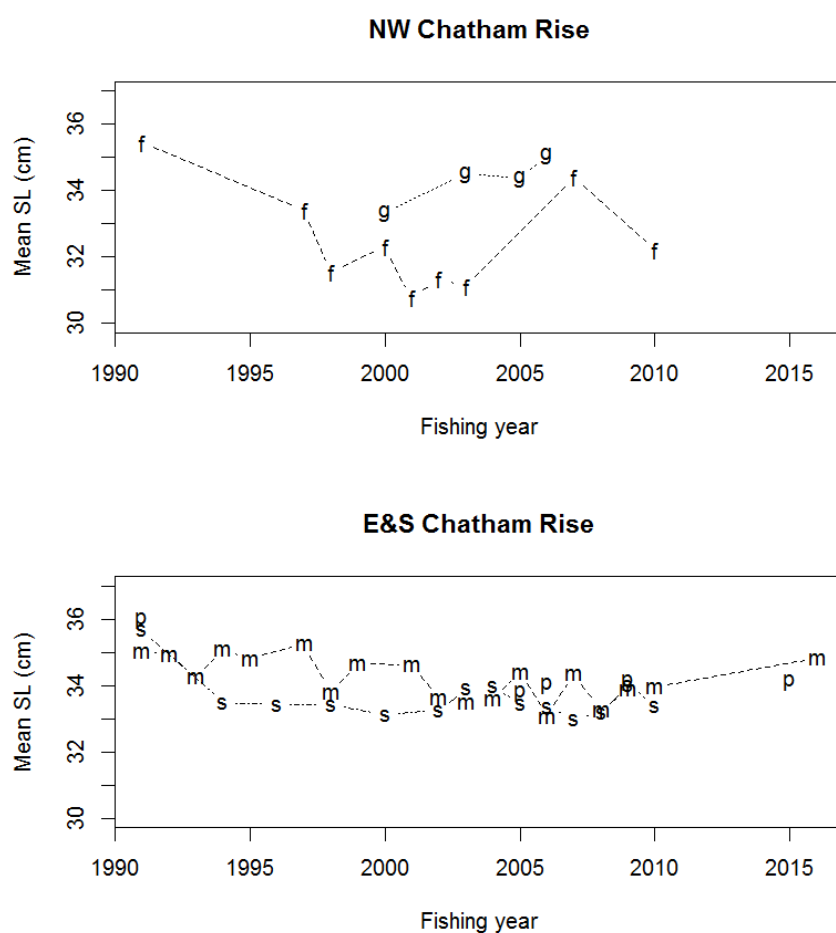


Figure 24: Mean length of orange roughy from stratified observer samples (see Table 5). f, Northwest Chatham Rise Flat; g, Northwest Chatham Rise Hills; m, East & South Chatham Rise main; s, East & South Chatham Rise surrounds; p, East & South Chatham Rise Plumes.

The overall samples of female orange roughy maturity stage had a good spatial coverage (Figure 25), with females at stage 3 (ripe) found in most areas sampled, those at stage 4 (running ripe) found over a smaller spatial area consistent with known major and minor spawning locations at (clockwise from top left) the Hole, Graveyard, Rekohu, Spawning Box, Northeast Hills, Not 'Till Sunday, the Andes, the Chiefs, and intermittently on the South Rise (most notably near Mt. Kiso). Samples including stage 4 females where catches were relatively large (more than 2 t) produced a similar pattern, with less occurrence on the South Rise.

The timing of spawning can be measured by the progression of stages 3, 4, and 5 (spent), with 50% at stage 4 or 5 often used as measures of the time of the start and end of spawning respectively. The female maturity stage data suggested that spawning was simultaneous throughout the Chatham Rise, and generally started in late June or early July (Figure 26). The occurrences of females at stages three and five earlier in the year could not be excluded as obvious errors.

The sex ratio of orange roughy was skewed towards females in most subareas, and towards males in Rekohu, Graveyard, and possibly Spawning Plume (Figure 27). This pattern suggests that males may predominate in spawning aggregations, whereas females may predominate in background areas and fisheries on hills. There were no obvious temporal trends in sex ratio in any subarea.

A classification tree analysis was used to investigate patterns in the sex ratio, using a similar methodology to the mean length analyses. The response term was the proportion female in each tow where at least twenty fish were measured. The resulting sex ratio-based stratification was limited to subarea and fishing year (Figure 28). The proportion female was lower for subareas on the north Chatham Rise known to support spawning aggregations. Outside of these areas, the proportion female varied by year.

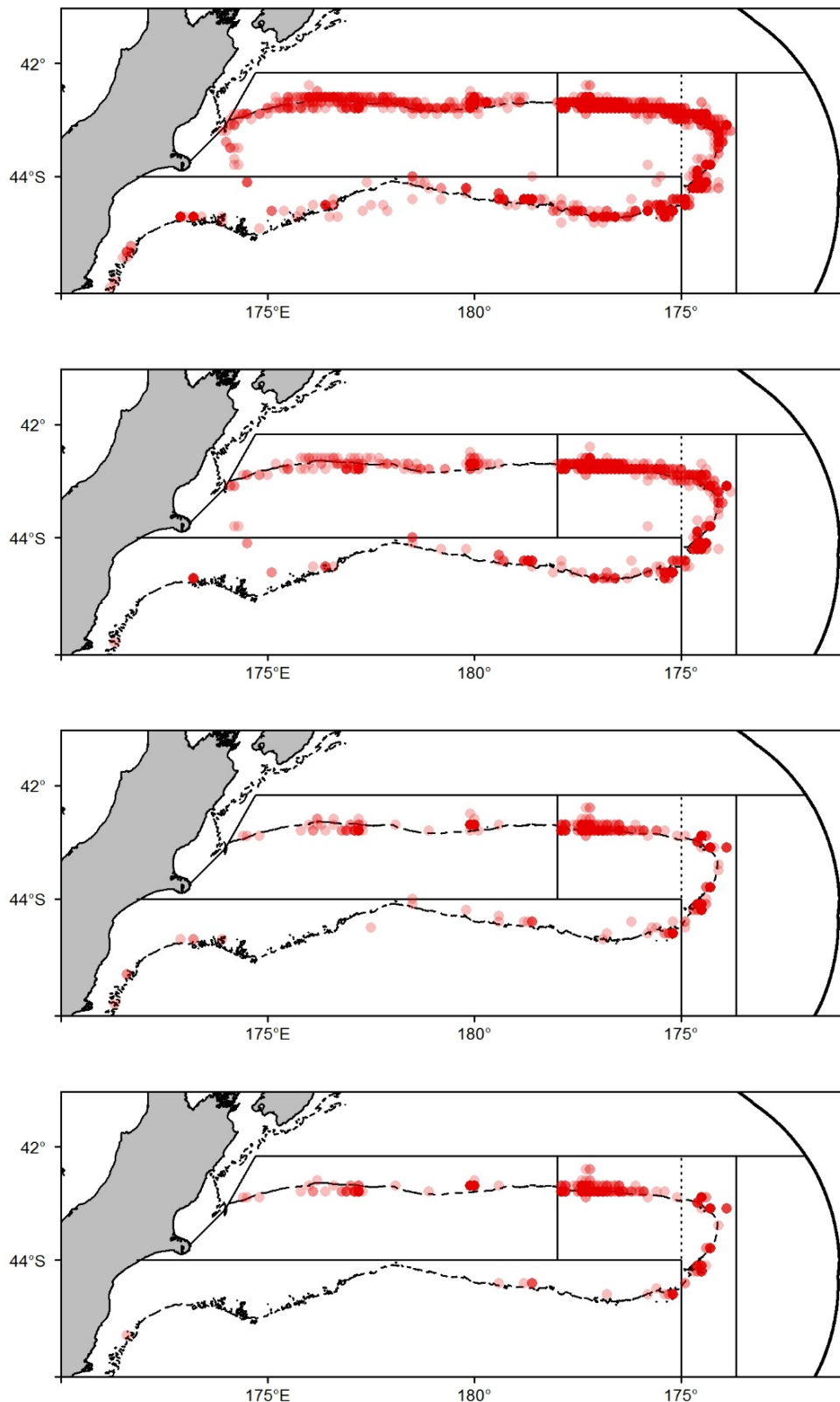


Figure 25: Location of female orange roughy sampled for mature stage on Chatham Rise. Tows which sampled female orange roughy from top; any maturity stage; ripe (stage 3); ripe and running (stage 4); ripe running and where catch weight was more than 2 t.

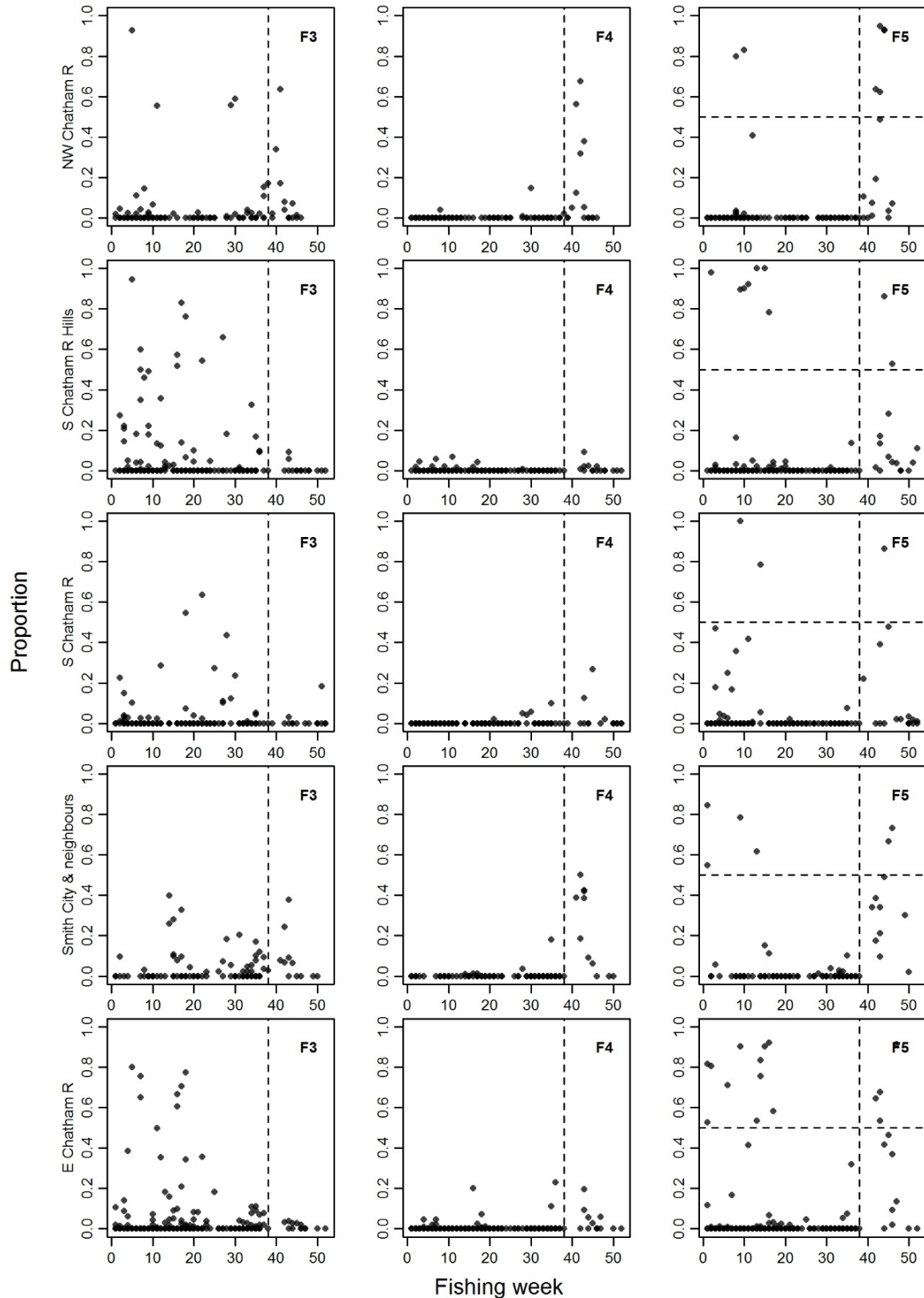


Figure 26: Proportion of female orange roughy in samples (dots) at maturity stages ripe (F3), running ripe (F4), and spent (F5), by week of the fishing year, and by subarea, for catches where 10 or more female orange roughy were sampled. The vertical broken line marks week 38, which is the 3rd week of June. The horizontal broken line in panels for F5 mark 0.5.

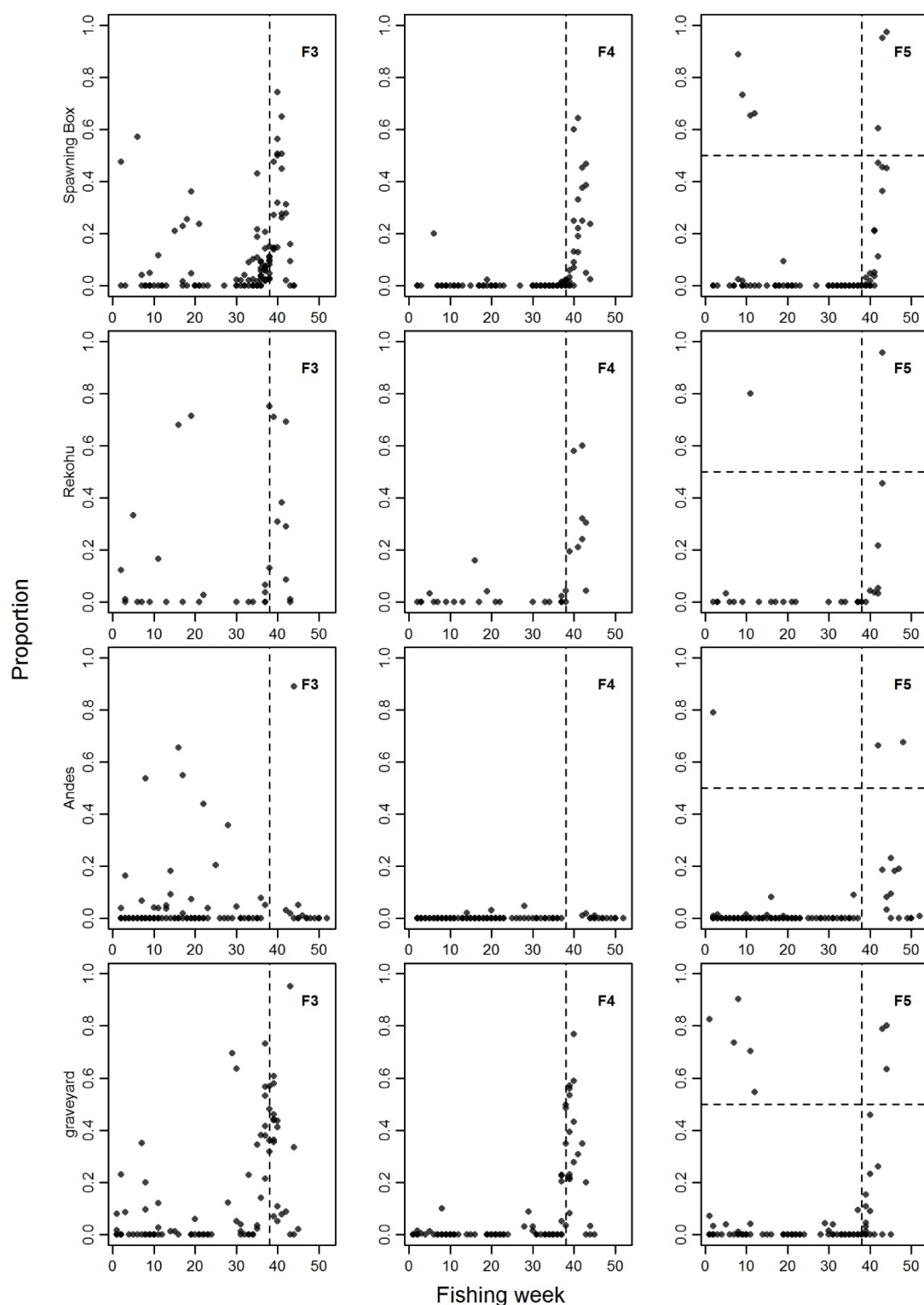


Figure 26 (cont.): Proportion of female orange roughy in samples (dots) at maturity stages ripe (F3), running ripe (F4), and spent (F5), by week of the fishing year, and by subarea, for catches where 10 or more female orange roughy were sampled. The vertical broken line marks week 38, which is the 3rd week of June. The horizontal broken line in panels for F5 mark 0.5.

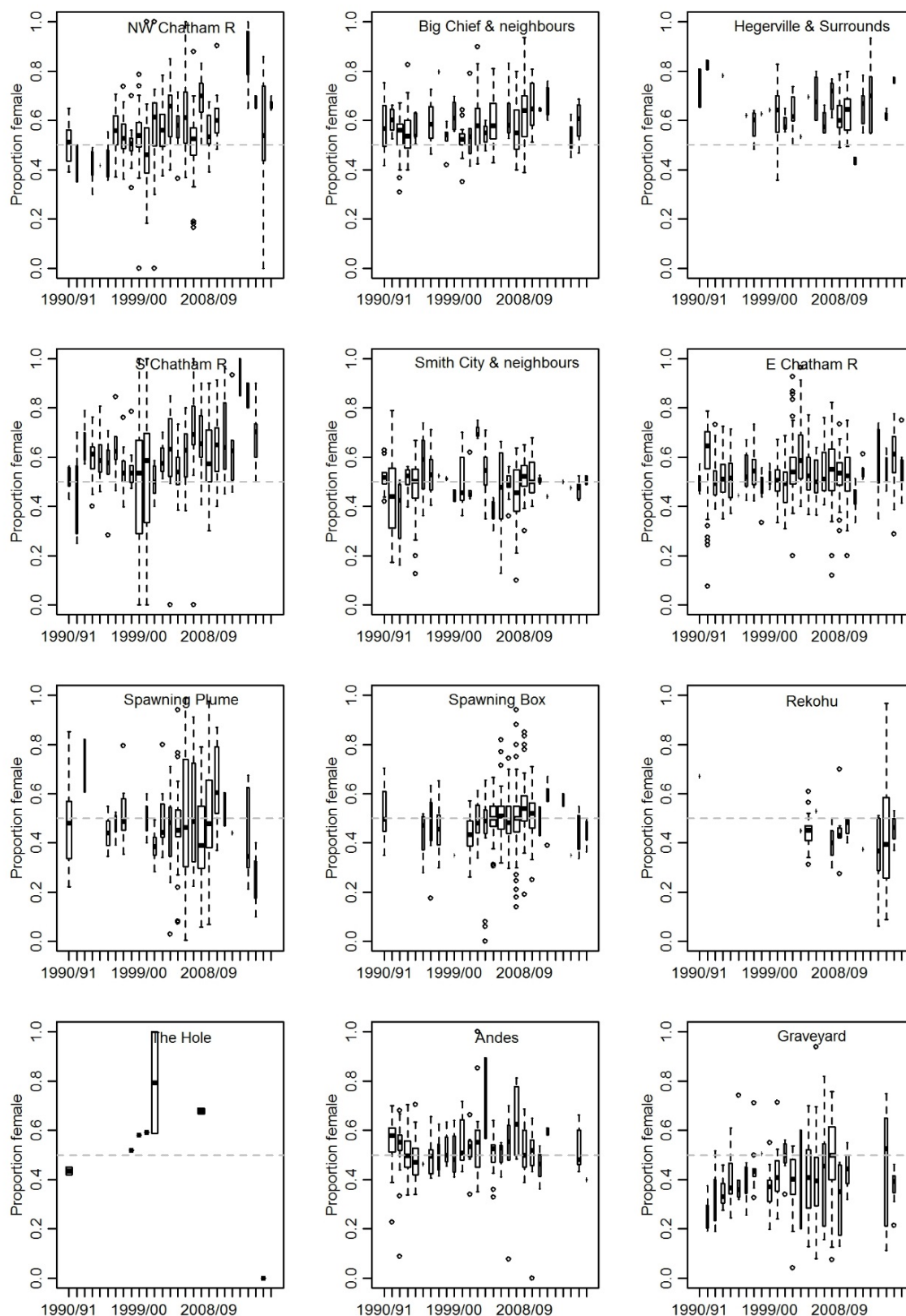


Figure 27: Box plot of annual proportion female of orange roughy by tow (unweighted) by subarea. Horizontal broken lines marks 50% female.

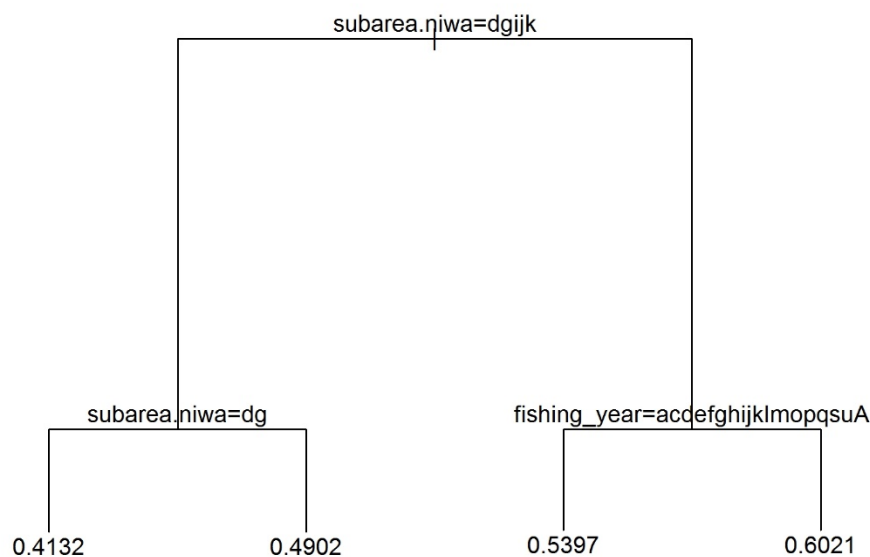


Figure 28: Classification tree for orange roughy proportion female by tow on Chatham Rise (n tows = 3492). Subarea.niwa dgijk are Graveyard, Rekohu, Spawning Plume, Spawning Box, and Smiths City & neighbours. Fishing years split on right hand branch are 1990–91, 1992–93 to 2002–03, 2004–05, 2006–07, 2008–09, 2010–11, and 2016–17 (otherwise 1991–92, 2003–04, 2007–08, 2009–10, 2011–12 to 2015–16).

4. DISCUSSION

The fishery characterisation suggested that virtually all of the suitable grounds for commercial catches of orange roughy on Chatham Rise has now been explored. The recent performance of the fishery, in terms of catch and catch rates, was much the same as that observed during the last characterisation (seven years previous), although the fishery unstandardized catch rates did increase over the intervening period when catches were reduced (catches being increased for 2015–16). This change would be consistent with the anecdotal reports of greater disturbance of orange roughy marks on features resulting in reduced catch rates.

There were substantial length composition data available for the fishery. When used in stock assessment models these data can be influential, because small changes in mean length can imply large changes in mean age (interpreted as changes in year class strength or fishing mortality rate), because of the slow growth of orange roughy. Variability between length composition samples within stocks was large, as is common for orange roughy, and had spatial and temporal components. However, systematic variability was not necessarily stable over time (in that median length from different time periods might stratify differently). As a result, whether strata for estimation of length compositions would remain robust into the future is unclear. An agreed sub-stock structure determined from holistic analyses may be the best way of determining fishery units for which length compositions will be generated, rather than using analyses of length data alone.

Sex ratios were sometimes skewed, although this was not as pronounced as in some other regions (e.g., Dunn 2017). It is possible that males were more prevalent on spawning grounds because males spawn more often than females (i.e., skip spawning less often), or because males linger on spawning grounds whereas females spawn and then leave. Years when the sex ratio changes, e.g., was closer to 50% female on the South Chatham Rise, might indicate sex-specific variability in the proportion of fish leaving to spawn elsewhere. An analysis of the relationships between sex ratio and CPUE for subareas might therefore provide some insight into the variability in the proportion spawning. In addition, changes in

the relative importance of the subarea fished may produce a biased sex ratio in the overall catch, and ultimately in the population; current stock assessment models in New Zealand ignore sex ratio.

5. ACKNOWLEDGMENTS

This work was funded by the Ministry for Primary Industries project DEE2016/21. My thanks to the members of the Deepwater Fisheries Assessment Working Group for peer-review of the research, and Owen Anderson (NIWA) for useful comments on the draft report. Thanks to Kevin Sullivan and Marianne Vignaux (both MPI) for comments and editorial review of the final draft.

6. REFERENCES

- Anderson, O.F.; Dunn, M.R. (2012). Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, 7A, and 7B to the end of the 2008–09 fishing year. *New Zealand Fisheries Assessment Report* 2012/20. 82 p.
- Clement & Associates Ltd (2015). New Zealand commercial fisheries: The atlas of area codes and TACCs 2013/14. Auckland, New Zealand. 116 p.
- Dunn, M.R. (2017). Orange roughy fisheries around northern New Zealand. *New Zealand Fisheries Assessment Report* 2017/46. 77 p.
- McMillan, P.; Clark, M. (2015). Summary of published sources of Chatham Rise orange roughy catch history, October 2015. Final Research Report to Ministry for Primary Industries SEA2015–01. 8 p.
- Ministry for Primary Industries (2016). Ministry for Primary Industries. Fisheries Assessment Plenary, May 2016: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1556 p.
- Rowden, A.A.; Oliver, M.; Clark, M.R.; MacKay, K. (2008). New Zealand’s “SEAMOUNT” database: recent updates and its potential use for ecological risk assessment. *New Zealand Aquatic Environment and Biodiversity Report No. 27*. 49 p.