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A summary of biological information on the New Zealand
fisheries for orange roughy (*Hoplostethus atlanticus*) for the
2003-04 fishing year

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EXECUTIVE SUMMARY

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1. Size and reproductive data on orange roughy, collected by observers of the Ministry of Fisheries Observer Programme (OP) and from NIWA research surveys, were examined and summarised by fishery. Data were available from 290 OP tows during the 2003–04 fishing year, from both inside and outside the New Zealand Exclusive Economic Zone (EEZ). Biological data collected during research surveys on the Chatham Rise and in the sub-Antarctic were also summarised.
2. The level of OP sampling was less than half that of the previous year, and the lowest since 1996–97. Although the overall number of samples was only two-thirds of the scheduled number, one area, ORH 1, received four times the sampling effort scheduled. In contrast, in ORH 2A South none of the 40 scheduled samples were collected. Coverage of fisheries within ORH 1 was particularly good, with the main fishing grounds sampled, but coverage of the east coast fisheries (ORH 2A, ORH 2B, and ORH 3A) and some of the ORH 3B fisheries was low. Sampling of fisheries outside the EEZ was also low, with two-thirds of the scheduled number of samples collected from the Louisville Ridge, and only one quarter of the scheduled samples collected from the Lord Howe/NW Challenger fisheries.
3. Sufficient length samples were obtained to determine size frequencies for 11 fishery/season combinations. These distributions were typically unimodal in most areas, although there was considerable variation between areas in the range of fish sizes and the calculated mean lengths. The smallest fish were from NW Rise (ORH 3B) (mean length 30.8 cm for males and 33.1 cm for females) and the largest from the Colville Ridge (43.6 cm for males and 47.0 cm for females). A large amount of biological data was collected from research surveys, but this was mostly restricted to the Northeast Chatham Rise.
4. In most areas, sex ratios calculated from scaled observer size frequency data did not indicate a strong dominance of one sex, with most of the calculated ratios falling within 20 percentage points of 50%. The most biased sex ratios were from the Colville Ridge spawning fishery (28.4% male) and the east Northland spawning fishery (85.0% male).
5. In several fisheries, sampling during the spawning period was sufficient to allow an estimate of the temporal progression of spawning to be made. The timing of spawning closely matched that of previous years in the East Northland fishery, but appeared to be earlier than usual in the Spawning Box fishery and possibly also in the East Rise fishery.

1. INTRODUCTION

This report documents the results of objective 3 of the Ministry of Fisheries project ORH2004/02 “Orange roughy stock assessment”, and objective 2 of Ministry of Fisheries project ORH2004/03 “Stock assessment of orange roughy fisheries outside the New Zealand EEZ” which both state:

“To analyse length frequency, sex ratio, and reproductive data for orange roughy collected by the Observer Programme and from other sources during the 2003–04 fishing year, for input into stock assessment models.”

Biological data collected by observers can be important inputs to stock assessment of orange roughy in New Zealand. This is especially true for areas where there are no independent estimates of biological parameters, such as age at recruitment or age at maturity, or of changes in population size structure over time available from research surveys. These parameters can be derived from observer-collected size and reproductive stage information where data meet certain requirements that minimise any bias associated with commercial fishing operations, such as non-random sample selection or lack of comparability (Francis & Tracey 2000). Such information from observer data has been incorporated into stock assessments for the Lord Howe Rise, northeast Chatham Rise, East Cape hills, and Mid-East Coast (MEC) fisheries (Clark & Tilzey 1996, Hilborn et al. 2000a, 2000b, Branch et al. 2002). Reproductive stage data collected by observers are also important for examining trends such as changes in timing and location of spawning activity (e.g., Smith et al. 2002). Changes in mean length over time determined from observer data have been used to identify areas of heavy exploitation and provide clues to recruitment patterns (Francis & Smith 1995). Sex ratio information from observer data has been used to identify a selectivity bias in a fishery (Francis 1996).

This report presents summaries of orange roughy size and reproductive state data collected from fisheries throughout the EEZ (project ORH2004/02), and from several fisheries outside the EEZ (referred to in this report as ET fisheries, project ORH2004/03), during the 2003–04 fishing year. These summaries are constructed and presented in a manner consistent with that used in previous analyses of orange roughy biological data (e.g., Anderson 2004) to provide a means of quickly identifying and obtaining data for input into stock assessment models.

This report also presents summaries of orange roughy biological data collected during a research survey on the Northeast Chatham Rise (Spawning Box and East Rise, ORH 3B), and the location of station positions where small amounts of orange roughy biological data were collected on other research surveys in 2003–04. For the first time in several years no data are available from the observer programme of the Orange Roughy Management Company Limited (ORMC), which has ceased to operate. Previous data from this programme are referred to in this document, however, and the abbreviations OP and ORMC are used to distinguish between data from the Ministry of Fisheries and industry programmes, respectively.

2. DATA COLLECTION

Orange roughy biological data were collected by OP observers hosted aboard commercial fishing vessels. Observers took measurements from random samples of about 100 fish (range 2–125) per trawl, from up to five trawls a day. The standard length (SL) and sex of these fish, and reproductive condition of female fish, were recorded along with the weight of the sample and of the entire orange roughy catch. These data are managed by staff at NIWA, Greta Point, and held on the Empress *obs_lfs* database.

Biological data collected from R.V. *Tangaroa*, F.V. *Tasman Viking*, and F.V. *San Waitaki* during an orange roughy research survey on the Northeast Chatham Rise in July 2004, and from *Tangaroa* during surveys of hoki on the Chatham Rise in December 2003 to January 2004 and a multispecies survey in the sub-Antarctic in November–December 2003 are also presented. These data are held at NIWA, Greta Point, on the Empress *trawl* database.

3. METHODS

The OP records and manages data according to broad areas based on Fishery Management Areas (Figure 1). For this summary, data were arranged by Quota Management Area (QMA) or by recognised fisheries within each QMA where there were sufficient data to produce meaningful size frequencies, and by recognised fisheries outside the EEZ (see Figures 2 and 3). These fishery areas are comparable to those used in previous analyses (e.g., Anderson 2004).

All data were error checked before being added to the databases, and again before any analyses were begun. Tow positions were plotted to identify any outliers or impossible tow sequences caused by misrecording of position, and length and catch data were checked for unlikely values.

Catch and effort data from the orange roughy commercial fisheries were summarised to determine the level of OP observer coverage achieved in each of the main fisheries in 2003–04. Coverage was determined based on the proportion of the total catch observed in each fishery. These data came from extracts from Ministry of Fisheries databases held on the Empress database *dw_cdb* at NIWA, Greta Point. The level of OP observer coverage, in number of samples, was also compared to the level of coverage scheduled for the year for each fishery by the Ministry of Fisheries.

3.1 Size structure

Length frequency distributions were determined from the OP sampling data for each fishery and season where at least five tows were sampled and more than 400 fish measured. Samples were combined when they were entirely preceding, entirely within, or entirely subsequent to the period 1 June to 31 August, to approximate pre-spawning, spawning, and post-spawning sampling respectively. Size frequencies were scaled according to the fraction of the catch sampled for that tow, so as to be representative of the total catch sampled. In the few cases where the sample weight was not recorded, it was estimated by applying the standard orange roughy length-weight function (Annala et al. 2001) to the length frequency from the sample. For each length frequency prepared, sex ratios (percentage male) and the mean length of male and female fish (with normal standard deviations) were calculated from the combined length composition.

The research survey of the Northeast Chatham Rise (ORH 3B) orange roughy fishery involved a trawl survey on background flat areas of the Spawning Box and East Rise, as well as target identification trawls on aggregations surveyed acoustically in the Spawning Box and on hills. A closer examination of size frequencies of orange roughy from the survey will form part of the survey analysis but, for the purposes of this summary, overall size frequencies were prepared from fish measured in each of the two areas (Spawning Box and East Rise), in the same way that observer data were treated. There were insufficient fish measured (less than 400) in both the Chatham Rise hoki and sub-Antarctic middle-depth species surveys to produce meaningful size frequencies.

3.2 Reproduction

Due to difficulties in interpretation of the macroscopic stages of male orange roughy, observers examined gonads only from female fish. These were checked for reproductive state and assigned to one of the following (macroscopic) categories.

- F1 Immature to early maturation
- F2 Maturing
- F3 Ripe
- F4 Running ripe
- F5 Spent

These categories are different from the eight categories used for orange roughy by NIWA research staff.

Gonad staging data were aggregated by month and fishery area and the proportion of female fish in each gonad stage was determined.

The reproductive states of female fish were examined to determine where and when spawning activity was occurring. Where time series data through the spawning period were available, plots were created to examine the progression of spawning. These were constructed by fitting a curve (a cubic “smoothing spline”, see Venables & Ripley (2000) for details) to daily values of the fraction of fish in each of the mature reproductive states (F2, F3/F4 combined, and F5) shown above. Equivalent plots were produced for both sexes from data collected during the Northeast Chatham Rise survey, and for female fish from data collected by OP observers in two other fisheries.

4. RESULTS

4.1 Distribution of samples

Ministry of Fisheries OP observers sampled 290 catches of orange roughy collected during 19 voyages with the number of samples per voyage ranging between 1 and 54 (median 10). The number of samples was less than scheduled in all areas except for ORH 1, where more than four times the scheduled number of samples was taken, and in the West Norfolk Ridge fishery (E.T.), where no sampling was scheduled (Table 1). About half of the 220 scheduled samples were collected from the Chatham Rise (ORH 3B), and a quarter to a third of the scheduled samples from the main E.T. fisheries. None of the 40 scheduled samples were collected from the ORH 2A South fishery, continuing a trend of very low sampling in this area over the last few years. The South of 46°S/Arrow Plateau areas of ORH 3B were sampled reasonably well. Overall, the total number of OP observer samples collected during the 2003–04 fishing year was only two-thirds of the scheduled number, was less than half the level of the previous year, and was the lowest overall level of sampling since the 1996–97 fishing year (Anderson 1999).

Monthly totals arranged by OP area, ORH 3B fisheries, ORH 1 fisheries, and other fisheries are shown in Table 2. A large fraction of the samples (61%) came from the SOE (Chatham Rise) and AKW (ORH 1) areas and a further 13% of samples were from the LOUR (E.T.) area. The other ORH 1 area (AKE), and the SUB (ORH 3B) and CET (E.T.) areas accounted for most of the remaining samples (21%). OP sampling provided 20 or more samples from each of the major fisheries on the Chatham Rise (northwest, east, southeast, and Spawning Box), with a lower level of sampling spread over several of the smaller “South of 46° S” fisheries, Pukaki in particular. Sampling was confined mainly to four fisheries in ORH 1, with 39 samples taken from the West Norfolk Ridge spread over 5 months. The Colville Ridge, East Northland, and Manukau fisheries were also well

sampled. The three central east coast QMAs (ORH 2A, ORH 2B, ORH 3A) were not sampled at all. Despite the overall low level of sampling, observer effort was well spread out over the fishing year, with 10 or more samples collected in nine of the months and only September not sampled at all. Fifty-seven percent of the samples came from October, February, and June.

Outside the EEZ, a large number of samples were collected from two voyages to the Louisville Ridge between June and August. A few samples were also collected from fisheries to the northwest of New Zealand's EEZ.

The positions of all tows from which OP samples were collected are shown in Figures 2 and 3. These figures also show the positions of all tows that caught orange roughy in the 2003–04 fishing year, according to TCEPR returns. Of the northern fisheries, the northwest Challenger grounds received considerable fishing effort, over a wide area, and nine samples were taken by observers. The more remote fisheries within ORH 1 were well covered by observers, especially the west Norfolk Ridge, but fisheries in the Bay of Plenty received no coverage. The level of coverage in ORH 1 was also high in comparison to the total commercial catch, with samples accounting for a third or more of the total estimated catch in four of the fisheries, including 97% of the Colville Ridge fishery catch (Table 3). Of the larger fisheries in other areas the Spawning Box and Louisville Ridge both received 9% coverage and the east Chatham Rise 7%. Two of the smaller fisheries in ORH3 B, Arrow Plateau (42%) and Auckland Islands (60%), also received a high relative coverage. The commercial fisheries on the Chatham Rise (ORH 3B) were well represented, with sampling well spread out over the four main fishery areas and several tonnes of fish measured in each. In the southern area of ORH 3B (south of 46° S), where fishing effort is spread over a wide area, samples were collected from five fisheries, collectively accounting for about 700 t of orange roughy catch in 2003–04 (Table 3). The sampling level in this region was greatest in the most productive of these fisheries, Pukaki, where observers covered 10% of the estimated catch in 14 samples. Coverage was extensive in the Louisville Ridge fishery, with samples collected from each of the North, Central, and South areas (see Clark (1998a, 1998b) for definitions of these areas) and more than 3 t of fish measured.

The locations of trawl stations in the three research surveys in which orange roughy were measured are shown in Figure 4. The data collected from the Northeast Chatham Rise survey complement those collected by observers from the Spawning Box and East Rise earlier in the year. Few orange roughy data were collected from the other two surveys, in middle-depth fishing grounds on the Chatham Rise and sub-Antarctic, which overlapped only the shallowest part of the orange roughy depth range, but these included several stations in the closed Puysegur fishery, where no trawling for orange roughy has been permitted since the 1996–97 fishing year. This survey has provided small amounts of biological data for orange roughy in several in recent years (see Anderson 2003, 2004).

Over 16 000 orange roughy were measured from a total (three vessel) catch of more than 690 t in the Northeast Chatham Rise survey, 229 orange roughy were measured from a catch of about 150 kg in the sub-Antarctic survey, and 22 orange roughy were measured from a catch of about 18 kg in the Chatham Rise hoki survey.

4.2 Size structure and sex ratios

Length frequency distributions by sex from OP samples are given in Figure 5. Strong unimodal distributions with generally even sex ratios and larger female fish, typical for orange roughy size structures, were found in most areas, e.g., the East Rise (Figure 5d). The main differences in the size distributions between areas were in the range of fish lengths measured and the position of the mode and, in a few areas such as the Louisville Ridge and West Norfolk Ridge (Figure 5g, k), broader size distributions with a less well defined peak. In the Spawning Box, fish sampled during the spawning months showed a size distribution similar in shape to that for fish sampled pre-spawning, with mean

lengths of both sexes less than 0.5 cm different, and sex ratios from both periods close to 50% male (Figures 5b, c).

Small fish, less than 25 cm, were uncommon in most areas, and appeared in the size distributions for only the NW Rise, SE Rise, and Manukau fisheries, where they represented only a few percent of the sampled population. Mean lengths of fish from the NW Rise fishery were slightly smaller than those from other areas (Table 4) with mean lengths of 30.8 cm (males) and 33.1 cm (females). In the fisheries from the Chatham Rise southwards few fish were measured at over 40 cm (generally less than 1–2%), with the exception of Pukaki, where 12% of the scaled sample were longer than 40 cm. In the northern (ORH 1) fisheries of east Northland, Colville Ridge, west Norfolk Ridge, and the Louisville Ridge (E.T.), fish greater than this size were common (Figure 5). The largest fish observed were in the Colville Ridge fishery where 93% of fish (sexes combined) were over 40 cm, mean lengths were 43.6 cm and 47.0 cm respectively, and fish of up to 56 cm were recorded. Observers have recorded similarly large fish in other years in this area (see Anderson 2001, 2003, 2004). As also noted previously, not all fisheries in ORH 1 contained large fish, with fish in the Manukau fisheries being of more average size (Figure 5j).

Sex ratios, based on scaled size frequency data, ranged from 28.4% male (Colville Ridge, spawning) to 85.0% male (east Northland spawning). Overall, there was no clear bias in the sex ratios in favour of one sex. Although 7 of the 11 fishery/area combinations showed a higher percentage of female fish, most of the sex ratios were close to 50:50, with 5 of the 11 calculated being within 10 percentage points of 50% male, and only 2 of the ratios calculated more than 20 percentage points from 50% male.

Two additional scaled length frequency distributions are presented from the Northeast Chatham Rise orange roughy research survey (Figure 6). Combined, these distributions represent data from more than 16 000 fish and 122 trawls. The size distribution for the Spawning Box showed a strongly unimodal distribution, with mean lengths 31.4 cm (male) and 32.8 cm (female) and a sex ratio of 42.7% male. These are slightly smaller than the mean lengths (32.9 cm (male) and 34.9 cm (female)) calculated from observer data from the same area at a similar time of year (see Figure 5b). The research data show that male fish in the East Rise were similar in length to those in the Spawning Box but female fish were smaller than in the Spawning Box and, unusually, slightly smaller than male fish from the same area (Figure 6, bottom). The sex ratio in the East Rise indicated a higher fraction of males than in the Spawning Box, but was not far from 50%. The observer size frequency for the East Rise spawning period (see Figure 5d) indicates mean fish lengths for both sexes which are 1–2 cm longer than shown by the research data, and a higher fraction of female fish.

4.3 Reproduction

Female fish were sampled for reproductive state by OP observers during spawning months (nominally June, July, and August) in several areas in 2004 and, for a few of these, an indication of the timing and location of spawning can be derived (Table 5). Much of the sampling in the ORH 1 fisheries coincided with the winter spawning fishery, with many fish in the samples from Colville Ridge, East Northland, and Tauroa Knoll in the ripe, running ripe, and spent stages. The records of large numbers of running ripe and spent fish in the Tauroa Knoll and West Norfolk ridge fisheries in October should be treated with caution, as this is far from the recognised spawning period for orange roughy. However, fish in this condition were also recorded (by different observers) in both of these areas at odd times in the previous year (Anderson 2004) and so the data are presented. Large numbers of fish in spawning condition were also recorded from the Spawning Box in July, and the Louisville Ridge in June, July, and August. Mature and spent fish were occasionally recorded in other areas at various times of the year.

There were sufficient reproductive data collected through the spawning period to make plots of the progression of spawning in several fisheries (Figures 7–9). Although there was a considerable amount of data from the Louisville Ridge fishery, there was little pattern in the data, and exploratory plots gave no clear indication of the timing of spawning. In the East Northland fishery (Figure 7, top), OP data show that the fraction of maturing female fish decreased from 60% to less than 10% in the week beginning 26 June, replaced by an increasing fraction of ripe/running ripe fish, which peaked on about 3 July. Spent fish began to appear in the samples from this date on, reaching about 50% by the middle of July. This timing is similar to the previous year (Anderson 2004).

In the Spawning Box fishery (Figure 7, bottom), a combination of OP and research data for female fish indicate that the peak of spawning occurred earlier than usual for this fishery, between about 4 July and 9 July. Previous estimates of peak spawning in the Spawning Box, from research and observer data, range between 14 July and 27 July (Anderson 2006). Spent fish began to appear in the samples from early July, and accounted for about 80% of mature fish by mid July. Research sampling began in this fishery just as OP sampling ceased, collecting a large amount of reproductive data for this fishery, and allowing the spawning progression, for both male and female fish, to be followed though most of July. The plot of spawning progression in male fish matches closely the plot for female fish (Figure 8), and supports the conclusion that spawning took place early in July.

On the East Rise, the research data were collected later in the spawning period, so that spent fish dominated in samples from 16 to 26 July (Figure 9). Ripe and running ripe fish still accounted for 10–20% (male) and 20–40% (female) of mature fish up until about 20 July, although the peak of this fraction is likely to have occurred several days to a week before sampling began on 16 July.

5. SUMMARY AND DISCUSSION

Observer coverage. The number of samples collected by OP observers this year was the least since 1996–97, reversing the trend of increasing coverage in this fishery over recent years. The number of samples was only two-thirds of that scheduled and less than half the level of the previous year. The spread of sampling was uneven, with the important ORH 2A South fishery not sampled at all (continuing the pattern of low to no coverage in this area) and others, such as ORH 1 and the Louisville Ridge (E.T.) fishery, again receiving a disproportionately high level of sampling. Thirty percent of the samples for 2003–04 were taken from ORH 1, and a further 39% were taken from the Chatham Rise fisheries. No samples were collected from the east coast fisheries in ORH 2A, ORH 2B, and ORH 3A. Sampling levels in ORH 1 were high (due mostly to the requirements of the Adaptive Management Programme currently operating in this fishery) and, as in the previous two years, samples were collected from the main fisheries in this QMA. Sampling levels in the ET fisheries were variable, with good coverage of the Louisville Ridge but very few samples from anywhere else and far less than scheduled in the Lord Howe/northwest Challenger fisheries. There was no sampling in the SW Chatham Rise, Fiordland, and Cook Canyon fisheries, and only sporadic sampling in other southern (ORH 3B) areas. The OP programme has so far been unable to compensate for the drop in sampling levels in exploratory areas of ORH 3B brought about by the demise of the ORMC observer programme, which has concentrated on this area in the past.

The level of sampling coverage was sufficient to determine length frequency distributions of orange roughly in 10 separate areas, and in one area (Spawning Box) a plot was prepared separately for pre-spawning and spawning periods.

Research coverage. The amount of biological data available from research surveys was relatively low, as only one deepwater fisheries survey was undertaken. However, the three-vessel survey of the Northeast Chatham Rise provided intense sampling in this area, and over 16 000 fish were measured. Very few fish were caught in the other two (middle depths) surveys (251 fish in total).

Size structure. Size structure was examined in 12 fishery/period combinations available from OP data, compared with 13 in 2002–03, 14 in 2001–02, 12 in 2000–01, and 20 in 1999–2000. Size distributions in most areas were typical of orange roughy, showing a single strong mode, but differed markedly among (often geographically close) areas in mean length and size range. There were no strong differences in size distributions between pre-spawning and spawning period fish in the Spawning Box fishery. Intensive sampling was carried out in some areas, particularly on the Chatham Rise, in ORH 1, and on the Louisville Ridge. More than 3600 fish were measured from 48 samples in the East Rise fishery, and more than 1000 fish were measured in the Spawning Box, SE Rise, NW Rise, and Manukau fisheries. Mean lengths, calculated from scaled size frequencies, varied considerably between areas. Mean lengths of fish in the Colville Ridge fishery were about 13 cm (male) and 14 cm (female) greater than those of fish in the NW Rise fishery. Sex ratios were close to 50:50 in most fisheries, although there were extreme sex ratios observed in the Colville Ridge (28% male) and East Northland (85% male) fisheries.

Reproduction. Gonad stage data sufficient for tracking the progress of spawning in the winter of 2004 were available from observer sampling in the East Northland and Spawning Box fisheries, and from research sampling in the Spawning Box and East Rise fisheries. The quantity of data available to create the plots was sufficient in each area to show clear patterns of change in the relative fractions of reproductive stages over time, and to approximately determine the extent and timing of the spawning season. The timing of the onset of spawning determined for the East Northland fishery was similar to that measured from observer data in 2003 (Anderson 2004). Spawning in the Spawning Box fishery occurred earlier than usual, and data collected by observers and from research surveys, sequential in time, were in good agreement in this fishery. Although the timing of spawning was not well determined for the East Rise, it may have also taken place earlier than usual as it was at least a week earlier than in 1998, the only other year in which timing has been reported for this area (Anderson 1999).

The collection of these data adds to a growing resource of biological information on orange roughy, which is increasingly being incorporated into the stock assessment process. For this reason it is important that the OP programme continues to collect data from these fisheries, with an emphasis on attaining, over time, coverage of all fisheries, and more consistent coverage of fisheries for which regular stock assessments are carried out.

6. ACKNOWLEDGMENTS

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7. REFERENCES

- Anderson, O.F. (1999). A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 1997–98 fishing year. New Zealand Fisheries Assessment Research Document 1999/22. 25 p. (Unpublished report held in NIWA library, Wellington.)
- Anderson, O.F. (2001). A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2001/45*. 24 p.
- Anderson, O.F. (2003). A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/21*. 25 p.
- Anderson, O.F. (2004). A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2002–03 fishing year. *New Zealand Fisheries Assessment Report 2004/57*. 26 p.
- Anderson, O.F. (2006). Review of the historical biological data for orange roughy collected by the MFish observer programme and other sources, and the use of these data in stock assessments. *New Zealand Fisheries Assessment Report 2006/15*. 41 p.
- Annala, J.H.; Sullivan, K.J.; O'Brien, C.J.; Smith, N.W.McL. (comps.) (2001). Report from the Fishery Assessment Plenary, May 2001: stock assessment and yield estimates. 515 p. (Unpublished report held in NIWA library, Wellington.)
- Branch, T.A.; Magnusson, A.; Hilborn, R.; Starr, P. (2002). Stock assessment of the New Zealand Mid-East Coast fishery of orange roughy (*Hoplostethus atlanticus*) for 2000–01. WG-Deepwater-02/30. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Clark, M.R. (1998a). A summary of information on the New Zealand fishery for orange roughy (*Hoplostethus atlanticus*) on the Louisville Ridge for the 1993–94 to 1995–96 fishing years. New Zealand Fisheries Assessment Research Document 98/6. 18 p. (Unpublished report held in NIWA library, Wellington.)
- Clark, M.R. (1998b). An update of commercial catch and effort information on the orange roughy (*Hoplostethus atlanticus*) fishery on the Louisville Ridge for the 1995–96 and 1996–97 fishing years. New Zealand Fisheries Assessment Research Document 98/26. 14 p. (Unpublished report held in NIWA library, Wellington.)
- Clark, M.R.; Tilzey, R. (1996). A summary of stock assessment information for orange roughy fisheries on the Lord Howe Rise: 1996. Bureau of Resource Sciences, Canberra. 23 p.
- Francis, R.I.C.C. (1996). Orange roughy sex ratios and catchrate distributions in the Chatham Rise Spawning Box. New Zealand Fisheries Assessment Research Document 96/13. 27 p. (Unpublished report held in NIWA library, Wellington.)
- Francis, R.I.C.C.; Smith, D.C. (1995). Mean length, age, and otolith weight as potential indicators of biomass depletion for Chatham Rise orange roughy. New Zealand Fisheries Assessment Research Document 95/3. 8 p. (Unpublished report held in NIWA library, Wellington.)
- Francis, R.I.C.C.; Tracey, D.M. (2000). Use of biological data in orange roughy stock assessments. *New Zealand Fisheries Assessment Report 2000/42*. 30 p.
- Hilborn, R.; Starr, P.J.; Ernst, B. (2000a). Stock assessment of the northeast Chatham Rise orange roughy. WG-Deepwater-00/35. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Hilborn, R.; Starr, P.J.; Ernst, B. (2000b). Stock assessment of the East Cape stock (2A North) orange roughy. WG-Deepwater-00/44. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Smith, P.J.; Robertson, S.; Horn, P.; Bull, B.; Anderson, O.; Stanton, B.R.; Oke, C. (2002). Multiple techniques for determining stock relationships between orange roughy, *Hoplostethus atlanticus*, fisheries in the eastern Tasman Sea. *Fisheries Research* 58: 119–140.
- Venables, W.N.; Ripley, B.D. (2000). *Modern applied statistics with S-Plus*. Springer-Verlag, New York. 501 p.

Table 1: Comparison of expected and actual number of OP orange roughy biological samples processed in 2003–04, and the actual number of OP samples processed in the previous two fishing years.

Area	Number of samples			
	Expected* 2003–04	Actual 2003–04	Actual 2002–03	Actual 2001–02
ORH 3B				
Chatham Rise	220	113	279	190
South of 46° S/Arrow Plateau	40	29	26	55
ORH 2A				
North	0	0	0	7
South	40	0	8	2
ORH 2B	0	0	2	1
ORH 3A	0	0	0	1
ORH 7A	0	0	0	3
ORH 1	20	90	116	52
ORH 10	0	0	0	0
ORH 7B	0	0	0	2
ET				
Lord Howe/NW Challenger	60	14	7	89
Louisville Ridge	60	39	155	37
South Tasman Rise	0	0	0	0
West Norfolk Ridge	0	5	12	40
Total	440	290	605	479

* Ministry of Fisheries research summary tender document figures

Table 2: Number of OP orange roughy biological samples by area and month for 2003–04, with the total number of samples and voyages in each area (see Figures 1 to 3 for area boundaries).

Summary by OP area

Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Voyages
AKW	11	–	1	4	–	–	–	18	28	–	–	–	62	4
AKE	–	1	–	–	–	–	–	–	17	10	–	–	28	2
CEE	–	–	–	–	–	–	–	–	–	–	–	–	0	–
SOE	7	–	6	18	48	5	8	12	5	6	–	–	115	10
SEC	–	–	1	–	–	1	2	1	–	–	–	–	5	3
SUB	17	–	–	–	–	–	–	1	–	–	–	–	18	3
SOI	2	–	–	–	–	–	–	–	–	–	–	–	2	1
SOU	2	–	–	–	–	–	–	–	–	–	–	–	2	1
CHA	–	–	–	–	–	–	–	–	–	–	–	–	0	0
HOWE	–	–	1	–	–	4	–	–	–	–	–	–	5	–
LOUR	–	–	–	–	–	–	–	–	25	8	6	–	39	2
CET	4	–	1	–	–	9	–	–	–	–	–	–	14	3
ALL	22	48	19	10	32	75	24	6	0	43	1	10	290	19

Summary by fishery area

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Voyages	No. fish measured
ORH 3B fisheries															
Arrow Plateau	–	–	–	2	1	–	–	–	1	–	–	–	4	2	281
Auckland Is.	2	–	–	–	–	–	–	–	–	–	–	–	2	1	100
Bounty Is.	2	–	–	–	–	–	–	–	–	–	–	–	2	1	176
East Rise	–	–	2	9	25	–	5	–	–	–	–	–	48	6	3 630
Macquarie	4	–	–	–	–	–	–	–	–	–	–	–	4	1	129
Pukaki	13	–	–	–	–	–	–	1	–	–	–	–	14	3	660
SE Rise	–	–	3	3	10	–	3	–	1	–	–	–	20	6	1 202
Spawning Box	–	–	–	1	4	–	–	10	2	6	–	–	23	4	1 948
Southland	–	–	–	–	–	1	2	–	–	–	–	–	3	1	30
NW Rise	–	–	2	3	8	5	–	3	1	–	–	–	22	6	1 129
ORH 1 fisheries															
Colville Ridge	–	–	–	–	–	–	–	–	12	1	–	–	13	1	450
East Northland	–	–	–	–	–	–	–	–	5	9	–	–	14	1	476
South Kermadec Ridge	–	1	–	–	–	–	–	–	–	–	–	–	1	1	16
Tauroa Knoll	4	–	–	–	–	–	–	–	–	–	–	–	4	1	322
West Norfolk Ridge	7	–	1	4	–	–	–	18	9	–	–	–	39	3	1 241
Manukau	–	–	–	–	–	–	–	–	19	–	–	–	19	1	1 071
Other fisheries															
West Norfolk Ridge (ET)	4	–	1	–	–	–	–	–	–	–	–	–	5	2	324
Lord Howe (ET)	–	–	1	–	–	4	–	–	–	–	–	–	5	2	288
Louisville Ridge (ET)	–	–	–	–	–	–	–	–	25	8	6	–	39	2	1 553
NW Challenger (ET)	–	–	–	–	–	9	–	–	–	–	–	–	9	1	387
ALL	43	1	10	22	48	19	10	32	75	24	6	0	290	19	15 413

Table 3: Summary of number and weight of samples taken by OP observers relative to the observed catch and estimated total catch in the fishery, 2003–04; observed catch totals are based on the areas defined in Figures 2 and 3, fishery catch totals are derived from estimated catches recorded on TCEPR forms and are approximate only.

Area	No. tows sampled	Weight of samples (kg)	Catch (t)		Percentage of fishery observed
			observed	fishery	
ORH 1					
West Norfolk Ridge	39	2 866	64	157	41
Tauroa Knoll	4	407	81	254	32
East Northland	14	1 064	29	49	59
Colville Ridge	13	1 411	87	90	97
South Kermadec Ridge	1	41	0.04	8	1
Manukau	19	1 136	28	220	13
ORH 3B					
Chatham Rise					
Spawning Box	23	2 427	240	2 785	9
NW Rise	22	1 325	28	3 012	1
East Rise	48	4 760	174	2 396	7
SE Rise	20	1 574	53	1 236	4
Southern/Arrow Plateau					
Arrow Plateau	4	503	55	132	42
Macquarie	4	233	2	119	2
Auckland Is.	2	141	5	9	60
Bounty Is.	2	208	5	117	4
Pukaki	14	1 076	44	457	10
Southland	3	28	0.1	2	4
ORH ET					
Lord Howe	5	400	8	141	6
NW Challenger	9	429	14	471	3
Louisville Ridge	39	3 203	123	1 414	9
West Norfolk Ridge	5	715	8	88	9

Table 4: Summary of numbers of fish measured, mean lengths, sex ratios (% male), and total catch sampled (t) for each fishery and reproductive period for which length distributions were prepared, from OP samples.

Area	Period	Number measured			Sex ratio (%male) (scaled)	Total catch (t)	Scaled Mean length (s.d.)	
		Male	Female	Total			Male	Female
NW Rise	pre-spawning	415	631	1 047	39.8	26	30.8 (3.9)	33.1 (3.3)
Spawning Box	pre-spawning	580	589	1 170	46.8	110	33.3 (2.5)	34.7 (2.9)
Spawning Box	spawning	522	256	778	56.0	130	32.9 (2.9)	34.9 (2.6)
East Rise	pre-spawning	1 362	2 267	3 630	39.1	173	33.1 (2.6)	34.1 (2.9)
SE Rise	pre-spawning	455	649	1 109	38.2	45	33.6 (2.8)	34.4 (3.6)
Pukaki	pre-spawning	348	312	660	48.5	44	35.2 (2.5)	37.9 (2.9)
West Norfolk R.	pre-spawning	446	452	898	46.1	27	41.0 (3.5)	42.4 (4.5)
Colville Ridge	spawning	185	265	450	28.4	86	43.6 (3.1)	47.0 (3.3)
East Northland	spawning	397	79	476	85.0	28	40.8 (2.3)	42.5 (2.9)
Manukau	spawning	687	384	1 071	66.0	27	33.2 (2.9)	34.9 (3.6)
Louisville Ridge (E.T.)	spawning	850	701	1 553	59.4	123	38.8 (3.5)	41.5 (4.2)

Table 5: Percentage of female orange roughy at each gonad stage in each subarea and month, from OP data. Only months in which at least 30 fish were staged are reported (see Section 3.2 for a description of the stage categories).

Area	Month	Percentage at stage					Number staged
		F1	F2	F3	F4	F5	
Colville Ridge	Jun	1	74	73	109	4	261
Manukau	Jun	43	338	3	0	0	384
East Northland	Jun	4	17	8	1	1	32
	Jul	2	2	12	25	6	47
Tauroa Knoll	Oct	27	40	58	21	13	159
West Norfolk Ridge	Jan	1	32	0	0	0	33
	May	17	180	0	0	1	199
	Jun	5	33	56	1	0	95
	Oct	9	14	108	26	15	172
NW Rise	Dec	7	32	0	0	9	48
	Jan	21	43	3	6	0	73
	Feb	34	143	26	0	0	203
	Mar	43	177	0	1	0	221
	May	3	70	9	0	0	82
	Jun	18	23	0	0	0	41
East Rise	Dec	23	29	0	0	0	52
	Jan	126	280	15	3	7	431
	Feb	189	694	19	2	22	926
	Apr	62	137	7	1	0	207
	Oct	304	265	37	0	0	606
SE Rise	Dec	13	81	3	0	0	97
	Jan	14	112	6	0	2	134
	Feb	91	235	2	0	3	331
	Apr	60	50	12	0	0	122
	Jun	28	43	0	0	0	71
Spawning Box	Dec	3	58	1	0	0	62
	Feb	16	113	2	0	4	135
	May	35	394	24	1	0	454
	Jun	9	73	2	0	0	84
Arrow Plateau	Jul	2	0	92	65	13	172
	Jan	11	96	3	0	0	110
	Jun	3	55	1	0	0	59
Auckland Is.	Oct	2	51	5	0	1	59
Bounty Is.	Oct	2	16	54	1	0	73
Macquarie	Oct	0	38	23	1	1	64
Pukaki	Oct	19	190	99	1	0	309
Lord Howe Rise (E.T.)	Mar	6	57	59	2	1	125
	Dec	5	33	0	0	0	38
Louisville Ridge (E.T.)	Jun	32	22	160	61	18	293
	Jul	3	1	12	88	38	142
	Aug	0	20	83	115	48	266
NW Challenger (E.T.)	Mar	5	39	105	7	25	182
West Norfolk Ridge (E.T.)	Oct	7	8	54	21	8	98
	Dec	3	37	0	0	1	41

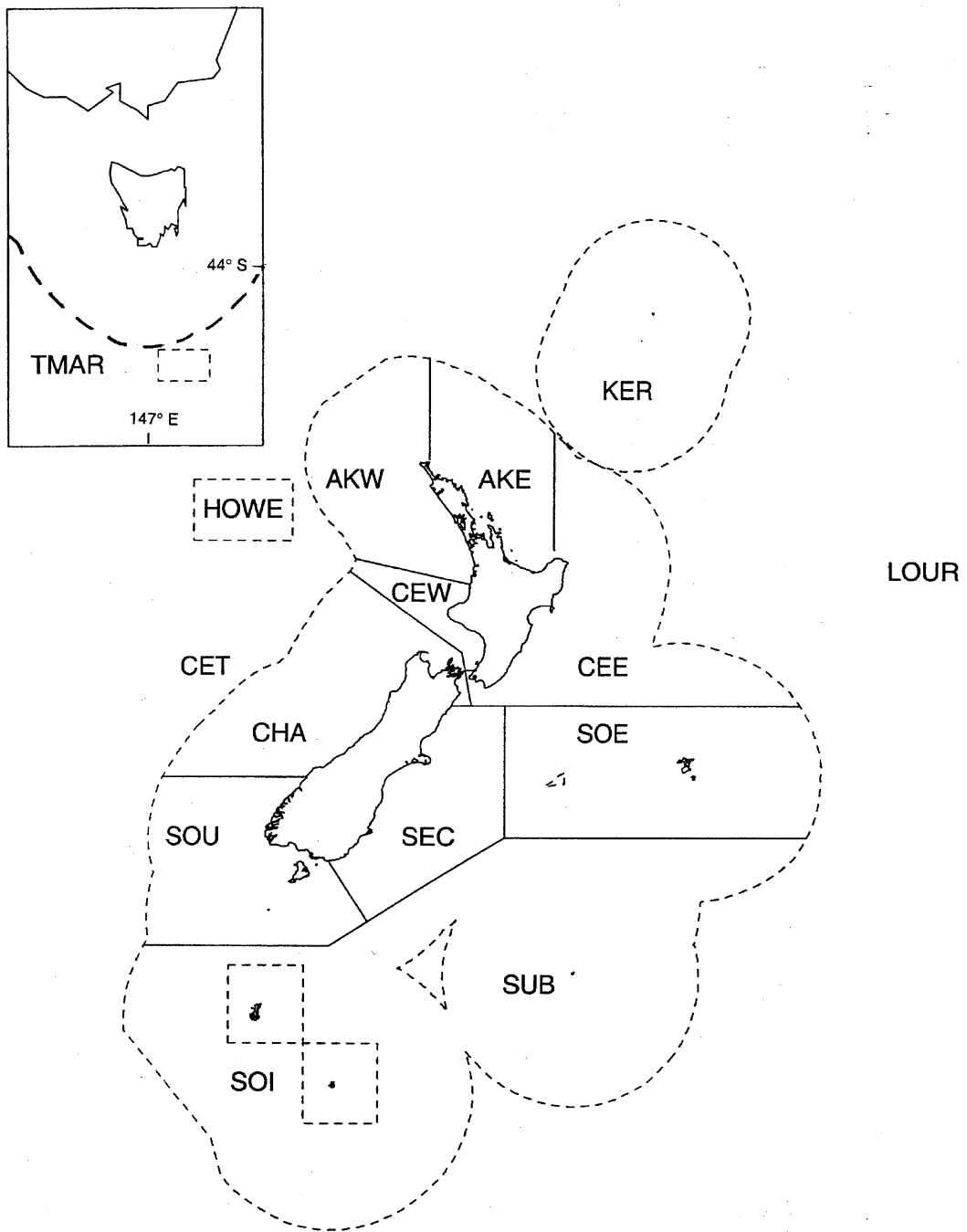


Figure 1: Ministry of Fisheries Observer Programme management areas.

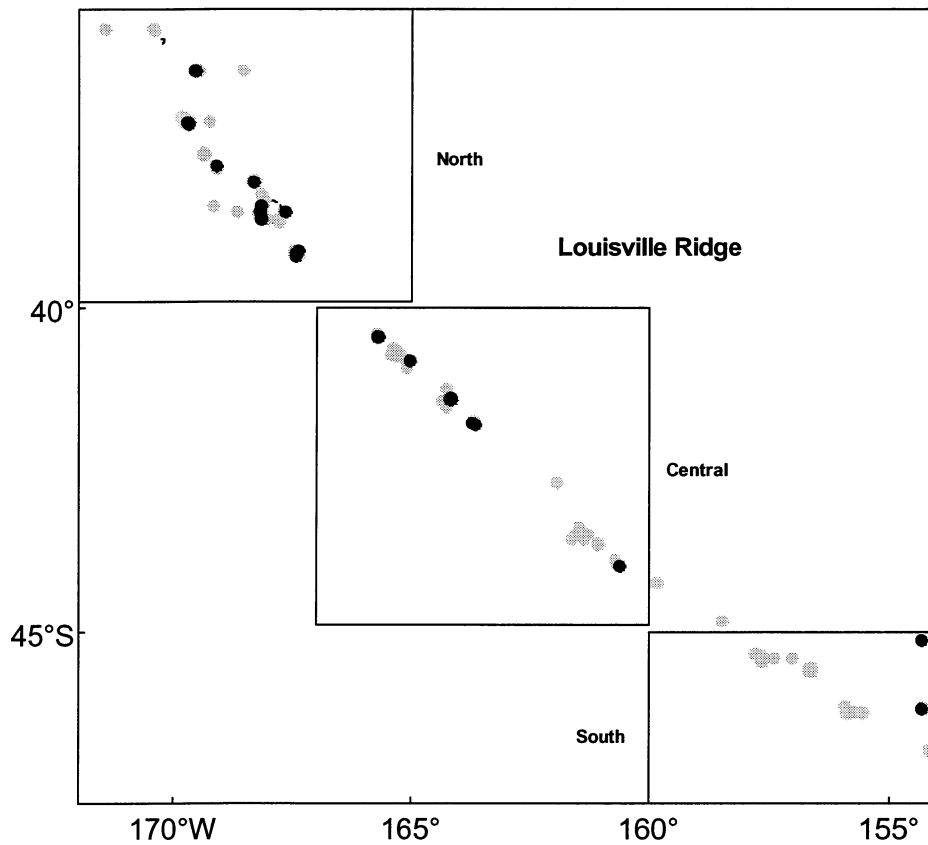
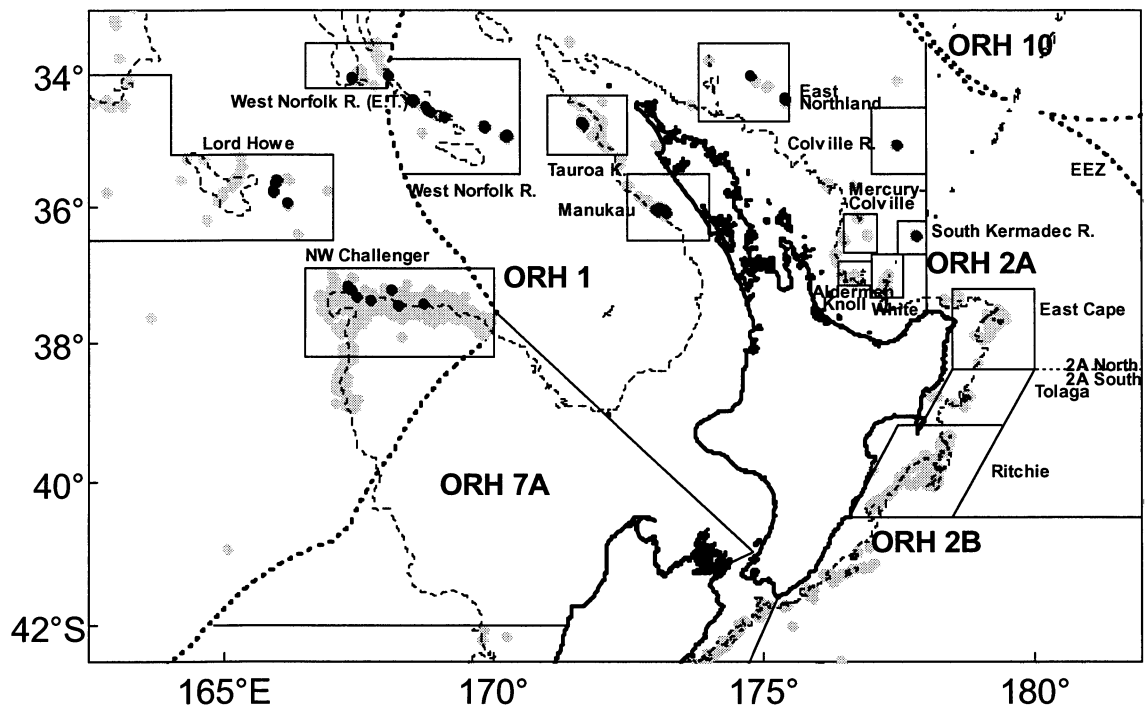


Figure 2: Location of fisheries used for analysis of biological data, position of trawls in the commercial fishery (grey dots), and location of samples of orange roughy taken by OP observers (black dots), during the 2003–04 fishing year. The dotted line shows the 1000 m depth contour.

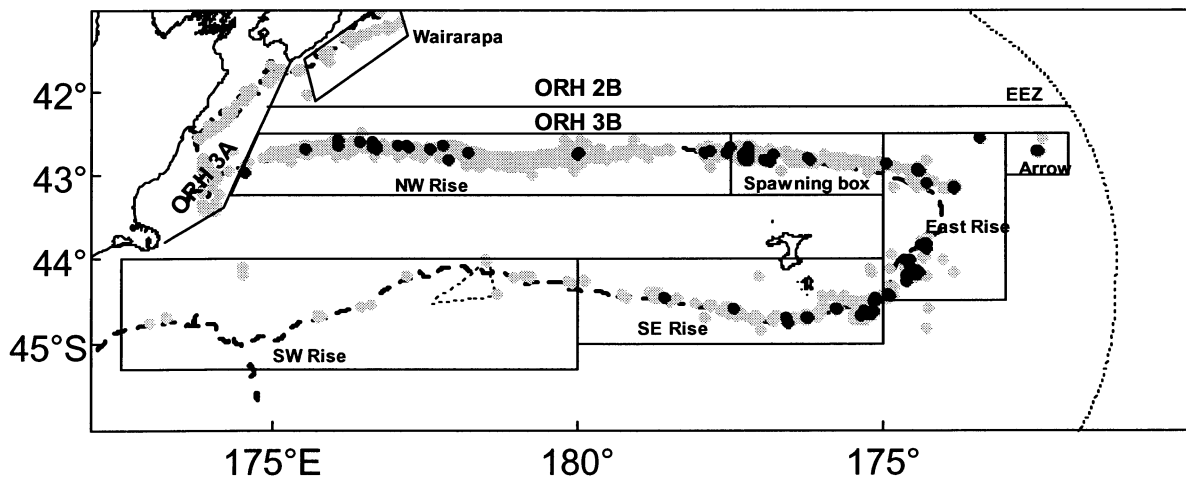
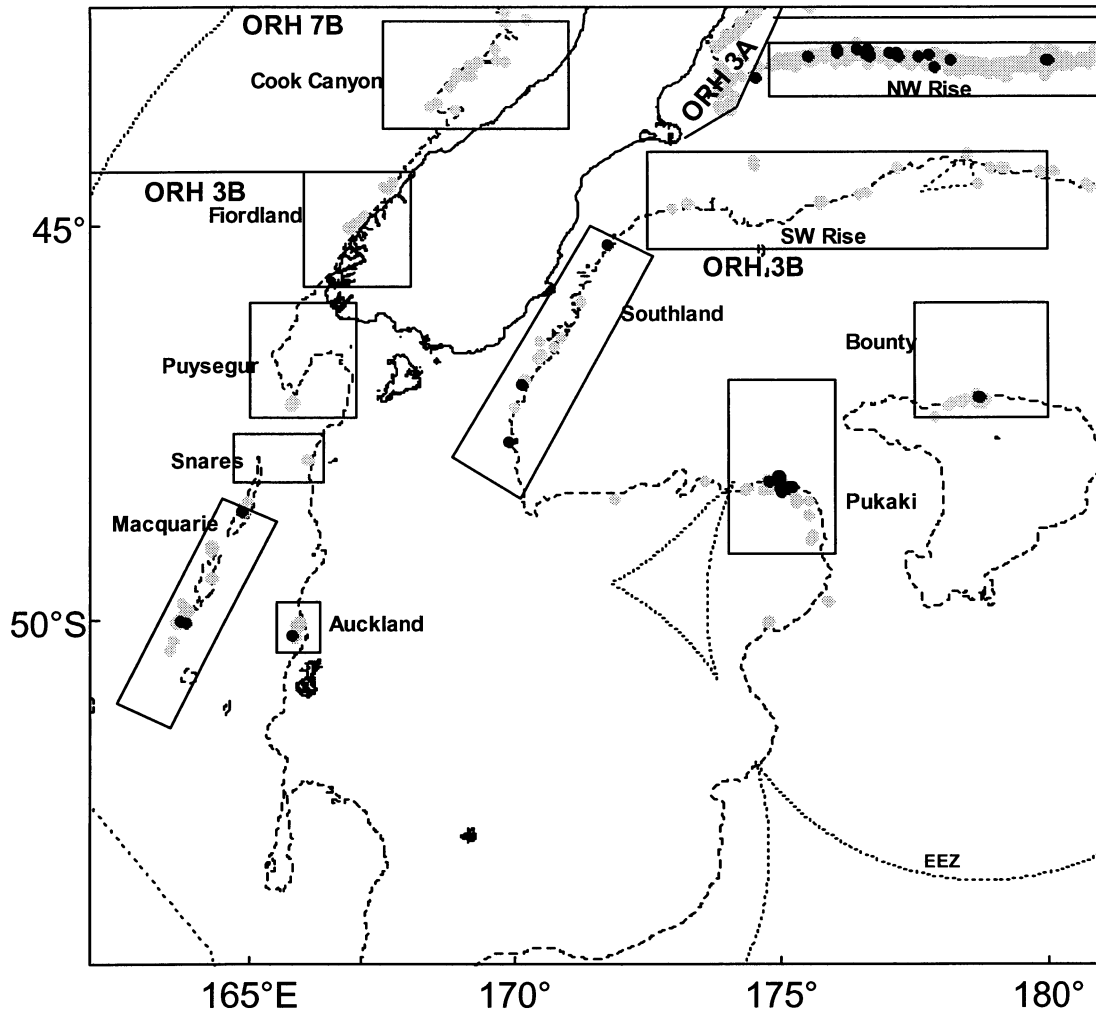


Figure 3: Location of fisheries used for analysis of biological data, position of trawls in the commercial fishery (grey dots), and location of samples of orange roughy taken by OP observers (black dots), during the 2003–04 fishing year. The dotted line shows the 1000 m depth contour.

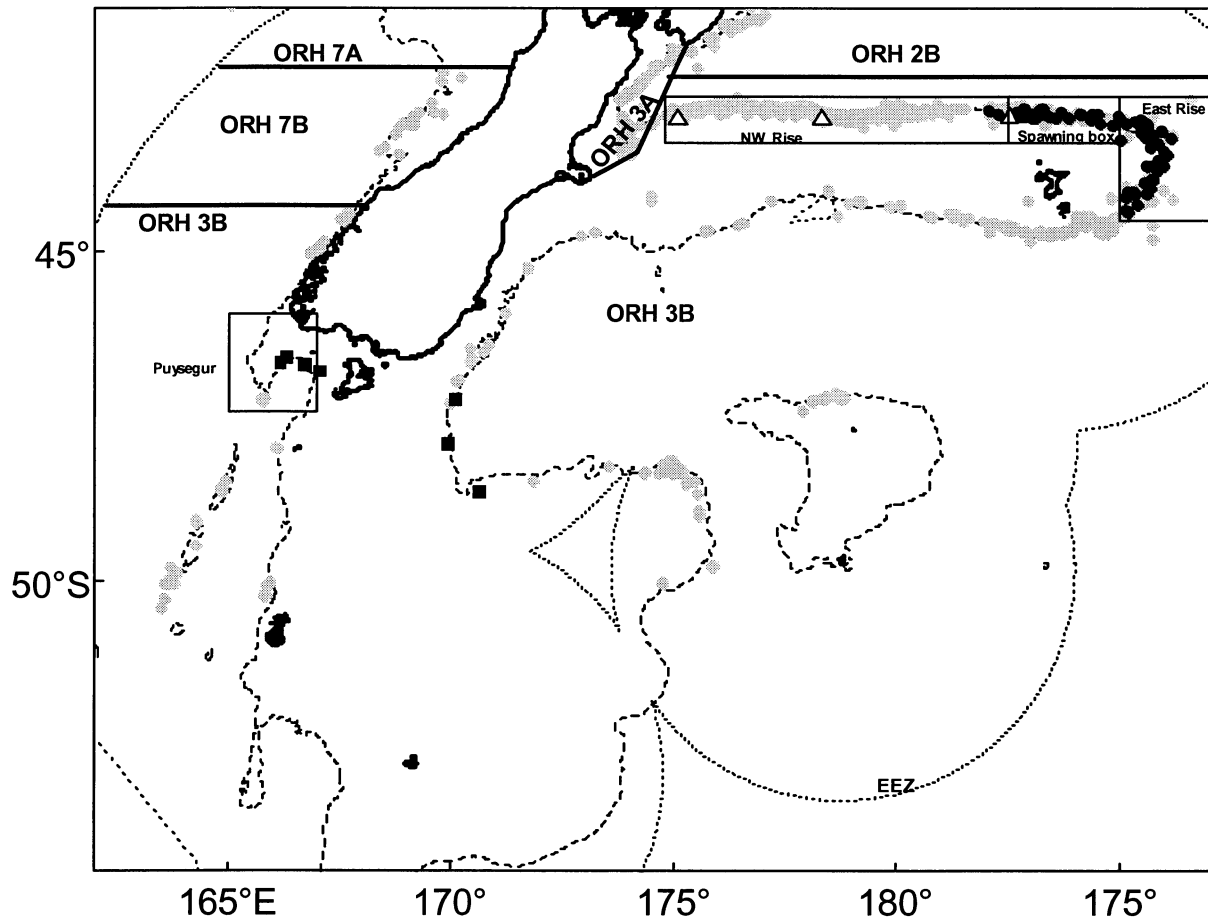


Figure 4: Location of fisheries and research trawls where orange roughy length data were recorded, and position of trawls in the commercial fishery (grey dots); closed circles, Northeast Chatham Rise orange roughy survey July 2004 (R.V. *Tangaroa*, F.V. *San Waitaki*, F.V. *Tasman Viking*); open triangles, Chatham Rise hoki survey December 2003–January 2004 (R.V. *Tangaroa*); closed squares, sub-Antarctic trawl survey November–December 2003 (R.V. *Tangaroa*). The dashed line shows the 1000 m depth contour.

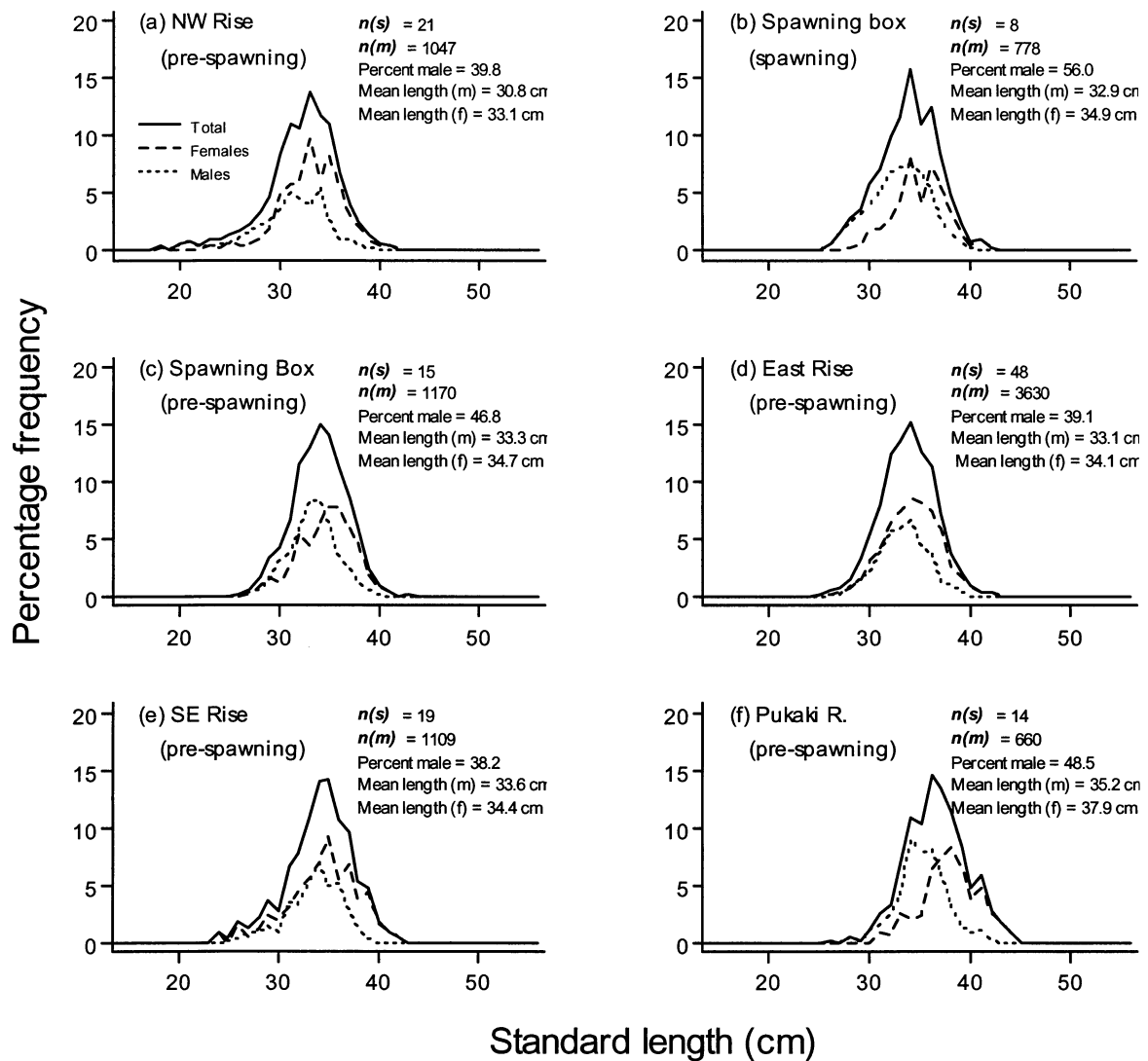


Figure 5: OP length frequency distributions (scaled by catch) of orange roughy by area and period, $n(s)$, number of samples; $n(m)$, number of fish measured.

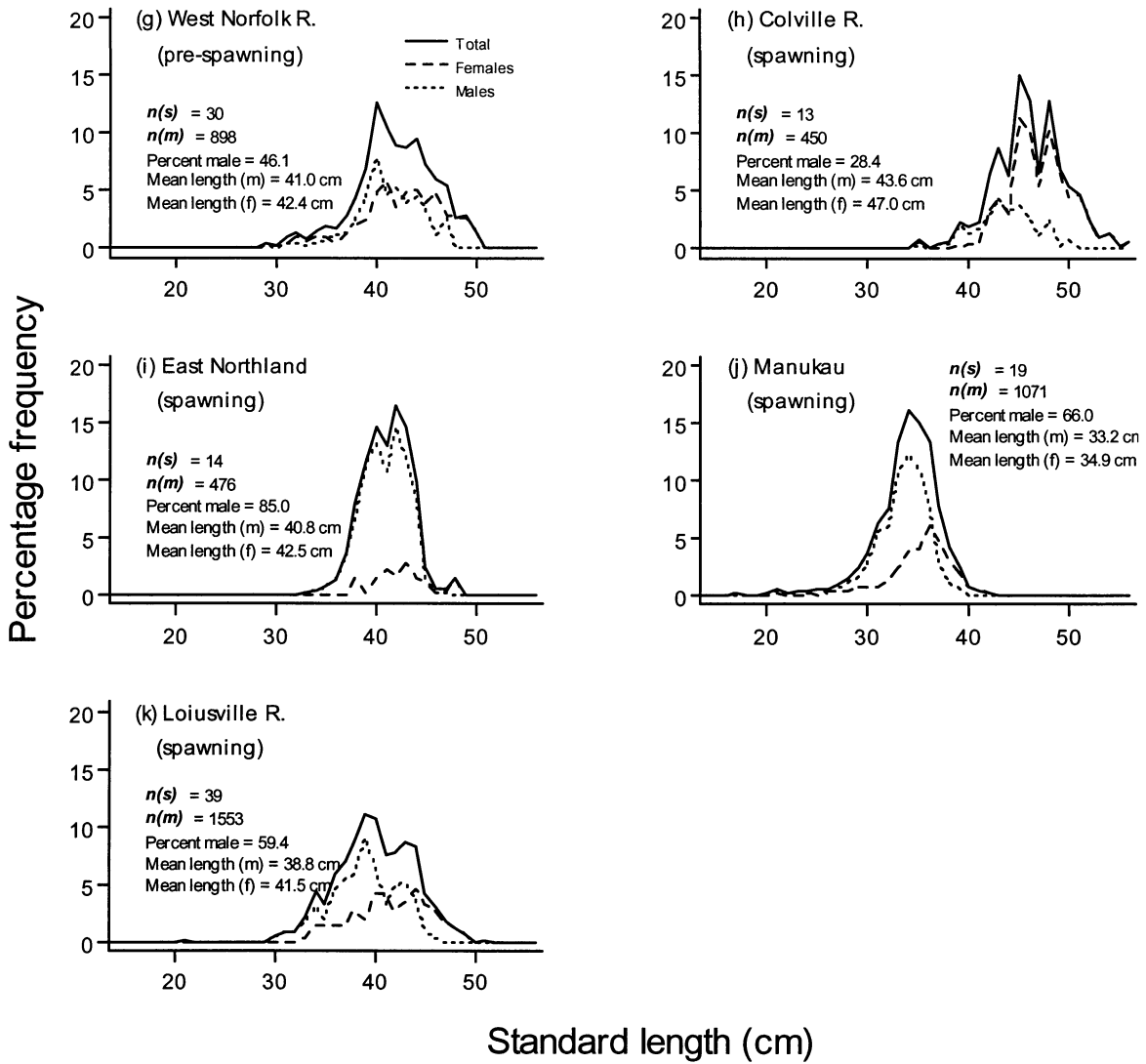


Figure 5 — continued.

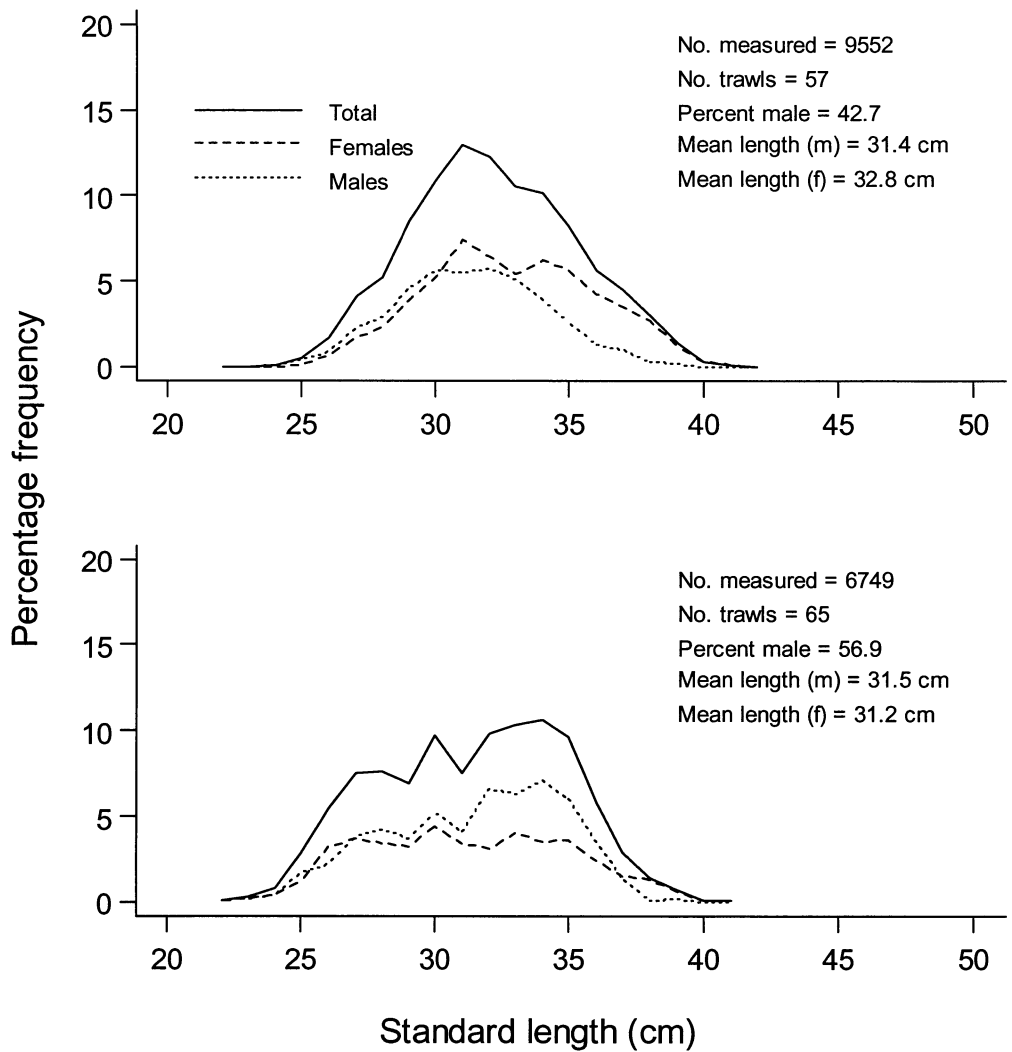


Figure 6: Orange roughy length frequency distribution (scaled by catch) from the Northeast Chatham Rise orange roughy research survey July 2004 (F.V. *Tasman Viking*, F.V. *San Waitaki*, R.V. *Tangaroa*). Top, Spawning Box; bottom, East Rise.

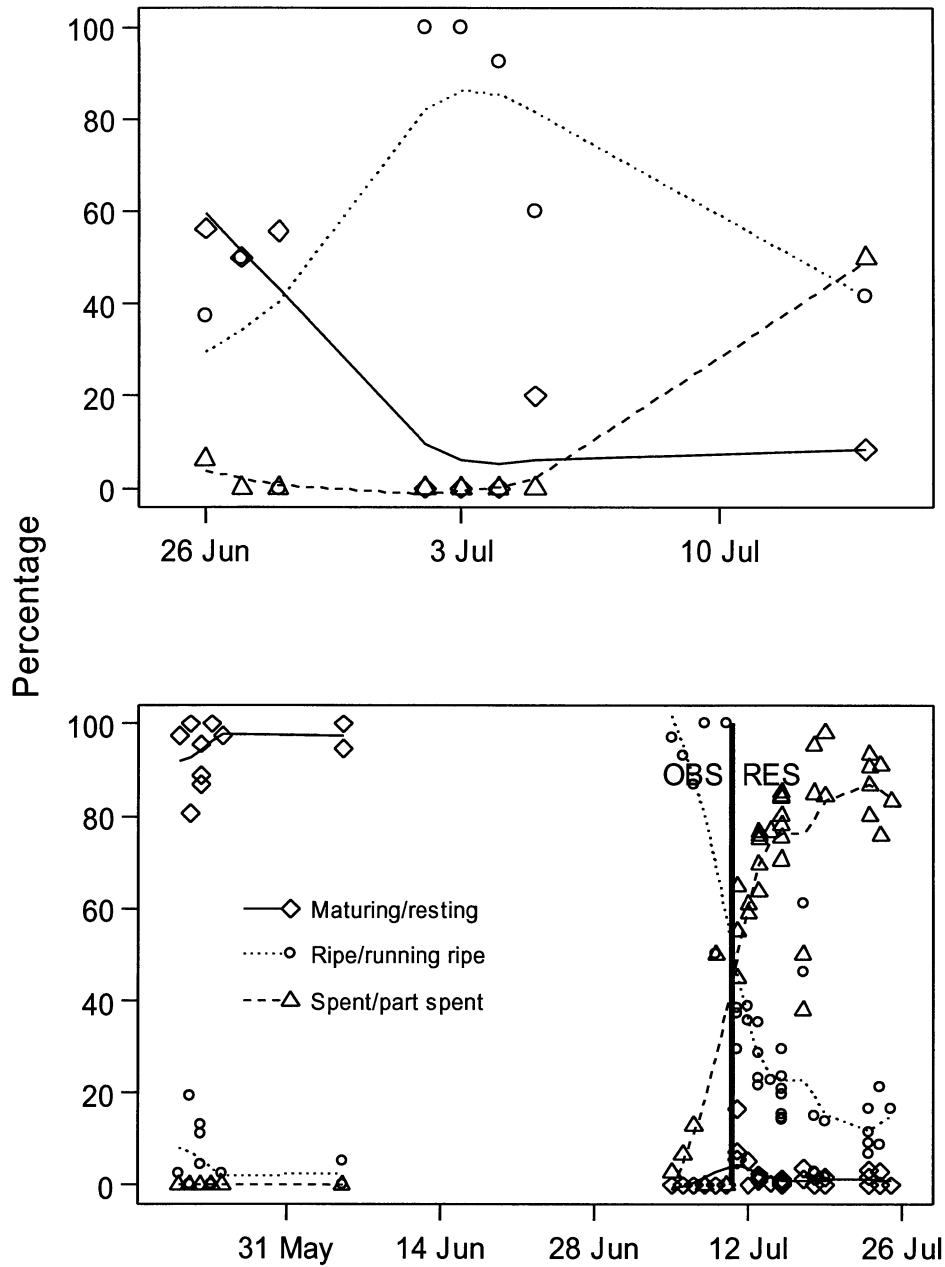


Figure 7: Daily changes in female orange roughy gonad stage proportions during the spawning season in two fisheries; top, East Northland (ORH 1) from OP data; bottom, Spawning Box (ORH 3B) from OP and research data combined. Each point indicates the fraction of all mature fish examined (aggregated by day (top) and tow (bottom)) which were in the reproductive state indicated by the symbol. The line in the bottom panel indicates the date at which observer coverage ceased and research coverage began

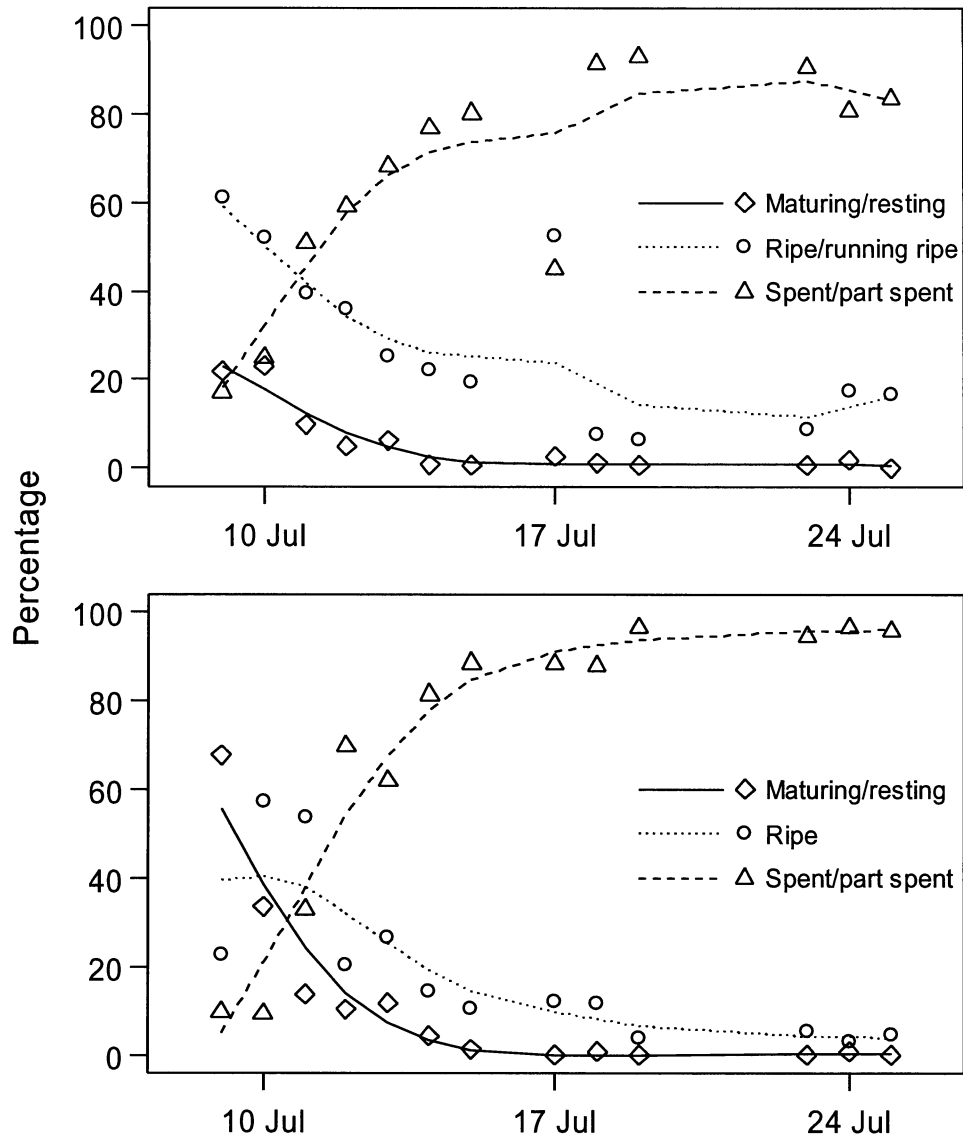


Figure 8: Daily changes in orange roughy gonad stage proportions during the spawning season in the Spawning Box (ORH 3B), from research survey data. Top, female fish; bottom, male fish. Each point indicates the fraction of all mature fish examined (in all samples taken on that day) which were in the reproductive state indicated by the symbol.

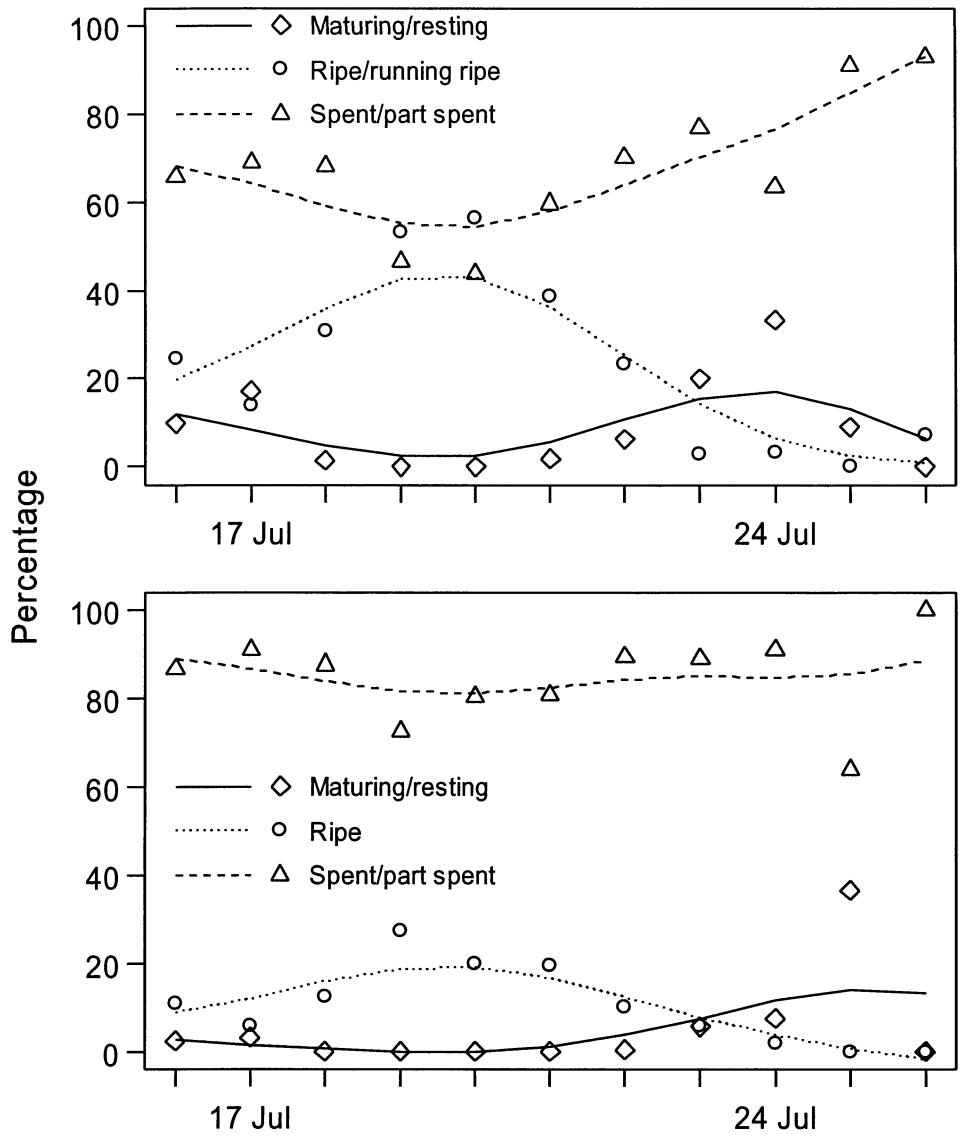


Figure 9: Daily changes in orange roughy gonad stage proportions during the spawning season in the East Chatham Rise (ORH 3B), from research survey data. Top, female fish; bottom, male fish. Each point indicates the fraction of all mature fish examined (in all samples taken on that day) which were in the reproductive state indicated by the symbol.