ISSN 1175-1584

MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2002–03 fishing year

O. F. Anderson

New Zealand Fisheries Assessment Report 2004/57
November 2004

A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2002–03 fishing year

O. F. Anderson

NIWA
Private Bag 14901
Wellington

New Zealand Fisheries Assessment Report 2004/57
November 2004

Published by Ministry of Fisheries
Wellington
2004

ISSN 1175-1584

Citation:
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.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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.**

1. Size and reproductive data on orange roughy, collected by observers of the Ministry of Fisheries Observer Programme (OP), the Orange Roughy Management Company Limited observer programme (ORM), and from NIWA research surveys were examined and summarised by fishery. Data were available from 605 OP tows and 6 ORMC tows during the 2002–03 fishing year, from both inside and outside the New Zealand Exclusive Economic Zone. Biological data collected during research surveys on the Chatham Rise, in the sub-Antarctic, and in ORH 2A South were also summarised.

2. OP sampling increased by 26% compared with the previous year, and although the overall number of samples was greater than scheduled, some areas received more sampling effort and others less effort than planned. Coverage of fisheries within ORH 1 was particularly good, with many of the known grounds as well as one relatively new one sampled, but coverage of the east coast fisheries in ORH 2A, ORH 2B, and ORH 3A was low with only 10 samples in total. Sampling of fisheries outside the Exclusive Economic Zone (EEZ) was patchy, with more than twice the scheduled number of samples collected from the Louisville Ridge, but only 7 out of 60 scheduled samples collected from the Lord Howe/Northwest Challenger fisheries. The ORMC observer programme collected samples from only the Pukaki and Bounty fisheries.

3. Sufficient length samples were obtained to determine size frequencies for 15 fishery/season/observer programme 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 ORH 2A South (mean length 28.8 cm for males and 30.2 cm for females) and the largest from the Colville Ridge (42.9 cm for males and 47.0 cm for females). A moderate amount of biological data was collected from research surveys, mostly from ORH 2A South where an acoustic survey of orange roughy stocks was carried out in June 2003. The size structure described from these data differed markedly from size data collected by observers from the same fishery earlier in the year.

4. 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 10 percentage points of 50%. The most biased sex ratios were from the East Northland spawning fishery (67.4% male) and the Southeast Rise pre-spawning fishery (36.5% male).

5. Sampling during the spawning period was sufficient in several fisheries to allow an estimate of the temporal progression of spawning to be made. In each case, the timing of spawning closely matched that of previous years (where it was known) and was always in June or July. The timing of spawning was estimated for the first time for two fisheries, Colville Ridge and East Northland

1. INTRODUCTION

This report documents the results of objective 3 of the Ministry of Fisheries project ORH2003/02 "Orange roughy stock assessment", and objective 3 of Ministry of Fisheries project ORH2003/03 "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 2002–03 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 identified 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 ORH2003/02), and from several fisheries outside the EEZ (referred to in this report as ET (extra-territorial) fisheries, project ORH2003/03), during the 2002–03 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 2003) 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 MEC stock (ORH 2A South), and the location of station positions where small amounts of orange roughy biological data were collected on other research surveys in 2002–03. A limited amount of data is also available from the observer programme of the Orange Roughy Management Company Limited (ORMC). Primarily, however, the length and gonad stage data presented come from observers employed by the Ministry of Fisheries observer programme. In this document 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 1–300) per trawl, from up to eight 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.

Since 1996–97, orange roughy biological data have also been collected through a second, industry managed, sampling programme which has focused mainly on Exploratory Fishing Areas within

ORH 3B (Langley 2001). For each day of fishing, the sampling programme collects biological data from the orange roughy catch from a randomly selected commercial trawl, and generally follows the procedures used by OP observers. These data are compatible with the Ministry of Fisheries observer data and they are stored together in the *obs_lfs* database at NIWA (Greta Point). The programme was virtually discontinued in 2002–03 with only 6 samples collected compared with 22 in 2001–02 and 64 in 2000–01. A summary of these (6) samples is included in this report.

Biological data collected from F.V. *Ocean Ranger* during an orange roughy research survey in ORH 2A South in June 2003 and from R.V. *Tangaroa* during surveys of hoki on the Chatham Rise in December 2002 and January 2003, and a multispecies survey in the sub-Antarctic in November 2002 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 2003).

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 observer coverage achieved in each of the main fisheries in 2002–03. 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 coverage, in number of samples, was also compared to the level of coverage scheduled for each fishery by the Ministry of Fisheries.

3.1 Size structure

Length frequency distributions were determined from the OP and ORMC sampling data for each fishery/season/sampling programme where at least five tows were sampled and more than 400 fish measured. Samples were combined when they were entirely before, entirely within, or entirely after 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 ORH 2A South orange roughy fishery was stratified over several hill and flat areas. Details of these strata and a close examination of size frequencies of orange roughy from the survey area were presented by Tracey & Ayers (unpublished results), but for this summary only an overall size frequency was prepared, to approximate the methods used for presenting observer data. There were insufficient fish measured (i.e., fewer than 400) in both the Chatham Rise and sub-Antarctic 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 ORH 2A South survey, and for female fish from data collected by OP observers in four other fisheries.

4. RESULTS

4.1 Distribution of samples

Ministry of Fisheries OP observers sampled 605 catches of orange roughy from 23 voyages with the number of samples per voyage ranging between 1 and 129 (median 17). The number of samples was less than scheduled in South of 46° S/Arrow Plateau, ORH 2A South, and Lord Howe/Northwest Challenger (Table 1). In other areas the number of samples collected was considerably greater than requested, with more than twice the 60 samples requested from the Louisville Ridge fishery and nearly six times the 20 samples requested from ORH 1. Fourteen samples were collected from areas where no sampling was scheduled (ORH 2B and West Norfolk Ridge (outside the NZ EEZ)). Overall, the total number of OP observer samples collected during the 2002–03 fishing year was 38% greater than scheduled, 26% greater than in 2001–02, and the most samples collected since the 1999–2000 fishing year. ORMC observers examined six samples of orange roughy from one voyage.

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 OP samples (46%) came from the SOE (Chatham Rise) area and a further 28% of samples were from areas outside the EEZ (LOUR, and CET) (see Figure 1 for OP area definitions). The northern areas AKE and AKW accounted for most of the remaining samples (19%). OP sampling covered the main fisheries on the Chatham Rise including the Northwest Rise, East Rise, Southeast Rise, and Spawning Box, with a lower level of sampling in the smaller Arrow Plateau and southwest Rise fisheries. Sampling was spread over several fisheries in ORH 1, particularly East Northland, West Norfolk Ridge, White Island, and the relatively new (and previously unsampled) Manukau fishery. The three central east coast QMAs (ORH 2A, ORH 2B, ORH 3A) received very little coverage, with eight samples from the Ritchie Banks fishery, two samples from the Wairarapa fishery, and none from either the East Cape or Kaikoura fisheries.

Sampling levels in the southern part of ORH 3B were modest, with a total of 26 samples collected from four areas. The demise of the ORMC observer programme has led to a low level of data collection from this area compared to recent years. OP sampling was confined mostly to October and the February–June period, with no samples collected anywhere in December or September, and fewer than ten in November and August.

Outside the EEZ, a large number of samples were collected from three voyages to the Louisville Ridge during a period encompassing the spawning period. A few samples were also collected from fisheries to the northwest of New Zealand's EEZ.

Sampling by ORMC observers was confined to October in two sub-Antarctic fisheries, Pukaki (five samples), and Bounty (one sample).

The positions of all tows from which samples were collected (both OP and ORMC) are shown in Figures 2 and 3. These figures also show the positions of all tows that caught orange roughy in the 2002–03 fishing year, according to TCEPR returns. Of the northern fisheries, the Northwest Challenger grounds received considerable fishing effort, over a wide area, but received only a low level of observer coverage. Most of the areas commercially fished in ORH 1 in 2002–03 were covered by observers, especially those in the Bay of Plenty and in the Manukau fishery, west of Manukau Harbour. The level of coverage in ORH 1 was also high in comparison to the total commercial catch; with samples accounting for between about 20% and 50% of the estimated catch in most fisheries (Table 3). Although two samples were taken in the Lord Howe (E.T.) fishery these represented fewer than 20 fish and therefore a tiny fraction of the approximately 200 t caught in the area. In the east coast fisheries in ORH 2A, ORH 2B, and ORH 3A, sampling was restricted mainly to the southwestern sector of the Ritchie (ORH 2A South) fishery (688 kg and 3% of the estimated catch sampled) with a further two samples taken from the Wairarapa fishery (ORH 2B). In contrast, the commercial fisheries on the Chatham Rise (ORH 3B) were well represented. Sampling was well spread out over the Northwest Rise and Spawning Box, and fishing effort on the main seamounts on the East Rise and to a lesser extent the Southeast Rise was well covered. A modest level of sampling was also achieved in the smaller fisheries on the Arrow plateau and southwest Rise. In the southern area of ORH 3B (south of 46° S), where fishing effort is spread over a very wide area, sampling was restricted to four fisheries, collectively accounting for about 950 t of orange roughy catch in 2002–03 (Table 3). The sampling level in this area was greatest in the Bounty fishery, where observers covered about 34% of the estimated catch in nine samples. One further sample was also taken from this area by ORMC observers. The Pukaki fishery was also covered by observers of both programmes, with seven samples from OP and five samples from ORMC observers. Coverage was extensive in the Louisville Ridge fishery, with each of the North, Central, and South areas (see Clark (1998a, 1998b) for definitions of these areas) well sampled. More than 9 t of fish from 155 tows were measured in this fishery, representing almost a fifth of the estimated 1300 t caught.

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 ORH 2A South survey complement those collected by observers from the same area, as the survey focused entirely on the northeastern sector of the fishery, where the main spawning aggregations are found. Relatively few orange roughy data were collected from the other two surveys (conducted on 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 trawling for orange roughy is currently not permitted and few biological data have been collected in recent years.

Over 4000 orange roughy were measured from a catch of 63 t in the ORH 2A South survey, 325 were measured from a catch of about 122 kg in the sub-Antarctic survey, and 88 were measured from a catch of about 74 kg in the Chatham Rise 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 near even sex ratios and larger female fish, typical for orange roughy size structures, were found in many areas, e.g., the Northwest Rise, Spawning Box and East Rise (Figures 5a, c, d). The main differences in the size distributions between areas were in the range of fish lengths measured and, in a few areas such as Ritchie and West Norfolk Ridge (Figure 5f, j), broader size distributions with a less well-defined peak. In the Northwest Rise, fish sampled during the spawning months showed a size distribution similar in shape to that for fish sampled pre-spawning, but the sex ratio was much less even (66% male compared with 55% male) and mean fish lengths were greater during the spawning season (Figures 5a, b).

Length frequency distributions from ORMC samples are presented for only one area, Pukaki (Figure 6). This figure shows a broad range of fish lengths (from about 29 to 50 cm standard length) and no strong single size mode for either sex. This may be due in part to the relatively small number of samples and fish measured.

Small fish, under 25 cm, were uncommon in most areas, and represented a significant portion of the size distributions (19% of scaled fish numbers, both sexes combined) only in the Ritchie fishery (see Figure 5f). Less than 1% of fish were smaller than 25 cm in all other fisheries where sufficient data were available to produce size frequencies. In all fisheries from the Chatham Rise southwards, few fish were measured at over 40 cm (generally less than 1–2%), whereas in the northern fisheries of East Northland, Colville Ridge, west Norfolk Ridge, west Norfolk Ridge (ET), and Louisville Ridge, fish longer than this were common (see Figure 5). The largest fish were in the Colville Ridge fishery where 78% of male fish and 98% of female fish were greater than 40 cm, mean lengths were 42.9 cm and 47 cm respectively, and fish of up to 55 cm were recorded. Observers have recorded similarly large fish in other years in this area (see Anderson 2001, 2003). Not all fisheries in ORH 1 contained large fish, however, with fish in the Manukau, Tauroa Knoll, and White Island fisheries being of more average size.

Mean lengths of fish from the Ritchie fishery were less than those from other areas (Table 4), with ranges of 28.8–42.9 cm (males) and 30.2–47.0 cm (females). Sex ratios, based on scaled size frequency data, ranged from 36.5% male (Southeast Rise pre-spawning) to 67.4% male (East Northland spawning). Overall, there was no clear bias in the sex ratios in favour of one sex, with 9 of the 15 fishery/area combinations showing a higher percentage of male fish. Most of the sex ratios were close to 50:50, however, with 5 of the 15 calculated being within 5 percentage points of 50% male, and only 5 of the ratios calculated more than 10 percentage points from 50% male.

An additional scaled length frequency distribution is presented from the ORH 2A South orange roughy research survey (Figure 7). The distribution, based on almost 4000 measured fish, was typically unimodal and showed that the fish in the area surveyed were of medium size (mean lengths 33.9 cm (m), 35.7 (f)) and about 30% male. This is in strong contrast to the pre-spawning period sampled by observers in the more southern part of the fishery (see Figure 5f), where mean fish lengths of both sexes were more than 5 cm shorter, with a more even sex ratio (45%).

4.3 Reproduction

Female fish were sampled for reproductive state by OP observers during spawning months (June and July) in several areas in 2002–03, and an indication of the timing and location of spawning can be derived from these data (Table 5). Much of the sampling in the ORH 1 fisheries was during the

winter spawning months, with many fish in the samples in the ripe, running ripe, and spent stages, especially in the Colville Ridge and East Northland fisheries. The records of large numbers of running ripe and spent fish in the Tauroa Knoll and West Norfolk Ridge fisheries in February are suspicious and may be due to miscoding. However, fish in spawning condition have occasionally been recorded in the past from these northern fisheries (e.g., Anderson 2003) and so the data are presented. Fish in spawning condition were also recorded from the Northwest Rise and Spawning Box in June, and the Louisville Ridge in June and July. Mature and spent fish were occasionally recorded in other areas at various times of the year.

There were sufficient reproductive data collected through the winter months to make plots of the progression of spawning in several fisheries (Figures 8 and 9). In the Louisville fishery, the fraction of ripe and running ripe female fish in the samples increased rapidly during June, reaching a peak towards the end of the month (Figure 8, top). At the same time, the fraction of maturing fish dropped to close to zero as the gonads in these fish ripened, and spent fish appeared in the samples from late June. The pattern is more confused after the end of June, possibly due to spent fish leaving the fishing grounds, but the general timing of spawning is clear, with the peak of the ripe/running ripe curve at about 28 June. Data are available from only a few days during spawning in the Colville Ridge fishery, but these show an increasing fraction of spent fish after 21 June, along with a decreasing fraction of ripe and running ripe fish. Peak spawning is likely to have taken place during the week of 22–29 June (Figure 8, centre). Peak spawning may have been a week or so later in the nearby East Northland fishery (Figure 8, bottom), where ripe and running ripe fish began to appear in samples from 13 June and increase in predominance up until the end of sampling on 9 July. This increase is matched by a decrease in maturing fish and an increase in spent fish during the same period, with the peak of spawning probably at about 7–9 July. In the Northwest Rise fishery, sampling ceased before the peak of spawning (Figure 9, top). At that time (19 June), ripe and running ripe fish were more prevalent in the samples than maturing fish, but there were no spent fish recorded. The peak of spawning was probably a week or two later, in late June or early July.

A large amount of reproductive data was gathered during the ORH 2A South research survey throughout the spawning period, and plots of the progression of spawning were produced for each sex (Figure 9, centre and bottom). The fraction of ripe and running ripe female fish remained at about 80% throughout the survey, while the fraction of maturing fish slowly decreased. Ripe male fish increased in predominance more slowly, with a still-increasing fraction at the end of sampling on 24 June. Spent fish of both sexes increased during the survey, and the peak of spawning was likely to have been near the end of the survey, at about 22–24 June

5. SUMMARY AND DISCUSSION

Observer coverage. The number of samples collected by OP observers this year was the greatest since 1999–2000, with the number of samples 38% greater than scheduled and 26% greater than in the previous year. The spread of sampling was poor, with some important fisheries, such as ORH 2A South, receiving very low levels of sampling, and others, such as the Louisville Ridge fishery, receiving a disproportionately high level. A full quarter of the samples for 2002–03 were taken from this fishery, and a further fifth were taken from the East Chatham Rise fishery. As in the two previous years, few samples were collected from the east coast fisheries in ORH 2A, ORH 2B, and ORH 3A. Sampling levels in ORH 1 were high and, as in 2001–02, samples were collected from most of the recognised fisheries in this QMA. Sampling levels in the ET fisheries were variable, with a high level in the Louisville Ridge but far less sampling than scheduled in the Lord Howe/Northwest Challenger fisheries. The West Norfolk Ridge (ET) fishery received a modest amount of (unscheduled) sampling. There was no sampling in the Fiordland and Cook Canyon fisheries and relatively low sampling levels in other southern (ORH 3B) areas. The low sampling effort in this region was exacerbated by the decline 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 roughy in 13 separate areas, and in one area (Northwest Rise) a plot was prepared separately for pre-spawning and spawning periods.

Research coverage. The amount of biological data available from research surveys was low compared to recent years, as only one deepwater fisheries survey was undertaken. Although almost 4000 fish were measured in the ORH 2A South survey, very few fish were measured in the other two (middle depths) surveys that caught orange roughy (413 fish in total). The size structure of orange roughy determined from the ORH 2A South survey showed much larger fish compared with the size structure produced from observer data from the same fishery, albeit at a different time of the year and in adjacent, but separate, fishing grounds. This may be due to a higher proportion of mature (and therefore older and larger) fish being present in the spawning aggregations sampled during the survey than would be expected outside the spawning areas at other times of the year.

Size structure. Size structure was examined in 13 fishery/period combinations available from OP data, compared with 14 in 2001–02, 12 in 2000–01, and 20 in 1999–2000. Sufficient ORMC data were available for examination in only one area, the Pukaki Rise, an area only lightly covered by OP observers and the same area where the single size frequency plot was produced from ORMC data in 2001–02. Intensive sampling was carried out in some areas, particularly on the Chatham Rise, in ORH 1, and on the Louisville Ridge. More than 4600 fish were measured from 60 samples in the Northwest Rise fishery, more than 9500 in the East Chatham Rise fishery, and several thousand fish were also measured in the Spawning Box, Southeast Rise, and Louisville Ridge fisheries. Mean lengths, calculated from scaled size frequencies, varied considerably between areas. Mean lengths of fish in the Colville Ridge fishery were about 14 cm (male) and 17 cm (female) more than those of fish (measured by observers) in the Ritchie fishery. Sex ratios were close to 50:50 in most fisheries and, although there were a few extreme sex ratios observed, they were less extreme than recorded in other recent years. In the Southeast Rise pre-spawning fishery, 36.5% of fish were male and in the East Northland spawning fishery 67.4% of fish were male.

Reproduction. Gonad stage data sufficient for tracking the progress of spawning in the winter of 2003 were available from observer sampling in the Louisville Ridge, Colville Ridge, East Northland, and Northwest Chatham Rise fisheries, and from research sampling in ORH 2A South. This is the best coverage of the spawning season of orange roughy achieved for several years. The quantity of data available to create the plots was variable, but 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 Louisville Ridge was about a week earlier than that determined from observer data in 2002 (Anderson 2003). Although the timing of spawning was not well determined for the Northwest Rise, it probably took place at about the same time as estimated for 2002 (Anderson 2003), and 1998 (Anderson 2000) from survey data. The timing of spawning in the Ritchie Banks fishery in ORH 2A South was also very similar to that estimated from research data in 2001 (Anderson & Langley 2002), and 1995. The estimates of the timing of spawning on the Colville Ridge and East Northland are the first made for these fisheries.

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. If the ORMC sampling programme cannot be revived, the OP programme may need to put more emphasis on southern (ORH 3B) fisheries.

6. ACKNOWLEDGMENTS

I thank the OP observers of the Ministry of Fisheries for their continued efforts and the Seafood Industry Council, Orange Roughy Management Company Ltd., and industry observers for the ORMC data. Thanks also to Matthew Dunn (NIWA) for reviewing of a draft of this report. The Ministry of Fisheries (projects ORH2003/02 and ORH2003/03) funded this work.

7. REFERENCES

Anderson, O.F. (2000). A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 1998–99 fishing year. *New Zealand Fisheries Assessment Report 2000/14.* 24 p.

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 2001–2002 fishing year. *New Zealand Fisheries Assessment Report 2003/21.* 25 p.

Anderson, O.F.; Langley, A.D. (2002). A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2000–01 fishing year. *New Zealand Fisheries Assessment Report 2002/33.* 28 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.)

Langley, A. (2001). Summary of biological data collected from the Exploratory Fishing Areas by the Orange Roughy Management Company Limited during the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2000/57*. 48 p.

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 (MFish observer programme) orange roughy biological samples processed in 2002–03, actual number of OP samples processed in the previous two fishing years.

	Number of samples			
Area	Expected* 2002–03	Actual 2002–03	Actual 2001–02	Actual 2000–01
ORH 3B				
Chatham Rise	220	279	190	208
South of 46° S/Arrow Plateau	40	26	55	82
ORH 2A				
North	0	0	7	2
South	40	8	2	5
ORH 2B	0	2	1	1
ORH 3A	0	0	1	19
ORH 7A	0	0	3	0
ORH 1	20	116	52	0
ORH 10	0	0	0	0
ORH 7B	0	0	2	7
ET				
Lord Howe/NW Challenger	60	7	89	55
Louisville Ridge	60	155	37	27
South Tasman Rise	0	0	0	0
West Norfolk Ridge	0	12	40	
Total	440	605	479	406

*Ministry of Fisheries research summary tender document figures

Table 2: Number of OP orange roughy biological samples by area and month for 2002–03, 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	–	–	2	13	2	3	–	14	1	–	–	46	6
AKE	–	–	–	–	–	2	–	–	57	11	–	–	70	4
CEE	–	–	–	–	–	–	4	6	–	–	–	–	10	1
SOE	13	–	–	42	126	9	3	28	52	–	2	–	275	10
SEC	2	–	–	–	–	–	1	1	–	–	–	–	4	2
SUB	22	–	–	–	–	–	–	–	–	–	–	–	22	2
SOI	3	–	–	–	–	–	–	1	–	–	–	–	4	2
SOU	–	–	–	–	–	–	–	–	–	–	–	–	0	–
CHA	–	–	–	–	–	–	–	–	–	–	–	–	0	–
HOWE	–	–	–	–	2	–	–	–	–	–	–	–	2	1
LOUR	–	–	–	–	–	–	–	10	79	64	2	–	155	3
CET	6	6	–	1	1	3	–	–	–	–	–	–	17	4
ALL	57	6	0	45	142	16	11	46	202	76	4	0	605	23

Summary by fishery area

ORH 3B fisheries	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Voyages	No. fish measured
Arrow Plateau	–	–	–	–	–	–	–	8	1	–	1	–	10	2	223
Auckland Is.	3	–	–	–	–	–	–	1	–	–	–	–	4	2	201
Bounty Is.	9	–	–	–	–	–	–	–	–	–	–	–	9	1	387
East Rise	–	–	–	26	88	4	2	13	–	–	1	–	134	6	9 611
Macquarie	6	–	–	–	–	–	–	–	–	–	–	–	6	2	334
Pukaki	7	–	–	–	–	–	–	–	–	–	–	–	7	2	106
SE Rise	3	–	–	14	12	2	–	2	–	–	–	–	33	6	2 532
Spawning Box	–	–	–	–	–	–	–	2	38	–	–	–	40	4	3 275
SW Rise	2	–	–	–	–	–	–	–	–	–	–	–	2	1	5
NW Rise	10	–	–	2	26	3	2	4	13	–	–	–	60	5	4 649
ORH 1 fisheries															
Colville Ridge	–	–	–	–	–	–	–	–	7	2	–	–	9	1	739
East Northland	–	–	–	–	–	2	–	–	14	9	–	–	25	2	1 398
South Kermadec Ridge	–	–	–	–	–	–	–	–	5	–	–	–	5	2	137
Tauroa Knoll	11	–	–	–	1	–	–	–	–	–	–	–	12	2	602
West Norfolk Ridge	–	–	–	2	12	2	3	–	–	–	–	–	19	3	1 243
ORH1 (other)	–	–	–	–	–	–	–	–	6	–	–	–	6	2	758
Alderman Knoll	–	–	–	–	–	–	–	–	8	–	–	–	8	2	312
Manukau	–	–	–	–	–	–	–	–	14	1	–	–	15	2	1 054
Mercury-Colville box	–	–	–	–	–	–	–	–	2	–	–	–	2	1	201
White I.	–	–	–	–	–	–	–	–	15	–	–	–	15	2	687
Other fisheries															
Ritchie Banks	–	–	–	–	–	–	2	6	–	–	–	–	8	1	657
Wairarapa	–	–	–	–	–	–	2	–	–	–	–	–	2	1	157
West Norfolk Ridge (ET)	6	5	–	1	–	–	–	–	–	–	–	–	12	3	718
Lord Howe (ET)	–	–	–	–	2	–	–	–	–	–	–	–	2	1	16
Louisville Ridge (ET)	–	–	–	–	–	–	–	10	79	64	2	–	155	3	4 891
NW Challenger (ET)	–	1	–	–	1	3	–	–	–	–	–	–	5	2	180
ALL	57	6	0	45	142	16	11	46	202	76	4	0	605	23	35 073

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, 2002–03; 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.

Area	No. tows sampled	Weight of samples (kg)	Catch (t)		Percentage of fishery observed
			observed	fishery	
ORH 1					
West Norfolk Ridge	19	2 702	44	218	20
Tauroa Knoll	12	773	63	209	30
East Northland	25	3 324	46	104	44
Colville Ridge	9	2 327	36	109	33
South Kermadec Ridge	5	319	0.3	10	4
Alderman Knoll	8	386	0.4	2	19
Manukau	15	1 201	96	185	52
Mercury-Colville box	2	406	8	39	20
White I.	15	1 011	2	18	12
ORH1 (other)	6	1 330	26	118	22
ORH 2A					
Ritchie	8	688	17	518	3
ORH 2B (Wairarapa)	2	231	25	82	31
ORH 3B					
Chatham Rise					
Spawning Box	40	4 299	688	3 144	22
NW Rise	60	5 645	553	2 244	25
East Rise	134	12 483	804	3 906	21
SW Rise	2	7	0.01	5	<1
SE Rise	33	3 345	129	1 455	9
Southern/Arrow Plateau					
Arrow Plateau	10	353	3	215	2
Macquarie	6	609	9	187	5
Auckland Is.	4	246	4	67	6
Bounty Is.	9	422	67	197	34
Pukaki	7	153	6	490	1
ORH ET					
Lord Howe	2	1	0.01	208	<1
NW Challenger	5	195	0.5	918	<1
Louisville Ridge	155	9 038	241	1 296	19
West Norfolk Ridge	12	1 436	9	35	26

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 and ORMC samples.

Area	Period	Number measured			Sex ratio (%male) (scaled)	Total catch (t)	Scaled Mean length (s.d.)	
		Male	Female	Total			Male	Female
OP data								
NW Rise	pre-spawning	1 623	1 745	3 368	54.6	134	32.1 (3.2)	32.7 (3.6)
NW Rise	spawning	846	433	1 281	65.7	419	33.7 (2.5)	35.8 (2.6)
Spawning Box	spawning	1 633	1 530	3 175	51.1	675	33.5 (2.8)	35.2 (2.9)
East Rise	pre-spawning	4 220	5 295	9 529	42.4	800	32.8 (2.6)	34.2 (3.0)
SE Rise	pre-spawning	1 017	1 515	2 532	36.5	129	32.3 (3.2)	33.6 (3.5)
Ritchie	pre-spawning	281	376	657	44.9	17	28.8 (4.7)	30.2 (5.0)
Louisville Ridge (E.T.)	spawning	2 274	2 271	4 548	52.6	212	37.0 (3.4)	38.8 (3.4)
West Norfolk R. (ET)	pre-spawning	426	292	718	67.0	9	39.7 (2.4)	41.3 (2.2)
Tauroa Knoll	pre-spawning	295	305	602	51.4	63	34.9 (2.6)	35.4 (2.8)
West Norfolk R.	pre-spawning	735	508	1 243	58.6	44	40.9 (4.1)	41.9 (4.4)
Colville Ridge	spawning	347	390	739	41.7	36	42.9 (3.5)	47.0 (3.0)
East Northland	spawning	768	476	1 244	67.4	44	40.4 (2.6)	43.1 (2.9)
Manukau	spawning	710	307	1 054	65.9	96	33.3 (2.9)	34.5 (3.2)
White I.	spawning	322	365	687	44.7	2	33.4 (3.0)	35.5 (3.5)
ORMC data								
Pukaki	pre-spawning	261	253	515	48.1	95	38.1 (4.3)	39.6 (3.9)

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).

		Percentage at stage					
Area	Month	F1	F2	F3	F4	F5	Number staged
Alderman Knoll	Jun	20	29	47	12	5	113
Colville Ridge	Jun	0	27	58	194	34	313
	Jul	0	1	1	30	45	77
East Northland	Mar	0	0	10	44	6	60
	Jun	1	97	42	8	4	152
	Jul	0	7	44	229	44	324
Mercury-Colville box	Jun	0	7	44	24	0	75
South Kermadec Ridge	Jun	3	24	14	2	2	45
Tauroa Knoll	Feb	0	0	2	7	34	43
	Oct	136	124	0	1	0	262
West Norfolk Ridge	Feb	39	225	8	44	97	413
	Mar	0	0	0	40	22	62
White I.	Jun	52	105	132	68	6	365
Manukau	Jun	45	214	11	0	0	270
	Jul	0	19	15	3	0	37
Ritchie	Apr	41	70	0	0	0	111
	May	148	116	0	1	0	265
Wairarapa	Apr	20	44	0	0	0	64
NW Rise	Jan	9	21	0	0	0	30
	Feb	319	714	0	1	0	1034
	Mar	43	49	0	0	0	92
	Apr	59	52	1	0	0	112
	May	46	148	1	0	0	195
	Jun	9	271	146	7	0	433
	Oct	89	176	16	1	0	282
Spawning Box	May	11	35	0	0	0	46
	Jun	51	1367	87	22	3	1530
East Rise	Jan	155	568	150	2	4	882
	Feb	1109	2113	162	3	33	3420
	Mar	67	94	0	0	0	161
	Apr	43	25	0	0	0	68
	May	393	371	0	0	0	764
	Aug	13	36	1	0	1	51
Arrow Plateau	May	13	48	0	0	0	61
	Jun	39	52	0	0	0	91
SE Rise	Jan	79	413	40	1	2	535
	Feb	191	286	21	0	4	502
	Mar	26	85	0	0	0	111
	May	71	40	0	0	0	111
	Oct	45	199	12	0	0	256
Pukaki	Oct	27	24	3	1	1	56
Macquarie	Oct	2	85	64	0	0	151
Auckland Is.	May	25	5	1	0	8	39
	Oct	28	20	1	1	8	58
Bounty Is.	Oct	41	103	6	3	5	159
West Norfolk Ridge (E.T.)	Jan	1	31	2	0	0	34
	Oct	32	64	11	1	0	108
	Nov	14	114	15	1	6	150
Louisville Ridge (E.T.)	May	17	154	0	0	0	171
	Jun	41	1008	236	143	1	1429
	Jul	122	100	78	341	164	805
	Aug	0	0	1	34	2	37
NW Challenger (E.T.)	Nov	12	38	4	0	0	54

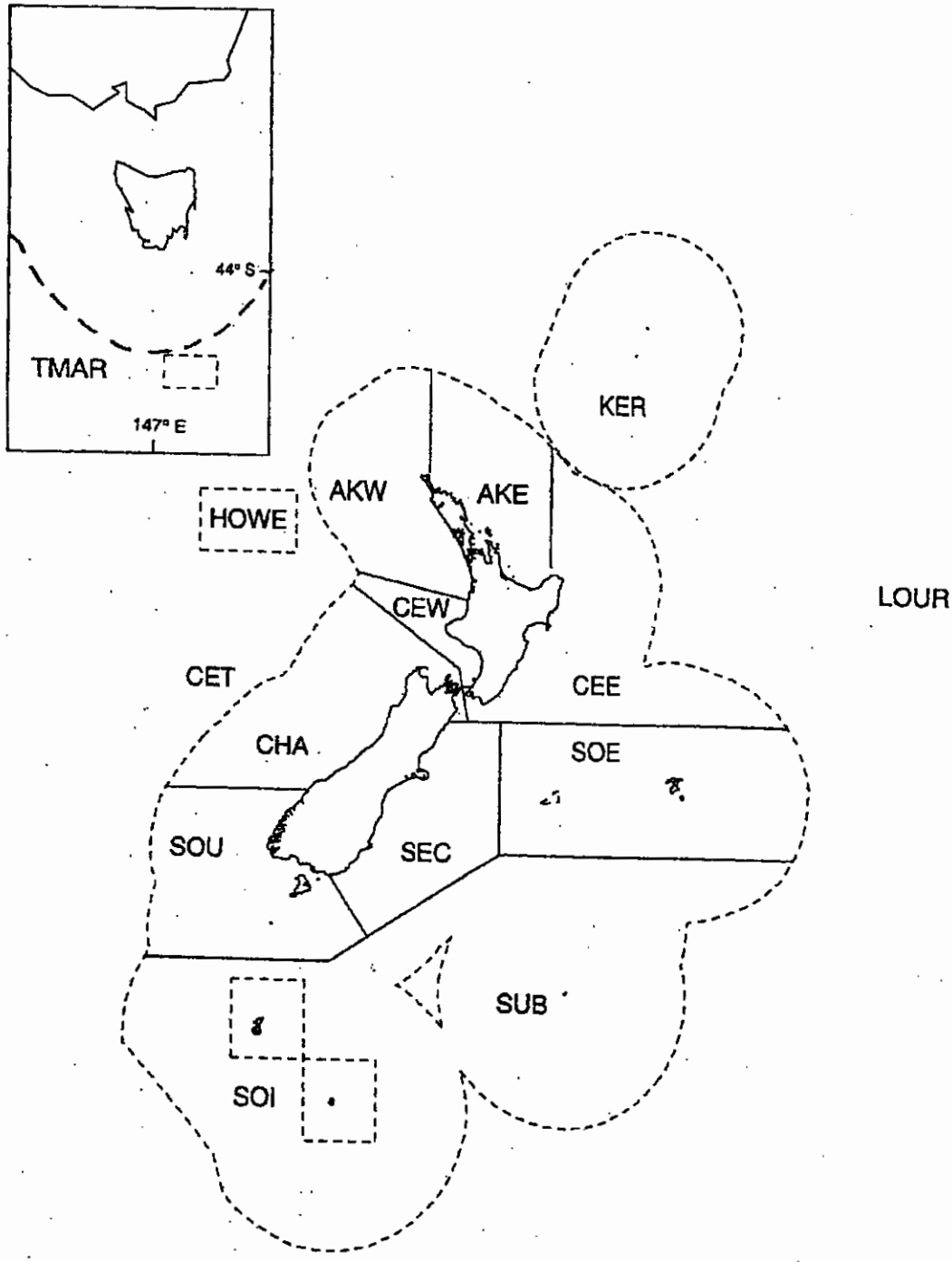
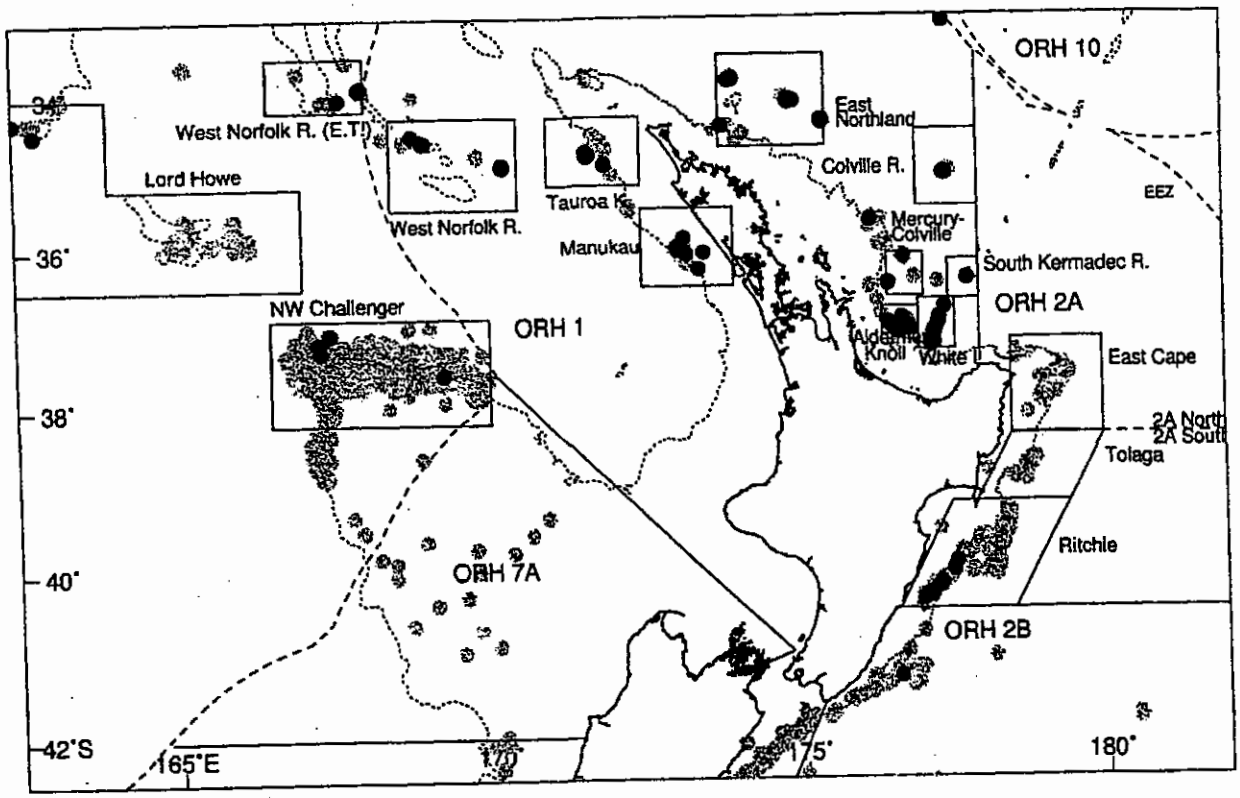


Figure 1: Ministry of Fisheries Observer Programme management areas.



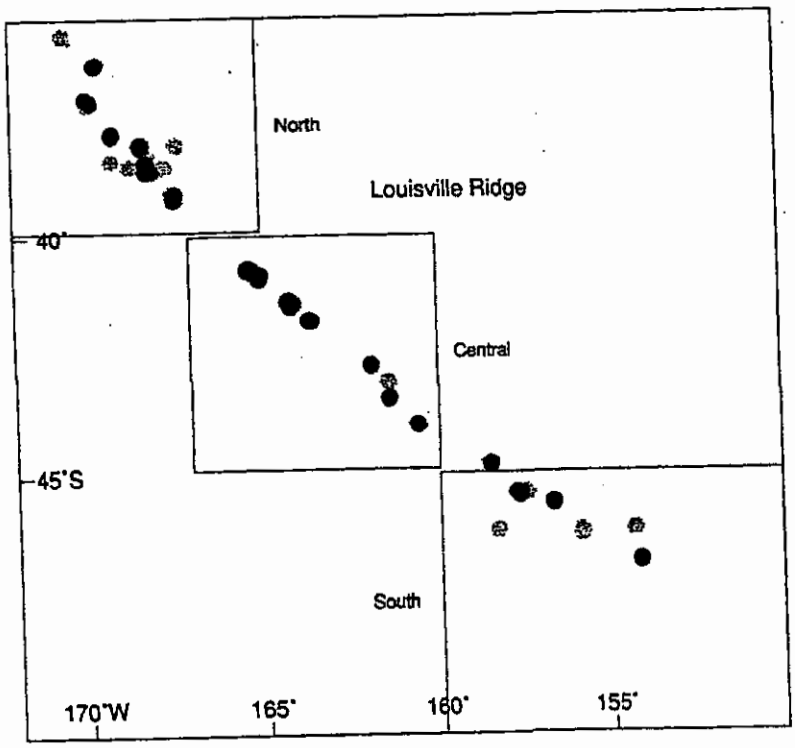


Figure 2: Location of fisheries used for analysis of biological data, position of trawls in the commercial fishery (grey dots), and location of samples of orange roughy taken by OP observers (black dots), during the 2002–03 fishing year. The dotted line shows the 1000 m depth contour.

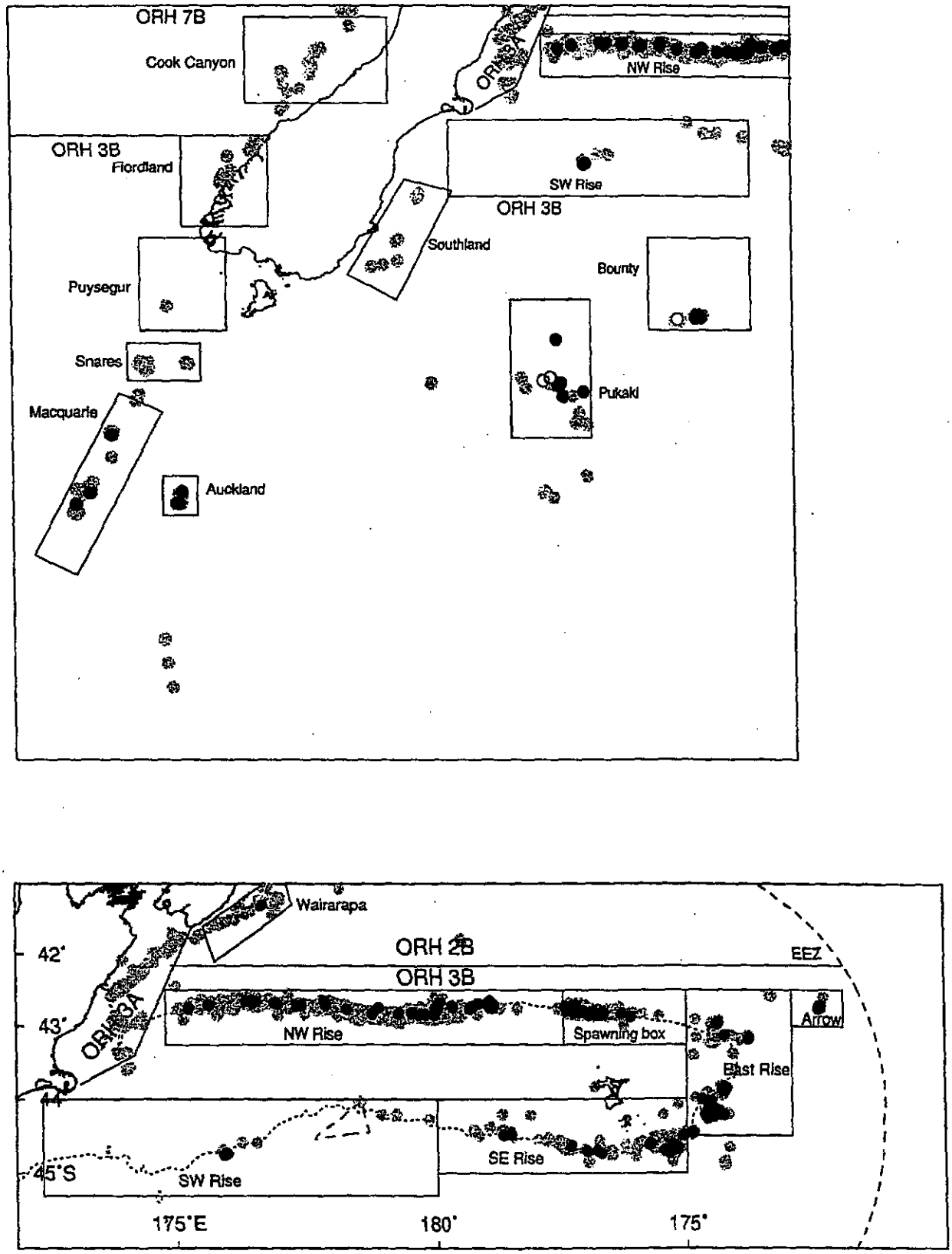


Figure 3: Location of fisheries used for analysis of biological data, position of trawls in the commercial fishery (grey dots), location of samples of orange roughy taken by OP observers (black dots), and location of samples of orange roughy taken by ORMC observers (white dots) during the 2002–03 fishing year. For reasons of confidentiality, the axis scales and details of bathymetry and geography have been omitted from the upper figure. The dotted line in the lower figure shows the 1000 m depth contour.

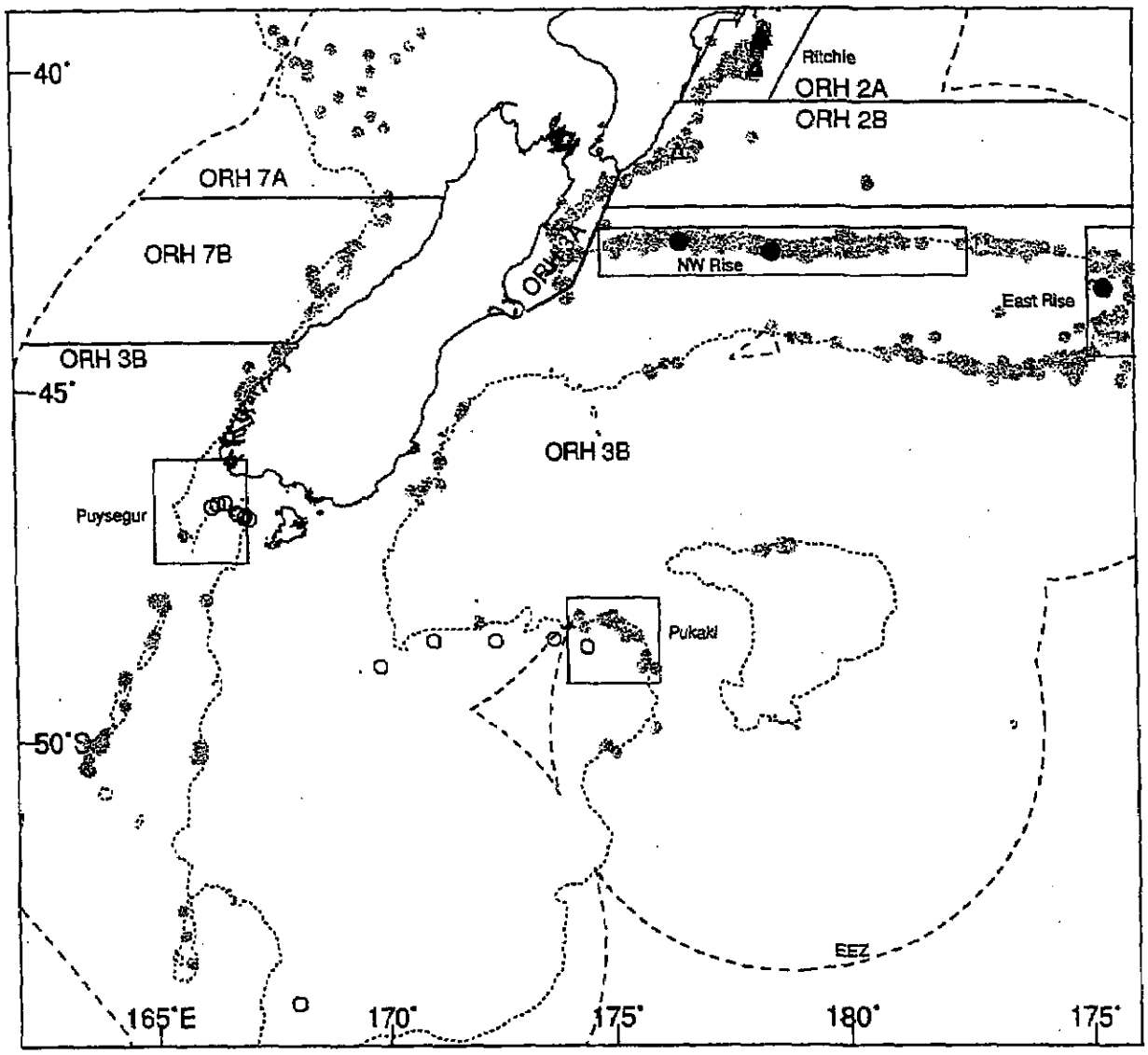


Figure 4: Location of fisheries and research trawls where orange roughy length data were recorded, and position of trawls in the commercial fishery (grey dots); closed circles, Chatham Rise hoki survey December 2002–January 2003 (R.V. *Tangaroa*); open triangles, ORH 2A South orange roughy survey June 2003 (F.V. *Ocean Ranger*); open circles, sub-Antarctic trawl survey November–December 2002 (R.V. *Tangaroa*). The dotted line shows the 1000 m depth contour.

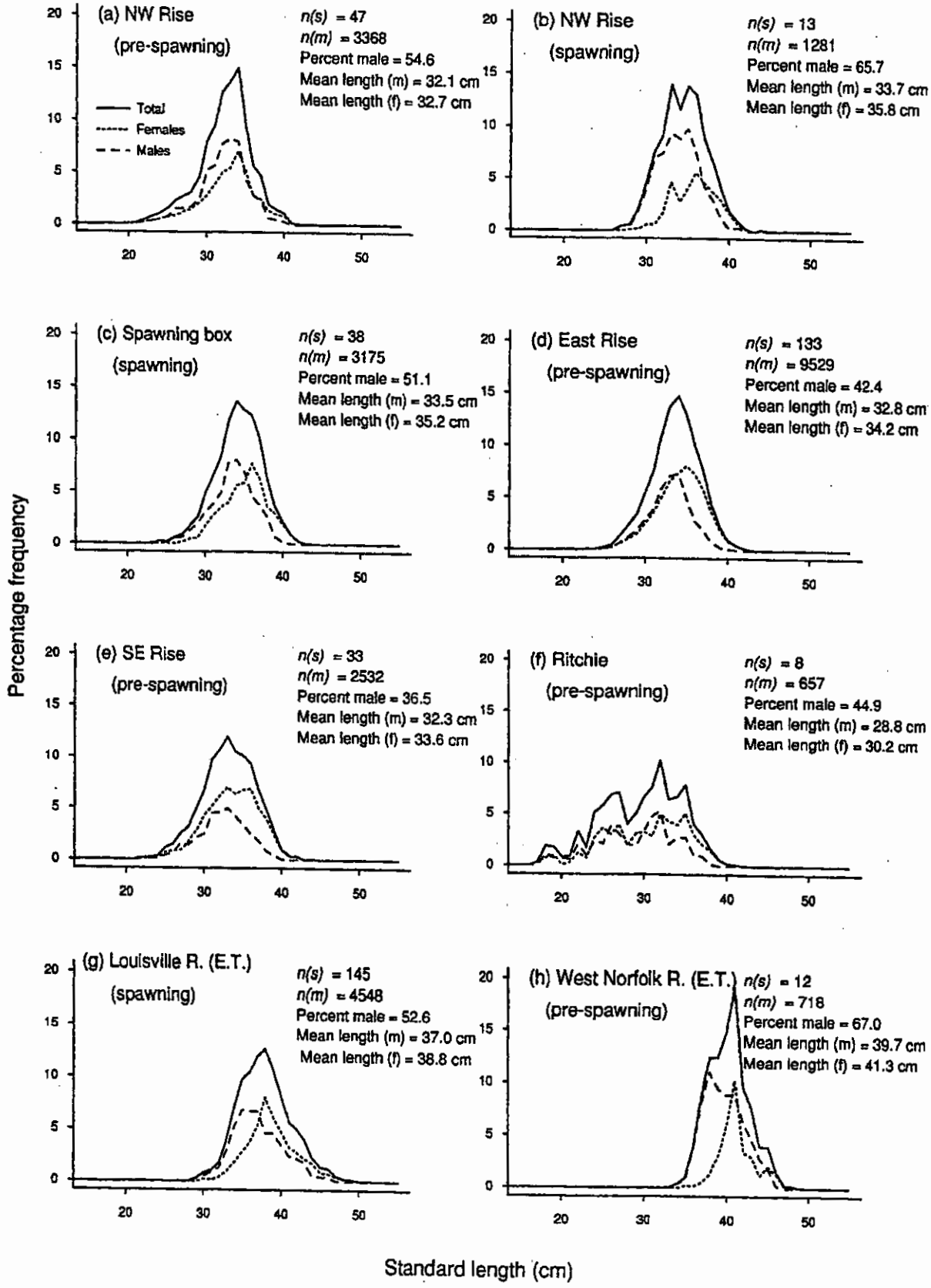


Figure 5: OP length frequency distributions (scaled by catch) of orange roughy by area and period, *n(s)*, number of samples; *n(m)*, number of fish measured.

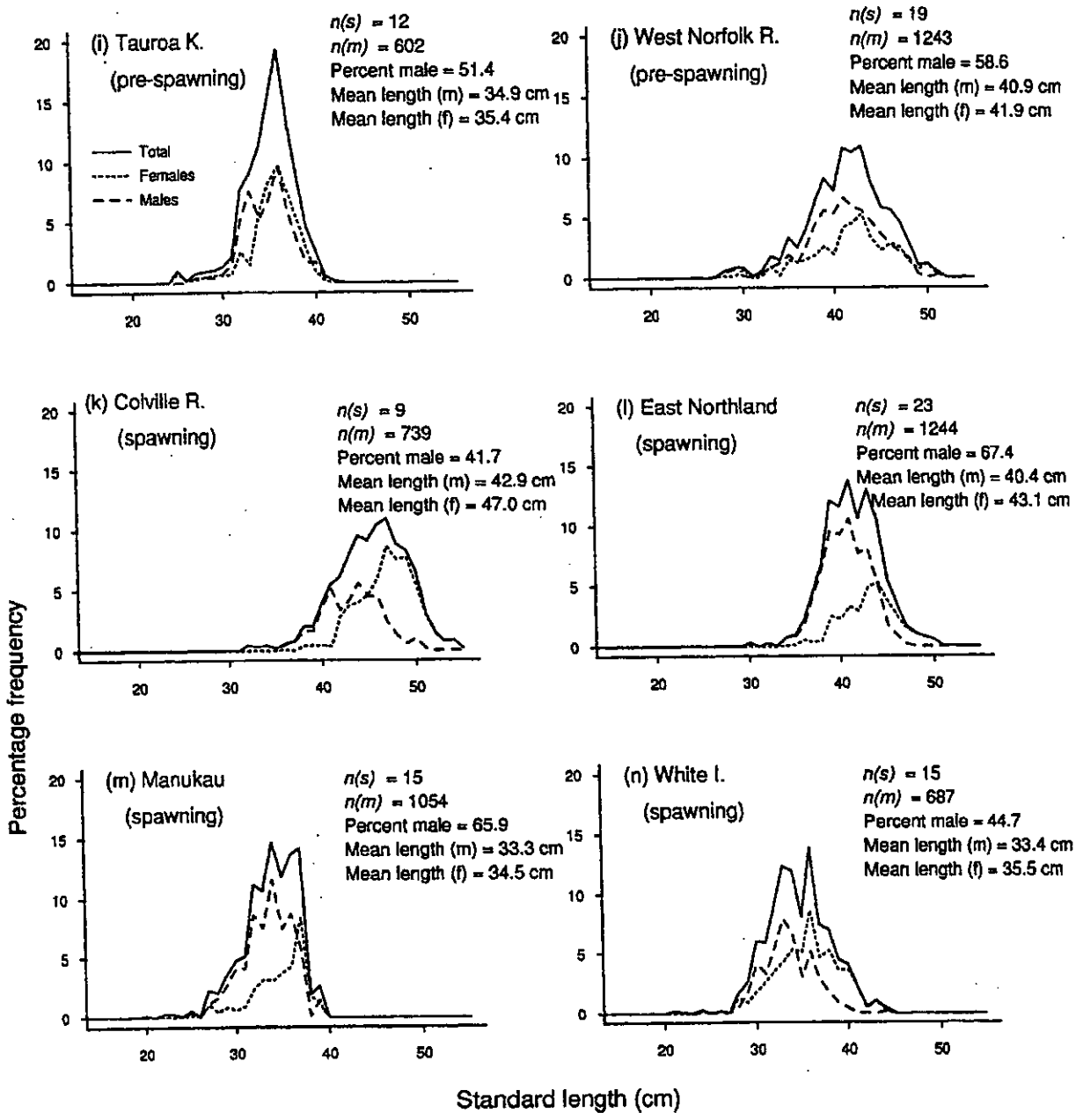


Figure 5 — *continued.*

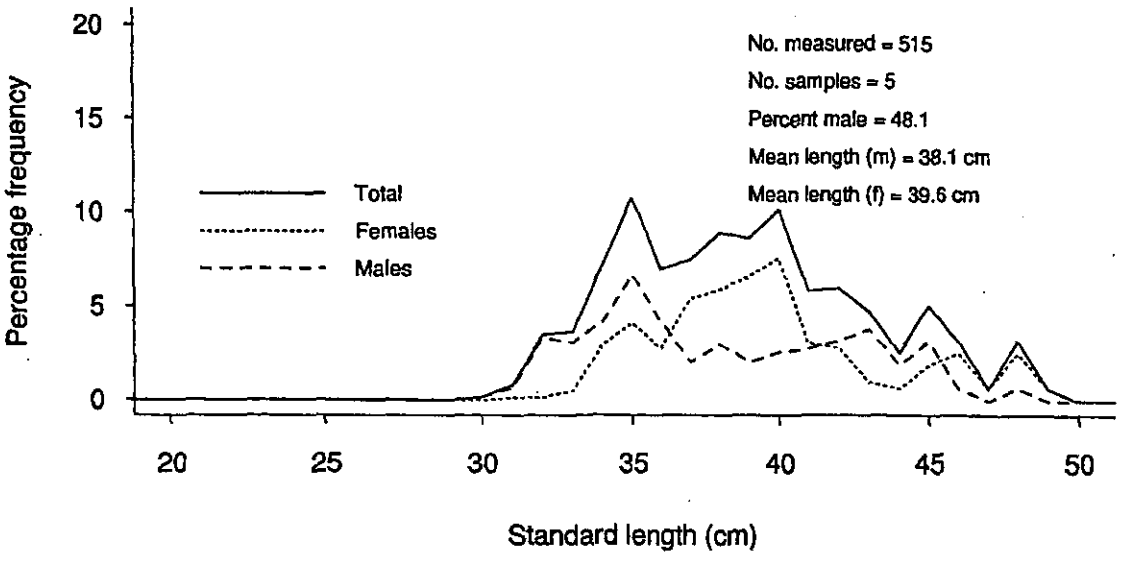


Figure 6: ORMC length frequency distributions (scaled by catch) of orange roughy by area and period.

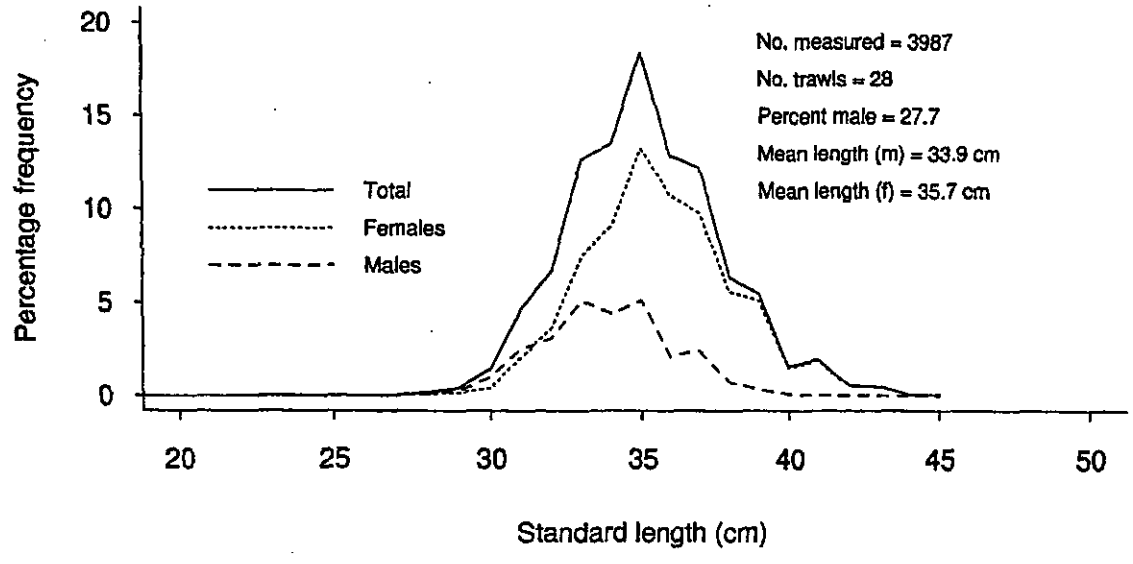


Figure 7: Orange roughy length frequency distribution (scaled by catch) from the ORH 2A South orange roughy research survey June 2003 (F.V. *Ocean Ranger*).

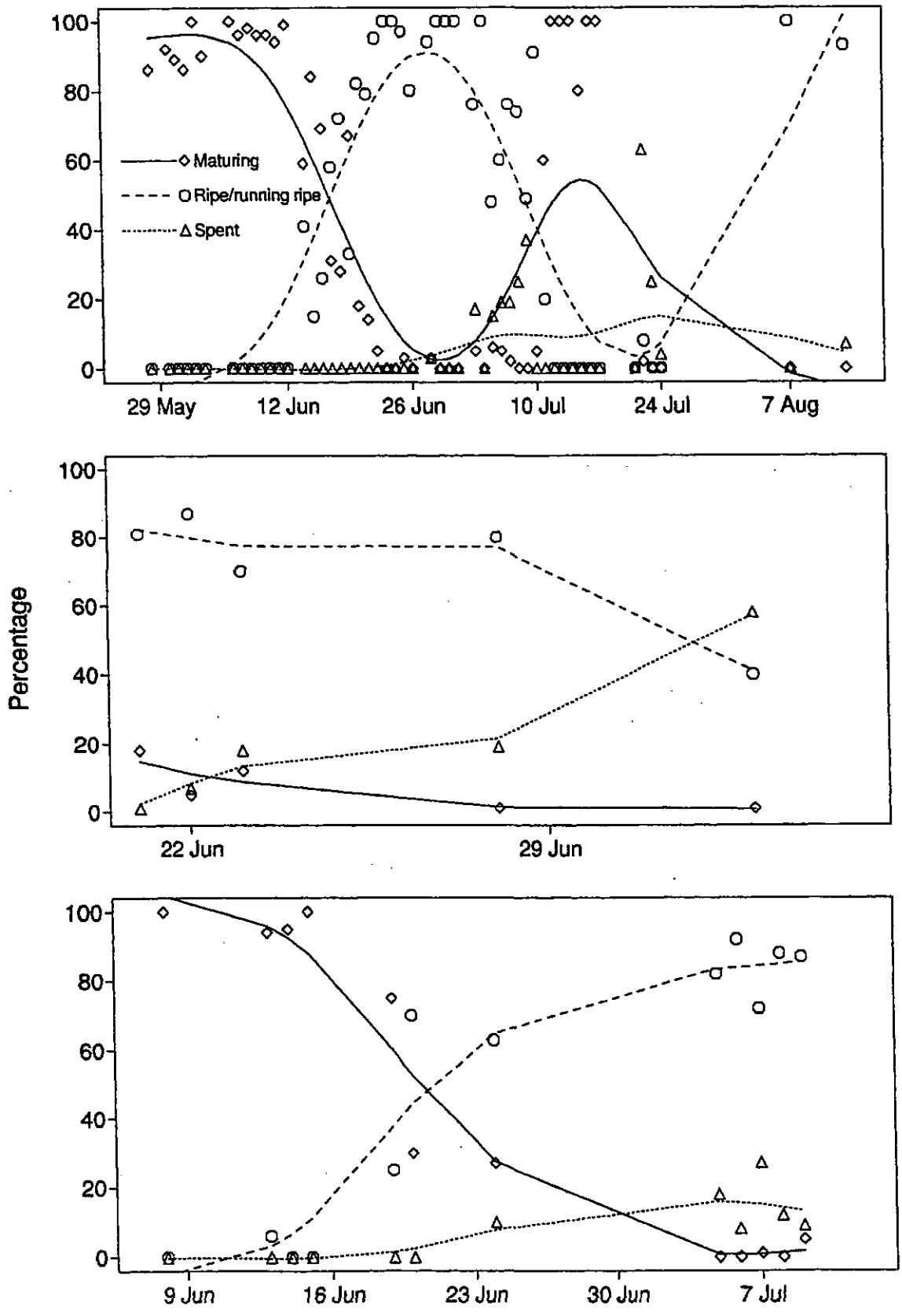


Figure 8: Daily changes in female orange roughy gonad stage proportions during the spawning season in three fisheries, from observer data; top, Louisville Ridge (ET); centre, Colville Ridge (ORH 1); bottom, East Northland (ORH 1). Each point indicates the fraction of all mature fish examined (in all samples taken on that day) which were in the reproductive state indicated by the symbol.

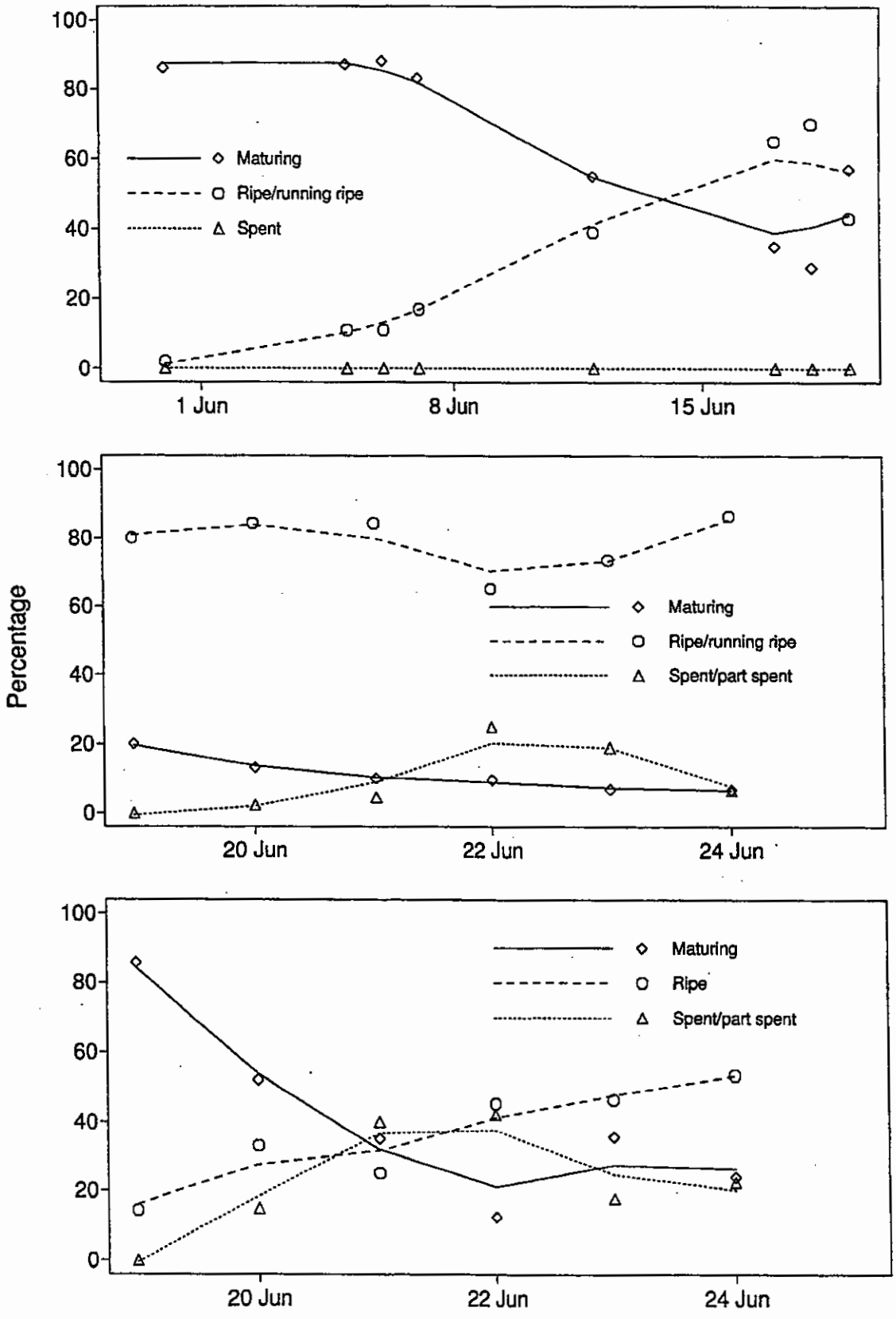


Figure 9: Daily changes in orange roughy gonad stage proportions during the spawning season in two fisheries; top, Northwest Rise (ORH 3B, female fish, from OP observer data); centre, ORH 2A South (female fish, from research survey data); bottom, ORH 2A South (male fish, from research survey data). Each 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.