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A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2005–06 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), a fishing industry observer programme (IOP), and from NIWA research surveys, were examined and summarised by fishery. Data were available from 480 OP tows and 141 IOP tows during the 2005–06 fishing year, almost exclusively from within the New Zealand Exclusive Economic Zone (EEZ). Biological data collected by NIWA staff from 174 research survey stations on the Chatham Rise and Challenger Plateau were also summarised.

2. The level of OP sampling was slightly greater than in 2004–05 and represented a moderate to high level of sampling in comparison with recent years, but was short of the 508 scheduled samples for the year. Coverage matched reasonably well the scheduled level of coverage in most areas, especially in the most intensely sampled fisheries (ORH 1 and the Chatham Rise (ORH 3B)) but there was no sampling in the east coast fisheries in QMAs ORH 2A, ORH 2B, and ORH 3A. Sampling in areas outside the EEZ was better than in 2004–05, especially in the Lord Howe/Northwest Challenger and on the Louisville Ridge. Coverage of the Spawning Box fishery in ORH 3B was particularly good, and similar to that in 2004–05, with 139 samples and over 15 000 fish measured. Several thousand fish were also measured in each of the East Rise, Northwest Rise, Puysegur (ORH 3B) and East Northland (ORH 1) fisheries. The level of IOP sampling was greater than previously achieved in any year, and focused on the main ORH 3B fisheries on the Chatham Rise and Pukaki Rise. The programme measured 14 000 orange roughy during the year, 3900 of them in the east Chatham Rise.

3. Sufficient length samples were obtained by OP observers to determine size frequencies for 15 fishery/season combinations, and by IOP observers for 7 fishery/season combinations. These distributions were broadly unimodal in shape in all areas, although there was variation between areas in the range of fish sizes and the calculated mean lengths. The smallest fish were from the Northwest Chatham Rise spawning and Northwest Challenger pre-spawning fisheries (mean lengths 30.2–31.9 cm for males and 31.3–33.5 cm for females) and the largest from the West Norfolk Ridge fishery (mean lengths 40.5 cm (males) and 42.4 cm (females). A large amount of length data was collected from the oreo research survey on the South Chatham Rise and the orange roughy survey on the Challenger Plateau, and size distributions were produced for these also.

4. In most areas, sex ratios calculated from scaled observer size frequency data did not indicate a strong dominance of one sex, with 12 of the 22 calculated ratios falling within 5 percentage points of 50%. The most biased sex ratios were from the East Northland spawning fishery (77.0% male) and the Tauroa Knoll pre-spawning fishery (31.8% male).

5. OP observer sampling in the Spawning Box fishery and research sampling in the Challenger fishery during the spawning period was sufficient to describe the temporal progression of spawning in those areas. The timing of spawning was earlier than usual for the Spawning Box fishery and typical, of recent years at least, for the Challenger Plateau fishery.

1. INTRODUCTION

This report documents the results of objective 3 of the Ministry of Fisheries project ORH2006/02 "Stock assessment of orange roughy", and objective 2 of Ministry of Fisheries project ORH2006/03 "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 2005–06 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 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 survey data. 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, Challenger, Northwest and Northeast Chatham Rise, East Cape hills, and Mid-East Coast (MEC) fisheries (Clark & Tilzey 1996, Hilborn et al. 2000a, 2000b, Branch et al. 2002, Smith et al. 2002a, Ward & Hicks 2005, Dunn 2007, A. McKenzie, NIWA, unpublished results). The use of observer data in orange roughy stock assessments was summarised by Anderson (2006a). 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. 2002b). 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 the Chatham Rise Spawning Box fishery (Francis 1996).

This report presents summaries of orange roughy size and reproductive state data collected by MFish and industry observers from fisheries throughout the EEZ (project ORH2006/02), and from several fisheries outside the EEZ (referred to in this report as ET fisheries, project ORH2006/03), during the 2005–06 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 2006b) to provide a means of quickly identifying and obtaining data for input into stock assessment models.

In addition to the analysis of observer data, this report also presents summaries of orange roughy biological data collected by NIWA staff during an industry-funded survey for orange roughy in June–July on the Challenger Plateau (ORH 7A), an MFish-funded survey of oreos on the South Chatham Rise (OEO4, ORH 3B) in November 2005, and provides station positions where small amounts of orange roughy biological data were collected on NIWA-run research surveys of middle depth species in 2005–06. Further, industry-run, orange roughy research surveys were carried out in June and July on the Spawning Plume (Chatham Rise, ORH 3B), and in the Puysegur fishery (southern ORH 3B). Biological data were collected on these surveys by OP observers and so are included in this report in the summaries of observer data.

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 1–400) 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.

Further orange roughy biological data are also available from the IOP programme, which has operated since 1996–97 but has collected generally decreasing amounts of data in recent years. On participating vessels, the sampling programme collects biological data from the orange roughy catch from a randomly selected commercial trawl for each day of fishing, and generally follows the procedures used by OP observers (but see Langley (2001) for a detailed description of the sampling protocols). A revival of this sampling programme has resulted in a large amount of data being available for the 2005–06 fishing year.

Biological data collected by NIWA staff are available from the orange roughy research survey on the Challenger Plateau (F.V. *Thomas Harrison*). Some further orange roughy biological data are also available from a survey of hoki on the Chatham Rise in December 2005 to January 2006 and from a multi-species survey in the sub-Antarctic in November–December 2005. 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 from both the OP and IOP programmes 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 to 4). These fishery areas are comparable to those used in previous analyses (e.g., Anderson 2006b).

All data were error checked before being added to the databases, and further checks were made 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 and IOP observer coverage achieved in each of the main fisheries in 2005–06. 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 and IOP 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. The OP 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. 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.

Length data collected by NIWA staff were treated in the same manner as those collected by observers. 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 five (macroscopic) categories (Table 1). Note that these are different from the categories currently used for orange roughy by NIWA research staff, which provide for a more complete separation of immature fish from mature fish and allow for partially spent and resting stages.

Gonad staging data from both OP and IOP observers were aggregated by month and fishery area and the proportion of female fish in each gonad stage was determined to broadly summarise the observed timing and location of orange roughy spawning activity for the year.

The reproductive states of female fish (and male fish from research survey data) were also examined at a daily level. Where time series of appropriate data through the spawning period were available, plots were created to examine the progression of spawning over time. These plots 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 (observer, F2, F3/F4 combined, F5; research female, F3/F9, F4/F5, F6/F8; research male, M3/M9, M4, M5/M8) shown in Table 1. Sufficient data for this purpose were available from only the Challenger Plateau survey (using all tows), and from OP data from the Chatham Rise Spawning Box fishery.

4. RESULTS

OP samples of orange roughy ranged from 0.2 kg to 519 kg from catches between 1 kg and 137 t. IOP samples were not weighed, although most consisted of 100 fish, and were from catches of between 76 kg and 45 t. NIWA research samples ranged from 0.3 kg to 960 kg and were taken from catches of between 0.3 kg and 56 t.

4.1 Distribution of samples

Ministry of Fisheries OP observers sampled 480 catches of orange roughy collected during 20 voyages with the number of samples per voyage ranging between 4 and 86 (median 14.5). Four areas had specific levels of sampling scheduled for 2005–06, and although in three of these areas these levels were exceeded, in the fourth (ORH 2A South) there were no samples collected by OP observers (Table 2). On the Chatham Rise, the 229 sample/days were slightly greater than the approximate number scheduled but 71 less than in the previous year. Close to twice the 40 scheduled sample/days were collected from non-Chatham Rise parts of ORH 3B, a similar level to the previous year, and the 108 sample/days from ORH 1 comfortably exceeded both the target for that area and the coverage achieved in the previous two years. In this fishing year, for the first time, a large fraction of the observer effort was unassigned to any area. This enabled opportunistic sampling in three areas outside the EEZ, especially Lord Howe/NW Challenger and the Louisville Ridge, and to a lesser extent the part of the West Norfolk Ridge lying outside the zone. The overall target of 508 sample/days, the highest since 1999–2000 (Anderson 2001), was not achieved, but the 480 sample/days was higher than in either of the last two years.

Sampling effort arranged by month and OP area is shown in Table 3, and sampling effort by month, sampling programme, and fishery is shown in Table 4. Almost half of the OP samples came from area SOE (Chatham Rise) with the remainder spread amongst areas SOU/SUB (Southland/Sub-Antarctic), AKE/AKW (ORH 1), and HOWE/LOUR (E.T.) regions.

Industry (IOP) observers sampled 141 catches of orange roughy on 23 voyages, the number of samples per voyage ranging from 1 to 22 (Table 4). These were mainly from fisheries within ORH 3B, especially the northwest, east, and southeast Chatham Rise, the Spawning Box and, in the south, Pukaki. Only 11 of the samples were taken from outside these areas, in the Kaikoura (ORH 3A), Wairarapa (ORH 2B), and Macquarie, Snares, Auckland, and Bounty (ORH 3B) fisheries.

Overall, observer sampling on the Chatham Rise was concentrated heavily on the Spawning Box where OP observers collected 139 samples and IOP observers collected 26 samples representing over 18 000 fish, mostly between April and July. Sampling levels were also high in the east and NW Rise areas where about 8300 and 5300 fish were measured, respectively, spread throughout much of the year. Elsewhere, in southern parts of ORH 3B, a moderate number of samples was collected from the Pukaki Rise, Bounty Is., and Puysegur (during the July industry survey). Sampling was spread among seven recognised fisheries in ORH 1, with OP coverage ranging from 2 samples in each of Colville Ridge and South Kermadec Ridge to 57 samples from June and July in east Northland. A moderate level of OP coverage was also achieved in West Norfolk Ridge, as has been the case in that area for the past few years, and in Dargaville and Tauroa Knoll. The three central east coast QMAs (ORH 2A, ORH 2B, ORH 3A) were not sampled at all by OP observers. This region has received little coverage in recent years, despite an allocation of samples to the OP programme, mainly due to the small size of the vessels operating in these fisheries. With the combined efforts of the two programmes, observer effort was moderately well spread out over the fishing year, with samples having been collected in each month, although the number of samples was 10 or fewer in January, February, and September. Overall, sampling reflected the spread of the commercial fishery, where there is an emphasis on the May/June/July spawning period for orange roughy. More than 60% of the samples were collected during these three months.

Outside the EEZ, the level of sampling was much improved over the previous year when only seven samples (from Louisville Ridge) were collected (Anderson 2006b). In 2005–06, more than 20 OP samples were collected from this fishery and also the NW Challenger fishery, with a few samples also collected from the Lord Howe and West Norfolk Ridge (E.T.) fisheries.

The positions of all tows from which OP samples were collected are shown in Figures 2 and 3, which also show the positions of all tows that caught orange roughy in the 2005–06 fishing year, according to TCEPR returns. Sampling was well spread over most of the northern fishing grounds, both in the fisheries outside the EEZ and those in ORH 1. Coverage was noticeably missing only from the smaller Bay of Plenty fishing grounds (White I., Aldermen Knoll, Mokohinau) and the southern parts of the NW Challenger fishery. A very high fraction of the commercial fishery was observed in two ORH 1 fisheries, East Northland (74%) and West Norfolk Ridge (83%) (Table 5), reflecting the requirement of the Adaptive Management Programme (AMP) operating in this QMA for intensive observer coverage. Coverage of some of the Chatham Rise fisheries was also high in relation to commercial catch, with over 3000 t of catch sampled overall, and sampling representing more than 60% of the 3300 t catch in the Spawning Box, more than half the NW Rise catch, and 40% of the SW Rise catch. Sampling was well spread out over the Spawning Box and the hill areas of the East and Southeast Rise, and to a lesser extent the Northwest Rise fishery, where there was a focus on the main hills area centred around 180° as well as one or two other locations in the west and east of the fishery. In the southern area of ORH 3B (south of 46° S), where fishing effort is spread over a wide area, samples were collected from several locations within the Pukaki, Bounty, and Puysegur fisheries, collectively accounting for about 350 t of orange roughy catch in 2005–06 (Table 5). A few trawls were also sampled in the Pukaki South fishery. Coverage was almost complete in the Puysegur

fishery, where the industry survey represented the only fishing in this (closed) area in 2005–06. More than half the total catch was observed in the small Bounty Is. fishery, and 10% of the 1500 t fishery on Pukaki.

OP observer coverage outside of the EEZ in the east covered each of the three areas defined by Clark (1998a, 1998b) in the Louisville Ridge fishery, representing 39% of the estimated 660 t of orange roughy caught there in 2005–06 (Table 5).

The positions of all tows from which IOP samples were collected are shown in Figure 4, which also shows the positions of all tows that caught orange roughy in the 2005–06 fishing year, according to TCEPR returns. Sampling was well spread over the north and east Chatham Rise, especially around the 180 hills, the Spawning Box, and the southeast corner of the Rise. Outside of these areas, sampling was limited to a few samples from a number of the smaller fisheries, mostly in southern parts of ORH 3B. Although some of the catch weight data were missing from the IOP biological samples, the percentage of the total fishery catch observed appeared to be generally low in the Chatham Rise fisheries, even considering the 180 t of catch observed in the Spawning Box fishery (Table 6). A much higher fraction of the total fishery catch was observed in the mostly smaller southern fisheries of ORH 3B, where all the Auckland Is. catch and much of the Macquarie Ridge catch was sampled, as well as a significant percentage of the larger Pukaki Rise fishery.

The locations of trawl stations in the four research surveys in which orange roughy were measured by NIWA are shown in Figure 5. The Challenger Plateau survey covered the same fishing grounds surveyed in 2005 (i.e. near the Pinnacles, Central Flat, and Westpac Bank features (see also Clark & Tracey (1994) for the locations of these fishing grounds). This survey represented the only fishing for orange roughy in this closed QMA in 2005–06. Orange roughy were frequently caught, although mostly in small numbers, during the oreo survey on the south Chatham Rise (OEO 4) in November 2005. Catches of orange roughy were even smaller in 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.

About 11 250 orange roughy were measured from a catch of 200 t in 79 tows in the Challenger Plateau survey, 374 orange roughy were measured from a catch of about 180 kg in 16 tows in the sub-Antarctic survey, 1856 orange roughy were measured from a catch of about 4.3 t in 78 tows in the oreo survey, and 84 orange roughy were measured from a catch of 42 kg in a single tow 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 6. 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 Spawning Box (Figure 6c, d). The main differences in the size distributions between areas were in the range of fish lengths measured and in the position of the mode. The smallest fish were found in the Northwest Chatham Rise and Bounty Plateau pre-spawning, and Northwest Challenger Plateau spawning fisheries (Figure 6a, g, o) and the largest in the East Northland and Louisville Ridge spawning, and West Norfolk Ridge pre-spawning fisheries (Figure 6k, n, m). In the Northwest Rise and Spawning Box fisheries, fish sampled during the spawning months were 1–2 cm larger than fish sampled earlier in the year, but in the East Rise mean lengths were virtually identical in both seasons (Figure 6a–f).

Small fish, less than 25 cm, were uncommon in most areas, and are noticeable only in the size distributions for the Northwest Rise pre-spawning and Dargaville spawning fisheries (Figure 6a, j). In the fisheries from the Chatham Rise southwards few fish were measured at over 40 cm, but in the

northern fisheries in the West Norfolk Ridge and Louisville Ridge fish larger than this were common (Figure 6m, n). The largest fish observed were in the West Norfolk Ridge fishery where over 62% of fish (sexes combined) were longer than 40 cm, mean lengths were 40.5 cm (male) and 42.4 cm (female), and fish measuring over 50 cm were recorded.

Sex ratios, based on scaled size frequency data, ranged from 31.8% male (Bounty Is., pre-spawning) to 77.0% male (East Northland, spawning) and tended to diverge more from a 50:50 ratio in spawning month samples (Table 7). Overall, there was no clear bias in the sex ratios in favour of one sex. Although 10 of the 15 fishery/area combinations showed a higher percentage of male fish, most of the sex ratios were close to 50:50, with 7 being within 5 percentage points of 50% male, and only 3 more than 20 percentage points from 50:50.

Length frequency distributions by sex from IOP samples are given in Figure 7. These distributions are based on numbers at length not scaled to catch weights due to a number of missing estimated catch values. As was shown for the OP data, these distributions are generally typically unimodal with close to even sex ratios and, except for the NW Chatham Rise spawning plot (Figure 7a), larger female fish. Sufficient data were available to produce plots for both spawning and non-spawning periods in two fisheries, NW Chatham Rise and the Spawning Box. There was little difference in the mean lengths by sex between the two plots for NW Chatham Rise fish (Figure 7a, b), but there was a larger fraction of small fish, especially females, in the spawning period data. This produced the unusual result that the mean length of female fish was smaller than that of male fish. Non-spawning period fish were slightly smaller than spawning period fish in the Spawning Box samples (Figure 7c, d), as may be expected, and sex ratios in both periods were close to even.

Sex ratios, based on unscaled size frequency data, fell within a relatively narrow range, from 37.7% male (NW Rise, spawning) to 58.8% male (Pukaki Rise, pre-spawning) (Table 7). Overall, there was no clear bias in the sex ratios in favour of one sex, and all seven of the sex ratios calculated lay within 9 percentage points of 50:50.

Scaled length frequency distributions were produced from the South Chatham Rise oreo (F.V. *San Waitaki*, R.V. *Tangaroa*) and Challenger Plateau (F.V. *Thomas Harrison*) orange roughy research surveys (Figure 8). The size structure of orange roughy on the South Chatham Rise shows a high proportion of small fish compared with any of the size distributions from observer data and smaller mean sizes than in any observed fishery. This is more likely to be due to the effect of the fine-meshed "rat-catcher" net used during this survey rather than to a particular abundance of small fish, but without sufficient comparable observer data from the same area it is difficult to be certain.

Small fish were also seen by research staff on the Challenger Plateau survey, with mean lengths of 29.6 cm (male) and 31.9 cm (female) for all areas combined (Figure 8). These mean lengths are very similar to those calculated in the same way from the 2004–05 survey in the same area (see Anderson 2006b).

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 2006 and, for a few of these, an indication of the timing and location of spawning can be derived (Table 8).

Much of the OP sampling in the ORH 3B fisheries on the Northwest Rise, Spawning Box, and Puysegur Bank coincided with the winter spawning fishery, with many fish in the ripe, running ripe, and spent stages. The high level of sampling in the East Rise was mostly outside the spawning season, although large numbers of running ripe and spent fish were seen in the samples from July.

Spawning fish were also common in the winter months' samples in the East Northland, Louisville Ridge, and Northwest Challenger fisheries. The observer-collected data from the industry survey in the Puysegur fishery showed that spawning was taking place in July, with a large fraction of ripe, running ripe, and spent fish.

IOP observers recorded female fish in spawning condition (running ripe and spent) in the Bounty I. fishery in August, suggesting that a spawning event was still underway at this late stage in the year (Table 9). There were a few ripe fish recorded in some other fisheries, Pukaki in March and May, SE Chatham Rise in February–April, and the Spawning Box in April and June, but only very occasionally were fish recorded by IOP observers in more advanced spawning condition.

There were sufficient reproductive data collected by OP observers through the spawning period to make plots of the progression of spawning only in the Spawning Box fishery (Figure 9). This plot shows a steadily decreasing fraction of fish in the maturing stage from close to 100% in early June to almost none by the middle of July. During this time the fraction of ripe and running ripe fish increased to between 20% and 40% from about 20 June. There was a gap in sampling between 26 June and 13 July during which time the fraction of spent fish rose from close to zero to over 50%. The peak of spawning is likely to have been during the first few days of July, which is earlier than usual for this fishery, but similar to that observed in 2004 (Anderson 2006a, 2006c).

Research data from the Challenger Plateau survey indicate an erratic pattern of ripe and running ripe fish of both sexes during the period of the survey (24 June to 4 July) but clearly decreasing toward the end of the survey for female fish as spent fish became more common, and a declining fraction of maturing fish of both sexes (Figure 10). The fraction of spent fish began increasing from about 28–30 June, reaching 20% spent at about 29–30 June, exactly the same dates as in 2005 (Anderson 2006b). This is considerably earlier than in any of the 10 years between 1984 and 1995 when timing was determined (Anderson 2006a).

5. SUMMARY AND DISCUSSION

Observer coverage. The 480 samples collected by OP observers in 2005–06 was a small increase over the previous year, and about average when compared to the past 5 or 6 years. The number of samples was 28 short of the expected number based on the schedule, but only one individual area allocation was not met (ORH 2A South). Sampling levels were not specifically allocated to fisheries outside the EEZ (a general allocation of 113 sample/days was set for these and other areas) but a good level of sampling was achieved in three of these fisheries, especially compared to the previous year. Sampling levels were good also in ORH 3B where 40 samples over and above the 260 sample/days scheduled were taken. Mostly these samples were from Chatham Rise fisheries, but sampling levels were also high in southern areas, especially Puysegur, Bounty, and Pukaki. Sixty-two percent of the samples for 2005–06 were taken from ORH 3B, and a further 20% were taken from ORH 1. Sampling levels in ORH 1 were high due to the 75 industry funded sample/days required for the Adaptive Management Programme operating in this fishery. There was no sampling in the EC and MEC stocks (East Cape, Ritchie Banks, Wairarapa, and Kaikoura fisheries), and little or no coverage in the smaller southern ORH 3B fisheries and the Cook Canyon (ORH 7B) fishery.

The 141 samples collected by IOP observers in 2005–06 was the greatest sampling effort since the inception of this programme. Samples were spread amongst the large Chatham Rise fisheries (ORH 3B) and, further south, the Pukaki Rise fishery.

The level of OP sampling coverage was sufficient to determine length frequency distributions of orange roughy in 12 discrete fisheries, and in 3 of them (Northwest Chatham Rise, Spawning Box, and East Rise) plots were prepared separately for pre-spawning and spawning periods. For IOP

sampling, length frequency distributions were produced for 5 discrete fisheries, with separate pre-spawning and spawning plots produced for the Northwest Chatham Rise and Spawning Box fisheries.

Research coverage. There was a moderate amount of biological data available from research surveys in 2005–06, with two orange roughy surveys and one oreo survey taking place during the year. The two-vessel oreo survey of the South Chatham Rise measured over 3000 orange roughy, and the Challenger Plateau orange roughy survey measured over 11 000 orange roughy. Biological data were also collected from an industry survey of orange roughy on the Puysegur Banks, but these were taken by observers and were summarised as observer data in this report. Few fish were caught in the other two (middle depths) *Tangaroa* surveys (458 fish in total).

Size structure. Size structure was examined in 15 fishery/period combinations available from OP data, compared with 12 in 2004–05 and 2003–04, 13 in 2002–03, 14 in 2001–02, 12 in 2000–01, and 20 in 1999–2000. In addition, size structure was examined in 7 fishery/period combinations available from IOP data. Size distributions were typical of orange roughy in all areas, showing a single strong mode, but differed among areas in the sample mean lengths and observed size ranges. Fish in samples from around the spawning period tended to be larger than fish from samples taken beforehand in the fisheries where there were comparable observer data (Northwest Rise and Spawning Box) but were of similar size between periods in the East Rise. Intensive sampling was carried out in some areas, particularly in ORH 3B. Over 11 000 fish were measured by OP observers from 98 samples in the Spawning Box spawning fishery, and 3500–4500 fish were measured by OP observers in the Spawning Box pre-spawning and Puysegur spawning fisheries. IOP observers measured close to 4000 fish in the east Chatham Rise pre-spawning fishery and about 2500 fish in the Pukaki pre-spawning fishery. Mean lengths, calculated from scaled size frequencies, varied among areas, ranging from about 30 cm to 40 cm (male) and from about 31 cm to 42 cm (female), and tended to be greater in the ORH 1 fisheries. Sex ratios were close to 50:50 in most fisheries, with the most extreme sex ratios observed in the Tauroa Knoll pre-spawning (32% male) and East Northland spawning (77% male) fisheries.

Reproduction. Gonad stage data sufficient for tracking the progress of spawning in the winter of 2006 were available from OP observer sampling in the Spawning Box fishery, and from research sampling in the Challenger Plateau fishery. 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 Spawning Box fishery was slightly earlier than usual, but spawning has now been early in this fishery for three consecutive years. The timing of spawning in the Challenger fishery was typical for recent years, but later than observed in the 1984–1995 period.

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 observer programmes continue 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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Table 1: Macroscopic orange roughy gonad stage codes and definitions used by MFish observers and NIWA research staff.

NIWA				Observer	
M1	Immature	F1	Immature	F1	Immature to early maturation
M2	Maturing	F2	Maturing	F2	Maturing
M3	Spermiated	F3	Mature	F3	Ripe
M4	Spermiated, running	F4	Ripe	F4	Running ripe
M5	Spent	F5	Running Ripe	F5	Spent
M8	Partially spent	F6	Spent		
M9	Resting adult	F7	Atretic		
		F8	Partially spent		
		F9	Resting adult		

Table 2: Comparison of expected and actual number of OP orange roughy biological sample/days processed in 2005–06, and the actual number of OP samples processed in the previous two fishing years.

	Number of samples			
Area	Expected* 2005–06	Actual 2005–06	Actual 2004–05	Actual 2003–04
ORH 3B				
Chatham Rise	220	229	300	113
South of 46° S/Arrow Plateau	40	71	79	29
ORH 2A				
North	0	0	3	0
South	40	0	2	0
ORH 2B	0	0	0	0
ORH 3A	0	0	0	0
ORH 7A	0	2	0	0
ORH 1	95**	108	56	90
ORH 10	0	0	0	0
ORH 7B	0	2	0	0
ET				
Lord Howe/NW Challenger	0	34	0	14
Louisville Ridge	0	22	7	39
South Tasman Rise	0	0	0	0
West Norfolk Ridge	0	12	0	5
ORH general	113	–	–	–
Total	508	480	447	290

*Ministry of Fisheries research summary tender document figures (assumes one sample per day)

**75 of these samples are industry funded through the Adaptive Management Programme operating in ORH 1.

Table 3: Number of OP orange roughy biological samples by area and month for 2005–06, 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
AKE	1	–	–	–	–	–	–	–	8	45	10	–	64	3
AKW	27	4	–	–	–	–	–	–	13	–	–	–	44	2
CET	–	–	–	–	–	8	–	4	1	4	–	–	17	3
CHA	–	–	–	–	–	–	–	–	–	–	–	4	4	1
HOWE	–	–	–	–	–	6	–	8	7	8	–	–	29	3
LOUR	–	–	–	–	–	–	–	–	–	10	12	–	22	1
SEC	3	1	–	–	–	–	–	–	–	–	–	–	4	1
SOE	5	12	8	–	–	–	10	47	115	26	–	6	229	11
SOU	–	–	–	–	–	–	–	–	–	35	–	–	35	1
SUB	25	–	–	–	–	–	–	7	–	–	–	–	32	3
ALL	61	17	8	0	0	14	10	66	144	128	22	10	480	20

Table 4: Number of OP/IOP orange roughy biological samples by area and month for 2005–06, with the total number of samples and voyages in each programme and area (see Figures 1 to 3 for area boundaries), and the total number of fish measured (both programmes combined). Cells with single values show counts of OP samples only, no IOP samples having been collected.

Summary by fishery

ORH 3B fisheries	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Voyages	N. fish meas.
Arrow Plateau	–	–	–	–	–	–	4	–	–	–	–	–	4	1	243
Bounty Is.	15	–	–	–	–	–	–	–	–	–	0/1	–	15/1	2/1	902
East Rise	–	4/5	6/5	–/6	–/5	–/5	1/11	7/2	18/2	5	0	–	41/41	6/14	8 278
NW Rise	8	6/1	–/1	–	–/2	–/1	2/3	2/10	19/6	–	–	–	37/24	6/9	5 316
Pukaki South	–	–	–	–	–	–	–	3	–	–	–	–	3	1	100
Pukaki	10	–/10	–/9	–	–	–/4	–	4/2	–	–	–	–	14/25	3/3	3 804
Puysegur	–	–	–	–	–	–	–	–	–	35	–	–	35	1/6	4 563
SE Rise	–	2/1	–/2	–/2	–/1	–/4	–/4	1	1	–	–	6	10/14	4/7	1 906
Spawning Box	–	–	1	–	–	–/1	3/6	37/7	77/12	21	–	–	139/26	7/2	18 039
SW Rise	–	1/1	1	–	–	–	–/1	–	–	–	–	–	2/2	1/2	240
Macquarie	–	–	–/1	–	–	–	–/1	–	–	–	–	–	–/2	–/2	203
Snares	–	–	–/1	–	–	–	–	–	–	–	–	–	–/1	–/1	101
Auckland	–	–	–/1	–	–	–	–	–	–	–	–	–	–/1	–/1	100
ORH 1 fisheries															
Colville Ridge	–	–	–	–	–	–	–	–	–	2	–	–	2	1	13
Dargaville	–	–	–	–	–	–	–	–	13	–	–	–	13	1	640
East Northland	–	–	–	–	–	–	–	–	5	43	9	–	57	2	2 353
Mercury-Colville Box	–	–	–	–	–	–	–	–	2	–	1	–	3	2	99
South Kermadec R.	1	–	–	–	–	–	–	–	1	–	–	–	2	2	70
Tauroa Knoll	10	–	–	–	–	–	–	–	–	–	–	–	10	1	837
West Norfolk R.	17	4	–	–	–	–	–	–	–	–	–	–	21	1	1 402
Other fisheries															
Challenger (ORH 7A)	–	–	–	–	–	–	–	–	–	–	–	2	2	1	34
Cook Canyon (ORH 7B)	–	–	–	–	–	–	–	–	–	–	–	2	2	1	28
Lord Howe (ET)	–	–	–	–	–	6	–	2	–	–	–	–	8	2	251
Louisville Ridge (ET)	–	–	–	–	–	–	–	–	–	10	12	–	22	1	1 567
NW Challenger (ET)	–	–	–	–	–	–	–	6	8	12	–	–	26	2	1 089
West Norfolk Ridge (ET)	–	–	–	–	–	8	–	4	–	–	–	–	12	2	469
Kaikoura (ORH 3A)	–	–	–	–	–	–	–	–/3	–	–	–	–	–/3	–/1	302
Wairarapa (ORH 2B)	–	–	–/1	–	–	–	–	–	–	–	–	–	–/1	–/1	107
ALL	61/0	17/18	8/21	0/8	0/8	14/15	10/26	66/24	144/20	128/0	22/1	10/0	480/141	20/23	53 056

Table 5: Summary of number and weight of samples taken by OP observers relative to the observed catch and estimated total catch in the fishery, 2005–06; observed catch totals are based on the areas defined in Figures 2 to 4, 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					
Colville Ridge	2	14	0.014	0.190	7.4
Dargaville	13	858	12	134	9.3
East Northland	57	3 658	245	333	74
Mercury-Colville Box	3	176	3.4	33	10
South Kermadec R.	2	168	4.6	26	18
Tauroa Knoll	10	1 082	32	197	16
West Norfolk R.	21	3 062	186	223	83
ORH 3B					
Chatham Rise					
East Rise	41	5 160	364	3 539	10
NW Rise	37	3 847	644	1 246	52
SE Rise	10	614	17	1 128	1.5
Spawning Box	139	19 557	2085	3 320	63
SW Rise	2	77	8.6	21	40
Southern/Arrow Plateau					
Arrow Plateau	4	444	7.6	62	12
Bounty Is.	15	964	33	57	57
Pukaki South	3	199	7.2	8	91
Pukaki	14	2 032	150	1 506	10
Puysegur	35	5 809	163	187	87
OTHER AREAS					
Challenger (ORH 7A)	2	25	0.05	178	0.03
Cook Canyon (ORH 7B)	2	28	0.03	0.17	16
Lord Howe (ET)	8	395	3.9	123	3.2
Louisville Ridge (ET)	22	3 221	258	663	39
NW Challenger (ET)	26	1 172	28	200	14
West Norfolk Ridge (ET)	12	1 141	45	727	6.2

Table 6: Summary of number of samples taken by IOP observers, and the observed catch and estimated total catch in the fishery, 2005–06; observed catch totals are based on the areas defined in Figures 2 to 4, 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) observed	Catch (t) fishery	Percentage of fishery observed
ORH 3B					
Chatham Rise					
East Rise	41		*82	3 539	*2.3
NW Rise	24		*35	1 246	*2.8
SE Rise	14		*13	1 128	*1.2
Spawning Box	26		*181	3 320	*5.5
SW Rise	2		*3	21	*14
Southern					
Auckland I.	1		7	7	100
Bounty Is.	1		–	57	–
Macquarie R.	2		20	29	69
Pukaki	25		231	1 506	15
Snares	1		0.5	1.5	33.3
OTHER AREAS					
Kaikoura (ORH 3A)	3		10	412	2.4
Wairarapa (ORH 2B)	1		–	115	–

* Catch data missing for some samples in these areas, therefore the total observed catch and % of fishery observed will be underestimated.

Table 7: 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 IOP samples.

Area	Period	Number measured Male	Female	Total	*Sex ratio (%male) (scaled)	Total catch (t)	*Scaled Mean length (s.d.) Male	Female
OP data								
NW Rise	pre-spawning	464	531	995	47.6	31	31.9 (3.4)	33.5 (3.2)
NW Rise	spawning	1 254	731	1 988	65.5	612	34.2 (2.4)	35.8 (2.8)
Spawning Box	pre-spawning	1 836	1 955	3 794	48.3	310	32.2 (2.8)	33.8 (2.9)
Spawning Box	spawning	5 575	6 069	11 646	49.7	1 773	33.0 (3.0)	34.6 (3.1)
East Rise	pre-spawning	816	869	1 685	49.2	133	32.5 (2.8)	33.6 (2.9)
East Rise	spawning	1 355	1 192	2 550	54.3	230	32.6 (2.8)	33.8 (3.4)
Bounty Is.	pre-spawning	496	335	831	56.6	32	31.1 (2.3)	33.8 (2.7)
Pukaki R.	pre-spawning	684	579	1 263	56.7	150	33.8 (2.2)	36.8 (2.4)
Puysegur	spawning	2 134	2 428	4 563	52.7	163	33.7 (2.8)	34.9 (3.1)
Dargaville	spawning	339	301	640	56.1	12	33.2 (3.6)	34.0 (4.1)
East Northland	spawning	1 720	633	2 352	77.0	245	34.9 (2.6)	36.6 (2.8)
Tauroa Knoll	pre-spawning	281	556	837	31.8	31	34.7 (3.0)	34.9 (2.9)
West Norfolk R.	pre-spawning	733	668	1 402	53.9	185	40.5 (2.4)	42.4 (2.7)
Louisville R. (E.T.)	spawning	923	644	1 567	63.3	257	38.7 (3.2)	41.8 (3.4)
NW Chall (E.T.)	spawning	422	417	839	73.1	18	30.2 (3.0)	31.3 (3.3)
IOP data								
NW Rise	pre-spawning	805	854	1 688	53.5	**10	32.0(3.7)	33.5(3.3)
NW Rise	spawning	365	221	602	37.7	**25	32.6(2.7)	32.1(4.8)
Spawning Box	pre-spawning	729	610	1 345	45.5	**5	32.1(2.6)	32.9(3.3)
Spawning Box	spawning	565	621	1 186	52.3	176	33.2(2.9)	34.6(2.9)
East Rise	pre-spawning	1 956	1 915	3 891	49.8	**76	33.3(3.1)	34.9(2.9)
SE Rise	pre-spawning	812	572	1 397	41.3	**13	33.5(3.4)	35.6(3.3)
Pukaki R	pre-spawning	1 046	1 494	2 540	58.8	231	34.9(2.4)	37.3(2.8)

* IOP sex ratio and mean length data are unscaled

** Catch data missing for some samples in these areas, therefore the total observed will be underestimated.

Table 8: 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
Arrow Plateau	Apr	2	0	92	4	2	129
Bounty Is.	Oct	89	5	0	1	5	335
Dargaville	Jun	10	81	8	1	0	301
East Northland	Jun	26	9	29	36	0	76
	Jul	19	3	21	31	26	320
	Aug	21	19	11	6	43	237
East Rise	Apr	23	77	0	0	0	47
	May	7	91	2	0	0	336
	Jun	19	79	1	0	0	779
	Jul	31	2	6	21	40	413
	Nov	98	1	0	1	0	194
	Dec	97	3	0	0	1	292
Lord Howe Rise (E.T.)	Mar	53	9	36	0	1	137
Louisville Ridge (E.T.)	Jul	28	36	24	12	0	268
	Aug	1	21	43	27	7	376
Mercury-Colville Box	Jun	2	75	23	0	0	57
NW Challenger (E.T.)	May	32	68	1	0	0	120
	Jun	16	9	21	25	29	322
	Jul	4	12	13	32	40	95
NW Rise	Apr	23	75	1	1	0	107
	May	4	96	0	0	0	107
	Jun	6	17	36	40	2	731
	Oct	80	14	4	0	2	81
	Nov	97	0	0	0	2	236
Pukaki South	May	0	95	5	0	0	40
Pukaki	May	0	90	9	0	0	223
	Oct	57	25	7	2	9	356
Puysegur	Jul	45	9	25	10	11	2 428
SE Rise	Sep	1	85	0	0	14	197
	Nov	98	2	0	0	0	50
Spawning Box	Apr	11	89	0	0	0	124
	May	5	94	1	0	0	1 781
	Jun	7	81	10	1	0	3 713
	Jul	6	2	8	24	60	2 356
	Dec	96	2	0	0	2	50
Tauroa Knoll	Oct	100	0	0	0	0	556
West Norfolk Ridge	Oct	92	7	0	1	0	532
	Nov	38	62	0	0	0	136
West Norfolk Ridge (E.T.)	Apr	7	5	87	1	0	117
	May	11	88	1	0	0	115

Table 9: Percentage of female orange roughy at each gonad stage in each subarea and month, from IOP 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
Auckland Is.	Dec	0	100	0	0	0	39
Bounty Is.	Aug	0	0	0	46	54	35
East Rise	Jan	11	81	8	0	0	301
	Feb	28	66	6	0	0	219
	Mar	31	58	11	0	0	229
	Apr	32	60	8	1	0	608
	May	8	89	1	0	2	101
	Jun	19	81	0	0	0	81
	Nov	20	75	4	0	1	238
	Dec	18	81	0	0	1	249
Kaikoura	May	85	15	0	0	0	184
Macquarie R.	Apr	3	91	6	0	0	34
NW Rise	Feb	27	65	8	0	0	37
	Mar	50	50	0	0	0	30
	Apr	19	73	8	1	0	142
	May	9	81	2	8	0	492
	Jun	36	55	8	0	1	365
	Nov	29	71	0	0	0	62
Pukaki	Mar	9	67	24	0	0	167
	May	1	85	13	0	0	89
	Nov	2	97	1	0	0	423
	Dec	0	100	0	0	0	278
SE Rise	Jan	31	65	4	0	0	116
	Feb	9	71	20	0	0	66
	Mar	13	47	40	0	0	215
	Apr	31	50	19	0	0	258
	Nov	6	94	0	0	0	51
	Dec	2	92	0	0	6	103
Snares I.	Dec	0	100	0	0	0	59
Spawning Box	Apr	36	44	20	0	0	381
	May	9	91	1	0	0	336
	Jun	3	63	31	0	3	563
SW Rise	Apr	35	58	6	1	0	83
	Nov	28	67	5	0	0	57
Wairarapa	Dec	11	89	0	0	0	65

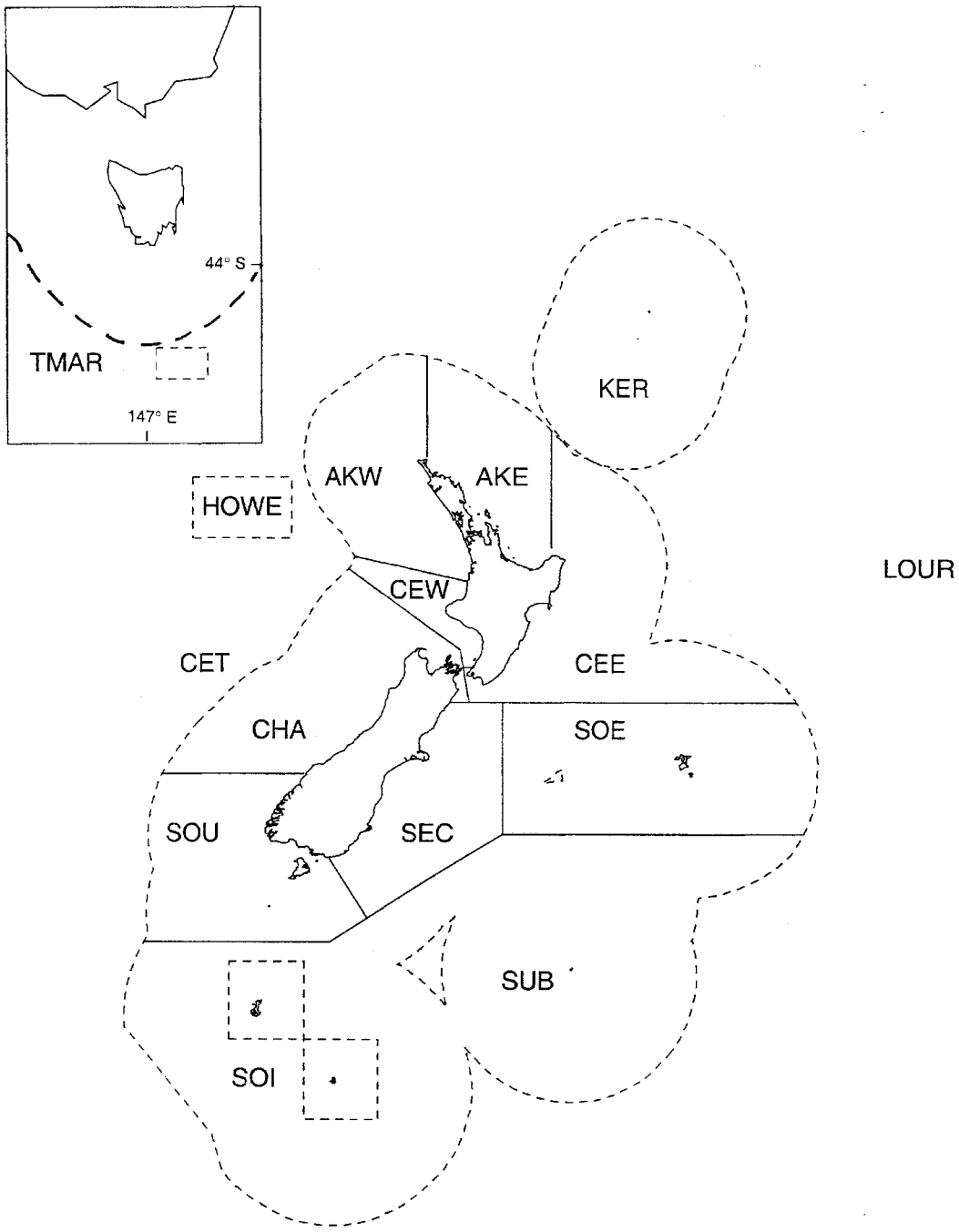

Figure 1: Ministry of Fisheries Observer Programme management areas.

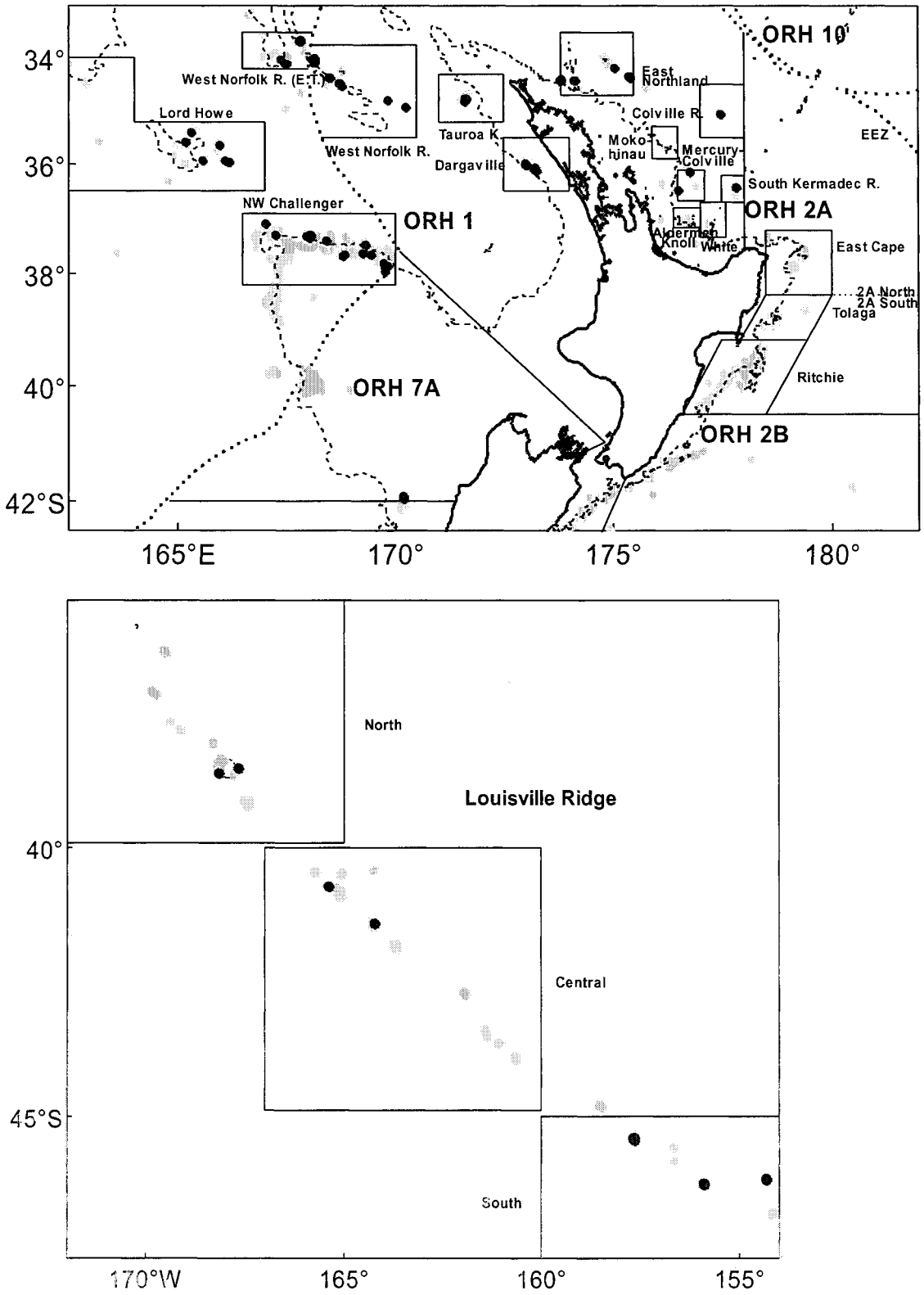

Figure 2: Location of fisheries used for analysis of biological data, position of trawls in the commercial fishery (grey dots), and location of samples of orange roughy taken by OP observers (black dots), during the 2005–06 fishing year. The dotted line shows the 1000 m depth contour.

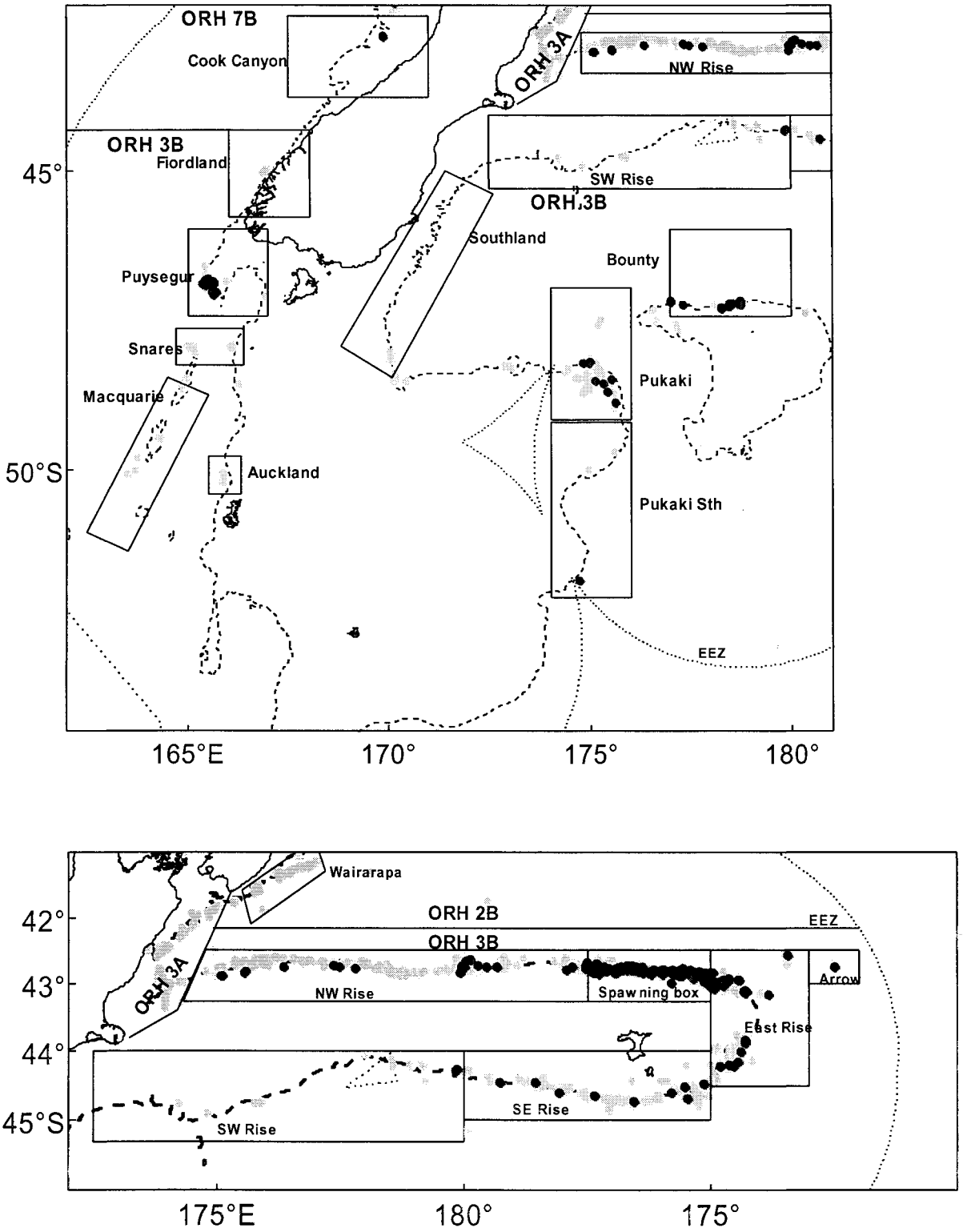

Figure 3: Location of fisheries used for analysis of biological data, position of trawls in the commercial fishery (grey dots), and location of samples of orange roughy taken by OP observers (black dots), during the 2005–06 fishing year. The dashed line shows the 1000 m depth contour.

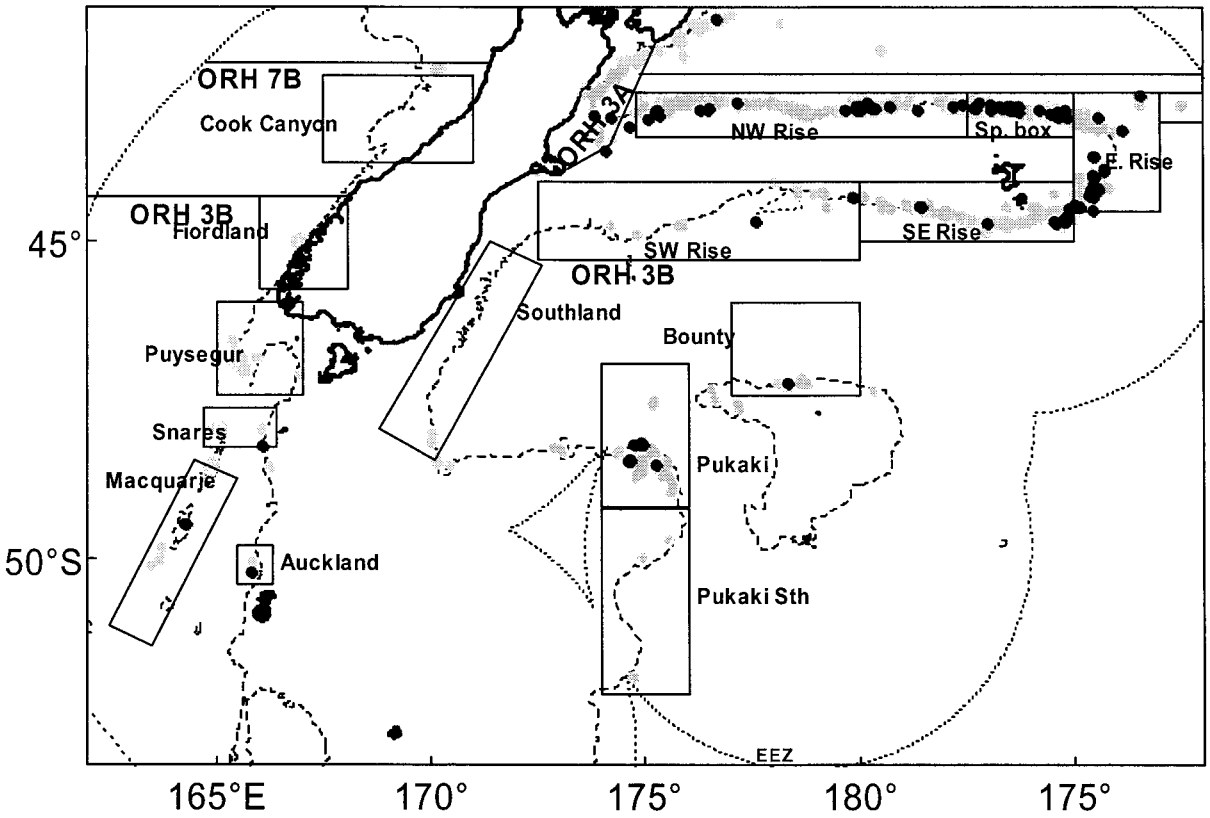

Figure 4: Location of fisheries used for analysis of biological data, position of trawls in the commercial fishery (grey dots), and location of samples of orange roughy taken by industry observers (IOP) (black dots), during the 2005–06 fishing year. The dashed line shows the 1000 m depth contour.

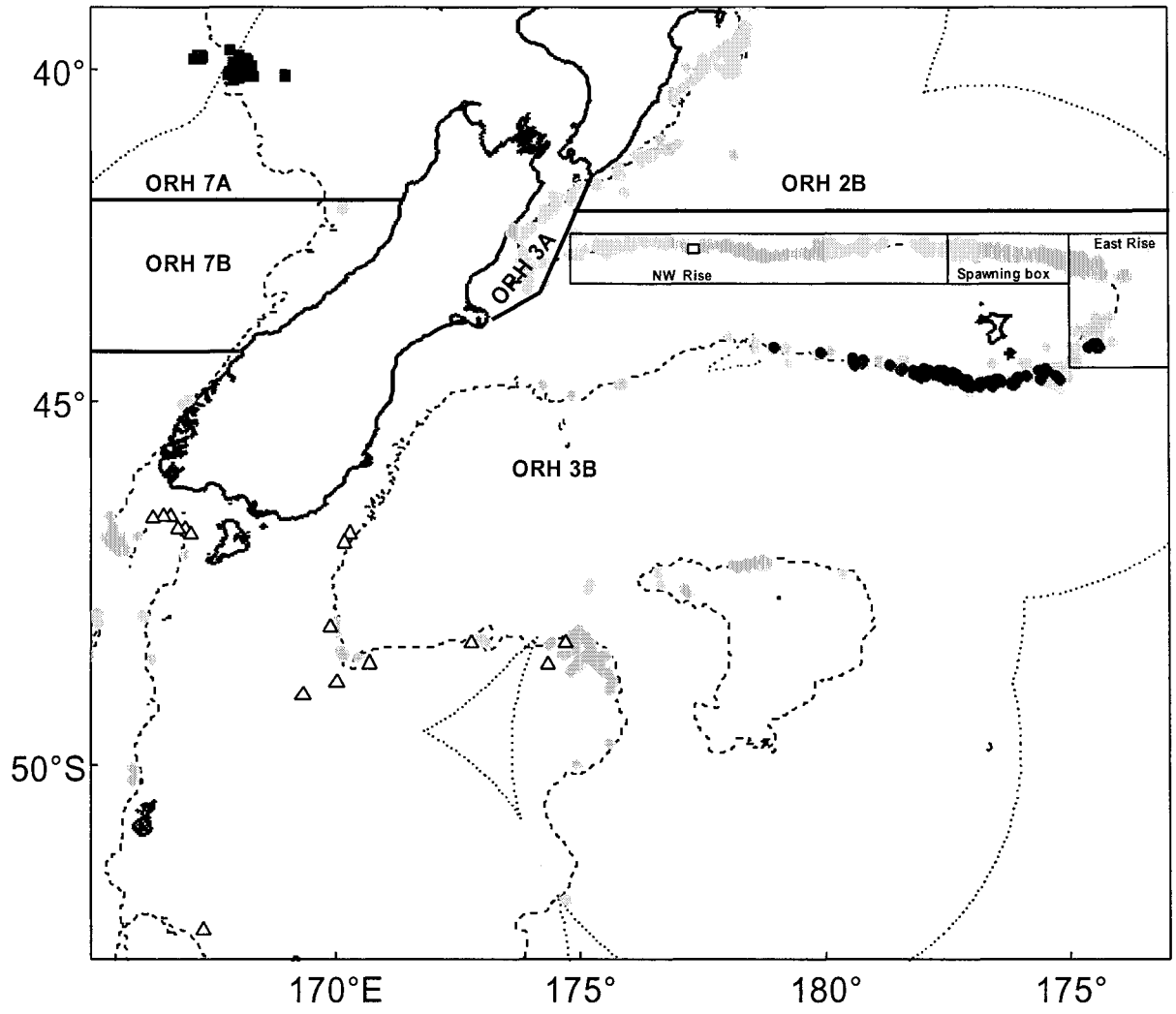

Figure 5: Location of fisheries and NIWA research trawls where orange roughy length data were recorded, and position of trawls in the commercial fishery (grey dots); closed circles, South Chatham Rise (OEO 4) oreo survey November 2005 (F.V. *San Waitaki*); open triangles, sub-Antarctic trawl survey November–December 2005 (R.V. *Tangaroa*); closed squares, Challenger Plateau orange roughy survey June–July 2006 (F.V. *Thomas Harrison*); open square, Chatham Rise hoki survey January 2006 (R.V. *Tangaroa*). The dashed line shows the 1000 m depth contour.

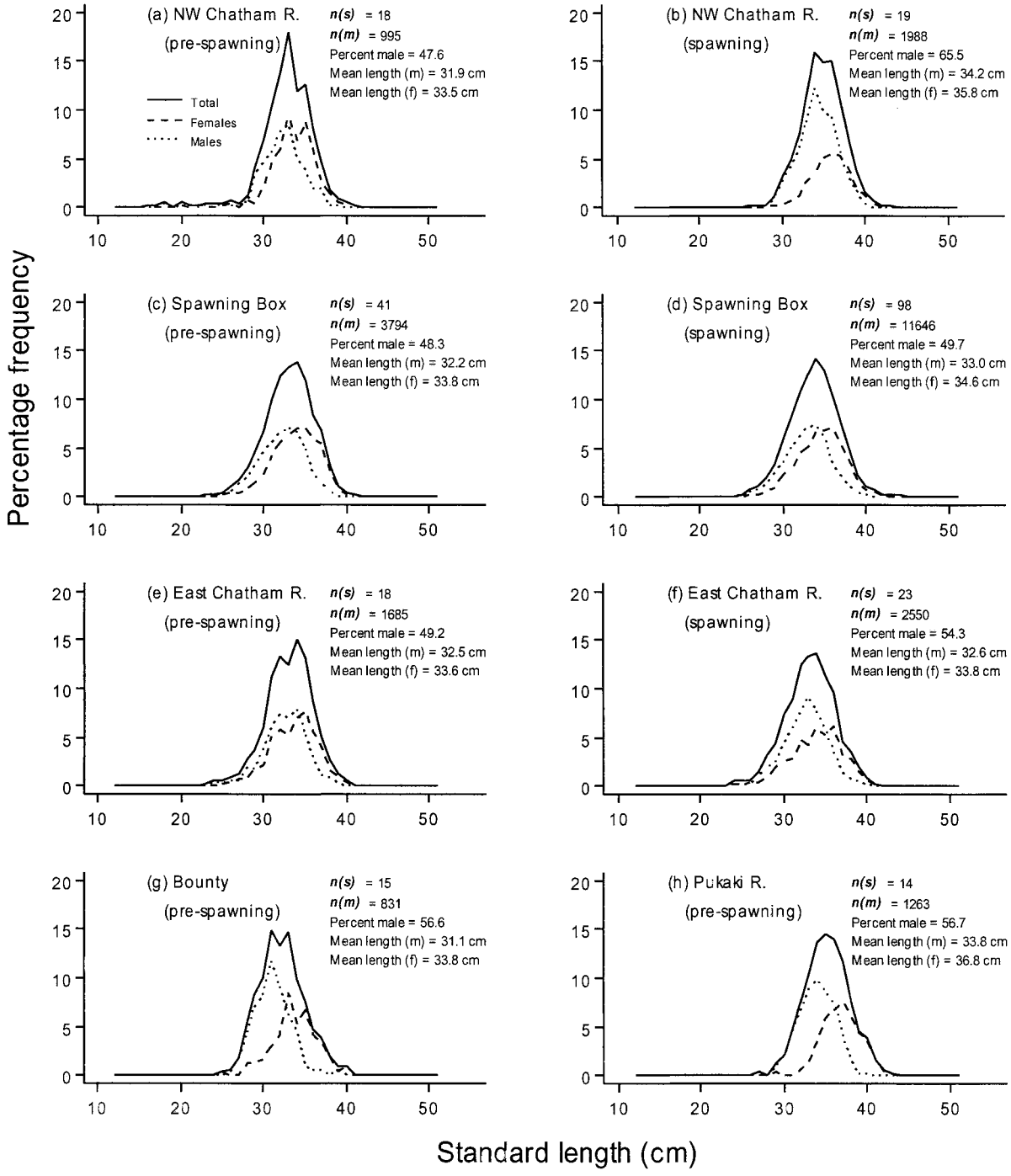

Figure 6: OP length frequency distributions (scaled by catch) of orange roughy by area and period, *n(s)*, number of samples; *n(m)*, number of fish measured.

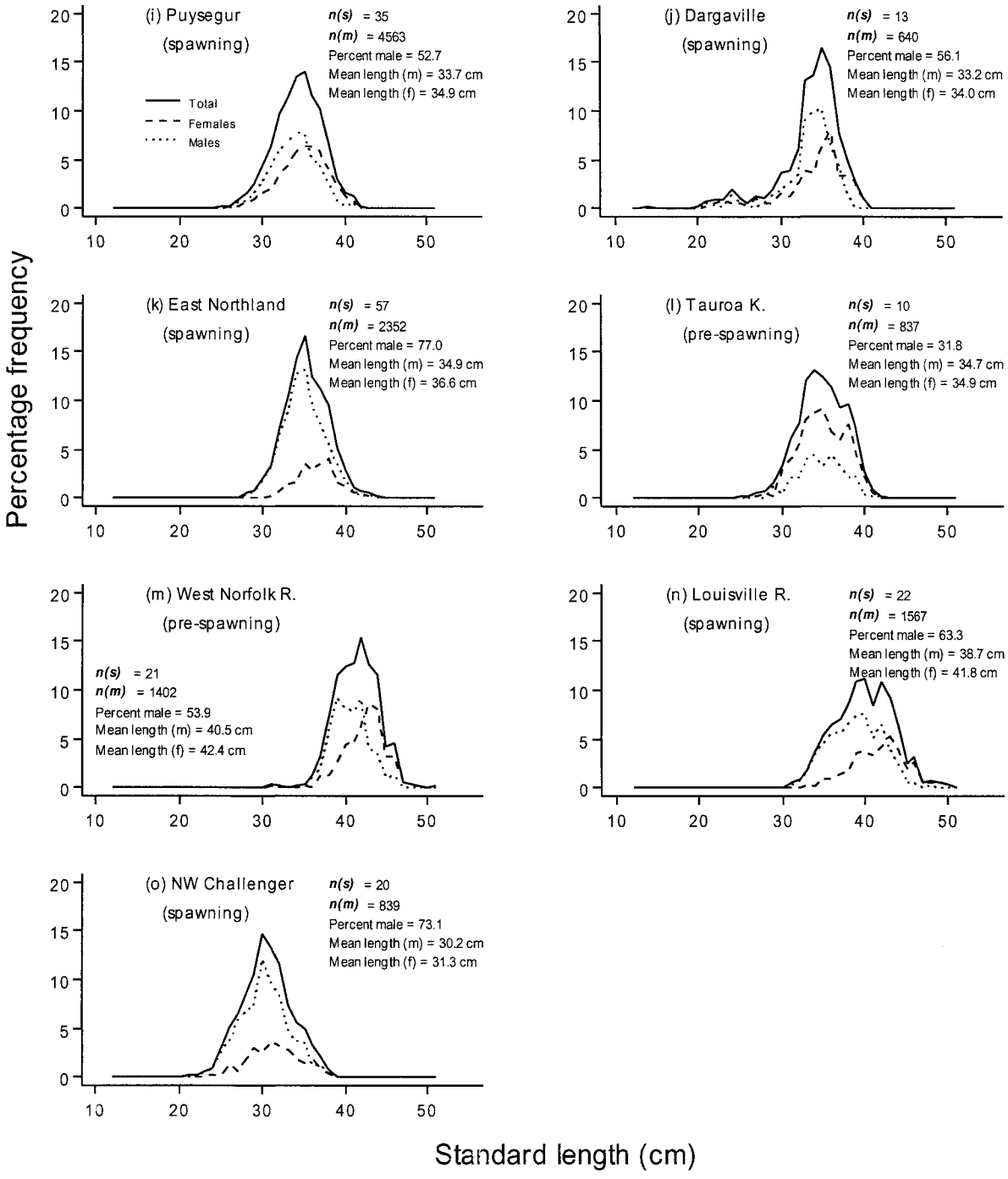

Figure 6 — ***continued.***

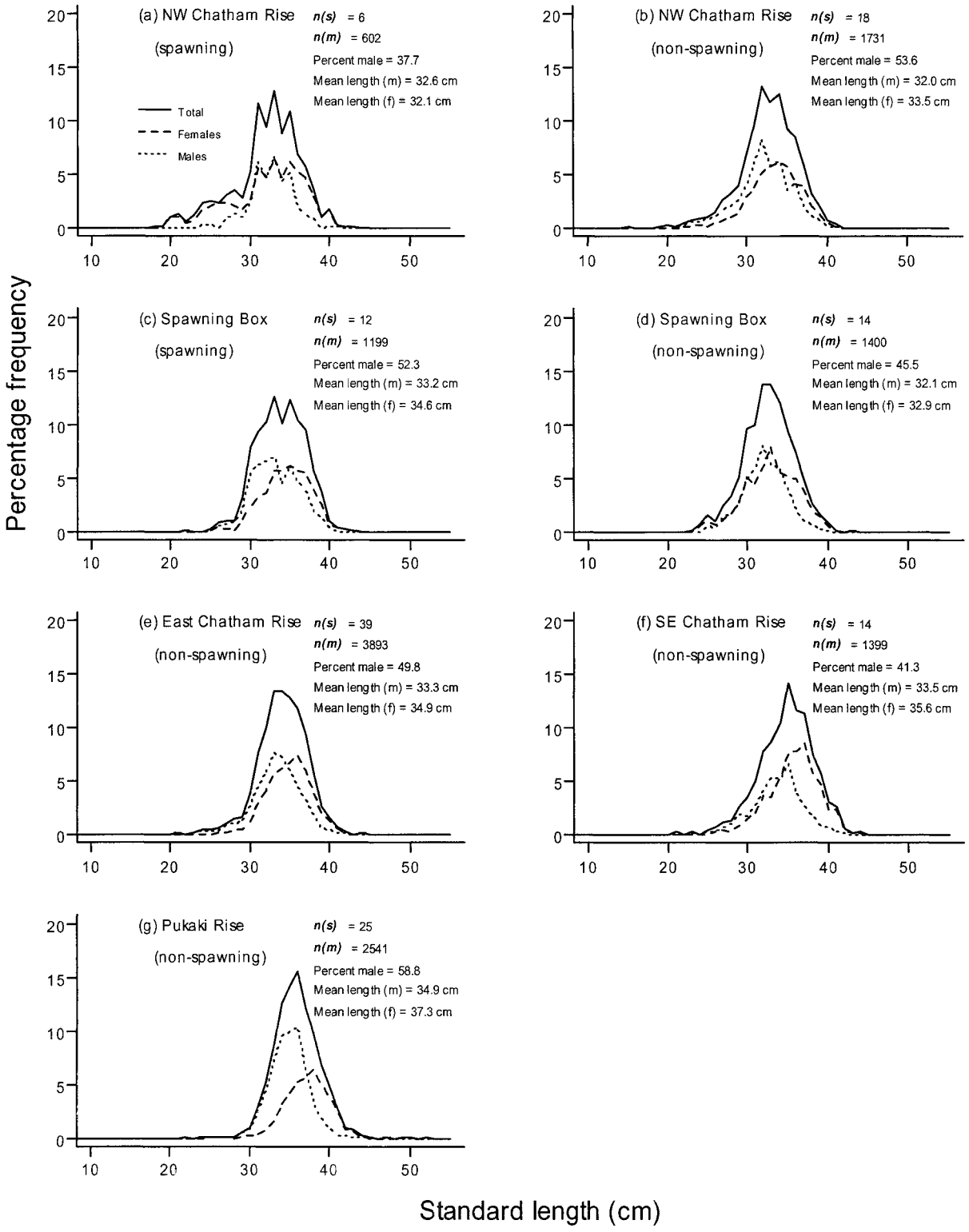

Figure 7: Industry Observer Programme length frequency distributions (unscaled) of orange roughy by area and period, *n(s)*, number of samples; *n(m)*, number of fish measured.

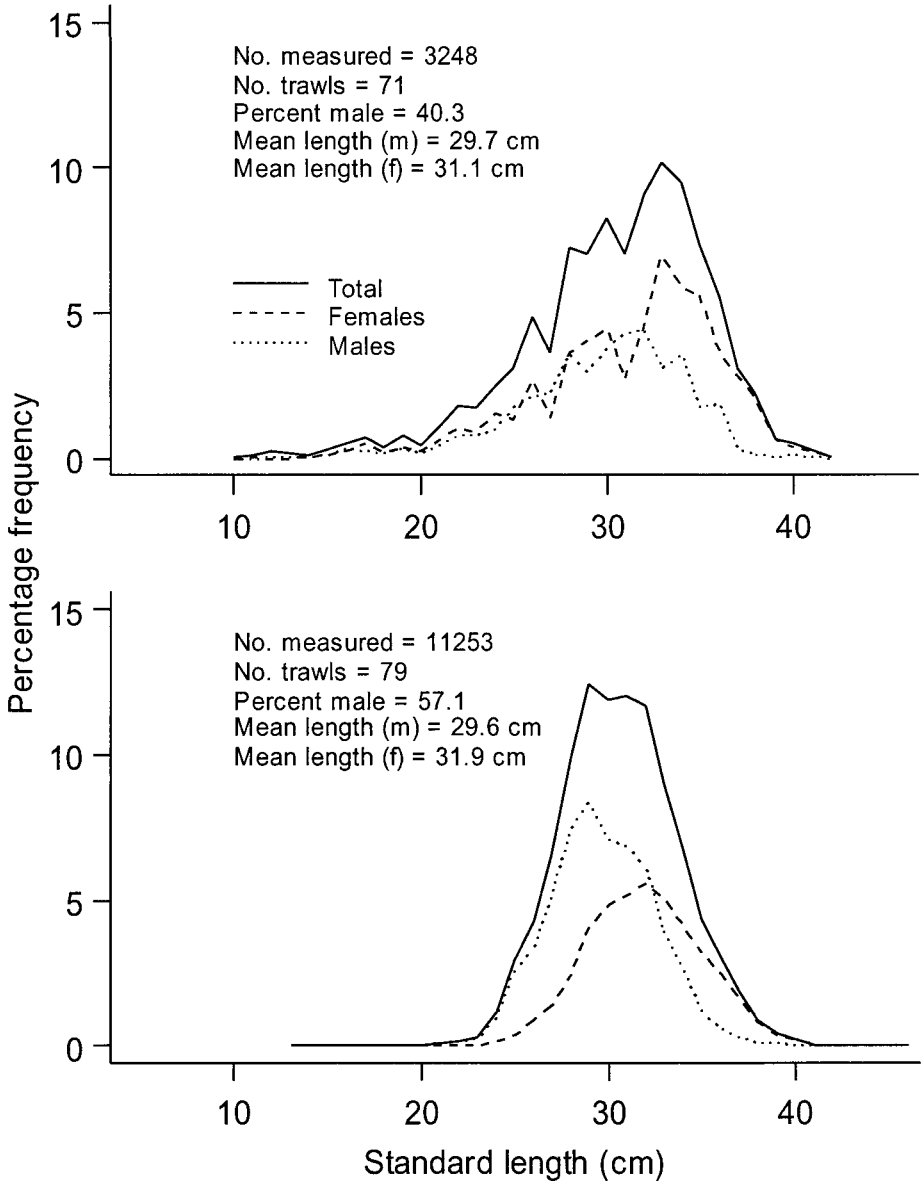

Figure 8: Orange roughy length frequency distribution (scaled by catch) from the South Chatham Rise oreo research survey November 2005 (F.V. *San Waitaki*), top; and (bottom) from the Challenger Plateau orange roughy survey June/July 2006 (F.V. *Thomas Harrison*).

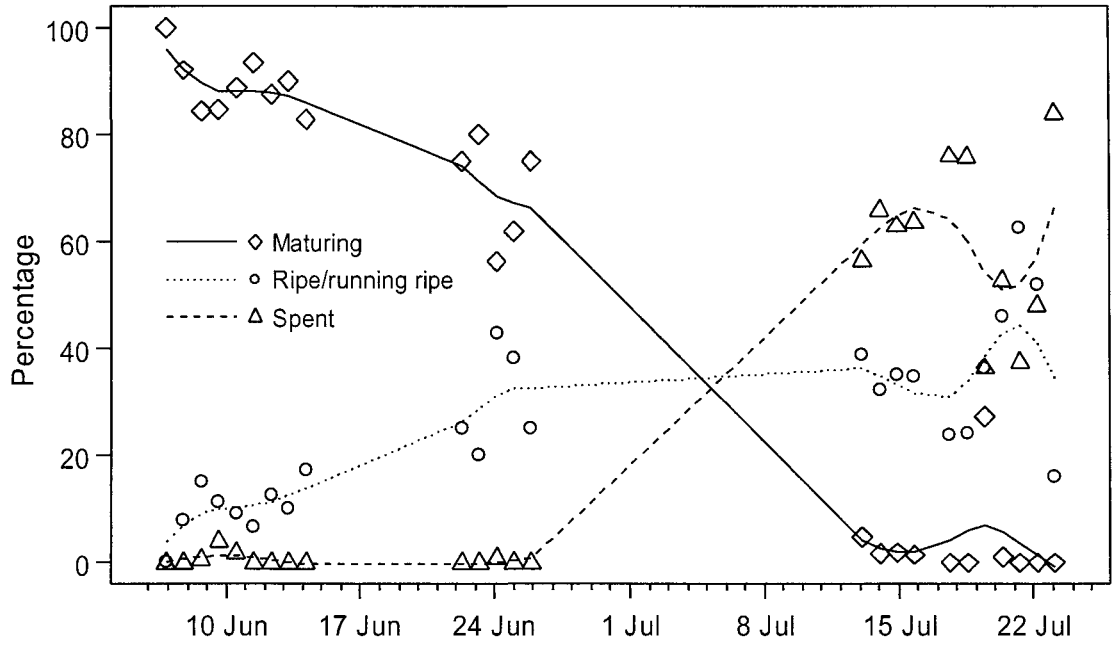

Figure 9: Daily changes in female orange roughy gonad stage proportions during the spawning season in the Spawning Box fishery (ORH 3B), from OP data. Each point indicates the fraction of all fish examined (aggregated by day) which were in the reproductive state indicated by the symbol.

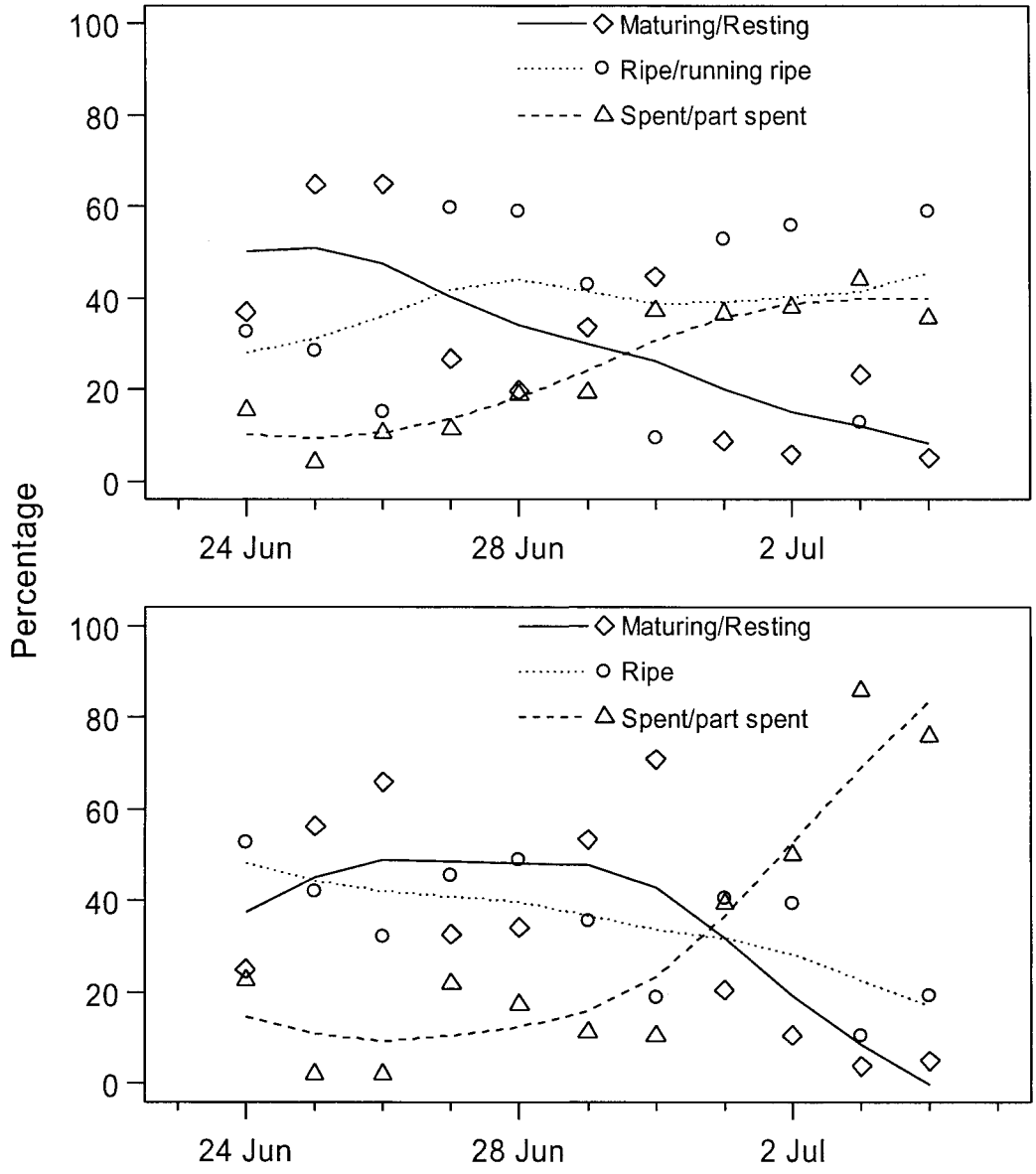

Figure 10: Daily changes in orange roughy gonad stage proportions during the spawning season in the Challenger Plateau (ORH 7A), from research survey data (F.V. *Thomas Harrison*). Top, female fish; bottom, male fish. Each point indicates the fraction of all fish examined (in all samples taken on that day) which were in the reproductive state indicated by the symbol.