ISSN 1175-1584

MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

Biological data from the orange roughy abundance surveys in the Mid-East Coast fishery

Di Tracey
Dieter Ayers

New Zealand Fisheries Assessment Report 2005/10
February 2005

Biological data from the orange roughy abundance surveys in the Mid-East Coast fishery

Di Tracey
Dieter Ayers

NIWA
Private Bag 14901
Wellington

New Zealand Fisheries Assessment Report 2005/10
February 2005

Published by Ministry of Fisheries
Wellington
2005

ISSN 1175-1584

Citation:
Tracey, D.M.; Ayers, D. (2005).
Biological data from the orange roughy abundance surveys in the Mid-East Coast fishery.
New Zealand Fisheries Assessment Report 2005/10. 26 p.

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

EXECUTIVE SUMMARY

Tracey, D.M.; Ayers, D. (2005): Biological data from the orange roughy abundance surveys in the Mid-East Coast Fishery.

New Zealand Fisheries Assessment Report 2005/10. **26 p.**

Size and reproductive data on orange roughy collected during research surveys in the Mid-East Coast fishery QMA 2A South orange roughy fishery during winter 2001 and 2003 were examined and summarised by mark types. The mark types had been classified for the acoustic data analysis and reflected the proportion of orange roughy caught in trawls targetting various marks in the survey area. Data from marks categorised as '*orange.roughy*' comprised high proportions of orange roughy and marks categorised as '*background*' were those where orange roughy were less dominant in the catch. Biological data collected on orange roughy caught in random trawls in outer strata well away from the main spawning region were also compared with the biological data from fish in the mark type trawls.

By applying the same mark type tow classifications to historical research surveys in the Mid-East Coast fishery, size and reproductive data were also analysed for the early surveys and compared with the most recent data.

An exploratory analysis was applied to the data sets to ascertain whether any major biological changes could be detected between years. There was a high variability of orange roughy size distributions within the survey region. Size frequency distributions showed a strongly unimodal distribution in the *orange.roughy* mark tows. Mean lengths were similar in the 2001 and 2003 samples; however, the 2001 data sets comprised almost 80% male, and the 2003 samples were only 45% male. Sex ratios indicated a shift between the winter 2001 and 2003 surveys.

In both the *background* mark tows and outer strata areas, the preliminary exploratory data analyses showed a higher proportion of smaller orange roughy (under 25 cm), and relatively fewer spawning fish, which produced strongly bimodal distributions. There was little difference between years.

Previous data from the region were investigated to determine if the trends found in the 2001 and 2003 data were persistent or if they were anomalous. For the historical dataset, the 1993 size distribution was most similar to the 2001 and 2003 surveys; the remaining distributions from the early series were less unimodal than the recent surveys. Mean lengths and sex ratios varied in the *orange.roughy* mark tows. No decline in mean length appears to have occurred over time. Length distributions from the *background* mark tows showed the expected broader distributions, and sex ratios varied. A notable reduction in small fish (under 30 cm) is apparent in the outer strata regions over time.

Historical reproductive data show the onset of spawning to be later in the earlier years than in the 2001 and 2003 surveys.

1. INTRODUCTION

The work described is one of two reports prepared as part of objective 1 of the Ministry of Fisheries project ORH200201A "Estimation of the abundance of small localised orange roughy populations". This report was a key activity carried out under objective 1, to support the abundance analyses.

In 2001 and 2003, surveys were conducted using acoustic methods to estimate the abundance of orange roughy in the Mid-East Coast fishery QMA 2A South (Figure 1) (Tracey & Doonan 2001, Doonan et al. 2002, 2003, 2004). As part of the surveys, trawling occurred on various mark types during both years and a specific mark classification scheme, described in detail by Hart et al. (2003), was developed. In 2001, most of the orange roughy abundance in the main survey strata (Figure 1) came from mark type *orange.roughy*, which had 83% orange roughy recorded in the tows sampling this mark, and from the mark type '*red marks.grey layer*', which comprised 71% orange roughy (Doonan et al. 2003). In 2003, these two mark types that contained high proportions of orange roughy were amalgamated into a single mark type classified as *orange.roughy*.

In both years, the marks containing these very high proportions of spawning orange roughy were located in the survey area Hill strata (North Hill, Hill 814, and Rock Garden) as well as in an area near a drop-off bottom feature named DB Rectangle (Figure 2).

In 2001 and 2003, trawls were also carried out in the various flat strata in the background areas away from the main orange roughy spawning strata. Some trawls in the background area were randomly allocated and others targetted specific mark types classified as *background*, '*grey layer.red flecks*', '*intense*', and '*red.flecks*'. The *background* marks tows contained mixed species including relatively low proportions of orange roughy (35% in 2001). The *grey layer.red flecks* mark comprised mostly macrourid (rattail) species and some orange roughy. The *intense* and *red.flecks* marks were generally shallower than 700 m and comprised mainly black cardinalfish, Johnson's cod, and very few orange roughy. Data from random trawls were also collected in 2001 from strata away from the main survey area (outer strata numbers 0001, 0002, and 0004 to 0008) (Figure 2). Due to time constraints these outer strata were not sampled in 2003.

Size distributions of orange roughy can differ between spawning aggregations (Francis & Tracey 2000, Tracey et al. 2001). The same applies for orange roughy found in the background areas, where a mix of spawning and non-spawning adults, as well as some pre-recruit size fish, can be found (Doonan & Coombs 2004). Orange roughy form dense aggregations in localised areas during the spawning season, typically on undersea hills. Surrounding these aggregations are dispersed fish at much lower densities extending over a wide region of generally flat sea floor The orange roughy in these background areas include fish in spawning condition and can account for a substantial proportion of the estimated biomass Doonan & Coombs (2004). Therefore size distributions of orange roughy populations can differ geographically as well as between mark density or mark type. Strong spatial and temporal (within-season) patterns in sex ratios from commercial and research data have also been found (Francis 1996).

Details of orange roughy mean lengths scaled by catch and sex ratio data calculated by year for each stratum in the Mid-East Coast orange roughy 2001 and 2003 acoustic surveys, were presented by Doonan et al. (2003) and Doonan et al. (2004). The purpose of this report is to compare biological data collected from target and random trawls carried out during the two surveys and also, where appropriate, to compare data from these surveys with biological data obtained from earlier trawl surveys carried out in the region. The initial analyses of the datasets were to be exploratory, to detect any major biological changes between years for orange roughy found in trawls on mark types *orange.roughy* and *background*, as well as in random trawls.

If the results from the preliminary descriptive analyses suggested any differences, additional orange roughy biological data collected were to be investigated from several earlier research trawl surveys that had been carried out in the Mid-East Coast region, and a more qualitative comparison was to be carried out.

2. METHODS

2.1 Sample area:

The main Mid-East Coast (MEC) survey area is shown in Figure 1. The main strata were surveyed in both 2001 and 2003, but the background strata to the west of the main strata region were surveyed only in 2001.

North Hill, Hill 814, Rock Garden, and the DB Rectangle area were delineated as separate strata (Figure 2). Other strata shown in Figure 2 are Ritchie A (RA) and Ritchie B (RB). These are the flat slope strata that were sampled both randomly and with target trawling on a mixture of mark types. There were an additional seven outer strata randomly sampled in 2001 (Figure 2) to obtain a measure of the extent of orange roughy distribution within the MEC region.

Locations of tows used in the 2001 and 2003 analyses from which data were extracted are shown in Figure 3 (2001 and 2003 surveys). These tows comprised both the high density *orange.roughy* mark aggregations, the more dispersed fish in the flat slope strata *background* mark tows, and the outer strata region random stations.

2.2 Vessels and trawl gear

The 2001 MEC acoustic survey was carried out using NIWA's research vessel *Tangaroa* and the trawler *Tasman Viking*. *Tangaroa* used the standard six-panel orange roughy bottom trawl with 100 mm codend for hill fishing, and the full wing trawl ('ratcatcher') with 60 mm codend for fishing on flat ground. For fishing on hills and smooth bottoms, *Tasman Viking* used an orange roughy winged bottom trawl, with small rubber rollers in place of steel bobbins.

Commercial vessel *Ocean Ranger* carried out the trawling component of the MEC survey in 2003. A standard six-panel wingless "rockhopper" orange roughy trawl was used. The codend mesh size was 100 mm for all trawls, except those in the background strata, where it was 60 mm.

2.3 Biological sampling

Catches from each successful tow were sorted and weighed by species to the nearest 0.1 kg. For catches too large to be weighed, the orange roughy catch was estimated from the weighed, processed catch using a conversion factor. A random sample of up to 200 orange roughy was selected from each tow and staged length frequency measurements (standard length to the nearest centimetre below, sex, and gonad stage) were made. For large catches, at least three samples of 200 orange roughy were taken from different parts of the net to ensure sampling was representative of the catch.

Size composition, sex ratio, and reproductive data were extracted and analysed from the two surveys. Historical data collected from random trawl surveys from 1986 to 1991 in the same region were then selected and analysed.

2.4 Data analysis – 2001 and 2003

An exploratory statistical analysis method was applied to the data sets to detect any major biological changes between 2001 and 2003.

Trawls from the 2001 and 2003 surveys were regrouped into two mark categories, *orange.roughy*, which comprises the mark types for the two surveys containing a high proportion of spawning orange roughy, and *background*, the mark types comprising lower proportions of spawning and non-spawning orange roughy and a mixture of bycatch species.

Orange roughy spawning plumes comprising the *orange.roughy* mark were located on hills (North Hill, Hill 814, and Rock Garden) as well as in DB Rectangle. Using this grouping of *orange.roughy* marks, separate analyses were carried out for the Hill and DB strata tows, and the tows in strata RA and RB. Table 1 summarises by voyage, the number of tows used in the analysis by voyage.

Biological data were also extracted and analysed from the random tows and from tows targeting the *background* marks in strata RA and RB as well as from the random tows carried out in 2001 in the outer strata 1, 2, and 4 to 8 (Table 1).

Differences in size data, sex ratios, and reproductive state between the *orange.roughy* and the *background* marks were investigated. Length distributions were scaled by the proportion sampled, and by the square root of the total catch from each tow.

2.5 Data analysis – historical

The preliminary descriptive analysis applied to the 2001 and 2003 data sets indicated a high variability of orange roughy size distributions within the survey region, as well as a shift in sex ratio between the surveys (see Results). Based on this result it was decided that a qualitative comparison of the historical trawl survey data should be conducted. The analysis of earlier surveys was an attempt to determine whether the shift in sex ratio represented a major change over time in the population structure, natural fluctuations in the population, or variation within an aggregation as has been observed when trawling in different parts of an orange roughy mark (i.e. sampling error).

Historical data were extracted for the following MEC random trawl surveys: 1986 *James Cook* (JCO8608) and *Otago Galliard* (GAL8603), 1987 *Arrow* (ARR8701), 1989 *Will Watch* (WIL8901), and 1993 *Tangaroa* (TAN9306). Tows for which data were extracted were primarily from the Ritchie Banks area within the MEC, but some data from the *Otago Galliard* survey came from tows to the north of Ritchie Banks. All surveys were carried out in the winter months, except for the *Will Watch* survey which took place in September – October. The areas from which historical data were selected covered a similar area to that surveyed in 2001 and 2003.

Although the 2001 and 2003 data were extracted and examined by mark type, information on mark density type was not recorded for the earlier surveys. A method was required to group tows from historical surveys so that they could be compared with the targeted *orange.roughy* mark type tows and the *background* mark type tows of recent surveys. Catch records from the historical surveys were examined and those deemed to be equivalent to either tows targetting orange roughy marks or tows in *background* marks were extracted for analysis following the criteria described below.

If the tow caught more than 500 kg of orange roughy, the proportion of the catch (by weight) that represented orange roughy was high (over 80%), and the proportion of orange roughy that were ripe or running ripe was greater than 50%, then the tow was deemed to be equivalent to an *orange.roughy* mark tow. Tows deemed to be *background* mark tows were those that caught less than 250 kg of orange roughy. This figure of less than 250 kg was chosen as it was approximately equivalent to the maximum amount of orange roughy caught in the *background* mark tows during the 2001 and 2003 surveys. Orange roughy data from all other historical tows, e.g., those with catches between 250–500 kg, were ignored as comparisons were required using most-alike data between the historical and the 2001 and 2003 catches.

Location of the tows used from the earlier data series are shown in Figure 4 for the *orange.roughy* mark tows, Figure 5 for the *background* mark tows, and Figure 6 for the *Will Watch orange.roughy* mark tows.

2.6 Reproduction

From the trips and tows outlined above, data were extracted describing gonad stages of the sampled fish. Daily estimates of the proportion of orange roughy at each gonad stage were plotted for both the recent and historical data (excluding the out-of-season *Will Watch* survey). The gonad stage plots were scaled by the proportion sampled and by the square root of the total catch from each tow.

3. RESULTS

3.1 2001 and 2003 surveys length and sex ratio data – combined then separate

Overall, orange roughy showed a strongly unimodal distribution in the *orange.roughy* mark tows carried out on the various hills and in DB strata, and these fish were larger than those in the *background* marks and outer strata areas (Figure 7). Mean lengths were 34.4 cm for males and 36.2 cm for females. For *orange.roughy* mark fish in the RA and RB strata, the distribution was broader and mean lengths for males and females were 33.6 and 35.5 cm respectively.

Length distributions in both the *background* and outer strata areas had higher proportions of smaller orange roughy (under 25 cm), and fewer spawning fish. The outer strata distribution for females was bimodal.

A higher proportion of females was found for both the *background* mark and outer strata trawls. The combined survey data sex ratios show an overall dominance of females.

The length frequency distributions of *background* marks were similar in 2001 and 2003 (Figure 8). Distributions were broad, with a relatively high proportion of smaller fish. On average, the females were about 3 cm longer than males and had a more peaked distribution. Both surveys found more females than males, but there was a decrease from 42% to 21% male in the samples between 2001 and 2003.

The length frequency distributions in *orange.roughy* marks separated by year (Figure 9) were different. The main difference was in the proportion of males in the samples. In 2001 the samples were almost 70% male. This dropped to about 17% in the 2003 survey. Again, females tended to be longer (by about 2 cm). The distributions were strongly unimodal with similar mean lengths, males 34.4 cm in 2001 and 34.4 cm in 2003; females 36.4 cm in 2001 and 36.2 cm in 2003.

A summary of mean length by sex and proportion of fish that were male is presented for *orange.roughy* and *background* trawls in Table 2.

3.2 Historical length and sex ratio

Length frequency distributions for the 1986 and 1987 surveys were similar in shape and less unimodal, particularly for males, than those for 1993 (Figure 10). However, the sample size for the 1987 dataset is small. More comparable in shape are the 1993, 2001, and 2003 distributions, although maximum lengths equal to or greater than 45 cm were recorded in 2001 and 2003 making the distributions in these later years wider (Figure 10).

Mean lengths for males in the *orange.roughy* mark tows differed. In 1986 the mean length was 35.3 cm, but in 1987 and 1993, the mean lengths were smaller, at 34.5 and 34.7 cm respectively. Females

were longer, and similar in mean length, at 36.5 cm in 1986, 36.2 cm in 1987, and 36.7 cm 1993. Male and female mean lengths from the historical data series *orange.roughy* mark tows were similar to those recorded in *orange.roughy* mark tows in 2001 and 2003 (Table 2). The mean length for females from the combined 1986 *Otago Galliard, James Cook orange.roughy* mark data was 36.5 cm, and the mean length for females for the 2003 *orange.roughy* mark tows was 36.4 cm. Males from both the *Arrow* 1987 and 2003 *orange.roughy* mark tows had a mean length of 34.5 cm.

The proportion of males for the two 1986 surveys was uneven, 75% on *James Cook* and 22% on *Otago Galliard*. Data from tows on *orange.roughy* marks from both vessels in 1986 are also presented as a combined distribution in Figure 11. The combined 1986 data and the *Otago Galliard* sex ratios were more similar to the 1987 *Arrow* survey.

The length frequency distribution from the *Will Watch* tows on *orange.roughy* marks are shown in Figure 12. Although it was an out of season survey, the mean fish lengths and the unimodal distribution show the *Will Watch* data to be similar to the more recent 2001 and 2003 spawning season distributions, although a tail to the left of the distribution (representing smaller fish) makes the distribution broader. To the right of the distribution are large fish, similar in size to those measured in 2001 and 2003 (Table 2).

Length distributions over time from the *background* mark tows (Figure 13) show the expected broader distributions and some evidence of bimodal peaks particularly in the 1986 *Otago Galliard* data and the 1987 data. Sex ratios also vary. Females dominated in all years.

For the *background* tows in the outer strata area, the 1986 *Otago Galliard* and 1987 *Arrow* length distributions in Figure 13 are similar and show a high proportion of fish under 30 cm. On the 1993 and 2001 *Tangaroa* surveys, when trawls were also carried out in similar locations on *background* marks in the outer strata, a great reduction in the smaller fish is apparent (see left hand plot Figure 8). Figures 3 and 5 show the location of the *background* and outer strata length data that are being compared between these years. Each of the surveys, from 1986 to 2001, sampled similar areas.

3.3 Reproductive data

Gonad development of orange roughy was monitored throughout all surveys. The trends observed in plots of daily progression of gonad condition for the 2001 and 2003 surveys (Figure 14) are based on few observations. In addition, these plots are based on counts of fish scaled by the square root of the total catch from each tow (similar to the length frequency plots above). As the data are summarised by day, this scaling changes the relative proportions of fish in each gonad stage on days when more than one tow was completed, but the scaling does not seriously affect the proportions.

The point at which 20% of fish were spent was estimated where possible from the time series plots of spawning female fish, and used as a reference point to define the onset of spawning (after Pankhurst 1988). This was achieved around 26 June in 2001 and 22 June in 2003 in the *orange.roughy* mark tows (Figure 14). In the *background* tows for these years, higher proportions of immature non-spawning fish were present (Figure 15). The presence of spent fish was high early on in the *background* tows in 2001 (Figure 15). However, due to the nature of spent proportions in this plot being always above 20%, these data are not appropriate to use to define onset of spawning.

Historical *orange.roughy* mark data from the surveys carried out in the spawning season show the onset of spawning to be later in the earlier surveys, varying between 19 June and 3 July. In the *orange.roughy* marks in 1986, it was around 29 June to 3 July (*Otago Galliard* samples) (Figure 16). If the 1986 survey data for both vessels are pooled (left hand column, Figure 17), then the onset of spawning occurs on 30 June. In 1993, 30 June was also the date for the onset of spawning (*Tangaroa* samples).

There were too few data points in the 1987 survey on *Arrow* to define the onset of spawning in the *orange.roughy* mark tows, but for the *background* tow data from the *Arrow* 1987 survey it appears to have occurred around 3 July (Figure 16).

In 1986, *background* mark data indicated 20% spent occurred some time around 3–4 July. There is, however, one exception to the later spawning in the earlier surveys. *Background* data for the 1993 survey show 20% spent some time after 19 June and before 2 July (no sampling occurred on *background* marks between these dates). We note that *background* marks with low proportions of spawning fish are not usually used to define the onset of spawning orange roughy.

Will Watch reproductive data are not presented as this survey was outside of the spawning season.

4. DISCUSSION

The exploratory data analysis of the 2001 and 2003 datasets suggested high variability of orange roughy size distribution and a shift in sex ratio. The qualitative comparison carried out on previous data was to determine if the trends were persistent.

The lack of apparent changes in mean length in the *orange.roughy* mark tows are consistent with several studies of size distributions of spawning aggregations of orange roughy and typical for a slow growing, long-lived species. Clark et al. (2000) noted that orange roughy size distributions in the Spawning Box on the Northeast Chatham Rise remained consistently unimodal over the 10 year period covered in their study and that there had been no apparent shift in the mode. Francis & Tracey (2000) found no consistent pattern in changes in mean length for most of their data series, although there was drop in orange roughy mean lengths for the subareas "Spawning Plume" and "Crack" within the Spawning Box dataset. The mean lengths between these two subareas also differed, highlighting the variability in size distributions that can be found within a single stock. Doonan & Coombs (2004) noted that length distributions differed in their study on the Northwest Chatham Rise. Length distributions of spawning fish in the background were similar to those of spawning fish on the hills, but overall, the hill fish were always more than 23 cm long and so were able to be separated from background fish when monitoring migration.

The results of this current study show size distributions can vary within a survey region (i.e., between high density and background areas), regionally (e.g., between the various hills and outer strata), and between the main mark types. Differences in the overall size frequencies are attributed to the sex ratio as well as to proportions of smaller fish caught in areas away from the main aggregations of orange roughy. Small immature and resting orange roughy sampled from the *background* marks and outer strata tows influenced the differences found in the length distributions. Comparing the earlier surveys carried out on *Arrow* and *Otago Galliard* with the 2001 survey, the length distributions in the *background* and outer strata show an apparent reduction in small fish over time.

Sex ratio effects on size frequencies were noted by Tracey et al. (2001) where length frequency data were analysed within regions and between snapshots during a survey of the Northeast Chatham Rise. Their study concluded that even though the sex ratios were variable between different sampling periods or snapshots in an aggregation, the combined data were likely to be more representative of the population than any one snapshot. This difference emphasises the need for repetitive sampling on marks as well as the need to analyse data by mark type.

It is clear that by examining size distribution data by mark type the precision of mark identification during acoustic surveys is improved. In addition, analysing size composition data by mark type enables more appropriate comparisons of mean length and sex ratio to be made over time than if pooled data are used. These comparisons help detect changes in both the aggregated spawning population and the fish in the background area.

Some difference was noted in this analysis in the overall shape of the size frequency distribution for *orange.roughy* mark tows. This could be due to differences in the actual tow location. For the historical surveys, most of the *orange.roughy* mark data came from Ritchie Hill (also known as Strawberry Mountain), which was the main spawning hill at the time (Figure 2). However, in 1986, *Otago Galliard* also trawled on orange roughy aggregations on a hill to the north of the Ritchie Hill. These spatially separate hill data from 1986 were combined for the analysis, as were spatially separate *orange.roughy* mark data from the 2001 and 2003 surveys. Although the extent to which data can be broken down and analysed can be questioned, we feel confident that the mark types from which data were extracted for this study were comparable both between years and spatially.

Sex ratios are typically uneven when *orange.roughy* marks that are highly structured by sex are sampled. Large catches can often have higher ratios of males or females depending on where in the spawning plume the tow has been made (Tracey et al. 2000).

Onset of spawning is defined by the presence of 20% spent females and this occurred around 22–26 June in both 2001 and 2003, indicating that spawning was consistent between the surveys and that timing of the survey was appropriate for the area in both years. The timing of spawning in 2001 and 2003 was noticeably earlier than in the historical surveys where sufficient data were available to monitor the spawning progression over time.

Doonan et al. (2004) noted from their analyses of the orange roughy gonad data in the DB Rectangle area that spawning in 2003 may have been later than in 2001, but that the 2001 and 1993 *Tangaroa* survey spawning periods were similar. However if the analyses for 1993 are carried out by mark type, then in 1993 the onset of spawning was in fact later than in 2001 and 2003.

These results indicate perhaps either the reproductive timing for orange roughy could be changing over time (due to environmental factors or from fishery induced effects), or timing of spawning in localised areas could be variable.

We acknowledge that ideally it would have been more appropriate to locate and compare data from similarly designed surveys from the past, and use those in the comparisons. However, the purpose of this study was to establish, from the data available, if there was any qualitative difference in biological characteristics in the MEC region. Some of the results presented in this paper could be explored further. For example, carrying out paired randomisation tests could help establish whether differences in size distributions and sex ratios are due to the different sample size of tows, and could possibly clarify the consequence of one tow's effect on the proportion of males in the size distribution. The proportion of the apparent reduction in small fish over time, as shown in the length distribution plots, could also be explored.

5. ACKNOWLEDGMENTS

We thank the various NIWA staff involved in collecting the biological data during the MEC surveys. Particular thanks to Project Leader Ian Doonan for statistical advice and help with interpreting results, Matt Dunn, Malcolm Clark, and Alan Hart for their comments on the manuscript, and Ralph Coburn for a very comprehensive review. Funding was provided by the Ministry of Fisheries under research project ORH200201A, Objective 1 "Estimation of the abundance of small localised orange roughy populations".

6. REFERENCES

Clark, M. R.; Anderson, O. F.; Francis, R. I. C. C.; Tracey, D. M. (1999). The effectsof commercial exploitation on orange roughy (*Hoplostethus atlanticus*) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. *Fisheries Research 45*. 217–238.

Doonan, I.; Hart, A.; Anderson, O.; Coombs, R.; Tracey, D. (2002). Voyage report (TAN0208, ORA0201). (Unpublished report held in NIWA library). 9 p.

Doonan, I.J.; Hicks, A.C.; Coombs, R.F.; Hart, A.C.; Tracey, D.M. (2003): Acoustic estimates of the abundance of orange roughy in the Mid-East Coast fishery, June-July 2001. New Zealand Fisheries Assessment Report 2003/4. 22 p.

Doonan, I.J.; Coombs, R.F.; Hart, A.C. (2004). Acoustic estimates of the abundance of orange roughy for the Mid-East Coast fishery, June 2003. New Zealand Fisheries Assessment Report 2004/54. 22 p.

Doonan, I.; Coombs, R. (2004). Relating hill spawning aggregations to dispersed orange roughy on the Northwest Chatham Rise, June–July 2002. Final Research Report for Ministry of Fisheries Research Project ORH2001/01 Objective 2. 28 p. (Unpublished report held by MFish, Wgtn.)

Francis, R. I. C. C. (1996). Orange roughy sex ratios and catchrate distributions in the Chatham Rise Spawning Box. New Zealand Fisheries Assessment Research Dovument 1996/13. 28 p. (Unpublished report held in NIWA library, Wgtn.)

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.

Hart, A.C.; Doonan, I.J.; Coombs, R.F. (2003). Classification of acoustic fish marks for the 2001 Mid-East Coast orange roughy survey. New Zealand Fisheries Assessment Report 2003/18. 24 p.

Pankhurst, N.W.; McMillan, P.J.; Tracey D.M. (1987). Seasonal reproductive cycles in three commercially exploited fishes from the slope waters off New Zealand. Journal of Fish Biology, 30: 193–211.

Pankhurst, N.W. (1988). Spawning dynamics of orange roughy, Hoplostethus atlanticus, in mid-slope waters of New Zealand. Environmental Biology of Fishes 21: 101–116.

Tracey, D.; Hart, A.; Bull, B. (2001). Biological data from the orange roughy abundance survey on the northeastern Chatham Rise, July 2000. Final Research Report for Ministry of Fisheries Research Project ORH1999/01A. 30 p. (Unpublished report held by MFish, Wgtn.)

Tracey, D.; Doonan, I. (2001). Voyage reports *Tasman Viking* and *Tangaroa* (Unpublished report held in NIWA library). 28 p.

Table 1: Trawls selected by survey from mark types in the Mid-East Coast (MEC) area 2001 and 2003. Voyage codes are TVI0101, *Tasman Viking*; ORA0301, *Ocean Ranger*; TAN0109, *Tangaroa*.

Strata	Voyage / station numbers		
Hill and DB Rectangle strata, *orange.roughy* mark tows.			
North Hill (RNOR)	TVI0101/6	ORA0301/12	
Hill 814 (00HR/H814)	TVI0101/13	ORA0301/6,7,8	
DB Rectangle (00DB)	TVI0101/14,29	ORA0301/3/4/24/27	TAN0109/6
Rock Garden (ROCK)	TVI0101/2	ORA0301/15,17,18,19	
RA and RB strata, *orange.roughy* mark tows.			
00RA	TVI0101/9,23,24		
00RB	TVI0101/15,16	TAN0109/8,15	
RA and RB *background* mark tows on slope (includes random tows),			
00RA	TVI0101/5,11,25, 27	ORA0301/9,10,11	TAN0109/1, 11,13
00RB	TVI0101/21	ORA0301/21,22,23	TAN0109/9,12
Outer strata random tows (0001,0002,0004,0006,0007,0008)			
Strata 001–0008	TV10101/4	TAN0109/16,20,21,22,17,19, 23,24,26,32,34,31,25,33,35	

Table 2: Summary of mean length (cm) and sex ratio for high density and *background* mark fish samples in 2001, 2003, and on historical surveys, Mid-East Coast (MEC) area.

Orange roughy (ORH) high density and background data	Number of fish measured	Mean length		Sex ratio (%male)
		males	females	
ORH marks 2001/2003	3025	34.4	36.3	44
ORH marks RA/RB 2001/2003	307	33.8	35.6	54
Background 2001/2003	172	31.6	34.7	25
Outer strata (2001 only)	477	27.8	32	34
ORH marks 2001	1543	34.4	36.4	69
ORH marks 2003	1482	34.5	36.2	17
Background 2001	78	31.2	33.6	42
Background 2003	94	31.8	34.9	21
ORH marks *Arrow* 1987	96	34.5	37.2	21
ORH marks *Otago Galliard* 1986	475	35.3	36.5	22
ORH marks *James Cook* 1986	242	36.5	37.6	75
ORH marks *Tangaroa* 1993	989	34.7	36.7	52
ORH marks *Otago Galliard, James Cook* 1986	717	35.3	36.5	23
ORH marks *Will Watch* 1989	242	34.3	37	36
Background *Arrow* 1987	821	28.6	32	40
Background *Otago Galliard* 1986	2323	29	30.8	46
Background *James Cook* 1986	157	35.9	37.7	36

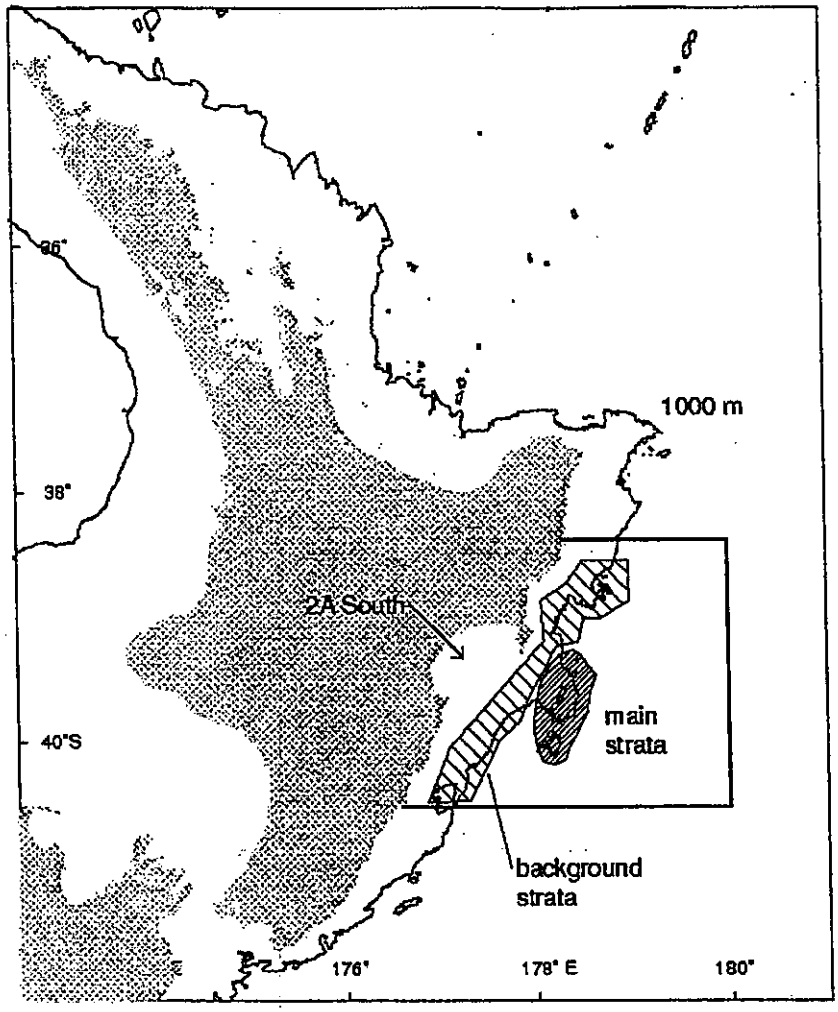

Figure 1: The Mid-East Coast (MEC) survey area showing the main strata surveyed in 2001 and 2003, and background strata surveyed only in 2001 (reproduced from Doonan et al. 2004).

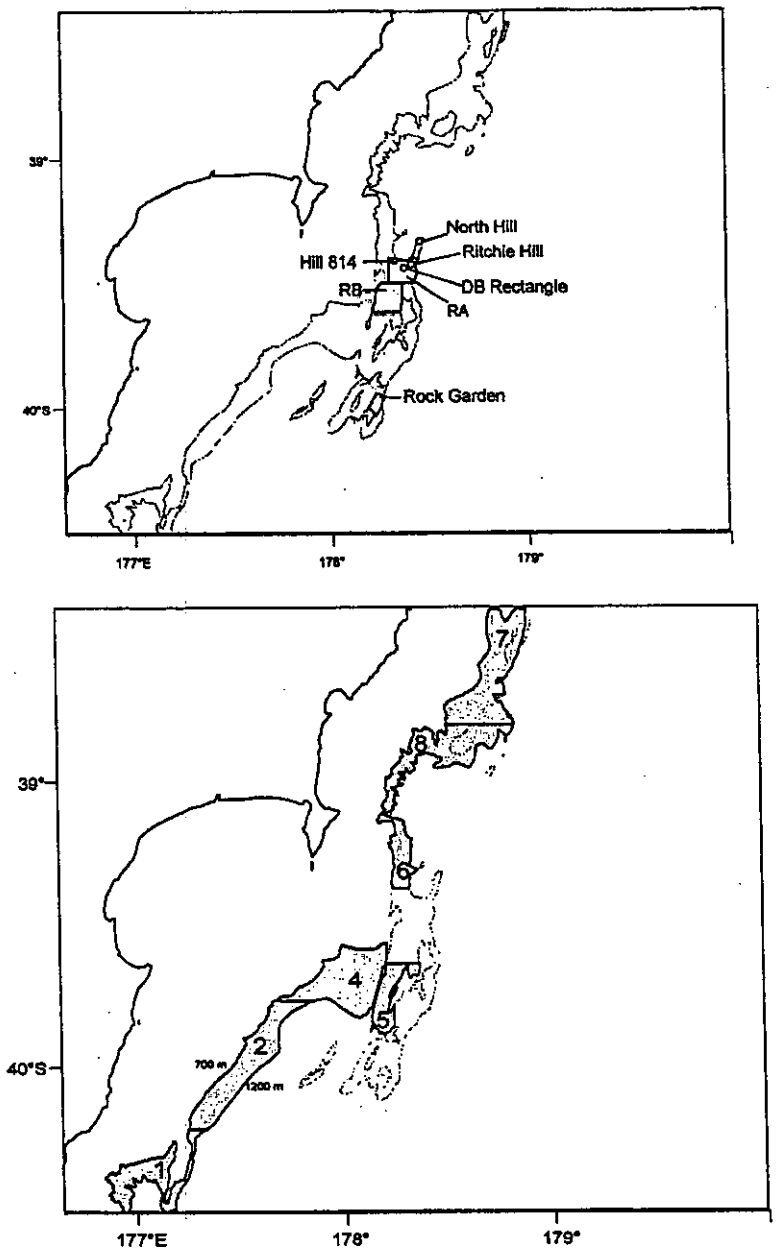

Figure 2: Location of main strata in MEC ORH2A South surveyed during the 2001 and 2003 Surveys showing in the top figure Hill 814 (Hill), North Hill (North), stratum DB Rectangle, the two background strata (RA, RB), hill strata Rock Garden (RG), and in the bottom figure, the location of the background strata that were surveyed during 2001.

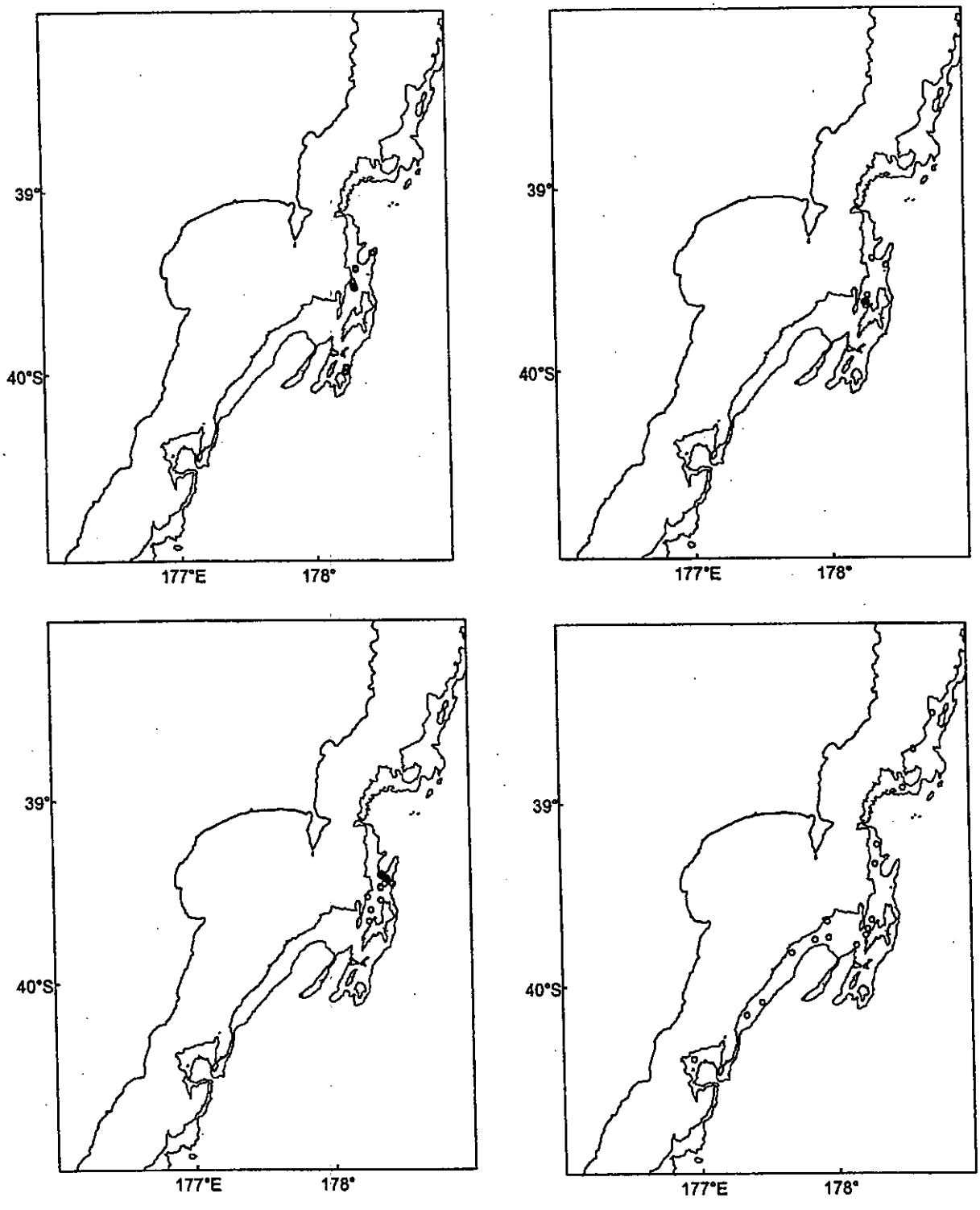

Figure 3: Locations of tows used in the 2001 and 2003 analyses. Top left: *orange.roughy* mark tows; top right: strata Ritchie A (RA) and Ritchie B (RB) tows; bottom left: *background* mark tows; bottom right: outer strata tows

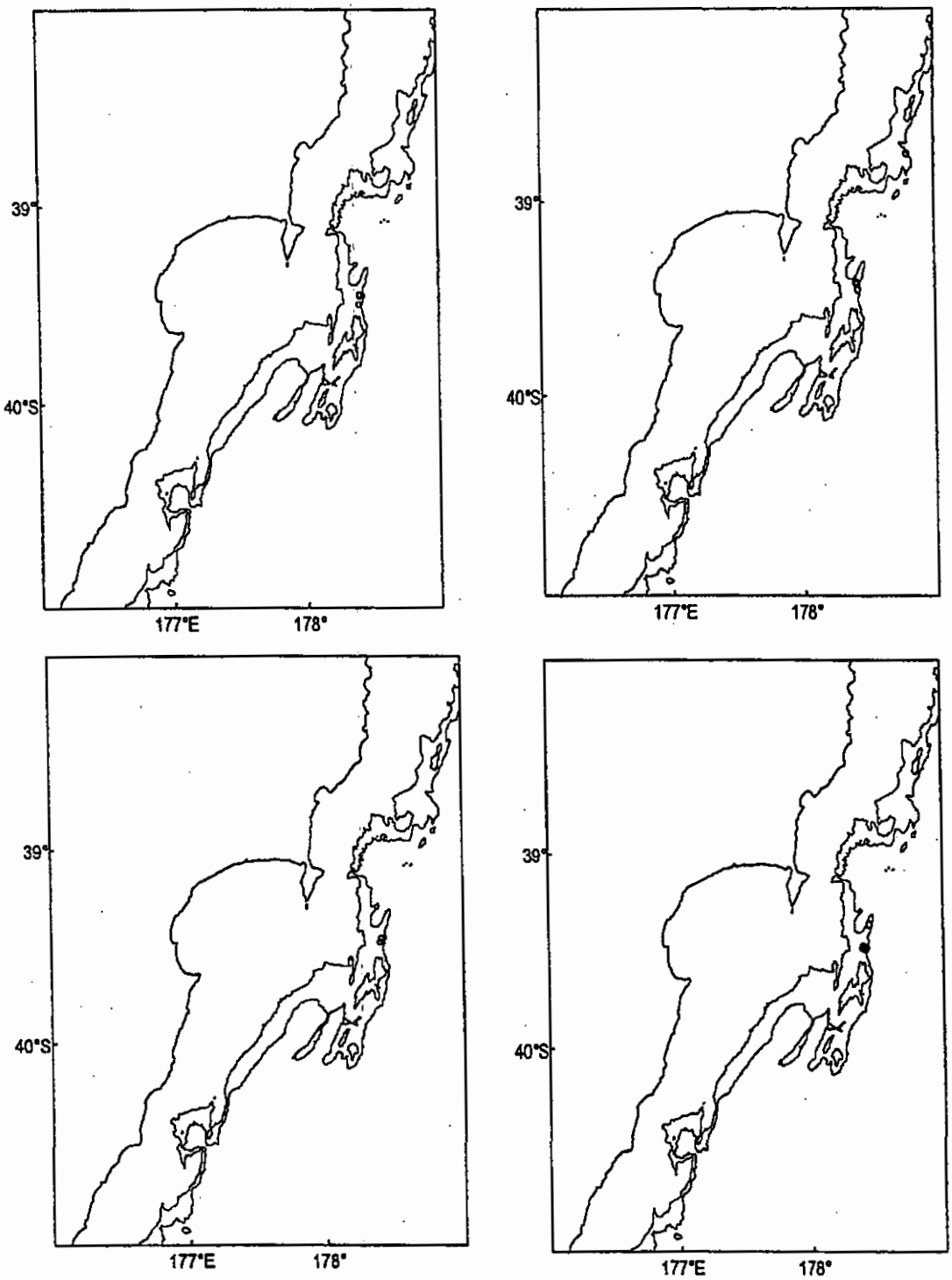

Figure 4: Locations of tows with catches defined as *orange.roughy* mark tows from previous winter surveys. Top left: *Arrow*; top right: *Otago Galliard*; bottom left, *James Cook*; bottom right, *Tangaroa*.

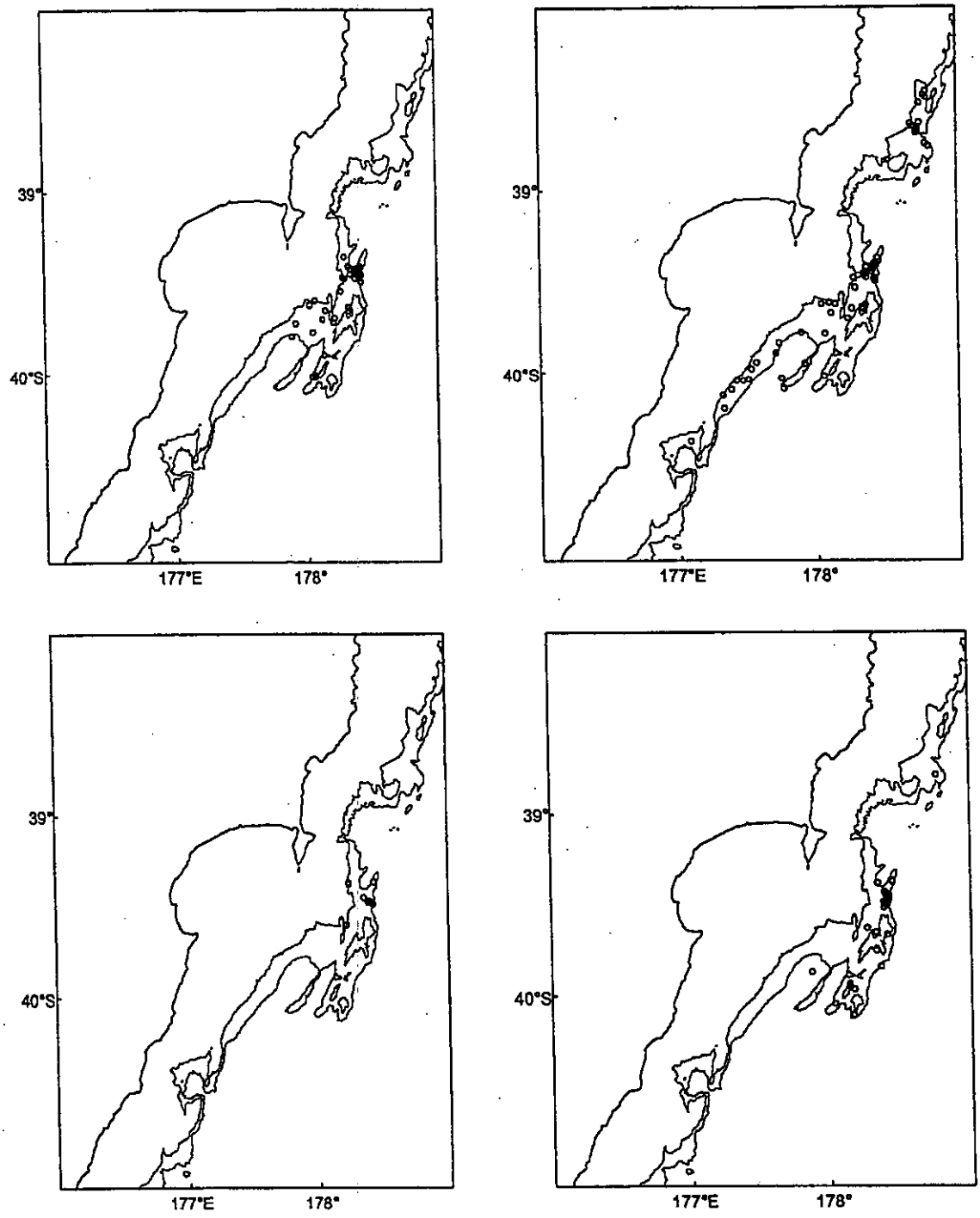

Figure 5: Locations of tows with catches defined as *background* mark from previous winter surveys. Top left: *Arrow*; Top right: *Otago Galliard*; Bottom left: *James Cook*; Bottom right: *Tangaroa*

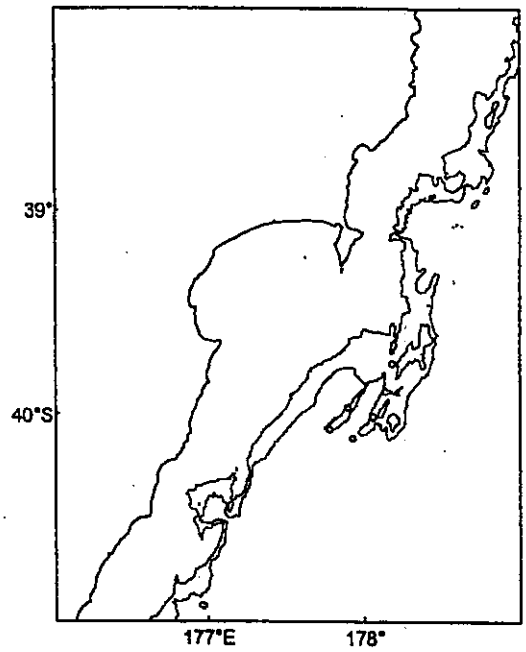

Figure 6: Location of catches defined as *orange.roughy* mark tows from the *Will Watch* survey used in the analyses.

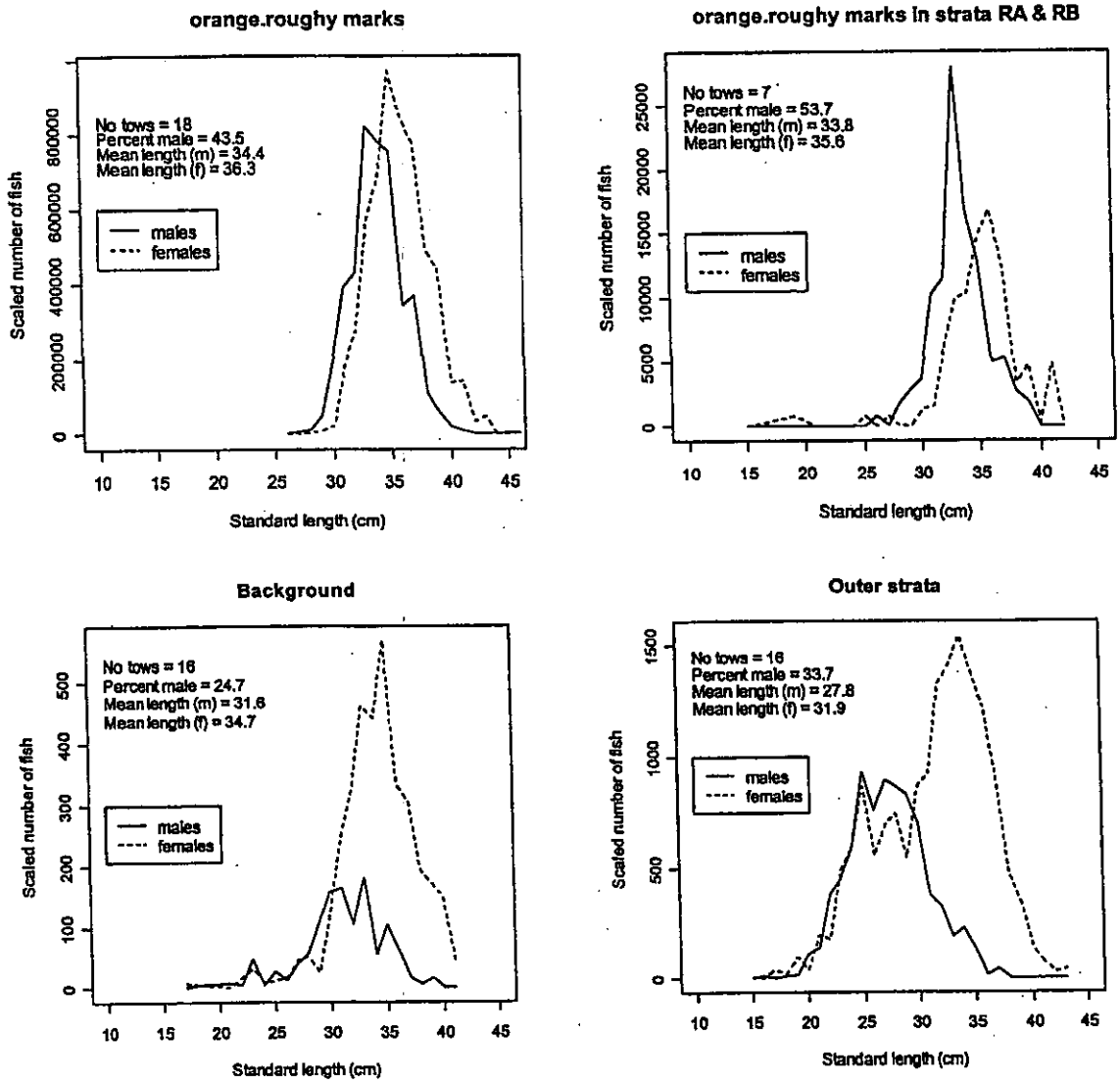

Figure 7: Combined length frequency distributions (scaled by proportion sampled and catch weight) of orange roughy by mark types and for the outer strata during the 2001 and 2003 surveys. *n(m)*, number of fish measured.

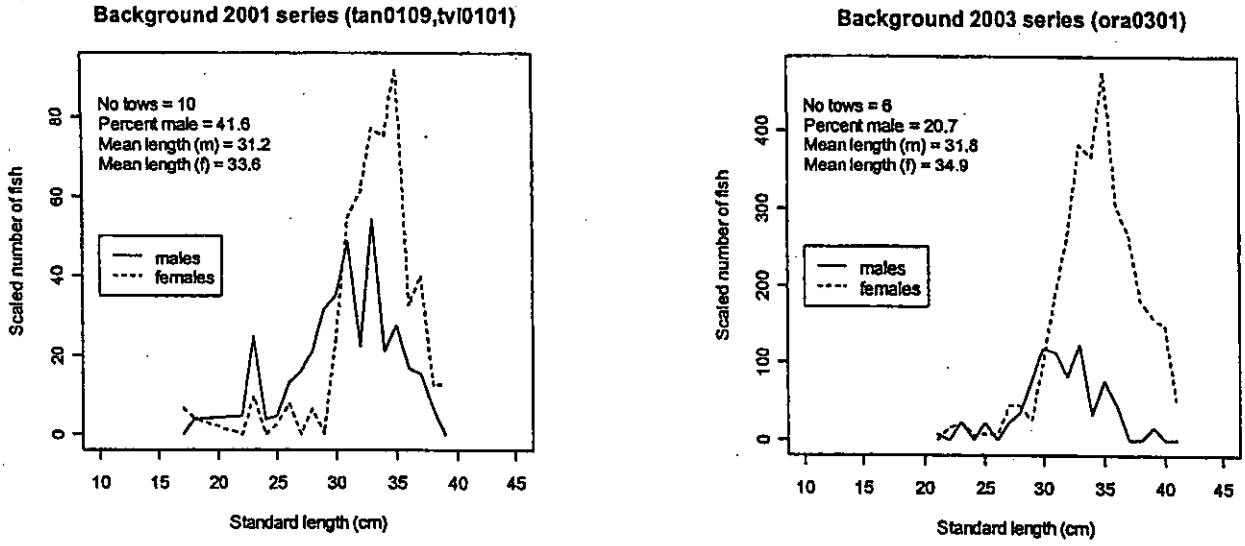

Figure 8: Research length frequency distributions (scaled by proportion sampled and catch weight) catch of orange roughy in the background mark tows observed during the 2001 and 2003 surveys. *n(m)*, number of fish measured.

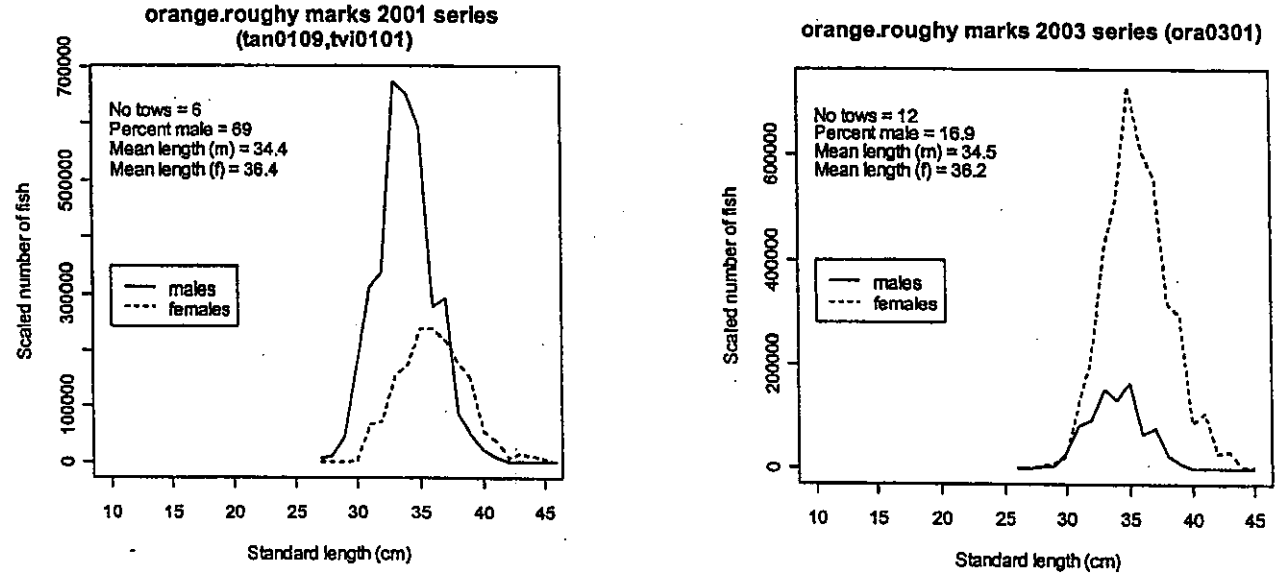

Figure 9: Length frequency distributions (scaled by proportion sampled and catch weight) of orange.roughy marks for 2001 and 2003. *n(m)*, number of fish measured.

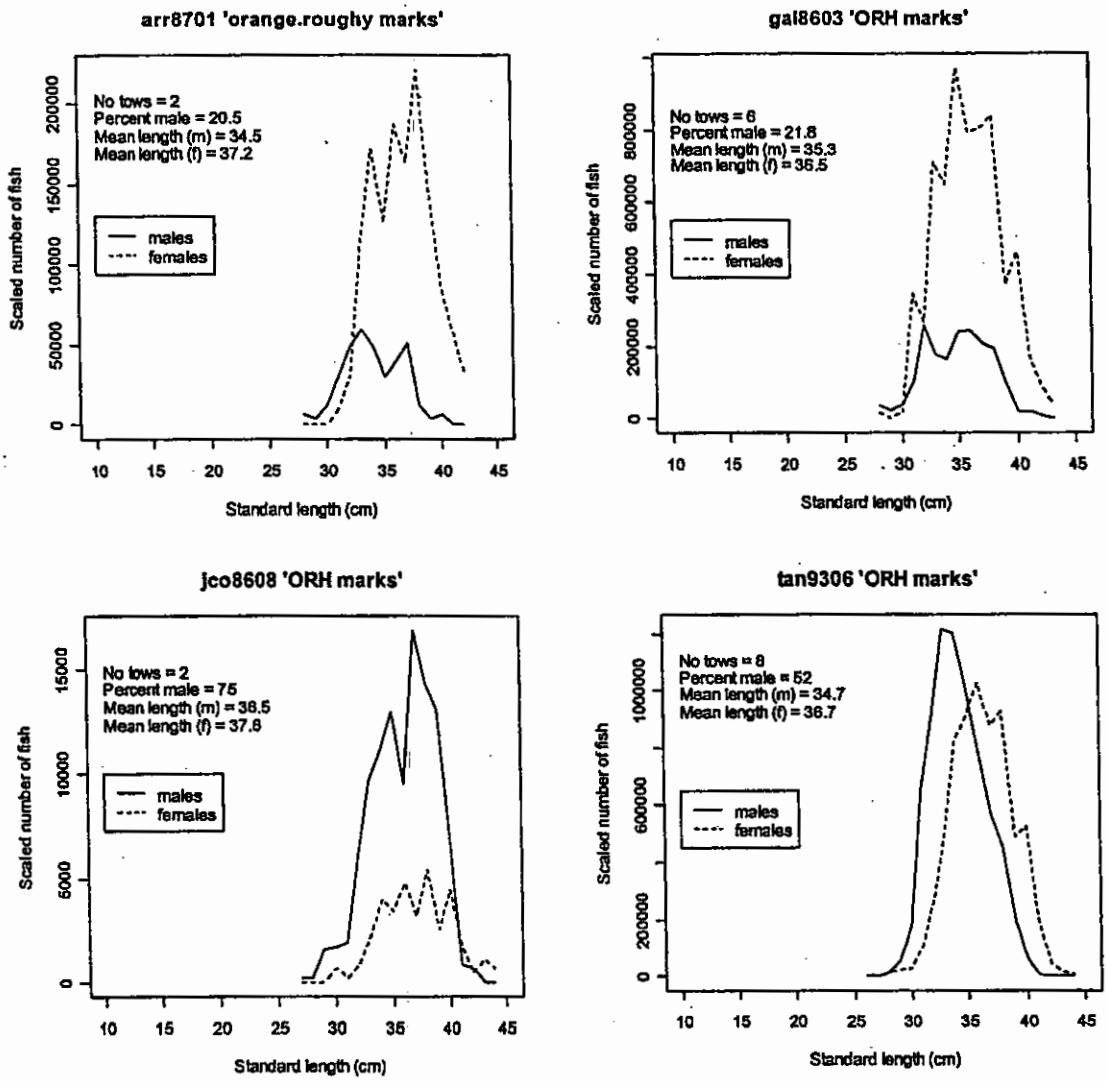

Figure 10: Length frequencies from 'orange.roughy marks' in historical surveys. Top left: 1987 *Arrow*; top right: 1986 *Otago Galliard*; bottom left: 1986 *James Cook*, bottom right: 1993 *Tangaroa*

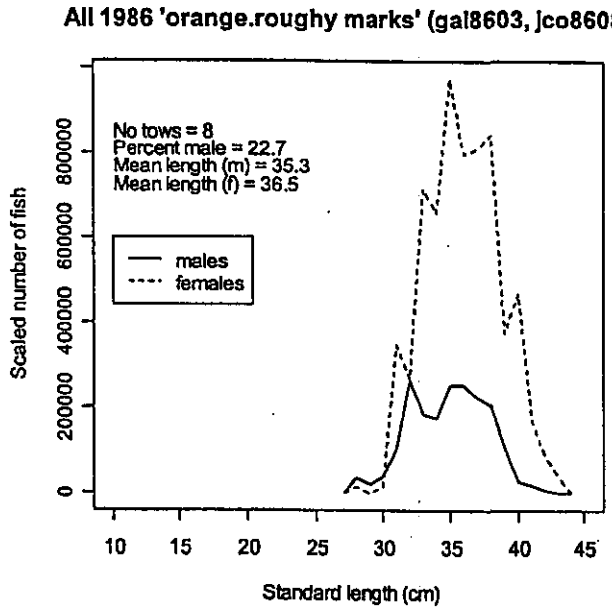

Figure 11: Length frequency distribution of orange roughy from 1986 *Otago Galliard* and *James Cook* data combined

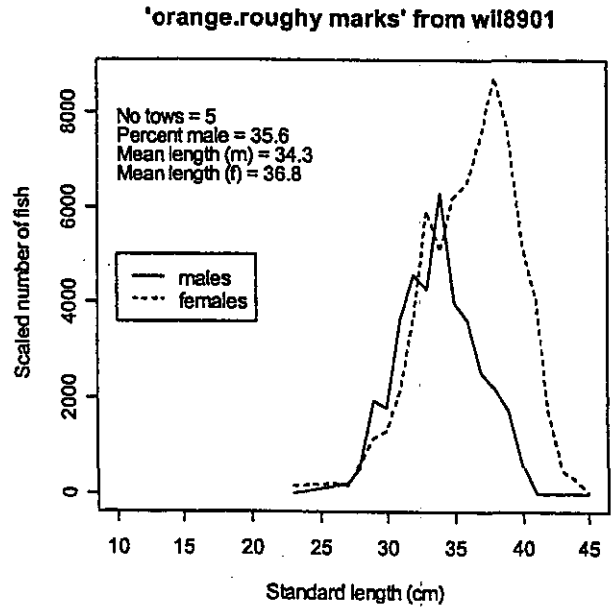

Figure 12: Length frequency distributions (scaled by proportion sampled and catch weight) of orange.roughy marks tows for the 1989 *Will Watch* survey. *n(m)*, number of fish measured.

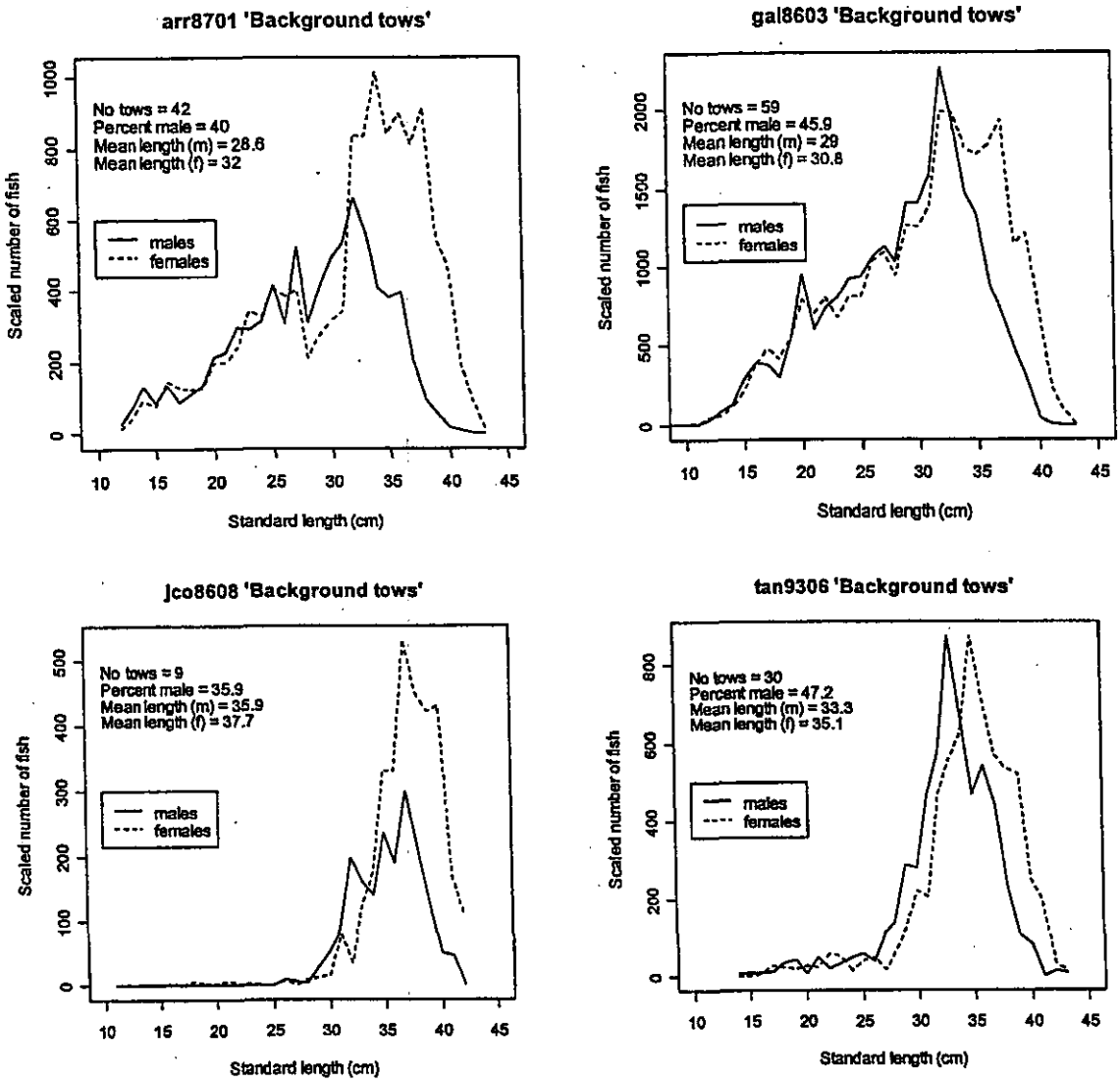

Figure 13: Length frequencies from of orange roughy from historical survey 'background' mark (<250kg roughy) tows. Top left: 1987 *Arrow*; top right: 1986 *Otago Galliard*; bottom left: 1986 *James Cook*, bottom right: 1993 *Tangaroa*

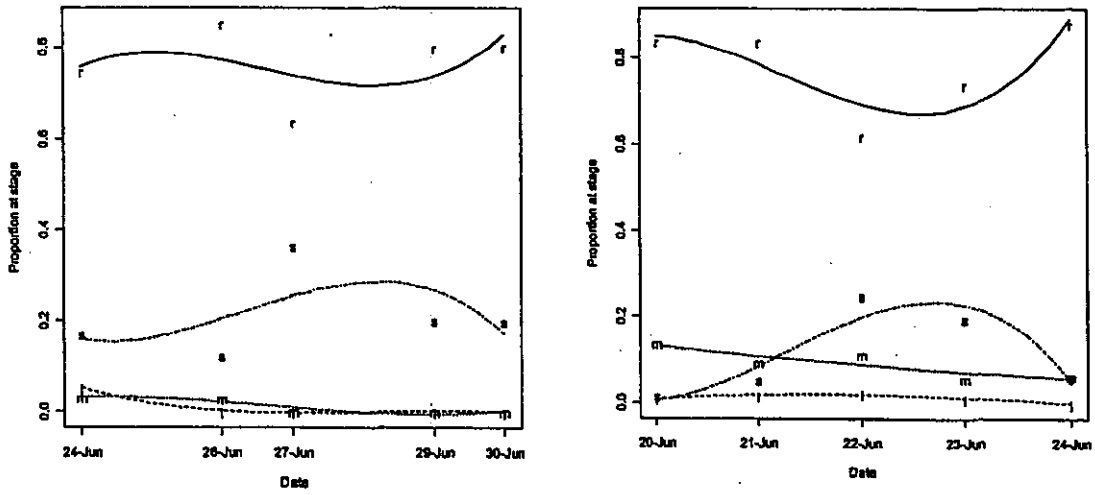

Figure 14: Daily changes in female *orange.roughy* mark tow gonad stage proportions by date during the spawning season. Left plot shows 2001 data, right plot shows 2003 data. i and dashed line denote immature fish; m and dotted line denote maturing fish; r and solid line denote ripe/running ripe fish; s and dotted and dashed line denote spent fish.

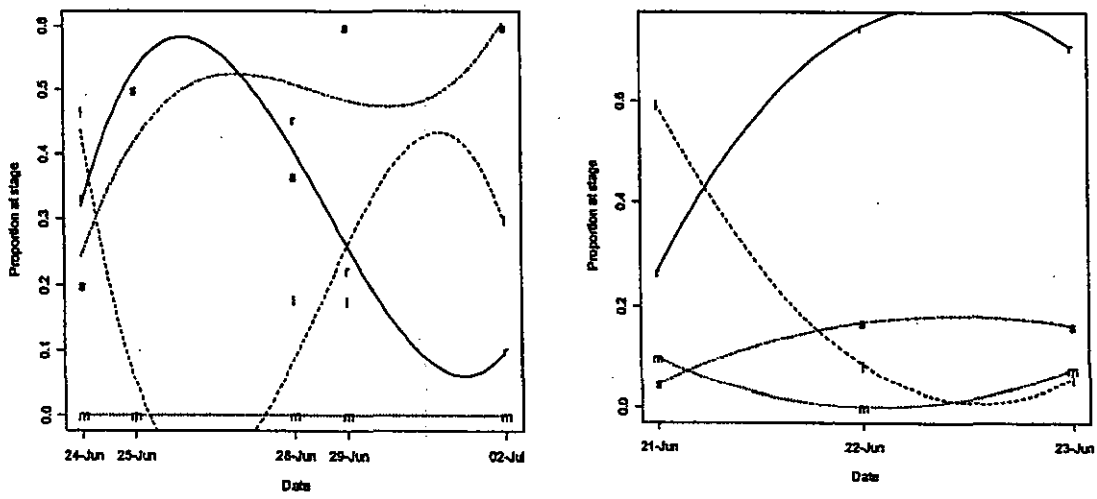

Figure 15: Daily changes in female *background* mark gonad stage proportions by date during the spawning season. Left plot shows 2001 data, right plot shows 2003 data. i and dashed line denote immature fish; m and dotted line denote maturing fish; r and solid line denote ripe/running ripe fish; s and dotted and dashed line denote spent fish.

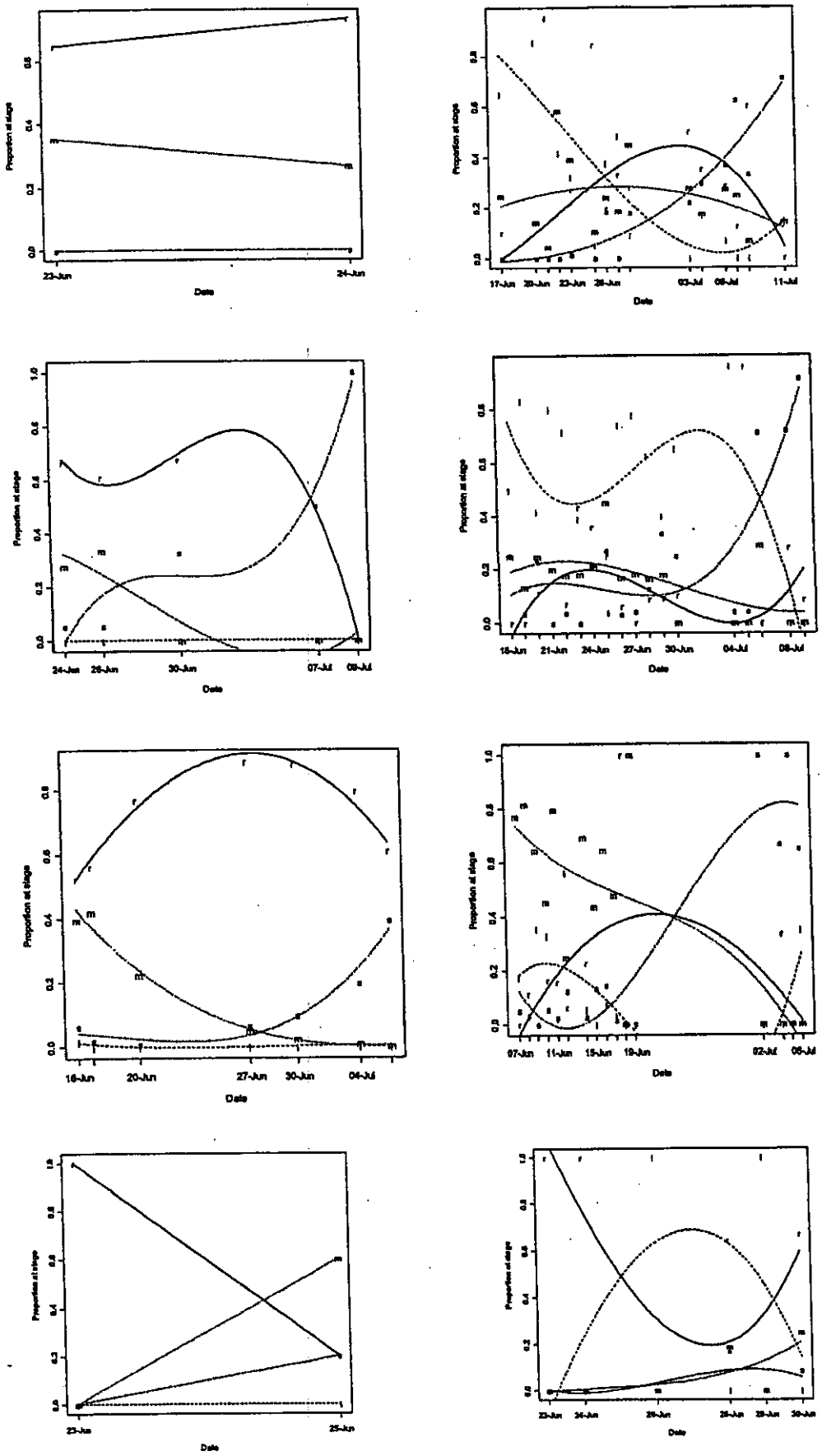

Figure 16: Daily changes in female orange roughy gonad stage proportions by date during the spawning season from the historical surveys. The left column represents *orange.roughy* mark tows, and the right column represents *background* mark tows. Row 1 is 1987 *Arrow*, row 2 is 1986 *Otago Galliard*, row 3 is 1993 *Tangaroa*, and the bottom row is 1986 *James Cook*.

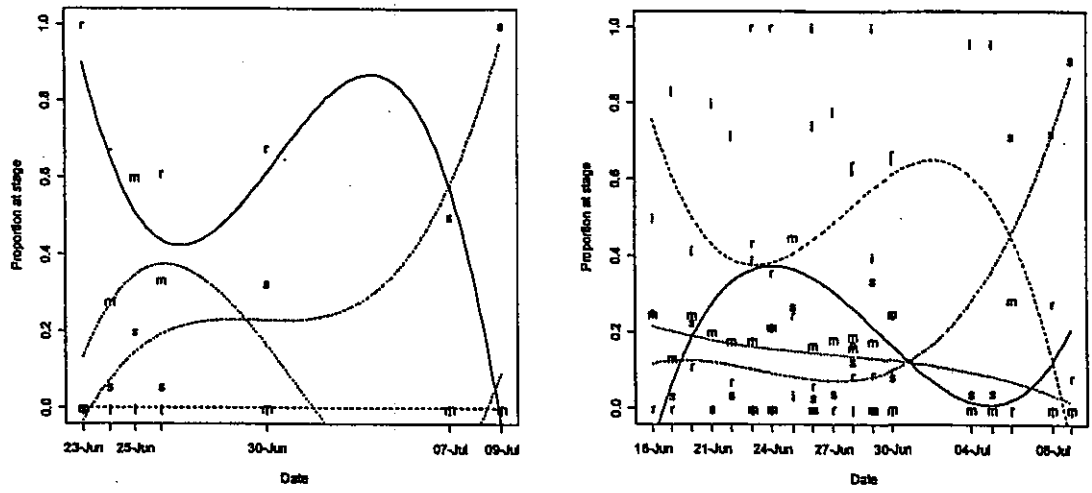

Figure 17: Daily changes in female orange roughy gonad stage proportions by date during the spawning season for 1986 surveys (jco8608 & gal 8603) combined. Left hand column is *orange.roughy* mark tows, right hand column *background* mark tows.