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EXECUTIVE SUMMARY

Doonan, I.J.; Dunn, M.R. (2011). Trawl survey of Mid-East Coast orange roughy, March-April 2010.

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A trawl survey of the Mid-East Coast (MEC) orange roughy management area was conducted using NIWA's 70 m fisheries research vessel *Tangaroa* in March-April 2010. The survey was a repeat of the 1992–94 surveys over the same area and used a similar design. The 2010 survey used the same vessel, trawl net, trawl warp lengths, and fishing protocols. The survey used a two phase design, with phase 1 stations selected from those that had already been used in one or more of the 1992–94 surveys. The 1992–94 surveys were re-analysed to ensure the time series (1992–94 and 2010) was comparable, and suitable for use in a stock assessment.

In 2010, a total of 187 trawl tows were completed in 33 strata, of which 142 were successful phase 1 stations, 29 were successful phase 2 stations, and 16 were rejected because of poor gear performance. A total catch of 107 t was recorded from all trawl stations. During the voyage 275 species or species groups were recorded. Gonad samples, stomachs, and otoliths were taken from orange roughy. Otoliths or dorsal fin spines were removed from 10 other bycatch species. A total of 14.31 km of fish were measured for length, consisting of 32 713 individual fish.

Two alternative methods were used to estimate abundance. Using the all-relevant-tows method, the total abundance of orange roughy was estimated to be 6800 t (c.v. 17%), which was lower than the average over the 1992–94 surveys, which was 15 300 t (15%). The greatest reduction in abundance was for pre-recruit orange roughy, i.e., from 8900 t to 3300 t. Similarly, using the first-at-site method for the 1992–94 surveys and for 2010, reducing the allocation of phase 2 tows to 10%, the total abundance of orange roughy was estimated to be 7100 t (c.v. 19%), lower than the average of the 1992–94 surveys of 16 200 t (16%). Again, the greatest reduction in abundance was for pre-recruit orange roughy, i.e., from 10 400 t to 3400 t.

Although efforts were made to ensure the 2010 survey was comparable to the 1992–94 surveys, the 2010 survey had a lower trawl net headline height, a slightly smaller door spread, a slightly larger wingtip distance, and a greater between tow distance. However, the surveys used the same vessel, net, towing practice, survey design, and even some officers; and the warp-to-depth ratios, expected phase 2 bias, total bycatch abundances, and orange roughy vulnerability (at size), were all similar. Overall, there was little evidence that the trawl net was less efficient for orange roughy in 2010, and the differences in net parameters seemed unlikely to explain the extent of the observed decrease in the biomass estimates for orange roughy.

1. INTRODUCTION

The Mid-East Coast (MEC) orange roughy stock has supported one of the largest and most persistent orange roughy fisheries around New Zealand. The landings peaked at 10 500 t in 1989–90 and were maintained for several years at this level before catch limits were reduced in the mid 1990s. The "fishing down" phase for this orange roughy stock was completed by the mid 1990s, by which time the cumulative reported landings exceeded 100 000 t (Dunn 2005).

A variety of fishery independent methods for estimating MEC orange roughy biomass have been used for stock assessment, including egg surveys and acoustic surveys to estimate absolute biomass, and trawl surveys to measure relative biomass (Clark 1996, Dunn 2005). Fishery dependent methods, specifically standardised catch per unit effort (CPUE) have been used for the MEC (Dunn 2005; Anderson & Dunn 2008), but are less desirable because they are particularly susceptible to bias (e.g., Clark et al. 2010).

The recent distribution of spawning orange roughy on the MEC, in particular a relatively small school size with a less predictable distribution, has made the acoustic biomass estimation technique problematic, and potentially subject to large biases (Doonan et al. 2004). Spawning biomass estimates from egg production surveys have not been repeated, as the large spawning aggregations which this method would seek to measure are no longer present. Amongst the fishery-independent stock monitoring methods, this leaves the trawl survey as the only viable option. It was found that repeating the survey method used in the 1992–94 RV *Tangaroa* surveys in 2010 could have substantial leverage in future stock assessments (Dunn 2009). As a result, in March-April 2010, a repeat trawl survey of the MEC was conducted using RV *Tangaroa*.

A primary concern for the 2010 survey was to ensure that it was sufficiently comparable with the 1992–94 surveys that the series could be used for stock assessment. To this end, the same vessel, trawl gear and operation and survey design were used in 2010 as in the 1992–94 surveys. However, the earlier surveys required some adjustments to make them consistent with the 2010 survey. This included excluding the most northern area of the 1992–94 surveys (the region of ORH 2A outside the MEC stock area, known as East Cape (EC), which was defined in 1994–95), using a consistent wingtip distance for biomass estimates, and reallocating some tows into consistent strata.

The work described in this report was carried out under Ministry of Fisheries project ORH2007/01, having the overall objective "*To estimate the abundance of orange roughy (*Hoplostethus atlanticus*) in selected areas.*", and the specific objective "*to estimate the abundance of orange roughy for the Mid East Coast (MEC) stock, from a trawl survey with a target coefficient of variation (c.v.) of the estimate of 20-30 %.*"

1.1 Review of previous trawl surveys

The first survey series of the MEC stock took place during 1985–87, at spawning time (June-July), and this was followed by a survey in September-October 1988 (Robertson & Grimes 1987, Fincham et al. 1987, Banks & Annala 1989). These surveys covered only part of the MEC stock distribution.

The precursor to the 1992–94 surveys took place during 1989 and 1990, and these surveys covered the whole of the MEC and EC (quota management areas ORH 2A, 2B, and 3A), depths from 600 m to 1500 m, and were conducted in September-October (Grimes 1990, 1991). The 1989–90 surveys established the survey area, strata and design used for the 1992–94 surveys (Figure 1), and also provided most of the tow positions that were re-used in the latter surveys. The design was stratified random, with two phases (Francis 1984), with a minimum of three stations allocated to each stratum. The vessels used were FV *Will Watch* and RV *Cordella*.

The *Tangaroa* survey series began in 1992, during March-April to avoid possible future clashes in vessel programming (Grimes 1994). The 1992 survey covered the same area as the 1989 and 1990 surveys, but included three new strata based on areas of high commercial catch and catch rates (over 5 t/tow) achieved during March 1990 and 1991. The three new strata covered a relatively small area, and therefore to allow a sufficient number of tows to be completed within them they were not stratified by depth. Except for the new strata, the 1992 survey repeated research trawl positions from the 1990 survey, but without maintaining the same tow direction.

The 1993 survey was similar to that in1992, with some minor modifications to strata. The East Cape and Tolaga sub-areas were combined into a single sub-area, resulting in four less strata, and two further strata were added based upon commercial catches. There was also a redistribution of tows amongst strata based on the 1992 survey results, and an increase in the overall number of tows (Tables 1 & 2). Except for the two new strata, the previous known tow positions were again used. The survey design was unchanged in 1994.

For the 1992–94 surveys, a standard tow length of 2.0 nautical miles at a towing speed of 3.0 knots over the ground was used. The distance towed was determined using Global Positioning System (GPS). During the surveys, some tows were shortened because the ground was too rough to complete the tow path. In a few cases, the trawl gear was flown above the bottom for a short period if it looked possible to get it down again within 20 minutes, and therefore extend the tow length to achieve the required 2.0 nautical miles. In the few instances where the trawl was flown (Table 3), the distance towed was recorded as the sum of the distances during which the net was in contact with the bottom.

The warp to depth ratio generally ranged from 1.7 to 2.1. The procedure used was to start the tow with an expected ratio of 1.7, and let out more warp as required. The tows on hills and deep tows tended to have a lower ratio, close to 1.8, to maintain better control of the net, and the shallower tows tended to have a ratio closer to 2.0. The net used in 2010 was the same as used in 1992–94, and was similar to that used during the 1989 and 1990 surveys. The net is commonly referred to as the "rough bottom roughy net", and it is an Alfredo-style trawl designed for use on rough ground, with large rollers fitted to the ground rope, cut-away lower wings, and a wingspread of about 25 m (Appendix 1).

To estimate orange roughy abundance, a constant door spread of 115 m was assumed for the 1992 survey, and 110 m for 1993–94, based upon door spread sensor readings (Grimes 1994, 1996a, 1996b). It was assumed that there was no herding of orange roughy by the trawl doors and sweeps, with vulnerability calculated to be 0.243 in 1992 and 0.227 in 1993 & 1994, given a trawl wingtip distance of 28 m in 1992 and 25 m in 1993–94 (I do not understand how you can know the vulnerability, do you mean the difference between door spread and wing spread? We do not; this is the term used by Grimes and the parameter name used in the biomass program he used) (Grimes 1994, 1996a, 1996b). Vertical and areal availability were assumed to be 1.0 (Grimes 1994, 1996a, 1996b). The reported total abundances by sub-area are shown in Table 4.

1.2 Survey design

The 1992–94 MEC surveys used a two-phase design, which introduces a modest negative bias, but protects the survey from extreme high estimates (Francis 1984). The proportion of phase 2 tows in the overall survey was 26% in 1992, 23% in 1993, and 21% in 1994. These are in line with the Francis (1984) recommendation of 25% for a new survey, but Francis (2006) recommends that only about 10% are needed if the design is based on past surveys.

Phase 2 tows appear to be needed for the MEC survey because the strata with the greatest estimated biomass have not been predictable (except for perhaps stratum 33). Later in this document, we complete simulations using data from the 1993 and 1994 surveys to investigate the likely size of the bias in biomass estimates resulting from the two phase design.

In the 1992 survey, phase 2 stations appeared to have been poorly applied, since 26 phase 2 stations (out of 51) were allocated to stratum 45, which only had 4 phase 1 stations, and this stratum contributed just 144 t (1%) to the total biomass. However, part of this stratum was split off into a commercial stratum after the phase 2 stations were completed, and the tows in the new commercial stratum were then repeated.

The design of the 1992–94 surveys was not a true stratified random design, but had fixed position phase 1 stations, and stratified random phase 2 stations allocation each year. The use of fixed stations during phase 1 reduced search time and gear damage. The MEC contains many rough ground areas, and the time required to complete a true stratified random phase 1 survey would have proven prohibitive. For the 1992–94 surveys, there was a core of 110 phase 1 stations, with some new phase 1 stations added, and others used only once (Table 5). Since stations could be fished in any direction, for example in response to swell direction, a repeated tow can be considered analogous to a site covering a disc of 1 to 2 nautical miles in diameter, rather than being a single tow path. There were at least 158 of these potential tow sites to choose from for phase 1 of the 2010 survey (Table 5).

A true fixed station design has a bias, but this is compensated for by a lower variance than a random design (random designs being unbiased). The extent of the bias in a fixed station design depends on the strength of any residual trends in density within a stratum (i.e., spatial and temporal correlations). If the bias is constant, then it becomes part of the survey catchability. However, adding more stations and re-distributing the numbers of stations between strata, as was done in 1993 and 1994 surveys, changes the size of the bias. If spatial correlation is weak then the bias is small and it becomes like a random design. Fixed stations surveys are considerably faster to complete (estimated to be about 40% faster for the MEC survey) because trawl tracks do not have to be surveyed first and if unsuitable, another site found nearby.

When fixed station positions from the 1992–94 survey data were examined, it appeared that some were repeated twice or more during the same survey. This could be just a consequence of the spatial scale at which we examined position data, or it could be due to the limited number of suitable tow positions in a stratum, especially when the phase 2 tows tended to be allocated to one or two strata in high densities relative to the stratum area.

The order of occupation of strata was different for all three surveys (Table 6). This was primarily because of weather conditions, which often vary throughout the survey area, with Wairarapa being especially prone to periods of relatively high winds.

2. METHODS

2.1 Orange roughy abundance estimation

2.1.1 Sites

For the 2010 survey, we planned to repeat stations fished during the 1992–94 surveys. As outlined above, actual tows tracks differed at the same (nominal) tow position, because different weather in each year required a different tow direction. A preliminary analysis found that many of the 1992–94 tow positions were clustered into sites approximately 2 nautical miles across, and that there was some evidence for spatial correlation of catch rates within sites. As a result, the potential tows were clustered into sites, and each of these sites was repeated in the 2010 survey. For the 2010 survey, one tow from each site was randomly selected as the tow line for the 2010 survey.

The list of phase 1 and known phase 2 sites were generated from a hierarchical cluster analysis based on squared Euclidean distance between tow mid-point locations. All tow locations from the 1992–94 surveys were used. The analysis was done using the *hclust* function in R (Murtagh 1985, R Development Core Team 2009) with the agglomeration method set to *average*. Sites were extracted from the resulting hierarchical tree using a *height* of 2.25 nautical miles. This tree height is slightly larger than the normal tow length of 2 nautical miles, so that end-on-end tows were selected as being in the same site. In a few cases, overlapping clusters were merged by hand (two clusters into one for strata 3, 31, 33; 3 clusters into one for stratum 13), and one cluster was split into two (stratum 4). Some examples of sites and their constituent tow lines, including two clusters merged into one site, are shown in Figure 2. Phase 1 sites were defined as those sites containing at least one tow in phase 1, for at least one of the 1992–94 surveys. The strata based on commercial hill fishing, strata 1 to 5, were done differently in each of the 1992–94 surveys, so three sites within each strata were designated as phase 1 sites by hand, for the 2010 survey.

The exception were the commercial strata (1 to 5), where 3 phase 1 sites were designated by hand and the others assigned as phase 2 sites since it was difficult to work out what was a phase 1 or II tow, i.e., in some years, some commercial strata had all tows designated as phase 2.

The number of sites identified for phase 1 was 144, and for phase 2 was 68. The tows assigned to each site for phase 1 and II are given in Appendix 2. The notion of a site, as defined here, meant that the 1992–94 surveys repeated some sites, mainly during phase 2 (Table 7).

2.1.2 Survey design

The 2010 survey repeated the design from the 1993-94 surveys (Figures 1 & 3, Tables 1 & 2), except that the EC sub-area was truncated at latitude 38° 23’ S, in accordance with the management boundary between the EC and MEC stocks that was in place since 1994–95.

The survey had a stratified design using 144 fixed phase 1 sites and a target of 20% phase 2 sites. Phase 2 tows were allocated to strata following Francis (1984), and selected from the list of additional known sites for each stratum. Where there were not enough sites, new potential sites were randomly generated within the target stratum. Each new site had to be at least two nautical miles from existing sites.

2.1.3 Data analysis

Abundance estimates using wingtip swept area were made for all orange roughy, juvenile (<32 cm standard length (SL)), and adults (≥ 32 cm SL) orange roughy, and also for main by-catch species. All abundance estimates, and stratum allocation of phase 2 tows, were made using the NIWA software *SurvCalc* (Francis & Fu 2009). *Survcalc* is a C++ computer program developed in 2008 to analyse data from stratified random surveys.

The trawl catch of adult orange roughy in the i^{th} trawl in stratum *s* was converted into fish weight density (d_{si}) using a fixed wingtip width of 25 m. A catchability (q) of 1 was assumed. Thus, the biomass will be given by:

$$\sum_{s}^{strata} A_s \bar{d}_s$$

where A_s is the stratum area of stratum *s*, and $\bar{d}_s$ is the mean density in stratum *s*.

The variance is given by:

$$\sum_{s}^{strata} A_s^2 \, {}^{V_s}\!/_{n_s}$$

where V_s is the sample variance estimate of densities and n_s is the number of tows in stratum *s*.

Orange roughy scaled length frequencies distributions by stratum and overall were calculated using *SurvCalc* from the length and weight samples collected during the survey.

The stratum areas for 2010 were the same as used in the 1993–94 surveys. For the abundance estimates for the 1992–94 surveys, the stratum areas used are those reported by Grimes (1994, 1996a, 1996b).

2.2 Survey execution

The survey work was carried out using NIWA's 70 m research vessel *Tangaroa*. All tows used a rough-bottom orange roughy trawl, having the same design as used in the 1992–94 surveys (Appendix 1). This an Alfredo-style trawl, with cut-away lower wings, 305 mm (12 inch) mesh in the forepart of the net reducing to 102 mm (4 inch) mesh, with a 100 mm mesh cod-end, robust ground gear consisting of steel and rubber bobbins, and an expected wingspread of about 26 m and headline height of about 6 m.

Trawl survey work was carried out 24 hours a day. Each trawl tow lasted for 2 nautical miles at 3 knots, whenever possible. The door-spread and headline height, and wing-tip width where possible, were recorded at five minute intervals during each tow from SCANMAR readings. Warp to depth ratios were the same as previously used at each site, and close to 2.0 except on hills, where they were roughly 1.8. To check that the net consistently conformed to the 1994 net plan, the trawl was regularly measured, and any components (e.g., sweeps or bridles) replaced if necessary (e.g., if there was any evidence of stretching after the trawl came fast). Prior to the survey, the net was shipped to Motueka Nets to confirm that it conformed to the net plan.

Any tows that were not successful on the first attempt were not repeated immediately, and the site was rested for at least 24 hours.

The catches from each valid tow were sorted and weighed by species on motion compensating scales to the nearest 0.1 kg. Large catches of fish were sub-sampled and the total catch estimated from the proportions in the sample. For catches too large to be weighed, the catch was estimated from the weighed processed catch using a conversion factor. From each tow, a random sample of up to 200 orange roughy, and 50–200 of other species were randomly selected from the catch to be measured and sexed. Up to 40 individuals of orange roughy were selected randomly for more detailed biological analysis, which included fish length, weight, sex, gonad stage and weight, and otolith extraction.

2.3 Survey recalculations for 1992–94

Two alternative estimates were completed. The first used the survey data as originally collected but with some minor changes ("all-relevant-tows"), and second used only the first trawl at each of the specified sites ("first-at-site").

Some tows in the original calculations were assigned to the wrong strata. These were tows within the new commercial strata, that had been assigned to the parent stratum (since they were done before the new commercial stratum was split off), which had not been corrected after the survey was completed (Table 8).

There was only one trawl in each of the new strata (truncated at latitude 38° 23' S) for the Tolaga sub-area in the 1993 and 1994 surveys, so only one station per stratum was available. In these cases, the single station was used as an estimate of abundance, with the coefficient of variation (c.v.) set to 95%. To implement this in *SurvCalc*, another tow was artificially generated and the catches of both tows in the stratum changed so the mean remained the same as the actual catch from the single tow, but the c.v. was 95%.

For the all-relevant-tows estimates, all tows with good performance were used.

For the first-at-site estimates, each phase 1 tow was from a different site. For the first-at-site estimates, the first tow at each site was used for phase 1 sites and phase 2 sites. Phase 2 tows on phase 1 sites were excluded which resulted in substantially fewer phase 2 tows than in the original surveys. Fewer phase 2 tows reduces the phase 2 bias so to make the 2010 survey comparable, the number of phase 2 tows were reduced in 2010 so that the phase 2 bias was similar to the first-at-site estimate for 1992–94 number of phase 2 tows is 10% of phase 1 tows).

All survey estimates were calculated assuming a constant wingtip width of 25 m.

2.4 Comparability across surveys

A key activity for this project was to assess comparability across the four surveys. Comparability can be thought of as having two components; catchability (variability caused by survey conditions, fish life history, environment etc) and bias (caused by, for example, using a phase 2 design). To help evaluate comparability, trawl operation and net parameter distributions were compiled, the abundance of by-catch species was estimated, and the bias from using phase 2 tows estimated.

Wingtip distance, doorspread distance, headline height, and warp length distributions were compiled for all surveys, and relationships investigated with each other, and also with depth and tow direction (up or down the slope).

Bycatch abundance was estimated for all of the regularly caught species, using the all-relevant-tows method, for the 1992–94 and 2010 surveys. The objective of this analysis was to see if there was an overall change in catch rate that would suggest a change in catchability or net efficiency.

2.5 Expected bias from using phase 2 stations

The estimation of the expected bias from using a two-phase design followed Francis (1984), using data from the 1993 and 1994 MEC surveys. The catch data were for recruited fish (≥32 cm SL). We assumed a completely random design. In preliminary investigations, the method was extended to fixed sites that had between year correlations at a site, but the overall expected bias was found to be similar to that estimated when using a completely random design. The method assumed that all abundances were lognormal with a common variance in log space. The East Cape stratum areas were adjusted to the Tolaga strata area for 2010. For 1993, stratum 5 was excluded, since it was not included in phase 1 of the 1993 survey. Thus, there were 160 phase 1 tows in 1993, and 166 phase 1 tows in 1994. Simulations of the phase 2 allocation based on results of phase 1 were carried out using 2000 simulations on each survey. The c.v. and bias were averaged over the two surveys. Simulations were carried out with phase 2 allocation at 5%, 10%, 15%, 20% or 25% of the number of phase 1 tows. For re-calculated abundances for 1993 and 1994 (Section 2.3), slightly lower numbers of phase 1 tows were used; for the first-at-a-site method there were 156 phase 1 tows for 1993 and 160 phase 1 tows in 1994. These were considered close enough to the initial estimates (160 and 166 phase 1 tows respectively) that extra calculations were not warranted.

3. RESULTS

3.1 Survey execution

A total of 187 trawl tows were completed in 33 strata, of which 142 were successful phase 1 stations, 29 were successful phase 2 stations, and 16 were rejected because of poor gear performance. Tow positions for valid tows are shown in Figure 4. There were two phase 1 stations not successfully completed, otherwise all planned tows were completed (Table 9). Tow details are given in Appendix 3. A total catch of 107 t was recorded from all trawl stations (Table 10).

Weather conditions were good throughout the voyage, and no time was lost due to unfavorable sea conditions (Appendix 4). The RV *Tangaroa* trawl survey overlapped with a Crown Minerals seismic survey off the Wairarapa coast. This survey consisted of two vessels, MV *Reflect Resolution* and *Ocean Pioneer*, with *Reflect Resolution* using a loud acoustic “boomer”, and multiple listening devices fixed on the seabed. The equipment on the seabed was not located near any *Tangaroa* survey sites. Nevertheless, because of concerns about the acoustic “booming” potentially influencing fish catchability, *Tangaroa* moved position to start work about 60 n. miles

(110 km) north of the seismic survey area, only returning to start the Wairarapa strata roughly 2 days after the seismic survey (their final transect, 100 km offshore) had been completed.

Commercial surface longlines initially prevented access to stations near the Rockgarden (Hill stratum 1 in Figure 1), and in Tolaga. Previous surveys had found relatively little orange roughy biomass in Tolaga, so this area at the time was abandoned in favour of Wairarapa, Clarence, and Kaikoura, where historical orange roughy biomass had been relatively high. Tolaga was revisited at the end of the survey, after a request to keep the Tolaga hill and surrounds clear of commercial gear was made via the Deepwater Group. The Tolaga strata were clear of commercial gear, and all but two Tolaga stations were successfully completed.

Sixteen stations were considered unsuitable for biomass estimation (Appendix 3). Most of these stations came fast (stations 10, 13, 51, 53, 60, 126, 147, and 148). Gear damage was suffered on stations 36, 62, 63, and 86, and included ripped wing and belly meshes or lost (imploded) floats or bobbins. The net damage on station 62 (in Tolaga) was extensive, and as a result the second net was used for all subsequent stations. Poor net statistics were recorded for stations 55, 85 and 184 (e.g., poor bottom contact or low headline height). On station 184 the poor net statistics were attributed to a large log stuck in the top of the net. Station 40 was rejected because the tow distance was too short.

On the second to last of the planned survey stations, on 10 April, *Tangaroa* caught roughly 50 t of alfonsino. The entire catch was successfully brought on board, but was too large to be processed. Therefore *Tangaroa* steamed to Napier to offload the fish to a commercial fish processor. As a result of this large catch there was insufficient time to complete the final remaining tow in stratum 17 (see Table 9).

Phase 2 tows for all strata except Tolaga were allocated on 3 April. Twenty-eight randomly allocated sites were investigated in stratum 23, of which 15 were successful. However, only 13 were in stratum 23 as two were mistakenly put into stratum 5 since the annotated charts used at sea were wrong. Three randomly allocated phase 2 sites were also completed in stratum 27, after completion of the Tolaga strata towards the end of the survey. The allocation of phase 2 tows to stratum 27 was determined from a revised phase 2 allocation (i.e., all phase 2 tows completed before Tolaga were excluded from a revised estimate of the phase 2 allocation). The net was flown above the seabed for four tows, with a median distance flown of 0.3 nautical miles.

Gonad samples were taken from 870 orange roughy and preserved in 10% buffered formalin, and stomachs were removed from 972 orange roughy and frozen (Table 11). Pairs of otoliths were removed from 2044 orange roughy (Table 11). A total of 1730 pairs of otoliths were removed from other species; predominantly basketwork eels, Johnson's cod, bigscale slickheads, smallscale slickheads, spiky oreo, smooth oreo, warty oreo, and white rattails. Dorsal spines were sampled from 60 leafscale gulper shark and 214 shovelnose dogfish.

During the voyage 275 species or species groups were recorded. These included 141 teleosts, including 35 macrouridae; 25 sharks, rays, and chimaeras; 16 octopus and squid; and 93 other invertebrates. A total of 14.31 km of fish were measured for length, consisting of 32 713 individual fish, measuring 10–167 cm in length (spiky oreo – frill shark), with an average length across all species of 50.0 cm. See Appendix 5 for a compilation of occurrence of fish species caught and biological measurements made. The green weight of the top 20 species is given in Table 10, with orange roughy accounting for 11.0% of the total catch from all trawls.

Invertebrate fauna represented 5 Porifera (sponges) 26 Cnidaria (anemones), corallimopharians (jewel anemones), corals (stony cup corals, black corals, sea fans, sea pens, soft corals, and jellyfish), 2 Mollusca (not cephalopods), 25 Crustacea (crabs and prawns), 1 polychaete (marine worm), 35 Echinodermata (sea stars and echinoderms), and a sipunculid (peanut worm). Other non-fish records included wood (taken on 58 tows), rocks, salps, rubbish, and discarded fishing gear (longlines).

3.2 Orange roughy abundance estimate

Wingtip measurements were made on 36 tows, and ranged from 23.9 m to 26.4 m, with a mean of 25.4 m and standard deviation of 0.7 m. The depth range for the wingtip measurements was 800 to 1200 m. There was no discernable trend in wingtip distance with depth. There were 20 pairs of concurrent door spread and wingtip measurements, and the mean ratio of wingtip to door spread was 0.245. This ratio was 0.231 in 1992 (n=4), and 0.226 in 1994 (n=43). For this report, we have assumed a constant 25 m for the wingtip distance in 2010, i.e., estimating wingtip from door spread using the estimated ratio was not done.

The spatial distribution of orange roughy catches in 2010 was similar to that reported in 1993 and 1994 surveys, with highest catch rates on the Wairarapa coast (Figure 5). The *SurvCalc* parameter files used to estimate abundance for 2010 are in Appendix 6.

For the all-relevant-tows method, the total abundance of orange roughy was estimated to be 6800 t (c.v. 17%). This was lower than the average for the 1992–94 surveys of 15 300 t (c.v. 15%), with the main reduction in biomass occurring for juveniles (Table 12; Figure 6). A comparison of length frequencies by sub-areas for the four surveys shows that the main reduction in juveniles occurred in the three southern sub-areas (Kaikoura to Wairarapa) (Figure 7). Abundance estimates by stratum for all four surveys are in Appendix 7 (Table 7.1).

Using the first-at-site method and 10% allocation of phase 2 tows, the total abundance of orange roughy for 2010 was estimated to be 7100 t (c.v. 19%). This was lower than the average for the 1992–94 surveys of 16 200 t (c.v. 16%), with the main reduction in biomass occurring for juveniles (Table 13). Abundance estimates by stratum for all four surveys are in Appendix 7 (Table 7.2).

For both the all-relevant-tows and first-at-site methods, the adult orange roughy biomass in 2010 was not significantly different from that in 1992–94, but the biomass for juveniles was significantly lower in 2010 (at the 5% level) (Tables 12 & 13). Appendix 7 (Table 7.3) gives the abundance estimate by stratum for bycatch species.

3.3 Comparability across surveys

The various trawl parameter estimates are shown for the 2010 and 1992–94 surveys in Tables 14 and 15. Door spread in 2010 was on average 6–7 m smaller, headline height in 2010 was about 1–1.7 m lower, and trawling speed in 2010 was on average 0.2 knots lower than in 1993 and 0.4 knots lower that in 1994, but the same as in 1992 (Figure 8). The only high correlations between trawl parameters were between headline height and door spread (Figure 9), and between wingtip distance and door spread (not shown). There were insufficient environment data, and variability, to allow comparisons between trawl parameters and weather conditions.

The 2010 total catch abundances were similar and within the ranges for the 1992–94 surveys (Table 16), and therefore at this level, the net appeared to be working similarly in 2010 to the previous surveys. This assumes that the total biomass of all species has remained the same, even though some species may have declined or increased during the 16 year gap.

3.4 Expected bias from using phase 2 stations

Table 17 shows the estimated bias from using different proportions of phase 2 tows. With more than a 10% allocation of phase 2 tows, the bias increased only slowly with greater allocation rate. There was little difference in the sample c.v.s for the different allocations of phase 2 tows.

The re-calculated abundances using the first-at-site method had phase 2 allocations of between 5% and 18% (Table 18). The re-calculated 2010 abundance assumed a 10% phase 2 allocation, therefore compared to the 1992–94 surveys no more than a 2% difference in phase 2 bias would be introduced. When using all relevant tows, the bias was about -10% for the 1993–94 surveys, and about -9 % for the 2010 survey (Tables 17 & 19).

3.5 Abundance estimates after excluding flown tows

As a sensitivity, all flown tows were excluded from all four surveys and the abundance re-estimated using the all-relevant-tows method. The percentage change in total abundance from excluding flown tows varied between 1 and 5% (Table 20).

4. DISCUSSION

The 2010 trawl survey was intended to provide a relative index of orange roughy biomass for use in quantitative stock assessment (Dunn 2005, 2009). The key requirement was therefore that the 2010 survey was as comparable as possible with the 1992–94 surveys. However, some differences in trawl parameters were observed between the 2010 and 1992–94 surveys, and the key questions are therefore (1) is this difference within the range of variability expected for the trawl, and (2) is the difference likely to substantially bias the time series with respect to the target species, orange roughy?

In 2010, the headline height was lower than in the 1992–94 surveys. The headline height expected for the orange roughy rough-bottom trawl net is 5–6 m (Grimes 1994), and therefore the headline height achieved in 2010 was either a little low, or within this range (see Figure 8). Conversely, the headline heights reported for the 1992–94 surveys tended to be a little higher than expected. The warp lengths used were similar in all surveys, so achieving a higher headline height in 2010 would have required more floats, or more layback, both of which would have exceeded the trawl net specifications (see Appendix 1).

The same orange roughy rough-bottom trawl was used by *Tangaroa* for surveys of spawning orange roughy on the north Chatham Rise in 1992 and 1994–96. These surveys reported a towing speed of 3.0–3.1 knots, a door spread of 114–121 m, and a headline height of 5.5–6.9 m (*Trawl* database, held at NIWA, Greta Point). The minimum door spread from the Chatham Rise surveys is actually greater than the median from the 1992–94 and 2010 MEC surveys, and the headline height higher than the 2010 MEC survey, and similar to or lower than the 1992–94 MEC surveys. Combined with statistics from the MEC surveys themselves (see Table 14), the available trawl net parameters have a fairly wide range, and the 2010 surveys do not seem to be anomalous.

For comparison, trawl surveys on Chatham Rise and Campbell Plateau using *Tangaroa* and a full-wing hoki trawl have reported a headline height between 6.3 and 7.4 m, and a door spread between 114.2 and 126.5 m (Neil Bagley, pers. comm.). The expected variability for this trawl is therefore up to 1.1 m for headline height, and 12 m for doorspread. Trawl surveys on Challenger Plateau using FV *Thomas Harrison* used an orange roughy trawl similar to the MEC survey trawl, during 2005–06 and 2009–10, and reported a headline height between 5.3 and 5.9 m, and a door spread between 134 and 143 m (Doonan et al. 2010). The expected variability for this trawl is therefore up to 0.6 m for headline height, and 9 m for doorspread. The MEC surveys therefore show a relatively high variability in trawl parameters, which may reflect the wider range of ground over which this trawl was used (flat soft seabed through to rough ground, hills and seamounts).

In 2010, the wingtip distance was 1–4% higher, and the door spread was 5–7% lower, than reported for the 1992–94 surveys. This affects the area swept, which is of direct importance to the estimated abundance. However, the difference in swept area seems small relative to the c.v. of the abundance estimate, and to the magnitude of the decline in orange roughy abundance between 1992–94 and 2010, and is therefore not a major concern for the use of the results in stock assessment.

The achieved headline height is unlikely to be a concern for orange roughy catch rates, since orange roughy dive on approach of a trawl. Headline height would have an effect on catch rates if the orange roughy density was so high that the water column was saturated with fish, which may occur in spawning plumes, but such fish densities were not encountered during the MEC surveys. However, the higher headline may indicate that the net was fished "lighter" in the 1992–94 surveys, perhaps to reduce the risk of net damage or coming fast. All of the MEC surveys experienced some net damage. Fishing lighter might affect orange roughy escapement below and through the ground gear. Whilst the trawl has heavy ground gear, and so is expected to be in contact with the bottom, the higher headline height in the earlier surveys may allow the net to bounce more often. However, bouncing ground gear was recorded on the station forms only for a handful of tows ($n<10$; although small and short bounces may not be readily observed). Bouncing was not reported on the vast majority of the tows, therefore this affect should be minimal.

Other differences between trawl parameters for the MEC surveys were mean towing speed and the proportion of tows where the net was flown. Mean towing speed for 1994 was higher than the other surveys by 0.2–0.4 knots. The net was flown only for a small number of tows (4–5 tows for all surveys except 1992, where there were 12 such tows). Again, these differences are relatively minor and would not account for the decline in orange roughy abundance between 1992–94 and 2010.

The average distance between tows was larger in 2010 than 1992–94, because of the 2010 survey design, where only one tow from each site was occupied. The use of sites meant that some sites had repeat tows during the 1992–94 surveys (mainly affecting phase 2 tows), with the number of tows affected being about 40 per survey. This matters if there is spatial correlation of catch rates within a site, and catch rates were indeed found to be correlated within 4–5 km. However, the abundance estimates from the all-relevant-tows and first-at-site methods were found to be similar, although the c.v.s increased when using the first-at-site method.

There was little difference in the total abundance of bycatch across the four surveys. This result suggested that net efficiency was not dramatically different in any one survey. A regular increase or decrease in the bycatch abundance in a single survey might indicate a change in net performance, assuming that such a regular change would have been unlikely to have occurred naturally (or because of fishing). Even given constant net efficiency, we would expect some differences in catch rates because catchability will vary, perhaps because of environmental variation. Variable catchability is usually allowed for in stock assessment models by adding a 20% process error to trawl survey abundance indices.

In summary, the 2010 survey was different from the 1992–94 surveys in that the headline height was lower (~20%); the door spread was slightly smaller (~ 5%); the wingtip distance was slightly larger (~ 4%); the between tow distance was greater (especially for phase 2 tows); and the 1994 mean towing speed was slightly faster. The similarities between the surveys were that the same vessel, net, towing practice, survey design, and even some officers, were used; the warp-to-depth ratios were the same; the expected phase 2 bias was the same; the total bycatch abundances were similar; and the orange roughy vulnerability was similar (similar length range caught). Overall, there is little evidence that the trawl net was less efficient for orange roughy in 2010, and the differences in net parameters seem unlikely to explain the extent of the observed decrease in the biomass estimates for orange roughy.

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Table 1: Sub-areas, hills, and codes used in the survey (as in the 1993 and 1994 surveys)

Area	Area code	Area (km^2)	QMA	Boundaries
Flat ground areas				
Kaikoura	KAIK	2 681	3A, 3B	174° 20'E to 42° 40' S
Clarence	CLAR	2 689	3A	42° 40' S to C. Palliser
Wairarapa	WAIR	4 202	2B	C. Palliser to C. Turnagain
Madden	MADD	2 184	2A	C. Turnagain to 177° 50' E
Portland	PORT	2 035	2A	177° 50' E to 39° 07' S excluding the Ritchie Banks
Ritchie Banks	RICH	1 400	2A	Ritchie Banks east of the Portland 1000 m contour
Tolaga (East Cape)	EAST	6 806	2A	39° 07' S to C. Runaway. In 1992, this sub-area was split into two: East Cape & Tolaga.
Commercial (Hill) strata				
Tim's Bank	TIMB	28	2A	
SW Ritchie	SWRI	50	2A	
Rockgarden	ROCK	100	2A	
Tolaga Hill	TOLA	30	2A	
Castlepoint	CLPT	50	3A	Small area north of the Castlepoint hills

Table 2: Stratum, stratum areas, and stations completed in the 1993 survey.

Stratum	Depth (m)	Area code*	Area (km^2)	Number of stations completed in 1993 Phase 1	Phase 2
1	600-1500	RICH, Tim's Bank	28	3	0
2	600-1500	RICH, SW Ritchie	50	6	0
3	600-1500	RICH, Rockgarden	100	3	1
4	600-1500	TOLA, Tolaga Hill	30	5	0
5	600-1000	WAIR, Castlepoint	50	0	6
11	600-800	KAIK	1 103	3	0
12	600-800	CLAR	552	4	0
13	600-800	WAIR	640	4	0
14	600-800	MADD	366	3	0
15	600-800	PORT	392	3	0
16	600-800	RICH	167	4	0
17	600-800	TOLA	481	3	0
21	800-1000	KAIK	517	10	4
22	800-1000	CLAR	685	6	0
23	800-1000	WAIR	550	9	1
24	800-1000	MADD	432	8	12
25	800-1000	PORT	499	4	0
26	800-1000	RICH	355	4	0
27	800-1000	TOLA	448	3	0
31	1000-1200	KAIK	4-41	4	0
32	1000-1200	CLAR	755	13	0
33	1000-1200	WAIR	1 575	19	20
34	1000-1200	MADD	412	3	1
35	1000-1200	PORT	450	11	2
36	1000-1200	RICH	357	3	0
37	1000-1200	TOLA	420	3	0
41	1200-1500	KAIK	619	3	3
42	1200-1500	CLAR	696	4	0
43	1200-1500	WAIR	1 388	5	0
44	1200-1500	MADD	974	7	0
45	1200-1500	PORT	695	4	0
46	1200-1500	RICH	344	3	0
47	1200-1500	TOLA	807	3	0
Total			21 997	170	50

Table 3: The number of tows and distance covered where the trawl net was flown over rough ground (excluding the Ease Cape sub-area).

Year	Number flown tows	Median distance flown (nautical mile)
1992	12	0.42
1993	5	0.30
1994	4	0.38
2010	4	0.30

Table 4: Total orange roughy biomass (t) estimates by subarea from the 1992–94 trawl surveys.

	Survey		
Area	1992	1993	1994
Kaikoura	5 174	4 581	1 456
Clarence	7 072	1 966	2 685
Wairarapa	2 156	3 857	5 888
Madden	1 464	1 424	1 089
Portland	1 086	931	521
Ritchie	833	629	280
East Cape/Tolaga	420	884	1 235
Total	18 205	14 272	13 154
c.v. (%)	29	20	13
Date range	5 Mar–2 Apr	16 Mar–10 Apr	16 Mar–10 Apr

Table 5: The number of phase 1 stations used in each of the 1992–94 trawl surveys of the MEC that were repeated (i.e., used at least twice over the 3 surveys), and the number of phase 1 stations which were used only once.

	Survey		
	1992	1993	1994
Stations that have been used twice or more	123	158	147
Once-only stations	21	16	0

Table 6: The order of occupation of strata for the 1992–94 trawl surveys.

Phase 1 order	1992	1993	1994
1	Kaikoura	Kaikoura	Clarence
2	Clarence	Clarence	Kaikoura
3	Wairarapa	Tolaga/ East Cape	Tolaga/ East Cape
4	Madden	Ritchie	Ritchie/
5	Portland	Portland	Portland
6	Ritchie	Madden	Madden
7	Tolaga/ East Cape	Wairarapa	Wairarapa

Table 7: The number of repeated tows in the 1992–94 MEC trawl surveys as a result of using the "site" allocation (excluding the East Cape).

Survey	Number of repeated sites	Total tows in abundance estimation
1992	34	171
1993	45	201
1994	41	201

Table 8: Tows that were originally assigned to the wrong strata. These were tows completed before the commercial strata were defined.

Survey	Station number	Original stratum	New stratum
1992	93	16	2
1992	94	26	2
1992	95	36	2

Table 9: Stratum areas, depths, allocated phase 1 stations, and number of successful phase 1 and II stations from the 2010 MEC orange roughy trawl survey.

Area	Stratum	Depth (m)	Area (km^{-2})	Proposed phase 1 stations	Completed phase 1 stations	Completed phase 2 stations
Kaikoura	11	600–800	1 103	3	3	–
	21	800–1000	517	9	8	–
	31	1000–1200	441	4	4	1
	41	1200–1500	619	3	3	3
Clarence	12	600–800	552	3	3	–
	22	800–1000	685	5	5	–
	32	1000–1200	755	8	8	–
	42	1200–1500	696	3	3	–
Wairarapa	5	Hill	50	3	3	2
	13	600–800	640	4	4	–
	23	800–1000	550	7	7	13
	33	1000–1200	1 575	16	16	6
	43	1200–1500	1 388	5	5	–
Madden	14	600–800	366	3	3	–
	24	800–1000	432	5	5	–
	34	1000–1200	412	3	3	–
	44	1200–1500	974	5	5	–
Portland	15	600–800	392	3	3	–
	25	800–1000	499	3	3	–
	35	1000–1200	450	9	9	1
	45	1200–1500	695	4	4	–
Ritchie	1	Hill	28	3	3	–
	2	Hill	50	3	3	–
	3	Hill	100	3	3	–
	16	600–800	167	3	3	–
	26	800–1000	355	3	3	–
	36	1000–1200	357	3	3	–
	46	1200–1500	344	3	3	–
Tolaga	4	Hill	30	3	3	–
	17	600–800	481	3	2	–
	27	800–1000	448	3	3	3
	37	1000–1200	420	3	3	–
	47	1200–1500	807	3	3	–
	Total		17 378	144	142	29

Tab1e 10: The catch of the main species by weight from all trawl stations in the 2010 MEC trawl survey. Excludes rocks and broken shell rubble. * catch from all species caught.

Species	Species Code	Weight (kg)	Percentage of the catch
Alfonsino		53 125.8	49.7
Orange roughy		11 801.7	11.0
Shovelnose dogfish		7 889.2	7.4
Smallscaled brown slickhead		4 740.1	4.4
Smooth oreo		4 736.4	4.4
Hoki		3 592.9	3.4
White rattail		2 329.2	2.2
Spiky oreo		2 030.8	1.9
Johnson's cod		1 368.3	1.3
Javelinfish		1 352.5	1.3
Owston's dogfish		895.4	0.8
Ribaldo		785.2	0.7
Baxter's dogfish		759.7	0.7
Serrulate rattail		621.5	0.6
Bollon's rattail		610.7	0.6
Pale ghost shark		589.7	0.6
Largescaled brown slickhead		588.0	0.6
Basketwork eel		570.4	0.5
Widenose chimaera		564.5	0.5
Leafscale gulper shark		503.7	0.5
Total catch*		106 903.8	

Table 11: Summary of orange roughy biological samples from the 2010 MEC trawl survey.

	Pre-recruit	Recruit	Total
Standard length range (cm)	12.1 – 31.9	32.0 – 43.4	12.1 – 43.4
No. sampled for:			
Length	4 319	2 573	6 892
Sex and macroscopic maturity stage	4 243	2 526	6 769
Weight	3 148	1 953	5 101
Gonad weight	1 983	1 127	3 110
Otoliths	1 290	754	2 044
Stomachs	568	404	972
Gonad histology	539	331	870

Table 12: Estimated 1992–94 and 2010 orange roughy abundance (t) and c.v. (%), using the method all-relevant-tows. Significance tests; NS, not significant; p ≤ ** 0.01; p ≤ * 0.001.**

		Population		
Survey		All	Juvenile	Adult
1992	Biomass	20 128	13 139	6 989
	C.v.	30	33	28
1993	Biomass	13 730	9 084	4 646
	C.v.	20	26	15
1994	Biomass	12 093	7 241	4 852
	C.v.	13	14	16
2010	Biomass	6 838	3 265	3 573
	C.v.	17	19	22
Combined 1992-94	Biomass	15 317	9 821	5 496
	C.v.	15	17	13
t-test	Combined 1992–94 vs 2010	3.3 **	3.7 ***	1.8 ^{NS}

Table 13: Estimated 1992–94 and 2010 orange roughy abundance (t) and c.v. (%) using the first-at-site method. The estimate for 2010 used a 10% allocation of phase 2 tows. Significance tests; NS, not significant; p ≤ ** 0.01.

		Population		
Survey		All	Juvenile	Adult
1992	Biomass	20 838	13 252	7 586
	C.v.	29	32	29
1993	Biomass	15 102	10 311	4 791
	C.v.	28	34	18
1994	Biomass	12 780	7 538	5 242
	C.v.	15	15	20
2010	Biomass	7 074	3 370	3 703
	C.v.	19	21	25
Combined 1992-94	Biomass	16 240	10 367	5 873
	C.v.	16	18	15
t-test	Combined 1992–94 vs 2010	3.2 **	3.5 **	1.7 ^{NS}

Table 14: Trawl parameters from the MEC trawl surveys: number of measurements (N), mean, median, inter-quartile range, minimum, and maximum. Door spreads over 150 m were excluded.

Survey	N	Mean	Median	Inter-quartile range		Minimum	Maximum
Warp length (m)							
1992	187	2018.8	2000	1700	2350	1100	2850
1993	206	1948.7	1955	1690	2180	1150	2850
1994	208	1951.4	2000	1700	2190	150	2900
2010	171	1905.9	1900	1650	2130	1200	2800
Start depth – finish depth (gear)							
1992	189	-40.9	-25	-94	9	-367	193
1993	210	-45.9	-23	-92	20	-500	180
1994	209	-40.4	-16	-85	16	-446	321
2010	171	-44.9	-28	-90	12	-481	195
Door spread (m)							
1992	76	110	111	106	115	81	123
1993	4	109.5	108.35	104.2	110.5	104.2	117
1994	99	111.3	111.1	108.1	114.1	100.8	126.9
2010	81	104.2	105.2	99.5	108.4	85	120.3
Wingtip spread (m)							
1992	4	26.4	26.4	25	26.5	25	28
1993	19	24.4	24.7	23.5	25	21	27
1994	53	25.1	24.9	24.4	25.6	20.7	28.6
2010	36	25.4	25.4	24.8	25.9	23.9	26.4
Headline height (m)							
1992	188	7.1	7	6.2	7.9	5	12.6
1993	209	6.4	6.2	5.7	7	5	10
1994	209	6.6	6.6	6.1	7	4.6	9.1
2010	171	5.4	5.3	5	5.7	4.2	7.9
Trawling speed (knots)							
1992	189	3	3	2.9	3	2.4	4
1993	204	3.2	3.2	3	3.3	2.1	3.7
1994	201	3.4	3.4	3.3	3.5	2.7	4
2010	171	3	3	3	3	2.7	3.5

Table 15: Median trawl warp to depth ratio in 100 m bins (mean depth of tow) for the MEC trawl surveys. E.g. depth bin 800 means depths between 800 and 899 m.

										Depth bin
Survey	600	700	800	900	1000	1100	1200	1300	1400	1500
1992	2.1	2	2	1.9	1.9	1.9	1.9	1.8	1.9	1.8
1993	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	-
1994	2	2	1.9	2	1.9	1.9	1.9	1.9	1.9	-
2010	2.2	2	1.9	1.9	1.9	1.9	1.8	1.8	1.9	1.7

Table 16: The total abundance of bycatch species for the 1992–94 and 2010 surveys, with and without orange roughy included. The c.v. is derived from those for individual species abundances. Bycatch species used were: Basketwork eel, Baxters lantern dogfish, Bollons rattail, Catshark, *Centrophorus squamosus*, *Centroscymnus crepidater*, Deepsea cardinalfish, Four-rayed rattail, Hoki, Javelin fish, Johnson's cod, Long-nosed chimaera, Lucifer dogfish, *Nezumia namatahi*, Notable rattail, Pale ghost shark, Ribaldo, Ridge scaled rattail, Roughhead rattail, Serrulate rattail, Shovelnose spiny dogfish, Silver roughy, Slickhead bigscaled brown, Slickhead smallscaled brown, Small-headed cod, Smooth skin dogfish, Smooth oreo, Spiky oreo, *Trachyscorpia capensis*, Unicorn rattail, Warty oreo, White rattail, and Widenosed chimaera. Alfonsino was excluded, which had an abundance of 183 000 t in 2010.

Year	Total bycatch (`000 t)	C.v. (%)	Total with orange roughy (`000 (t)	C.v. (%)
1992	44	12	64	12
1993	52	9	66	8
1994	41	9	53	8
2010	51	11	58	10

Table 17: Expected bias and c.v. of abundance using varying amounts of phase 2 allocation of tows (5%, 10%, 15%, 20% and 25% of the number of phase 1 tows).

Phase 2 allocations (% of Phase 1 tows)	Expected c.v. (%)	Expected bias (%)
5	15.0	-5.8
10	14.0	-7.8
15	13.8	-8.8
20	13.0	-9.3
25	13.0	-9.8

Table 18: The number of tows, number of phase 2 tows, and ratio of phase 2 to phase 1 tows, for the MEC trawl surveys, using the first-at-site method, and for 2010 using 10% allocation of phase 2 tows.

Year	Number of tows	Number of phase 2 tows	Ratio of phase 2 / phase 1 tows (%)
1992	137	13	10.5
1993	156	7	4.7
1994	160	24	17.6
2010	156	14	10

Table 19: The number of tows, number of phase 2 tows, and ratio of phase 2 to phase 1 tows, for the MEC trawl surveys, using the all-relevant-tows method.

Year	Number of tows	Number of phase 2 tows	Ratio of phase 2 / phase 1 tows (%)
1992	171	36	27
1993	201	44	28
1994	201	43	27
2010	171	29	20

Table 20: The percentage change in total orange roughy abundance estimate after excluding flown tows.

Year	Abundance change
1992	+5%
1993	-1%
1994	-1%
2010	+1%

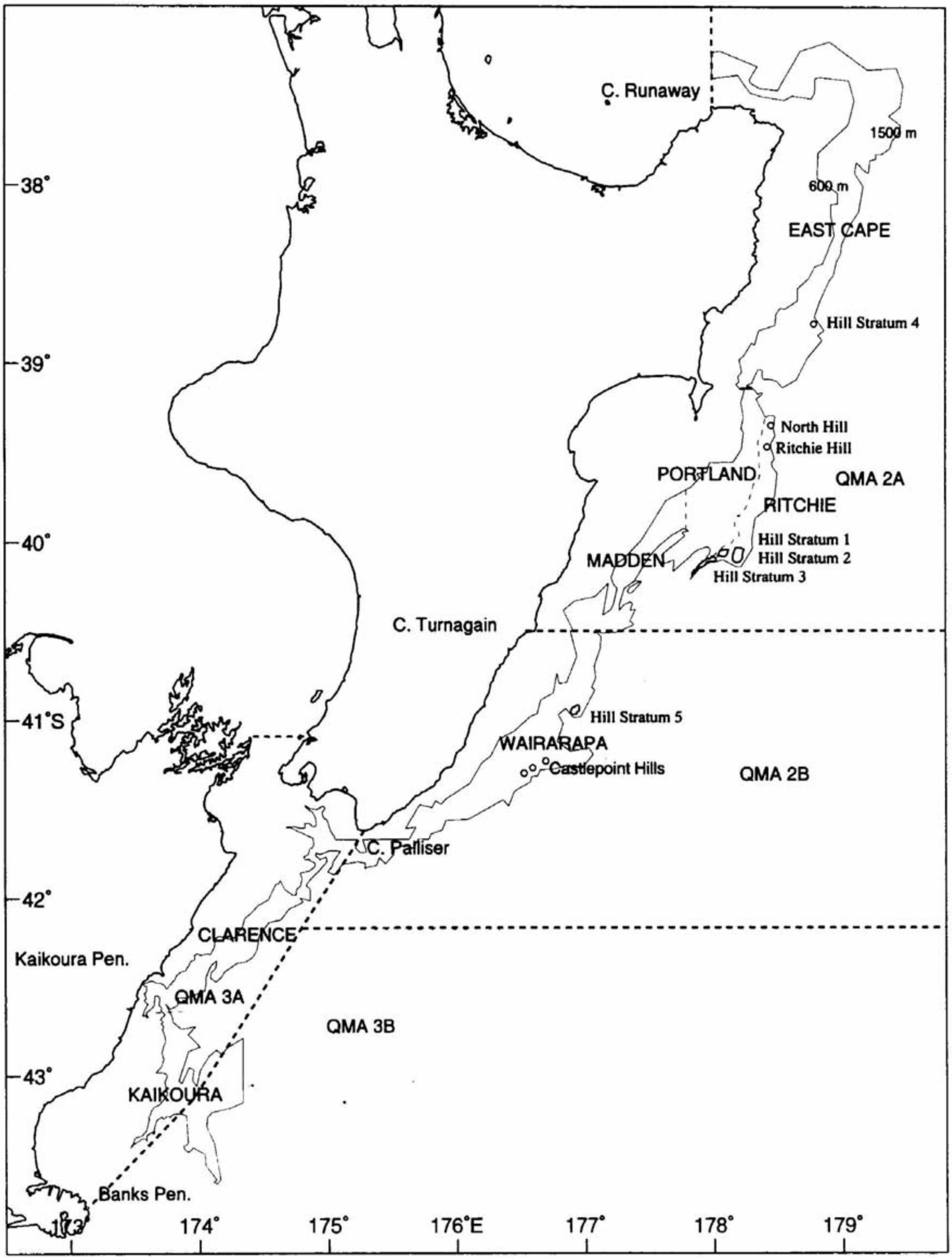


Figure 1: Survey area for the 1992–94 trawl surveys with the commercial ("Hill") strata used in 1993 & 1994 (Hill Stratum 1-3 were used in 1992). In 1993 & 1994, East Cape was a combined sub-area made up of East Cape in the north and Tolaga in the southern half of the sub-area shown in the plot. In 1992, there were two sub-areas, East Cape and Tolaga.

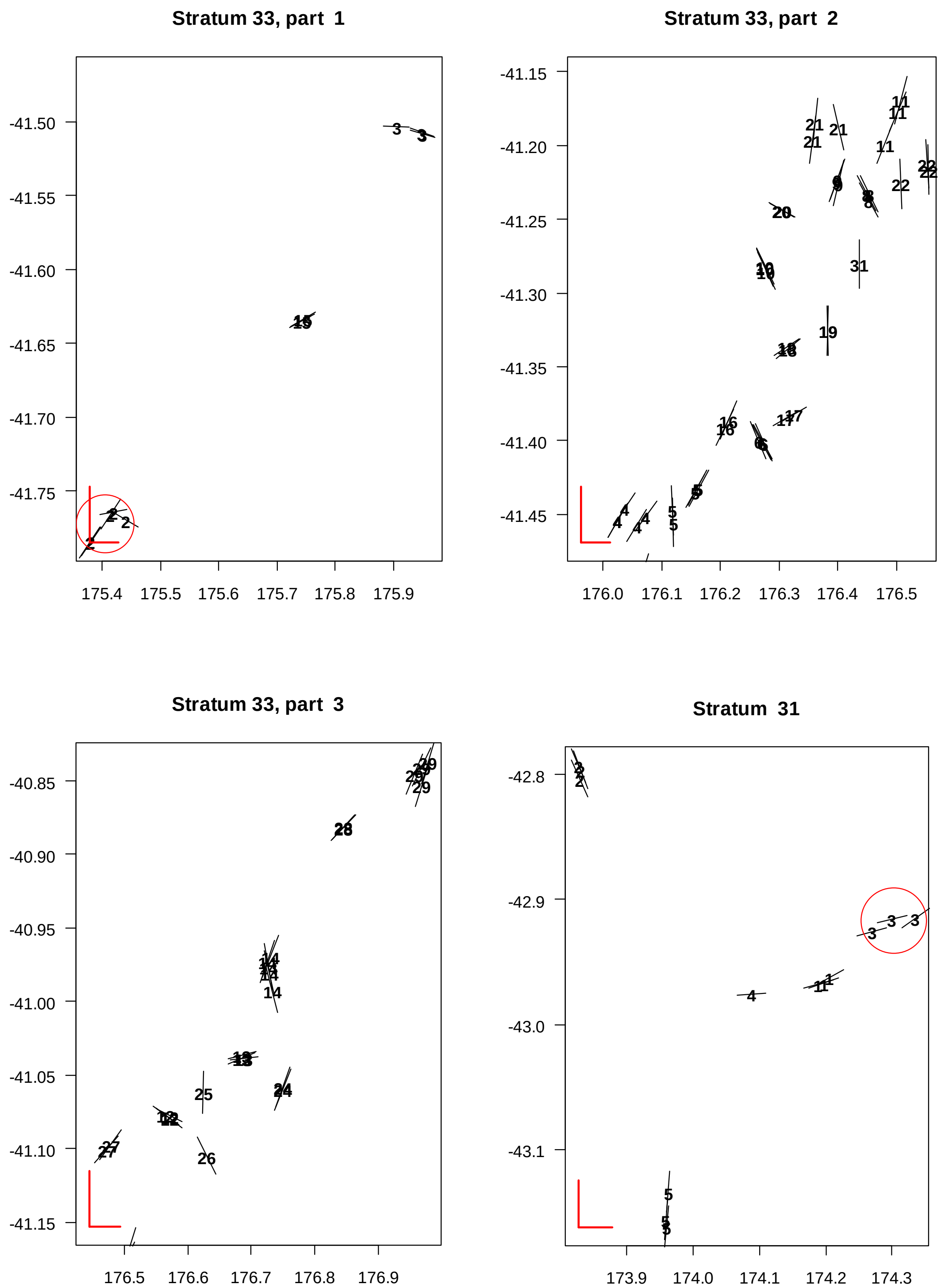


Figure 2: Tow positions showing clustering into sites. Examples plots are for strata 33 & 31. Red bars represents 2.25 nautical niles. Red circles on stratum 33 site 2 (top left) and stratum 31 site 3 (bottom right) are sites formed by merging 2 clusters by hand.

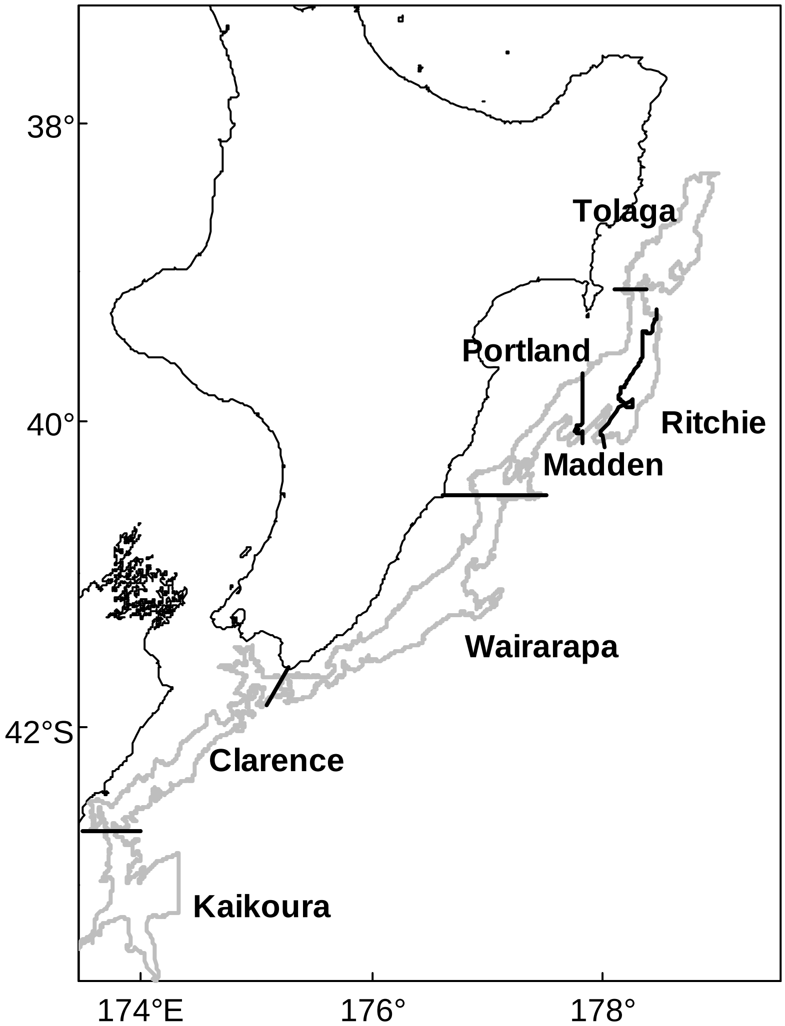


Figure 3: Survey sub-areas for the 2010 MEC trawl survey. Gray lines are the survey area and these are based on the 600 and 1500 m isobaths.

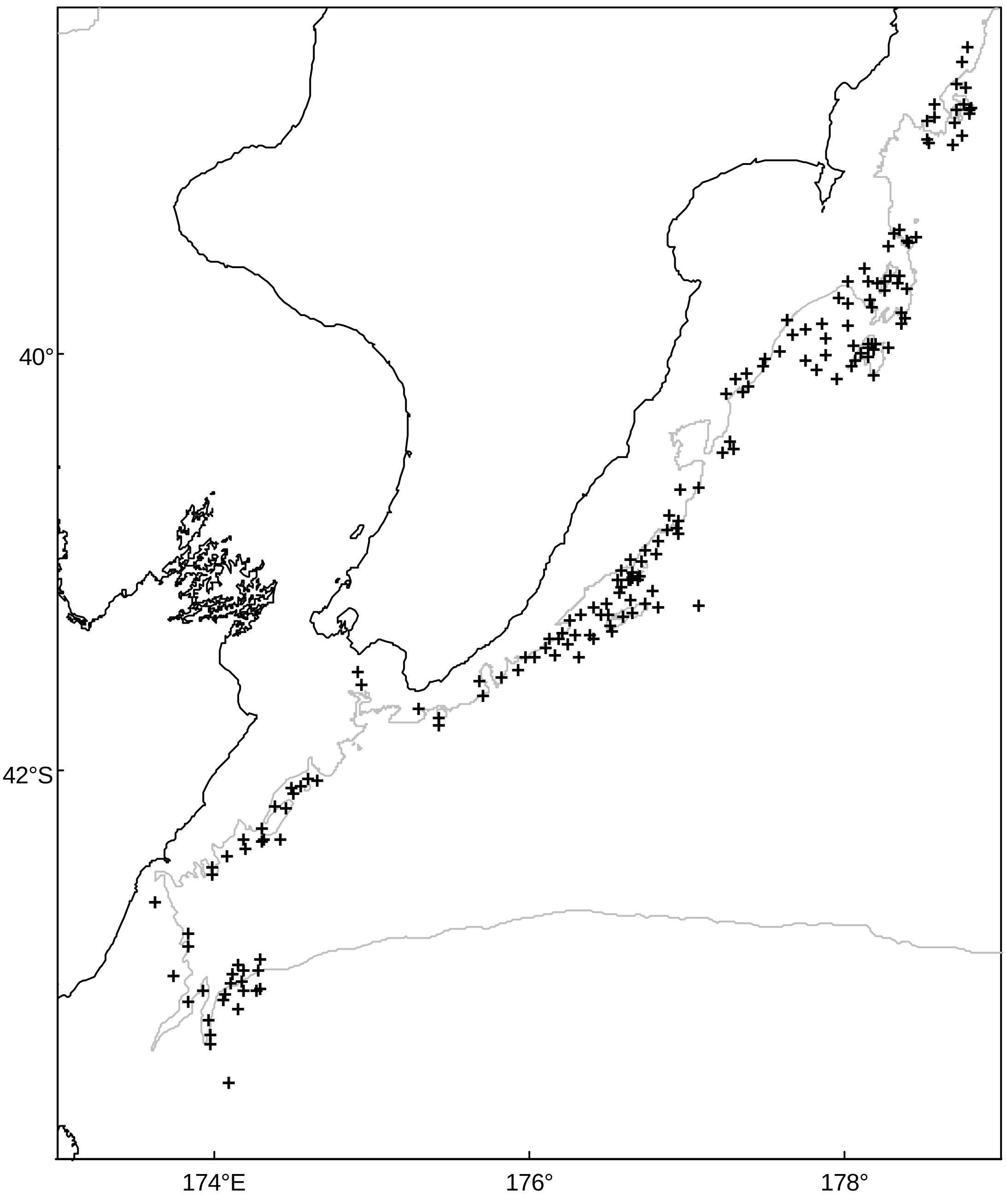


Figure 4: Location of valid biomass stations for the 2010 MEC orange roughy survey. Faded line is the 1000 m isobath.

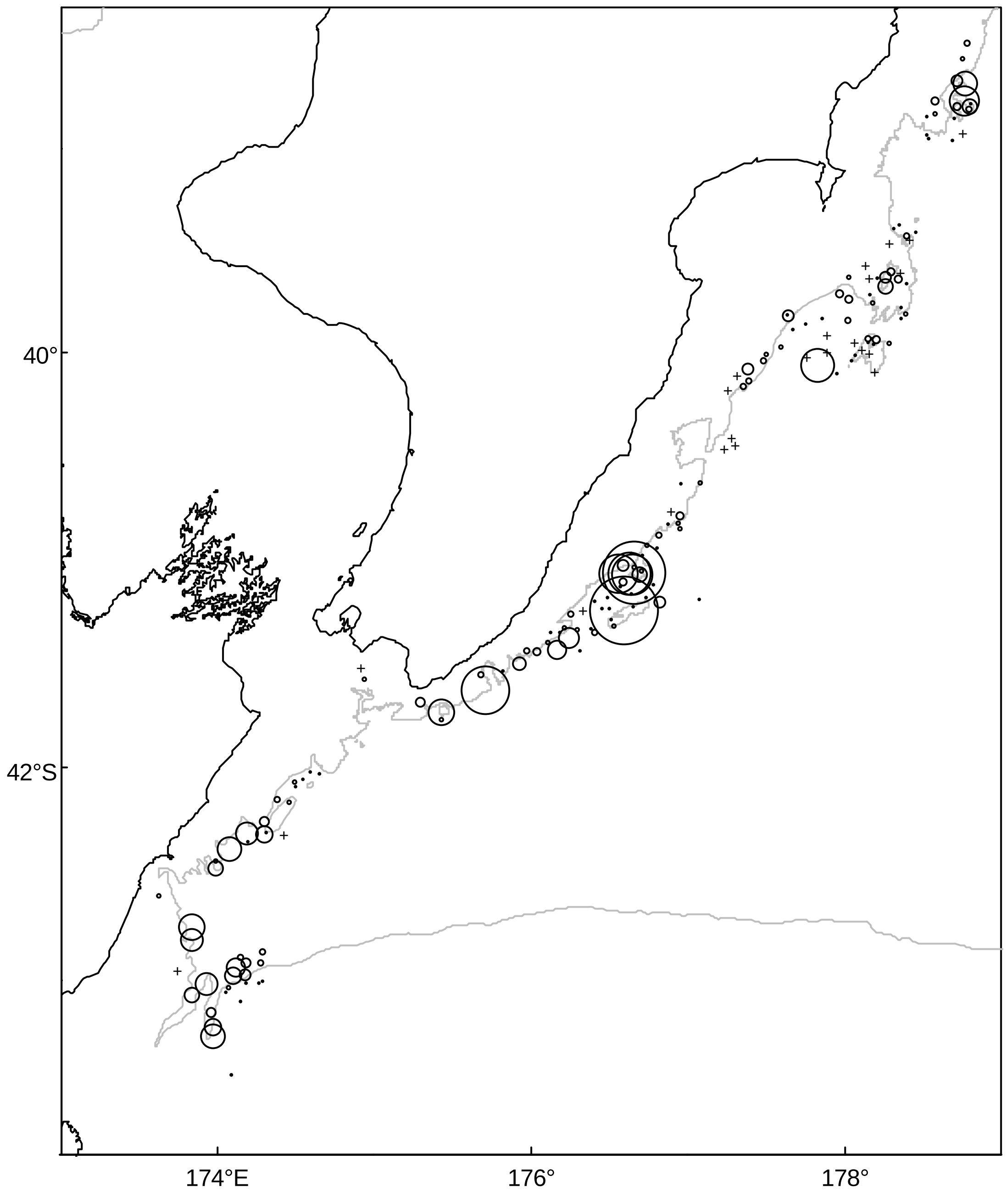


Figure 5: Total orange roughy catch rate (kg.km^{-1}) for valid biomass stations and the 2010 MEC trawl survey, plotted by tow start position. Circle area is proportional to catch rate; maximum 487 kg.km^{-1}. +, zero catch of orange roughy. Faded line is the 1000 m isobath.

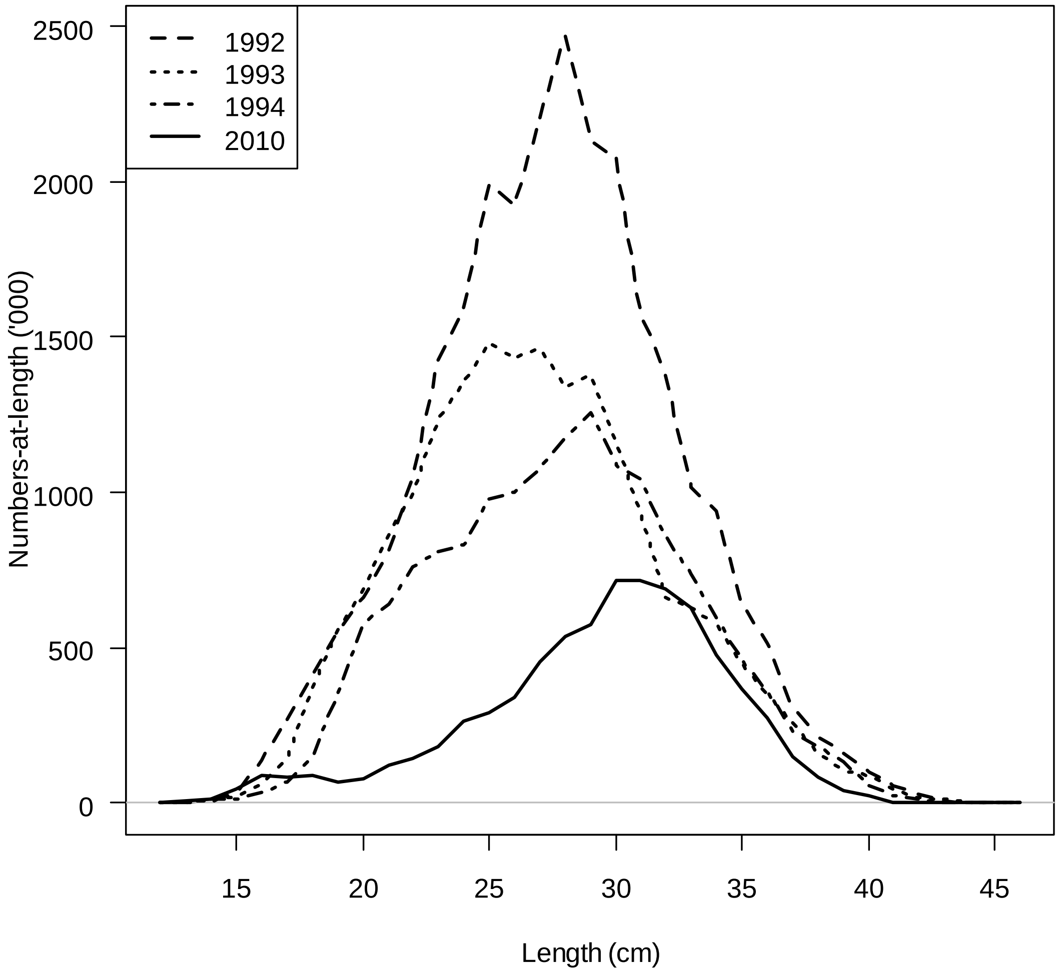


Figure 6: Estimated orange roughy numbers-at-length for the four MEC trawl surveys, 1992–94 and 2010, using the all-relevant-tows method.

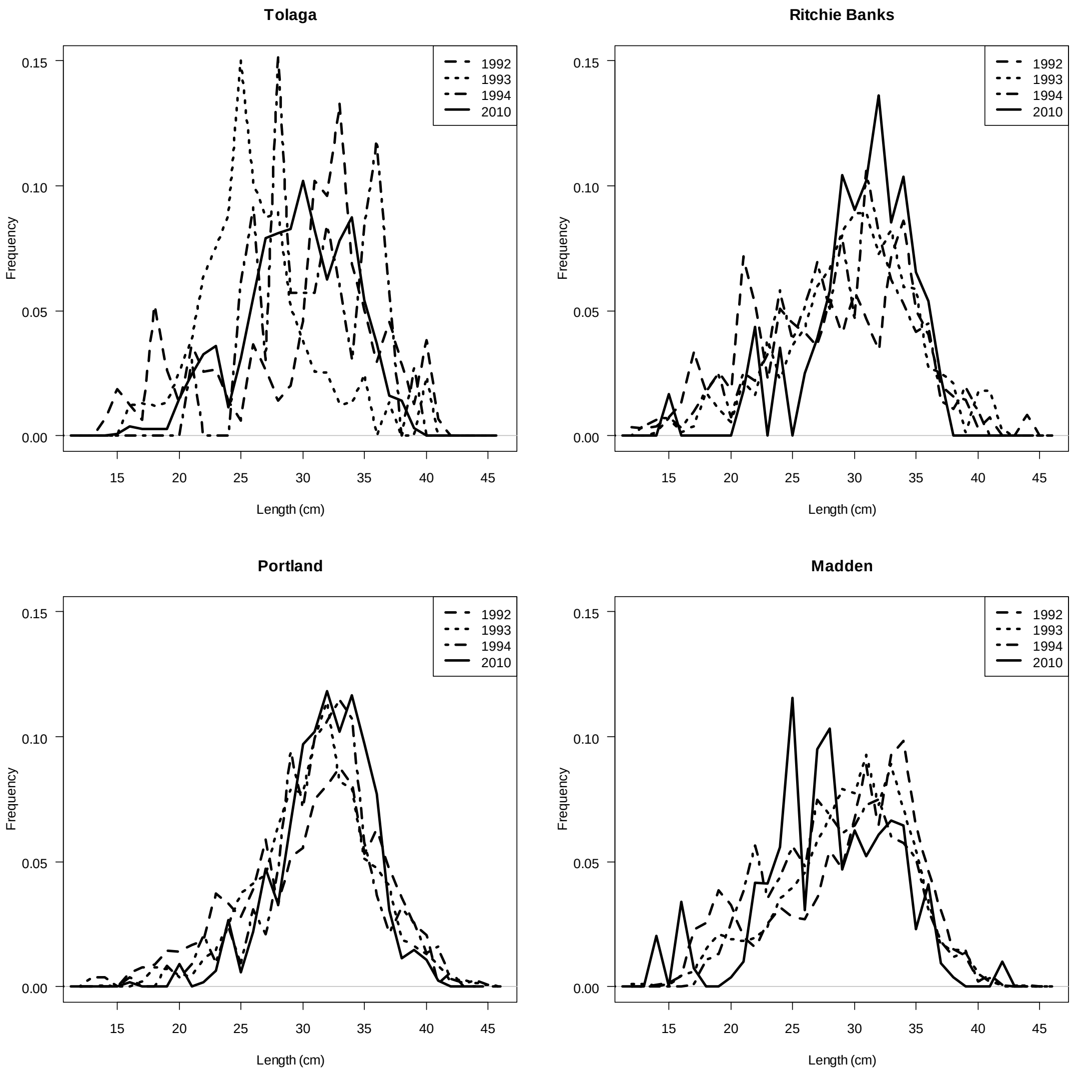


Figure 7: Orange roughy length frequency distributions for the four MEC trawl surveys by sub-area. Frequencies were constructed assuming a 1:1 sex ratio.

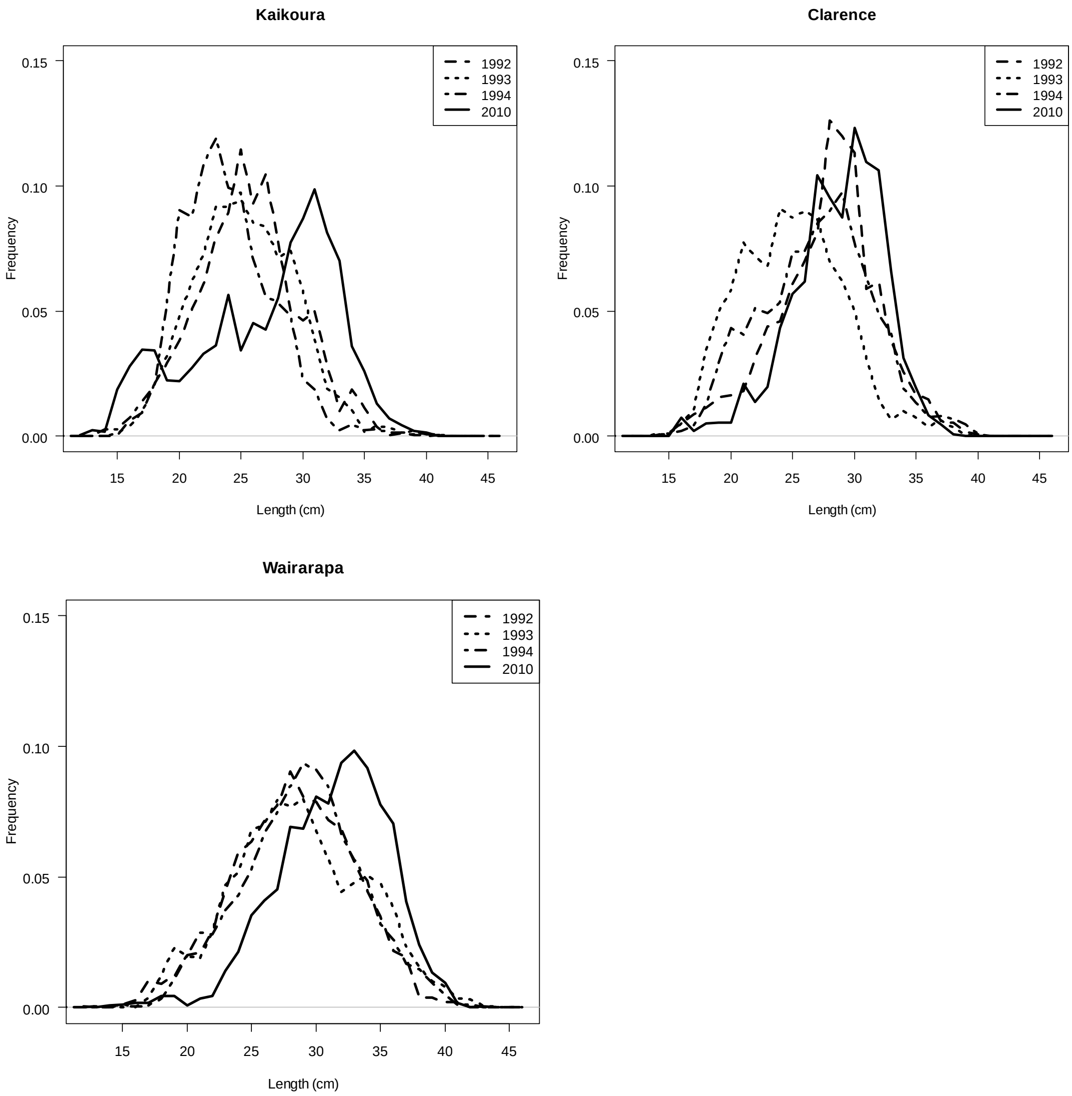


Figure 7 (cont.): Orange roughy length frequency distributions for the four MEC trawl surveys by sub-area. Frequencies were constructed assuming a 1:1 sex ratio.

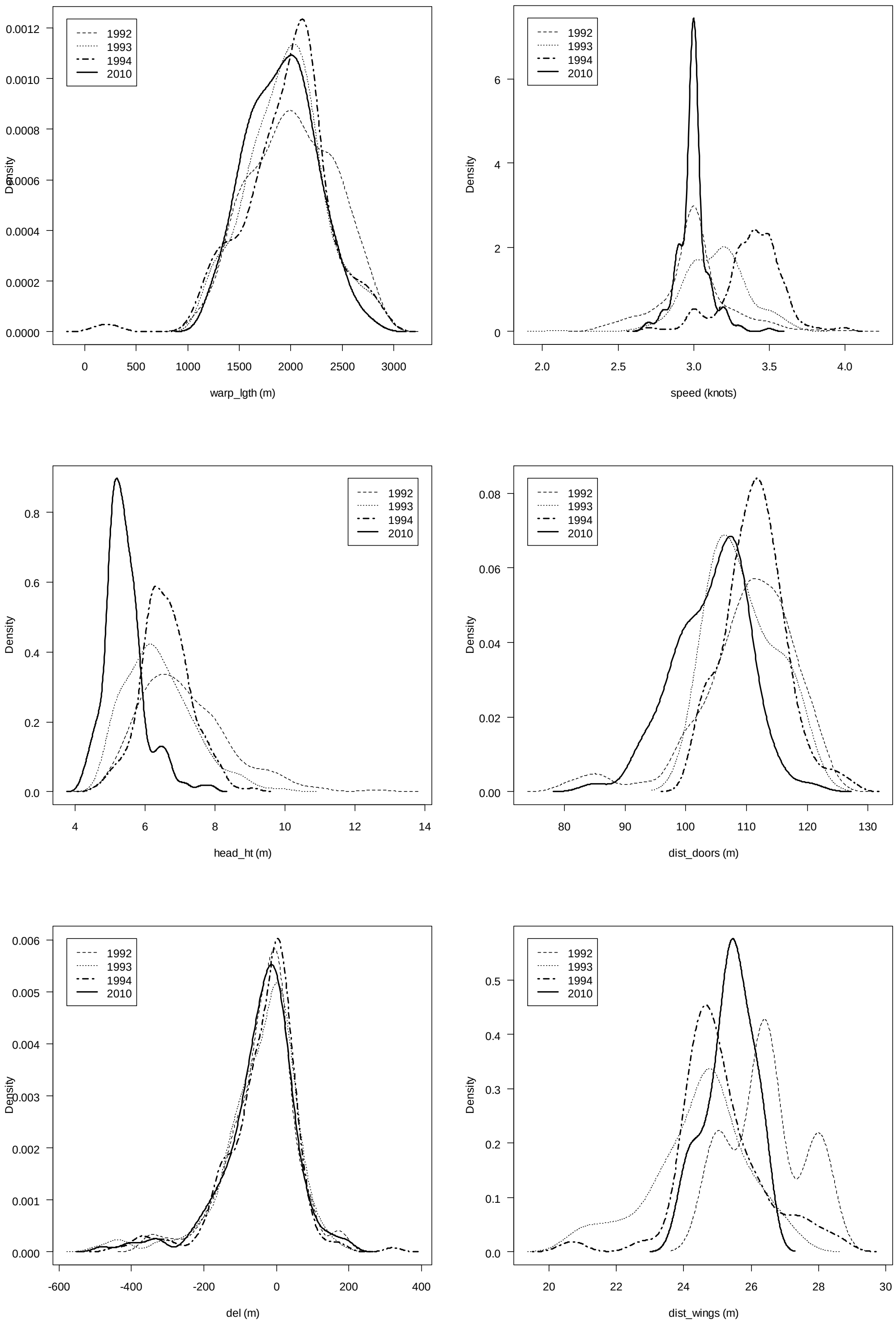


Figure 8: MEC trawl survey trawl parameter distributions. Door distances were trimmed at 150 m. Del = start – finish depth.

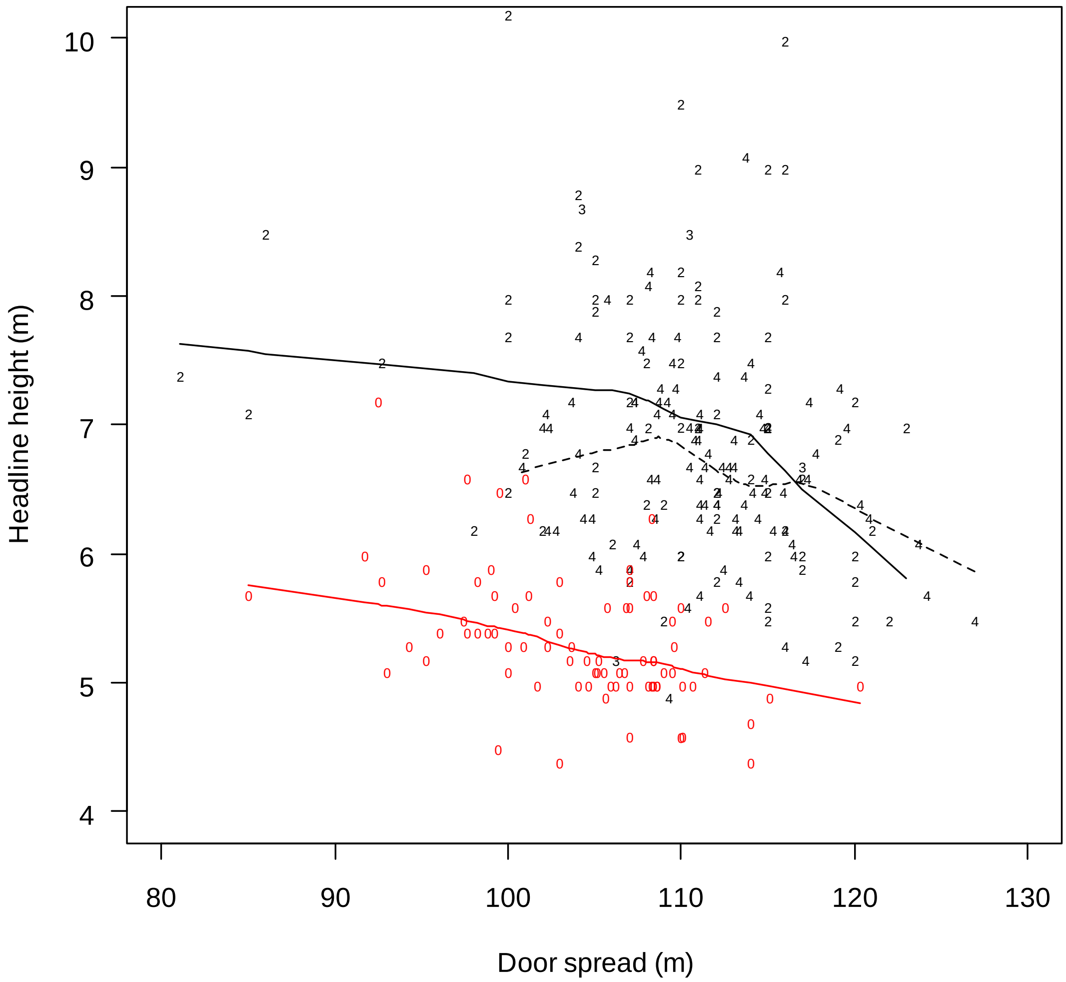
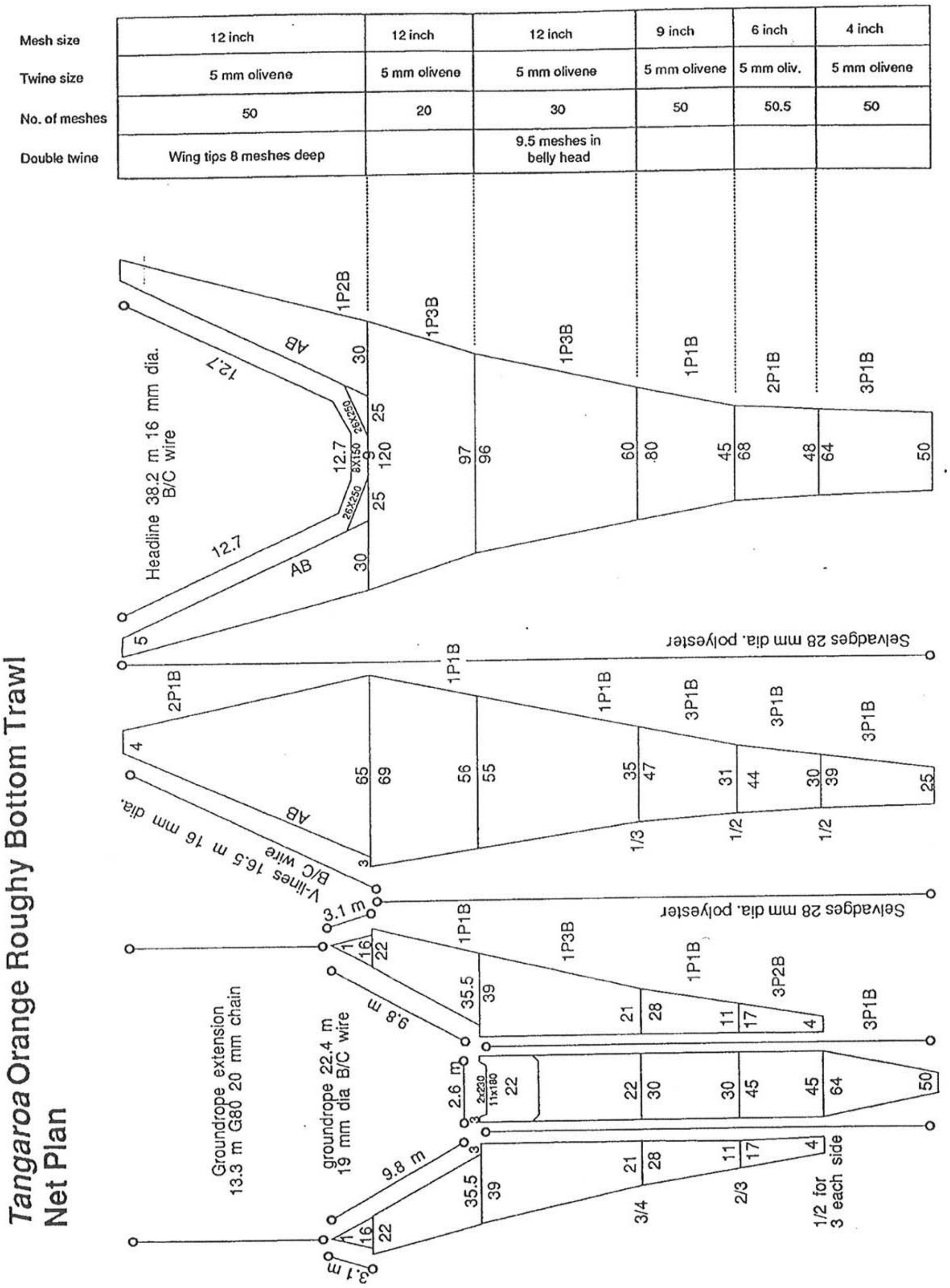
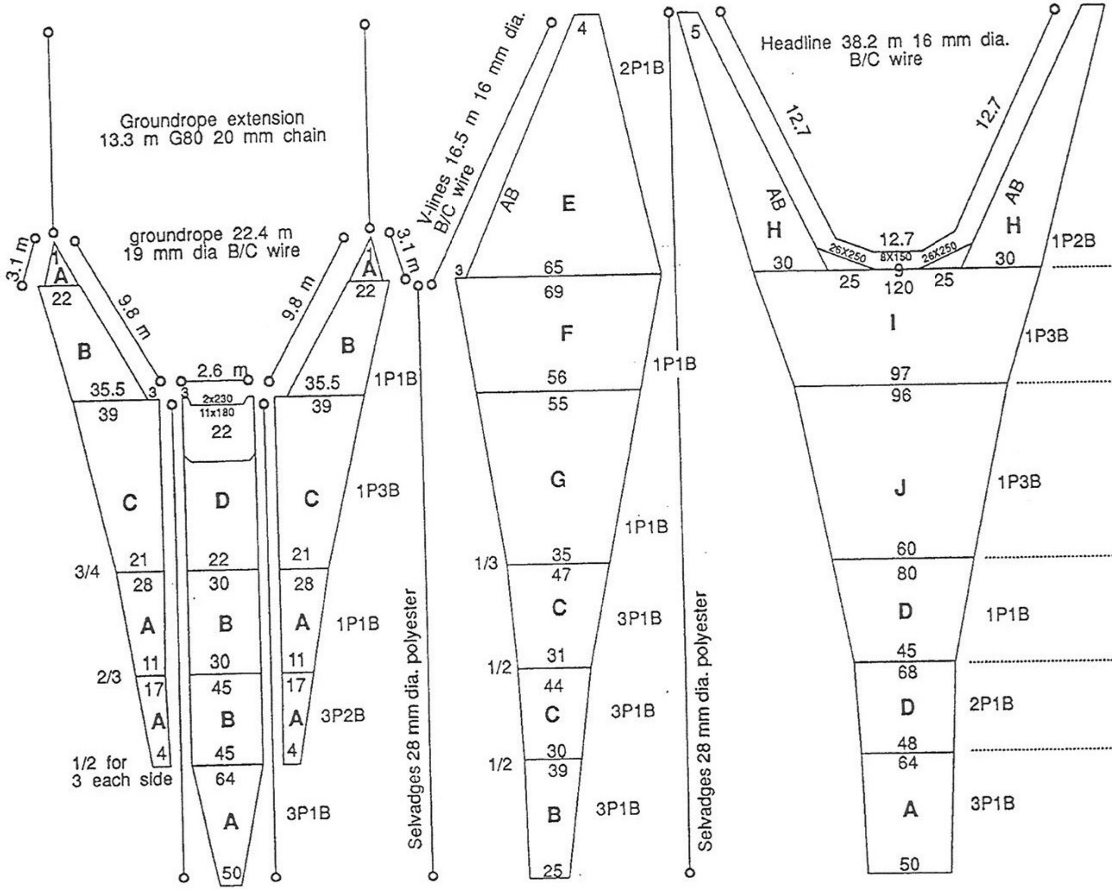


Figure 9: Headline height versus door spread for the MEC trawl surveys. Points labelled 2, 1992; 3, 1993; 4, 1994; 0, 2010. Lines show lowess smoothers through the data; dark solid line, 1992; dotted line, 1994; lower solid line, 2010.

Appendix 1: net plans

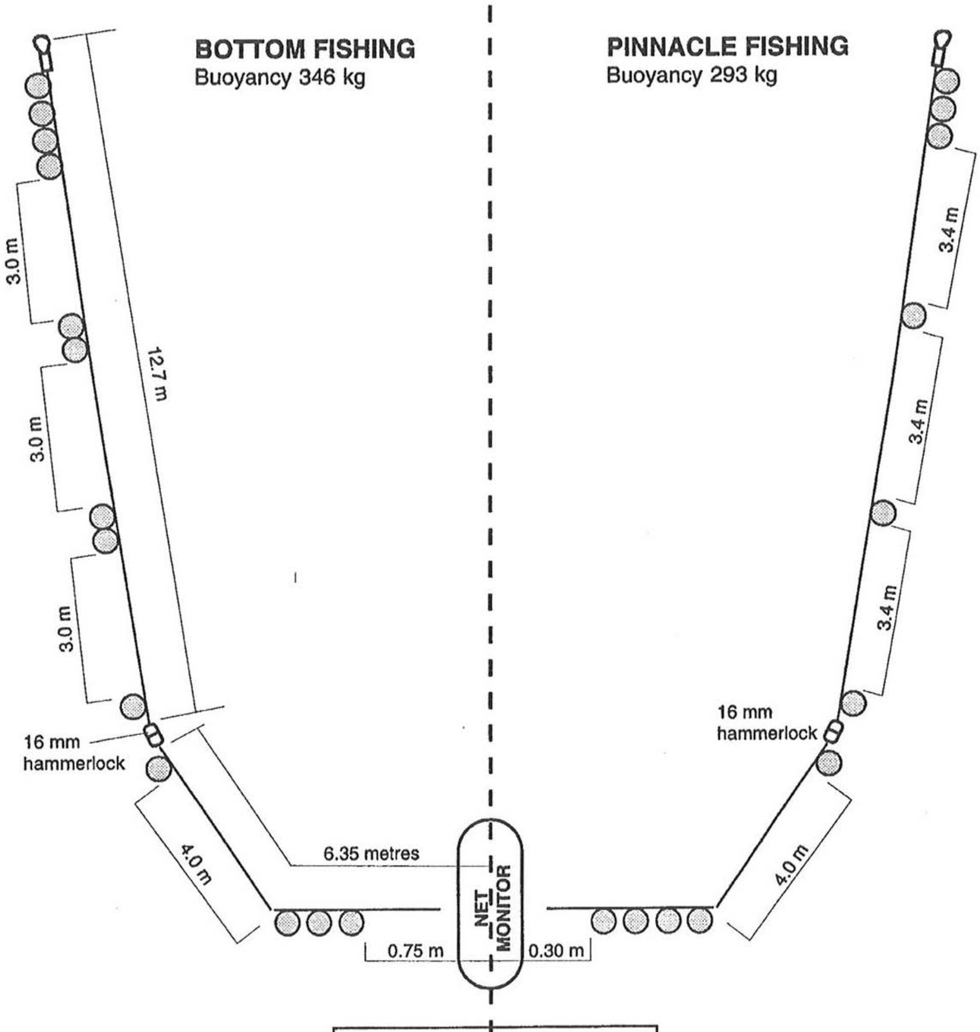


Tangaroa Orange Roughy Bottom Trawl
Panel Plan



Mesh size	12 inch	12 inch	12 inch	9 inch	6 inch	4 inch
Twine size	5 mm olivene	5 mm olivene	5 mm olivene	5 mm olivene	5 mm oliv.	5 mm olivene
No. of meshes	50	20	30	50	50.5	50
Double twine	Wing tips 8 meshes deep		9.5 meshes in belly head			

ORANGE ROUGHY BOTTOM TRAWL FLOAT PLAN



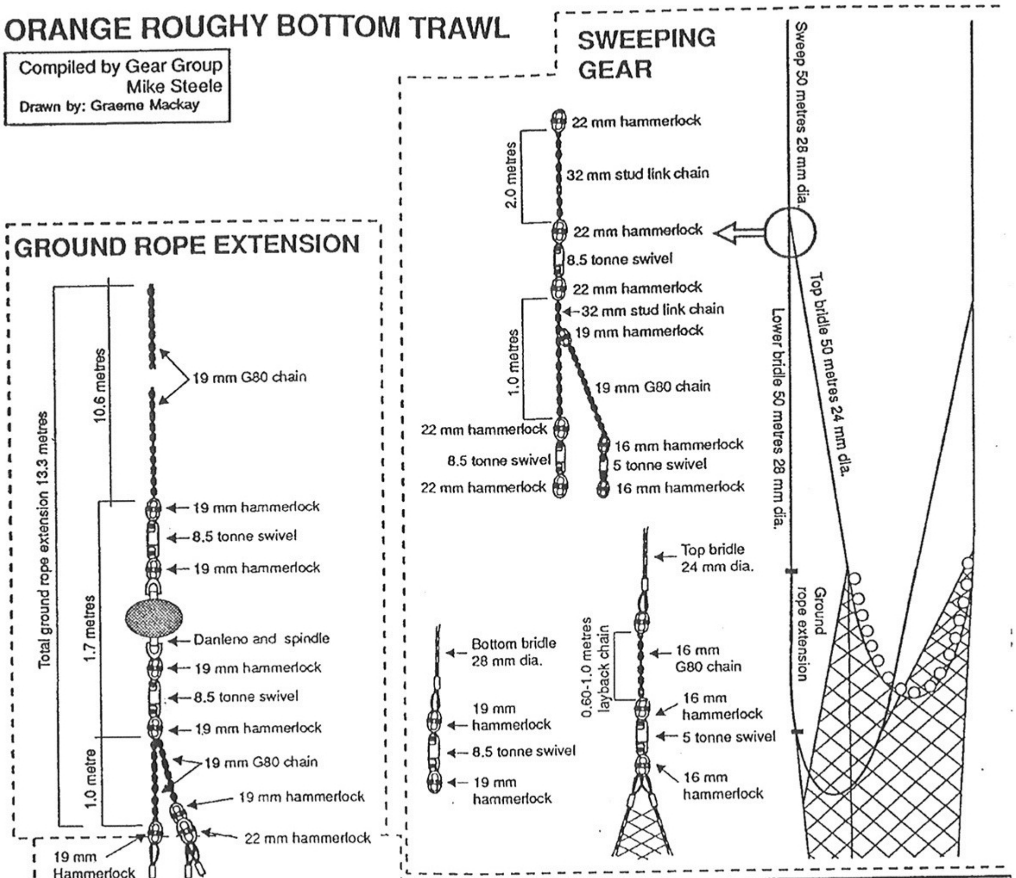
HEADLINE COMPONENTS
3 - 12.7 m lengths 16mm dia. 6x24 braid covered wire
2 - 16 mm hammerlocks

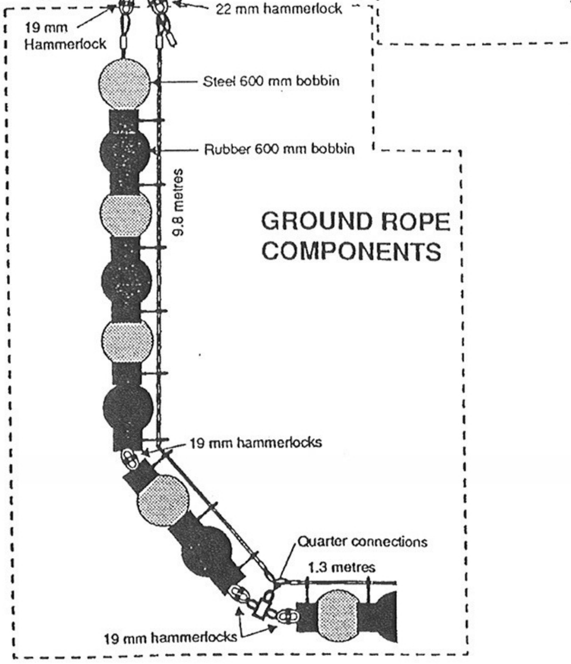
26 - Nichimo UBE floats CT-3615 360 mm 13.3 kg buoyancy	22 - Nichimo UBE floats CT-3615 360 mm 13.3 kg buoyancy

GEAR GROUP
Mike Steele
Drawn: Graeme Mackay

ORANGE ROUGHY BOTTOM TRAWL

Compiled by Gear Group
Mike Steele
Drawn by: Graeme Mackay

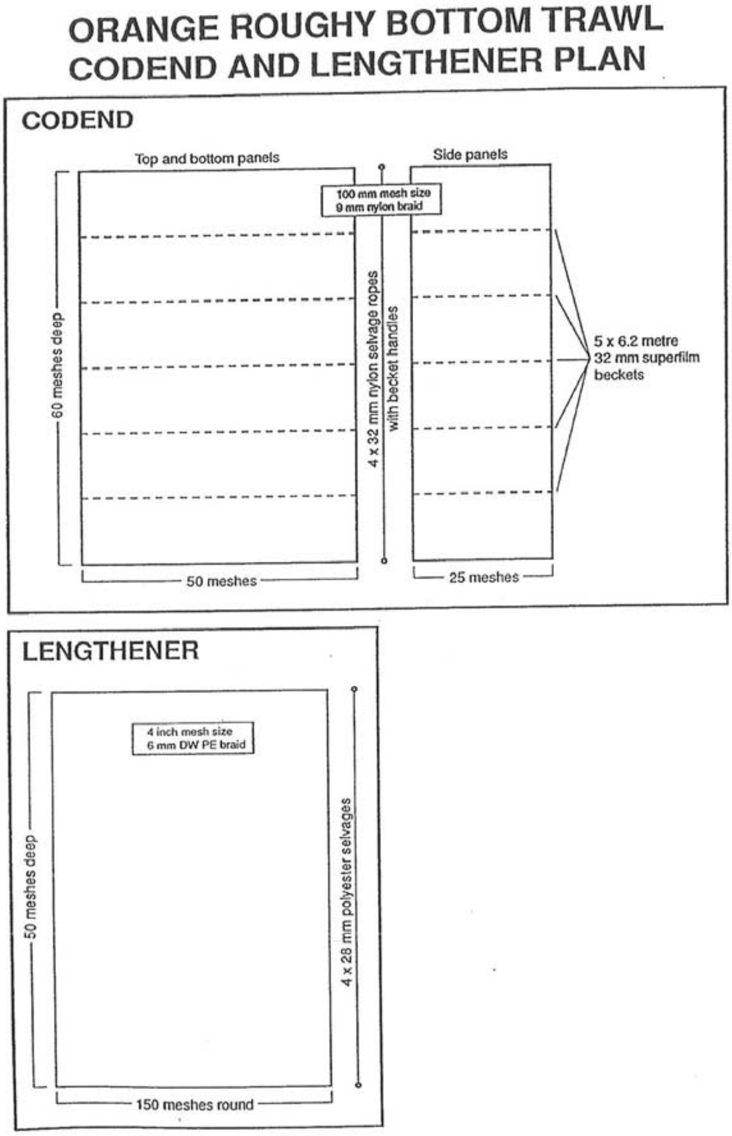




GROUND ROPE COMPONENTS
10 - 600 mm STEEL BOBBINS
9 - 600 mm RUBBER BOBBINS
22 - LANCASTERS
- RUBBER SPACERS
2 - QUARTER CONECTIONS
6 - 19 mm HAMMERLOCKS
1 - 22 METRE LENGTH OF 16 mm G80 CHAIN
1 - 3 SECTION FISHING LINE 18 mm 6x19

GROUND ROPE EXTENSION
4 - 1 METRE LENGTHS G80 19 mm CHAIN
4 - 8.5 TONNE SWIVELS
12 - 19 mm HAMMERLOCKS
2 - 22 mm HAMMERLOCKS
2 - DANLENO AND SPINDLE
2 - 10.6 METRE LENGTHS 19 mm G80 CHAIN

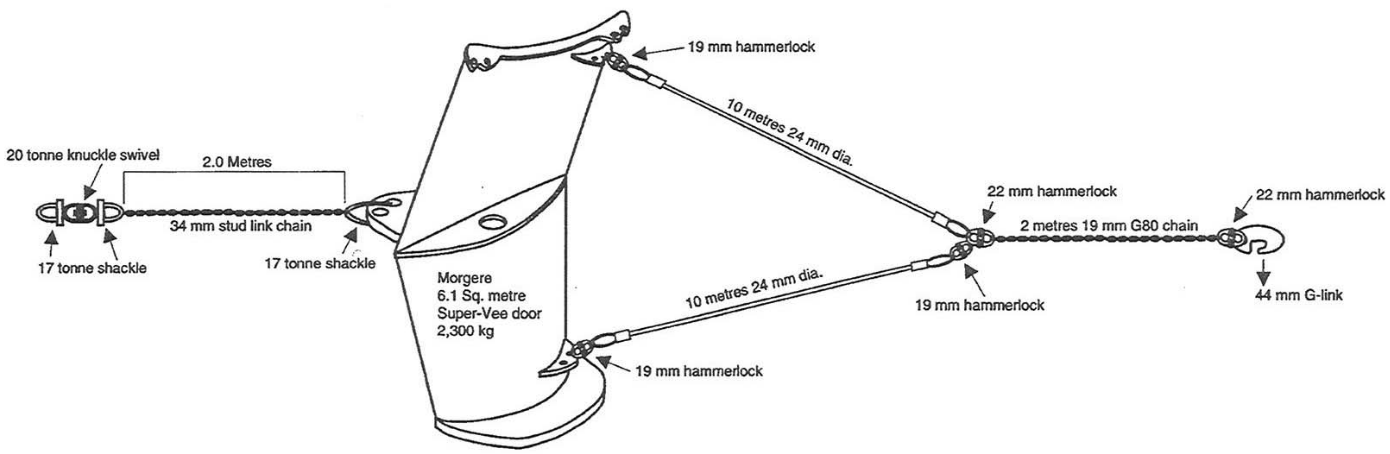
SWEEPING GEAR
2 - 50 METRE 24 mm 6x19 PPC WIRE ROPE
4 - 50 METRE 28 mm 6x19 PPC WIRE ROPE
6 - 19 mm HAMMERLOCKS
4 - 5 TONNE SWIVELS
6 - 8.5 TONNE SWIVELS
2 - 3 METRE LENGTH 32 mm STUD LINK CHAIN
2 - 1 METRE 19 mm G80 CHAIN
10 - 16 mm HAMMERLOCKS
10 - 22 mm HAMMERLOCKS
2 - 0.60-1.0 METER 16 mm G80 CHAIN LONG LINK


ORANGE ROUGHY BOTTOM TRAWL
CODEND AND LENGTHENER PLAN
CODEND
Top and bottom panels
Side panels
100 mm mesh size
9 mm nylon braid
60 meshes deep
4 x 32 mm nylon selvage ropes
with becket handles
5 x 6.2 metre
32 mm superfilm
beckets
50 meshes
25 meshes
LENGTHENER
4 inch mesh size
6 mm DW PE braid
50 meshes deep
4 x 28 mm polyester selvages
150 meshes round

ORANGE ROUGHY BOTTOM TRAWL DOOR RIG

Compiled by Gear Group
Mike Steele
Drawn by Graeme Mackay

DOOR RIG COMPONENTS
1 – PAIR 6.1 SQ. METRE MORGERE SUPER-VEE DOORS 2,300 kg
4 – 10 METRE LENGTHS 24 mm 6x24 PPC WIRE ROPE
6 – 19 mm HAMMERLOCKS
4 – 22mm HAMMERLOCKS
2 – 2 METRE LENGTHS 19mm G80 CHAIN
2 – 2 METRE LENGTHS 34mm STUD LINK CHAIN
6 – 17 TONNE RATED D-SHACKLES
1 – 20 TONNE RATED KNUCKLE SWIVEL
2 – 44 mm G-LINKS



The *RV Tangaroa* trawl doors:

- Size 6.1 square meters
- Manufactured by Kernohan Engineering Nelson
- Weight 2.3 t in air
- Last major overhaul around 2005

Warps:

- 28 mm, 6x19 construction, steel core galvanised wire rope.
- Brand ex Cookes (manufactured in Auckland)
- Diameter 28 mm
- Top 2000 m about 3 years old, bottom 2000 m about 18 months old
- Left hand and right hand lay.

Winches:

- Main trawl winches are Hydraulic Brattvagg self tensioning
- Control unit Hydraulic Brattvagg 1991 to ~June 2008. Scantrol ~June 2008 to present
- Date of last major winch overhaul 2002.
- Date of last control system check 23 November 2009
- Winch settings available on request (contact N. Bagley, NIWA)

Sweeps:

- 6 x19 galvanised wire rope
- Diameter 28 mm
- Length 50 m
- RH lay

Bottom Bridle:

- 6 x19 galvanised wire rope
- Diameter 28 mm
- Length 50 m
- RH lay

Top Bridle:

- 6 x19 galvanised wire rope
- Diameter 24 mm
- Length 50 m
- RH lay

Net Electronics:

- Net monitor: Original Kajo Denki KCN 300 replaced with CN22 in mid 1990's. New CN22 net monitor headline unit (January 2010).
- SCANMAR doorspread and wingspread sensors. Various ages i.e. replaced as required.

Appendix 2: Sites and their associated tows

Table 2.1: Sites and their associated tows. Site code is ssll, where ss is the stratum number and ll is a letter code, A, B, …, e.g., "11B" is in stratum 11 and it is the B(second) site. Tow code is yy-ss, where yy is year and ss is station number in that year, e.g., "93-178" is station 178 in the 1993 survey. There are 115 sites that are common to all years (and by design to 2010, but in practice there were 114 since one common Phase 1 tows could not be done).

Site common to all 3 years (=1)	Site	Assigned tows					
1	1A	93-96	92-177	94-95	92-179		
1	1B	93-98	92-180	94-96			
1	1C	94-84	92-181	93-97	92-178		
1	2A	93-101	92-184	94-88			
1	2D	92-183	94-87	93-100			
1	2E	93-105	94-90	92-186			
	3A	94-85	93-220				
1	3B	94-82	92-188	92-189	93-92	92-187	
	3D	93-93					
	4A	93-66	94-56	93-63	93-65	94-58	94-57
	4B	93-67	94-59				
	4C	94-60	93-64				
	5B	94-206	94-140	94-143	93-195	93-198	
	5C	93-199	94-144	93-196	94-202	94-141	
	5D	94-142	93-197				
1	11A	93-17	92-16	94-29			
1	11B	93-5	94-37	92-3			
1	11C	93-12	94-38	92-14			
1	12A	94-25	92-20	94-46	93-21		
1	12B	92-23	94-22	93-23			
1	12C	93-47	94-1	92-37			
1	13A	92-66	94-135	93-140			
1	13B	93-159	94-158	92-54			
1	13C	93-145	92-59	94-138			
1	13D	92-64	93-142	94-136	94-210	94-211	
1	14A	94-115	93-124	92-77			
1	14B	93-136	92-69	94-127			
1	14C	94-126	92-70	93-135			
1	15A	92-82	94-74	93-79			
1	15B	92-83	93-77	94-73			
1	15C	92-107	93-80	94-65			
1	16A	92-105	93-84	94-75	93-85	94-76	92-103
	16B	94-94	92-93				
1	16C	93-86	94-104	92-102			
	17A	92-115					
Not done in 2010	17B	92-120					
1	17D	94-62	92-116	93-69			

Site common to all 3 years (=1)	Site	Assigned tows						
1	21A	92-1	94-35	93-8				
1	21B	92-15	94-30	93-16				
1, not done in 2010	21C	92-17	93-18	94-28	93-177			
1	21D	93-7	92-2	93-174	94-36			
1	21E	94-43	92-4	93-175	93-3			
1	21F	93-4	94-42	92-10				
1	21G	92-12	93-13	94-39				
1	21H	94-40	93-176	93-14	92-13			
	21I	93-2	93-6	94-45	94-44			
1	22A	93-33	94-14	92-28	93-32	92-27	94-13	
1	22B	92-22	94-23	93-22				
1	22C	93-35	94-11	92-31				
1	22D	93-46	94-2	92-36				
	22E	94-17	93-29					
1	23A	93-169	94-166	92-39				
1	23B	92-40	93-168	94-165				
1	23C	93-161	92-46	94-159				
1	23D	94-151	93-153	92-47				
1	23E	92-55	93-160	94-156				
1	23F	93-141	92-65	94-131				
	23G	94-152	93-154	94-199				
1	24A	93-212	93-130	94-122	93-211	94-121	92-72	93-131
1	24B	93-205	92-71	93-208	94-125	93-207	93-134	
1	24C	94-118	93-127	93-215	93-217	93-216	92-73	
	24D	93-213	93-128	94-119	93-129	94-120	93-214	
	24E	93-209	93-133	93-210	94-124	94-123	93-132	
1	25A	92-89	93-76	94-101	92-88	93-114	94-102	
1	25B	92-84	93-78	94-72				
1	25C	94-103	92-86	93-118				
1	26B	94-78	93-87	94-77	92-99	93-88	92-100	
1	26D	92-104	93-83	94-69				
1	26F	94-68	92-108	93-74				
1	27B	94-55	92-124	93-62				
	27C	92-126						
	27E	92-121						
1	31A	93-1	94-33	92-5				
1	31B	93-19	94-27	92-18				
1	31C	93-9	92-6	94-32				
1	31E	93-15	92-11	94-41				
1	32A	93-26	93-27	94-19	92-26	94-20		
	32B	93-43	94-3					
1	32C	93-30	94-16	92-29	93-28	94-15		
1	32D	94-12	93-34	92-32	94-175			
1	32F	94-6	93-39	94-169	92-34	93-40	94-7	

Site common to all 3 years (=1)	Site	Assigned tows					
1	32G	93-41	92-35	94-4	93-42	94-171	94-5
	32H	94-8	93-37	94-9	94-176		
	32I	94-10	93-38				
1	33A	94-150	93-151	92-48			
1	33B	94-178	93-178	93-170	94-167	92-38	
1	33C	92-41	93-167	94-164			
1	33D	92-42	93-165	93-180	94-162	94-182	
1	33E	92-43	94-187	93-164	94-161	93-182	
1	33F	92-45	93-163	93-166	94-163		
1	33G	92-51	94-147	93-152			
1	33H	93-155	92-52	94-154			
1	33I	92-53	93-157	94-155			
1	33J	93-158	94-157	92-56			
1	33K	93-156	92-57	94-153			
1	33L	94-145	93-147	92-60			
1	33M	93-146	92-61	94-139			
1	33N	94-208	94-137	93-201	93-144	92-62	
	33AB	93-202	94-133				
	33AC	94-209	93-204	94-132	93-203		
1	34A	92-74	93-126	94-117			
1	34B	93-125	92-75	94-116			
1	34C	94-114	93-123	92-76			
1	35A	94-93	93-107	92-81			
1	35B	93-117	94-105	92-85			
1	35C	92-90	94-92	93-106	92-156	94-91	93-102
1	35E	94-99	93-218	92-162	92-87	93-113	93-219
1	35F	92-151	93-81	94-70			
1	35G	93-82	94-71	92-152			
1	35H	92-153	94-106	93-116			
1	35I	94-98	92-161	92-157	94-107	93-111	93-112
1	35J	93-115	94-100	92-163			
1	36C	94-79	93-89	92-98			
1	36D	92-109	94-67	93-72			
	36E	93-91	94-83				
1	37A	94-63	93-70	92-112			
	37C	92-117					
	37D	92-125					
1	41A	93-11	92-8	94-34			
1	41B	92-19	94-26	93-20			
1	41E	94-31	93-10	92-7			
1	42A	93-25	94-21	92-25			
1	42B	92-24	94-24	93-24			
1	42C	94-18	93-31	92-30			
1	43A	92-49	94-149	93-150			
1	43B	92-63	94-134	93-143			
1	43C	92-44	93-162	94-160			

Site common to all 3 years (=1)	Site	Assigned tows					
1	43D	93-149	92-50	94-148			
1	43E	94-146	92-58	93-148			
	44A	93-137	94-128				
1	44B	92-67	94-130	93-139			
1	44C	93-138	94-129	92-68			
1	44D	93-121	94-112	92-78	94-113	93-122	
1	44E	94-110	93-120	93-119	94-109	92-79	
1	45A	92-92	92-155	93-110	94-97	92-158	
1	45B	92-146	94-64	93-71	92-144		
1	45D	92-171	93-109	92-169	92-175	94-111	92-165
1	45F	92-168	92-80	93-108	94-108		
1	46A	92-96	94-81	93-94			
1	46B	93-90	94-80	92-97			
1	46C	93-73	92-110	94-66			
1	47A	92-118	93-68	94-61			
	47C	92-111					
	47D	92-119					
115							

Appendix 3: Station details and catch of orange roughy.

Table 3.1: MEC trawl survey 2010 station details and orange roughy catch. * indicates station considered unsuitable for biomass estimation.

Station number	Stratum	Date (start)	Time (start)	Depth (start) (m)	Start latitude (S)	Start longitude (E)	Distance (NM)	Orange roughy (kg)
1	13	19-Mar-10	1234	621	40 45.82	176 53.11	2.02	0
2	13	19-Mar-10	1427	669	40 38.61	176 57.41	2.02	3
3	14	19-Mar-10	2317	653	40 10.61	177 14.76	2.02	0
4	24	20-Mar-10	0155	993	40 10.06	177 21.24	2.20	25
5	24	20-Mar-10	0426	934	40 08.76	177 23.49	2.17	23
6	14	20-Mar-10	0618	670	40 06.62	177 18.72	2.02	0
7	24	20-Mar-10	0816	813	40 04.91	177 22.84	1.95	52
8	24	20-Mar-10	1007	864	40 02.76	177 28.91	1.97	23
9	24	20-Mar-10	1211	862	40 00.45	177 30.12	2.00	10
*10	14	20-Mar-10	1627	775	39 49.33	177 38.31	1.03	14
11	34	20-Mar-10	2002	757	39 49.18	177 38.59	1.84	4
12	25	20-Mar-10	2319	862	39 37.97	178 01.28	2.01	12
*13	15	21-Mar-10	0138	644	39 34.24	178 07.30	0.04	0
14	15	21-Mar-10	0252	648	39 34.38	178 07.59	1.90	0
15	15	21-Mar-10	0448	754	39 38.14	178 09.14	2.01	0
16	25	21-Mar-10	0711	846	39 43.21	178 09.64	2.13	4
17	35	21-Mar-10	0936	1071	39 40.64	178 15.10	2.05	91
18	35	21-Mar-10	1138	1003	39 45.71	178 10.63	2.01	11
19	35	21-Mar-10	1412	1058	39 44.29	178 01.34	1.99	34
20	35	21-Mar-10	1636	1063	39 42.95	177 57.81	2.00	32
21	35	21-Mar-10	1914	1195	39 50.86	178 01.41	1.94	21
22	2	21-Mar-10	2155	820	40 01.12	178 04.00	2.02	3
23	3	22-Mar-10	0033	788	40 00.34	178 09.16	0.48	0
24	3	22-Mar-10	0200	744	40 05.43	178 11.35	2.01	0
25	35	22-Mar-10	0537	1141	40 03.65	177 49.20	2.01	462
26	44	22-Mar-10	0757	1308	40 01.31	177 45.23	1.95	0
27	34	22-Mar-10	1027	1143	39 58.34	177 35.35	2.01	9
28	34	22-Mar-10	1227	1118	39 53.77	177 40.39	2.02	7
29	44	22-Mar-10	1443	1222	39 52.18	177 45.33	2.00	1
30	45	22-Mar-10	1728	1264	39 50.26	177 51.84	2.00	1
31	45	22-Mar-10	1944	1310	39 54.67	177 53.33	1.96	0
32	35	22-Mar-10	2215	1140	39 59.28	177 53.18	1.97	0
33	2	23-Mar-10	0042	1206	40 06.46	177 57.23	2.00	2
34	2	23-Mar-10	0350	869	40 02.50	178 03.13	1.72	5
35	16	23-Mar-10	0617	605	39 59.08	178 06.23	1.90	0
*36	45	23-Mar-10	0840	1496	39 56.52	178 03.27	1.95	0
37	1	23-Mar-10	1151	735	39 56.28	178 09.18	2.14	16
38	1	23-Mar-10	1341	707	39 57.52	178 09.07	1.04	3
39	3	23-Mar-10	1600	906	39 57.75	178 10.90	1.97	2
*40	46	23-Mar-10	1818	1288	39 57.80	178 16.77	0.58	4
41	36	23-Mar-10	2006	1029	39 56.37	178 12.15	1.28	16
42	1	23-Mar-10	2150	690	39 56.26	178 10.27	1.61	2
43	46	24-Mar-10	0053	1310	39 50.20	178 22.05	1.51	1
44	36	24-Mar-10	0334	1016	39 48.72	178 22.98	1.02	4
45	26	24-Mar-10	0540	830	39 47.05	178 21.82	1.90	3
46	16	24-Mar-10	0817	725	39 40.19	178 23.94	2.07	0

Station number	Stratum	Date (start)	Time (start)	Depth (start) (m)	Start latitude (S)	Start longitude (E)	Distance (NM)	Orange roughy (kg)
47	26	24-Mar-10	1027	850	39 38.77	178 20.45	2.01	27
48	16	24-Mar-10	1230	798	39 36.30	178 21.24	2.01	0
49	35	24-Mar-10	1506	1063	39 36.29	178 17.69	1.89	24
50	35	24-Mar-10	1723	1043	39 37.76	178 15.64	2.01	61
*51	25	24-Mar-10	1933	994	39 38.44	178 12.61	0.33	5
52	25	24-Mar-10	2109	830	39 38.39	178 12.63	1.92	4
*53	15	24-Mar-10	2335	752	39 29.58	178 15.76	1.10	0
54	26	25-Mar-10	0254	856	39 26.83	178 24.85	1.71	0
*55	36	25-Mar-10	0525	1009	39 25.96	178 23.88	0.69	3
56	36	25-Mar-10	0725	1015	39 26.00	178 23.86	1.89	18
57	46	25-Mar-10	0936	1265	39 24.90	178 27.54	1.82	1
58	45	25-Mar-10	1210	1266	39 23.01	178 21.37	1.92	7
59	37	25-Mar-10	1625	1163	38 56.12	178 31.27	1.99	5
*60	17	25-Mar-10	1854	597	38 54.13	178 34.25	1.07	0
61	17	25-Mar-10	2333	756	38 49.54	178 34.34	1.73	9
*62	17	26-Mar-10	0122	616	38 49.14	178 29.96	0.48	0
*63	27	26-Mar-10	0539	815	38 26.11	178 44.30	1.49	1
64	35	26-Mar-10	1517	998	39 23.98	178 19.00	1.60	3
65	46	26-Mar-10	2027	1285	39 57.18	178 16.65	1.77	7
66	14	27-Mar-10	0102	760	39 49.45	177 38.37	0.98	33
67	44	27-Mar-10	0616	1487	40 24.86	177 16.25	1.52	0
68	44	27-Mar-10	0849	1400	40 26.94	177 18.00	2.04	0
69	44	27-Mar-10	1117	1306	40 28.17	177 13.67	2.01	0
70	23	27-Mar-10	1537	830	40 47.71	176 56.59	1.46	24
71	33	27-Mar-10	1734	1086	40 51.31	176 57.09	2.00	12
72	33	27-Mar-10	2051	1122	40 53.56	176 49.25	2.06	23
73	43	27-Mar-10	2347	1211	40 57.11	176 48.32	1.50	3
74	33	28-Mar-10	0203	1053	40 59.05	176 42.89	1.56	6
75	13	28-Mar-10	0355	774	40 58.87	176 38.83	2.02	6
76	33	28-Mar-10	0557	1092	41 02.32	176 39.58	2.01	14
77	5	28-Mar-10	0811	973	41 03.45	176 42.35	2.02	12
78	5	28-Mar-10	1031	965	41 04.50	176 41.55	2.02	107
79	5	28-Mar-10	1233	968	41 04.82	176 38.81	2.00	668
80	33	28-Mar-10	1510	1051	41 04.44	176 33.46	1.98	589
81	43	28-Mar-10	1739	1215	41 08.17	176 34.05	2.00	6
82	33	28-Mar-10	2055	1199	41 10.47	176 38.59	2.01	2
83	43	28-Mar-10	2230	1325	41 07.67	176 46.88	1.79	1
84	43	29-Mar-10	0138	1473	41 12.03	177 04.38	1.41	1
*85	33	29-Mar-10	0425	1166	41 12.67	176 48.96	1.95	13
*86	23	29-Mar-10	0636	920	41 13.65	176 41.82	2.07	56
87	23	29-Mar-10	0946	1000	41 14.95	176 35.90	1.82	1 640
88	33	29-Mar-10	1210	1145	41 14.48	176 27.48	2.02	1
89	33	29-Mar-10	1416	1151	41 11.41	176 29.27	2.01	4
90	33	29-Mar-10	1628	1198	41 12.47	176 24.71	2.01	1
91	33	29-Mar-10	1859	1028	41 16.06	176 15.49	1.98	20
92	13	29-Mar-10	2054	800	41 20.16	176 12.53	1.85	8
93	23	29-Mar-10	2243	870	41 21.75	176 07.82	1.57	0
94	23	30-Mar-10	0029	928	41 21.74	176 11.10	2.02	6
95	33	30-Mar-10	0222	1035	41 23.24	176 15.05	2.01	170
96	23	30-Mar-10	0503	980	41 21.49	176 24.82	2.00	24
97	43	30-Mar-10	0740	1395	41 27.00	176 19.17	1.96	7
98	33	30-Mar-10	0947	1126	41 26.00	176 09.80	2.02	140
99	33	30-Mar-10	1155	1042	41 27.01	176 01.77	2.00	26

Station number	Stratum	Date (start)	Time (start)	Depth (start) (m)	Start latitude (S)	Start longitude (E)	Distance (NM)	Orange roughy (kg)
100	23	30-Mar-10	1406	868	41 26.90	175 58.34	1.72	19
101	33	30-Mar-10	1633	1094	41 30.26	175 55.55	2.00	84
102	23	30-Mar-10	1846	980	41 32.34	175 49.80	1.72	5
103	23	30-Mar-10	2126	800	41 33.58	175 40.84	1.92	22
104	33	31-Mar-10	0046	1071	41 46.00	175 25.42	2.00	14
105	12	31-Mar-10	0524	630	41 30.96	174 54.44	2.00	0
106	22	31-Mar-10	0710	828	41 34.39	174 56.36	2.01	12
107	32	31-Mar-10	1155	1155	42 02.05	174 39.21	2.01	5
108	32	31-Mar-10	1349	1070	42 01.39	174 35.82	2.01	2
109	32	31-Mar-10	1555	1093	42 03.39	174 32.81	2.00	4
110	32	31-Mar-10	1821	1115	42 03.93	174 29.36	2.02	12
111	32	31-Mar-10	2040	1144	42 05.61	174 30.38	2.01	2
112	22	31-Mar-10	2242	1000	42 09.77	174 27.31	2.02	10
113	32	1-Apr-10	0058	1096	42 08.89	174 23.23	2.02	17
114	22	1-Apr-10	0254	970	42 15.49	174 18.21	2.02	39
115	22	1-Apr-10	0451	988	42 18.65	174 18.94	2.00	4
116	42	1-Apr-10	0653	1430	42 18.49	174 24.99	2.12	0
117	32	1-Apr-10	0923	1035	42 18.85	174 18.00	1.99	127
118	32	1-Apr-10	1119	1004	42 18.23	174 11.37	2.00	198
119	42	1-Apr-10	1334	1226	42 21.22	174 11.71	2.01	2
120	42	1-Apr-10	1616	1297	42 23.32	174 04.91	1.60	191
121	12	1-Apr-10	1829	744	42 26.46	173 59.25	1.93	9
122	22	1-Apr-10	2022	872	42 28.34	173 59.14	2.00	99
123	12	1-Apr-10	2340	710	42 36.20	173 37.59	2.02	10
124	41	2-Apr-10	0222	1201	42 44.99	173 50.23	2.01	273
125	31	2-Apr-10	0447	1060	42 48.52	173 50.28	2.00	245
*126	21	2-Apr-10	0743	810	42 54.83	173 46.70	1.61	83
127	11	2-Apr-10	0958	600	42 56.92	173 44.88	1.99	0
128	21	2-Apr-10	1226	874	43 00.66	173 55.55	1.71	173
129	21	2-Apr-10	1425	940	43 02.02	174 04.13	2.01	11
130	21	2-Apr-10	1609	875	43 03.43	174 03.40	1.99	5
131	31	2-Apr-10	1828	1030	43 08.90	173 57.64	2.01	40
132	21	2-Apr-10	2040	960	43 13.23	173 58.66	2.01	129
133	21	2-Apr-10	2233	916	43 15.53	173 58.65	2.01	244
134	11	3-Apr-10	0209	697	43 26.39	174 05.51	1.91	2
135	11	3-Apr-10	0520	690	43 05.74	174 09.16	2.00	2
136	21	3-Apr-10	0717	920	43 00.70	174 11.45	2.02	0
137	31	3-Apr-10	0919	1061	42 58.27	174 10.24	2.03	65
138	41	3-Apr-10	1112	1224	42 55.20	174 11.17	2.01	48
139	41	3-Apr-10	1335	1401	42 53.56	174 09.45	2.02	25
140	31	3-Apr-10	1543	1143	42 55.27	174 16.76	2.00	20
141	21	3-Apr-10	1812	853	43 00.18	174 17.43	2.04	1
142	21	3-Apr-10	2017	872	43 01.03	174 15.86	2.01	3
143	41	3-Apr-10	2248	1232	42 52.19	174 17.30	2.00	24
144	41	4-Apr-10	0132	1208	42 56.15	174 07.19	2.01	156
145	31	4-Apr-10	0407	1076	42 58.51	174 06.53	2.00	129
146	41	4-Apr-10	0911	1335	43 03.85	173 50.08	1.85	134
*147	21	4-Apr-10	1133	876	42 54.44	173 46.80	1.33	24
*148	41	4-Apr-10	1413	1239	42 55.74	173 52.36	1.03	16
149	23	5-Apr-10	0615	810	41 41.25	175 18.15	1.42	28
150	23	5-Apr-10	0935	996	41 44.30	175 25.71	1.81	255
151	23	5-Apr-10	1408	806	41 37.75	175 42.80	2.00	915
152	23	5-Apr-10	1852	937	41 24.16	176 06.24	2.01	14

Station number	Stratum	Date (start)	Time (start)	Depth (start) (m)	Start latitude (S)	Start longitude (E)	Distance (NM)	Orange roughy (kg)
153	33	5-Apr-10	2129	1065	41 20.60	176 17.51	2.00	14
154	33	5-Apr-10	2335	1025	41 20.70	176 22.97	2.00	1
155	23	6-Apr-10	0227	949	41 19.58	176 31.72	2.01	13
156	23	6-Apr-10	0423	798	41 17.81	176 30.73	1.91	4
157	33	6-Apr-10	0610	1050	41 14.63	176 30.49	2.00	6
158	23	6-Apr-10	0925	880	41 14.06	176 39.51	2.03	1
159	33	6-Apr-10	1121	1200	41 12.64	176 49.06	2.02	54
160	33	6-Apr-10	1354	1076	41 11.32	176 44.30	2.00	4
161	33	6-Apr-10	1735	1194	41 14.83	176 19.44	2.01	0
162	23	6-Apr-10	2310	865	41 01.92	176 34.81	1.77	48
163	33	7-Apr-10	0158	1153	41 06.49	176 35.09	2.03	33
164	5	7-Apr-10	0513	1000	41 04.64	176 38.00	1.73	605
165	5	7-Apr-10	0717	934	41 04.19	176 39.50	2.01	1463
166	23	7-Apr-10	1030	920	40 56.10	176 43.90	2.00	8
167	23	7-Apr-10	1328	877	40 50.07	176 52.65	2.00	4
168	23	7-Apr-10	1703	930	40 49.83	176 56.15	1.98	8
169	23	7-Apr-10	2134	875	40 38.08	177 04.48	2.00	10
170	45	8-Apr-10	0757	1478	39 56.74	178 03.42	1.96	0
171	15	8-Apr-10	1223	758	39 27.64	178 16.54	2.00	0
172	47	8-Apr-10	1833	1326	38 54.81	178 45.02	1.52	0
173	4	8-Apr-10	2133	690	38 47.40	178 47.54	2.01	109
174	4	8-Apr-10	2339	695	38 46.81	178 48.49	2.03	7
175	4	9-Apr-10	0131	694	38 48.33	178 47.82	2.01	23
176	27	9-Apr-10	0430	986	38 39.94	178 42.72	2.01	57
177	37	9-Apr-10	0655	1167	38 40.69	178 46.45	1.76	198
178	27	9-Apr-10	0856	952	38 45.52	178 45.37	2.03	365
179	47	9-Apr-10	1147	1432	38 57.77	178 41.44	2.01	1
180	47	9-Apr-10	1452	1296	38 57.16	178 32.63	1.51	2
181	37	9-Apr-10	1716	1000	38 51.43	178 42.27	2.00	6
182	27	9-Apr-10	2106	912	38 45.55	178 34.38	2.00	31
183	27	10-Apr-10	0005	892	38 33.37	178 45.16	2.01	14
*184	27	10-Apr-10	0258	889	38 28.08	178 44.50	0.52	8
185	27	10-Apr-10	0511	799	38 28.82	178 46.81	2.02	19
186	27	10-Apr-10	0858	825	38 47.61	178 42.61	2.01	35
187	17	10-Apr-10	1156	726	38 50.53	178 31.39	1.51	3

Appendix 4: Timetable

18 March	Mobilisation of *Tangaroa*. Departed Wellington at 1930 hrs on 18 March. Rigged trawl gear, and proceeded to survey area.
19 March	First shot on Wairarapa coast abandoned due to an earlier than anticipated start of the seismic survey by *MV Reflect Resolution*. In order to avoid possible effects that the seismic survey might have on fish catachability, *Tangaroa* relocated roughly 110 km north, and then worked north completing survey stations in north Wairarapa and south Portland.
20 March	Worked north, completed survey stations in Madden, and south Portland.
21–24 March	Worked from shallow to deep across the Madden and Portland strata, including the stations in the Rockgarden hill strata.
25–26 March	Completed tows in Ritchie and worked north into Tolaga. Repeated net damage was suffered on the Tolaga stations, with net 1 damaged beyond immediate repair on the second Tolaga station. Substantial net damage and repair occurred on two further stations. Five commercial fishing vessels had set longlines across the Tolaga hill and surrounding area, preventing access to eight stations.
27 March	The longline gear was not clear of the Tolaga stations, and as a result *Tangaroa* left the Tolaga stratum for Wairarapa, completing remaining stations in the Ritchie and Madden strata on the way. Access to a station near the Rockgarden hills was not possible because of commercial longlines.
28–30 March	Completed stations in Wairarapa.
31 March – 1 April	Completed stations in Clarence.
2 April – 3 April	Completed stations in Kaikoura. The Phase 1 stations were completed late on the 3rd April.
4 April	Completed Phase 2 stations in Kaikoura, and then steamed overnight to Wairarapa.
5 April – 8 April	Completed Phase 2 stations in Wairarapa.
8 April	Steamed north to Tolaga, repeating two tows in the Portland stratum on the way; these were tows that were unsuccessful during phase 1 of the survey. The Tolaga area was found to be free of commercial fishing gear.
9 – 10 April	Completed stations in Tolaga outstanding from phase 1, and 3 phase 2 stations. The second to last planned tow caught roughly 40 t of alfonsino, and because this could not be processed at sea, *Tangaroa* steamed to Napier to offload the fish.
11 April	*Tangaroa* left Napier for Wellington at 0830.
12 April	*Tangaroa* arrived in Wellington, berthing at 0800 hrs.

Appendix 5: Occurrence and biological measurements for fish species caught

Table 5.1: MEC trawl survey 2010 number of stations where each fish species was caught (Occurrence), the number of tows where each species was sampled, and the number of fish measured for length, weight, sex, and macroscopic maturity stage. Weight, sex, and macroscopic maturity stage samples are a subset of the length samples. Data for all valid stations.; where the tow was invalid orange roughy were sampled for biological statistics, but all other species were measured for catch weight only. Only statistics for species caught in five or more valid stations are shown.

				Number of fish measured			
Common name	Code	Occurrence	No. samples	Length	Weight	Sex	Maturity stage
Abyssal rattail	CMU	19	17	76	76	69	20
Abyssal rattail	CTR	25	22	74	74	65	34
Alfonsino	BYS	12	11	410	153	410	391
Banded bellowsfish	BBE	17	8	67	42	3	0
Banded rattail	CFA	18	14	52	50	43	3
Basketwork eel	BEE	93	84	359	359	348	176
Baxters lantern dogfish	ETB	120	112	630	616	630	589
Bigscale slickhead	SBI	90	86	891	856	874	414
Black cardinalfish	EPT	13	13	37	23	29	29
Black ghost shark	HYB	29	28	51	51	51	50
Black javelinfish	BJA	15	15	16	16	16	7
Black oreo	BOE	5	5	6	6	6	5
Black slickhead	BSL	11	9	26	23	18	7
Bollons rattail	CBO	30	22	373	272	261	110
Brown chimaera	CHP	17	17	21	21	21	20
Catshark	APR	51	44	75	75	75	67
Leafscale gulper shark	CSQ	37	36	62	62	62	61
Longnosed velvet dogfish	CYP	100	94	381	380	381	336
Cooks rattail	CCO	6	2	6	6	0	0
Deepwater spiny skate	DSK	9	4	4	4	4	3
Filamentous rattail	GAO	17	16	31	31	21	14
Four-rayed rattail	CSU	129	115	2435	1440	768	283
Frill shark	FRS	6	6	6	6	5	5
Giant chimaera	CHG	7	7	8	8	8	5
Giant lepidion	LPS	8	8	8	8	8	2
Hake	HAK	29	28	49	49	49	47
Hoki	HOK	92	86	1306	837	1305	1049
Humpback rattail	CBA	19	17	18	18	15	6
Javelinfish	JAV	56	46	897	717	561	148
Johnson’s cod	HJO	169	153	2324	2119	2255	1152
Kuronezumia leonis	NPU	9	9	9	9	7	2
Large headed slickhead	BAT	17	15	79	79	62	23
Lighthouse fish	PHO	19	2	3	3	0	0
Ling	LIN	14	13	35	35	35	35
Lizardfish	BFE	18	10	18	18	16	8
Long-nosed chimaera	LCH	98	91	370	358	369	264
Longnosed skate	PSK	17	14	17	17	17	4
Lookdown dory	LDO	5	5	9	9	9	3

Common name	Code	Occurrence	No. samples	Number of fish measured Length	Weight	Sex	Maturity stage
Lucifer dogfish	ETL	33	29	131	118	131	111
Mahia rattail	CMA	15	12	25	23	20	1
Nezumia namatahi	NNA	30	19	43	43	34	18
Notable rattail	CIN	102	81	587	444	160	93
Olivers rattail	COL	27	19	563	222	85	52
Orange roughy	ORH	159	158	6892	5101	6889	6873
Pale ghost shark	GSP	97	89	354	354	353	297
Pineapple rattail	PIN	25	22	64	64	48	29
Pink frogmouth	CHX	8	1	1	1	0	0
Plunkets shark	PLS	10	9	16	16	16	15
Pointynose ghost shark	HYP	10	10	20	20	20	20
Prickly deepsea skate	BTS	27	16	21	21	21	15
Psychrolutes spp.	PSY	18	2	2	2	2	0
Rhinochimaera	RCH	64	58	140	140	140	45
Ribaldo	RIB	78	70	380	380	380	336
Ridge scale rattail	MCA	54	48	252	252	242	207
Robust cardinalfish	EPR	8	4	5	5	2	2
Roughhead rattail	CTH	37	31	157	129	137	58
Roughhead rattail	CHY	32	22	97	97	83	77
Sea perch	SPE	26	21	104	95	94	33
Seal shark	BSH	29	28	43	43	43	41
Serrulate rattail	CSE	155	144	2190	1950	1673	666
Shovelnose dogfish	SND	117	109	1347	1139	1347	1235
Silver roughy	SRH	43	30	358	262	239	26
Slickhead (unidentified)	SLK	5	2	38	38	0	0
Small headed cod	SMC	38	28	99	99	99	39
Smallscale slickhead	SSM	90	84	2274	1652	2180	730
Smooth deepsea skate	BTA	12	8	11	11	11	4
Smooth oreo	SSO	55	53	979	644	979	893
Smoothskin dogfish	CYO	81	77	185	185	185	179
Southern Ray’s bream	SRB	8	7	12	12	12	4
Spiky oreo	SOR	85	78	1495	1067	1472	1317
Spineback	SBK	13	10	18	18	16	12
Spinyfin	SFN	9	9	10	10	10	4
Supanose rattail	CFX	5	4	17	17	14	11
Talismania longifilis	TAL	5	5	5	5	5	1
Trachyscorpia capensis	TRS	31	28	37	37	34	11
Unicorn rattail	WHR	56	50	480	415	458	219
Upturned snout rattail	CJX	8	8	12	12	11	7
Velvet rattail	TRX	11	10	10	10	8	4
Violet cod	VCO	10	8	14	14	10	3
Warty oreo	WOE	60	57	598	564	591	584
White rattail	WHX	129	116	1293	1233	1240	701

Appendix 6: SurvCalc parameter files

```
### Parameter file for all-relevant-tows version.###

# calculate biomass and LFs
# SurvCalc -B -f ORH. -F txt -x stn.catch.txt > ORH.out.txt
# needs neptune2 to run

@trips tan1003

@species tan1003
codes   ORH

@preferences tan1003
distance_towed recorded_distance recorded_speed*time from_lat_long
width_swept constant_doorspread
catch_weight recorded

@constant_doorspread tan1003
value 25

@output_tables
sub_biomass_by_stratum T
biomass_by_species T
biomass_by_species_stratum T
LFs_by_stratum T
LFs_by_station T
Number_measured T
LF_totals T

@output_precision
quantity density   biomass   LF_number   c.v.    gain
type   dec_place  dec_place  sig_fig  dec_place  dec_place
precision    0      0      8      1      0

@input_from_database
database Empress
database_name trawl
@where
t_station gear_perf < 3 #all tows are research

@sub_populations ORH
sexes all all
Lmin    0 32
Lmax 32 100
labels Juvenile Adult

@LF_scaling numbers_in_population

@lw_coeff tan1003_ORH
a 0.0525
b 2.866
```

Parameter files for version where Phase tows are 10% of Phase 1 tows

```
# calculate biomass and LFs
#reduced Phase 2 to 10% = 14 tows (str 23 11)(27 3)
# SurvCalc -B -f ORH10pcP2. -F txt -x stn.catch.txt > ORH10pcP2.out.txt
#
# needs neptune2 to run


# file is same as above except for the @where clause
@where
t_station gear_perf < 3 and (categories !="P2" or station_no match
    "152|166|93|156|151|168|150|155|100|162|169|182|183|186")
```

Appendix 7: Estimated abundance from the 1992–94 and 2010 MEC trawl surveys: for orange roughy, by stratum, and for species other than orange roughy, total abundance.

Table 7.1: Re-calculated 1992–94 abundances and c.v., number of tows (N),and area using all relevant tows and the 2010 abundance.

	1992				1993				1994				2010			
Stratum	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)
1	28	5	45	56	28	3	17	46	28	3	14	86	28	3	2	51
2	50	7	653	89	50	5	43	94	50	4	13	77	50	3	2	34
3	100	4	23	56	100	3	69	89	100	2	7	39	100	3	1	100
4					30	5	59	84	30	5	5	37	30	3	15	69
5					50	5	111	54	50	9	648	56	50	5	318	44
11	1 103	3	665	98	1 103	3	97	98	1 103	3	163	55	1 103	3	16	50
12	552	3	975	96	552	3	134	74	552	4	84	48	552	3	37	50
13	640	4	90	98	640	4	585	69	640	8	831	62	640	4	29	44
14	366	3	74	100	366	3	30	31	366	3	314	97	366	3	88	100
15	392	3	119	78	392	3	30	51	392	3	99	81	392	3	0	0
16	211	3	0	0	167	3	4	84	167	4	4	100	167	3	0	100
17	481	3	13	100	481	§2	137	95	481	§2	0	0	481	2	38	46
21	517	8	4 400	71	517	14	3 584	73	517	10	744	62	517	8	415	48
22	685	5	571	40	685	6	819	42	685	6	572	44	685	5	240	54
23	550	6	464	45	550	8	610	36	550	11	1 358	28	550	20	971	60
24	432	3	593	52	432	20	888	36	432	8	560	16	432	5	121	28
25	499	4	123	33	499	4	255	70	499	4	114	19	499	3	35	42
26	400	6	121	40	355	4	359	50	355	4	156	43	355	3	38	85
27	448	4	37	79	448	§2	69	95	448	§2	113	95	448	6	415	64
31	441	5	169	26	441	4	294	9	441	4	212	65	441	5	475	41
32	755	6	6 023	78	755	13	685	21	755	23	1 484	35	755	8	375	57
33	1 575	14	1 625	57	1 575	35	2 454	24	1 575	37	2 870	36	1 575	22	944	49
34	412	3	188	37	412	4	469	41	412	3	128	53	412	3	29	22
35	450	13	813	55	450	13	605	37	450	11	269	51	450	10	358	59
36	401	3	59	45	357	3	106	79	357	3	59	25	357	3	69	27
37	420	4	120	39	420	§2	14	95	420	§2	56	95	420	3	358	93

	1992				1993				1994				2010			
Stratum	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)
41	619	3	561	88	619	6	615	45	619	3	337	67	619	6	744	36
42	696	3	351	36	696	4	328	53	696	3	545	53	696	3	604	99
43	1 388	5	235	85	1 388	5	96	33	1 388	5	181	49	1 388	5	58	29
44	974	4	786	94	974	7	37	50	974	7	87	39	974	5	2	100
45	707	28	164	25	695	4	63	28	695	4	39	33	695	4	17	80
46	376	3	57	14	344	3	31	78	344	3	26	53	344	3	13	66
47	807	3	11	100	807	§2	31	95	807	§2	0	0	807	3	10	59
Totals	17 473	171	20 128		17 377	205	13 728		17 377	205	12 092		17 378	171	6 837	
True N		171				201				201				171		

§ One tow, but doubled up to make SurvCalc work; catch altered so mean is unchanged and the c.v. is 95%.

Table 7.2: Re-calculated 1992–94 abundances and c.v., number of tows (N),and area using the first-tow-at-a-site method and the 2010 abundance at 10% allocation of Phase 2 tows.

	1992				1993				1994				2010			
Stratum	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)
1	28	3	69	55	28	3	17	46	28	3	14	86	552	3	37	50
2	50	7	653	89	50	5	43	94	50	4	13	77	28	3	2	51
3	100	2	7	13	100	3	69	89	100	2	7	39	50	3	2	34
4	–	–	–	–	30	3	93	88	30	3	5	62	100	3	1	100
5	–	–	–	–	50	3	58	67	50	5	825	79	30	3	15	68
11	1 103	3	665	98	1 103	3	97	98	1 103	3	163	55	50	3	141	78
12	552	3	975	96	552	3	134	74	552	3	104	47	1 103	3	16	50
13	640	4	90	98	640	4	585	69	640	6	1 010	68	640	4	29	44
14	366	3	74	100	366	3	30	31	366	3	314	97	366	3	88	100
15	392	3	119	78	392	3	30	51	392	3	99	81	392	3	0	0
16	211	2	0	0	167	2	6	100	167	3	6	100	167	3	0	100
17	481	3	13	100	481	§2	137	95	481	§2	0	0	481	2	38	46
21	517	8	4 400	71	517	9	5 188	77	517	9	825	62	517	8	415	48
22	685	4	671	40	685	5	674	56	685	5	679	41	685	5	240	54
23	550	6	464	45	550	8	610	36	550	9	1 432	31	550	18	1 064	60
24	432	3	593	52	432	5	544	23	432	5	430	12	432	5	121	28
25	499	3	127	45	499	3	292	85	499	3	104	25	499	3	35	42
26	400	5	89	50	355	3	459	45	355	3	178	50	355	3	38	85
27	448	4	37	79	448	§2	69	95	448	§2	113	95	448	6	415	64
31	441	5	169	26	441	4	294	9	441	4	212	65	441	4	440	56
32	755	6	6 023	78	755	9	721	20	755	12	1 199	39	755	8	375	57
33	1 575	14	1 625	57	1 575	29	2 259	28	1 575	30	3 265	39	1 575	16	1 236	51
34	412	3	188	37	412	4	469	41	412	3	128	53	412	3	29	22
35	450	5	1 476	78	450	9	788	39	450	9	320	51	450	9	396	59
36	401	3	59	45	357	3	106	79	357	3	59	25	357	3	69	27
37	420	4	120	39	420	§2	14	95	420	§2	56	95	420	3	358	93
41	619	3	561	88	619	5	730	42	619	3	337	67	619	3	767	69
42	696	3	351	36	696	4	328	53	696	3	545	53	696	3	604	99

	1992				1993				1994				2010			
Stratum	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)	Area (km^2)	N	Biomass (t)	C.v. (%)
43	1 388	5	235	85	1 388	5	96	33	1 388	5	181	49	1 388	5	58	29
44	974	4	786	94	974	5	38	69	974	5	91	52	974	5	2	100
45	707	10	132	42	695	4	63	28	695	4	39	33	695	4	17	80
46	376	3	57	14	344	3	31	78	344	3	26	53	344	3	13	66
47	807	3	11	100	807	§2	31	95	807	§2	0	0	807	3	10	59
Totals	17 473	137	20 839	29	17 377	160	15 103	28	17 377	164	12 779	15	17 378	156	7 071	
True N		137				156				160				156		

§ One tow, but doubled up to make SurvCalc work; catch altered so mean is unchanged and the c.v. is 95%.

Table 7.3: For species other than orange roughy, abundances (Abd, t) and c.v. (%) from the 1992–94 and 2010 surveys using all relevant tows. Also shown is the mean abundance over the 1992–94 surveys, the ratio of the change between the mean 1992–94 abundance to that from 2010, and the t-test of the mean 1992–94 abundance to 2010 (coded yellow for significant at the 5% level).

Species		2010		1992		1993		1994		Ratio	Combined 92-94		t-test
Code	Common name	Abd	C.v.	Abd	C.v.	Abd	C.v.	Abd	C.v.	A2010/ A92-94	Abd	C.v.	
BYS	Alfonsino	182 267	100	0	0	7 120	91	9	58	7 670	2 376	91	1.0
BEE	Basketwork eel	698	11	470	16	1 120	14	755	12	89	782	8	-0.8
ETB	Baxters lantern dogfish	752	15	535	19	2 543	53	1 022	15	55	1 366	33	-1.3
CBO	Bollons rattail	1 256	43	713	34	1 191	33	995	30	130	966	19	0.5
APR	Catshark	76	20	63	26	61	29	66	22	120	63	15	0.7
CSQ	*Centrophorus squamosus*	499	24	312	23	534	36	291	25	132	379	19	0.8
CYP	*Centroscymnus crepidater*	410	11	1 698	13	2 874	63	1 018	41	22	1 863	33	-2.3
EPT	Deepsea cardinalfish	328	89	2 683	94	95	28	200	41	33	992	85	-0.7
CSU	Four-rayed rattail	406	19	238	17	347	14	265	15	143	283	9	1.5
HOK	Hoki	5 465	30	7 664	37	6 822	38	5 340	15	83	6 609	20	-0.5
JAV	Javelin fish	2 272	22	553	22	1 165	34	1 434	16	216	1 050	15	2.3
HJO	Johnson's cod	1 465	17	388	13	604	10	561	12	283	518	7	3.8
LCH	Long-nosed chimaera	418	19	261	16	340	14	367	19	130	322	10	1.1
ETL	Lucifer dogfish	38	20	10	34	17	37	17	25	263	15	19	2.9
NNA	*Nezumia namatahi*	11	20	1	58	1	33	3	43	689	2	29	4.1
CIN	Notable rattail	96	38	15	56	30	20	24	11	414	23	15	2.0
GSP	Pale ghost shark	660	8	472	23	784	24	994	32	88	750	17	-0.6
RIB	Ribaldo	972	13	763	13	901	20	758	12	120	808	9	1.1
MCA	Ridge scaled rattail	313	13	422	56	283	11	217	12	102	307	26	0.1
CTH	Roughhead rattail	147	24	0	0	0	0	0	0		0		
CSE	Serrulate rattail	558	15	275	14	356	8	313	11	177	314	6	2.8
SND	Shovelnose spiny dogfish	12 023	21	9 845	17	13 426	17	14 905	22	94	12 725	11	-0.2
SRH	Silver roughy	147	46	77	51	67	29	54	48	222	66	26	1.2
SSM	Slickhead bigscaled brown	6 223	10	5 108	15	9 079	14	4 234	11	101	6 140	8	0.1
SBI	Slickhead smallscaled brown	826	9	591	12	787	18	638	18	123	672	10	1.5
SMC	Small-headed cod	30	24	11	30	28	26	22	28	146	20	17	1.2

Species		2010		1992		1993		1994		Ratio	Combined 92-94		t-test
Code	Common name	Abd	C.v.	Abd	C.v.	Abd	C.v.	Abd	C.v.	A2010/ A92-94	Abd	C.v.	
CYO	Smooth skin dogfish	691	15	457	17	553	22	588	21	130	533	12	1.3
SSO	Smooth oreo	7 304	58	5 822	44	2 276	37	2 047	30	216	3 382	27	0.9
SOR	Spiky oreo	2 946	36	1 520	42	2 609	53	2 009	41	144	2 046	28	0.7
TRS	*Trachyscorpia capensis*	23	27	10	46	15	29	3	51	250	9	23	2.1
WHR	Unicorn rattail	593	23	7	67	33	61	95	27	1 324	45	24	4.0
WOE	Warty oreo	536	36	780	57	343	40	160	45	125	428	37	0.4
WHX	White rattail	2 304	12	1 539	10	1 812	12	1 659	11	138	1 670	6	2.2
RCH	Widenosed chimaera	439	16	298	18	431	18	319	15	126	349	10	1.1