Abundance estimates of orange roughy on the Northeastern and Eastern Chatham Rise, July 2007: wide-area trawl survey and hill acoustic survey (TAN0709)

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EXECUTIVE SUMMARY

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The Northeastern Chatham Rise was surveyed for orange roughy from 4 to 27 July, 2007 (Voyage TAN0709). The overall research objectives were to obtain two abundance estimates, and to conduct experiments on the target strength of orange roughy and other experimental work (reported elsewhere). The abundance estimates were from acoustic surveys of the fish aggregations, and a trawl survey of the dispersed fish covering the wide area of the flat slope of the Northeast Rise. The survey work was similar to that completed in 2004, except that the wide-area acoustic survey was dropped to allow time for the experimental work.

The wide area trawl survey was carried out by RV *Tangaroa* and targeted the dispersed portion of the orange roughy population using a stratified random design, covering an area of 13 147 km^2. The trawl survey estimate of biomass, assuming a swept area (wingtip distance) of 25.4 m, for the dispersed population was 17 000 t (c.v. 13%) for all fish, and 7100 t (17%) for mature fish (fish length 33 cm and over).

The acoustic survey of the orange roughy aggregations was split into two parts: a survey of the hills and a survey of the main aggregation in the Spawning Box. The aggregation in the Spawning Box was surveyed by the Deepwater Management Group (DWMG), and results from this work are reported elsewhere. The aggregations on the northeast hills, Camerons and Smiths City, were acoustically surveyed once by RV *Tangaroa*. There was insufficient time to complete trawling on the hills to estimate species composition. As a result, the species composition estimated during the 2004 survey was used to partition the acoustic backscatter. The combined hill spawning biomass estimate for Camerons and Smiths City was 763 t (NIWA target strength) and 772 t (Kloser& Horn target strength) with a c.v. of 99%.

1. INTRODUCTION

Orange roughy *(Hoplostethus atlanticus)* are widely distributed in 700–1500 m depth within the New Zealand EEZ. They are a very slow-growing, long-lived fish and may live over 130 years (Doonan 1994, Andrews et al. in press). Their maximum size in New Zealand waters is about 50 cm (standard length), with an average adult size of about 35 cm (Clark et al. 2000). Spawning occurs between June and early August in many areas around New Zealand.

From the beginning of the Chatham Rise orange roughy fishery in the late 1970s, the highest fish densities occurred in a relatively small area where most of the spawning took place, known as the 'Spawning Box'. The dense aggregations of spawning orange roughy form characteristic plume-like marks on echosounders, and are commonly referred to as 'plumes'. Currently, there is usually one main plume in the Spawning Box, which appears in early July and dissipates in late July and early August. It is formed in an area of flat seabed, and is not tied to an obvious feature, such as a canyon, pinnacle, or seamount. Small spawning aggregations are known to occur on the hills at the eastern end of the Chatham Rise, and also further to the west at the Northwest Hills ('Graveyard') complex. The spawning orange roughy in the Spawning Box and on the hills at the eastern end are assumed to be part of the same stock for assessment (ORH 3B, East and South Rise), whilst the Northwest Hills are considered to be part of a separate stock (ORH 3B, Northwest Rise). Outside the spawning season, orange roughy form aggregations for feeding, but these are typically smaller and less consistent than those formed for spawning.

Abundance (biomass) information is essential to effectively manage commercial fish stocks, but this can be very hard to obtain for deepwater species such as orange roughy (Clark 1996). Both trawl and acoustic techniques have been used to obtain biomass estimates for orange roughy in the northeast Chatham Rise area. The early biomass information for the north Chatham Rise orange roughy came from stratified random trawl surveys, which started in 1981 and showed that over the early years of the fishery a marked contraction in the geographical extent of orange roughy during the spawning season took place (Clark et al. 2000, Dunn et al. 2008). These surveys were abandoned after the 1994 survey, because the biomass estimates became very imprecise.

Since the mid1990s the focus of research has been on acoustic surveys, as the large single-species aggregations that spawning orange roughy form seem to make them ideal subjects for this technique. Acoustic methods for estimating orange roughy biomass have been developed over the last 21 years in New Zealand and Australia (Do & Coombs 1989, Elliot & Kloser 1993, Kloser et al. 1996). NIWA carried out pilot acoustic surveys for orange roughy on the Chatham Rise in 1986 (Do & Coombs 1989), 1995, and 1996. Surveys which provided biomass estimates that were used in stock assessments began with the 1998 survey on the Northeast Hills and Spawning Box on the Chatham Rise (Doonan et al. 1999), which was repeated in 2000 (Doonan et al. 2001), and in 2004 (Doonan et al. 2006). CSIRO carried out an acoustic survey of the main plume in the Spawning Box in July 1998 (Kloser et al. 2000). Surveys of the spawning plume in the Spawning Box, and occasionally the Northeast Hills, have also been conducted from an industry vessel using a hull transducer between 2002 and 2008 (I. Hampton, Fisheries Resource Surveys, pers. comm., Dunn et al. 2008).

Outside the spawning aggregations, there can be substantial quantities of orange roughy dispersed over a very large area (background area) at low densities. The first acoustic survey to measure the background orange roughy was carried out in 1998, and surveyed a restricted area around the spawning plume on the northeast Chatham Rise (Doonan et al. 1999). The ratio of biomass in the background to that in the plume was estimated to be 1.05, indicating there was roughly as much mature orange roughy in the background area as there was in the plume. More extensive background areas were covered in the 2002 northwest Chatham Rise survey (about 20 000 km^2, Doonan et al. 2003b). The ratio of biomass in the background to aggregations was estimated to be 3.1 (1.4 if tow 45 was excluded from the background survey) for the northwest Chatham Rise. In the 2000 northeast Chatham Rise survey, the background fish were not surveyed.

Because a substantial biomass may be outside the plumes, monitoring of both parts of the population at the same time is required to determine whether or not biomass estimates and trends in one part of the stock are indicative of the whole, or whether such trends are a result of changes in the proportion of orange roughy in each of the two components (aggregations and the background). However, surveying the background component is problematical; either one uses a trawl survey to obtain a relative estimate, or an acoustic method which provides an absolute estimate but has problems with determining the species mix accurately.

Wide area surveys were re-introduced in 2004 on the northeast and eastern Chatham Rise at the same time as surveys were completed of the aggregations (Figure 1, Doonan et al. 2006). Three abundance estimates were made; one of the aggregations using the acoustic method, and two of the background, one using acoustics, and another using a stratified random trawl survey.

The 2007 survey repeated the 2004 survey, except that the acoustic wide-area survey was dropped to allow time for experimental work on orange roughy target strength, and trials with moored camera systems. The wide-area trawl survey was carried out by NIWA using RV *Tangaroa* and the results are reported here; the results of the experimental work are reported elsewhere (Macaulay et al. 2008, Macaulay & Devine 2008). As in 2004, the 2007 survey work on the aggregations was divided between two organisations with NIWA surveying the hills (reported here), and the Deepwater Group (DWG) independently surveying the Spawning Plume using FV *San Waitaki* (reported elsewhere). The acoustic hill survey targeted Camerons and Smiths City and used a star design method (Doonan el al. 2003a). No other hills were surveyed in 2007.

This report addresses the Ministry of Fisheries project ORH2006/01, which had the overall objective "*To estimate the abundance of orange roughy (*Hoplostethus atlanticus*) in selected areas*", and the three specific objectives.

1. *To carry out a combined trawl and acoustic survey of the Spawning Box and Northeast flat areas on the Chatham Rise in ORH 3B.*

2. *To carry out a series of experiments to improve the estimation of target strength of orange roughy.*

3. *To resolve outstanding issues with the analysis and interpretation of acoustic survey results by experimental work in the field and the re-analysis of earlier data.*

The report describes the result of the first specific objective.

2. METHODS

The methods for the wide-area survey design and the hill surveys were the same as used in 2004 (Doonan et al. 2006).

2.1 Survey design

2.1.1 Aggregations acoustic survey

Two hills, Camerons and Smiths City, were chosen for surveying using the acoustic method (Figure 2). Each feature was surveyed using a radial star pattern (Doonan et al. 2003a) where each star was centred on the top of the main mark and included four transects at approximately equally spaced angles. In each snapshot, an initial search was carried out on the hills with the hull acoustic system, and only hills with marks were surveyed. The data from the trawls on the hills completed in 2004 (12 tows/hill) were used for species composition and lengths. These trawls targeted the marks being surveyed in 2004: i.e., they were not assigned randomly, but they were expected to sample the mark in different directions.

The acoustic biomass estimates were conducted in 2007 for completeness, and as a reference to the 2004 surveys. However, as priority was given to additional experimental work in 2007, completing a trawl survey to estimate mark composition was considered beyond the scope of the survey. This would have required a large number of tows to provide a convincing estimate of mark composition: the previous survey in 2004 proved controversial, even though it included 12 tows per hill.

In 2007, RV *Tangaroa* also collected data using an experimental system (attached to the headline of the trawl) which collected simultaneous video and target strength measurements.. To protect the experimental gear, the trawl was "flown" through the marks, and did not contact the seabed. The resulting data did not give species composition directly, but offered insights into the composition of the aggregations. The results of this study are reported elsewhere.

2.1.2 Wide-area trawl survey

The trawl survey of the background flat areas used a stratified random design. The stratification was the same as the 2004 survey (Doonan et al. 2006), which was based on a statistical analysis of orange roughy densities and biomass estimates from the 1988 to 1994 trawl surveys (Anderson & Fenaughty 1996, Tracey & Fenaughty 1997).

The 2004 survey area was split into six subareas along a smoothed version of the 1000 m depth contour, and within these subareas up to four strata were defined based on depth (Table 1, Figure 3). In the 2007 survey, subarea 1 was excluded because the biomass there in 2004 was low, and most of the ground there was too rough to use the survey trawl net.

The net used was the NIWA full wing trawl ("ratcatcher"). The ratcatcher has upper and lower wings, with a wingspread of about 25 m, a door spread of about 115 m, a headline height of about 3.3 m, 6 inch mesh in the wings, 40 mm mesh (full inside mesh) codend, and low (200 mm bobbins) ground gear. This net has smaller meshes and ground gear than the standard rough bottom orange roughy trawl, and ensured closer bottom contact and that smaller fish entering the net were retained. This was considered important in 2004 for obtaining more comprehensive and representative catches, and consequently better estimates of the species composition for the wide-area acoustic surveys. In 2007, this net was used in order to maintain comparability with the 2004 survey.

2.2 Biological sampling

Biological samples from the trawl catches were used to estimate species and size composition, and other biological parameters. Trawl catches from each successful tow were sorted and weighed by species to the nearest 0.1 kg. For catches too large to be weighed, the orange roughy catch was estimated from the weighed, processed catch using a conversion factor.

A random sample of 200 orange roughy was selected from each tow and staged length frequency measurements were made (i.e., length frequency to the nearest full centimetre below, by sex and gonad stage). For large catches, at least three samples of 200 orange roughy were taken from different parts of the net to ensure sampling was representative of the catch. A further 20 roughy (more for large catches) were randomly selected for more detailed examination: data collected included standard length (mm), weight (to the nearest 5 g), sex, macroscopic gonad stage, and the removal of otoliths.

Gonad stages were based on those of Pankhurst et al. (1987), with the addition of a further partially spent stage, and one of for mature-resting fish:

Stage	Male	Female
1	Immature	Immature
2	Early maturation	Early maturation
3	Maturing (mature)	Maturing (mature)
4	Ripe/running	Ripe
5	Spent	Running ripe
6	–	Spent
7	–	Atretic
8	Partially spent	Partially spent
9	Resting (mature)	Resting (mature)

The bycatch species were identified, weighed, and for the fish bycatch individual length measurements (to the nearest full centimetre below) and weights (to the nearest 5 g) were collected from random subsamples of up to about 50 fish per species per tow.

Orange roughy mean lengths scaled by catch and sex ratio data were calculated for each stratum. Each hill was counted as a stratum. The length-weight relationship for all species was estimated from the data collected during the survey.

2.3 Estimating absolute abundance

2.3.1 Acoustic principles

The conventional approach of echo-integration was used to estimate areal backscatter of acoustic energy by fish (Burczynski 1982, Do & Coombs 1989, Doonan et al. 2001), which was then apportioned to species using the species composition estimated from trawling. Areal backscatter was converted into total numbers of fish over all species per square metre by using a weighted (by number) average of the target strength over the species composition. The number of orange roughy per square metre was the total number times the fraction (in numbers) of orange roughy in the species composition. Biomass was obtained by converting numbers into weight per square metre using the average weight, and multiplying up to the stratum area. Average weight was estimated from the trawl catches.

The detailed mathematical analysis used to estimate abundance from the survey results was the same as that used by Doonan et al. (1999) and a generic derivation is given in Appendix A. Corrections were made to the backscatter for shadowing (method of Barr, see Doonan et al. (1999)), towed body motion (Dunford 2005), and absorption of sound by seawater (Doonan et al. 2003c).

2.3.2 Acoustic equipment

The acoustic data were collected with NIWA's Computerised Research Echo Sounder Technology (*CREST*) (Coombs et al. 2003) and the configuration used was the same as that described by Doonan et al. (2001). The backscatter data were collected with a split-beam system towed at about 500 m deep. The towbody was calibrated 7 months before on the south Chatham Rise (Doonan et al. 2008, Gauthier unpublished results). The calibration broadly followed the approach described by Foote et al. (1987). A 38.1 mm ± 2.5 µm diameter tungsten carbide sphere with nominal target strength of –42.4 dB was used as a calibration standard. The system was operated at 38.156 kHz and transmitted at 4 s intervals. The calibration data are summarised in Table 2.

2.3.3 Estimation

The overall procedure for estimating abundance was the same as used in previous orange roughy surveys (Bull et al. 2000, Doonan et al. 2001) (Appendix A), except that the proportions of species (by number) from each catch were weighted by the square root of the catch size rather than catch size alone. Square root weighting was used because the small number of trawls meant that the proportion estimates were not robust to a large catch with an atypical composition; square root weighting gave a more robust estimate. Only the abundance of spawning orange roughy in the areas surveyed was estimated, where spawning roughy were defined as those with a macroscopic gonad stage of 3 or higher. The variability associated with each estimate was estimated, and a sensitivity analysis carried out. The following sections expand on aspects of the overall analyses that are specific to this survey.

2.3.3.1 Marktypes

There have been large acoustic marks enveloping the hill tops on Camerons and Smiths City, which, when first encountered in the 1998 and 2000 surveys, were interpreted to be almost purely orange roughy. These aggregations were composed of relatively intense backscatter, up to 150 m high and 800 m in diameter. They were easily separated out in an echogram from the midwater layers that sometimes intersected these aggregations, and which were much less intense than the aggregation mark. Often the aggregation was separated from the midwater layers by a clear zone. Mark intensity varied substantially throughout the aggregations, and the bottom of the aggregation was often separated from the sea bed by about 5 m, which was especially apparent when the transducer was 400 to 500 m deep. In small areas in the middle of the mark, the intensity was so extreme that it was saturated in the echograms when applying the colour coding protocol for orange roughy acoustic analysis. However, very intense marks imply that the species in the aggregation mark had a large air-filled swimbladder and consequently it was unlikely to be orange roughy. For example, such strong marks have been routinely observed for black cardinal fish, which form intense white “ball-like” marks, usually well above the hill top.

Species composition in the marks was based on the 2004 trawls (12 per hill). The 2004 trawling on Camerons indicated that the proportion of orange roughy was highly variable and catches were, in general, much lower than expected compared to results from the survey in 2000 and the DWG surveys in the preceding two years. The representiveness of some trawls during the DWG surveys was questioned by the Ministry of Fisheries Deepwater Working Group, because they were made down one tow line known to produce good catches of orange roughy. Preliminary investigations showed that the species composition varied from the top of the hill relative to that from the sides. The Ministry of Fisheries Deepwater Working Group decided to use all available trawl data, but to “regularise” some of the tows so that all tows consisted of data from the top and sides of the hill, and to down-weight tows made down the same tow line. Hence, the following Camerons tows were averaged.

- *San Waitaki*: tows 22, 23, 24, and 25 were averaged (all went down the same tow track).
- *Tasman Viking*: tows 3 (top) and 4 (top) were averaged, and the latter was averaged with tow 5 (side), to generate a “top+side” tow.

For the NIWA surveys of Smiths City, both FV *Tasman Viking* and FV *San Waitaki* made tows in various directions, and most trawled over marks of some sort. These trawls were all used without combining them. The 2004 trawl data used in the estimate for Camerons and Smiths City are shown in Table 3.

2.3.3.2 Target strength

The target strength relationships used in this assessment were the same as those used by Doonan et al. (2001), except for smooth and black oreos. The relationships between target strength and length are given in Table 4. For orange roughy, the relationships were either based on measurements of live fish in a tank (McClatchie et al. 1999) combined with in situ results from Barr & Coombs (2001), and called the "NIWA" relationship in this report (intercept of –74.34 dB), or an alternative based on the Kloser & Horne (2003) results, which had an intercept –77.82 dB with the same slope as the "NIWA" relationship.

The target strengths for the oreo species were derived from a Monte-Carlo analysis of in situ and swimbladder data (Macaulay et al. 2001, Coombs & Barr 2004) and the relationships used were:

$TS_{\text{SSO}} = -82.16+24.63\log_{10}(L)+1.0275\sin(0.1165L-1.765)$

for smooth oreo and

$TS_{\text{BOE}} = -78.05+25.3\log_{10}(L)+1.62\sin(0.0815L+0.238)$

for black oreo, where *TS* is the target strength and *L* the total fish length in cm.

For other common species, relationships based on swimbladder modelling were used (Macaulay et al. 2001). Generic relationships were used for other species as detailed by Doonan et al. (1999).

2.3.3.3 Estimating variance and bias

Variation was estimated from the sampling variability of acoustic transects and trawl catches, and the uncertainty in the target strengths of orange roughy and bycatch species. The three sources of variation were combined using bootstrapping. For each bootstrap iteration, the trawl catches and transect backscatter were re-sampled within each stratum. Target strength variations were treated in one of three ways. For orange roughy, the data used to estimate the target strength-length relationship were re-sampled and the relationship re-estimated. For species where the target strength was derived from swim-bladder data, and for smooth oreo, the intercept of the target strength-length relationship was adjusted by a random amount that was drawn from a normal distribution with a zero mean and a standard deviation of 3 dB. For species that used a generic target strength-length relationship, re-sampling was nested in a way that reflected how the data were collected and combined to form the relationships (Doonan et al. 1999). Abundance estimates were then recalculated. The process was repeated for 500 bootstrap iterations and c.v.s of the bootstrapped abundance estimates were calculated.

Bias was investigated using sensitivity analyses where target strengths were varied by 2 or 3 dB, catchabilities relative to that for orange roughy changed by a factor of 2, and species were omitted from the species composition one at a time.

2.4 Estimation of the trawl biomass index

Biomass indices were calculated by the area swept method described by Francis (1981). Biomass and its standard error were calculated from the following formulae:

$$B = \Sigma(X_i a_i)/cb$$

$$S_B = \sqrt{\Sigma S_i^2 a_i^2 / c^2 b^2}$$

where *B* is biomass (t), X_i is the mean catch rate (kg/km) in stratum *i*, a_i is the area of stratum *i* (km^2), *b* is the width swept by the gear (wingspread rather than doorspread, $25.4\text{x}10^{-3}$ km), *c* is the catchability coefficient (an estimate of the proportion of fish available to be caught by the net), S_B is the standard error of the biomass, and S_i is the standard error of X_i. Approximate 95% confidence limits (CL) were calculated as:

$$CL = B \pm 2S_B$$

The coefficient of variation (c.v.) is a measure of the precision of the biomass estimate:

$$c.v. = S_B/B*100$$

The catchability coefficient, *c*, is the product of the vulnerability, vertical availability, and areal availability (defined by Francis 1989). The effective width of the gear when fishing orange roughy schools has generally taken to be the wingend spread, and was used here. The equivalent assumption in the Francis (1989) scheme is to set vulnerability to 0.12, i.e., the ratio of the wingend to the trawl doorspread. Here, we set vulnerability to 1.0, and so we ignore herding. Vertical availability is unknown, but was assumed equal to 1.0 because no fish marks were observed above the headline of the net during the survey. Areal availability was assigned a value of 1.0 because the estimated biomass was intended to apply solely to the area surveyed, and, also, this can be easily changed when used in a stock assessment.

Length-weight parameters were used to apportion biomass by length groupings. A length-weight regression for 3085 orange roughy measured and weighed during the survey was:

$$W = 5.58x10^{-5} * L^{2.85} \quad \text{(W in kg, L in cm, } R^2 \text{ of regression 95\%)}$$

Biomass estimates were given for total and mature biomass. Mature biomass assumed fish of 33 cm or greater length were mature. This was derived from the mean age at maturity of 29 years (from the otolith transition zone readings, Francis & Horn (1997)), which equates to close to 33 cm using the von Bertalanffy parameters given in the 2005 Plenary Report (Sullivan et al. 2005).

3. RESULTS

The survey took place between 4 and 27 July 2007 (voyage TAN0709). All planned survey work was completed. For orange roughy, 7306 fish were measured for length of which 6600 had additional biological data taken. For other species, 13 600 were measured for length. Trawl station details are given in Appendix B, and the species catch list is given in Appendix C.

3.1 Hill acoustic survey

Two Northeastern Hills (Smiths City and Camerons) were surveyed with single snapshots on 16 and 17 July. The number of acoustic transects and experimental trawls are given in Table 5.

The combined estimated hill abundance (spawning) for Camerons and Smiths City was 763 t (NIWA TS) and 772 t (Kloser & Horn TS) with a c.v. of 99% (Table 6). The c.v. does not include a contribution of error for the shadow zone correction. The estimates of non-spawning biomass of orange roughy were low (Table 7). The sensitivities are given in Table 8, and indicated relatively low biomass of orange roughy in all cases, except when Johnson's cod was excluded from the species mix. The sources of variance for the biomass estimates are summarised in Table 9.

3.2 Wide-area trawl survey

Sixtytwo trawls over 16 strata were completed, within the total strata area of 13 147 km^2. Each trawl tow lasted for 1.5 n.miles at 3 knots.

About 234 species were recorded during the survey (Table 10). By weight, orange roughy was by far the most abundant single species caught during the trawl survey. The main bycatch species were various rattails, slickheads, and a deepwater dogfish (Table 10). Orange roughy was also one of the most ubiquitous species, occurring in 98% of the trawls (Table 11). Eight out of the ten most ubiquitous species were the same for both the 2004 and 2007 surveys, and included orange roughy, Johnson's cod, serrulate rattail, four-rayed rattail, notable rattail, Baxter's dogfish, basketwork eel, and shovelnose spiny dogfish (Table 11, Doonan et al. 2006). In 2004, the top 10 most ubiquitous species also included spineback eels and robust cardinalfish, and in 2007 they included small-headed cod and humpback rattail.

The population length frequencies for the most abundant bycatch species (in numbers) are given in Figure 4. The rattails were all relatively small, with length modes at 30–35 cm TL, and few measured less than 20 cm TL, suggesting they were either rare in the populations, or had low catchability (escapement through the meshes?). Most of the two slickhead species were of a similar size, at 30–45 cm FL, but a number of larger small scale slickheads were caught (over 50 cm), of which most were found to be female (unpublished data).

A number of unusual species were caught in 2007, including one specimen of a new rattail species of the genus *Nezumia*, and also rare specimens of an eel (*Venefica* sp., Family Nettastomatidae), tubeshoulder (*Normichthys* sp.), red-mouth whalefish (*Rondoletia loricata*), and morid cod (*Gadella norops*).

Immature orange roughy were most numerous in the flat area around the northeast hills, "resting" adult orange roughy (macroscopic gonad stage 2) were found throughout the survey area, and maturing, ripe, and running fish were found mostly in the Spawning Box and in subarea 3 (Figure 5). Spent orange roughy were most frequent in the Spawning Box, but there were substantial numbers also found in subareas 3 and 4. These distributions of spent orange roughy reflect, in part, the timing of the survey, as the percentage spent was lowest in subarea 3, the first area surveyed, and then generally increased as time went on (Table 12). Each subarea was surveyed sequentially, so any difference in spawning dynamics by subarea could not be investigated. The survey timing by subarea was within 3 days of that in 2004 (Table 12).

3.2.1 Trawl survey biomass estimates

The trawl survey estimates of orange roughy biomass for the wide area dispersed portion of the population were estimated for all fish, for recruit-sized fish (33 cm SL and over), and for pre-recruits (under 33 cm SL). Wingtip biomass estimates were 17 000 t (c.v. 13%) for all fish, 7100 (17%) for recruits, and 9820 t (13%) for pre-recruits. Abundances by stratum are given in Table 13.

Biomass (t) and c.v. estimates were also calculated directly from macroscopic maturity stage data (rather than knife-edged with length), and apportioned the 17 000 t of total biomass as 1720 t (11%) for immature fish, 590 t (33%) for maturing fish, 6780 t (19%) for ripe to spent fish, and 7820 t (16%) for resting fish (resting, yet to spawn for the first time, and atretic). Of the total biomass, 44% was actively spawning this year, and 26% was classified as spent. Macroscopic maturity stage was measured for 80% of the total biomass catch.

The greatest biomass of mature orange roughy was in subarea 2, and then decreased following the subareas around from 2 to 6. Total biomass was largest in subareas 2 and 4, followed by subarea 3, then subareas 5 and 6. The spawning plume was located in strata 21 and 22.

Abundance estimates from the trawl survey are also reported for the eight most abundant bycatch species (Table 14). The most abundant bycatch species, by far, was the four-rayed rattail, with an estimated 63.2 million fish. For comparison, based on a mean orange roughy weight of 1.2 kg, the total number of orange roughy would be about 14 million fish. The abundance of four-rayed rattails was about 4-fold greater than the next most abundant bycatch species, which were the notable (16.8 million) and serrulate (11.5 million) rattails. In terms of biomass, however, orange roughy was the most dominant species (17 000 t), with only shovelnose spiny dogfish having a comparable biomass (16 200 t). The other bycatch species had biomass estimates of under 5 000 t. The c.v.s of the bycatch biomass estimates were good, and in the range 6–32%.

4. DISCUSSION

4.1 Hill acoustic surveys

In 2004, the species composition for the hill surveys (Smiths City and Camerons) was problematical and was counter to pre-survey 2004 survey expectations, which had been that a large orange roughy spawning biomass would be present on the northeast hills. Consequently, the results were controversial: the 2004 combined hill estimate was an order of magnitude lower than that from the previous NIWA survey in 2000 (and also those from DWG surveys carried out between 2001 and 2003). Trawl catches in 2004 contained a predominance of Johnson's cod (Camerons) or smooth oreo (Smiths City), and had varied amounts of orange roughy, with most tows having only small catches. Only a few tows had large catches of orange roughy, and these came from a very restricted sector on the hills. In contrast, the tows in 2000 had large catches of orange roughy, with smaller amounts of Johnson's cod or smooth oreo.

Evidence from experimental work in 2007 using the combined acoustic and video system attached to the trawl headline and flown over the summit of the hills was inconclusive, although they were flown through dense marks seen on the hull sounder on Cameron's and light marks on Smiths. Of the six tows completed, three had (as expected) trivial amounts of catch. Two tows on Cameron's had small amounts of Johnson's cod (144 and 28 individuals), which was by far the largest component in the catch, and one on Smiths had 13 Baxter's dogfish, again the largest component of the catch. Only five roughy were caught in the six tows. However, orange roughy are known to dive towards the seabed when disturbed, and so might have easily escaped under the ground rope during these experiments.

Gavin Macaulay has analysed the video and target strength data from the experimental tows (NIWA, unpublished report) and concluded that orange roughy were not the dominant species in the visible marks, although these data were not conclusive. In the video data, Macaulay identified 9 orange roughy, 38 fish that definitely were not orange roughy, and a few hundred other images that could not be identified either way. Macaulay also identified a few hundred single target tracks from the echogram data. The individual target strengths outside the mark could be compared to those inside it by lining up the positions of the target strength tracks to the mark in the hull sounder echogram. This comparison showed a clear pattern, with a mean target strength at about -49dB away from the mark, and target strength at about -32 dB when close or inside the mark (or where it would have been). The latter target strengths are far too high for orange roughy, and Macaulay concluded that it was unlikely that the marks were composed of mainly orange roughy. On one occasion, a weak acoustic layer was observed starting on the top of Cameron's and extending down the side of the hill. Integration of this layer at 38 KHz and 120 KHz gave a ratio that was consistent for fish with a small air bladder, i.e., not orange roughy. These analyses suggest orange roughy was not the dominant species contributing to the acoustic marks on Camerons or Smiths City. If orange roughy are not in the aggregations, then the hill orange roughy biomass estimates given here will have little or no relationship to the true amount of orange roughy present.

The abundance estimates (c.v. in parentheses, %) for the northeast Hills in 2007 were similar to those obtained in the 2004 survey by *Tangaroa* (Doonan et al. 2006)

Hill	2007	2004	
		Snapshot 1	Snapshot 2
Camerons	474 (123)	435 (106)	207 (93)
Smiths City	289 (106)	337 (82)	236 (71)

As the same catches (species partitioning) and parameters were used for the estimates in both years, the differences effectively describe the change in the amount of acoustic backscatter measured in each year, i.e., the amount of acoustic backscatter measured in the 2004 and 2007 surveys was similar.

4.2 Background trawl surveys

Mature and total abundances of orange roughy were essentially unchanged from 2004 to 2007. The 2004 estimates for total and mature biomass were 17 000 t (cv 10%) and 7200 t (12%), compared to 17 000 t (c.v. 13%) and 7100 (17%) in 2007. This indicates no change in orange roughy biomass in the background area covered by the trawl survey between 2004 and 2007.

Further analysis of the orange roughy biological sample data indicated that there was a shift of the left limb of the length frequency distribution by 1 cm to larger fish in 2007 (Figure 6). The shift was statistically significant over lengths 20–23 cm using a randomisation test. In the randomisation test, stations from the 2004 and 2007 surveys were pooled by strata, stations were randomly allocated to each survey year with no replacements, and the length frequency re-calculated. From a preliminary investigation, the frequencies were differenct over the lengths 20–23 cm. In the test, the difference of the 2004 length frequency from the 2007 length frequency was calculated and the mean of these over 20–23 cm recorded. The distribution of these means (Figure 7) was compared to the mean from the actual data and this was at the 97.5% quartile and so statistically significant for a one-sided test (i.e., a shift to the left of the 2007 length frequency from that from 2004).

There was a 3 year time gap between length frequencies, which can be checked against the implied time shift from the shift of the left limb of the length frequency distribution, by converting lengths to ages using growth parameters used in the east Chatham Rise orange roughy assessment (Ministry of Fisheries 2008). This was a first order comparison as the length-at-age distribution was not explicitly taken into account. At frequencies 0.04 and 0.02 (*see* Figure 5), the left hand limb has shifted by 0.8–1.4 cm. The length shift can be converted into time by using the estimated growth, which gives a time interval of 0.9 yr and 1.5 yr. This assumes that there was no spread in the length-at-age distribution. If the shift in the first length mode is considered (27.2 cm in 2004), the shift is 1.7 cm over 3 years. Two years growth from 27.2 cm would produce a 1.2 cm gap. Although the results do not exactly correspond, they suggest changes in the length frequency distribution between the two trawl surveys which would be broadly consistent with the growth rate of orange roughy.

When the length frequencies were split up into gonad stages, the general shape of each gonad stage length frequency was similar between the years (Figures 8 & 9). The main change was that the large numbers of immature fish (stage 1) in 2004 were gonad stage 2 in 2007, and also larger. This would be consistent with the shift in the left limb of the length frequency. These patterns also imply that there was relatively little recruitment, and either a recruitment pulse has entered the fishery, or a recruitment "hole" may be approaching the fishery (Dunn et al. 2008).

The highest abundance of juvenile orange roughy was found around the northeast hills. This would be consistent with the areas frequented by pre-recruit orange roughy (orange roughy nursery grounds) being found within the trawl survey area (Dunn et al. in press). Therefore the rarity of smaller (under 20 cm SL) orange roughy in the trawl survey catches would be a result of low catchability (i.e., net selectivity), or alternatively could be as result of low abundance (low recruitment).

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Table 1: Flat strata for the 2007 NE Chatham Rise survey.

Subarea	Stratum code	Position boundaries	Depth cut-offs (m)	Area (km^2)
Northeast Rise (between 42˚ 35’ S and 43˚ 15’ S)				
2	21	177˚ 30’ W – 176˚ 50’ W	800–850	200
	22		850–950	366
	23		950–1100	480
	24		1100–1350	691
3	31	176˚ 30’ W – 175˚ 00’ W	825–950	1169
	32		950–1150	1280
	33		1150–1250	453
Eastern Rise (east of 175˚ 00’ W)				
4	41	North of 43˚ 20’ S	825–950	1638
	42		950–1150	1574
	43		1150–1250	847
5	51	43˚ 20’ S – 44˚ 00’ S	825–975	1415
	52		975–1150	936
	53		1150–1250	403
6	61	South of 44˚ 00’ S	825–975	405
	62		975–1150	491
	63		1150–1250	460

Table 2: Calibration data for the 38 kHz systems used for the abundance survey. V_T is the in-circuit voltage at the transducer terminals for a target of unit backscattering cross-section at unit range. *G* is the voltage gain of the receiver at a range of 1 m with the system configured for echo-integration (20 log R).

System	Towed body 2
Transducer serial no.	28327
Nominal 3dB beam-width (°)	7.0x6.9
Effective beam angle (sr)	0.0083
Effective pulse length (ms)	0.78
V_T (V)	1 279
Transducer depth (m)	100–300
G	14 491

Table 3: 2004 trawl catch data used in the acoustic analysis of the Northeastern Hills abundances, ordered by date. Species codes are: "ORHnS" non-spawning orange roughy; "BEE" basketwork eel; "CYO" *Centroscymnus crepidater*; "ETB" Baxter's lantern dogfish; "HJO" Johnson's cod; "SSO" Smooth oreo; "WOE" warty oreo. Vessel codes are: "TAN" *Tangaroa*; "TVI" *Tasman Viking*; "SWA" *San Waitaki*. Column codes are: "W" catch weight (kg); "Cr" catch rate (kg/km); "Spp" species code. Station numbers are only unique within a vessel code. ‡ trawl data are composites of more than one trawl (see text for details).

Vessel code	Station number	Date	Distance towed	Spawning orange roughy W	Spawning orange roughy Cr	Species other than spawning orange roughy: Largest catch Spp	Largest catch W	Largest catch Cr	Second largest catch Spp	Second largest catch W	Second largest catch Cr
Smiths City											
SWA	20	16 Jul	0.4	2746	6864	SSO	875	2188	HJO	320	800
SWA	21	16 Jul	0.82	82	100	ETB	290	354	HJO	160	195
TAN	31	16 Jul	0.25	0	0	ETB	202	810	BEE	9	34
TAN	32	16 Jul	0.06	737	12276	ETB	220	3658	CYO	16	265
SWA	26	17 Jul	0.6	171	286	ETB	300	500	HJO	280	467
TVI	7	18 Jul	0.33	665	2016	ORHnS	310	938	ETB	216	655
TVI	8	19 Jul	0.24	255	1060	SSO	500	2083	ORHnS	145	606
TVI	15	21 Jul	0.19	23	123	ETB	1000	5263	ORHnS	46	244
TVI	16	21 Jul	0.27	38	140	ETB	450	1667	ORHnS	20	75
TVI	17	21 Jul	0.66	15	22	WOE	660	1000	HJO	448	679
TVI	22	22 Jul	0.38	67	178	SSO	2718	7152	ETB	473	1244
TVI	28	22 Jul	0.48	166	345	SSO	652	1359	HJO	400	833
Camerons											
SWA‡	22	16 Jul	0.4475	10837	24217	HJO	1378	3078	ORHnS	594	1328
TVI‡	3	18 Jul	0.565	1290	2284	HJO	534	946	ORHnS	270	478
TVI	11	20 Jul	0.6	455	759	HJO	130	216	ORHnS	32	54
TVI	14	21 Jul	0.37	42	112	HJO	600	1622	ETB	50	135
TVI	19	21 Jul	0.59	131	222	HJO	700	1186	ETB	60	102
TVI	20	22 Jul	0.68	154	226	HJO	923	1358	SSO	48	71
TVI	27	22 Jul	0.57	153	268	HJO	1500	2632	ETB	100	175

Table 4: Length–target strength relationships used where relationships are of the form TS = a + b $\log_{10}$(length) + c sin(c1 length – c2).

Species	Code	Intercept (a)	Slope (b)	Sin term used c	c1	c2
Orange roughy (*Hoplostethus atlanticus*) (NIWA)	ORH	-74.34	16.15			
Basketwork eel (*Diastobranchus capensis*)	BEE	-76.7	23.3			
Black javelinfish (*Mesobius antipodum*)	BJA	-70.6	17.8			
Black oreo (*Allocyttus niger*)	BOE	-78.05	25.2	1.62	0.082	-0.24
Four-rayed rattail (*Coryphaenoides subserrulatus*)	CSU	-92.5	31.8			
Hoki (*Macruronus novaezelandiae*)	HOK	-74	18.0			
Javelinfish (*Lepidorhyncus denticulatus*)	JAV	-73.5	20.0			
Johnson's cod (*Halargyreus johnsonii*)	HJO	-74.0	24.7			
Notable rattail (*Caelorinchus innotabilis*)	CIN	-107.8	44.9			
Ribaldo (*Mora moro*)	RIB	-66.7	21.7			
Ridge scaled rattail (*Macrourus carinatus*)	MCA	-95.5	35.6			
Robust cardinalfish (*Epigonus robustus*)	EPR	-70.0	23.2			
Serrulate rattail (*Coryphaenoides serrulatus*)	CSE	-135.0	59.7			
Smooth oreo (*Pseudocyttus maculatus*)	SSO	-82.16	24.63	1.03	0.117	1.77
White rattail (*Trachyrincus aphyodes*)	WHX	-62.1	18.1			
Cod-like		-67.5	20.0			
Deep water swimbladdered		-79.4	20.0			
No swimbladder		-77.0	20.0			

Table 5: Acoustic surveys: numbers of trawl and transects by stratum (all using the towed system).

Stratum	Survey design	Date (in July)	Number of trawls	Number of flybys	Number of transects
Hills survey					
Camerons	Star	16	2	1	4
Smiths Citys	Star	17	2	1	4

Table 6: Acoustic spawning abundance (t) by hill (c.v. in brackets) . "-" no data. The c.v.s exclude contribution from the shadow zone correction.

	Abundance (t)	
Hill	NIWA TS 1	Kloser & Horne TS
Camerons	474 (123)	478 (123)
Smiths City	289 (106)	294 (106)

Table 7: Acoustic non-spawning abundance (t) by hill (c.v. in brackets) . "-" no data. The c.v.s exclude contribution from the shadow zone correction.

	Abundance (t)	
Hill	NIWA TS	Kloser & Horne TS
Camerons	41 (119)	41 (119)
Smiths City	52 (95)	53 (95)

Table 8: Sensitivity estimate for the NE hills (Camerons + Smiths City) spawning orange roughy biomass using the NIWA TS.

Case	Percent change
Catchability	
Other species' catchability twice that for target roughy	69
Other species' catchability half that for target roughy	-42
Target strength	
Non-roughy species: change intercept by +3 dB	-49
Non-roughy species: change intercept by -3 dB	95
Orange roughy species: change intercept by +2 dB	-1
Orange roughy species: change intercept by -2 dB	1
Exclude on species from the composition	
Johnson's cod	1472
Baxter’s lantern dogfish	6
Smooth oreo	4
Basketwork eel	2

Table 9: Coefficient of variation of the spawning orange roughy estimate for the hill surveys from each source alone. An approximate method to get the total c.v. from the individual sources is to use $\sqrt{\prod_i \left(1+c_i^2\right)-1}$ which, gives a total c.v. of 0.91 compared to the estimated total c.v. of 0.99.

	c.v.
Source	Camerons + Smiths Citys
Catch	49
Backscatter	35
Target strength of other species	56
Target strength of orange roughy	0

Table 10: The total catch weight (kg) and occurrence (as % of all tows) of the 10 most abundant species by weight caught in biomass tows (ratcatcher) during the TAN0709 trawl survey.

Common Name	Scientific name	Occurrence (%)	Catch
Orange roughy	*Hoplostethus atlanticus*	98	6 979.3
Shovelnose spiny dogfish	*Deania calcea*	89	4 922.7
Basketwork eel	*Diastobranchus capensis*	91	1 795.6
Slickhead, bigscaled brown	*Alepocephalus australis*	74	1 365.3
Johnson's cod	*Halargyreus johnsonii*	97	907.5
Four-rayed rattail	*Coryphaenoides subserrulatus*	97	906.7
White rattail	*Trachyrincus aphyodes*	68	718
Baxter’s lantern dogfish	*Etmopterus baxteri*	92	662.3
Ribaldo	*Mora moro*	40	655.2
Serrulate rattail	*Coryphaenoides serrulatus*	100	530.1

Table 11: The total catch weight (kg) and occurrence (as % of all tows) of the 10 most frequent species by occurrence for the biomass tows (ratcatcher) during the TAN0709 trawl survey.

Common name	Scientific name	Occurrence (%)	Catch
Serrulate rattail	*Coryphaenoides serrulatus*	100	530.1
Orange roughy	*Hoplostethus atlanticus*	98	6 979.3
Johnson's cod	*Halargyreus johnsonii*	97	907.5
Four-rayed rattail	*Coryphaenoides subserrulatus*	97	906.7
Notable rattail	*Coelorinchus innotabilis*	95	357.9
Baxters lantern dogfish	*Etmopterus baxteri*	92	662.3
Basketwork eel	*Diastobranchus capensis*	91	1 795.6
Shovelnose spiny dogfish	*Deania calcea*	89	4 922.7
Small-headed cod	*Lepidion microcephalus*	85	145.7
Humpback rattail(slender rattail)	*Coryphaenoides dossenus*	85	126.3

Table 12: Wide-area survey: proportion of spawning fish that were spent, by sex and stratum. Stratum number is the concatenation of subarea and depth code, e.g., stratum 32 is the column headed 3 and row labelled 2.

						Subarea
Depth code		2	3	4	5	6
Male						
1		28	13	34	37	59
2		23	49	67	57	81
3		51	76	85	79	95
4		74	-	-	-	-
Female						
1		52	12	55	29	52
2		22	23	61	69	86
3		45	76	93	84	100
4		14	-	-	-	-
Median date for	2007	14	8	18	20	22
trawls, in July	2004	11	10	17	23	24

Table 13: Estimates of mature and total biomass (t) from the trawl survey by stratum (see Figure 3), rounded to 2 digits (c.v.s in parentheses, rounded to the nearest %), based on a swept area of 25.4 m (i.e. distance between trawl wingtips).

		Total biomass		Mature biomass	
Stratum	Number of trawls	Mean density (kg/km^2)	Abundance (t)	Mean density (kg/km^2)	Abundance (t)
21	3	3 500	690 (64)	2 400	470 (63)
22	5	3 000	1 100 (41)	2 200	810 (45)
23	5	3 400	1 600 (13)	2 100	1 000 (13)
24	3	2 100	1 400 (95)	1 400	940 (95)
31	5	1 600	1 900 (25)	690	800 (34)
32	5	1 200	1 600 (28)	540	690 (30)
33	5	530	240 (21)	160	74 (23)
41	3	1 300	2 100 (14)	170	290 (57)
42	3	1 400	2 200 (47)	640	1 000 (39)
43	3	590	500 (59)	130	110 (61)
51	4	130	180 (26)	49	69 (38)
52	5	1 700	1 600 (65)	530	490 (52)
53	3	180	72 (65)	84	34 (68)
61	3	2 100	830 (31)	150	62 (44)
62	4	870	430 (20)	360	180 (32)
63	3	1 000	480 (48)	130	61 (42)
Total	62		17 000 (13)		7 100 (17)

Table 14: For the eight most prevalent species other than orange roughy, estimates of total numbers and biomass (t) from the trawl survey based on a swept area of 25.4 m (i.e. distance between trawl wingtips).

		Population size		Abundance	
Species code	Species	(Millions)	c.v. (%)	(t)	C.v. (%)
CSU	Four-rayed rattail	63.2	39	3275	22
CIN	Notable rattail	16.8	14	904	10
CSE	Serrulate rattail	11.5	8	1618	6
BEE	Basketwork eel	8.9	13	4560	9
SND	Shovelnose spiny dogfish	8.1	23	16184	20
SBI	Slickhead, bigscaled brown	7.3	22	3660	16
HJO	Johnson's cod	3.8	10	2342	11
SSM	Slickhead, smallscaled brown	1.8	26	1019	32

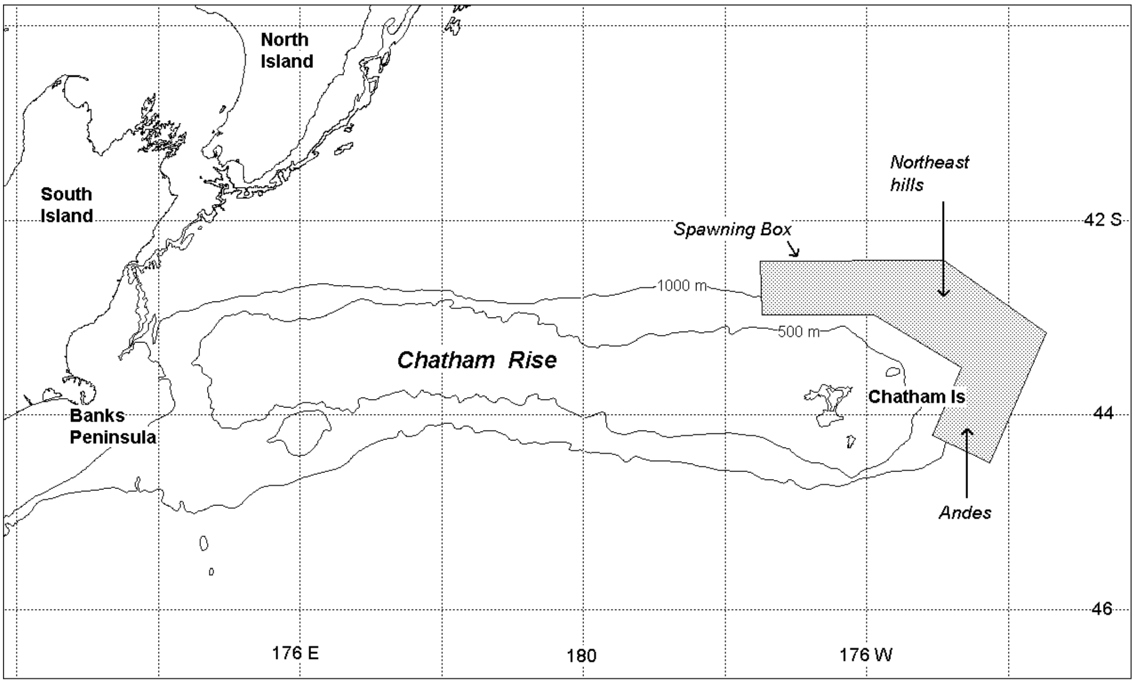

Figure 1: The 2007 survey area with the position of the two main hill complexes. The main spawning plume is towards the western-most end of the shaded area in a depth of about 750 m.

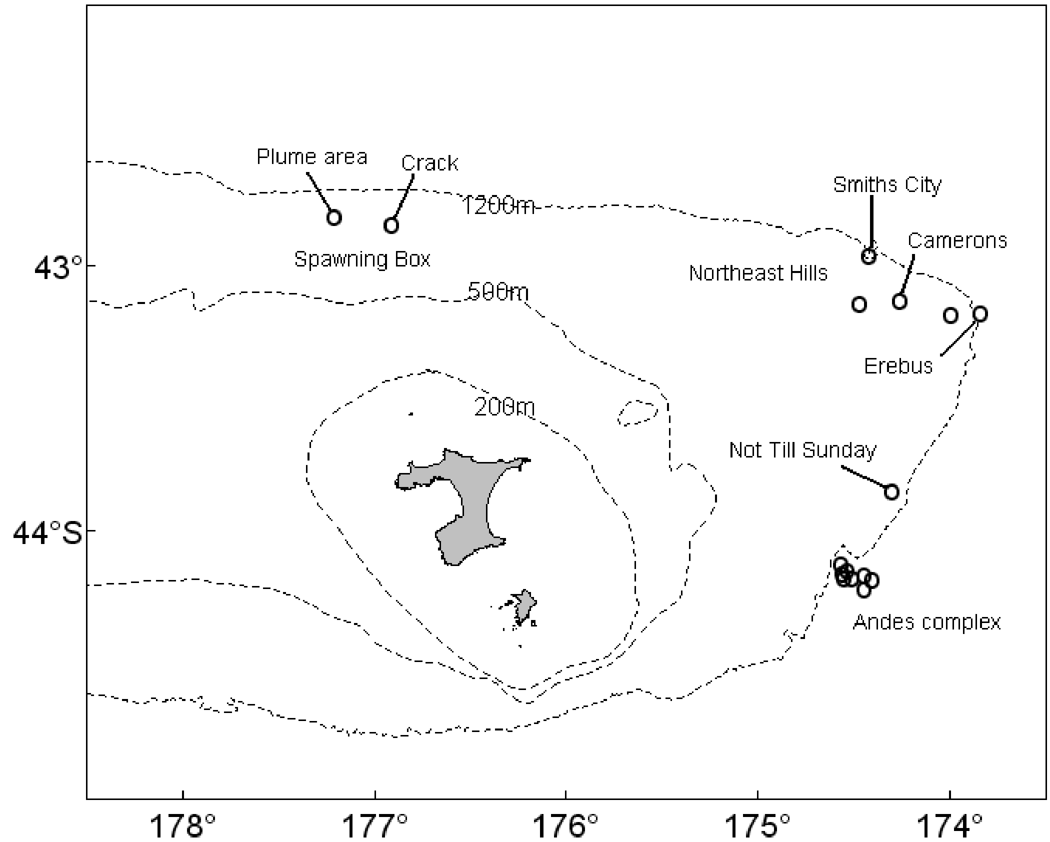

Figure 2: Hills surveyed in 2007 (Smiths City and Camerons) and the other main hills that were inspected in 2004 for orange roughy aggregations. For reference, the approximate position of the Spawning Plume is shown ("Plume area").

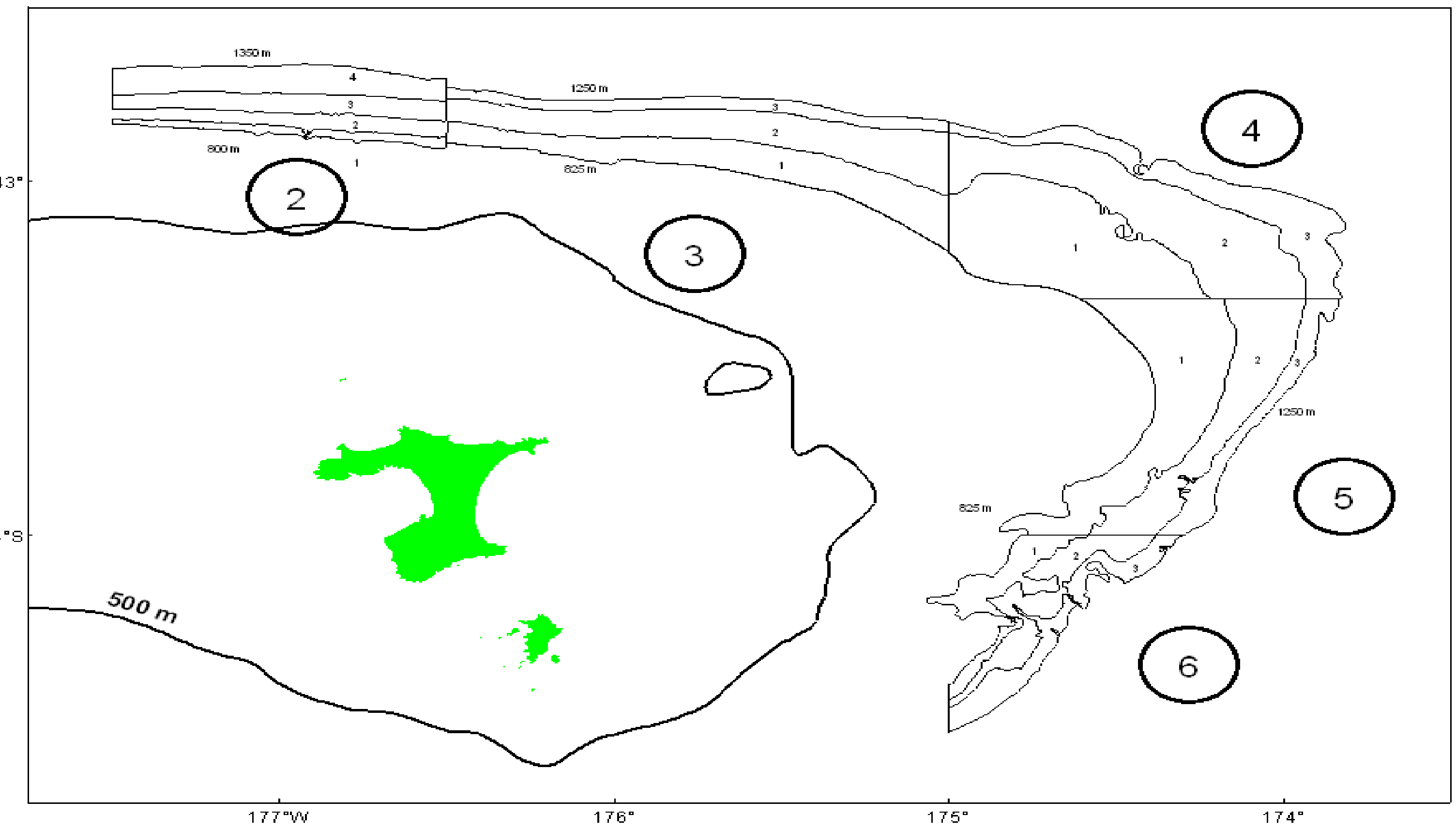

Figure 3: Strata for the wide area background trawl survey. Subareas are in circles. Stratum codes are "sm", where s is the subarea and m the number within the subarea (small numbers located within each stratum), e.g., stratum 42 is the middle stratum in subarea 4. Subarea 1 was excluded in 2007.

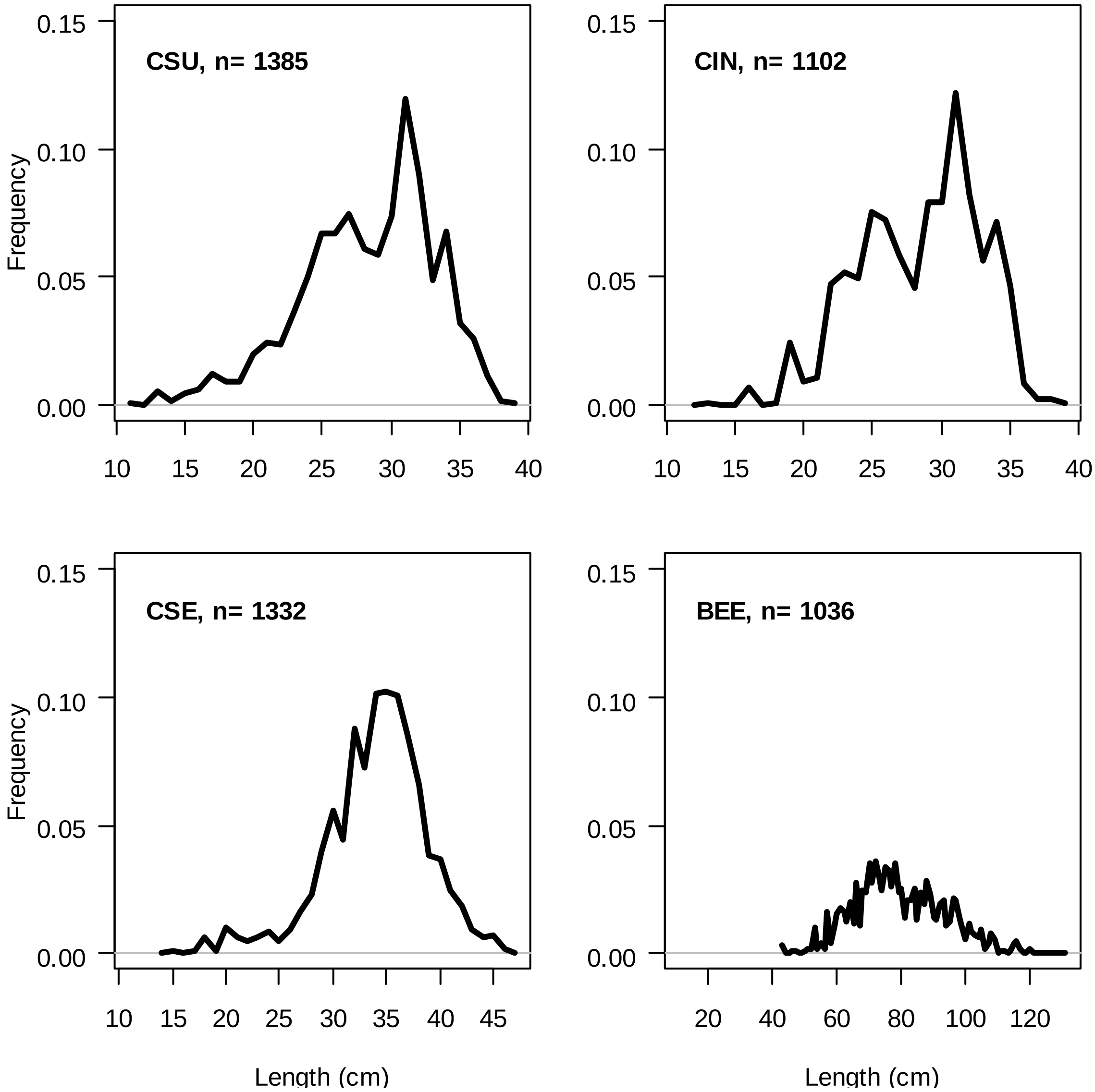

Figure 4: Population length frequency for the eight most prevalent species, other than orange roughy. Species for species codes are in Table 14. "n" is the total samples measured.

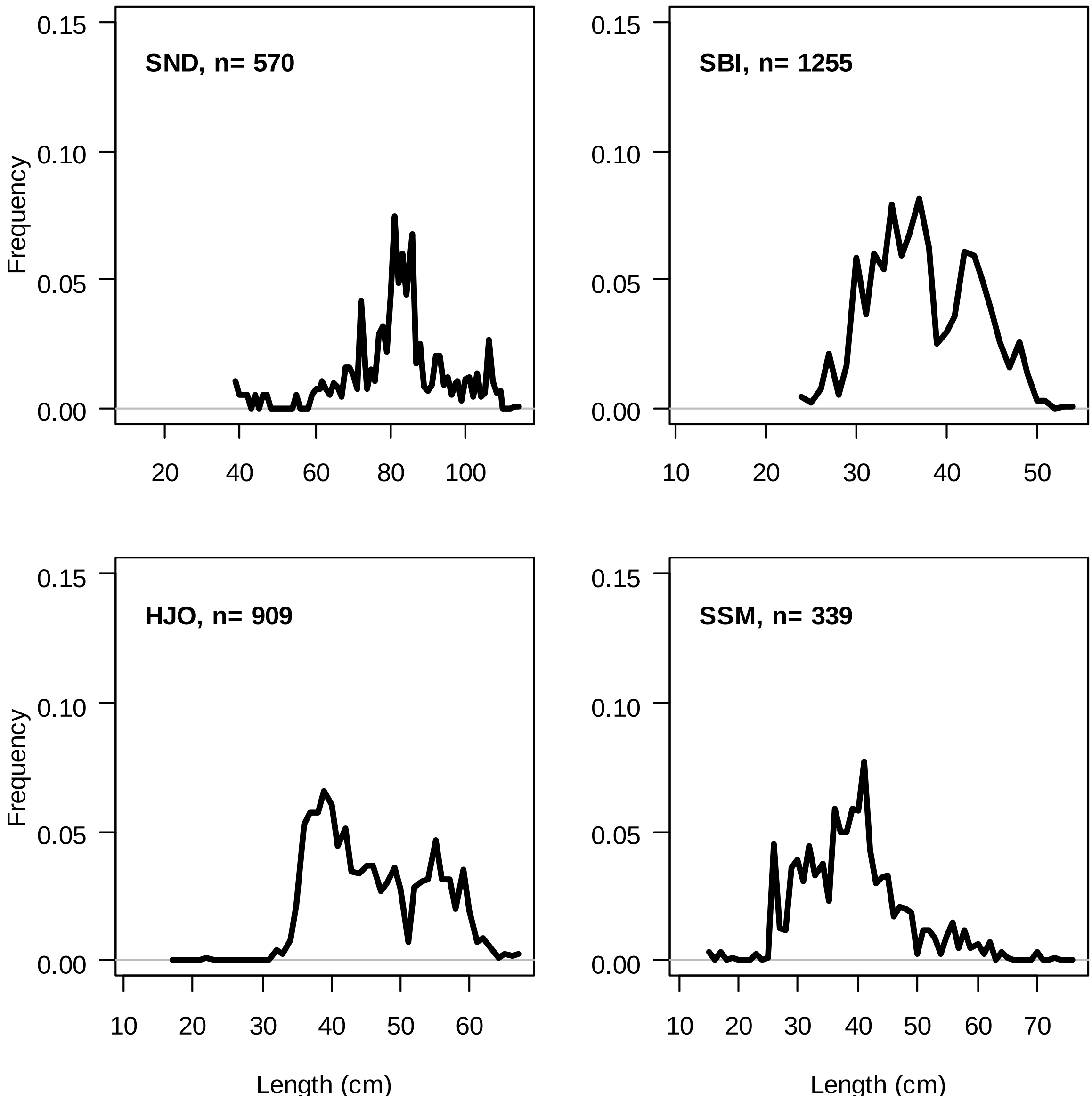

Figure 4 (cont.): Population length frequency for the eight most prevalent species, other than orange roughy. Species for species codes are in Table 14. "n" is the total samples measured.

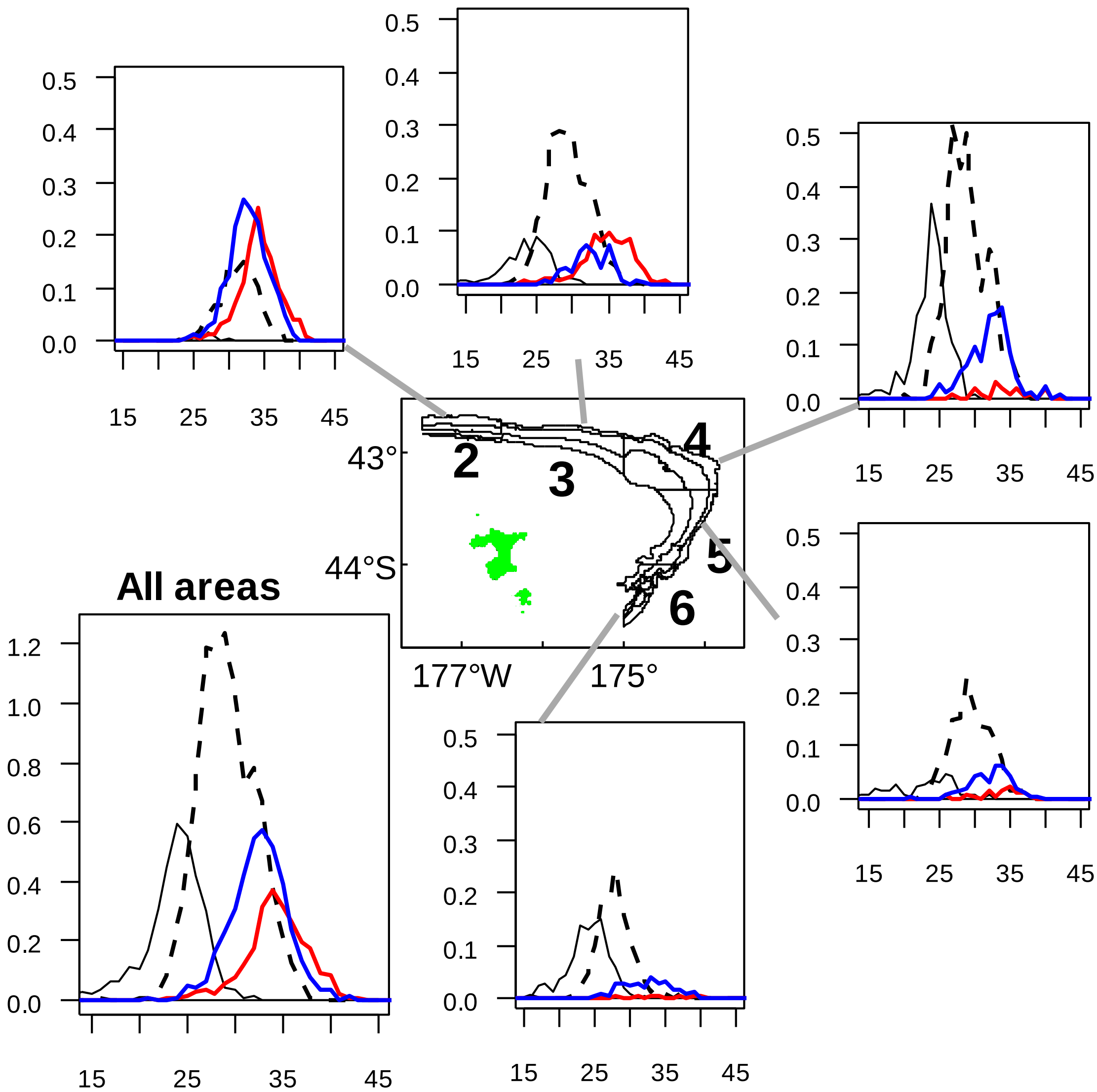

Figure 5: Spatial distribution of orange roughy by macroscopic maturity stage (see Section 2.4) in trawl biomass ratcatcher tows completed during 2007. Y-axes are numbers of fish (millions) and the x-axes are length (cm). Thin solid line, stage 1 (immature); dotted line, stages 2, 7, and 9 ("resting"); grey thick line, stages 3,4, and female 5 (ripe and running ripe); thick solid line, stages 8, male 5, and female 6 (spent).

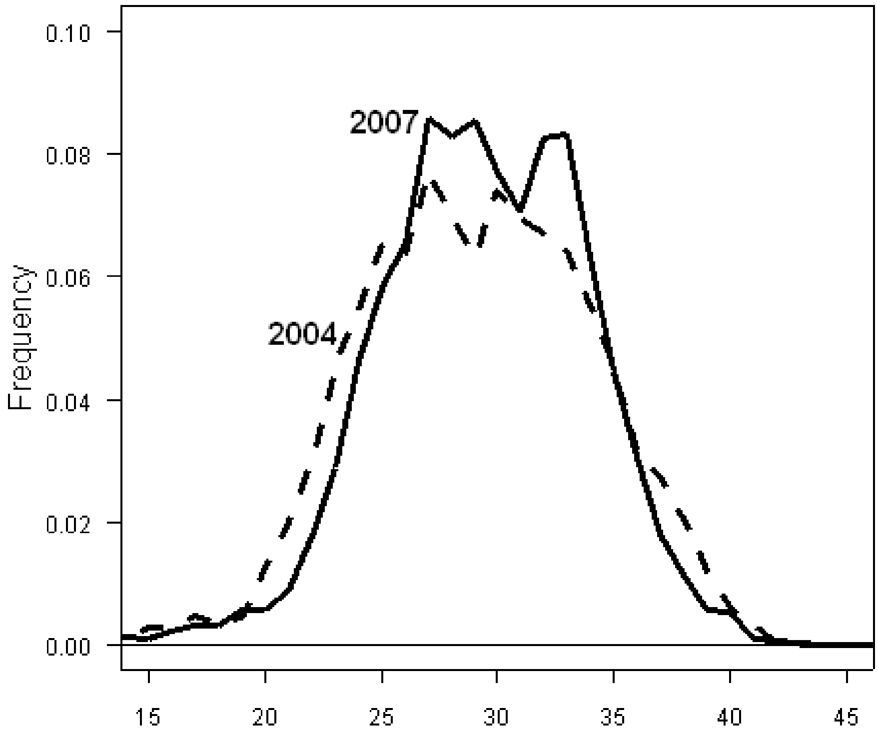

Figure 6: Length frequency from the 2004 survey compared to that from the 2007. Frequencies made up by explicitly using a sex ratio of 1:1.

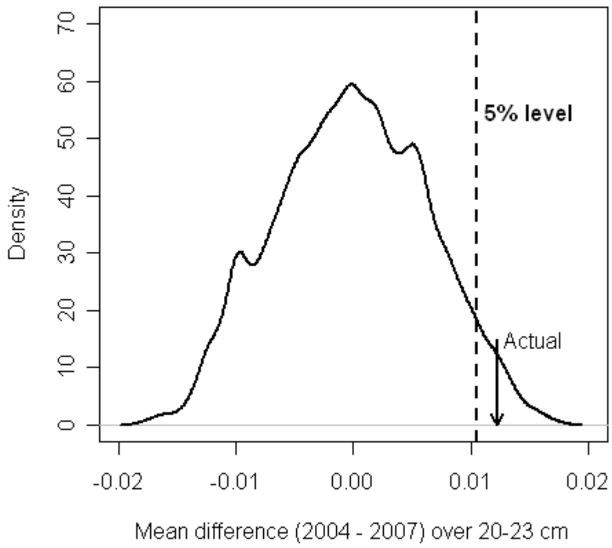

Figure 7: Randomisation distribution for the mean of the differences of the frequencies for 2005 from that for 2007 over lengths 20–23 cm. Frequencies made up by explicitly using a sex ratio of 1:1. Arrow marked "Actual" is the result for the actual data and is at the 100 -2.5% quantile.

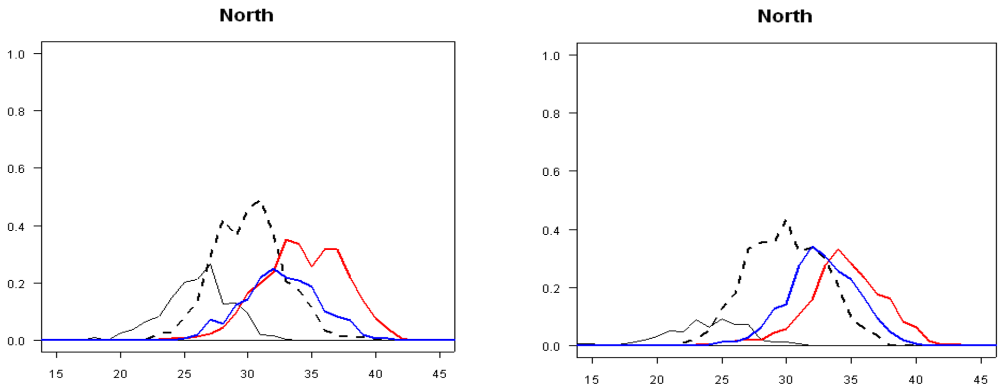

Figure 8: Length frequency of the northern part of the survey area (subareas 2 and 3) by gonad stage from the 2004 survey (left) compared to that from the 2007 (right). Frequencies made up by explicitly using a sex ratio of 1:1. Thin solid line, stage 1 (immature); dotted line, stages 2, 7, and 9 ("resting"); grey thick line, stages 3, 4, and female 5 (ripe and running ripe); thick solid line, stages 8, male 5, and female 6 (spent).

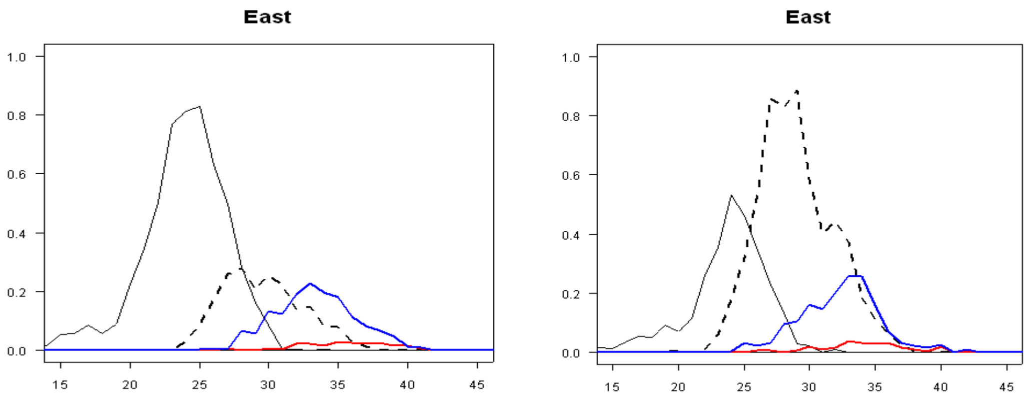

Figure 9: Length frequency of the eastern part of the survey area (subareas 4, 5, and 6) by gonad stage from the 2004 survey (left) compared to that from the 2007 (right). Frequencies made up by explicitly using a sex ratio of 1:1. Thin solid line, stage 1 (immature); dotted line, stages 2, 7, and 9 ("resting"); grey thick line, stages 3, 4, and female 5 (ripe and running ripe); thick solid line, stages 8, male 5, and female 6 (spent).

Appendix A: Generic mark-stratum analysis for acoustic surveys

The following provides an account of the estimation of abundance when using mark-classes and strata for a generic deepwater species, called DEEPWATER in what follows, with code “XXX”. In general, biomass is estimated separately for the flats and the seamounts. For the former, the acoustic data are classified into mark-types where marks equate approximately to echogram images. The mark classification schemes are a result of analyses of concurrent data collection from trawling and the echogram of the mark trawled on. The biomass of DEEPWATER in each mark-type is estimated from the backscatter for each mark, the proportion by number of DEEPWATER in that type (estimated by trawling), the mean acoustic cross-section (target strength) for the mix of species in that mark-type, and the mean weight of the DEEPWATER in that mark-type. These are then summed over each stratum, scaled up by the stratum area, and then summed over all strata.

Most seamounts (or isolated plumes) are surveyed using star transects and the biomass on each mount is estimated using the method of Doonan et al. (2003a). If there are too many seamounts to survey, seamounts are grouped into classes and a random selection within each is surveyed. The mean biomass is calculated for each seamount class, multiplied by the total number of seamounts in that class, and summed over all classes to give total biomass for all seamounts in the trawl survey area.

Seamounts

The total abundance for all seamounts (*Hills*), B_{Hills}, is given by:

$$\sum_{h}^{Hill-classes} N_h \overline{B}_h \ ,$$

where $\overline{B}_h$ is the mean DEEPWATER abundance on seamounts in the *h*-th seamount class, and N_h is the number of seamounts in the class. Each seamount abundance is estimated using Equation 1 above, where *i* indexes the seamount and there is only one mark-type used (plume = *m*). A ‘star’ transect pattern is used to survey most seamounts, and for this method the mean backscatter, $abscf_{i,plume}$ in $B_{i,plume}$ is over-sampled in the centre of the star and under-sampled at the edges. As most marks are usually entered in the middle of the star with relatively large sections of the transect outside the mark, the mean is biased high in relation to the area (taken from the two ends of the transect). To compensate for this effect, the mean backscatter for each transect is a weighted mean over all segments (10 pings in length) of the transect where the weights are proportional to the distance from the fifth ping in the segment to the centre of the star.

Appendix B: summary of trawl data

Table B1: Summary of wide-area abundance and hill mark ID tow details for TAN0709. All tows used the ratcatcher except hill tows, which used the orange roughy rough bottom trawl with video and transducer attached to the headline. Gear performance code range from 1=good to 3=poor and 4 abandoned.

Station number	Stratum	Date	Latitudes	Longitude	Depth (m)s	Gear performanc	Tow s peed (knots)	Distance towed (nm)	Mean headline height (m)	Distance between doors (m)
6	0031	7 Jul	42 52.78 S	176 27.54 W	838	1	3	1.49	2.8	114
7	0032	7 Jul	42 46.74 S	176 21.49 W	1138	1	2.7	1.35	2.8	116
8	0033	7 Jul	42 45.02 S	176 23.59 W	1215	4	2.9	1.37	2.8	-
9	0033	7 Jul	42 46.20 S	176 16.74 W	1218	1	3	1.47	2.8	120
10	0033	8 Jul	42 45.78 S	176 21.99 W	1185	1	2.9	1.51	2.8	121
11	0033	8 Jul	42 45.73 S	175 49.16 W	1236	1	2.9	1.51	2.6	120
12	0032	8 Jul	42 49.80 S	175 49.50 W	-	4	-	0.38	-	-
13	0032	8 Jul	42 50.46 S	175 51.06 W	1024	4	3	2.19	-	-
14	0032	8 Jul	42 50.75 S	175 48.94 W	1023	1	3	1.46	2.7	122
15	0031	8 Jul	42 54.99 S	175 44.58 W	894	1	3	1.5	2.7	123
16	0031	8 Jul	42 58.72 S	175 22.57 W	875	1	3	1.5	2.8	121.4
17	0031	8 Jul	43 05.89 S	175 09.35 W	835	1	3	1.51	2.7	116.4
18	0031	9 Jul	43 01.01 S	175 09.49 W	921	1	3	1.49	2.7	118.3
19	0032	9 Jul	42 57.63 S	175 12.61 W	956	1	3	1.51	2.7	122.8
20	0032	9 Jul	42 51.35 S	175 03.54 W	1132	1	3	1.5	2.7	115
21	0033	9 Jul	42 49.67 S	175 09.95 W	1199	1	3	1.54	2.6	115
23	0033	9 Jul	42 48.82 S	175 20.56 W	1214	1	3	1.5	2.7	119
24	0032	9 Jul	42 49.44 S	175 29.87 W	1105	1	2.8	1.5	2.7	116.3
43	0022	12 Jul	42 50.98 S	176 47.03 W	858	1	3	1.5	2.5	124
44	0021	12 Jul	42 52.05 S	176 40.61 W	830	1	3	1.5	2.5	120.6
45	0022	12 Jul	42 50.69 S	176 33.16 W	899	1	2.9	1.5	2.7	118.6
46	0023	12 Jul	42 46.29 S	176 38.22 W	1074	1	3	1.52	2.7	118
47	0024	12 Jul	42 41.98 S	176 40.60 W	1283	1	2.9	1.5	2.7	116.3
54	0023	13 Jul	42 46.04 S	176 46.91 W	1060	1	3	1.52	2.4	123
55	0024	13 Jul	42 42.95 S	176 54.56 W	1204	1	3	1.51	2.5	119
56	0022	14 Jul	42 49.44 S	176 54.34 W	910	1	3	1.51	2.6	119.2
57	0021	14 Jul	42 50.93 S	176 59.33 W	826	1	3	1.5	2.6	118
58	0023	14 Jul	42 47.91 S	176 59.66 W	963	1	2.9	1.5	2.6	120
59	0023	14 Jul	42 46.01 S	177 05.35 W	1034	1	3	1.53	2.6	-
60	0023	14 Jul	42 46.04 S	177 12.18 W	1027	1	3	1.49	2.5	114
61	0024	14 Jul	42 43.28 S	177 17.96 W	1178	1	3.2	1.55	2.6	120
62	0022	14 Jul	42 48.17 S	177 18.78 W	903	1	3	1.53	2.7	115.6
63	0022	14 Jul	42 48.10 S	177 06.02 W	940	1	3.1	1.53	2.7	119.2
64	0022	14 Jul	42 53.16 S	176 46.73 W	789	3	2.9	0.81	2.7	117
65		14 Jul	42 52.90 S	176 49.90 W	-	4	-	-	-	-
76	0021	15 Jul	42 52.51 S	176 44.81 W	811	1	3.1	1.51	2.6	119
77	CAMM	16 Jul	43 08.44 S	174 16.67 W	784	1	2.5	0.35	15	97
78	CAMM	16 Jul	43 08.42 S	174 16.63 W	-	1	2.5	0.84	15	74
79	CAMM	16 Jul	43 07.90 S	174 17.50 W	800	2	2.5	0.41	12	75
80	CAMM	16 Jul	43 08.01 S	174 16.73 W	795	-	-	0	-	-
81	SMIT	17 Jul	42 57.58 S	174 25.10 W	950	1	2.5	0.81	15	90
82	SMIT	17 Jul	42 57.83 S	174 24.34 W	950	1	2.5	0.34	12	60
83	SMIT	17 Jul	42 56.96 S	174 25.15 W	1039	1	2.5	0.14	15	62
85	0043	17 Jul	42 52.57 S	174 40.74 W	1184	1	3	1.5	2.8	114.5
86	0042	17 Jul	42 55.62 S	174 42.01 W	1076	1	3	1.52	2.8	123
87	0041	18 Jul	43 00.19 S	174 48.79 W	933	1	3	1.51	2.7	118.4
88	0041	18 Jul	43 06.90 S	174 42.30 W	875	1	3	1.48	2.7	119.8

Station number	Stratum	Date	Latitudes	Longitude	Depth (m)s	Gear performanc	Tow s peed (knots)	Distance towed (nm)	Mean headline height (m)	Distance between doors (m)
89	0042	18 Jul	42 59.41 S	174 31.26 W	1036	1	3	1.51	2.6	122
90	0043	18 Jul	43 02.93 S	174 14.05 W	1150	1	3	1.53	2.7	124
91	0043	18 Jul	43 07.10 S	173 52.75 W	1222	1	3	1.49	2.7	111
92	0042	18 Jul	43 17.51 S	174 04.13 W	1054	1	3	1.5	2.6	125.4
93	0052	18 Jul	43 22.42 S	173 57.41 W	1136	1	3	1.5	2.8	119.3
94	0053	18 Jul	43 25.89 S	173 55.42 W	1209	1	2.9	1.51	2.6	116.5
95	0041	18 Jul	43 17.93 S	174 38.54 W	835	1	3.1	1.52	2.5	119.8
96	0052	19 Jul	43 24.34 S	174 02.17 W	1060	1	3	1.51	2.4	123
97	0051	19 Jul	43 27.47 S	174 14.28 W	921	1	3	1.51	2.4	124.5
98	0051	20 Jul	43 38.71 S	174 12.98 W	958	1	3	1.52	2.6	125.6
99	0052	20 Jul	43 41.75 S	174 09.61 W	1087	1	3	1.48	2.6	120
100	0053	20 Jul	43 53.79 S	174 17.78 W	1158	1	2.9	1.5	2.7	122
101	0052	20 Jul	43 52.05 S	174 21.50 W	1070	1	3	1.5	2.7	120
102	0053	20 Jul	43 57.99 S	174 18.87 W	1185	1	3	1.51	2.8	123
103	0052	20 Jul	43 56.75 S	174 28.42 W	1018	1	3	1.56	2.6	122.4
104	0051	20 Jul	43 50.82 S	174 31.82 W	878	1	3	1.51	2.7	116.6
105	0051	20 Jul	43 52.63 S	174 37.63 W	843	2	3.1	1.51	2.6	118.1
106	0061	20 Jul	44 01.02 S	174 42.69 W	915	1	3.1	1.52	2.6	120
107	0062	21 Jul	44 01.15 S	174 30.67 W	1060	1	3	1.49	2.6	116
108	0063	21 Jul	44 05.55 S	174 29.29 W	1164	1	3.1	1.51	2.6	112.4
109	0062	21 Jul	44 05.74 S	174 43.55 W	1051	1	3	1.51	2.6	112
110	0062	22 Jul	44 11.93 S	174 43.07 W	1046	2	3	1.5	2.7	117
111	0063	22 Jul	44 14.12 S	174 40.44 W	1176	1	2.9	1.5	2.7	115
112	0062	22 Jul	44 21.58 S	174 51.13 W	1092	1	3	1.5	2.6	120.5
113	0063	22 Jul	44 22.98 S	174 48.62 W	1157	1	3	1.51	2.6	118.5
114	0061	22 Jul	44 23.54 S	175 00.02 W	855	2	3	1.49	2.5	120.8
115	0061	22 Jul	44 25.27 S	174 59.30 W	913	2	2.9	1.45	2.7	121
116	0063	22 Jul	44 29.09 S	174 53.74 W	1199	4	2.8	0.38	2.7	127

Appendix C: Summary of recorded species (TAN0709). Occurrence is the percentage of all tows (including tows additional to those for the trawl biomass survey) where the species was caught, and weight (kg) is the total catch from all tows.

Species code	Common name	Scientific name	Occurrence (%)	Weight (kg)
Fish, General				
ORH	Orange roughy	*Hoplostethus atlanticus*	79	23090.7
SSM	Slickhead, smallscaled brown	*Alepocephalus* sp.	40	2027.6
HJO	Johnson's cod	*Halargyreus johnsonii*	83	1805.2
SBI	Slickhead, bigscaled brown	*Alepocephalus australis*	58	1535
RIB	Ribaldo	*Mora moro*	33	722.5
BSL	Black slickhead	*Xenodermichthys copei*	29	395.4
SSO	Smooth oreo	*Pseudocyttus maculatus*	48	387.9
HOK	Hoki	*Macruronus novaezelandiae*	37	334
EPR	Robust cardinalfish	*Epigonus robustus*	55	161.7
SMC	Small-headed cod	*Lepidion microcephalus*	56	146
WOE	Warty oreo	*Allocyttus verrucosus*	27	111.5
VCO	Violet cod	*Antimora rostrata*	30	75.9
PSY	Psychrolutes	*Psychrolutes microporos*	18	47.6
LIN	Ling	*Genypterus blacodes*	5	37
TRS	Trachyscorpia capensis	*Trachyscorpia capensis*	15	36.6
SOR	Spiky oreo	*Neocyttus rhomboidalis*	20	33.1
SPE	Sea perch	*Helicolenus* spp.	10	31.9
HAK	Hake	*Merluccius australis*	4	31.4
BAT	Large headed slickhead	*Rouleina attrita*	3	23.8
CAX	White brotula	*Cataetyx* sp	11	11.7
GNO	Gadella norops	*Gadella norops*	20	10.7
DSS	Deepsea smelt	*Bathylagus* spp	35	10
PHO	Lighthouse fish	*Photichthys argenteus*	37	8.1
STA	Giant stargazer	*Kathetostoma giganteum*	1	7.3
TAR	Tarakihi	*Nemadactylus macropterus*	2	7.3
BOE	Black oreo	*Allocyttus niger*	4	5.8
EPT	Deepsea cardinalfish	*Epigonus telescopus*	1	4.6
ECR	Messmate fish	*Echiodon cryomargarites*	29	4.3
ZEL	Scalloped dealfish	*Zu elongatus*	1	4.2
LPA	Lampanyctus spp	*Lampanyctus* spp.	24	3.3
LDO	Lookdown dory	*Cyttus traversi*	3	3.2
LYC	Lyconus sp	*Lyconus* sp	3	3.2
BFE	Deepsea lizardfish	*Bathysaurus ferox*	3	3
MPH	Big-scale fish	Melamphaidae	21	2.9
TOP	Pale toadfish	*Ambophthalmos angustus*	2	2.4
ROS	Rotund cardinalfish	*Rosenblattia robusta*	18	2.2
LPD	Lampadena spp	*Lampadena* spp.	13	1.8
PDS	False frostfish	*Paradiplospinus gracilis*	3	1.8
RBM	Ray’s bream	*Brama brama*	1	1.8
RCO	Red cod	*Pseudophycis bachus*	1	1.8
SUS	Schedophilus sp	*Schedophilus* sp.	1	1.4
FRO	Frostfish	*Lepidopus caudatus*	2	1.3
AGI	Giant hatchetfish	*Argyropelecus gigas*	8	1.2
MRL	Moray cods	Muraenolepididae	1	1.2
NOR	Tubeshoulder	*Normichthys* sp	7	1.2
SRB	Southern rays bream	*Brama australis*	1	1.2
CHA	Viper fish	*Chauliodus sloani*	10	1

Species code	Common name	Scientific name	Occurrence (%)	Weight (kg)
IDI	Idiacanthus spp	*Idiacanthus* spp	7	1
MEL	Melanonus gracilis	*Melanonus gracilis*	6	1
MEZ	Melanonus zugmayeri	*Melanonus zugmayeri*	4	1
COT	Bonyskull toadfish	*Cottunculus nudus*	1	0.9
TUB	Tubbia tasmanica	*Tubbia tasmanica*	1	0.9
DIS	Discfish	*Diretmus argenteus*	6	0.8
LAN	Lantern fish	Myctophidae	7	0.8
TET	Squaretail	*Tetragonurus cuvieri*	1	0.8
OMI	Opostomias micripnus	*Opostomias micripnus*	2	0.7
CHX	Pink frogmouth	*Chaunax pictus*	3	0.6
LPS	Giant lepidion	*Lepidion schmidti*	2	0.6
SDE	Seadevil	*Cryptopsaras couesi*	1	0.6
ANO	Fangtooth	*Anoplogaster cornuta*	4	0.5
DIA	Diaphus spp	*Diaphus* spp.	5	0.5
TAL	Talismania longifilis	*Talismania longifilis*	1	0.5
BAN	Borostomias antarcticus	*Borostomias antarcticus*	1	0.4
BCR	Blue cusk eel	*Brotulotaenia crassa*	1	0.4
FIS	Fish		1	0.4
RHY	Common roughy	*Paratrachichthys trailli*	1	0.4
SFN	Spinyfin	*Diretmoides parini*	1	0.4
STE	Sternoptyx spp	*Sternoptyx* spp.	3	0.4
ABR	Shortsnouted lancetfish	*Alepisaurus brevirostris*	1	0.3
AST	Snaggletooths	Astronesthidae	2	0.3
CUB	Cubehead	*Cubiceps* spp.	2	0.3
GRC	Grenadier cod	*Tripterophycis gilchristi*	1	0.3
GYM	Gymnoscopelus spp	*Gymnoscopelus* spp.	2	0.3
LPH	Haplophryne mollis	*Haplophryne mollis*	1	0.3
NAN	Deepsea smelt	*Nansenia* spp	3	0.3
SRH	Silver roughy	*Hoplostethus mediterraneus*	2	0.3
HOW	Pelagic cardinalfish	*Howella brodiei*	1	0.2
LUC	Luciosudus sp	*Luciosudus* sp.	1	0.2
MEJ	Humpback anglerfish	*Melanocetus johnsonii*	2	0.2
MEN	Melanostomias spp	*Melanostomias* spp.	1	0.2
MST	Melanostomiidae	Melanostomiidae	1	0.2
SDI	Sternoptyx diaphana	*Sternoptyx diaphana*	1	0.2
SLK	Slickhead	Alepocephalidae	1	0.2
STO	Stomiatidae	*Stomias* spp	1	0.2
AHE	Common hatchetfish	*Argyropelecus hemigymnus*	1	0.1
BMO	Borostomias mononema	*Borostomias mononema*	1	0.1
CHM	Swallowers	Chiasmodontidae	1	0.1
HOL	Tubeshoulder	*Holtbyrnia* sp	1	0.1
RDE	Rhadinesthes decimus	*Rhadinesthes decimus*	1	0.1
SID	Tubeshoulders	Platytroctidae	1	0.1
MAL	Loosejaw	Malacosteidae	25	
PER	Persparsia kopua	*Persparsia kopua*	27	
Fish, Chimaeras				
RCH	Widenosed chimaera	*Rhinochimaera pacifica*	24	214.8
LCH	Long-nosed chimaera	*Harriotta raleighana*	34	112.2
GSP	Pale ghost shark	*Hydrolagus bemisi*	26	91.9
CHP	Chimaera, brown	*Chimaera* sp	20	81.5
HYP	Pointynose blue ghost shark	*Hydrolagus trolli*	2	16.8
GSH	Ghost shark	*Hydrolagus novaezealandiae*	2	7.5

Species code	Common name	Scientific name	Occurrence (%)	Weight (kg)
HYB	Black ghost shark	*Hydrolagus* sp	3	7.4
HHA	Smallspine spookfish	*Harriotta haeckeli*	2	3.7
Fish, Marine eels				
BEE	Basketwork eel	*Diastobranchus capensis*	74	2023.6
SBK	Spineback	*Notacanthus sexspinis*	59	153.3
SCO	Swollenhead conger	*Bassanago bulbiceps*	32	95.9
HCO	Hairy conger	*Bassanago hirsutus*	33	71.4
HAL	Abyssal halosaur	*Halosauropsis macrochir*	14	28
HPE	Common halosaur	*Halosaurus pectoralis*	9	27.1
SNE	Snubnosed eel	*Simenchelys parasiticus*	16	5.6
NOC	Notocanthus chemnitzi	*Notocanthus chemnitzi*	2	2.2
NEM	Slender snipe eel	*Nemichthys scolopaceus*	5	1.6
SAF	Grey cutthroat eel	*Synaphobranchus affinis*	3	0.4
AVO	Snipe eel	*Avocettina* spp.	1	0.2
NEX	Snipe eels	Nemichthyidae	1	0.1
Fish, Flatfish				
MAN	Finless flounder	*Neoachiropsetta milfordi*	25	29.2
Fish, Macrouridae				
CSU	Four-rayed rattail	*Coryphaenoides subserrulatus*	74	956.4
WHX	White rattail	*Trachyrincus aphyodes*	49	747.3
CSE	Serrulate rattail	*Coryphaenoides serrulatus*	73	551.2
CIN	Notable rattail	*Caelorinchus innotabilis*	74	377.6
CMA	Mahia rattail	*Caelorinchus matamua*	40	174.6
MCA	Ridge scaled rattail	*Macrourus carinatus*	45	173.8
CHY	Roughhead rattail	*Caelorinchus trachycarus*	40	158.2
JAV	Javelin fish	*Lepidorhynchus denticulatus*	35	144.8
CBA	Humpback rattail(slender rattail)	*Coryphaenoides dossenus*	57	128.6
CFA	Banded rattail	*Caelorinchus fasciatus*	23	31.9
CTR	Abyssal rattail	*Coryphaenoides striaturus*	24	30.1
CMU	Abyssal rattail	*Coryphaenoides murrayi*	16	27.2
CBI	Two saddle rattail	*Caelorinchus biclinozonalis*	2	26.5
CTH	Roughhead rattail	*Caelorinchus acanthiger*	27	25.4
CBO	Bollons rattail	*Caelorinchus bollonsi*	7	23.9
WHR	Unicorn rattail	*Trachyrincus longirostris*	17	17.7
NNA	Nezumia namatahi	*Nezumia namatahi*	37	10.6
CKA	Kaiyomaru rattail	*Caelorinchus kaiyomaru*	21	8.7
BJA	Black javelinfish	*Mesobius antipodum*	11	8.4
CKX	Spottyfaced rattails(roughhead)	*Caelorinchus trachycarus & C. acanthiger*	1	5.4
CMX	Coryphaenoides mcmillani	*Coryphaenoides mcmillani*	15	4.9
GAO	Filamentous rattail	*Gadomus aoteanus*	5	3.7
VNI	Blackspot rattail	*Ventrifossa nigromaculata*	12	1.8
TRX	Velvet rattail	*Trachonurus gagates*	4	0.8
CJX	Upturned snout rattail	*Caelorinchus mycterismus*	1	0.7
PIN	Pineapple rattail	*Idiolophorhynchus andriashevi*	1	0.4
BAC	Codheaded rattail	*Bathygadus cottoides*	1	0.2
NPU	Kuronezumia leonis	*Kuronezumia leonis*	1	0.2
TVI	Trachonurus villosus	*Trachonurus villosus*	1	0.2

Species code	Common name	Scientific name	Occurrence (%)	Weight (kg)
Fish, Rays & Skates				
PSK	Longnosed deepsea skate	*Bathyraja shuntovi*	11	43.1
DSK	Deepwater spiny skate(arctic skate)	*Amblyraja hyperborea*	4	42.9
SSK	Smooth skate	*Dipturus innominatus*	4	28
BTH	Bluntnose skates deepsea skates	*Notoraja* spp.	14	6.6
BTS	Notoraja spinifera	*Notoraja spinifera*	3	2.6
BTA	Notoraja asperula	*Notoraja asperula*	4	1.1
Fish, Sharks & Dogfish				
SND	Shovelnose spiny dogfish	*Deania calcea*	69	5181.2
ETB	Baxters lantern dogfish	*Etmopterus baxteri*	77	750.6
CYP	Centroscymnus crepidater	*Centroscymnus crepidater*	50	558.4
SOP	Pacific sleeper shark	*Somniosus pacificus*	1	450
CYO	Smooth skin dogfish	*Centroscymnus owstoni*	38	231.5
CSQ	Centrophorus squamosus	*Centrophorus squamosus*	14	120.7
APR	Catshark	*Apristurus* spp	24	56.8
BSH	Seal shark	*Dalatias licha*	3	23.6
SPD	Spiny dogfish	*Squalus acanthias*	2	20.2
ETM	Etmopterus sp	*Etmopterus* sp.	2	4.1
Crustacea, Crabs				
NEB	Neolithodes brodiei	*Neolithodes brodiei*	21	33.6
LMU	Lithodes murrayi	*Lithodes murrayi*	11	30.5
VIT	Deep sea spider crab	*Vitjazmaia latidactyla*	45	29.5
NEC	Nematocarcinus sp.	*Nematocarcinus* sp.	19	6.3
CVI	Two-spined crab	*Carcinoplax victoriensis*	4	0.6
CRB	Crab		1	0.4
PAG	Pagurid	*Paguroidea*	1	0.2
Crustacea, Decapod				
LHO	Lipkius holthuisi	*Lipkius holthuisi*	37	22.7
ACA	Acanthephyra spp	*Acanthephyra* spp.	12	2.7
APE	Acanthephyra pelagica	*Acanthephyra pelagica*	14	2
PED	Scarlet prawn	*Aristaeopsis edwardsiana*	7	1.2
PAS	Pasiphaea spp	*Pasiphaea* spp	9	1.1
ONO	Oplophorus novaezeelandiae	*Oplophorus novaezeelandiae*	3	0.5
ARI	Aristeus sp	*Aristeus* sp	2	0.4
FUN	Funchalia spp	*Funchalia* spp	2	0.4
NAT	*Natant decapod*		2	0.3
PBA	Pasiphaea barnardi	*Pasiphaea barnardi*	2	0.3
NAU	Notostomus auriculatus	*Notostomus auriculatus*	1	0.2
SER	Sergestes spp	*Sergestes* spp.	2	0.2
AFO	Royal red prawn	*Aristaeomorpha foliacea*	1	0.1
PTA	Deepwater prawn	*Pasiphaea aff. tarda*	1	0.1
Crustacea, General				
GNA	Gnathophausia sp	*Gnathophausia* sp	10	1.3
MYS	Mysid		2	0.3
ISO	Isopod		1	0.1
Crustacea, Lobster				
PLY	Polychelidae	*Polycheles* spp.	29	4.3

Species code	Common name	Scientific name	Occurrence (%)	Weight (kg)
Echinoderms				
BRG	Brisingida	*Brisingida*	48	103.4
EEX	Enypniastes eximia	*Enypniastes eximia*	9	86.7
HTH	Sea cucumber	*Holothurian unidentified*	36	53.7
TAM	Tam o shanter urchin	Echinothuriidae	27	49.5
PMO	Pseudostichopus mollis	*Pseudostichopus mollis*	19	23.9
ECT	Echinothuriidae (family)	Echinothuriidae (family)	23	19.5
GRM	Sea urchin	*Gracilechinus multidentatus*	9	14.6
DPP	Diplopteraster sp.	*Diplopteraster* sp.	6	5.7
ZOR	Rat-tail star	*Zoroaster* spp	7	2.6
GOR	Gorgonocephalus spp	*Gorgonocephalus* spp.	4	1.7
ODT	Pentagonal tooth-star	*Odontaster* spp	6	1.5
PAO	Pillsburiaster aoteanus	*Pillsburiaster aoteanus*	8	1.5
HTR	Starfish	*Hippasteria trojana*	1	1.2
SOT	Solaster torulatus	*Solaster torulatus*	2	1.1
ASR	*Asteroid (starfish)*		6	1
DMG	Dipsacaster magnificus	*Dipsacaster magnificus*	3	1
PNE	Proserpinaster neozelanicus	*Proserpinaster neozelanicus*	3	0.9
GPA	Sea urchin	*Goniocidaris parasol*	6	0.8
CPA	Pentagon star	*Ceramaster patagonicus*	2	0.7
PKN	Abyssal star	*Plutonaster knoxi*	2	0.7
CMP	Cheiraster monopedicellaris	*Cheiraster monopedicellaris*	1	0.4
LAG	Laetmogone spp.	*Laetmogone* spp.	2	0.4
PSI	Geometric star	*Psilaster acuminatus*	3	0.4
BES	Benthopecten spp.	*Benthopecten* spp.	2	0.3
CJA	Sun star	*Crossaster multispinus*	2	0.3
PRU	Pseudechinaster rubens	*Pseudechinaster rubens*	2	0.3
CMT	Feather star	*Comatulida*	1	0.2
HEC	Henricia compacta	*Henricia compacta*	1	0.1
OBE	Cidarid urchin	*Ogmocidaris benhami*	1	0.1
Molluscs, General				
MOL	*Molluscs*		2	0.2
Molluscs, Octopus				
OPI	Umbrella octopus	*Opisthoteuthis* spp.	5	12
OCT	Octopus	*Pinnoctopus cordiformis*	1	10.2
DWO	Deepwater octopus	*Graneledone* spp	8	5.1
Molluscs, Squid				
MIQ	Warty squid	*Moroteuthis ingens*	39	258.4
MRQ	Warty squid	*Moroteuthis robsoni*	13	35.5
TSQ	Todarodes filippovae	*Todarodes filippovae*	18	18.9
VSQ	Violet squid	*Histioteuthis* spp	10	4.1
OSQ	Octopoteuthiidae	Octopoteuthiidae	5	3.7
NOS	Nz southern arrow squid	*Nototodarus sloanii*	2	1.7
CHQ	Cranchiid squid	Cranchiidae	4	0.6
SQX	Squid		2	0.3
Molluscs, Univalves				
FMA	Fusitriton magellanicus	*Fusitriton magellanicus*	14	3.2
GVO	Golden volute	*Provocator mirabilis*	4	0.6
GAS	Gastropods	Gastropoda	1	0.2

Species code	Common name	Scientific name	Occurrence (%)	Weight (kg)
Cnidaria				
JFI	Jellyfish		17	49.3
ACS	Deepsea anemone	*Actinostolidae*	34	48.7
EPZ	Epizoanthus sp.	*Epizoanthus* sp.	53	12.4
HMT	Deepsea anemone	*Hormathiidae*	11	5.4
ANT	Anemones	Anthozoa	14	4.7
LLE	Bamboo coral	*Lepidisis* spp.	9	3.3
LIP	Deepsea anemone	*Liponema* spp.	5	3
STP	Solitary bowl coral	*Stephanocyathus platypus*	10	1.7
BOC	Deepsea anemone	*Bolocera* spp.	2	0.9
PNN	Purple sea pen	*Pennatula* spp.	3	0.6
THO	Bottlebrush coral	*Thouarella* spp.	1	0.5
HDR	Hydroid	Hydrozoa (Class)	2	0.3
LSE	Leiopathes secunda	*Leiopathes secunda*	1	0.3
BOO	Bamboo coral	*Keratoisis* spp.	1	0.2
COB	Black coral	Antipatharia (Order)	1	0.2
SOC	Soft coral	Alcyonacea (Order)	2	0.2
CAY	Caryophyllia spp	*Caryophyllia* spp.	1	0.1
CRE	White hydrocoral	*Calyptopora reticulata*	1	0.1
COF	Flabellum coral	*Flabellum* spp.	12	
Other				
ROK	Rocks stones	Geological specimens	14	32.1
SAL	Salps		3	3.8
PYC	Sea spiders	*Pycnogonida*	2	0.3
COZ	Bryozoan	Bryozoa (Phylum)	2	0.2
SPN	Sea pen		1	0.2
Porifera				
GLS	*Glass sponge*		9	3.1
ERE	Basket-weave horn sponge	*Euplectella regalis*	7	1.6
HYA	Floppy tubular sponge	*Hyalascus* sp.	2	1.1
ONG	Sponges	Porifera (phylum)	3	0.9
TLD	Furry oval sponge	*Tetilla leptoderma*	1	0.2
PHB	Grey fibrous massive sponge	*Phorbas* spp.	1	0.1
THN	Yoyo sponge	*Thenea novaezelandiae*	1	0.1
Worm, Polychaete				
POL	Polychaete	Polychaeta	1	0.1