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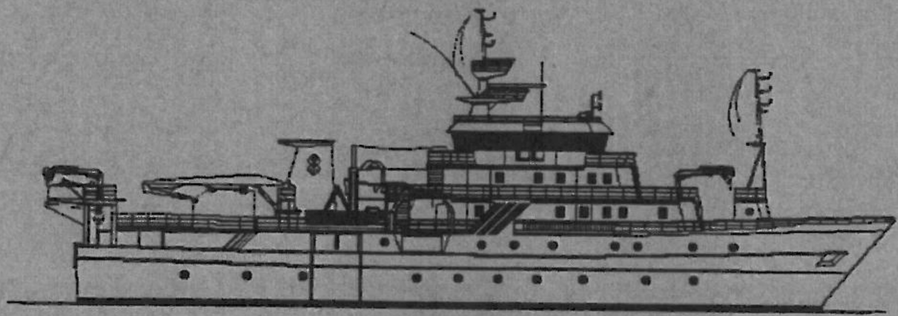

SURVEYS OF FISH RESOURCES OF NAMIBIA

Cruise Report No 4/98

Orange roughy survey
1 July – 25 July 1998

Ministry of Fisheries & Resources
Swakopmund, Namibia

Institute of Marine Research
Bergen, Norway

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Cruise Report No 4/98, Part 1

Orange roughy survey

1 July – 25 July 1998

by

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ABSTRACT

The second biomass assessment survey on orange roughy in Namibian waters took place from 1st to 25th July 1998. The survey was conducted with the *R.V Dr Fridtjof Nansen, FV Emanguluko* and *FV Southern Aquarius*. The objectives of the survey were to determine the distribution, mean density and abundance of orange roughy on three of the known fishing grounds (Johnies, Frankies, and Rix) and in areas adjacent to the aggregations. Further development of a suitable methodology for abundance estimations using acoustics was to be determined, including to establish if hull mounted transducers are suitable for surveying deep water species in Namibia.

The *RV Dr Fridtjof Nansen* undertook the acoustic surveying while most of the trawling was conducted by commercial vessels. Johnies was acoustically surveyed 6 times, Frankies 3 times and Rix 8 times. A total of 133 bottom trawl hauls were conducted by the two commercial vessels in two coverages, of which a total of 99 semi-randomised trawl hauls were used for swept-area purposes and all were used for acoustic target identification. A further 7 bottom, and 8 midwater trawl hauls were conducted by the *RV Dr. Fridtjof Nansen.*

Biological samples were collected and analysed from all of the trawl hauls. Orange roughy dominated the catches of the central areas of the grounds. A few large catches of orange roughy were made in the spawning aggregations, such that in total orange roughy made up 95 %, 63%, and 93% respectively of the catches for Johnies, Frankies, and Rix. The proportion of orange roughy in the catches decreased when moving away from the central areas of the fishing grounds. In the surrounding areas of the aggregation most catches were less than 1 tonnes and were dominated by species like black oreo (Allocyttus niger), hake (Merluccius capensis), and various species of grenadiers and rat-tails.

The sex ratio of orange roughy in the catches varied between coverages of the grounds, with Johnies having the proportion of 47 : 52 , Frankies 58 : 41, and Rix 43 : 56% males : females respectively, the remainder being juveniles. Length at 50 % maturity for females occurred at 21.3 cm at Johnies, 22.6 cm at Frankies, and at 26.7 cm at Rix. The 50%

maturity for males showed a similar 21.7 cm, 22.5 cm, and 27.0 cm for the same grounds. The level of spawing activity varied with time between grounds and between sexes within a ground. The highest proportion of running and spent males was found at Johnies, while highest proportion of spent females was found on the last day of the survey at Rix. There were differences in the development of the maturity stages between the first and second coverage of Frankies and Rix. At Johnies the proportion of running and spent females increased somewhat during the survey period but this was less pronounced for males.

Data on fish density (acoustic back-scatter and trawl catch rates) were analysed in several ways to obtain estimates of abundance. The merits of each method are discussed. A combination of acoustic to assess the density and biomass of roughy in spawing aggregations, and random swept-area trawling to estimate densities of roughy associated with, but outside of these aggregations may yield the most valid estimate of the total abundance. However, as each of these techniques has its own biases, combining the two may not be strictly appropriate.

The biomass for all three grounds, using largest survey area, was estimated by targeted acoustics to between 34 and 38 000 tonnes, (approximately 19 000 tonnes, 13 000 and 5 800 tonnes for Johnies, Frankies and Rix respectively). This estimate decreased to 16 000 tonnes when only the areas with confirmed catches were included in the calculations. This method produced the highest biomass estimate for the three grounds. Alternatively the biomass using the scrutinized method for the whole area of Johnies was estimated to be between 19 600 tonnes and 23 000 tonnes. This estimate decreased to between 1 400 tonnes and 7 000 tonnes when only the identified aggregations area were considered. The biomass estimate for the whole area of Frankies, using scrutinized acoustics method, was shown to be between 4 000 tonnes and 17 000 tonnes. This estimate decreased to 2 200 tonnes when calculations were done on the 3 aggregations only. The biomass estimate for Rix, using scrutinized method, was shown to be between 5 600 tonnes and 9 000 tonnes for the whole area and the verified aggregation area. The biomass for all three grounds using the scrutinized method was estimated to be between 9 500 tonnes and 35 700 tonnes. Combined Acoustic and swept area (outside strata 1) estimated biomass to 11 714 tonnes for Johnies and Frankies together. Trawlbased acoustics assessment method was tried for Johnies, and estimated orange roughy was 51 000 tonnes. The method is strongly dependant on the catch composition in all layers because of the low backscatter for orange roughy and that trawling is only in the bottom channel.

The biomass for the three grounds was calculated by using the swept area method, as 30 250 tonnes, of which 8 150 at Johnies, 2 400 tonnes at Frankies and 19 700 tonnes at Rix.

The limitations of the different methods are discussed, and emphasis is put on the value of the survey data as relative estimates indicating stock changes over time rather than giving an absolute estimation of biomass.

A number of experiments were to be conducted to assess the behaviour of orange roughy in order to estimate, and where possible, reduce, some of the major biases known to occur when surveying roughy acoustically or by trawling. Strong winds and high swells prevented surveywork for two days and caused surveying at reduced speed for another three days. Due to equipment failures many of the planned experiments could not be conducted.

Despite the rather poor weather conditions that were experienced throughout much of the survey, relative biomass estimates of comparable or better validity compared to 1997 were attained. Repeated coverages of the grounds, close co-operation between fishing and research vessel, and efficient utilisation of the technical equipment and scientific knowledge available ensured this.

CHAPTER 1 INTRODUCTION

1.1 Objectives

Overall research objectives

Deep sea fish species are a major focus of the Namibian fishing industry at present. This is a group of fish stocks about which little is known, both in Namibia and elsewhere. Owing to their high value, even stocks of a moderate size will be of large financial importance to Namibia. These species are however expected to be very slow growing, and hence will be highly susceptible to over-fishing.

The major species targeted by the Namibian deepwater industry at present is orange roughy, therefore research is directed primarily at this species. The fishery has expanded rapidly over the past three years and therefore it is critical that an index of abundance is established very quickly.

Various stock assessment techniques have been attempted elsewhere, but with limited success. The combination of trawl sampling and acoustic sampling compliments each other to some extent, and seem to offer the most promising hope of providing an accurate estimate of abundance.

Orange roughy occur in dense aggregations close to the sea bed in deep water as well as they occur at varying and low densities as demonstrated by trawl catches. They scatter acoustic signals poorly as they have an oil-filled swimbladder. Proven detected echoes are received from stooks of fish within aggregations, indicating the high density of these shoals, therefore the acustics could be a feasible tool for determining biomass of the shoals. Many of these characteristics are however expected to cause a series of challenges that will need to be investigated before a specifically adapted acoustics method can be used for providing absolute estimates.

An acoustic survey conducted in July 1997 on three of the aggregations known to occur within the Namibian EEZ showed promising results. The distribution could be clearly delineated, and assessed acoustically. Trawling enabled the successful identification of these shoals.

The current survey aimed to investigate some of the problems of assessing deep-water shoaling species while providing the second relative estimate of the abundance in the three most important areas of known orange roughy concentrations.

The *RV Dr Fridtjof Nansen* will not be available for surveys for many more years and a suitable methodology must be developed for local vessels. It is intended that the *RV Welwitchia* should participate in the 1999 survey in order to begin implementing the survey methodology to this vessel. This survey therefore continued to establish a survey technique that can be used by the *RV Welwitchia* to monitor the biomass of these species for management purposes.

As little acoustic research has previously been conducted on orange roughy aggregations in Namibia, this survey was necessarily experimental in nature. The objectives and methods detailed below were therefore adapted as the survey progressed.

The survey therefore had a number of objectives, of which the first was considered of primary importance:

1) To determine the distribution, mean density and abundance of three of the known spawning aggregations of orange roughy in order to obtain an index of abundance relative to the 1997 survey.

Objectives 2) to 5) were also considered of crucial importance, before objective 6) could be achieved:

2) To investigate the differences between swept-area (commercial) and acoustic estimates.
3) To determine the proportion of fish outside of aggregations.
4) To develop a suitable methodology to determine orange roughy abundance using acoustics combined with trawling.

5) To establish if hull-mounted and protruding keel mounted transducers are suitable for surveying deep water species, or if towed transducers will be required.

6) To reduce the biases in the current abundance estimates.

Four crucial aspects pertaining to objective 6) that needed specific investigation were:

7) To make preliminary investigations into orange roughy behaviour to indicate if the back-scattering properties of single orange roughy *in situ* may be observed.

8) To estimate the amount of fish in the bottom shadow zone and to investigate methods to reduce this bias.

9) To determine the species composition of aggregations and dispersions, especially of fish forming stooks/heaps at the bottom or dispersed layers in the pelagic zone.

10) To determine the true survey variability by conducting multiple consecutive acoustic and trawl assessments of a small aggregation.

Data collected during the above work was also to be analysed:

11)To investigate the spatial and temporal variability in density of each aggregation, both horizontally and vertically.

As part of one of the overall aims of the deep water fisheries research, and fisheries research in general, data was collected:

12)To determine length-frequency, length-weight relationship and maturity parameters of each aggregation.

13)To make an initial estimate of orange roughy conversion factor from whole fish to headed and gutted fish.

14)To investigate indications of gas in swim-bladders of juvenile orange roughy to verify if the gas is of a physiological character or an artefact.

15)To collect stomach contents, otoliths and tissue samples for later analysis

16)To collect data on deep-water fish species to update the FAO Species Identification Guide «The Living Marine Resources of Namibia»

17)To monitor the oceanographic conditions at the aggregations, specifically of profiles of temperature, dissolved oxygen, and salinity.

Finally, it is important that Namibian researchers are able to conduct future surveys without reliance on foreign expertise. The final objective was therefore seen as critical:

1) To train Namibians in the techniques used during the survey.
2) To train observers to grade 3 specialisation in deep water species, and introduce them to research surveying and management methods.

In addition to the above work on orange roughy, similar experiments were to be conducted on alfonsino, and possible other deep water species, if suitable distributions were found and time permitted.

While every effort was made to follow this survey plan, the Cruiseleader had the authority to change the survey as circumstances and opportunities arose.

1.2 Participation

The Scientific staff from the Institute of Marine Research (IMR) in Bergen, Norway were:

John Dalen	IMR Cruise Leader	1–25/7
Bjarte Kvinge	IMR Instrument Chief	1-25/7
Jarle Johannesen	IMR Instrument Technician	1–25/7

The scientific staff from the National Marine Information and Research Centre (NatMIRC), Swakopmund, Namibia were:

Dave Boyer	Namibian counterpart to cruise leader	1-25/7
Bjørn Staalesen	Namibian orange roughy scientist	1-25/7
Arved Staby	Namibian orange roughy scientist	1-25/7
Carola Kirchner	Namibian orange roughy scientist	13-25/7
Paul Kainge	Namibian demersal technician	1-25/7
Johnny Gamatham	Namibian demersal technical assistant	1-25/7
Malakia Shimhanda	Namibian demersal technical assistant	1-25/7
Shaun Wells	Namibian demersal technical assistant	1-25/7

The following Fisheries Observers from the Directorate of Operations (MFMR), Walvis Bay, Namibia participated:

Dave Kaanandunge	Namibian Fisheries observer No. 37	1-13/7
John Koita	Namibian Fisheries observer No. 22	1-13/7
Theopolina Uugulu	Namibian Fisheries observer No. 29	1-13/7
Frieda Iita	Namibian Fisheries Observer No. --	1-13/7
Patrick Elunga	Namibian Fisheries observer No. 15	13-25/7
Mathias Iyambo	Namibian Fisheries observer No. 38	13-25/7
Asser Katunahange	Namibian Fisheries observer No. 21	13-25/7
Johannes Sacheus	Namibian Fisheries observer No. 11	13-25/7

Several consultants were contracted to assist with the survey. These were:

Malcolm Clark	New Zealand consultant to MFMR	13-25/7
Ian Hampton	RSA acoustic consultant to DWFWG	13-25/7
Kent Carpenter	FAO Fish taxonomist	1–13/7
Jean D. le Garrec	Glomar manager	1–13/7
Benoit Caillart	Glomar scientist	1-13/7
Alan Rees	Gendor scientist	13-25/7

Table 1. Summary of acoustic surveys by area

Ground	Date & Time (UTC)	Survey number	Transect interval	Log No.	Depth range (m)	Latitudinal range (S °min)	Comments
Johnies	7/7 18h00 - 9/7 01h00	1	2 nm	2089 - 2322	500 - 1200	26°12' - 26°40'	
Johnies	9/7 02h30 - 9/7 15h00	1a	2 nm	2329 - 2408	600 - 1200	26°25' - 26°35'	6 extra transects in poor weather
Johnies	14/7 02h00 - 16/7 00h40	2	2 nm	2937 - 3227	500 - 1200	26°15' - 26°40'	17 transects
Johnies	16/7 01h20 - 17/7 11h50	3	0.5 nm	3234 - 3336	600 - 800	26°17' - 26°26'	19 transects
Johnies	17/7 00h30 - 17/7 19h40	4	0.5 nm	3373 - 3466	600 - 800	26°17.8' - 26°26.3'	
Johnies	17/7 23h40 - 18/7 05h40	5	0.25 nm	3482 - 3525	650 - 750	26°20.5' - 26°23'	12 transects
Johnies	18/7 08h30 - 18/7 11h10	6	0.25 nm	3531 - 3552	650 - 750	26°20.5'- 26°23'	8 transects
Frankies	4/7 16h00 - 6/7 00h30	1a	2 nm	1537 - 1786	500 - 900	24°15' - 24°49'	Includes extra transects added to F.Flats and 3 Sisters
Frankies	6/7 8h40 - 6/7 22h15	1b	2nm	1805 - 1924	550 - 850	24°20' - 24°44'	
Frankies	19/7 03h00 - 20/7 05h00	2	1 nm	3675 - 3891	550 - 850	24°21' - 24°45'	550-750 in north
21 Jump St.	20/7 06h00 - 20/7 9h30	3	1 nm	3894 - 3917	500 - 750	24°23.5' - 24°25.5'	3 transects between survey 2 transects
Frankies Flats	20/7 10h30 - 20/7 17h45	4	0.25	3923 - 3979	550 - 700	24°31'5 - 24°34'5	
3 Sisters	20/7 18h30 - 21/7 07h40	5	0.25	3984 - 4075	650 - 850	24°39' - 24°41'	
Rix	2/7 06h00-3/7 05h00	1	2 nm	1239 - 1393	500 - 1100	22°20' - 22°40'	
Rix	3/7	1a	2 nm	1404 - 1425	500 - 1200	22°29' - 22°31'	Extra transects to survey 1
Rix	21/7 22h15 - 22/7 18h30	2	1nm	4210 - 4338	500 - 1100	22°36' - 22°24'	
Rix	22/7 21h00 - 23/7 04h30	3	1nm	4348 - 4408	650 - 1000	22°27'5 - 22°36'5	
Rix	23/7 10h45 - 23/7 14h45	4	Random	4435 - 4460	650 - 900	22°27' - 22°34'	
Rix	23/7 14h50 - 23/7 17h40	5	Random	4460 - 4483	650 - 900	22°27' - 22°37'	
Rix	23/7 18h00 - 23/7 20h40	6	Random	4486 - 4508	650 - 900	22°30' - 22°37'	
Rix	23/7 21h00 - 23/7 23h40	7	Random	4510 - 4533	650 - 900	22°27'5 - 22°36'5	
Rix	24/7 00h10 - 24/7 03h00	8	Random	4536 - 4560	650 - 900	22°37' - 22°29'	

For the estimation of the biomass using swept area methods, the commercial vessel conducted 71, 35 and 27 random tow at Johnies, Frankies and Rix respectively (Table 2). Targeted trawl-hauls were not included in this method except from when in strata 1.

Table 2 Summary of swept-area surveys by area

Area	**Dates**	**No. of tows**	**Total ORH catch (kg)**	**Total catch (kg) (all species)**
Johnies	7/7 -9/7 14/7 - 20/7	71	186 441	195 276
Frankies	4/7 - 7/7 20/7 - 22/7	35	6 213	9 778
Rix	2/7 - 3/7 23/7 - 24/7	27	50 979	54 969

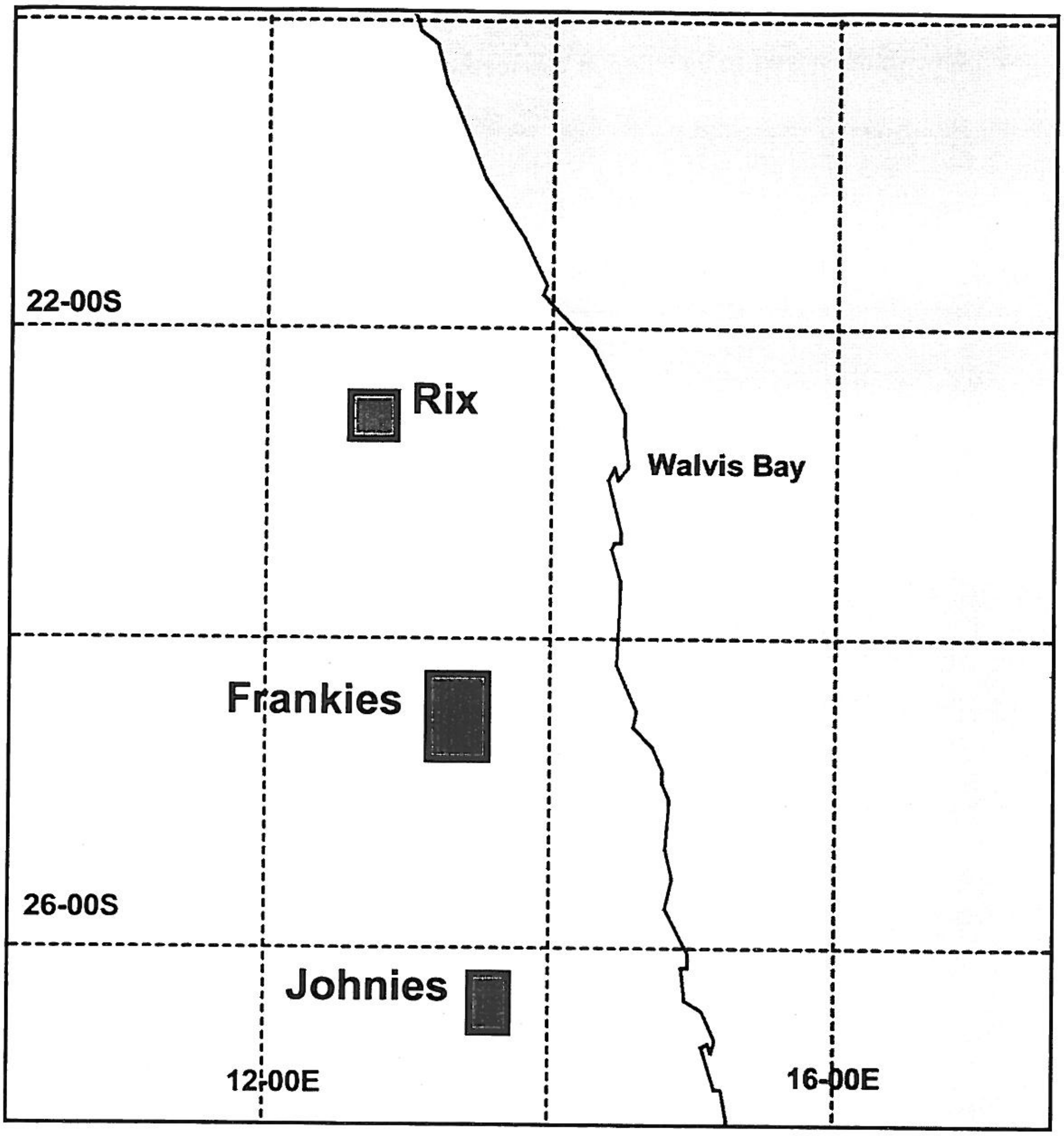


Figure 1 General locality map of the areas covered during the orange roughy survey, July 1998.

CHAPTER 2 MATERIALS AND METHODS

2.1 Hydrography and meteorology

A 'Sea Bird 911 plus' with an additional oxygen sensor was used for salinity, temperature and oxygen measurements. 'Sea Bird' software was used for data visualisation. Water samplers mounted on a 'Sea Bird Carousel' were activated at sea surface and just above bottom surface for collection of water samples. These were used for oxygen calibrations and conductivity corrections and thus were prior to analysis treated with standard 'Winkler' solutions.

During the first leg a total of 6, 8 and 12 CTDO stations were carried out on Rix, Frankies and Johnies respectively. On the second leg of the survey the number of CTDO stations was 9, 9, and 11 in the same ground sequence. In most cases a minimum of two stations were done on an east-west axis, thereby covering different bottom depths. The stations were semi-randomly spread out over the whole survey area, with the aim of having data collected in certain strata. In addition to CTDO data, water samples were also taken.

Wind speeds and directions were recorded throughout the survey (Appendix 15).

2.2 Trawl sampling

2.2.1 Vessels and gear

Trawling operations were carried out by both the *Dr Fridtjof Nansen* and the support commercial fishing vessel. The *RV Dr Fridtjof Nansen* used both bottom and midwater trawl gear mainly when targeting marks above the bottom, or when the commercial vessel was committed to other fishing tasks. Most trawling for the identification of acoustic 'targets', and all stratified random trawl survey work, was undertaken by the commercial vessels.

Two fishing vessels supported the survey this year:

- FV *Emanguluku*, a 35 m factory stern trawler, 433 GRT, 1400 kW power, operated by Glomar Fishing Ltd.

- FV *Southern Aquarius*, a 55 m factory stern trawler, 1154 GRT, 1850 kW power, operated by Gendor Fishing Ltd.

Both vessels deployed the same deep water net and gear set-up throughout the survey. The net is based on the standard New Zealand 'Arrow' rough bottom trawl, with cut-away lower wings. Sweep and bridle lengths were 100 m and 50 m respectively. A 'rockhopper' bobbin rig was used. The net had a 5-6 m headline height when towed at 3-3.5 knots. Wingspread is estimated at 15 m.

During targeting fishing for species identification, a fine-mesh liner was used inside the normal codend (110 mm mesh). A 19 mm mesh was used by *FV Emanguluku* throughout the survey, while a 40 mm mesh size was used by *Southern Aquarius* for the targeted trawls on Johnies. This liner was removed for trawl survey tows, in order to ensure gear performance (aimed at measuring catch rates of orange roughy, not at retaining small fish) was comparable to the 1997 survey.

2.2.2 Trawl catch sampling

The catches from all trawlhauls were sorted by species. Length, weight, and sex were collected for orange roughy, hake and oreos, and gonad stage data were collected for orange roughy. A random sample of about 200 individuals of each species was taken from each catch. When a large catch was made, several smaller samples were taken to ensure a representative sample structure was obtained. Some length frequency data were collected for other bycatch species on an irregular basis. The total number sampled, the sample weight and total weight of each species caught was recorded.

Small catches on the commercial vessels (less than approx. 500 kg) were fully sorted and weighed. When a large catch was taken, factory product figures from each tow were used to back-calculate the whole-round weight. Counts were taken of the number of trays of fish for each tow, multiplied by their average weight, and then again by the official conversion factor of 2.1. Although not used, some conversion factor trials were undertaken.

Samples of muscle were collected from Johnies and Frankies grounds for genetic (micro-satellite) work being carried out on orange roughy by NIWA; and further samples of muscle, liver, and heart were taken for genetic (allozyme) studies being carried out by Rau University, RSA. Otoliths were also taken from orange roughy sampled on *Dr Fridtjof Nansen.*

The catch-effort and biological information for each trawl was captured on standard NatMIRC data sheets. The information was transferred to the *Dr Fridtjof Nansen* where it was entered into various spreadsheets for analysis.

2.3 Biological analysis

The methodology followed during biological sampling is outlined in Appendix 16

2.3.1 Length frequency distribution

Length frequency data were weighted by the proportion of each trawlhaul sampled to represent the total catch per trawlhaul.

2.3.2 Reproductive stages

The reproductive stages follow the system commonly used in New Zealand and Australia after Pankhurst *et al* (1987):

Stage	**Female**	**Male**
1	Immature/resting	Immature/resting
2	Early maturation	Early maturation
3	Maturation	Maturation
4	Ripe	Ripe/running ripe
5	Running ripe	Spent
6	Spent	

The maturity data were adjusted for catch sizes. Ogives are expressed by the logistic growth curve.

(1)

$$\%maturity = \frac{100}{1+e^{(a+b*L_e)}}$$

and

(2)

$$L_{50} = \frac{-a}{b}$$

where a and b are estimated, L_e is the proportion mature in length category, and L_{50} is the length at 50 % maturity.

2.4 Acoustic

2.4.1 Survey grids

Acoustic surveying was conducted continuously throughout the cruise. Separate coverages were run with east-west transects, for most coverages in a semi-randomized stratified design with average spacing within strata. Strata were pre-selected, partly based on prior knowledge of fishing effort and hence expected fish density, and partly on depth. Average transect spacing varied beteen 0.5 nm for high density strata and 2.0 nm for fringe strata.

A summary of the various surveys that were conducted during this cruise is presented in Table 1.

Johnies

Johnies was surveyed 6 times in total. Two initial surveys were conducted to determine the distribution and behaviour of orange roughy. These had equally-spaced transects at 2 nm intervals.

Survey 1 covered the same strata as defined during the 1997 survey, plus the area to the southwest of these strata where considerable commercial activity had been targeted during the first 6 months of 1998 (Figure 3 and Appendix 26).

Additional transects were interspersed between these transects in the main area of distribution, but as weather conditions were particularly poor the data collected from these transects were not used in the data analysis. Indeed, these additional transects were eventually abandoned as signal attenuation caused by air bubbles was so severe, even below the protruding keel transducer.

Survey 2 was conducted at the beginning of the second part of the cruise during ideal weather conditions. Transects with a 2 nm spacing were again used, the transects being offset by 1 nm from the first survey. The same area was surveyed as in survey 1, but the north-western deep area was also surveyed.

Surveys 3 and 4 concentrated on the main area of distribution, essentially the centre of Johnies.Transects were set 0.5 nm apart, the second set of transects being offset by 0.25 nm from the first transects. These provided a more detailed description of the area of distribution of aggregations and therefore it was possible to conduct Surveys 5 and 6 closely around these aggregations at 0.25 nm spacing.

Frankies

As with Johnies, Frankies was surveyed twice to determine the distribution of roughy (Figure 3 and Appendix 27). Frankies Flats and Three Sisters had a number of aggregations so these two areas were surveyed more intensively in second leg, using 0.25 nm transect spacing. Little was found on 21 Jump St. in first leg, so only a brief repeat survey of this area was made.

Trawling on aggregations were generally only carried out after acoustic surveys had been completed. This was done to allow the aggregations to distribute naturally on the ground, without disturbance from trawling activities.

Rix

An initial survey was conducted on Rix at the beginning of the survey using 2 nm transect spacing. As the spawning activity of the orange roughy at Rix was less developed than Johnnies, and due to the distance between the grounds, Rix was only surveyed again at the end of the survey period (Figure 3 and Appendix 28).

In the second leg of the survey commercial vessels only moved off Rix as the *Dr Fridtjof Nansen* arrived. By the time the repeated intense surveys were conducted the commercial vessels had been off the ground for more than 24 hours.

Prior to the survey, commercial activity had been concentrated in strata 1. An area with several aggregations was found several miles south of the strata 1. The survey area with narrow spacing between transects was therefore extended into the southern part of Strata 2. Thus surveying of the central part of Rix took more time than anticipated.

The second and third coverage of Rix used transects spaced at 1 nm, the third coverage being offset by 0.5 nm to the second. Then 5 repeated coverages were conducted on the area of aggregations; the central quota area plus about 5 nm to the south and west. Transects were randomly selected to be able to do variance calculations.

2.4.2 Hardware

RV Dr. Fridtjof Nansen was equipped with two Simrad EK 500 echo sounders. During this survey they were recording at 18 and 38 kHz respectively. The 18 kHz transducer was hull mounted and had an opening angle of 10.9 °, while the 38 kHz transducer had an opening angle of 6.8 ° and was mounted on a protruding keel which was positioned 2.5 m below the hull throughout the survey. Echosounder settings are listed in Appendix 30. The latest echo sounder calibration prior to the survey was conducted on the 17 September 1997 before the survey while in August 98 after the survey appendix 30). Acoustic data were logged over a phased range of 500 m such that bottom signal was always recorded. The fixed phase range was changed manually. The depth intervals covered were from 500 to 1200 m at Johnies, between 500 and 850 m at Frankies, and from 500 to 1100 m at Rix.

2.4.3 Data processing

The Bergen Echo Integrator (BEI) was used to integrate the acoustic area backscattering coefficient (s_A), and to scrutinize the echograms in 5 nm units. The threshold used during scrutinization and echogram interpretation was -76 dB. Shoals of orange roughy were identified based on prior knowledge and targeted trawls, and isolated in a layer drawn only to contain the shoals, towards the bottom channel. All scrutinized data was stored in the BEI database with a resolution of 0.1 nm horizontally and 10 m vertically. Relevant data was then extracted, and exported to Excel for post processing. During post processing s_A values of the 10 m bottom channel directly underneath each orange roughy shoal were assumed to be orange roughy and were added to each shoal using the 0.1 nm values to get the total s_A value for the shoal.

The following relations were applied to convert s_A-values (mean integrator value per unit area) to numbers of fish:

(3) $$TS = 10 \log (\sigma/4\pi) = 20 \log L - 81 \ [dB]$$

(4) $$\sigma = 1/(10^7 * L^{-2})$$

(5) $$n = s_A * A * (1/\sigma) = s_A * A * 10^7 * L^{-2}$$

where TS is the average acoustic target strength of one individual fish, *L* is the length of the fish, expressed in centimeters, σ is the backscattering cross section of a single fish and A is the area of the strata in question. The TS used originates from investigations carried out in Tasmania (Kloser, R., et.al. 1997) The amount of backscattering (σ) of other species was derived from the proportion of that species frequency and their specific TS.

Back scattering data were allocated to orange roughy using several different methods. These are discussed in some detail below. The first two methods; targeted acoustics and scrutinized acoustics, yielded mean s_A values per transect, from which mean s_A value per coverage was calculated, and hence numbers of fish and biomass (Appendix 25). In the third method, trawl based acoustics, the acoustic data were used to calculate mass of fish per interval, and then mass per strata and ground were calculated. Finally, the swept area calculated biomass as per standard swept-area methods.

2.5 *Assessment Methodology*

2.5.1 Targeted acoustics

Aggregations of roughy were identified from the acoustic data based on their acoustic appearance, usually supported by targeted trawlhauls. As a general rule, only targets that could be identified with some reasonable level of confidence as pure orange roughy were included in the estimation of density with this method. Targets with a mixed species composition, even if orange roughy did form the major proportion, were not included as the mean backscattering cross-section from the topical orange roughy distributions was considerably lower (1/10) compared to the other species with their occuring size distributions (except compared to hake - see below).

The s_A values of each aggregation were recorded from the BEI. Due to the particular configuration of the BEI, the pelagic component of the aggregation was separated from other targets using the «school-box» module, while the s_A of the part of the aggregation in the bottom 10 m channel was estimated by excluding all other targets.

The mean s_A values was calculated for each transect:

(6)

$$\overline{S_A} transect = \sum s_A[ORH] / n$$

Where s_A[ORH] = the s_A value allocated to orange roughy for each interval

and n = transect length

The mean s_A for the entire survey is calculated weighting each s_A value/transect by transect length, as follows:

(7)

$$\overline{S_A} survey = \overline{S_A} transect * n / \sum n$$

The mean s_A for each survey was then calculated and hence the total biomass estimate derived. A description of the formulas used for the method is given in Appendix 29.

2.5.2 Scrutinized acoustics

The echo abundance (s_A values) derived from the echosounder bottom and near-bottom community were allocated to various groups of organisms based on both their absolute and relative (inter-group) comparison) s_A values, and their topical appearance on the echograms. They were as follows:

- Orange roughy
- Hake
- Other demersal species (mainly sharks, rat-tails, oreos)
- Mesopelagic species (including mainly myctophids, prawns, and zooplankton)
- Other pelagics (mainly pomfrets)

Mesopelagic species, other pelagics, orange roughy aggregations and dispersed hake tended to have characteristic acoustic appearances, which after a few trawls to confirm the species composition, could be allocated to their categories by visual examination of the acoustic echograms.

More dispersed targets, especially between the depths of about 600 m and 1000 m could not be identified to species or species group from the echograms. These allocations were largely based on the species composition identification in the vicinity, particularly of trawls taken at a similar depth.

As orange roughy has a much lower target strength than the other species, the s_A values attributed to roughy could not be allocated pro rata to the trawl catch composition. The roughy component of the total s_A values were very crudely estimated from the tables in Appendix 25, based on the target strength of roughy and other species used in the 1997 survey report (Huse, I. et.al, 1997).

The initial coverage of all three grounds was conducted with little knowledge about the appearance of roughy aggregations or dispersions. As a result, the targeted and scrutinised methods could not be applied. Therefore the trawlbased method was used for these surveys.

2.5.3 Trawl sample based acoustics

This method tried to allocate the roughy s_A component proportional to the trawl sample composition. The total s_A of the bottom 10 m channel was averaged in each stratum. This was then allocated to the various species or species-groups according to the mean species composition of all random trawls in that strata, corrected according to the following:

The survey echograms were checked for Orange Roughy aggregations in the pelagic zone. In cases where the mark was identified as Orange Roughy the s_A-values were recorded for every five nautical miles. For the bottom zone (10m) all s_A-values for demersal species were recorded for every five nautical miles.

Pelagic zone:- Orange roughy was assumed to occur only in aggregations in the pelagic zone (more than 10 m from the bottom). Therefore s_A values of the pelagic component redorded using the «targeted acoustics» method were used in this analysis.The s_A-values were converted to mean scattering cross-section per kg of Orange Roughy $(\overline{\sigma}_{kg})_{ORH}$ for every five nautical miles using Eq. (6) Appendix 29. (All zero s_A-values were included). Weight of Orange Roughy/nm^2 for every five nautical miles was obtained using Equation A29.1. A mean weight of Orange Roughy/nm^2 ($(\overline{\rho}_{ORH})_{Pel}$) and the variance thereon ($Var(\overline{\rho}_{ORH})_{Pel}$) was obtained for every stratum.

Bottom zone:- The weight of Orange Roughy/nm^2 (ρ_{ORH}) for every five nautical miles was determined by using random trawl information (viz. the mean weight for each species (Orange Roughy, hake, rat-tails, sharks and Oreo dories) in a haul for every stratum) and using equation A29.1 A mean weight of Orange Roughy/nm^2 ($(\overline{\rho}_{ORH})_{Bot}$) and the variance thereon ($Var(\overline{\rho}_{ORH})_{Bot}$) was obtained for every stratum.

To obtain a mean weight of Orange Roughy/nm^2 ($(\overline{\rho}_{ORH})_{Com}$) and a variance ($Var(\overline{\rho}_{ORH})_{Com}$) for both zones the mean and the variance of the mean of the pelagic and the bottom zone were added:

(8)

$$(\bar{\rho}_{ORH})_{Com} = (\bar{\rho}_{ORH})_{Pel} + (\bar{\rho}_{ORH})_{Bot}$$

$$Var(\bar{\rho}_{ORH})_{Com} = Var(\bar{\rho}_{ORH})_{Pel} + Var(\bar{\rho}_{ORH})_{Bot}$$

Note: The variance of the mean is the standard error squared.

The biomass for each stratum (B_{ORH}(h)) was determined:

(9) $$B_{ORH}(h) = A(h) * (\bar{\rho}_{ORH})_{Com}(h)$$

where A is the area of the stratum and (h) denotes the stratum.
The variance of the biomass was determined by

(10) $$Var(B_{ORH})(h) = Var(\bar{\rho}_{ORH})(h) * A^2(h)$$

To obtain the total biomass and variance on the biomass of the ground was estimated by using the following equations:

(11) $$B_{ORH} = \sum_{h=1}^{10} B_{ORH}(h)$$

(12) $$Var(B_{ORH}) = \sum_{h=1}^{10} Var(B_{ORH})(h)$$

2.5.4 Swept area

Random trawl survey design

A two-phase stratified random survey design (Francis 1984) was used on Johnies, but lack of time prevented this on the other two grounds, where a single phase survey was carried out. The number and distribution of trawls between strata was determined by the time available, results of last year's survey, and the need to cover a wider area than that of solely the known aggregations to reduce risks of missing fish distribution. The positions of the random tows were generated by a randomisation programme (NIWA random station programme) applied to each stratum. Tows were separated by 2 nm. The random position was designated as the vessel position at the start of the tow when the trawl started fishing on the bottom. The direction of the tow was generally along the depth contour where practical, in a north-south orientation specified by the scientists, but the skipper's discretion, weather, and the nature of the bottom also determined the direction of each tow. The duration of each trawl was approximately 30 minutes or 1.5 nm on the bottom.

The *FV Emanguluku* carried out a number of random trawl shots on the three grounds. This provided very useful information on distribution and relative abundance, but these data have not generally been used in swept-area analyses since they were conducted with innerliner in the trawl. It was felt that the fishing power of *FV Emanguluku* and *FV Southern Aquarius* could differ, and combining results would not be valid. The difference in timing of the vessels fishing on the different grounds, and the poor weather during the first half encountered by *FV Emanguluku* (which could reduce trawling efficiency) might also confuse results. Therefore, only trawls carried out by *FV Southern Aquarius* have been used.

2.5.5 Trawl survey stratification

Stratification of each fishing ground was based on the survey design in 1997 in which each ground was divided into six strata. There was a core region (stratum 1) where high catch rates by commercial vessels had been recorded during 1994-97, or during the 1997 survey. This stratum was designed to cover the area of main aggregations, and so its position could differ slightly between surveys. Tows in this stratum, which is by definition small and tight around the known area of high density, were not selected by random position, but involved an element of trawling on known tow lines (e.g. Three Sisters), or where fish aggregations were expected. A surrounding buffer zone (stratum 2) was defined where small aggregations might be expected, with variable catch rates. Additional strata were wrapped around these, both north and south at the known optimal depth range (strata 3 and 4), as well as shallower (stratum 5) and deeper (stratum 6) to ensure that the total likely area of orange roughy distribution was covered, and to minimise the risk of later finding aggregations outside the survey area. Stratification was modified for the second half of the survey, using information about fish distribution obtained from the first half of the survey, as well as from commercial fishing data from 1997-98, and improved knowledge of bathymetry. At Johnies, additional strata (9 and 10) were added in deeper water, and to the south. Stratification at Frankies was unchanged, but at Rix strata 2 and 6 were further subdivided (Figure 4).

Johnies:

1 High density area, defined approximately by latitude and longitude, between depths of 640-680 m

2 Buffer zone, 600 - 700 m

3 North area, 600-700 m

4 South area, 600-700 m

5 Inside stratum, 500-600 m

6 Outside, central stratum, 700-900 m

7 Outside, northern stratum, 700-900 m

8 Outside, southern stratum, 700-900 m

9 Out-outside, central-southern stratum, 900-1100 m

10 Southern region, 600-900 m

Frankies

1 High density areas:

1a) Three Sisters (650-800m)

1b) Frankies Flat (550-700m)

1c) 21 Jump St (550-650m)

2 Buffer zone, 550-700m

3 North area, 550-700m

4 South area, 550-700m

5 Inside stratum, 500-550m

6 Outside stratum, 700-900m

Due to time constraints, only strata 1 (a, b, c), 2, 3, and 6 were surveyed.

Rix

1 Northwest Box 700-850 m

2n Buffer zone, northern area, 550-900 m

2s Buffer zone, southern area, 550-900 m

3 Northern region, 550-900m

4	Southern region, 550-900 m
5	Inside stratum, 500-550 m
6n	Outside area, central-northern, 900-1000 m
6s	Outside area, central southern, 900-1000 m
7	Outside area, northern section, 900-1000 m
8	Outside area, southern section, 900-1000 m

Due to time constraints, only strata 1, 2n, 2s, and 6 were trawled.

2.5.6 Abundance estimation

Biomass indices were calculated for the survey area from random trawl data using standard area-swept methodology (after Francis 1981). Biomass, and its standard error, were calculated from the following formulae:

$$(13) \quad B = \Sigma (X_i a_i) / cb$$

$$(14) \quad S_B = \sqrt{(\Sigma s_i^2 a_i^2)} / c^2 b^2$$

where B is biomass (t), X_i is the mean catch rate (kg.km^{-1}) in stratum i, a_i is the area of stratum i (km^2), b is the width swept by the trawl gear, 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, s_i is the standard error of X_i.

The coefficient of variation (CV) is a measure of the precision of the biomass estimate, and is calculated by:

$$(15) \quad CV = S_B / B * 100$$

Strata areas were defined once detailed bathymetry was confirmed, and random trawl stations were generated. The mean catch rate from trawls (note target trawls were not included) was applied to the area of these strata. A minimum of two trawls per stratum was required. No correction is made for possible herding by the trawl gear, or escapement of fish from the path of the trawl. It is assumed that all fish in the water column of height equal to that of the head rope above the trawl path are caught by the gear (i.e. $c = 1$) The effective area of bottom swept by the trawl (b) has been taken as the distance between the wing-ends.

Biomass index values presented in this report have been derived from the NIWA 'PC-biomass' programme, written in 'C'. Note that it uses km as its distance and area inputs, and so the results given in later sections have been converted back to nautical mile units. The rounding involved in this gives very minor variations in the results.

2.5.7 Acoustic/swept area

This method takes the biomass results from method 1, based on identified aggregations of orange roughy, and adds to it the biomass estimated from trawlhauls over the area of lower fish density where trawling may be a more effective sampling tool than acoustics. The area-swept method is used as described above, but trawlhauls which towed into the aggregations identified from acoustics were excluded.

Plots were made of the distribution of aggregations identified by acoustics, and of trawl lines and catch rates. This enabled recognition of where trawlhauls towed into an aggregation.

Where all trawlhauls in a stratum encountered aggregations, then the entire stratum was removed from the analysis. If only a few trawlhauls hit the aggregations, then these were removed, and the area of the stratum was recalculated (decreased) to account for the area covered by the aggregations

2.6 Experiments

2.6.1 Repeated surveys

On the last day of the survey, after completion of two broad surveys at Rix at 1 nm transect spacing (Surveys 2 and 3, Table 1), the area between 22° 27 S and 22° 37S (where the highest densities had been found on surveys 2 and 3), was surveyed repeatedly on 5 independently randomised grids. The grids consisted of 5 transects each, running between

650 and 900m depth. This was done to investigate between-survey variances and test the practicality of conducting random-transect acoustic surveys on roughy.

Randomisation of the transect spacing was done by dividing the latitudinal distance (10 miles) into 50 notional strips 0.2 miles wide, and choosing 5 strips at random for each survey. The choice of strips had somewhat arbitrary restriction that the minimum distance allowed between adjacent strips in any one survey was 0.4 miles (i.e. 2 strips). This produced a series of independently randomised grids with restrictions on spacing within grids, but not between grids.

The surveys were run continuously for 17 hours in weather which although poor, was not bad enough to degrade the results significantly.

2.6.2 Dropped sonde

A 38 kHz single-beam transducer was lowered into a roughy aggregation while the *R.V.Dr.Fridtjof Nansen* was drifting. The transducer was lowered in 50 m depth-intervals and the acoustics signal recorded for approximately 5 minutes at each interval. The EK500 was set to simulated speed of 10 knots, and to integrate at 1 nm simulated distance intervals.

This experienced was tried once.

2.6.3 Observations of fish behaviour during trawling

The *F.V.Southern Aquarius* deployed her bottom trawl net. The *R.V.Dr.Fridtjof Nansen* sailed approximately above the *F.V.Southern Aquarius* trawl net and recorded the acoustic signal on both the 38 and 18 kHz systems of the EK500, the latter to avoid interference from *FV Southern Aquarius's* 50 kHz netmonitor. This experiment was only attempted once.

CHAPTER 3 RESULTS

3.1 *Relevant conditions*

3.1.1 Hydrography

Temperature, salinity and oxygen profiles were established for aggregation areas in particular (**App. 1 – 6** for Johnies, **App. 7 – 10** for Frankies and **App. 11-14** for Rix). Bottom temperature varied between 3 to 6 ^{0}C in the areas. Salinity at deeper levels were stable around 34.5 ‰. Oxygen levels in the bottom layers were between 1 and 4 ml/l. On all three grounds there were decreases in oxygen levels down to approximately 400, and the level increased again at approximately 600 m and deeper. Comparison between water bottle sample and oxygen meter on the CTDO showed a 9.3 % average difference between the two. The bottlesamples had the higher value, possibly due to airbubbles in the glassbottle the sample was stored in. The relative difference between CTDO and bottles were quite stable.

3.1.2 Meteorology

During the cruise the wind (Appendix 15) and the swells affected the acoustic sampling and the trawling to the extent that all together 3 days were conducted at reduced speed and 2 days were lost for surveying.

3.1.3 Sound absorption

The sound velocity and absorption for three stations are given in Appendix 31 and Appendix 32. The sound velocity at 750 m was estimated to 1481 m/s at 750 m and the absorption factor (α) was estimated to 9.53 at 750 m (from station 721 and station 741). The Simrad EK500 was set with an absorption of 10 dB/km throughout the survey. The difference between actual (9.53 dB/km from st 721 and st741) and set (10.0 dB/km) absorption of 0.47 dB gives a 11 % correction to the s_A values obtained in the survey.

3.1.4 Catch composition

A total of 148 trawls was made by the three vessels during the survey. These were a combination of targeted trawls directed onto acoustic marks as observed and recorded by scientists on *Dr Fridtjof Nansen*, and random trawls for the stratified random trawl survey.

The distribution of trawls on the three grounds is shown in Figure 3. The numbers of trawls on the three grounds by the vessels is detailed below **Table 3** (R=random, T=target, PT=pelagic trawl, BT=bottom trawl):

Table 3 Trawls per area per vessel (R=random, T=targeted)

Area	Trawl type	*Emanguluku*	*Southern Aquarius*	*Dr Fridtjof Nansen*	
				PT	BT
Johnies	R	10	33		
	T	10	18	2	5
Frankies	R	13	22		
	T	0	0	3	2
Rix	R	11	10		
	T	0	6	3	0
Total		**44**	**89**	**8**	**7**

Trawl station and catch details for each tow are attached as Appendix 17. A full list of all species caught is given in Appendix 31. The *Dr Fridtjof Nansen* used different trawl gear, and fished in a different manner to the commercial vessels, and so below we describe species catch from the commercial trawls only.

The total catch of all species was about 278 100 kg. Orange roughy was the main species caught on all grounds, and comprised 94% of the total. Hake was also frequently caught, with catches amounting to 5 700 kg. Sharks (a number of species of deepwater dogfish) were also common in some areas. The catch of orange roughy and the other main species or groups is summarized in Table 4:

Table 4 Total catch of the main groups of fish (in kg, percentage of total catch in parentheses) on the three survey grounds.

Species	Johnies	Frankies	Rix
Orange roughy	204 307 (95.9%)	6 214 (63.5%)	51 061 (92.7%)
Deepwater hake[1]	3 357 (1.6%)	1 828 (18.7%	580 (1.0%)
Oreos[2]	878 (0.4%)	343 (3.5%)	1 432 (2.6%)
Sharks[3]	1 868 (0.9%)	831 (8.5%)	5 340 (9.7%)
Rat-tails[4]	1 279 (0.6%)	139 (1.4%)	76 (0.1%)
Total catch	213 063 kg	9 779 kg	55 053 kg

[1] All *Merlucchius paradoxus* [2] Primarily *Allocyttus verrucosus*
[3] Primarily *Deania calcea, Centroscyllium fabricii, Centroscymnus crepidater*
[4] Primarily *Coelorhinchus acanthiger, Nezumia micronychodon*

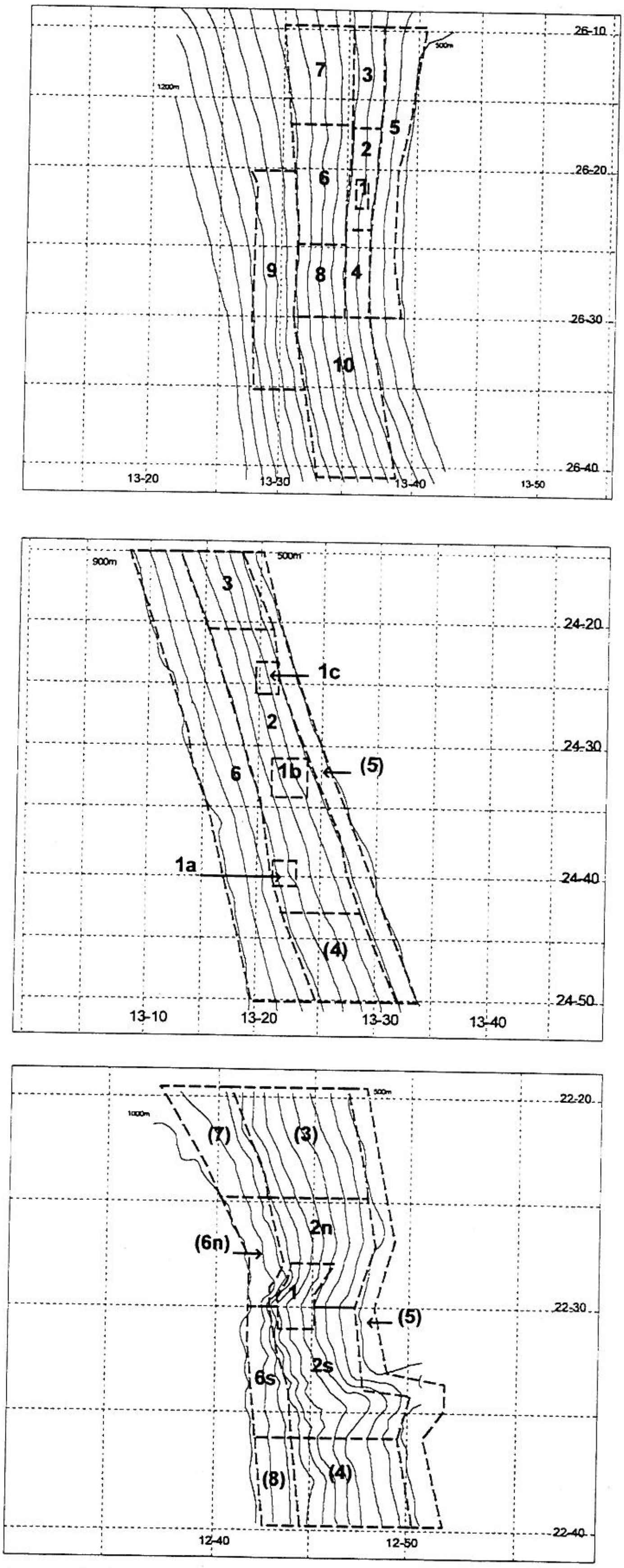


Figure 2 Strata boundaries, numbers, and depth contours for the survey areas at Johnies(top), Frankies (middle), and Rix (bottom) in 1998 (strata in parentheses were not fished this year).

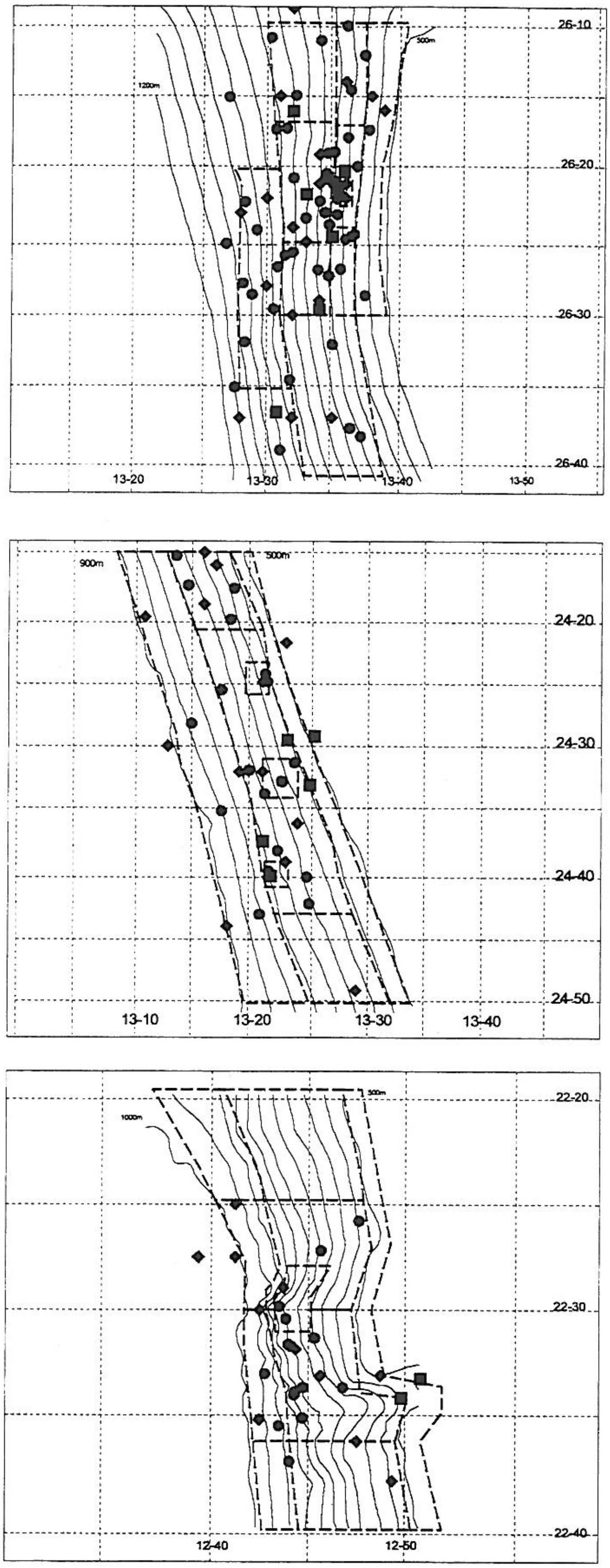


Figure 3 Position of trawls carried out on the 3 grounds by FV *Emanguluku* (red diamond), FV *Southern Aquarius* (black circle), and RV *Dr Fridtjof Nansen* (blue square).

3.1.5 Distribution of orange roughy

Results of trawling by both *Emanguluku* and *Southern Aquarius* have been combined to evaluate the general distribution of orange roughy and other species. In the following sections data from target and random trawls have been used.

Johnies

Large catches of orange roughy were recorded in the central region (Figure 4), with stratum 1 yielding consistently good catches. Catches of around 1 tonnes/trawl also occurred in a southwesterly direction from this central region, especially in the first half of the survey. Catches were small to the north and south, as well as at depths of less than 600 m or greater than 900 m. There were no indications of other aggregations within the survey area. The new strata, added because of the extended distribution of commercial catches in the early months of 1998, gave generally low catch rates. Orange roughy made up 95% of the total catches (by weight).

In addition to catches of orange roughy being small away from the central area, the proportion of orange roughy in the outer trawls was generally low (Figure 4). Orange roughy dominated the catch in stratum 1, and in trawls to the southwest, but other species formed the bulk of catches elsewhere. Hake (blue) dominated in shallower water (stratum 5). Areas to the north and south gave mixed catches, with oreos, dogfish, and rattails contributing to the catch.

Frankies

Trawlhauls were carried out over the central and northern area of Frankies from depths of 500 m to 900 m (Figure 5). No large catches were made at any time during the survey. The largest catch was about 3 800 kg, taken on the «Three Sisters» hills. Trawlhauls made on the northern slopes of the «Three Sisters», on «Frankies Flat», and in the region of «21 Jump St» gave small catches.

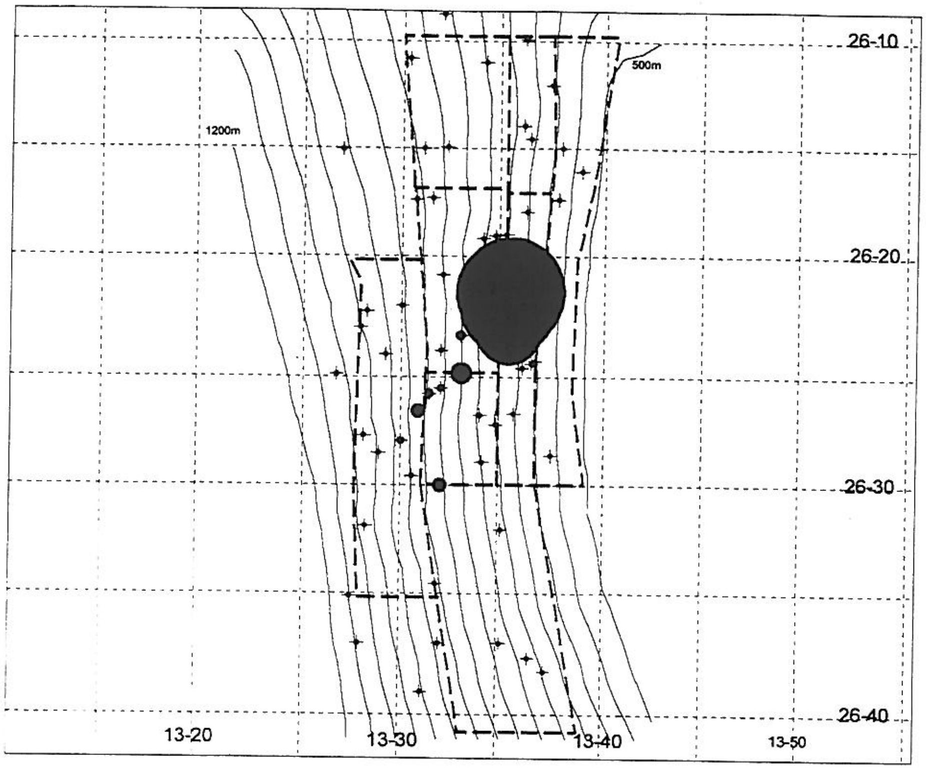
The catch composition at Frankies was relatively mixed. Orange roughy accounted for only 63% of the total catch. Hake dominated trawl catches in a broad depth band from 500 m to 700 m (Figure 5), below where sharks and oreos were more prominent. Orange roughy had a very localised distribution, and only formed the majority of catch in the three 'high density' areas of stratum 1, and in one tow to the north in an area known as «Smiftons».

Rix

Trawlhauls were carried out in the central area of Rix between 550 m and 1 050 m (Figure 6). Most recorded small catches of orange roughy, but several in an area to the south of that commonly fished commercially gave good catches, with the largest being 30 000 kg. Catches were also generally small in stratum 1 which was the center of commercial fishing in the last year (known as 'North Bank'). Orange rouhgy made up 93 % of the total catches (by weight).

Orange roughy were mainly at depths of 750 m to 900 m, where they dominated species composition (Figure 6). Hake were fairly scattered, but dogfish (*Centroscymnus* spp.) were widespread, and more abundant in catches than on the other grounds.

The large orange roughy catches were made at 650 to 850 meters depth and more shallow at Johnies than at Rix (Figure 7).



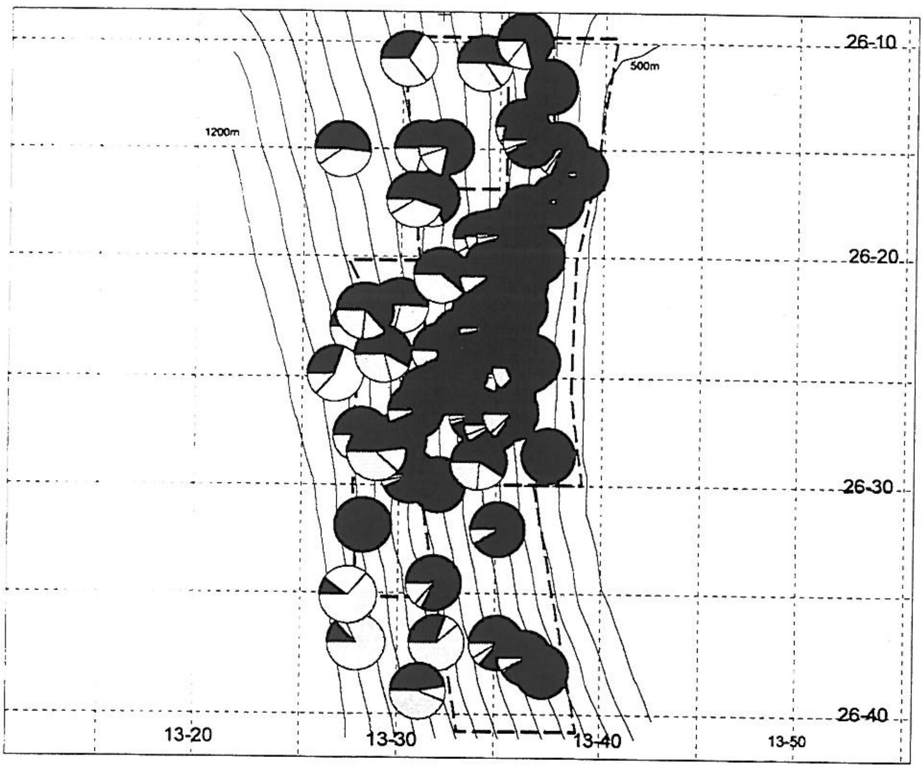
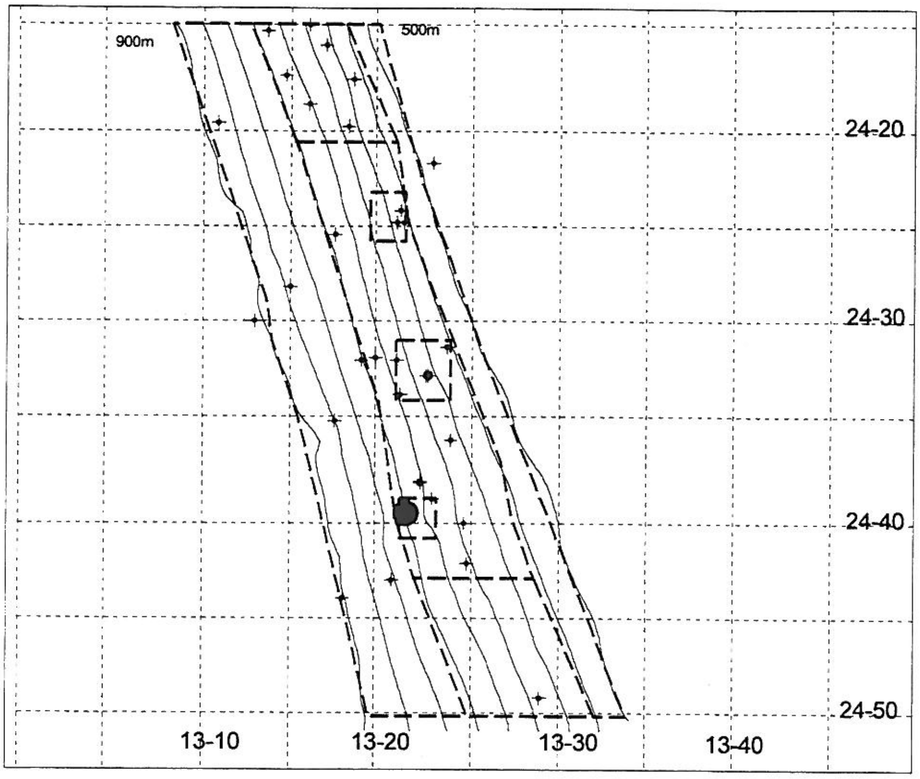


Figure: 4
Catch of orange roughy (top panel) at Johnies in all research trawls by *Emanguluku* and *Southern Aquarius* during the survey (catch per trawl, circle size proportional to catch, maximum = 53t); and catch composition per trawl (lower panel) (ORH=red, RAT=green, SHA=black, HKE=blue, OEO=yellow, OTH=dotted).



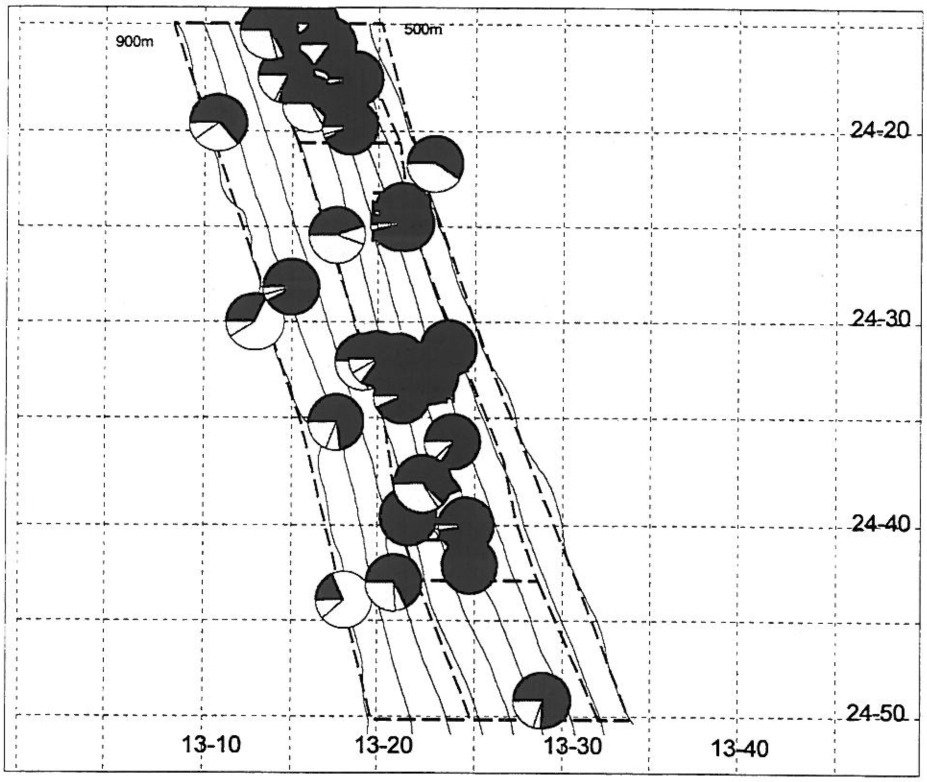


Figure 5 Catch of orange roughy (top panel) at Frankies in all research trawls by *Emanguluku* and *Southern Aquarius* during the survey (catch per trawl, circle size proportional to catch, maximum = 53t on Johnies); and catch composition per trawl (lower panel) (ORH=red, RAT=green, SHA=black, HKE=blue, OEO=yellow, OTH=dotted).

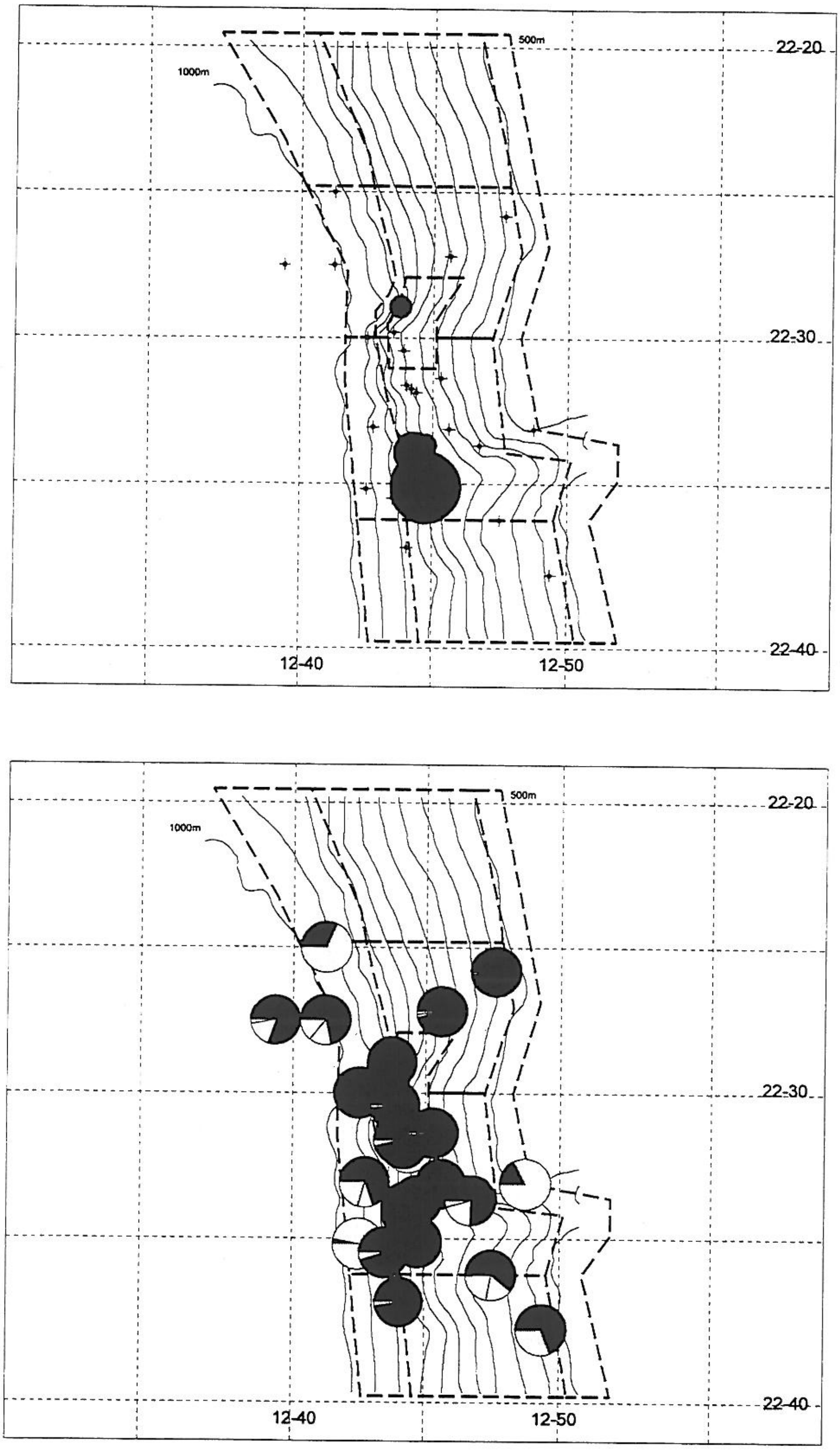
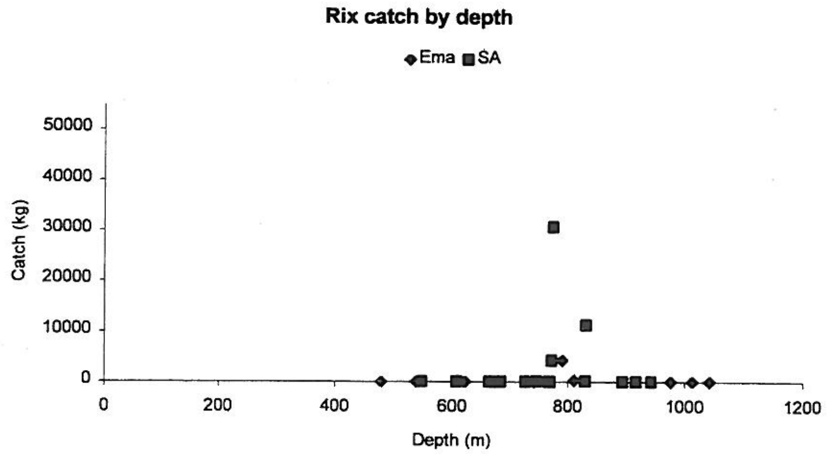
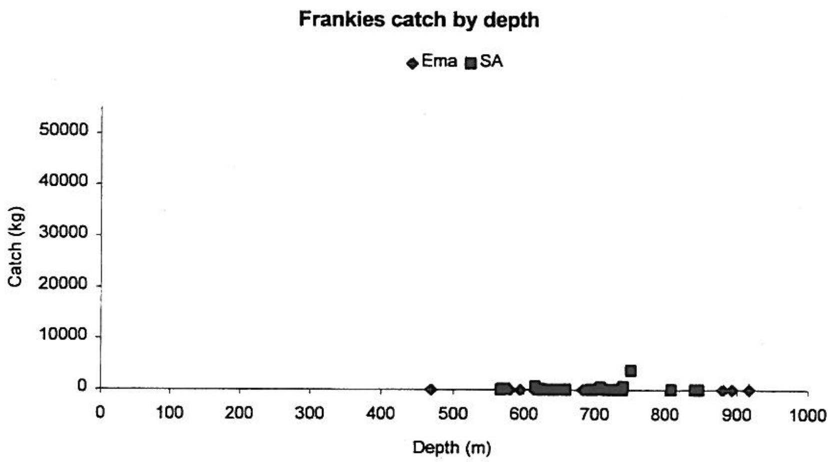


Figure 6 Catch of orange roughy (top panel) at Rix in all research trawls by *Emanguluku* and *Southern Aquarius* during the survey (catch per trawl, circle size proportional to catch, maximum = 53t on Johnies); and catch composition per trawl (lower panel) (ORH=red, RAT=green, SHA=black, HKE=blue, OEO=yellow, OTH=dotted).





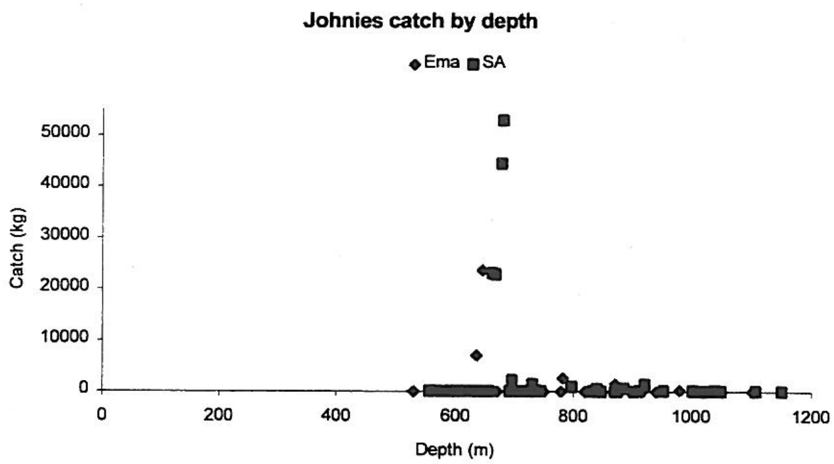


Figure 7 Plots of orange roughy catch by depth for trawls on Rix, Frankies, and Johnies during survey (random and targeted trawls are combined).

3.2 *Biology*

3.2.1 Length frequencies

Length distributions of orange roughy for Johnies, Frankies and Rix varied somewhat between with coverages, with a particularily high proportion of smaller fish in the first coverage of Frankies. This may partly be due to the use of small meshed inner lining, but also to the few fish sampled. The mean length increased from the southern (Johnies) to the northern (Rix) ground. Mean length at Johnies was 25.3cm (1.leg) and 26.0 cm (2.leg) (Figure 8a and 9 a), while catches at Frankies were few and had a mean length of 17.8 cm and 27.3 cm (Figure 8b and 9b). Conversely catches from first coverage of Rix gave a higher mean, 28.5 cm to 27.8 cm, than second coverage (Figure 8c and 9c), although the inner lining was just used in the first coverage.

The orange roughy sex ratio in the catches varied between coverages of the grounds, with Johnies having the proportion of 58% and 41%, Frankies 47 % and 52%, and Rix 43% and 56% males and females respectively (and the remaining were undetermined juveniles).

Length distribution of orange roughy caught by the FV Emanguluko

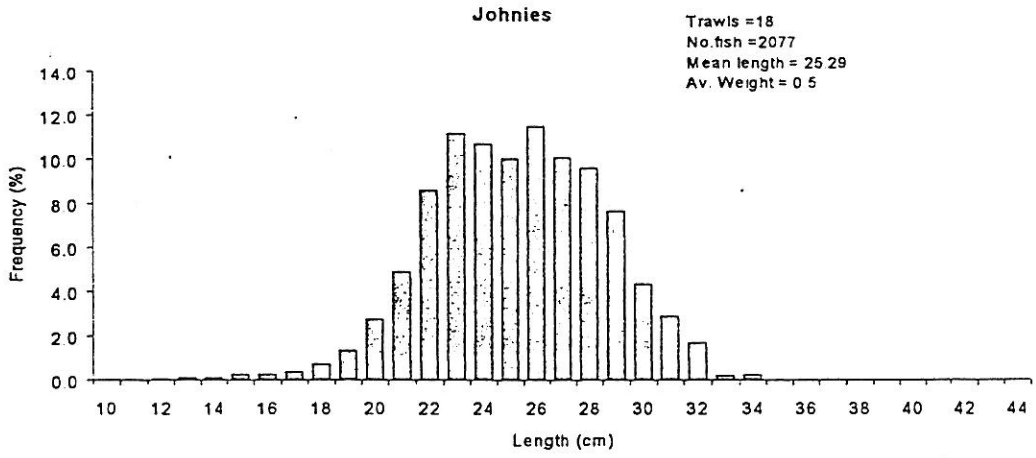


Figure 8a: Length distribution of orange roughy for Johnies (sexes combined and numbers weighted by catch size)

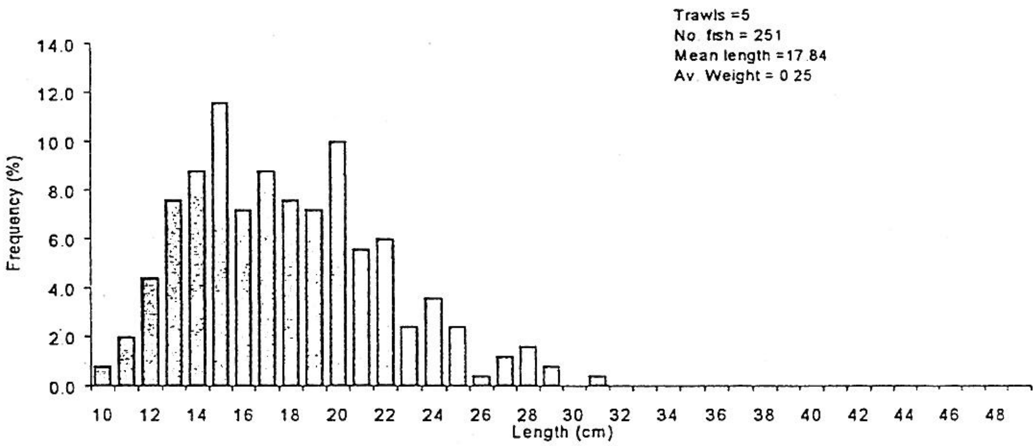


Figure 8b: Length distribution of orange roughy for Frankies (sexes combined and numbers weighted by catch size)

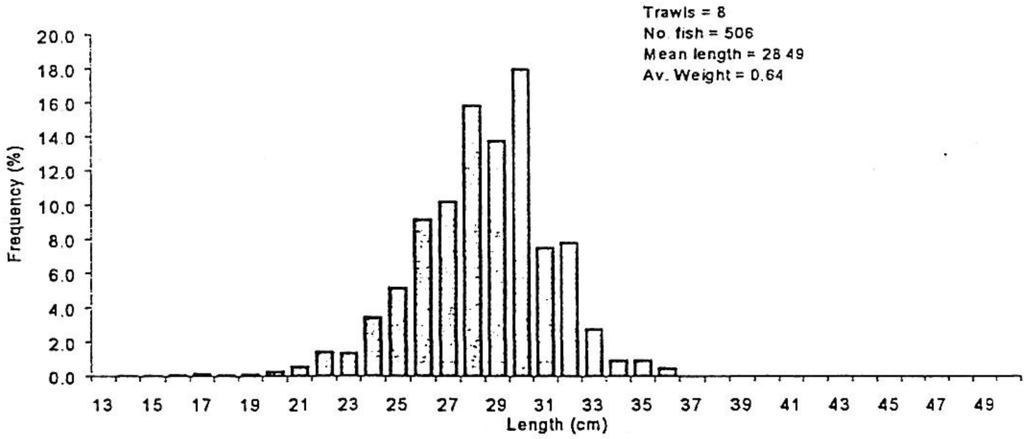


Figure 8c: Length distribution of orange roughy for Rix (sexes combined and numbers weighted by catch size)

Length distribution of orange roughy for catches made by *FV* Southern Aquarius

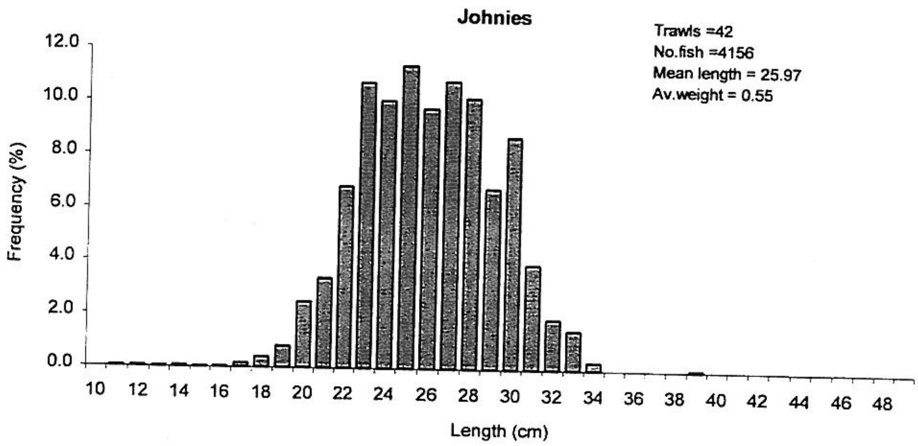


Figure 9a: Length distribution of orange roughy for Johnies (sexes combined and numbers weighted by catch

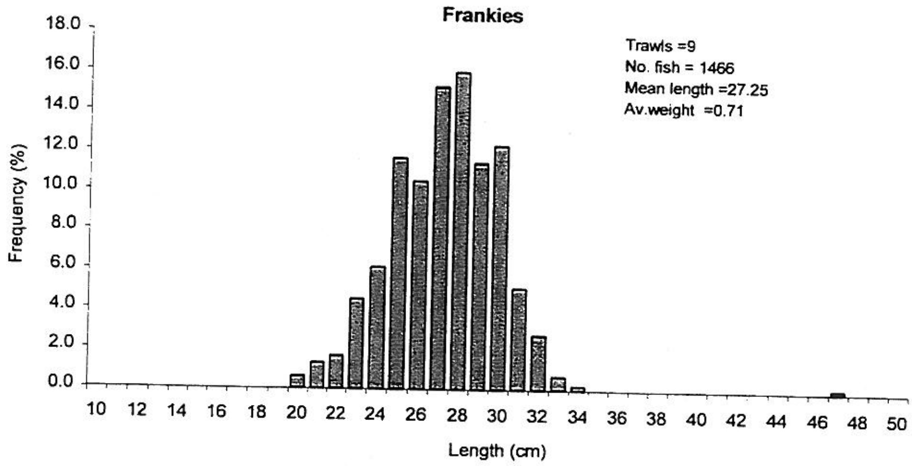


Figure 9b: Length distribution of orange roughy for Frankies (sexes combined and numbers weighted by catc

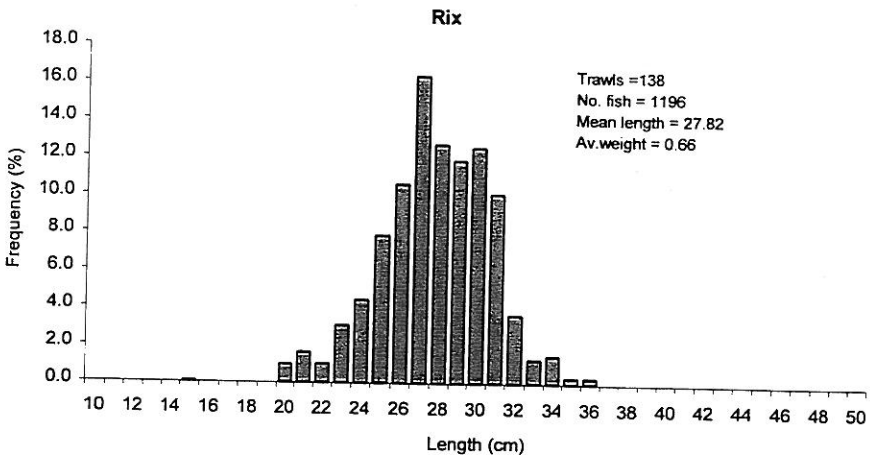


Figure 9c: Length distribution of orange roughy for Rix (sexes combined and numbers weighted by catch size

Length distributions for hake (*Merlucchius paradoxus*) rattails (fam. Macrouridae), and oreo dories (Oreosomatidae.) were also obtained (Appendix 19). Only deep water hake (*Merlucchius paradoxus*) was caught, which had a uniform distribution +/- 10 cm from the 51.7 cm mean length. The standard length of hake from the catches ranged from 29 cm to 82 cm. Rattails varied from 19 cm to 56 cm with the mean at 36 cm. (This is a combined graph for several species as distribution is only used in acoustic measurements. Oreo dories catches were dominated by warty oreo dories (*Allocyttus verrucosus*).1

3.2.2 Length weight relationship

Length weight relationships for orange roughy for each of the three surveyed grounds show very similar pattern, even though the number of fish included differ between 1.leg (Table 5) and 2.leg (Figure 10 a,b,c, Figure11 a, b,c, and Table 5). Frankies differ the most, probably from the lack of small orange roughy in the *FV Southern Aquarius* catches.

Table 5 Length weight relationship for Orange roughy in the surveyed areas.

Vessel	**Ground**	**Number of fish sampled**	**Growth Ln $y=ax^b$**	**Regression fit R^2**
Emanguluko	Johnies	2 095	Ln $y=0.145x^{2.540}$	0.975
Emanguluko	Frankies	146	Ln $y=0.178x^{2.547}$	0.955
Emanguluko	Rix	497	Ln $y=0.120x^{2..596}$	0.946
Southern Aquarius	Johnies	3 998	Ln $y=0.145x^{2.540}$	0.966
Southern Aquarius	Frankies	1 421	Ln $y=0.178x^{2.490}$	0.849
Southern Aquarius	Rix	1 123	Ln $y=0.120x^{2.600}$	0.918

Length-weight relationship of orange roughy caught by the *FV Emangulukp.*

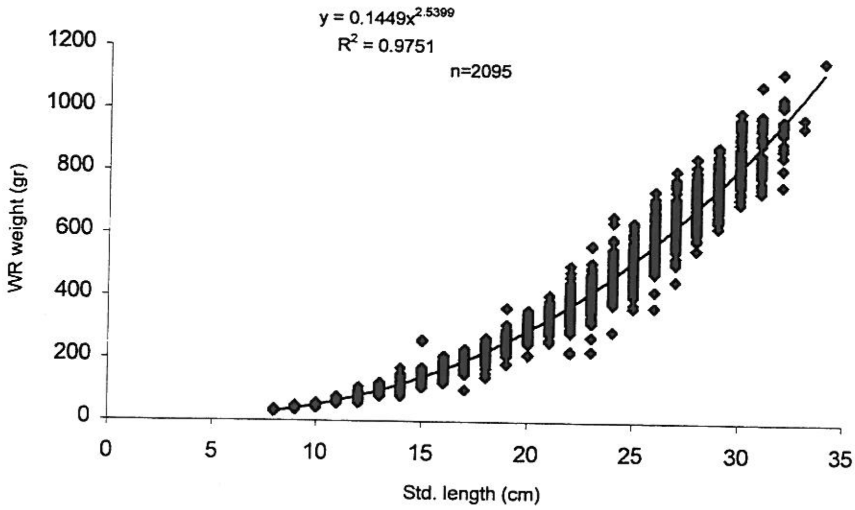


Figure 10a: Length-weight relationship of orange roughy for Johnies.

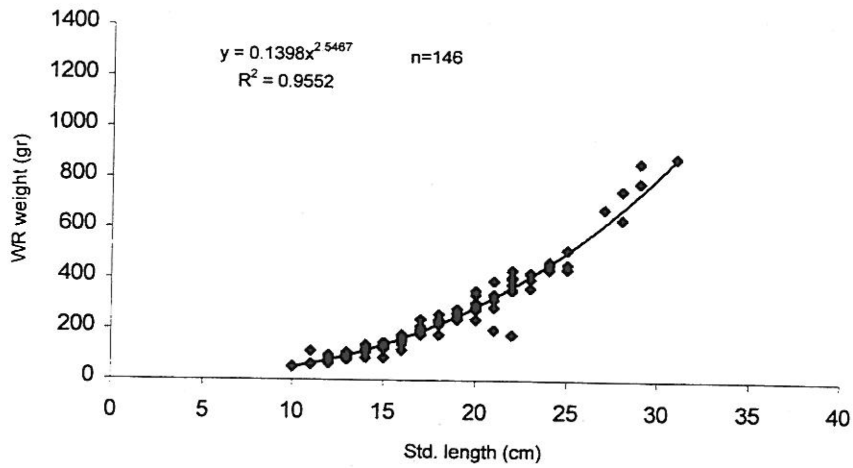


Figure 10b: Length-weight relationship of orange roughy for Frankies.

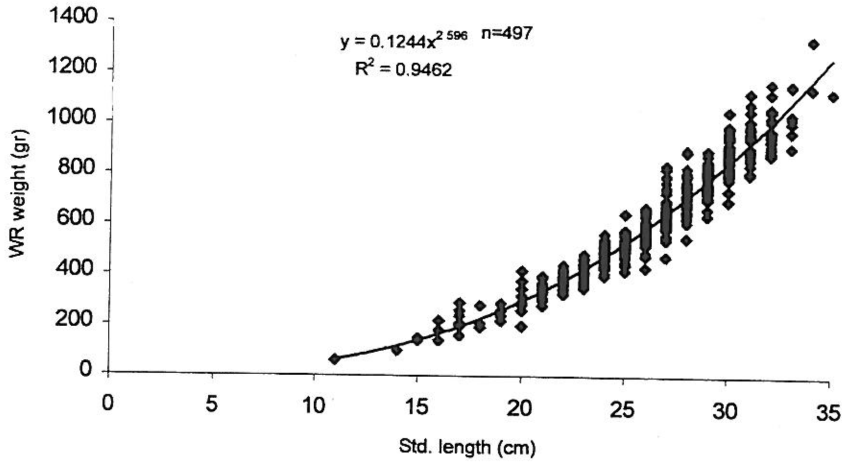


Figure 10c: Length-weight relationship of orange roughy for Rix.

Length-weight distribution of orange roughy caugth by the *FV Southern Aquarius*.

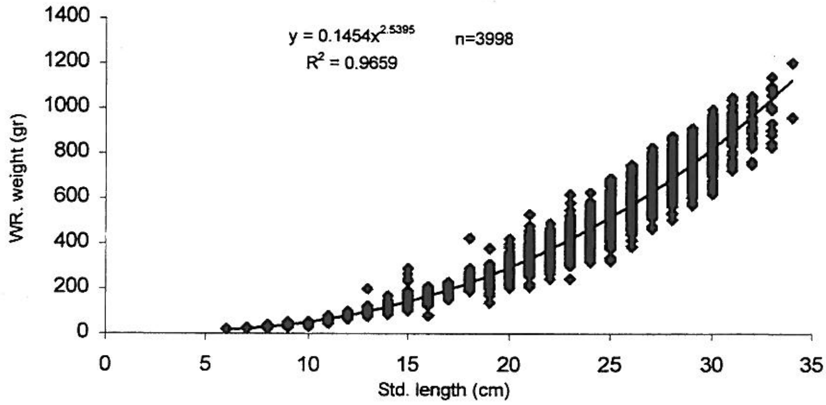


Figure 11a: Length-weigth distribution of orange roughy for Johnies.

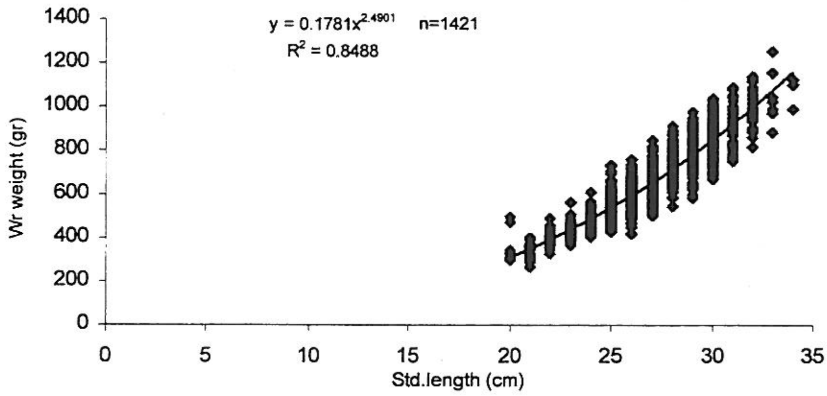


Figure 11b: Length-weigth distribution of orange roughy for Frankies.

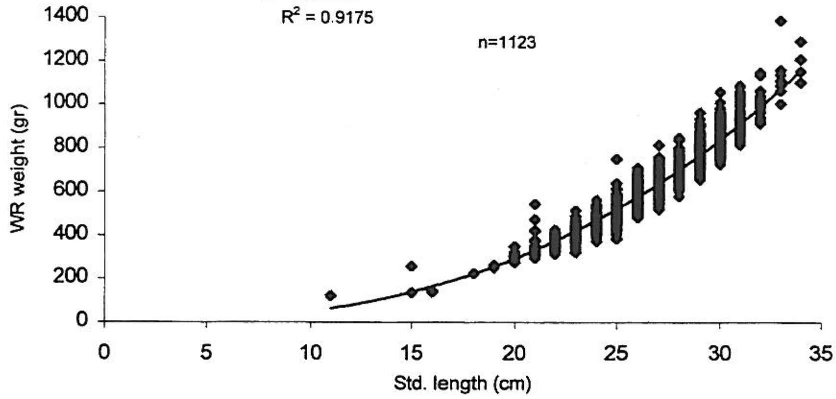


Figure 11c: Length-weigth distribution of orange roughy for Rix.

Hake *(Merlucchius paradoxus*) was the main commercially utilized bycatch in most of the trawlhauls (by weight).

3.2.3 Reproduction

The highest proportion of running and spent males was found at Johnies (2.leg), while highest proportion of spent females was at Rix on the last day of the survey. There was a significant change in the proportion of the running and spent orange roughy between the first and second coverage of Frankies and Rix. At Johnies the proportion of running and spent females increased somewhat between the two coverage's, but not as pronounced as for males (Figure 12).

The length at 50 % maturity was estimated per ground and per sex by combining length with the proportion of orange roughy in a stage 3 (Maturing) and above state in the catches. For males the length at 50% maturity for occured at 21.7 cm, 22.5 cm, and 27.0 cm (Figure 13). For Frankies the point of 50 % maturity is not so readily defined, as lengths from 18 to 23 cm are around 50 % level (see trendline, Figure 13). For females the length at 50 % maturity was significantly higher (26.7 cm) for Rix than Frankies (22.7 cm) and Johnies (21.3 cm) (Figure 14).

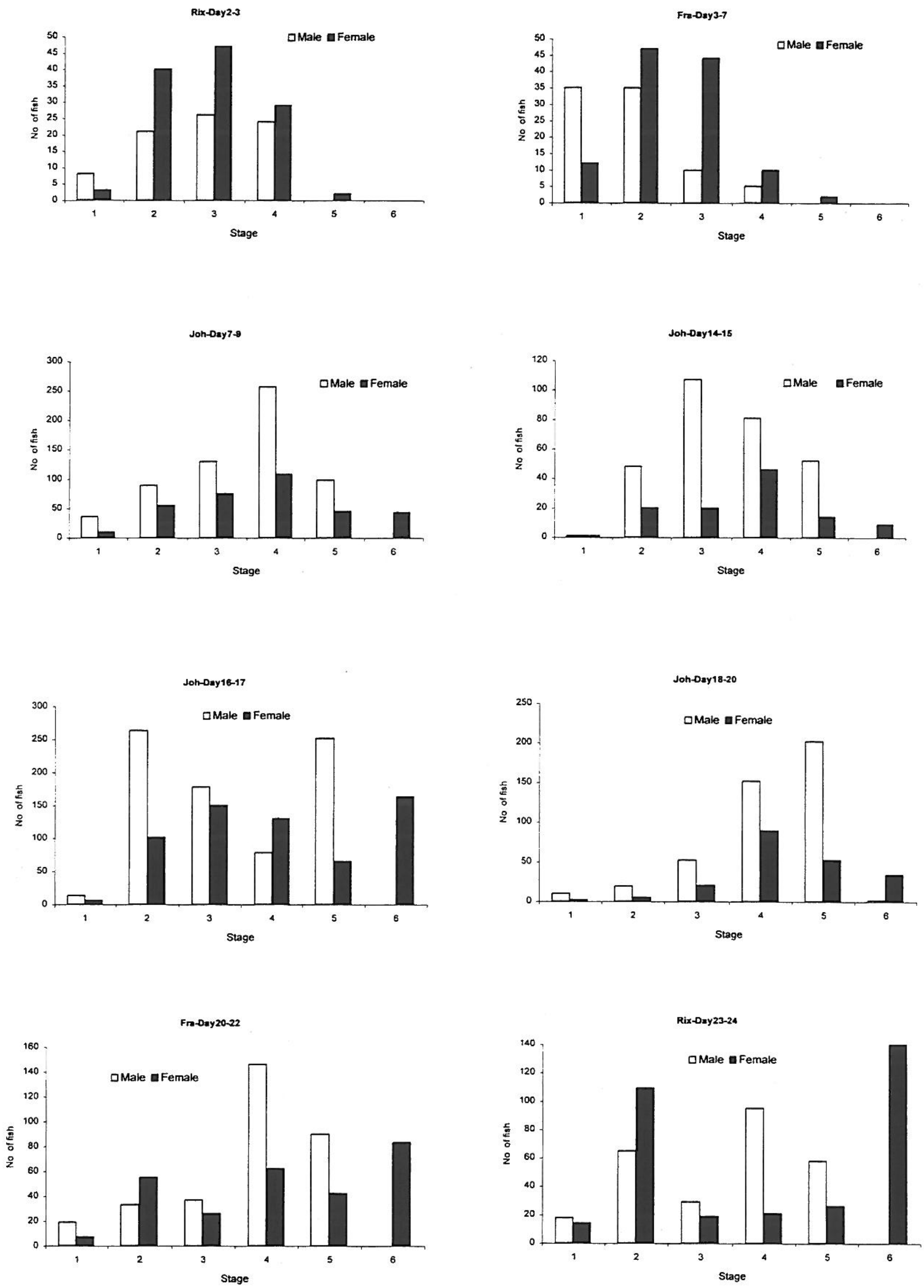


Figure12 Development of maturity stages through the survey

Maturity ogives for orange roughy - males.

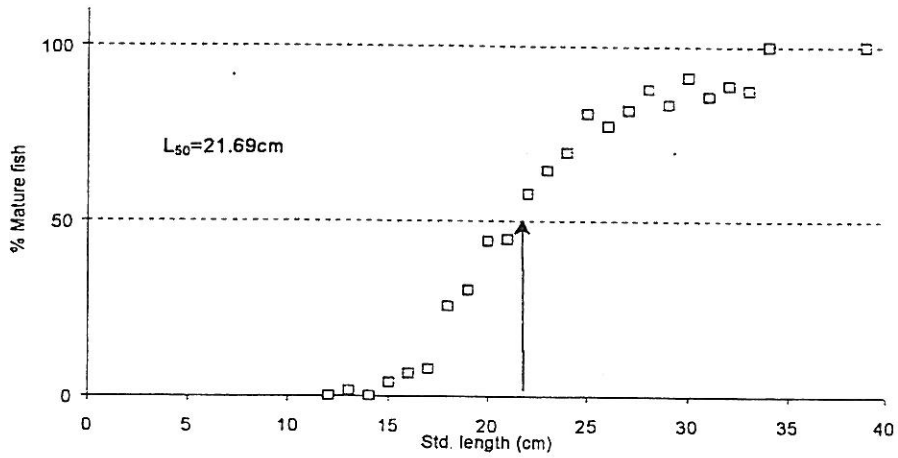


Figure 13a: Maturity ogives for male orange roughy on Johnies (not weighted by catch).

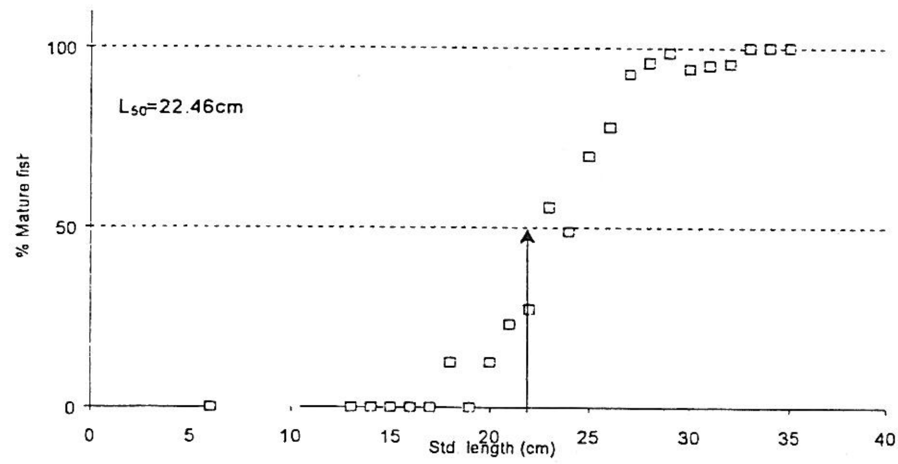


Figure 13b: Maturity ogives for male orange roughy on Frankies (not weighted by catch).

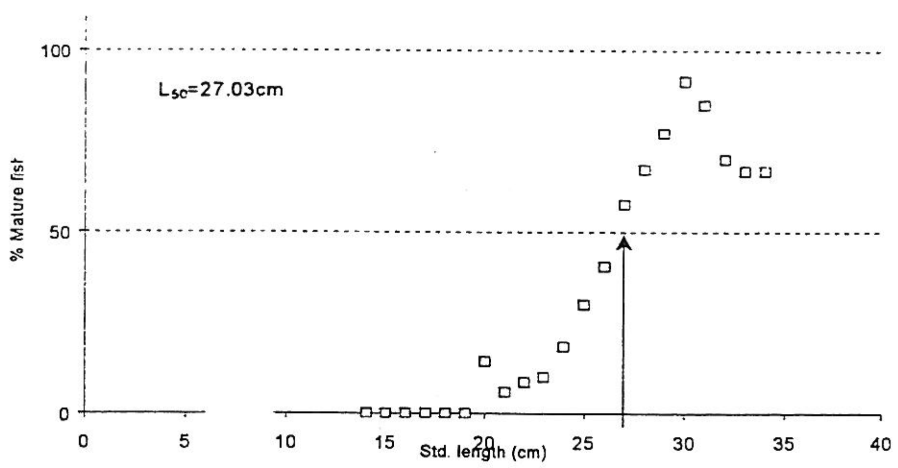


Figure 13c: Maturity ogives for male orange roughy on Rix (not weighted by catch).

Maturity ogives for orange roughy - females

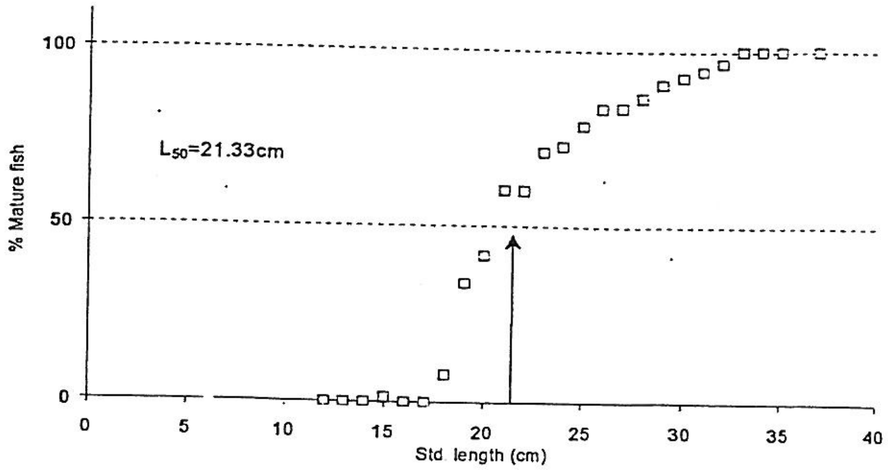


Figure 14a: Maturity ogive for female orange roughy on Johnies (not weighted by catch)

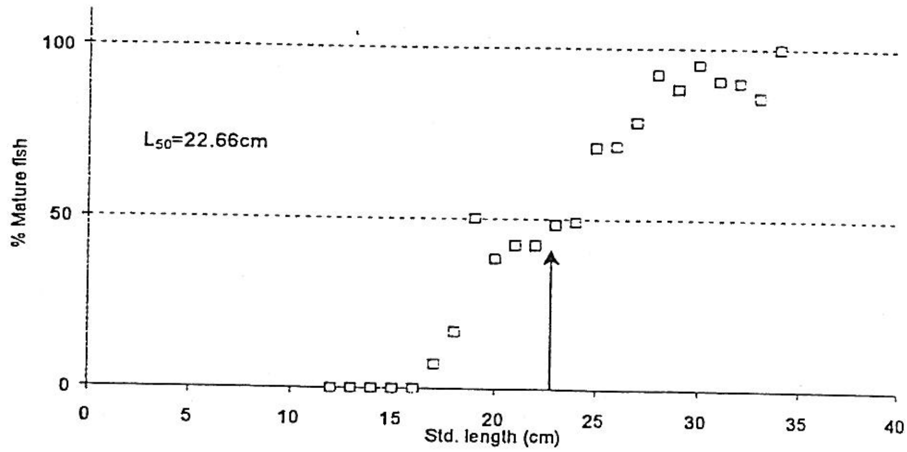


Figure 14b: Maturity ogive for female orange roughy on Frankies (not weighted by catch)

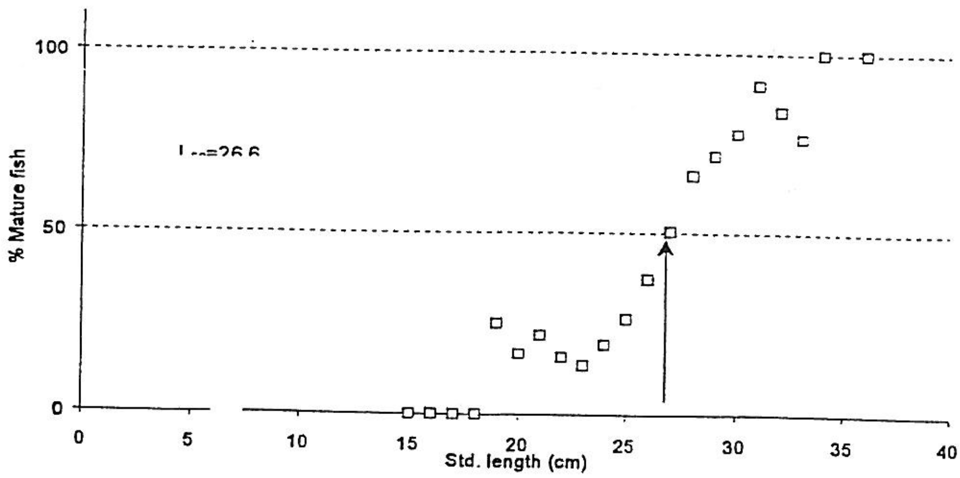


Figure 14c: Maturity ogive for female orange roughy on Rix (not weighted by catch)

3.3. Biomass assessment

3.3.1 Targeted acoustics – Johnies

The targets identified as orange roughy schools are given in Appendix 20 and the survey estimates in Table 6.

Table 6 Biomass estimates for Johnies – targeted acoustics

Survey	Total length (nm)	No. transects	Mean length (nm)	No of Schools	Spacing (nm)	Area (nm^2)	Mean S_A (m^2/nm^2)	Number Millions	Biomass (tonnes)	CV
1	167.4	15	11.16	5	2.00	335	6,40	29,61	18 618	51.9
2	215.2	16	13.79	2	2.00	430	4.26	25,93	16 305	79.3
3	71.9	19	3.78	0	0.50	36	No ORH schools identified			-
4	67.8	19	3.57	1	0.50	34	15,4	10.79	4 316	65.0
5	35.9	13	2.76	4	0.25	9	19,7	3.66	1 463	48.9
6	18.6	8	2.33	6	0.25	5	62,7	6.03	2 410	23.7
										3 030

S_A value corrected for 11% acoustic absorption

The only positively identified aggregations were found in or very close to the spawning box centered around S 26°35'. No catches of greater than 2 tonnes were made outside of this area, although some smaller catches of virtually pure orange roughy were made, particularly to the south-west of the spawning box.

The only clear aggregations were detected in surveys 4 (one aggregation), 5 (four aggregations) and 6 (six aggregations). All were in the same area. Some possible aggregations were found during surveys 1 (five aggregations) and 2 (two aggregations), but their identity was far from certain, therefore while biomass estimates have been calculated, these must be used with caution. Whether the failure to detect aggregations during these first three surveys is due the patchiness (and small amounts) of the orange rougy, or due to the general behaviour resulting in the orange roughy being present but not aggregating, is uncertain. No recognisable aggregations were intercepted during survey 3.

During survey 5 the orange roughy in aggregations were hard on bottom, suggesting that some considerable bias may have been introduced by fish occurring in the dead-zone. By comparison, heaps and stooks of orange roughy were recorded during survey 4 and 6 and the general distribution seemed to be more pelagic.

3.3.2 Scrutinised acoustics– Johnies

The scrutinized acoustic method is essentially the same as targeted acoustics with an addition because of the few catches outside aggregations (Table 7).

Table 7 Biomass estimates for Johnies –scrutinized acoustics

Survey	Total length of survey coverage (nm)	No. Transects	Mean length pr transect (nm)	Spacing (nm)	Area (nm^2)	Mean s_A (m^2/nm^2)	Number Millions	Biomass (tonnes)	CV
1	167.4	15	11.16	2.00	335	7.9	36.6	23 043	18.0
2	220.7	16	13.45	2.00	441	5.1	31.3	19 649	35.0
3	71.9	19	3.78	0.50	36	10.1	5.0	3 151	28.0
4	67.8	19	3.57	0.50	34	23.7	11.1	6 989	39.1
5	35.9	13	2.76	0.25	9	20.9	2.6	1 632	44.3
6	18.6	8	2.33	0.25	5	82.2	5.7	3 564	23.9
S_A value corrected for 11% acoustic absorption								4 062	

3.3.3 Trawl sample based acoustics – Johnies

Trawl sampled based acoustic combine the catch composition in an area with the detected and allocated part of the area backscatter from orange in the 10 m bottom channel and the very close depth zone above the aggregations. By using trawl-based acoustics the orange roughy biomass was estimated at 51 386 tonnes (CV = 14%) for Johnies (Table 8). Strata 6 and 9 showed to have the highest biomass of orange roughy.

Table 8: Biomass estimates and CV % per strata for Johnies

Strata	Area	Biomass	CV %
1		2 082	no data
2		4 472	34
3		8 526	42
4		3	45
5		4 599	53
6		10 327	40
7		6 574	38
8		1 053	42
9		13 421	19
10		329	25
Total		51 386	14

Corrected for 11% acoustic absorption.

3.3.4 Swept area estimates – Johnies

Two sets of swept-area results are presented here:

- Strata 1 to 10, which includes the new areas surveyed in 1998
- Strata 1 to 8, which is directly comparable to the 1997 survey

Only trawl-data from *Southern Aquarius* is included, and all target trawls have been discarded. All random trawls performed well, and none were excluded because of gear damage or poor bottom contact. The distribution of random trawls is given in Figure 4. Trawls were spread throughout the area, with at least two trawls per stratum, and the highest concentration in strata 1, 2 and 6.

Catch rates were at times very high in stratum 1 (Figure 4), with values approaching 50 000 kg.n.mile^{-1}. The depth band of stratum 1 covered 640 to 680m, with most large catches occurring at 660 to 680 m. Catch rates in other strata were low.

The total swept area estimate of orange roughy, based on all the randomly placed trawls taken in each strata is presented in Table 9.

Table 9 Swept area biomass estimates for Johnies, total 1998 survey area.

Strata	# trawls	Area Nm^2	Mean CPUE kg/nm	Std.Dev. CPUE	Biomass Tonnes
1	4	1.8	24 904	17 287	5 557
2	6	11.4	186	440	264
3	2	14.7	2	2	5
4	2	10.2	1	1	1
5	3	38.6	1	1	3
6	5	28.6	243	315	861
7	2	30.9	4	1	14
8	2	16.6	134	189	274
9	5	44.3	189	388	1032
10	3	53.9	21	32	136
	Total	251.0		Total	8 147

Corrected for 11% acoustic absorption

Highest fish densities, and hence catch rates, were recorded in stratum 1. This stratum dominated the biomass, even though it is a very small area. Stratum 9 was the next largest biomass. It had moderate catch rates, but is a relatively large area. Strata 2 and 6, which were important in 1997, were relatively minor in 1998 survey. The overall coefficient of variation of the biomass estimate is 27.5%.

The comparable biomass estimate to that of the 1997 survey is derived from summing the values for strata 1 through 8. The parameter values from Table 9 remain unchanged. The total biomass was 6 978.9 t, with a CV of 29.0%.

3.3.5 Combined acoustics/swept area estimates – Johnies

The location of orange roughy aggregations identified from the targeted acoustic method were plotted, and trawls which fished these aggregations were excluded from area-swept analyses. For Johnies, the aggregations all occurred in Stratum 1, and all 4 trawls in this stratum were therefore excluded from the analysis. No aggregations with trawls occurred outside this area, and so the combined method simply takes the acoustic aggregation estimate, and adds the trawl results for strata 2 to 10.

Mean estimates are given below:

Stratum	**Acoustic**	**Trawl**
1	3 030*	
2		263
3		4
4		1
5		3
6		861
7		14
8		274
9		1032
10		136
Total		**5 618**

* Corrected for 11% acoustic absorption

The combined value is almost equally divided between aggregation and surrounding strata. This reflects that the characterization of orange roughy schools was good but with fish outside the main aggregation in stratum 1.

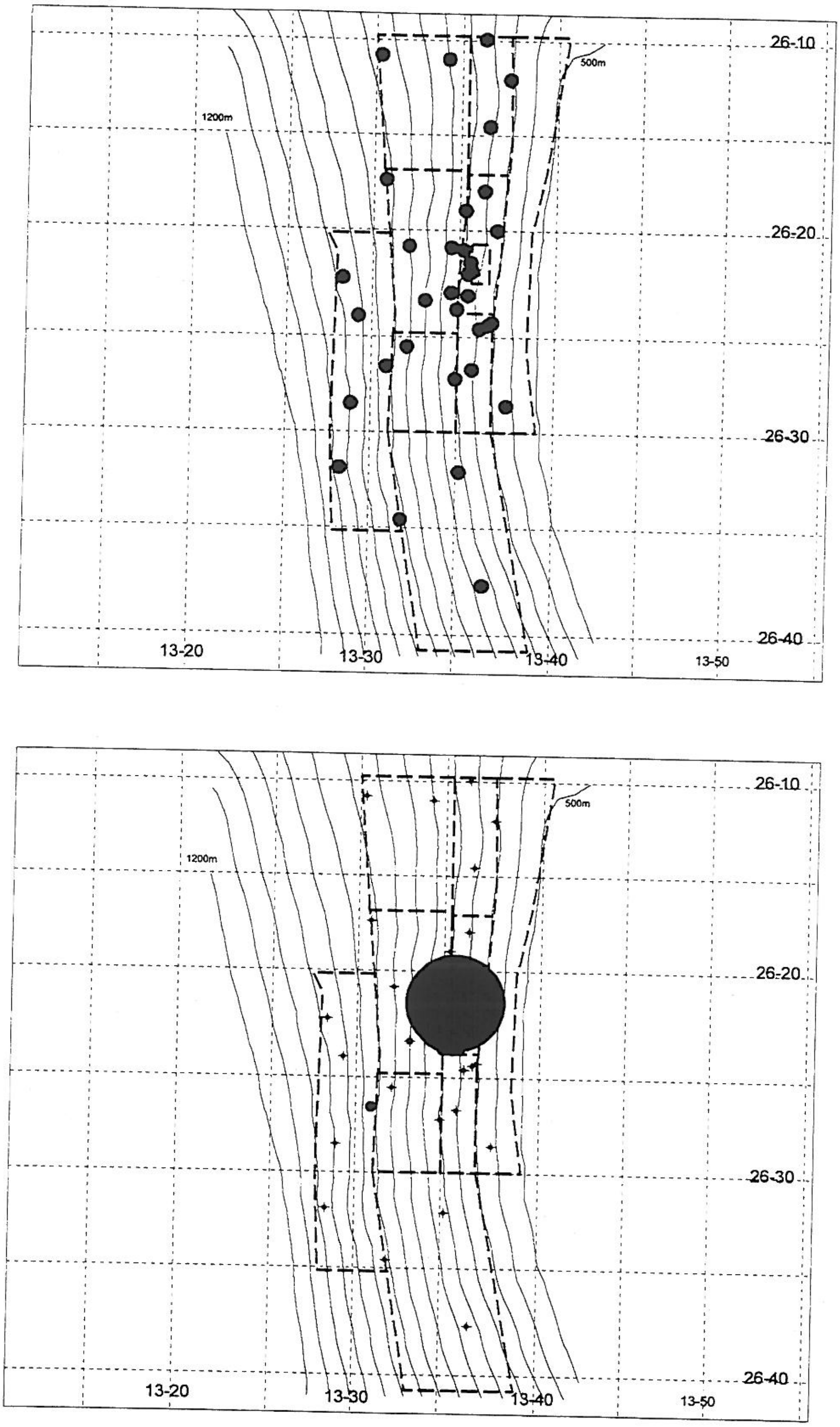


Figure 15 Location of research trawl survey tows (top panel) on Johnies by *Southern Aquarius*, and catch rate (kg/n.mile, maximum circle size = 48000 kg/n.mile) of orange roughy (lower panel).

3.3.6 Targeted acoustics – Frankies

In general, all of the surveys of Frankies were considered to yield valid estimates and therefore the unweighted average of these should be used (Table 10).

During Survey 1 some clear well-defined targets were recorded. Three aggregations in 3 Sisters accounted for some 61% of the total back-scatter, while a single aggregation in Frankies Flats accounted for 17%. The remaining comes from a roughy-like column of fish detected well to the south of this region. As the target was not sampled, nor have any commercial catches found roughy in this area, the identity of this target remains uncertain. If removed, this aggregation will reduce the overall estimate for this coverage by about 22%.

Survey 1b recorded some well-defined, but weak targets in Frankies Flats and Three Sisters, and one very small mark in 21 Jump St. While the density of schools estimated during this coverage was considerably less than during the first coverage, the estimate is considered valid.

Survey 2 of Frankies on transects 1 nm apart detected 4 aggregations in 3 Sisters, 2 in Frankies Flats, 1 in 21 Jump St. and a small target to the north of 21 Jump St. These aggregations were estimated to contribute 70%, 24%, 3% and 3% to the estimate.

The intensive surveys of the three areas of Frankies (viz. 3 Sisters, Frankies Flats and 21 Jump St. all provided valid estimates. The targets were generally well clear of the bottom. No targets were detected at 21 Jump St while 5 clear targets were seen at Frankies Flats. A number of targets were detected at 3 Sisters, but these tended to be rather diffuse, although they were clear of the bottom. As the weather was deteriorating during this coverage, this estimate must be used with some care. A bubble compensating factor of 1.2 was applied to the acoustic back-scatter due to dampening of returned signal due to bubbles under the transducer.

Table 10 Biomass estimates for Frankies – targeted acoustics

Survey	Total length of survey coverage (nm)	No. Transects	Mean length pr transect (nm)	No of schools	Spacing (nm)	Area (nm^2)	Mean s_A (m^2/nm^2)	Number Millions	Biomass (tonnes)	CV
1 a	203.5	15	11.31	4	2.00	407	3.58	18.86	**13 278**	**54.3**
1 b	88.8	13	6.83	Diffuse Schools	2.00	178	1.53	3.53	**2 486**	**52**
2	180	25	7.20	8	1.00	180	4.07	9.50	**6 686**	**48.0**
3 21 Jump St	19	3	6.33	1	1.00	19	0	-	**-**	
4 F. Flats	52.7	13	4.05	5	0.25	13	8.65	1.46	**1 025**	**61.3**
5 3 sisters	94.7	17	5.57	Diffuse schools	0.25	24	7.30	2.27	**1 597**	**54.5**
									6 268	

Corrected for 11% acoustic absorption.

3.3.7 Scrutinised acoustics – Frankies

During most coverages almost all orange roughy appeared to be in aggregations, hence the similar estimates obtained (Table 11) as by the targeted method. This was not so much the case for 1b and 5 as they showed weak and diffuse marks on the grounds.

Table 11 Biomass estimate for Frankies – scrutinized acoustics

Survey	Total length pr coverage (nm)	No. Transects	Mean length pr transect (nm)	Spacing (nm)	Area (nm^2)	Mean s_A (m^2/nm^2)	Number Millions	Biomass (tonnes)	CV
1 a	203.5	18	11.31	2.00	407	4,5	23.76	**16 722**	**44.3**
1 b	88.8	13	6.83	2.00	178	2.43	5.61	**3 950**	**31.7**
2	180	25	7.20	1.00	180	4.32	10.1	**7 100**	**46.6**
3 21 Jump st	19	3	6.33	1.00	19	0	0.00	**-**	**-**
4 F.Flats	52.7	13	4.05	0.25	13	12,2	2.05	**1 442**	**47.6**
5 3 sisters	94.7	17	5.57	0.25	24	3.51	1.09	**769**	**19.4**
								7 496	

Corrected for 11% acoustic absorption.

3.3.8 Trawl sample based acoustics – Frankies

It is not applicable to use this method due to slight uncertainty in the value of targetstrength causes large uncertainty in the biomass estimate, which is due to the weak back scatter properties.

Few samples per strata make the method susceptible to big variation in biomass estimates because of difference in catchsize, as the catch composition per trawlhaul strongly affect the biomass estimate because of the low target strength of orange roughy.

3.3.9 Swept area estimates – Frankies

Stratification for Frankies was unchanged from 1997, but only strata 1 (a,b,c), 2, 3, and 6 were covered this year. The location of random trawls is shown in Figure 5. A total of 22 tows were completed, with one rejected through poor performance.

Catch rates were much lower than at Johnies, or at Rix. The maximum was about 10 000 kg.n.mile^{-1}, taken on the hills of the «Three Sisters» stratum (1a). This stratum also had several other tows with catch rates above 1 000 kg per nm. The only other area to have any notable catch was «Frankies Flat». Catch rates in all other strata were very low.

The swept-area estimate for Frankies and data for each stratum are given below in Table . Because catch rates last year were quite variable between the three sub-areas of stratum 1, they are treated separately this year.

Table 12 Swept area biomass estimates for Frankies

Strata	# trawls	Area nm^2	Mean CPUE Kg/nm	Std.Dev. CPUE	Biomass Tonnes
1a	4	4.9	3 021.1	4 663.2	1 848.5
1b	2	7.3	366.7	306.1	330.0
1c	2	4.1	88.0	42.0	44.3
2	6	98.1	0.3	0.6	4.2
3	4	30.1	30.9	61.6	115.3
6	3	150.0	3.4	4.2	63.9
	Total	294.5		Total	2 406.2

The total biomass index was about 2 400 t, with a CV of 60%. Biomass was concentrated in stratum 1, on the «Three Sisters», with some on «Frankies Flat». Other strata contributed little to the overall index.

The comparable biomass estimate from 1997, with the three subareas of stratum 1, and exclusion of strata 4 and 5, was 30 974.6 t.

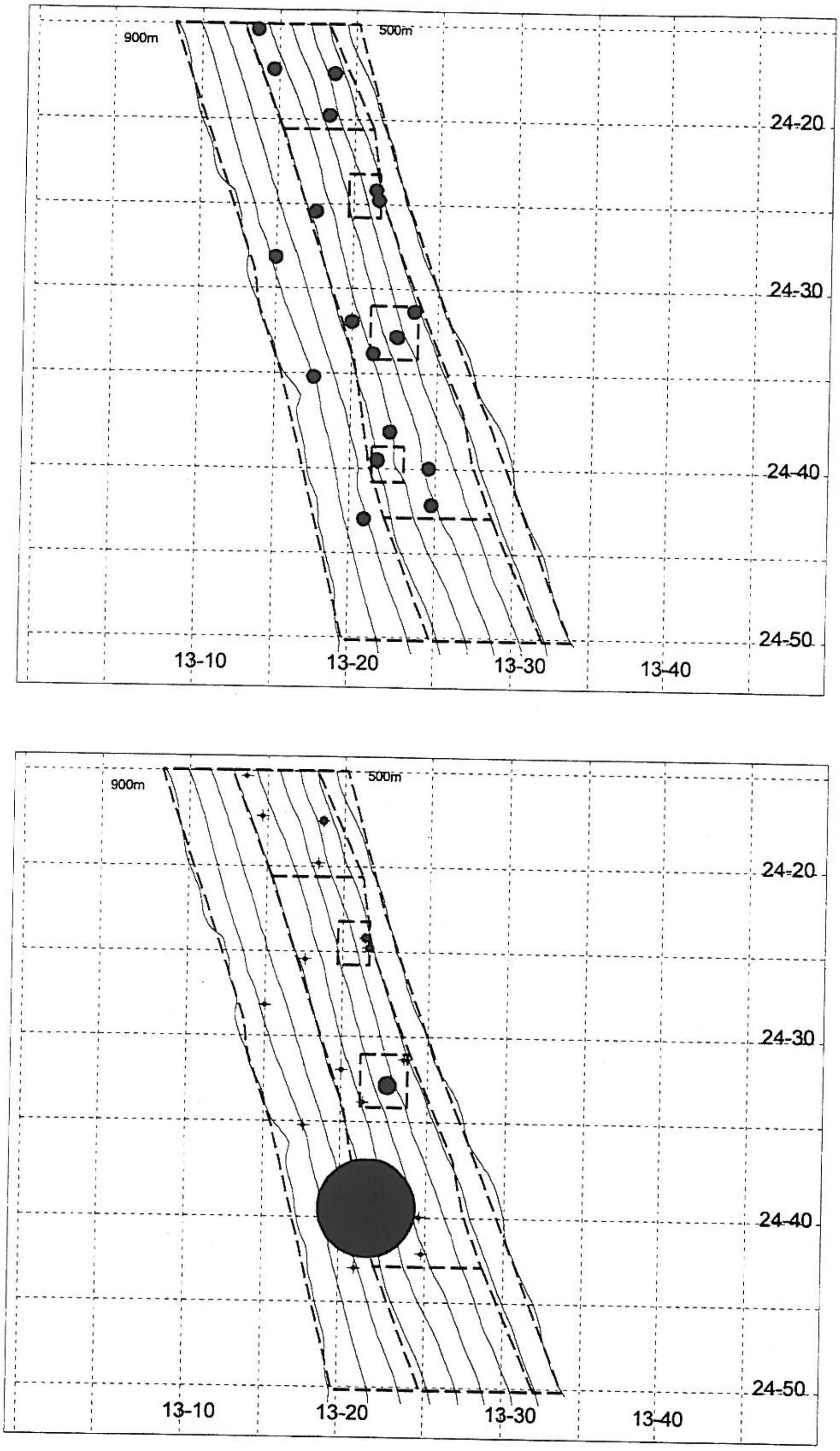


Figure 16 Location of research trawl survey tows (top panel) on Frankies by *Southern Aquarius*, and catch rate (kg/n.mile, maximum circle size = 10000 kg/n.mile) of orange roughy (lower panel).

3.3.10 Combined acoustics/swept area estimates – Frankies

For this approach, all random trawls were excluded from strata, or parts of strata, where schools of orange roughy were included in the acoustic estimate of section 3.4.6. This identified orange roughy aggregations on «Frankies Flat», and the hills of the «Three Sisters. Trawls on these features were removed from the biomass calculations for swept-area, and the data analysed for trawl strata 1c, 2, 3, and 6.

The mean estimates are summarised below:

Stratum	**Acoustic**	**Trawl**
1a + 1b	2 622*	
1c		44
2		4
3		115
6		64
Total combined:		**2 849**

* Corrected for 11% acoustic absorption

3.3.11 Targeted acoustics – Rix

The first coverage detected one clear aggregation and two aggregations of uncertain identity. These were, however all included in the final estimate, which must therefore be used with some circumspection (Table 13).

Surveys 2 to 8, including multiple random surveys were all conducted on aggregations that were in general, not closely associated with bottom. However targets were usually associated with areas of rough bottom, particularly at the top edge of a drop-off. It is possible that dead-zone and side lobe reflections may have affected the results.

Surveys 2 and 3 both detected 6 clear targets, while the repeated random surveys detected 4, 2, 3, 4, and 3 targets respectively.

All coverages are considered equally valid. One should however note the difference in the coverages of the grounds per survey.

Table 13 Biomass estimates for Rix – targeted acoustics

Survey	Total length (nm)	No. transects	Mean length (nm)	No of Schools	Spacing (nm)	Area (nm^2)	Mean s_A (m^2/nm^2)	Number Millions	**Biomass (tonnes)**	**CV**
1	107.1	11	9.74	3	2.00	214	2.7	6.89	**5 250**	**77.9**
2	109.2	12	9.10	6	1.00	109	8.3	18.78	**8 041**	**45.1**
3	42.5	10	4.25	6	1.00	43	13.5	11.86	**5 346**	**38.6**
4	14.5	5	2.90	4	Random	28	30.5	17.65	**8 888**	**34.7**
5	15.4	5	3.08	2	Random	28	28,3	16.34	**7 751**	**83.5**
6	18.8	5	3.76	3	Random	28	21.5	12.48	**6 033**	**55.3**
7	14	5	2.80	4	Random	28	33.8	19.54	**8 703**	**42.3**
8	14.8	5	2.96	3	Random	28	27.4	15.85	**7 055**	**46.4**
Corrected for 11% acoustic absorption									7 133	

3.3.12 Scrutinised acoustics – Rix

Most orange roughy were located in aggregations; hence results are rather similar to targeted acoustics method (Table 14).

Table 14 Biomass estimates for Rix – scrutinized acoustics

Survey coverage	Total length of survey coverage (nm)	No. Transects	Mean length pr transect (nm)	Spacing (nm)	Area (nm^2)	Mean s_A (m^2/nm^2)	Number Millions	**Biomass (tonnes)**	**CV**
1	107.1	11	9.74	2.00	214	3.0	7.83	**5 959**	**69.3**
2	109.2	12	9.10	1.00	109	7.7	10.20	**7 769**	**40.6**
3	42.5	10	4.25	1.00	43	16.9	8.80	**6 700**	**38.7**
4	14.5	5	2.90	Random	28	30.7	10.40	**7 914**	**42.3**
5	15.4	5	3.08	Random	28	29.7	10.06	**7 658**	**83.4**
6	18.8	5	3.76	Random	28	21.8	7.38	**5 616**	**58.1**
7	14	5	2.80	Random	28	35.0	11.86	**9 027**	**42.6**
8	14.8	5	2.96	Random	28	28.8	9.76	**7 426**	**46.4**
Corrected for 11% acoustic absorption								7 260	46

3.3.13 Trawl sample based acoustics – Rix

It is not applicable to use this method due to slight uncertainty in the value of targetstrength causes large uncertainty in the biomass estimate, which is due to the weak back scatter properties.

Few samples per strata make the method susceptible to big varition in biomass estimates because of difference in catchsize, as the catch composition per trawlhaul strongly affect the biomass estimate because of the low target strength of orange roughy.

3.3.14 Swept area estimate – Rix

It was hoped that there would be sufficient time this year to undertake enough trawling at Rix to provide a base swept-area estimate. However, in the two days the *Southern Aquarius* worked the area, 10 random tows were completed, of which one was rejected through gear damage.

Stratification for Rix was refined from 1997, with subdivision of strata 2 and 6 to reflect distribution of catch from the 1997 survey, as well as initial acoustic survey results. The location of random trawls is shown in Figure 6.

Catches were small with low catch rates in all but one tow in stratum 2s (Figure 6). The location of this was consistent with larger catches taken in target identification trawls in this southern part of the survey area. Catch rates in stratum 1 were low.

The swept-area estimate for Rix and data for each stratum is given below in Table 15. However, with a total of just 9 tows, these data should be regarded with little confidence.

Table 15 Swept area biomass estimates for Rix, *Southern Aquarius* trawls.

Strata	# trawls	Area nm^2	Mean CPUE kg/nm	Std.Dev. CPUE	Biomass tonnes
1	2	4.9	29.2	30.0	17.9
2s	3	23.3	6 836.1	11 833.0	19 683.1
2n	2	17.8	0.2	0.3	0.5
6	2	9.3	4.6	2.6	5.3
	Total	55.3		Total	19 706.8

Biomass was concentrated in stratum 2s, on the general slope at depths around 800 m. Other strata contributed little to the overall index. The CV was 99.8%.

The general nature of the bottom in the Rix area is undulating and hard. Trawls are often short, and carried out in a range of directions to work small patches of trawlable ground. This means that differences in the standard fishing 'power' of the *Emanguluku* and *Southern*

Aquarius could be less than on a smooth bottom. Therefore, in an attempt to improve the estimate at Rix, an analysis combining the random tows done by both vessels was attempted. This added 5 trawls in the above strata from *Emanguluku* (Table 16).

Table 16 Swept area biomass estimates for Rix, *Southern Aquarius* plus *Emanguluku* trawls.

Strata	# trawls	Area nm^2	Mean CPUE kg/nm	Std.Dev. CPUE	Biomass tonnes
1	3	4.9	1 019.6	1 715.6	623.9
2s	5	23.3	4 104.3	9 165.3	11 817.6
2n	2	17.8	0.2	0.3	0.5
6	4	9.3	37.0	66.7	42.6
	Total	55.3		Total	12 484.5

The CV of this estimate was 94.6%. Stratum 2s required more intensive trawling, and even with the extra trawls it is uncertain how representative the overall catch rate and biomass results from this stratum are. All swept-area results for Rix should be regarded with caution.

3.3.15 Combined acoustic/swept area – Rix

It was not felt to be sensible to use this method, because of the limited trawl survey data.

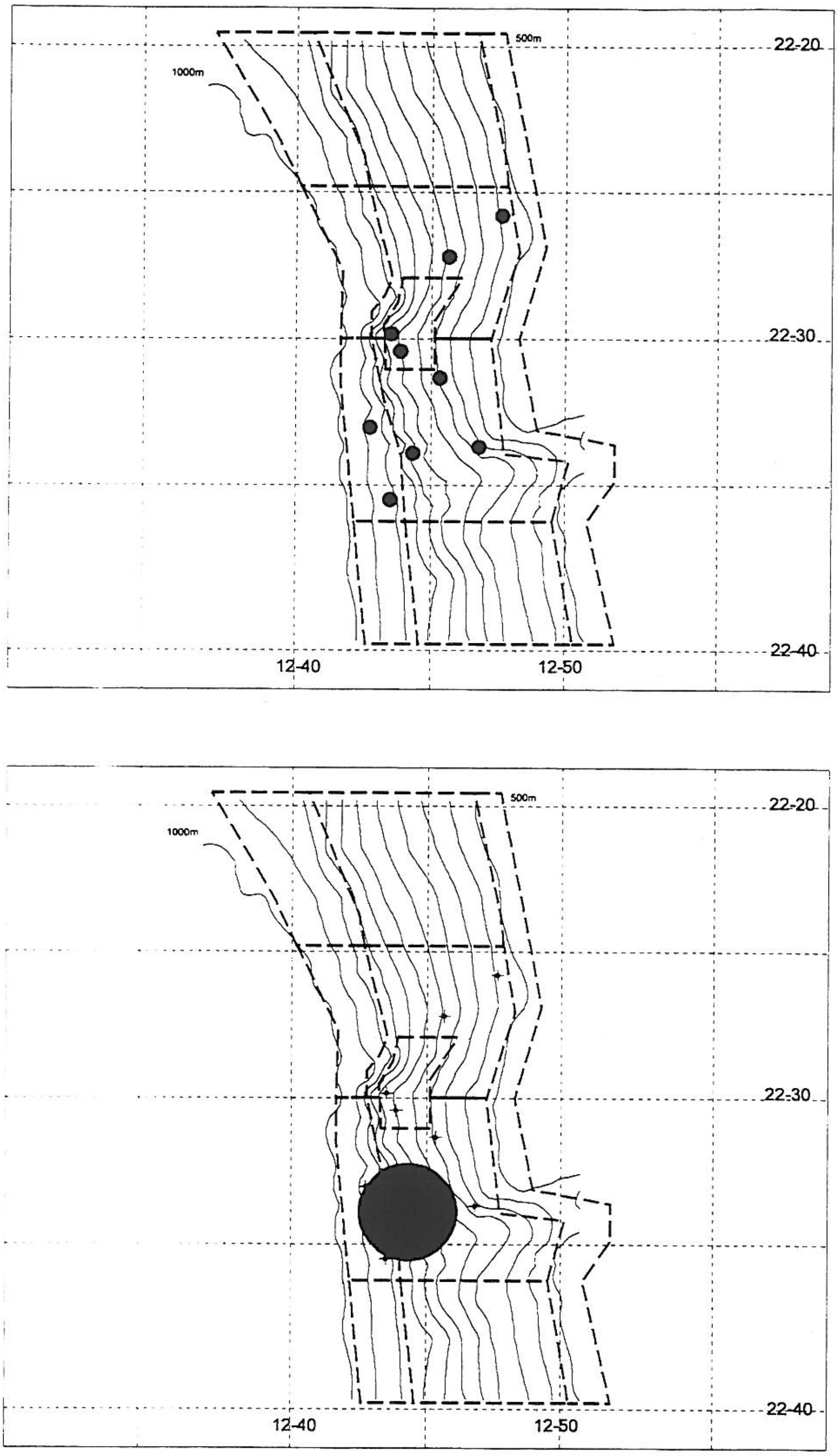


Figure 17 Location of research trawl survey tows (top panel) on Rix by *Southern Aquarius*, and catch rate (kg/n.mile), maximum circle size = 21000 kg/n.mile) of orange roughy (lower panel).

3.4 *Experiments*

3.4.1 Repeated surveys

The targeted and scrutinised estimates for surveys 4 to 8 at Rix are relatively close to one another (Sections 3.3.11 and 3.3.12), despite the the large CVs for the individual surveys (a consequence of the low number of transects). The combined estimate for the 5 surveys, treating all equally, is 8 532 tonnes (7 686*) (CV = 0.24) for the targeted acoustic method, and 8 356 tonnes (7 528*) (CV = 0.25) for the scrutinised acoustic method.

3.4.2 Dropped sonde

Due to the lack of time and rough weather this kind of experiment was only attempted once. A swell of approximately 2 m resulted in considerable vertical movements of the transducer. This may likely have introduced horisontal and rolling like movements of the transducer too. Regardless of these disturbances, the orange roughy aggregation could be seen when the transducer was about 150 m above the fish, but as soon as it was lowered any closer to the aggregation the orange roughy could not be observed any more. A likely reason for this is that the orange roughy sensed the low frequency sound waves set up by the moving transducer, and thereby moved away from the observation volume.

3.4.3 Observations of fish behaviour during trawling

An attempt was made to detect orange roughy around Southern Aquarius' trawl by positioning the Fridtjof Nansen over the trawl, but trawl marks were only observed as the net was being retrieved close to surface. This sort of experiment requires a large degree of trial and error and is not easy to integrate into a survey where surveytime is a premium.

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* corrected for 11 %absorption

3.5 Observertraining

8 observers participated in a grade 3 special training course during the survey. The purpose of the course was to introduce the observers to deep water fisheries specific biological sampling strategies, biological characteristics, deep water gear technology, management tools and scientific surveys. The observers were divided in to pairs. Each observer participated in one leg of the survey, half of it on the commercial vessel and half of it on the Dr Fridtjof Nansen for theory lessons and biological sampling. All observers adapted well to the sampling teams and showed interest in and understanding of both the theoretical and the practical tasks given to them.

CHAPTER 4 DISCUSSION

The nature of the orange roughy survey in July 1998 is a complex one. The depth ranges that are covered are moving towards the limits of performance for the modern equipment onboard RV Dr Fridtjof Nansen and the commercial vessels. The appearance of the orange roughy and its strongly aggregating behaviour makes it a challenging fish specie to try to assess by traditional acoustical and swept area methods. Data were collected on many of the biases that are believed to affect acoustic and/or swept-area survey estimates. Where possible these data have been analysed and reported here. In some instances considerable amounts of data have been collected and these require dedicated time to fully interpret. Some of the data collected will be made full use of in the species identifiation guide, the observer training and in conversion factor studies. Several of the other objectives could not be attempted (e.g. target strength estimations) due to extended periods of adverse weather conditions or equipment failure. The seasonality in aggregating behavior also brings several aspects of uncertainty into the assessment and the timing of the survey.

Survey timing

Timing of the survey is a critical issue. Orange roughy typically form dense aggregations for spawning, and are fairly synchronous in the timing of spawning activity. The extent of possible turnover on Namibian grounds is unknown, but is not thought to be an issue in several New Zealand fisheries except when intensive trawling pressure disrupts and breaks up schools. Given a stable spawning distribution, the problem can arise with timing if the survey is too soon before spawning (and fish are still moving into the survey area), or too late (once fish have stated to emigrate).

Trawl data give two clues on whether timing was appropriate or not. The first is in the distribution of catches. The *Emanguluku* trawled on each ground between 2 and 9 July, with the *Southern Aquarius* covering the period from 14 to 24 July. The location of trawls differed between the two vessels, but generally they towed on a combination of scattered random positions, and targeted acoustic marks. The catches of each vessel are shown in Figure 18 and Figure 19. On Johnies, large catches were taken by the two vessels in stratum 1. Some smaller catches occurred to the southwest, but these were not substantial compared to the core area. It is possible that these represent scattered pockets of fish moving in or out of the main spawning ground, but overall the data indicate the distribution of fish was relatively stable during the period of the survey. This years survey showed very little fish outside the main aggregations and rise the question to what degree there is still a buffer zone of incoming fish to spawning ground or if the aggregation represent the bulk part of the stock.

The second source of data is information on gonad stage of fish. It is generally accepted with orange roughy that distribution is most stable at the time of spawning, characterised by high levels (greater than 50%) of ripe and running fish. Proportions of maturing, or spent, stages should be lower. The maturity stages combined with the catch composition and distribution indicate that the survey covered the main part of the spawning orange roughy on all three grounds, therefore, the timing of the survey was appropriate with respect to the timing of spawning.

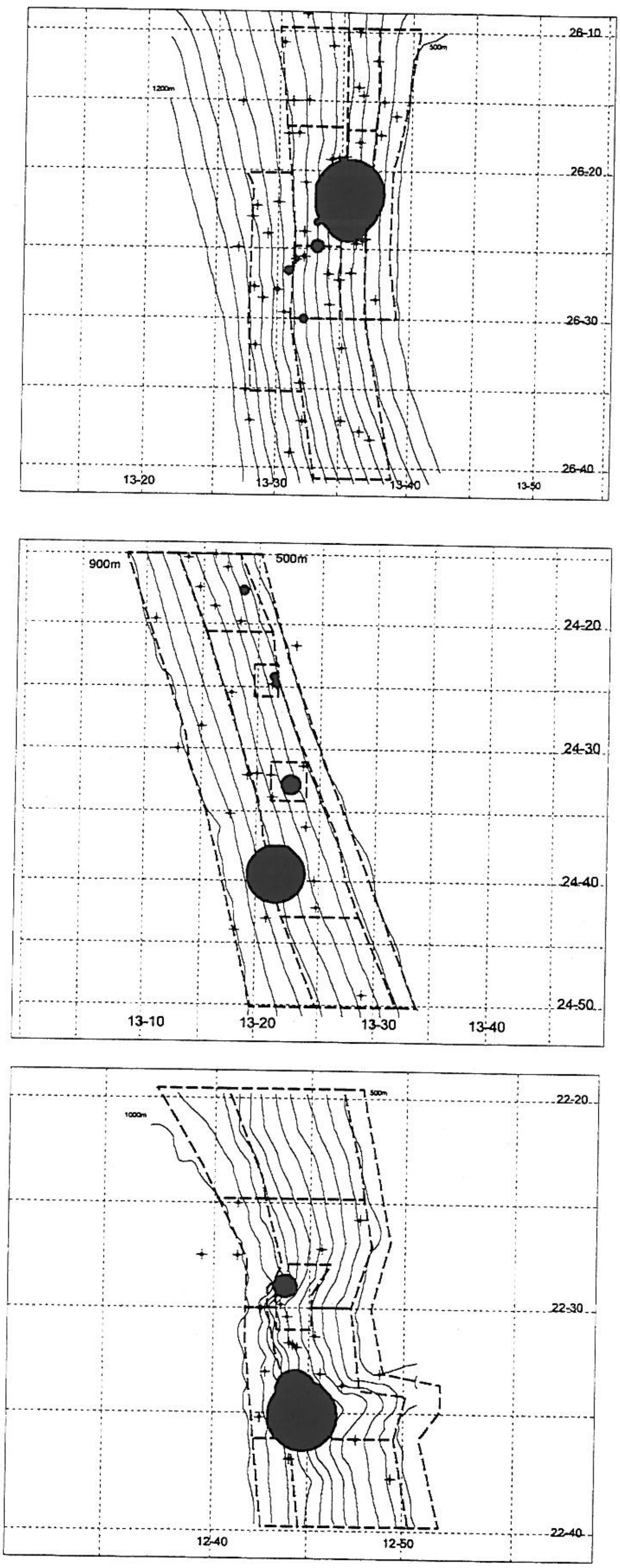


Figure 18 Distribution of catch per trawl between 2-9 July (*Emanguluku*, red), and 14-24 July (*Southern Aquarius*, blue) on the three grounds (circle size proportional to catch, maximum size 50 t on Johnies, 5 t on Frankies, 30 t on Rix).

4.1 Hydrography and meteorology

During the survey all together 55 CTD stations were carried out on the three grounds to capture data in the most important stratas. The bottom temperature for the survey area varied between 9^0 C for Johnies at 400 m to less than 4^0 C deeper than 950 meters at Johnies and Rix. The optimal temperature range for orange roughy is considered to be between 4 ^{O}C and 6 ^{O}C and the falls within the temperature range in the survey area.

The sound velocity and acoustic absorption factor (α) were calculated after Francois and Garrison (1982) using the registrations from CTD station 721 and station 741 to get values from similar depths as last year (750 m). The calculated absorption of 9.53 dB is 0.47 dB lower than the Simrad EK 500 setting at 10 dB used in the survey. This results in an error on the s_A values of 11 % that has to be deducted from the acoustic estimates.

4.2 Trawl sampling

For the 1. Leg of the survey the *FV Emanguluko* used small meshed inner lining to capture if there was small orange roughy present on the ground together with commercial sized orange roughy. This was not very successful, little small fish was caught, and the inner lining was just used for the initial targeted trawls at Johnies on the 2. Leg with *FV Southern Aquarius* to avoid differences in gear performance compared to 1997 trawl survey. The difference in size, horsepower, reaction to bad weather conditions also made it uncertain to what extent the two vessels catch performance could be compared. The trawl sampling was as described in the procedure of the 1997 survey. Some conversion factor experiments were undertaken but is not included in this report. The weather conditions made it difficult to sample properly, and the sampling teams did a good job making the best possible out of the sampling. Also the facilitation of the sampling was generally good from the crews on all three vessels side.

Reproduction

The highest proportion of running and spent males was found at Johnies (2.leg), while highest proportion of spent females was at Rix on the last day of the survey. Based on the male stages Johnies were already in spawning state, but with a lower proportion of females spawning at that time. The differences in the development of the maturity stages between the first and second coverage of Frankies and Rix confirm the build up for spawning. At Johnies the proportion of running and spent females increased somewhat between the two coverage's, but not as pronounced as for males. The relatively high proportion of nonspawning (stage 1 and stage 2) males and females during the spawning season, calls for further monitoring of the development on the grounds. Especially to see if several peaks of spawning can be observed throughout the year and if a large proportion of fish do not spawn each year.

The proportion of males was highest at Johnies (58%) and lowest at Rix (43 %). From the length at 50 % maturity it is evident that the fish was larger at spawning on Rix (26.7 cm) than Johnies (21.3 cm) and Frankies (22.7 cm). Compared to the 1997 the females have similar length at 50 % maturity per ground. This difference in length at 50 % maturity indicate that the grounds are either strongly separated and that they have developed different spawning strategies or that the larger fish seek northwards when maturing. Given the short period of fishing (since 1995) and the slow growth of orange roughy it is unlikely that the fish at Johnies already have adapted to the fishing pressure by lowering the length at maturity with 25 % compared to Rix. Further the orange roughy at Frankies have not changed the length at 50 % maturity even though very little orange roughy were found at peak spawning (and also so far this Quota year from commercial catches).

4.3 Biology

Length frequencies varied with ground and coverages, partly because of two different meshsizes in the codend during first and second leg. The Emanguluko was likely to catch more small fish in the trawl as it had a small meshed inner lining for the whole leg, while Southern Aquarius only used the inner lining for the targeted trawls at Johnies. Mean length per ground was increased northwards, with Johnies being approximately 2 cm shorter than Rix and Frankies being more than 0.5 cm shorter than Rix.

More than 6 200 orange roughy sampled from all together 60 trawl hauls at Johnies, so the distribution should be representative for the area. Compared to last years 26.5 cm (n= 4 770) mean length for Johnies it is a decrease of between 0.5 cm (from *Southern Aquarius*) and 1.3 cm (from *Emanguluko*). The length weight relationship for the Southern Aquarius differed with less than 1 % from the 1997 survey so no condition factor changes could be observed between the two surveys.

From Frankies more than 1 700 orange roughy were sampled. 250 of these were from *Emangulukos* small meshed innerlining trawls. These catches showed that immature orange roughy down to 8 cm were readily caught, and confirmed their presence in the same areas as the adult fish. This should be investigated further as research on the separation of the grounds and migration between grounds becomes prioritised. Compared to last years mean length the average at Frankies of 27.25 cm was 0,65 cm less (2.4 %) and the length weight relationship showed a decrease in weight of 6,3 % (n_{97}=694 and n_{98}=1 421) at 30 cm.

For Rix 21 trawlhauls contained orange roughy. From this the average length from Emanguluko catches was 28.5 cm (n=506) and from Southern Aquarius catches 27.8 cm (n=1196). Survey 1997 showed an average length of 27,9 cm , in between the two 1998 values. The Rix distribution had a higher percentage of the catches around the mean values than the other two grounds. Although orange roughy down to 13 cm was registered. No length weight relationship was determined for Rix in the 1997 survey. The two length weight relationships for Emanguluko and Southern Aquarius were almost identical for 1998.

4.4 Survey methodology

4.4.1 Survey Design

The designs used on this survey, which were simple forms of adaptive sampling, were effective in concentrating survey effort into regions where it was most needed, although they were unlikely to have been optimum, in that transect spacing was not set or adjusted according to estimates of mean density or variance. (A practical difficulty in adapting the design in this way is that estimates of density and variance estimates were not immediately available during the survey due to the time needed to scrutinise the acoustic data and incorporate the trawl information on target identity).

The adaptive approach used, in which areas where no roughy were detected on the initial wide survey(s) were not subsequently re-surveyed, will be negatively biased if a significant portion of the biomass is missed on the initial survey(s) and is therefore excluded from further analysis. Although it appears unlikely from geostatistical estimates of aggregation size made from the 1997 survey data that any major aggregations would have been missed on transects spaced 1 mile apart, the possibility cannot be excluded, especially if the aggregations were smaller this year than last year.

The experiment in randomising transects, carried out at Rix in Leg 2, was successful in that it proved practicable, and has enabled valid estimates of sampling variance to be obtained for each of the 5 surveys. The fact that the 5 estimates were similar, both to one another and to the two other estimates made at Rix in Leg 2 is reasonably convincing evidence (given the large CVs) that during the course of these surveys there was no bias variable enough to overide the sampling variance. In contrast, the large difference between the two replicate estimates at Johnies (Surveys 4 and 5) made within the same day could indicate a significant change in the bias, especially since it did appear as if the aggregations had moved off the bottom by the time of the second survey (which gave the higher estimate).

4.4.2 Technical considerations for the acoustic survey

Target identification

Partly because of their scarcity, and the reliance on a commercial vessel to identify specific targets, it took some time before roughy aggregations could be identified with any confidence from distinctive echo characteristics. Apart from the very occasional characteristic «plume» or «cloud» clear of the bottom, classification was done as much by locality (particularly the depth zone) and the presence of similar marks on adjacent transects at the same depths, as by the echo characteristics *per se*. It was never possible to recognise the presence of roughy in the diffuse near-bottom layers which were commonly found both inshore and offshore of the aggregations, although trawls on these layers usually did capture some roughy. As this is an intractable problem with current acoustic technology, effort in improving target identification should be concentrated on identifying the aggregations, both through collecting more data on aggregation morphology, and by gaining a better understanding of their dynamics. The possibility of identification through multi-frequency signatures could also be investigated.

Estimation of roughy density in mixed layers

As previously discussed, the estimation of roughy density when roughy is a minor component in a mixture of species having far greater target strengths per unit weight is a major problem because of great uncertainty regarding the target strengths of the species in the mixture, and trawl selectivity. (Note that in the 1997 survey, a comparison between *Southern Aquarius* and *RV Fridtjof Nansen* catches indicated a substantial selectivity against smaller fish in *Aquarius*' catches). The likely difference between species in avoidance behaviour to the trawlgear, raise the question to what extent the catches are the true representation of species present on the aggregation surveyed acoustically and by trawl. Even if the species composition is right, the difference in Target Strength between species is uncertain. Since orange roughy has a low target strength each percent of difference in the species representation will have a huge impact on the biomass estimate. Given these problems it would seem wisest at this stage not to use acoustics to estimate roughy density in mixed layers, other than to obtain a semi-quantitative estimate of this component for methodological and behavioural investigations.

Dead zone problems

As discussed previously, a significant portion of the roughy biomass on this survey may have been missed (at least in some of the areas) by being too close to the bottom to be detected, especially when on uneven ground. The general conclusion is that the dead zone problem, which was thought to have been relatively minor on the 1997 survey, may have to be re-visited. Some preliminary analysis of the verticle density profile of roughy aggregations was conducted during the survey, but this proved to require time-consuming data manipulation and hence little was achieved.

The general conclusion is that the dead zone problem, which was thought to have been relatively minor on the 1997 survey, may have to be re-visited, especially as a subjective assessment of the data suggested that this problem was greater than in 1997.

Experimental work

Because of the lack of time for experimental work, and to some extent, inadequate equipment (see Section 2) few of the secondary objectives of the survey were addressed, and none was investigated thoroughly enough to provide useful results. Much of the intended work (which was mostly scheduled for Leg 1) would have entailed extensive experimentation, involving in most cases a large degree of trial and error. In future, it may be better to conduct this work independently of the survey, where possible, in order to devote sufficient time to it.

Equipment performance

A number of items of equipment were not operational, the most serious of which were the FOCUS deep-towed transducer system, and the Simrad netsonde. The former precluded any form of investigation into dead zone problems by comparing the effect of range on near-bottom echoes, while the lack of any form of display of fish targets below or above the headline greatly reduced the usefulness of the midwater trawl for target identification, and precluded any investigations into the reaction of roughy to the trawl.

Calibration

Calibration was not undertaken prior to the survey. Posterior calibration in Angolan waters for the survey immediately after the orange roughy survey showed a 2 % deviation from previous calibration.. This has not been accounted for in the biomass estimates.

Future equipment needs

Very serious consideration should be given to securing a suitable multi-frequency deep-tow system for acoustic surveys of orange roughy off Namibia, both for *in situ* target strength measurements, and investigation into dead zone problems. An alternative, less expensive, option might be an adequately stabilised drop transducer or pair of transducers on a well-matched cable which could be drifted over roughy targets at short range. Such a system would require a less-specialised winch, and could be used on different vessels, increasing the scope for experimental work.

Another need is for a local PC-based data-capture and echo-integration system which could be used by NatMIRC staff, both on board and ashore, to re-process raw acoustic data files in whatever way is desired. (At present, acoustic data files are only available for re-analysis after being screened through the Bergen Echo Integration system on *RV Fridtjof Nansen,* which makes further analysis reliant on the initial screening and data output decisions that have been made during the survey, and removes many re-processing options from local staff). Adaptive survey design used for acoustic whereby initial surveys defined the main areas of aggregations and subsequent surveys concentrated on these areas. A possible source of bias could have been introduced by aggregations being missed during these preliminary surveys and hence not being included in the intensive surveys. The intensive surveys were designed on information collected during two surveys of each area, once during the first part of the trip and again during the second part. Further commercial activities in the period leading up to the survey, and the results of the random trawls conducted by the *FV.Emanguluko* and *FV Southern Aquarius* tended to support the use of the adaptive survey methodology.

When wind conditions were greater than 20 knots a bubble correction factor was applied to the acoustic data. This was generally 5%, but when visible attenuation of signals occurred, on the echo charts, this was increased to 10%. If the wind exceeded 35 knots, attenuation was so severe that acoustic data collection was not possible.

The difference between targeted and scrutinised estimates largely determined by the amount of roughy occurring in dispersed mixed demersal layers. For example, the scrutinised estimates derived from Surveys 3 and 4 of Johnies are each about 3000 tonnes higher than the estimates derived from the targeted method. Conversely the estimates by both methods during Surveys 5 and 6 are almost identical. This suggests that for some reason, possible the aggregating behaviour reached a peak, roughy were more aggregated during Surveys 5 and 6.

The difference between acoustic estimates of Frankies of coverage 2 and 3+4+5 of Frankies could be due to sampling error.

The adaptive nature of the survey on Frankies, whereby small sub-areas were surveyed intensively, may have resulted in some aggregations being missed. All the evidence suggest that this was rather unlikely and if any aggregations did occur outside of the three regions surveyed, then they must have been very small.

On the Rix ground most of the biomass was found in the south where no commercial catches have previously been taken. Due to communication problem commercial activity continued in the north-western corner of box until the first survey started. In addition, during the previous few days there had been several boats fishing this ground. Therefore it is possible that fish had moved southwards away from commercial activity. Alternatively the fish may have become dispersed. The final surveys on Rix were conducted several days after all commercial activity had ceased, and before the *FV.Southern Aquarius* had started trawling in the area of the aggregations.

4.4.3 Targeted acoustics

Targeted trawling by the commercial vessels to identify acoustic targets was reasonably successful at Johnies (at least during Leg 2) where most of the trawls were done, and where the vessels were generally close to *RV Fridtjof Nansen.* In the other two areas there was often a long time gap (sometimes many days) between detection of a target by *RV Fridtjof Nansen* and identification by trawl, raising doubts whether the targets captured were those detected by *RV Fridtjof Nansen,* or were even representative of them. At this stage, when much has still to be learned regarding recognition of roughy marks, it may be worth sacrificing some survey time to carry out more of the targeted trawling from the survey vessel, as direct verification of target identity shortly after detection would enable confidence in classifying targets to be built up more rapidly. This would have to be done with discretion however, because of the length of time required to shoot and retrieve the trawl, and the possibility of large, wasteful catches of roughy should the net pass through an aggregation. Methods of allowing the bulk of the catch to escape under these conditions should be considered.

Biomass estimation

The biomass estimates made by the Targeted Acoustics method rely heavily on the ability to recognise roughy aggregations, the assumption that these aggregations consist entirely of roughy, and the conclusion that most of the biomass is concentrated in them. These conditions did seem to apply for most of the surveys in Leg 2, although the fact that no aggregations were detected on a number of the surveys indicates that the method will not always be applicable. It furthermore indicates that the proportion in aggregations may vary considerably, even over relatively short time periods, introducing a potentially large and variable bias. The inclusion of the dispersed component through the Scrutinised Acoustic method does correct for this to some extent, but the larger the correction, the more susceptible the estimate becomes to errors in extracting the roughy component of the mixed layers. If, as it appears at present, orange roughy can only be estimated acoustically when the biomass is concentrated in recognisable aggregations, future work should be concentrated on understanding the dynamics of aggregation formation and dispersal to give the targeted acoustic method the best chance of success.

4.4.4 Scrutinised acoustics

Estimates of dispersed orange roughy (not in aggregations) based on the acoustical appearance of echoes and trawl catches are considered to be inaccurate. Firstly, it proved to be extremely difficult to estimate the proportion of orange roughy in scattered layers of fish; pairs of trawls on apparently similar marks in the same general area often having proportional differences by an order of magnitude. Secondly, due to low target strength of orange roughy compared to other species, even small proportions of fish with swimbladders masked any echo produced by orange roughy. An example, target containing 50 % orange roughy and 50 % hake would have an acoustic back scatter where 2.5 % were from orange roughy and the rest from the hake.

4.4.5 Trawl sample based acoustics

The method is strongly dependent on the catch composition in all layers because of the low backscatter for orange roughy and that trawling is only in the bottom channel. This assumption has to be taken into account when evaluating the method.

Once the data from Johnies had been analysed it was decided that this method was not applicable for further use due to even a slight uncertainty in the value of target strength causing large uncertainties in the biomass estimate, due to the weak back-scatter properties of roughy. Few samples also per strata made the method susceptible to big variation in biomass estimates because of difference in catch size, as the catch composition per trawl-haul strongly affect the biomass estimate because of the low target strength of orange roughy.

4.4.6 Swept area estimates

The trawl data were intended to fulfill three functions:

- Identification of acoustic targets
- Relative swept-area estimates
- Relative species composition

With attempts to cover three grounds, the number of tows was appreciably less than would have been done if the survey was designed solely for biomass estimation. Emphasis was placed on Johnies for swept-area work, as this was the ground with the largest biomass from 1997, historically the largest fishery, and also where the trawl work in 1997 didn't sample the distribution very well. Less effort was put into Frankies and Rix, given time constraints towards the end of the survey. This is reflected in the relatively high CVs on Frankies and Rix, which could have been lower if more tows were carried out. At Frankies, the trawl results are representative of abundance of fish at the time, and although not precise, the general level of the biomass index is appropriate. At Rix, however, little confidence is put into the swept-area result.

The involvement of two vessels further constrained the use of trawl data for valid swept-area estimation. Although the same trawl gear was used, the size and power of the two vessels was very different. This may, or may not, affect effective fishing power of the trawl on the bottom, but in trawl survey work worldwide use of the same vessel in a time series is a critical criterion in accepting results. If future survey work is undertaken, one vessel should be used to facilitate comparison WITHIN the survey, and the same vessel should be used each year to facilitate comparison BETWEEN surveys.

Gear parameters are also critical when evaluating trawl results. The area swept is a direct scaling factor on the biomass result, and if herding, or escapement occur relative to the wing-tip distance applied here, then the estimate applied as **absolute** may be incorrect. Vertical distribution is also important, as trawl gear may herd down orange roughy, which will inflate the catch rate. No marks were seen above the trawl headline during any trawls, so if this was a factor it had already occurred before the net reached the fish. The important point to take from the above is that trawl surveys are generally used as **relative** estimates, so that these sorts of factors do not matter if they remain consistent between years. If used as absolute, it must be recognised that there are numerous sources of bias, some potentially very large.

The main limitations of the trawling method are very dense aggregations causing short tows (with poorly defined catch per distance), distribution of fish above the bottom, and distribution over rough ground. Gear saturation was a minor aspect of the trawl survey. During the random trawl survey, only two trawls (both in Johnies stratum 1) were hauled because of marks on the net monitor indicating a large catch was being taken. The second aspect is unknown, as midwater trawl work during the survey was not extensive, and did not prove or disprove vertical extent. There were areas of foul ground, but most of the region is trawlable given appropriate trawl gear and experienced skippers.

The trawl swept-area estimates are based on all fish, not just those of recruited size. However, the proportion of the scaled length frequencies consisting of small, immature, fish that would be classed as non-recruited, is small, and would make little difference. Unless the proportion of pre- and recruited fish is changing markedly between surveys, the use of total biomass will not bias relative results.

4.4.7 Combined acoustics/swept area

In 1997 the targeted acoustic biomass estimates of roughy in aggregations and swept-area estimates of dispersed roughy were combined in an attempt to provide a «total» biomass estimate of the entire roughy component of the stock associated with the aggregations. This methodology is repeated here.

Results from acoustics and swept-area trawl should probably be regarded separately. They were combined here partly through a feeling that acoustics does not pick up dispersed fish well, and from interest in seeing how the numbers compared. However, we have no way of reliably assessing whether the estimates from the two methods are comparable. Intuitively it seems unlikely that they are. Trawl survey estimates need to be corrected by a factor (q, the catchability coefficient) to relate relative to absolute biomass. This is generally derived from a time series of data, where stock reduction analysis estimates virgin biomass, and the correction factor to scale relative indices to this. This parameter can vary between grounds, in New Zealand from 0.5 to 1.5. Similarly, there are a number of substantial uncertainties in the acoustic method which make the estimates also best viewed as relative.

4.5 Biomass estimates

Area-swept estimates are considered reasonable for Johnies and Frankies, but not for Rix. Even though the initial strata from 1997 were further subdivided, and a sub-set of strata fished rather than all, there were insufficient tows in stratum 2s to achieve either an accurate, or precise, result. It was not expected that most of the biomass would be in this stratum, with very little in the main commercial area of stratum 1. Rix also proved a difficult area to fish, with the nature of the bottom meaning it took longer to find patches of trawlable ground, and there was a higher chance of gear damage. Although only 2 trawls from Rix were rejected because of this, most tows suffered some torn meshes in either the lower wings or bellies.

The stratification now established for the trawling appears appropriate. However, the distribution of fish on Johnies and Rix is somewhat variable (at least between 1997 and 1998), and some preliminary trawling is required to determine the location of the high-density strata. Stratum 1 at Johnies last year was based on the depth range of commercial catches, translated into a rectangle and with latitude and longitude boundaries. The aggregations in 1998 were deeper than in 1997, and so although still in stratum 1 (640-680m), some trawls fell outside the longitude boundaries. There is no problem with this stratum moving slightly to encompass the area of the aggregation - in fact it is important that stratification is flexible to fulfill its function. However, this meant that the purpose of stratum 2 wrapping around the central aggregations in all directions became limited on the western (deeper) side, as there was just a 20 m window between 680 m and 700 m.

The vertical extension of orange roughy plumes potentially results in large amounts of fish passing over the headline, giving an under-estimate of the true density. Vertical herding of fish down into the trawl opening has, however, been observed in other roughy fisheries, and is likely to occur in Namibia. This will result in an over-estimate of the true abundance in the path of the net. It is not known how these factors may balance out.

A further problem with the trawl data, particularly for combining acoustic backscattering values to the trawl species composition, comes from mesh selection of smaller fish species. This probably results in an under-representation of many of the smaller species which could account for much of the backscatter. This can result in a much larger proportion of the total S_A value being accredited to orange roughy, and an over-estimate of biomass.

4.6 Experiments

The 5 repeat surveys in the Rix area were valuable, both as an exercise in conducting random-transect surveys, and for the insight gained on sources of sampling error. They showed that it is entirely practicable to use random-transect designs on roughy surveys, albeit with some restriction on the randomisation to avoid sampling the same targets more than once in any grid. Setting up the random grids was facilitated by the information on roughy distribution and target characteristics that had been obtained from the previous systematic surveys of the Rix area, particularly those done immediately prior to the random surveys.

Given the high CVs in each of the surveys, the close agreement between the 5 estimates (Sections 3.3.11 and 3.3.12) is probably somewhat fortuitous. The results do however indicate that during this survey, at least, sources of variation other than sampling variance (e.g. variations in the proportion of the population detectable acoustically, or changes in target strength) were insignificant compared to the sampling variance. The estimates obtained by combining the 5 surveys have an acceptably low CV (24 –25 %), which can be rigorously interpreted because of the randomisation of the transects. Another advantage is that transect spacing in the complete set of 25 transects is random, enabling cross-track spatial structure to be better defined by geostatistical techniques than is possible with systematic grids, where the cross-track correlation structure can only be examined at multiples of the transect spacing.

4.7 Comparison with 1997 results

Orange roughy distribution

The overall distribution of orange roughy was similar between 1997 and 1998 surveys. This is expected from experience with New Zealand and Australian orange roughy fisheries, where both the location, and timing, of the spawning event is very consistent over time.

The aggregations on Johnies were slightly deeper (20 m) than in 1997, but still centred on the same latitude band. The signs on Frankies, although large aggregations were not encountered, also suggested the centres of abundance remain the «Three Sisters» and to a lesser extent «Frankies Flat». The fishery at Rix is the youngest, and it was a surprise to both scientists and the officers on the commercial vessels, that good catches were taken to the south of the 'North Bank', and west of «Willie's Valley». This was south of where most catches were taken during the 1997 survey (Figure 6), and also in an area not covered by the main commercial fishery. It is not clear whether this area represents a shift in distribution (even though only a few miles), or whether the fish were missed in 1997. The acoustic survey last year covered the grounds, but there was limited support trawling to verify mark composition.

Trawl catch rates and biomass

Trawl catch rates in Johnies decreased strongly between 1997 and 1998 in the strata surrounding the main area of aggregation (stratum 1). Catch rates in strata 2 and 6 went from 11 802 and 9 701 kg.n.mile^{-1} respectively in 1997 to 440 and 315 kg.n.mile^{-1} in 1998 (Table 17). However, the catch rates in stratum 1 were generally similar between the two years, with means of 29 638 and 24 904 kg.n.mile^{-1} in 1997 and 1998 respectively.

Table 17 Swept-area comparison of mean catch rate and biomass on Johnies in 1997 and 1998.

Stratum	Catch rate (kg/n.mile)		Biomass (t)		%of total	
	1997	1998	1997	1998	1997	1998
1	29 638	24 904	6 615	5 557	11.5	79.6
2	11 802	440	16 695	264	29.0	3.8
3	1	2	2	4	-	-
4	3	1	4	1	-	-
5	<1	1	1	3	-	-
6	9 701	315	34 293	861	59.5	12.3
7	8	1	31	14	-	-
8	4	189	8	274	-	3.9
Total			57 650	6 979		

The biomass index decreased from 57 650 t to 6 979 t. This was largely due to the low catch rates in strata 2 and 6, which because of their relatively large area accounted for almost 90% of the biomass in 1997.Their contribution in 1998 was 16%. Although the catch rates and biomass in stratum 1 were similar between the two years, the relative importance increased in 1998 to make up almost 80% of the total biomass. The fish in 1998 appeared to be more localised in stratum 1. Aggregations did not extend out to the west and to the south as in

1997, where high catch rates were taken in strata 2 and 6. It is possible that the distribution was more localised with higher fish densities in stratum 1, but this was not reflected in catch rates which were similar in 1997 and 1998 (and not higher in 1998).

These changes have been associated with a shift in the frequency of catch rates. In the Table 18 below the proportion of catch rates of a certain magnitude are summarised for the two years: In 1997 25% of random trawls had a catch rate over 20 t.n.mile^{-1}, but this dropped to 6% in 1998. The frequency of low catch rates increased from 64% to 79%.

Table 18 Comparison of catch rate frequencies between 1997 and 1998 surveys at Johnies (catch rate in kg.n.mile^{-1}).

Catch rate	1997	1998
0-499	0.64	0.79
500-999	0	0.06
1000-4999	0.04	0.03
5000-9999	0.04	0.03
10000-19999	0.04	0.03
≥20000	0.25	0.06

Similar changes occurred at Frankies (Table 19). Catch rates and biomass decreased in the main strata of 1a («Three Sisters») and 1b («Frankies Flat»). Stratum 1a was the only area where reasonable catches occurred during the survey. Its relative importance increased from 55 to 77% of the total biomass.

Table 19 Swept-area comparison of mean catch rate and biomass on Frankies in 1997 and 1998.

Stratum	Catch rate (kg/n.mile)		Biomass (t)		%of total	
	1997	1998	1997	1998	1997	1998
1a	34 107	3 021	17 186	1 848	55.4	76.8
1b	10 972	367	9 873	330	31.8	13.7
1c	201	88	n/a	44	-	1.8
2	185	-	2 245	4	7.2	-
3	429	31	1 598	115	5.1	4.8
6	5	3	93	64	-	2.7
Total			30 995	2 406		

The magnitude of changes seen on both Johnies and Frankies over a one year period is of concern. With only two surveys it is uncertain whether these changes are a true representation of a marked decrease in stock size, or whether availability or catchability have in some way changed. However, there was typically good correspondence between what was seen with acoustics, and what was caught in trawls. No substantial catches were taken where no marks were seen.

Another explanation for reduced abundance is that fish have for some reason decided not to move to the grounds from elsewhere for spawning this year, or have shifted location of spawning. However, this is not known to occur in New Zealand or Australian orange roughy fisheries, where spawning aggregations are consistent in their location and timing. It is known that not all fish spawn each year, but this would not account for the almost complete absence of fish at Frankies. Movement between spawning grounds is unlikely, given that length frequency distributions differ between Johnies, Frankies, and Rix, and these have remained similar between 1997 and 1998.

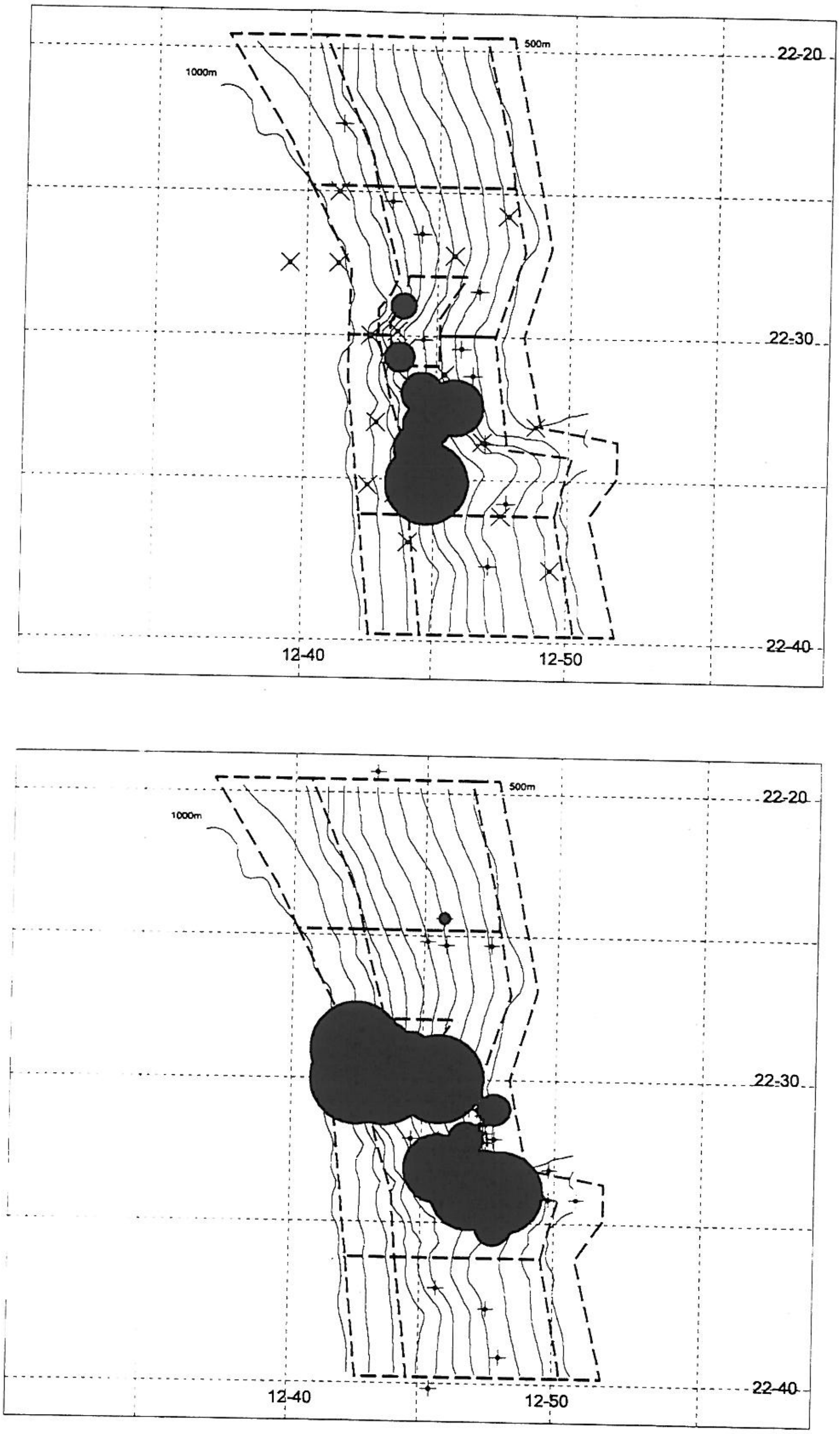


Figure 19 Distribution of orange roughy catch (catch per tow) during 1997 (red) and 1998 (blue) surveys of Rix (top panel, all research tows included), and commercial catches through to mid-1997 (lower panel). Circle size is proportional to catch, maximum circle size = 40000 kg/trawl.

CHAPTER 5 CONCLUSIONS

The survey was conducted in two legs with two different commercial vessels assisting the *RV Dr Fridtjof Nansen* in undertaking the random and targeted trawling for swept area purposes and for species identification. Alltogether 133 trawls were undertaken by the commercial vessels, and 15 by *RV Dr Fridtjof Nansen.* Comparing the two commercial vessels catch performance was difficult due to difference in size, horsepower, and reaction to bad weather conditions.

Bad weather conditions caused the loss of two whole days of surveying and an additional three days with reduced survey activity.

Acoustic survey was undertaken by *RV Dr Fridtjof Nansen* with a 38 KHz transducer mounted on the protractable keel and a hullmounted 18 KHz transducer. The 18 KHz was not used throughout the whole survey, as the weather conditions caused bubble saturation close to the hull.

Both acoustic and trawl surveying showed little orange roughy outside the main known grounds, except from Rix, where trawl sampling found the main aggregation south of the stratum 1 «box».

Targeted acoustic, Scrutinized acoustic, Trawl-sample based acoustic and Swept-area estimates were obtained.

For Johnies the acoustic estimate from targeted acoustic were 2 675 to 4 791 tonnes for the aggregations found. The high estimates of survey one and two (20 666 tonnes and 18 098 tonnes) must be used with caution as the schools were not verified. The scrutinized estimate was between 3 956 tonnes and 7 758 tonnes and the survey one and two (25 578 and 21 810) used with same precaution as for targeted acoustic. Compared to 1997 targeted acoustics decreased from 20 718 tonnes to between 2 675 to 4 791 tonnes and scrutinized acoustic decreased from approximately 38 000 tonnes to 3 956 tonnes and 7 758 tonnes.

Swept area estimates for Johnies were 8 147 tonnes (included stratum nine), with 5 557 tonnes in the stratum one and 1 032 in the new area stratum nine. Compared to last year the estimate at Johnies decreased from 57 650 tonnes to 6 979 (excluded stratum nine), mostly due to the absence of fish in the large stratum six of 1997 survey. Fish was more localized in stratum one in 1998.

For Frankies the acoustic estimate from targeted acoustic were 2 911 to 7 421 tonnes for the aggregations found. The high estimates of survey one (14 738 tonnes) must be used with caution as the schools were not verified. The scrutinized estimate was between 2 455 tonnes and 7 881 tonnes and the survey one (18 561 tonnes) must be used with same precaution as for targeted acoustic. Compared to 1997 targeted acoustics decreased from about 13 100 tonnes to between 2 911 to 7 421 tonnes and scrutinized acoustic decreased from approximately 13 300 tonnes to between 2 455 and 7 881 tonnes.

Swept area estimates for Frankies were 2 406 tonnes, with 1 848 tonnes in the stratum one. Compared to last year the estimate at Frankies decreased from 30 995 tonnes to 2 406, mostly due to the absence of fish in stratum **one a** (Three Sisters) and stratum **one b** (Frankies Flat) and also in stratum two, three and six.of the 1997 survey. Very few aggregations were seen at Frankies during the survey.

For Rix the acoustic estimate from targeted acoustic were from 5 827 (whole area surveyed) to 9 866 tonnes for the aggregations found. The repeated surveys of the aggregation area gave a good impression on survey variability. The scrutinized estimate was between 6 234 tonnes and 10 020 tonnes, with the largest estimate for the repeated random survey of the aggregation. Compared to 1997 targeted acoustics decreased from about 15 940 tonnes to between 5 827 (whole area surveyed) to 9 866 tonnes and scrutinized acoustic were not available for 1997 due to few trawls in the area.

Swept area estimates for Rix were 19 706 tonnes, with 19 683 tonnes in the stratum two and only 18 tonnes in stratum one of 1997 survey. Only nine trawls are included in the estimate. There were no swept area estimate for Rix in 1997 to compare with 1998 estimates.

LITERATURE CITED

Francis, R.I.C.C., 1981: Stratified random trawl surveys of deepwater demersal fish stocks around New Zealand. *Fisheries Research Division Occasional Publication No. 32.* 28.p

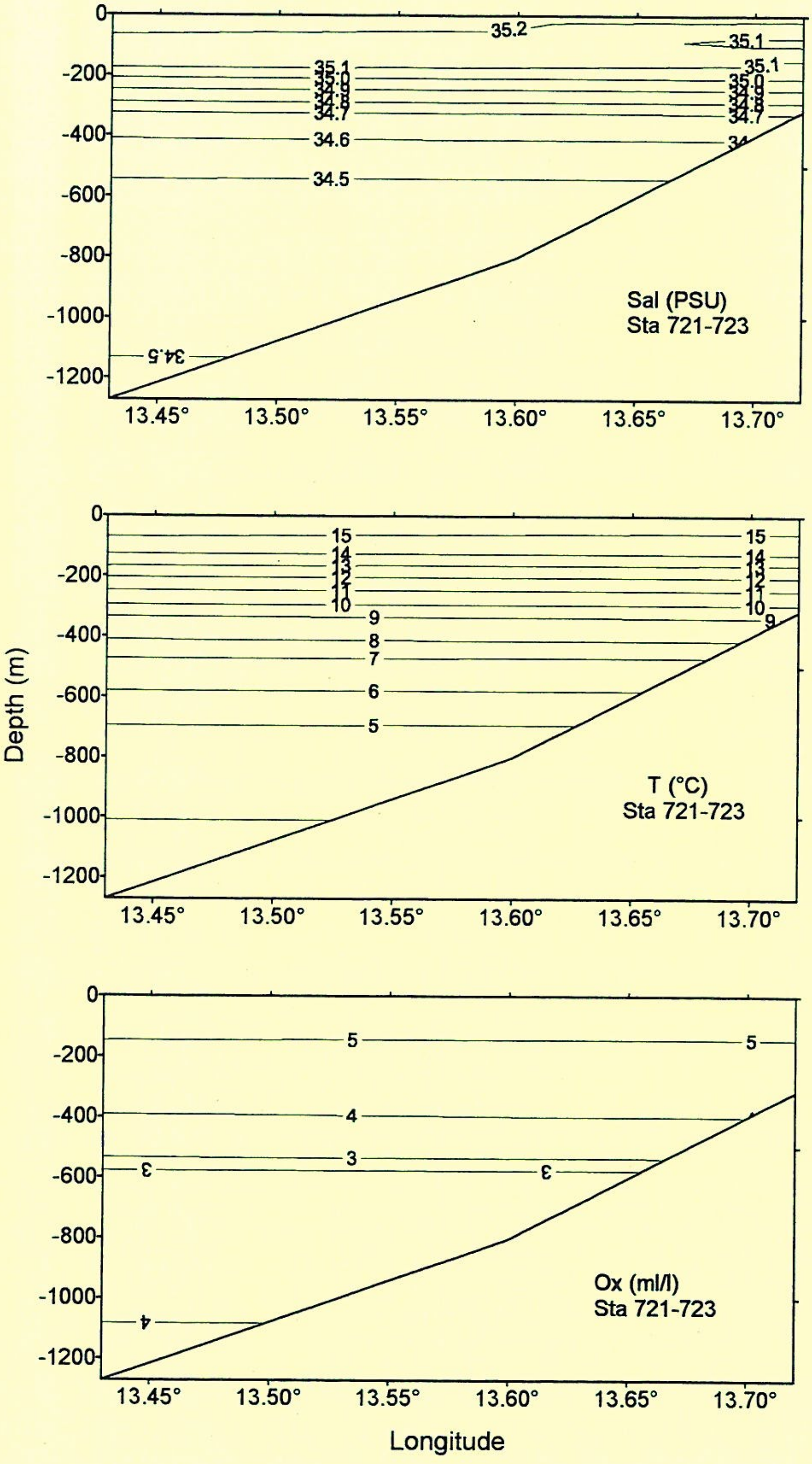
Francois, R. E.. and Garrison, G.R., 1982, Soundabsorption based on an ocean measurement. Parts II: Boric acid contribution and equation for total absorption. *Journal of Acoustic Society of America*, 72. 1879 – 90.

Huse, I., Dahl, M., Øvredal, J.T., Boyer,D., Traut, J., Staalesen, B., Staby, A., Fossen, I., Clark,M., and Kloser, R., 1997, *Orange roughy survey, 15 July - 1. August 1997, Cruise report no 4/97, NORAD-FAO/UNDP PROJECT GLO 92/013. Cruise Reports «Dr. Fridtjof Nansen».*

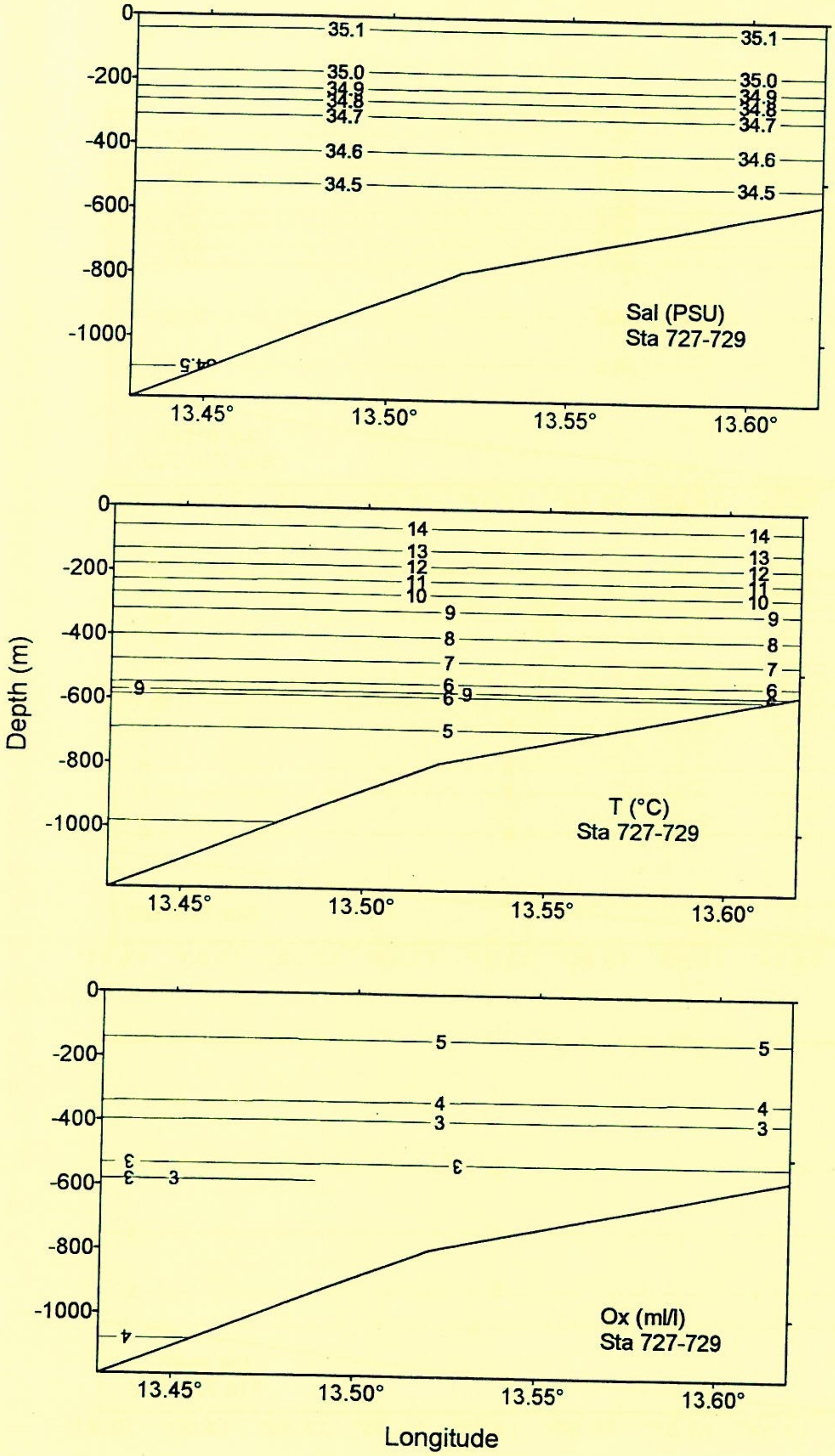
Kloser, R., Williams, A. and Koslow, J.A., 1997, Problems with acoustic target strength mesurements of a deepwater fish, orange roughy (*Hoplosthethus atlanticus,* Collett). *ICES Journal of marine Science 54:60-71.*

Appendix

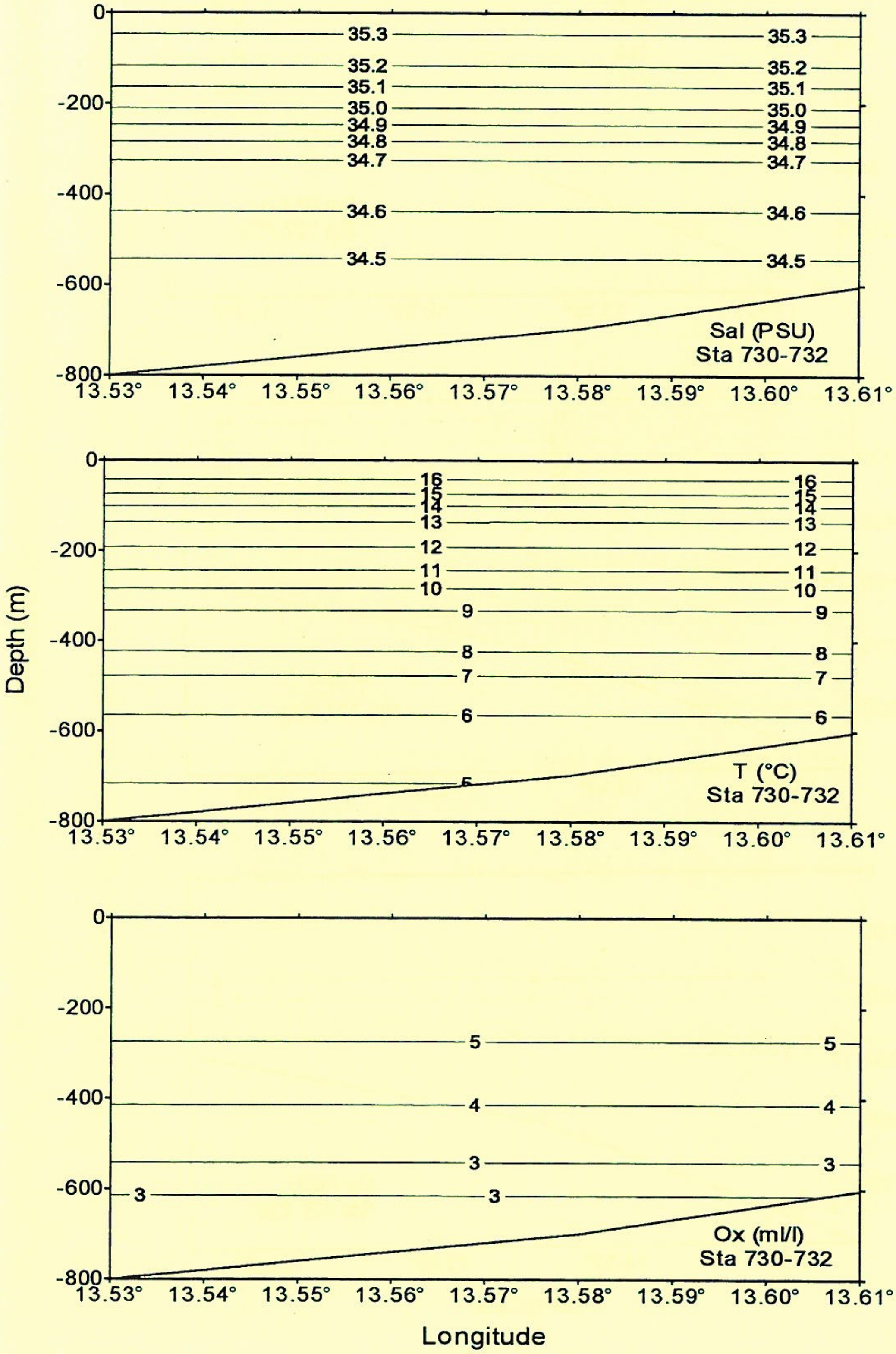
Appendix 1 :Salinity, Temperature and Oxygen graphs for Johnnies.
[date: 8/7/98 ; latitude: 26*40']



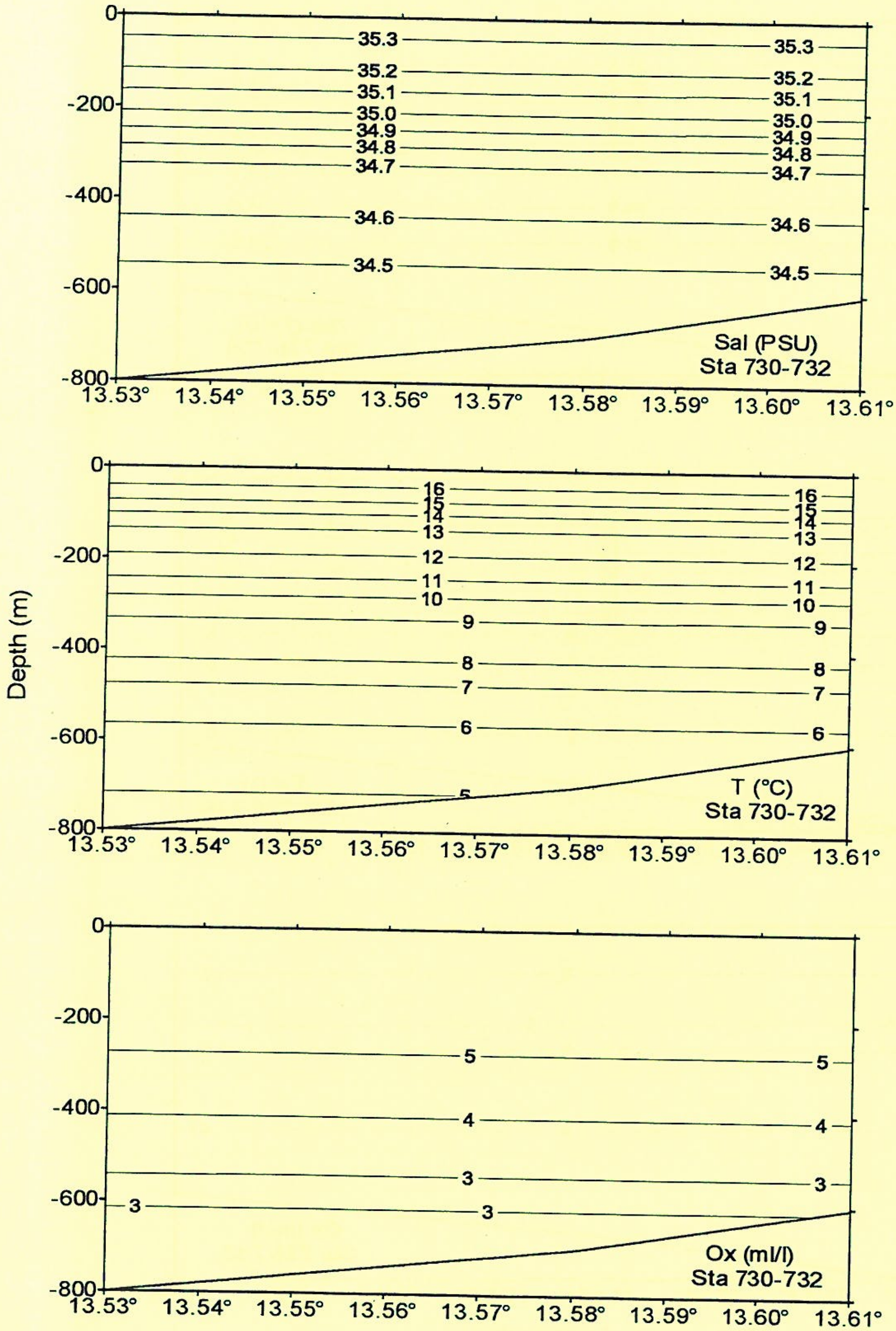
Appendix 2: Salinity, Temperature and Oxygen graphs for Johnnies.
[date; 9/7/98 ; latitude: 26*31']



Appendix 3: Salinity, temperature and oxygen graphs for Johnies.
[date: 7/17/98 ; latitude: 26*17']



Appendix 4: Salinity, temperature and oxygen graphs for Johnies.
[date: 7/17/98 ; latitude: 26*21.25']



Appendix 5: Salinity, temperature and oxygen graphs for Johnies.
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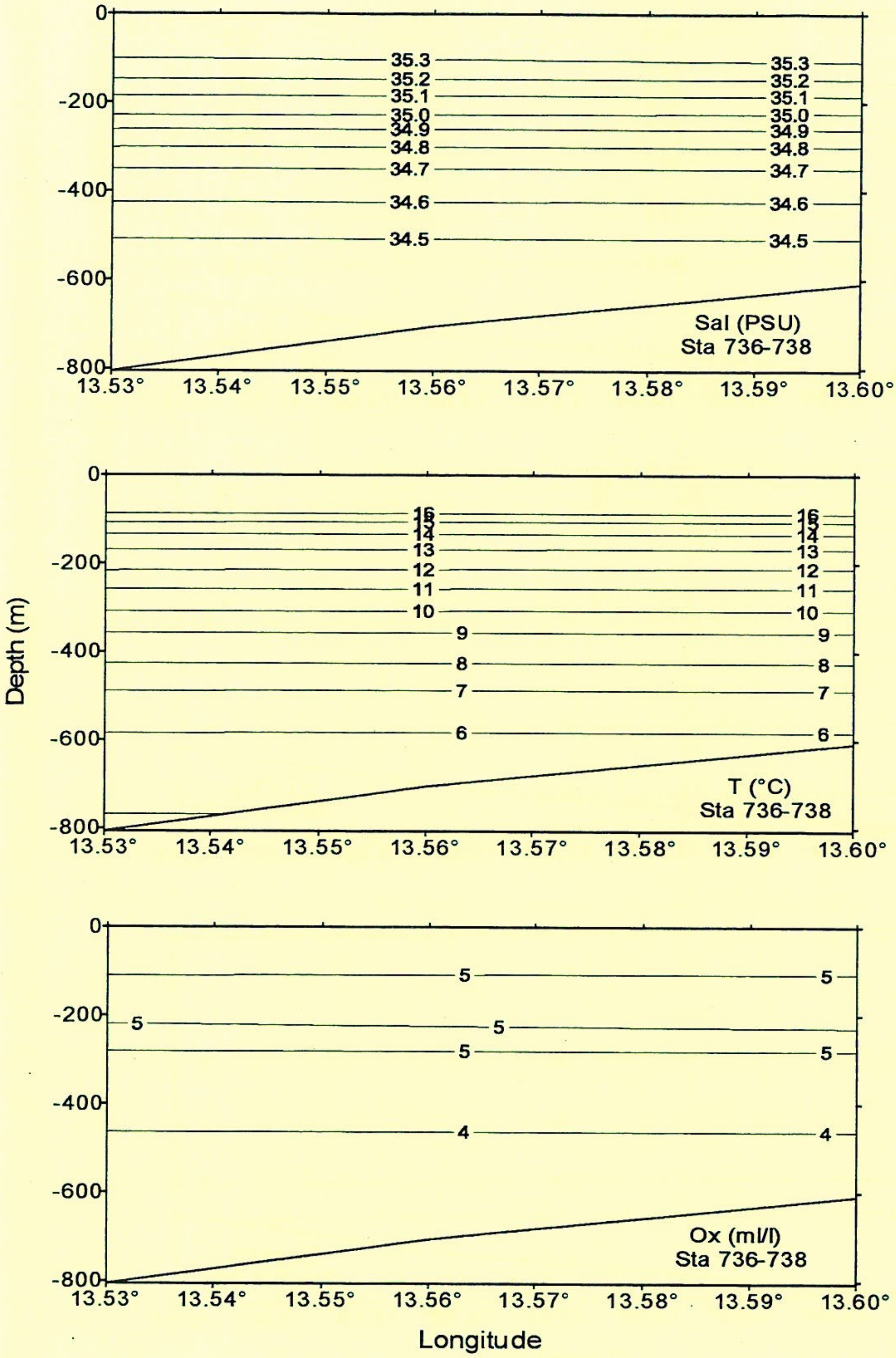
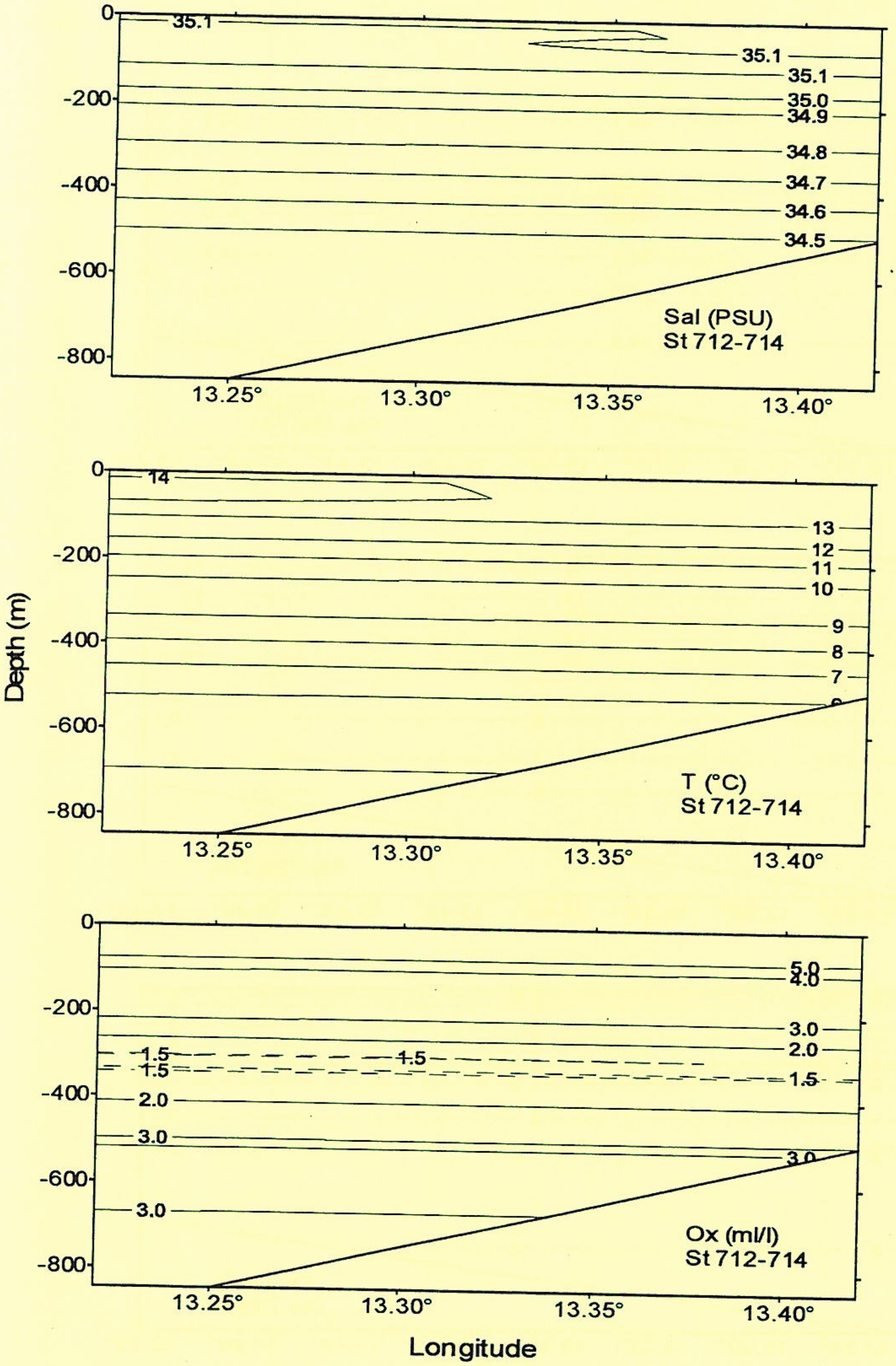
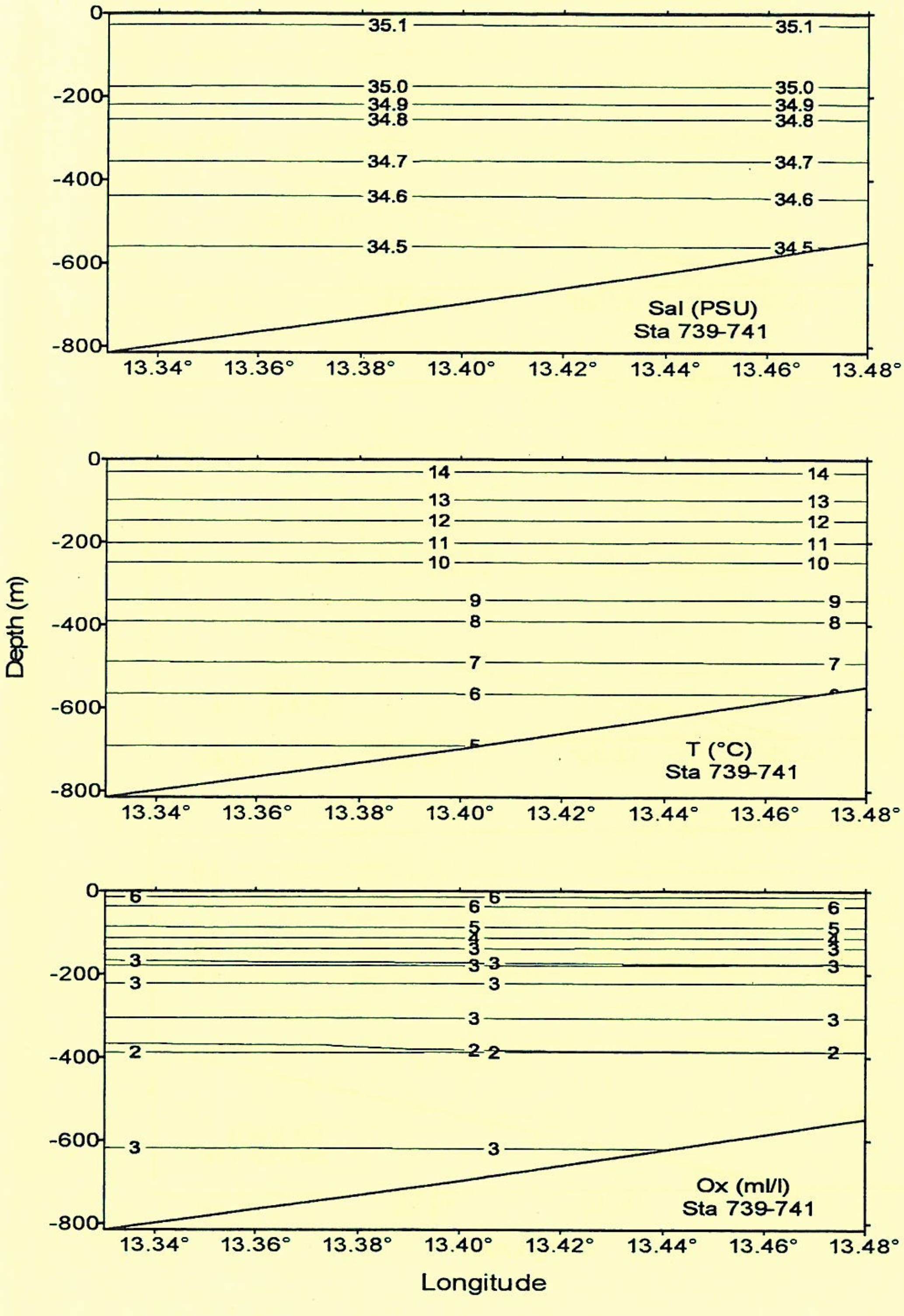


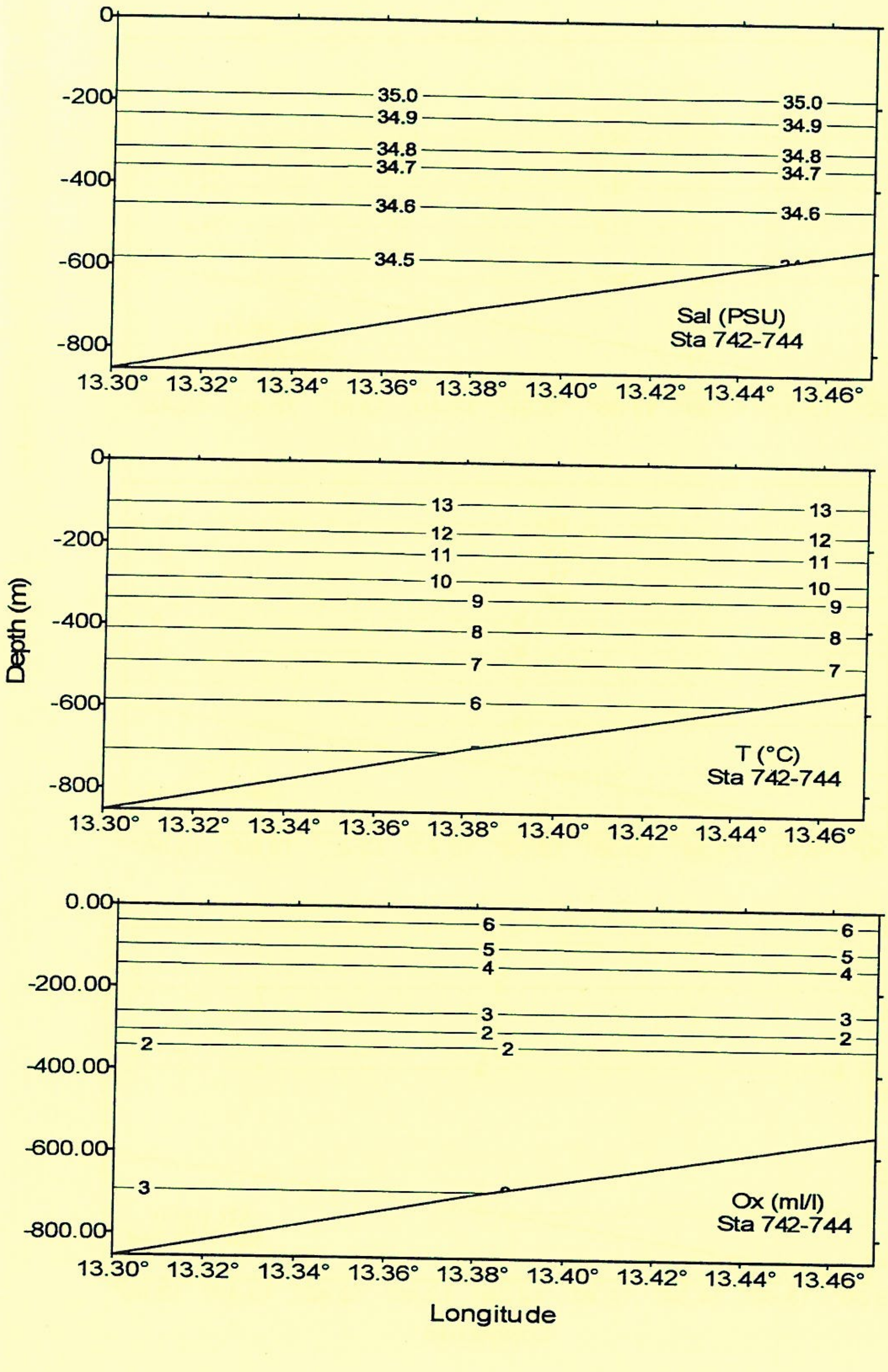
Appendix 6: Salinity, temperature and oxygen graphs for Frankies. [date: 7/8/98 ; latitude: 24*31']



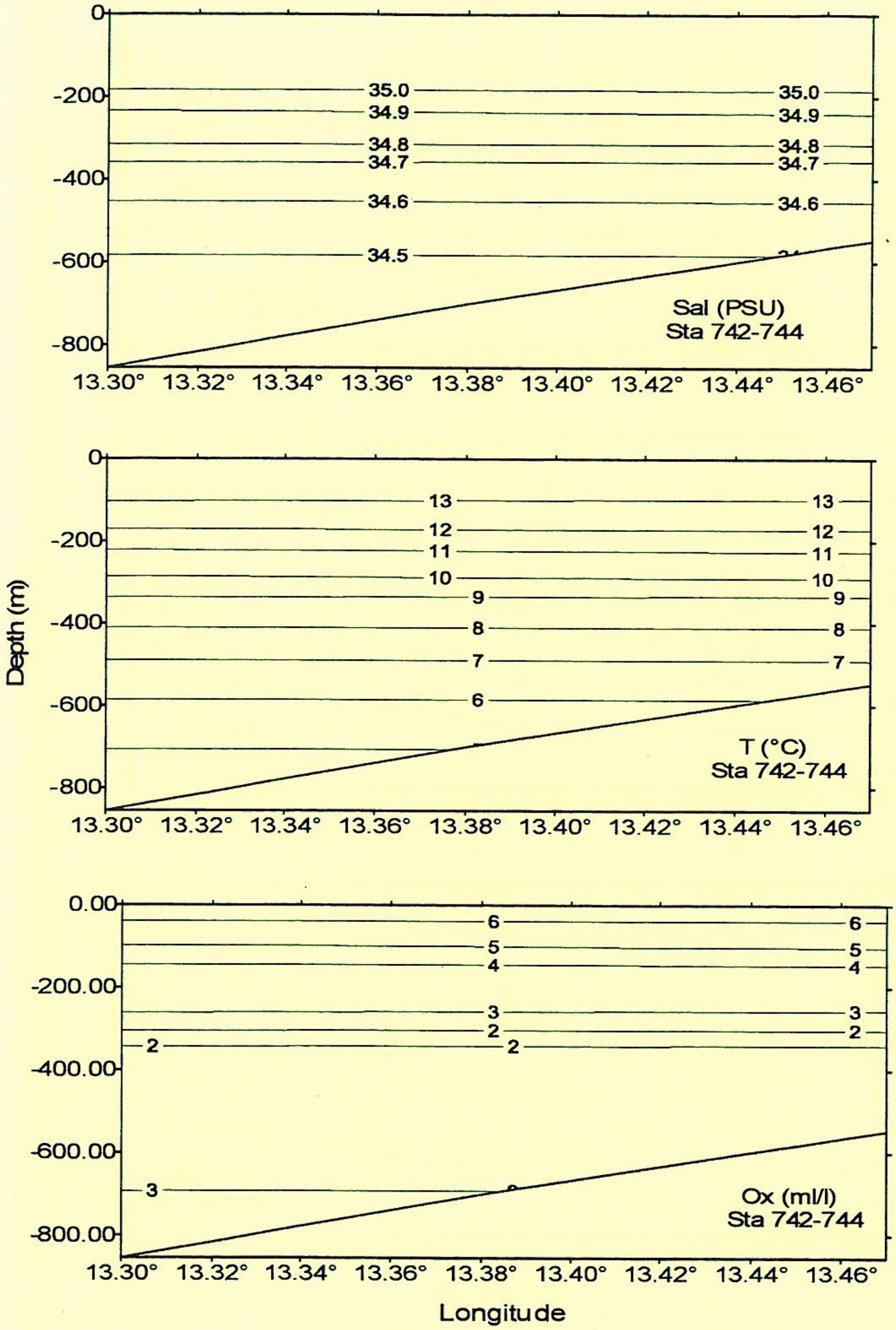
Appendix 7: Salinity, temperature and oxygen graphs for Frankies.
[date: 7/19/98 ; latitude: 24*45']



Appendix 8: Salinity, temperature and oxygen graphs for Frankies.
[date: 7/19/98 ; latitude: 24*40']



Appendix 9: Salinity, temperature and oxygen graphs for Frankies.
[date: 7/19/98 ; latitude: 24*32']



Appendix 10: Salinity, temperature and oxygen graphs for Frankies.
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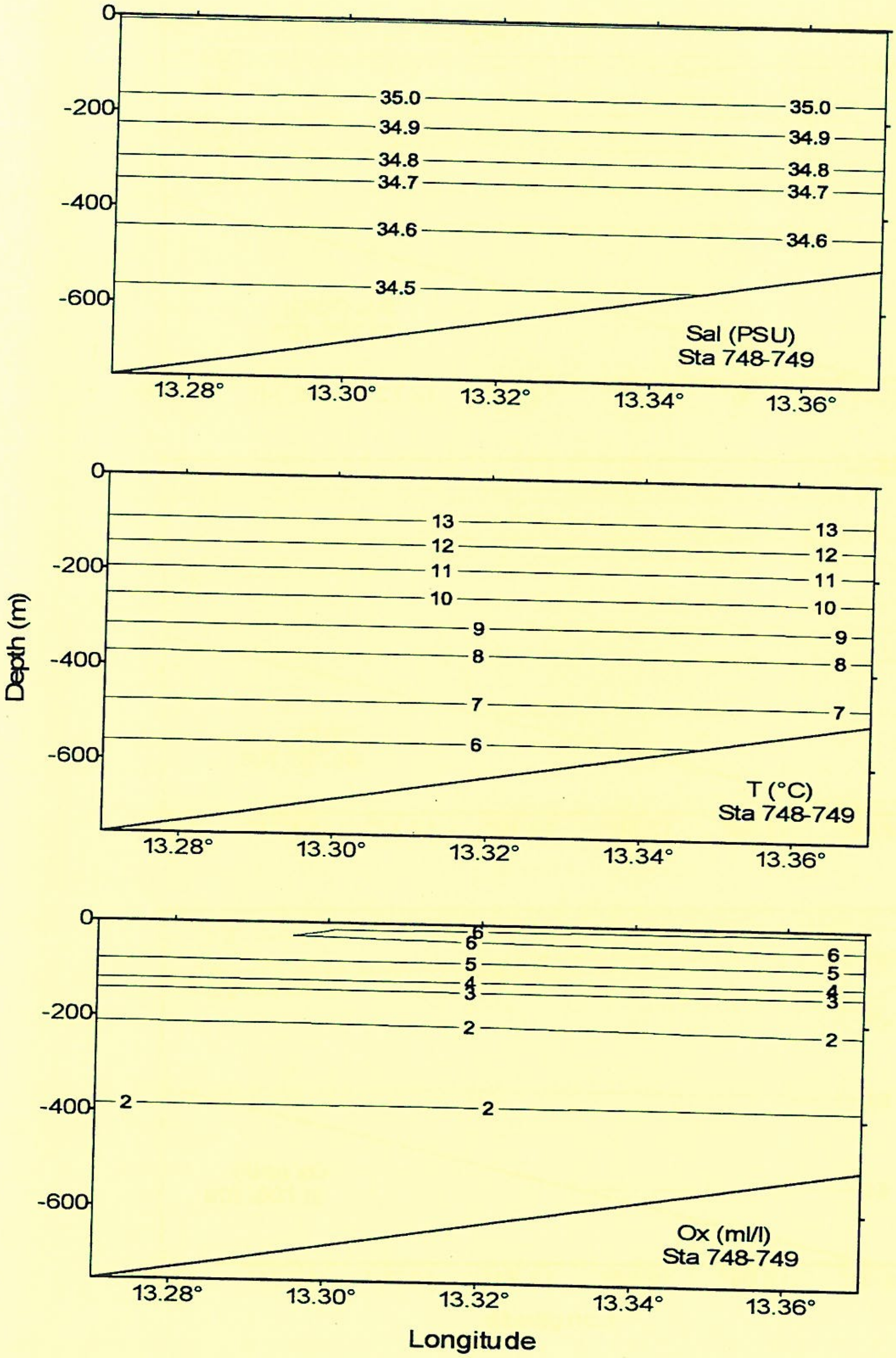
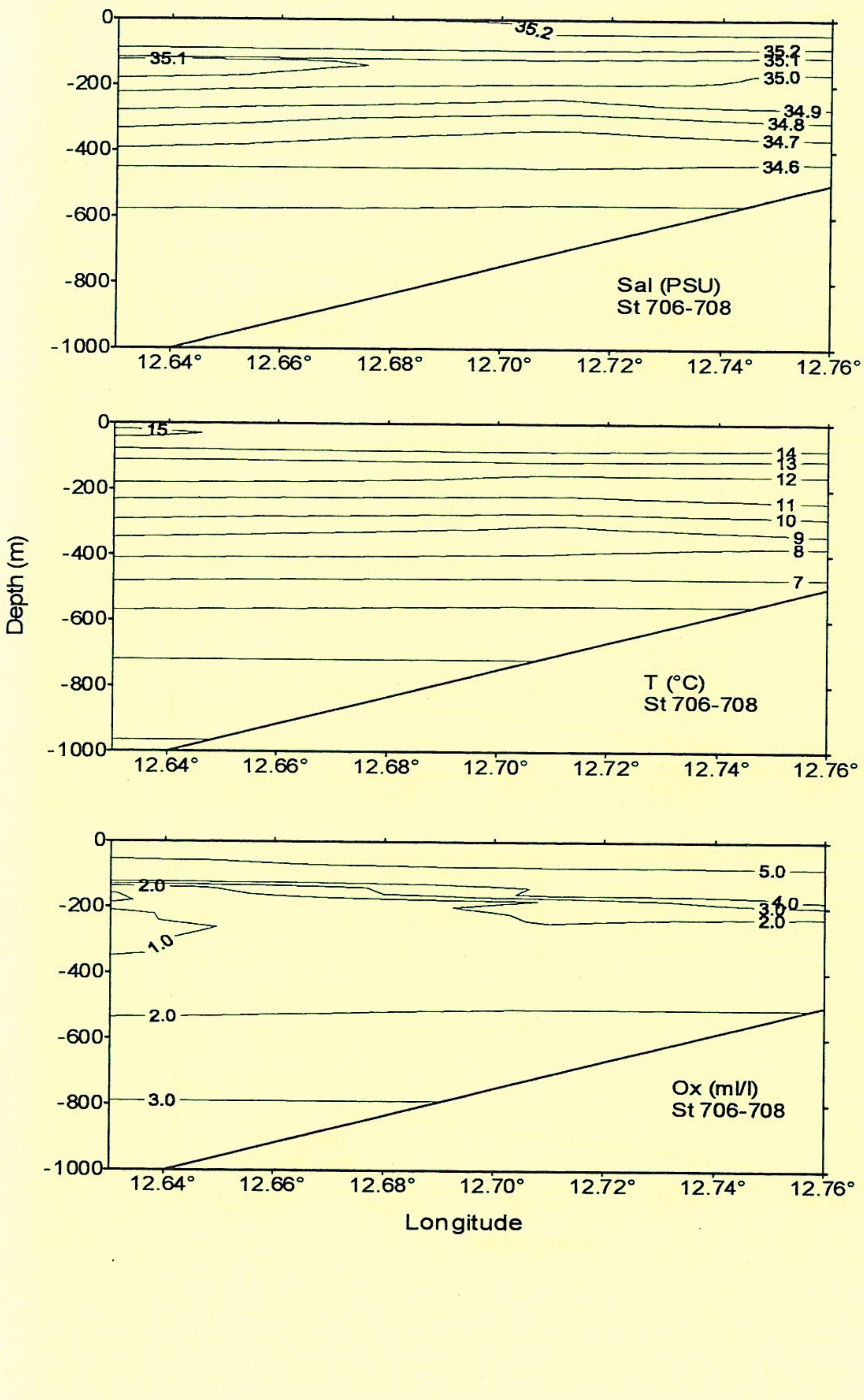
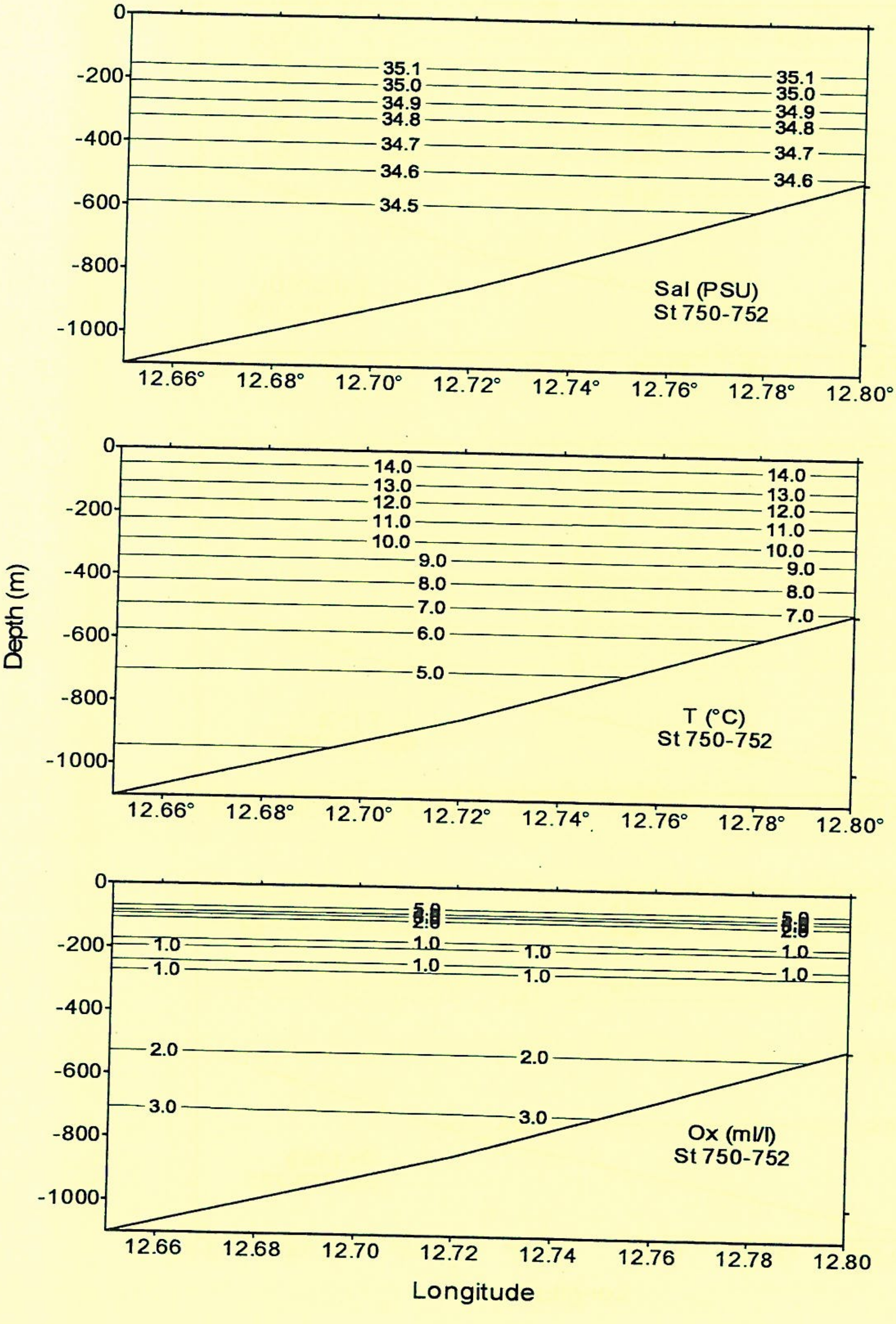


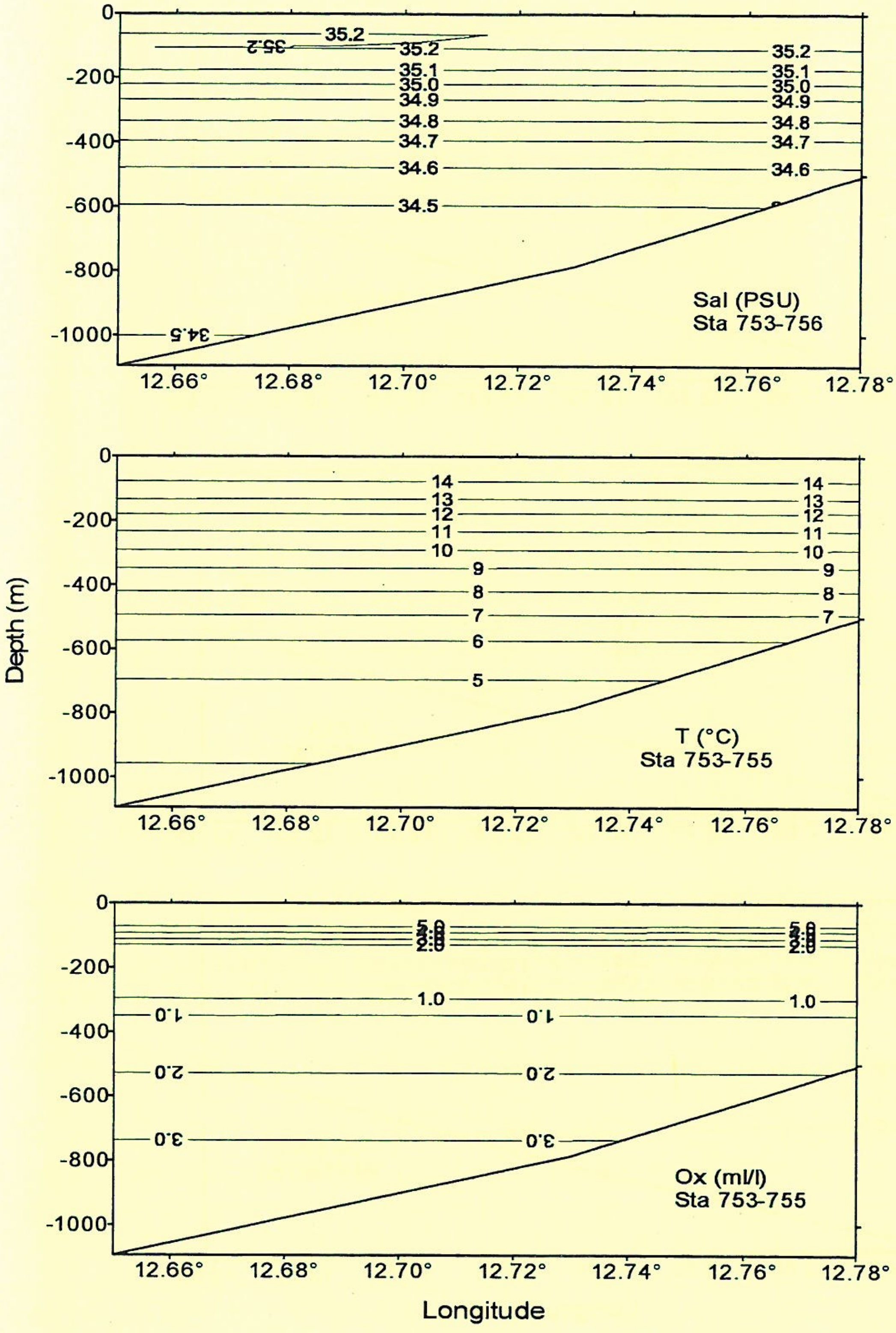
Appendix 11: Salinity, temperature and oxygen graphs for Rix.
[date: 703.048/98 ; latitude: 22*31']]



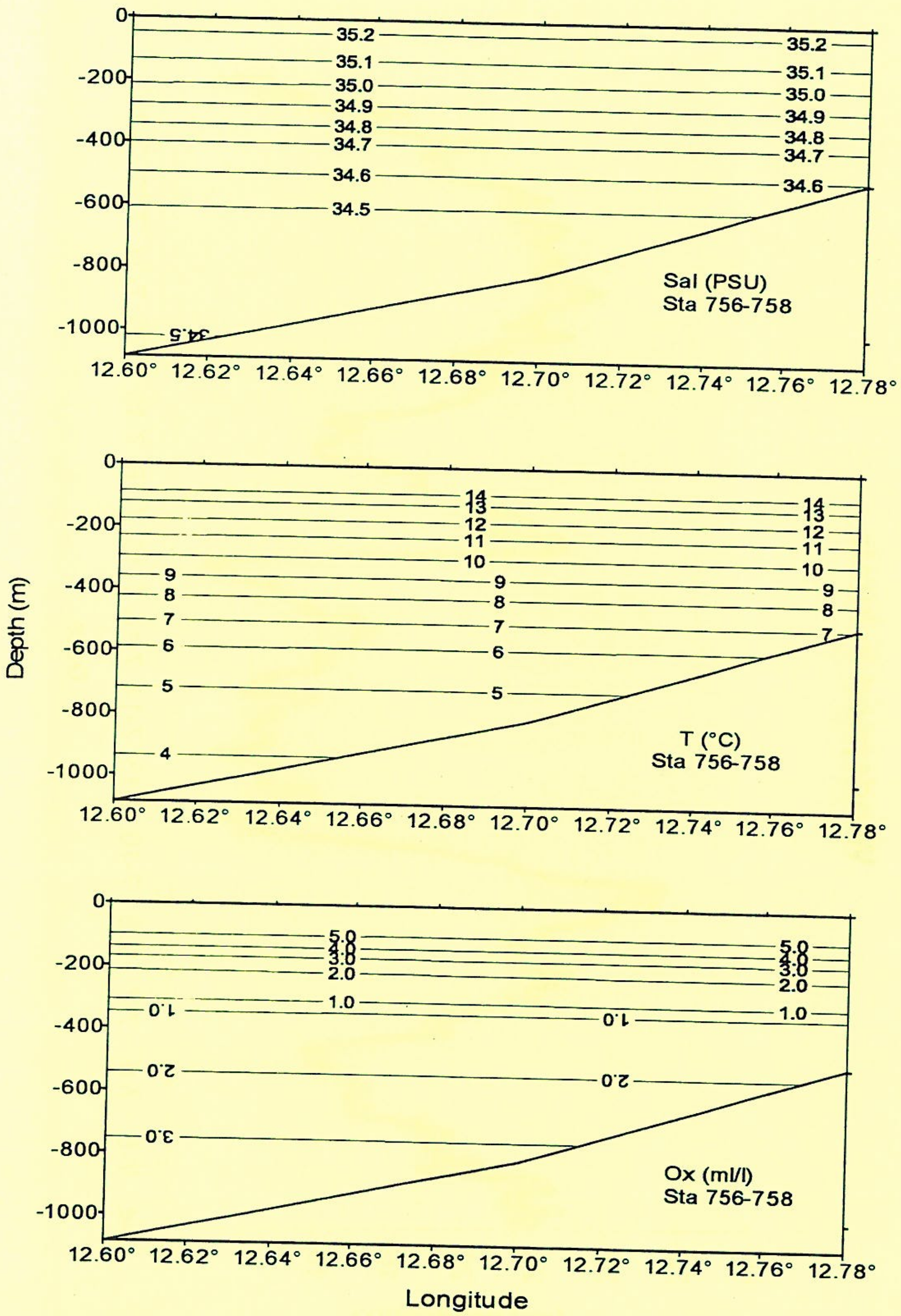
Appendix 12: Salinity, temperature and oxygen graphs for Frankies. [date: 7/21/98 ; latitude: 24*36']



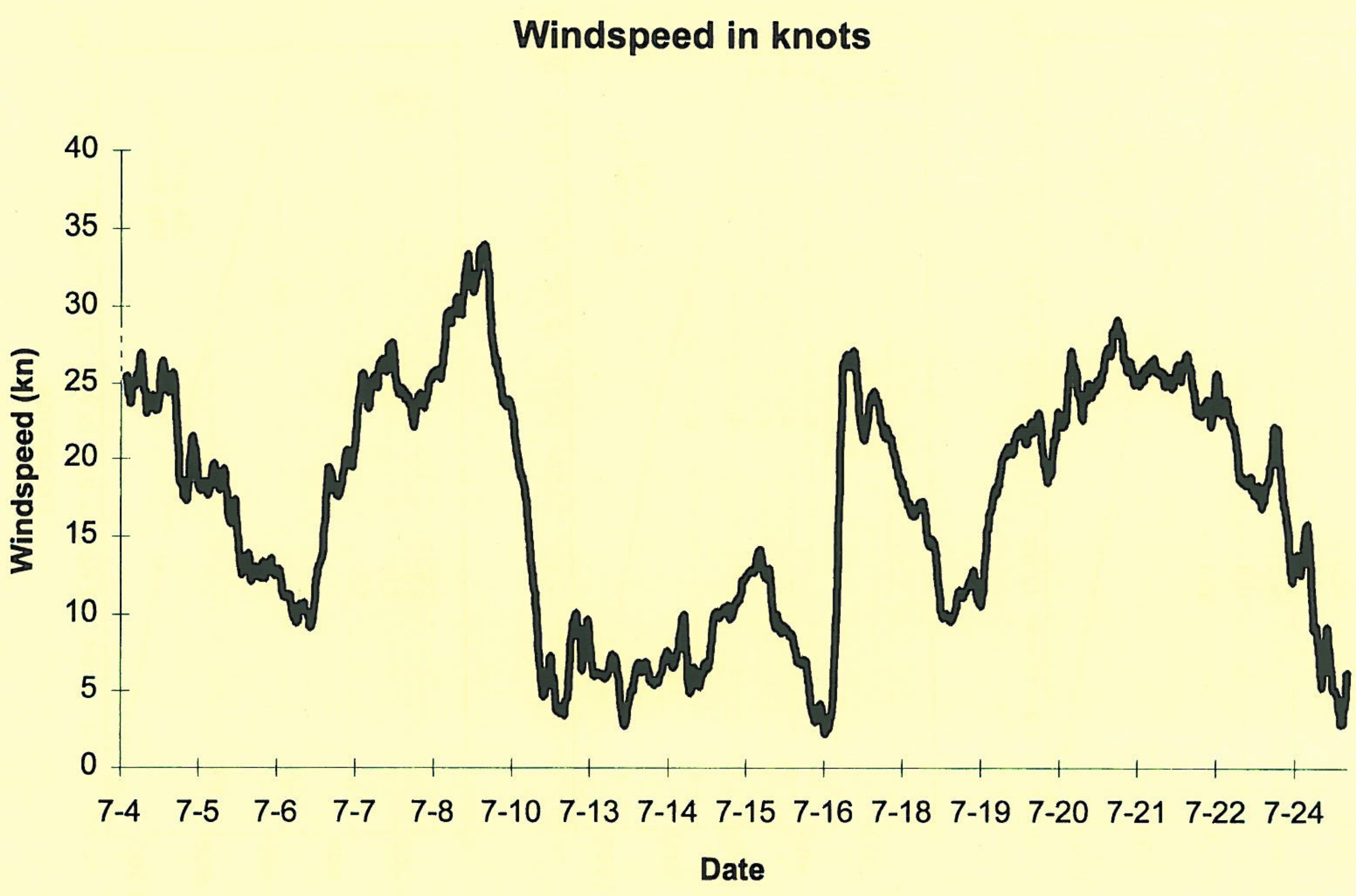
Appendix 13: Salinity, temperature and oxygen graphs for Rix.
[date: 7/21/98 ; latitude: 22*29']



Appendix 14: Salinity, temperature and oxygen graphs for Rix. [date: 7/22/98 ; latitude: 22*24']]



Appendix 15: Windspeed (kn) experienced during the survey.



Appendix 16: Biological sampling procedure

Title: **Samplingprocedure onboard vessels.**	
Author: **Bjoern Inge Staalesen**	Responsible: **Deep Water Fisheries group**
Version: **1.0**	Editing tool : **MS Word 6.0**
Due from: **12/06/97**	Filename: **Dwsample.doc**
Date of approval:	Approved by:

PURPOSE

This procedure gives a guideline in sampling of biological data from trawls of deep water fishspecies.

DEFINITIONS

Deep Water - Offshore fishing areas limited by depths of not less than 400 m and which comes under the management of the Deep Water Fisheries Committee.

Otolith- Calcified small body situated in the fish's inner ear, characterized by its microscopic growthzones used for agedetermination.

Tare- Setting the scale to zero value.

BACKGROUND

Biological sampling is a basis for collecting descriptive data for studies on the nature and development of the different fishspecies.

CRITICAL FACTORS

Biological sampling must be executed using calibrated scales, with unique marking of each sample and with consistent measuringtechnique. Any change in sampling strategy or method should be noted in the logsheet or put on as an attachment to this.

SAMPLING

Sampling deep water fishspecies can be done by one or two samplers.
If one person is sampling or time is limited, the focus should be on length frequency, weight, sex , gonadstageing and otoliths.

For Orange roughy and Alfonsino the whole sampling procedure is to be followed. For Oreo dorys, Cardinalfish and other commercially valuable species catch weight, sample weight and length and weight measurements (min. 100 fish) and gonadstageing are essential. The whole procedure is always to be followed for the main catchspecie, independent on specie.

Before sampling

Responsible	Step	Activity
Both samplers	1	Samples are collected from the trawlcatch in baskets. Each sample of the main catchspecies should contain approximately 200 fish.
One of the samplers	2	Preparation of the sampling equipment. Necessary equipment are: Logsheets, length frequency sheet, pencil, sharp knife for gutting and cutting the skullroof (get the otoliths), measuringboard (0,1 cm accuracy), tweezers, paper envelopes (for the otoliths)and a scale with steady state. Logsheets and length frequency sheet are placed in a dry area, easily available. Measuringboard is put on a table, and the scale is tared. Baskets should be available for disposals and for gutted fish.

During sampling

Responsible	Step	Activity
Sampler 1	1	**Length** is measured to the nearest 1 cm. Orange roughy is measured in standard length, Alfonsino in forklength, Oreo dories in totallength and other species according to standard methods. Whole fish is **weighed** in kilograms to the nearest 1 is measured by weighing the same fishes after being processed. Length and weight measurements should continue until a minimum of 200 fish from **each haul** are measured. **Sex, stage** (see **table 1.1**) and **gonadweight** are registered. Gonads are weighed to the nearest 1 g. Stageing continues until a number of 50 females are reached. **Stomach** is weighed to the nearest 1 g. and stomach fullness (%) is estimated.
Sampler 2	1 (simultaneously to no 1)	Logsheet is filled in with all information given by sampler 1.
Sampler 2	2	**Otoliths** (earstones) are taken out by cutting the roof of the head off with a forward cut. The otoliths become visible as two white bodies, one

		on each side of the median skullbone (occipital bone). Use a tweezers to pick up the otoliths, clean them in water, dry off the mucous and put them in an otolithbag with an unique recognizable marking on (Date, vessel, number, length, sex and stage). This is to be done before leaving the samplingarea. Otoliths should be taken as follows: 5 from catches from 0-2 mtons 10 from catches from 2-10 mtons 30 from catches larger than 10 tons

After sampling

Responsible	**Step**	**Activity**
One of the samplers	1	Collect all samples and store them for future agereading. Logsheets are completed with catchweight and sampleweight and collected in a file to be punched into the database.

Table 1.1: Staging of Orange roughy and Oreo dories (after Pankhurst et. al.,1987).

Sex	**Stage**	**Characteristics**
Female	1	Immature or regressed; ovary clear
	2	Ovary pink or clear, small oocytes visible against the light
	3	Opaque white (Oreo dories) or orange (Orange roughy) oocytes present.
	4	Mature ovary; hyaline oocytes present
	5	Ovulated; eggs flow freely when light pressure is applied to abdomen
	6	Spent; ovary flaccid and bloody; residual eggs sometimes present in oviduct.
Male	1	Immature or regressed; testis threadlike
	2	Testis increased in size, but no milt expressible
	3	Partially spermiated; viscous milt expressible
	4	Fully spermiated; hydrated, freely flowing milt
	5	Spent; testis, “blood” or grey, no milt expressible

REFERENCES

Fotland, A, et al., 1995, Handbok for proevetaking av fisk versjon 3.1, Havforskningsinstituttet

Pankhurst, N. W.; McMillan, P. J. and tracey, D. M., 1987, Seasonal reproductive cycles in three commercially exploited fishes from the slope waters off New Zealand.
Journal of fish biology., 30, no. 2, pp. 193-211; 1987

Appendix 17: Station and catch summary for trawls conducted by *Fv* Emaguluko and *FV* Southern Aquarius

Summary of station and catch data from Southern Aquarius, survey trawling.

TowNo	Type	Stratum No.	Day	START Lat	START (min)	START Lon	START (min)	FINISH Lat	FINISH (min)	FINISH Lon	FINISH (min)	DEPTH Start	DEPTH Finish	DISTANC nm	TIME Start	TIME Finish	CATCH TOTAL (KG) ORH	OTH	RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH	TEMP
OHNIES																												
45	T	10	14	26	38.3	13	37.3	26	36.8	13	36.3	693	700		1901	1930	4.2	111.1	50.4	3.8	51.2	2.6			3.1	3.6	96.4	5.1
46	T	9	14	26	39.2	13	31.1	26	37.5	13	30.7	1003	1004		2112	2142	64.6	141.9	11.6	12.0	8.3	17.4			92.7	31.3	68.7	3.8
47	T	9	14	26	34.9	13	27.6	26	36.8	13	27.8	1150	1150		2349	19	4.3	45.7	0.3	0.5	0.0	12.4			32.5	8.6	91.4	3.4
48	R	10	15	26	32.0	13	35.0	26	33.1	13	35.0	711	729	1.09	2.46	316	3.2	148.1	92.4	10.1	31.9	0.0			13.8	2.1	97.9	5.1
49	R	10	15	26	37.7	13	36.4	26	36.1	13	35.5	720	720	1.8	447	517	2.9	165.4	73.0	10.4	66.3	4.0			11.2	1.7	98.3	5.1
50	R	10	15	26	34.4	13	31.8	26	32.9	13	31.2	911	922	1.61	635	705	91.6	59.9	16.2	11.2	6.6	6.1			19.8	60.5	39.5	4.3
51	T	9	15	26	27.8	13	28.2	26	27.9	13	27.5	1020	1053		830	838	28.6	30.9	5.3	9.5	0.0	6.4			9.8	48.0	52.0	4.3
52	T	9	15	26	25.1	13	26.9	26	23.1	13	27.2	1106	1080		1010	1040	35.0	141.1	3.2	14.2	0.0	99.8			23.9	19.9	80.1	4.1
53	T	8	15	26	26.9	13	33.9	26	25.4	13	33.4	730	751		1245	1315	173.5	104.5	34.2	6.0	49.8	5.2			9.3	62.4	37.6	4.8
54	T	1	15	26	21.8	13	35.6	26	20.1	13	35.3	662	675		1436	1506	23000.0	17.7	0.5	17.3	0.0	0.0			-0.1	99.9	0.1	5.4
55	T	6	15	26	17.2	13	31.5	26	18.8	13	31.4	673	676		1835	1925	45.2	74.4	15.9	4.0	16.7	26.3			11.6	37.8	62.2	4.5

TowNo	Type	Stratum	Day	START Lat	START (min)	START Lon	START (min)	FINISH Lat	FINISH (min)	FINISH Lon	FINISH (min)	DEPTH Start	DEPTH Finish	DISTANC nm	TIME Start	TIME Finish	CATCH TOTAL (KG) ORH	OTH	RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH	TEMP
JOHNNIES																												
56	T	6	15	26	18.9	13	34.6	26	20.7	13	34.6	729	723		2100	2130	6.4	101.5	42.5	9.2	12.8	26.2			10.9	5.9	94.1	5
57	T	7	16	26	15.1	13	27.1	26	16.6	13	27.7	1009	998		4	35	15.5	108.8	13.2	12.5	21.9	48.3			13.0	12.5	87.5	4.2
58	T	7	16	26	15.0	13	32.2	26	16.4	13	32.4	833	834		243	315	0.3	43.5	9.8	5.3	18.8	7.5			2.3	0.7	99.3	4.7
59	T	5	16	26	17.3	13	37.8	26	17.6	13	37.7	571	575		454	501	0.5	50.6	1.8	5.2	36.0	2.0			5.7	1.0	99.0	4.8
60	T	2	16	26	21.0	13	35.0	26	22.1	13	34.9	702	700		736	756	12.7	108.3	29.6	6.9	55.4	10.7			5.8	10.5	89.5	5.2
61	T	6	16	26	20.3	13	34.5	26	21.2	13	34.3	729	733		927	942	3.9	59.4	23.2	4.1	12.6	8.7			10.9	6.2	93.8	5.1
62	T	6	16	26	22.2	13	34.0	26	20.9	13	33.8	737	750		1121	1141	77.0	101.0	29.0	17.1	44.4	4.2			6.3	43.3	56.7	5.2
63	T	8	16	26	25.9	13	31.4	26	26.6	13	31.3	884	886		1330	1415	675.1	13.1	1.8	0.0	1.3	2.5			7.6	98.1	1.9	4.5
64	T	9	16	26	29.56	13	30.52	26	25.24	13	30:69	953	958		1545	1655	132.7	52.4	3.8	23.1	1.85	9.45			14.3	71.7	28.3	4.5
65	T	1	16	26	22.02	13	35.31	26	20.73	13	35.8	677	660	1.42	1825	1845	44470.0	0.0	0.0	0.0	0.0	0.0			0.0	100.0	0.0	5.2
66	R	9	17	26	26.69	13	30.84	26	28.2	13	30.91	920	917	1.52	535	605	1340.0	100.0							100.0	93.1	6.9	4.6
67	R	9	17	26	28.57	13	28.89	26	29.84	13	28.73	1049	1046	1.27	727	757	12.7	58.4	5.2	16.3	0.0	10.1			26.9	17.8	82.2	3.6
68	R	9	17	26	31.82	13	28.34	26	30.02	13	28.12	1039	1078	1.76	950	1020	74.5	5.0	7.1	12.3	0.0	0.7			-15.0	93.7	6.3	4.1

TowNo	Type	Stratum	Day	START Lat	START (min)	START Lon	START (min)	FINISH Lat	FINISH (min)	FINISH Lon	FINISH (min)	DEPTH Start	DEPTH Finish	DISTANC nm	TIME Start	TIME Finish	CATCH TOTAL (KG) ORH	OTH	RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH	TEMP
OHNNIES																												
69	R	8	17	26	27.3	13	34.7	26	25.99	13	34.07	733	728	1.41	1340	1404	0.0	131.3	82.0	18.9	18.4	5.4			8.6	0.0	100.0	5.2
70	R	8	17	26	25.7	13	32	26	27.6	13	31.6	840	850	1.87	1510	1540	500.0	16.2	4.5	4.4	0.7	6.4			0.2	96.9	3.1	4.9
71	R	2	17	26	20.8	13	35.06	26	22.81	13	35.18	696	681	2	1748	1818	2170.0	25.7	7.0	11.2	4.4	1.2			2.1	98.8	1.2	5.3
72	R	6	17	26	23.36	13	32.96	26	21.55	13	32.88	798	809	1.81	1946	2016	830.0	65.4	6.1	45.1	0.0	5.5			8.6	92.7	7.3	4.9
73	R	6	17	26	23.8	13	34.73	26	21.99	13	33.94	731	740	1.93	2205	2235	1340.0	16.7	2.3	5.8	0.0	0.7			8.0	98.8	1.2	5.2
74	R	1	18	26	23.11	13	35.32	26	20.75	13	35.77	668	684	2.36	10	40	22820.0	0.0	0.0	0.0	0.0	0.0			0.0	100.0	0.0	5.8
75	R	2	18	26	24.59	13	36.45	26	21.98	13	35.96	612	633	2.61	412	452	0.0	356.2	6.2	0.0	350.0	0.0			0.1	0.0	100.0	5.9
76	R	6	18	26	17.28	13	30.66	26	18.4	13	30.67	902	910	1.08	630	700	20.8	88.7	5.5	14.7	20.0	39.3			9.3	19.0	81.0	4.1
77	R	6	18	26	20.62	13	32.04	26	22	13	32.04	846	842	1.37	822	850	15.3	107.9	6.3	43.9	8.5	0.0			49.2	14.7	85.3	4.6
78	R	4	18	26	24.78	13	35.98	26	26.57	13	36	630	633	1.72	1016	1046	1.6	187.3	26.1	25.6	94.8	0.7			20.1	1.5	98.5	6.2
79	R	4	18	26	26.83	13	35.6	26	26.69	13	35.59	655	643	1.86	1148	1223	0.0	46.19	21.0	5.2	13.4	1.4			126.4	0.0	100.0	5.7
80	R	5	18	26	26.65	13	37.52	26	26.41	13	37.54	557	556	2.24	1330	1402	0.0	327.5	6.4	1.1	320.0	0.0			0.0	0.0	0.0	6.2
81	R	1	18	26	21.88	13	35.54	26	20.44	13	35.69	657	664	1.44	1645	1710	17500.0	0.0							0.0	0.0	0.0	5.7

TowNo	Type	Stratum	Day	START Lat	START (min)	START Lon	START (min)	FINISH Lat	FINISH (min)	FINISH Lon	FINISH (min)	DEPTH Start	DEPTH Finish	DISTANC nm	TIME Start	TIME Finish	CATCH TOTAL (KG) ORH	OTH	RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH	TEMP
JOHNNIES																												
82	R	5	18	26	24.46	13	36.66	26	26.15	13	36.75	606	596	1.7	1833	1903	0.1	176	0.5		175				0.5	0.1	99.9	6
83	R	2	18	26	18.82	13	35.13	26	20.58	13	35.13	699	700	1.76	2104	2135	11.5	61.6	19.05	17.6	21.2	2.1			1.6	15.7	84.3	5.4
84	R	2	18	26	19.81	13	36.86	26	18.04	13	36.72	609	625	1.78	2240	2310	0	576	11.15	7.7	555				2.1	0.0	100.0	6.2
85	R	6	19	26	20.68	13	34.38	26	22.38	13	34.2	732	732	1.71	18	48	59	88.8	22.2	2.4	49				15.2	39.9	60.1	5.2
86	R	9	19	26	24.16	13	29.24	26	25.98	13	29.2	1005	1007	1.81	220	242	13.6	29.4		11.3		5.4			12.7	31.6	68.4	3.7
87	R	7	19	26	11.17	13	34.06	26	9.53	13	33.93	746	744	1.67	605	635	7.1	129	33.7	11.1	19.4	18.1			46.7	5.2	94.8	4.7
88	R	3	19	26	10.16	13	36.08	26	8.54	13	36.93	655	660	1.72	849	919	1.4	183.9	50.1	8.2	73.8	26			25.8	0.8	99.2	5.2
89	R	3	19	26	14.57	13	36.36	26	12.93	13	36.33	652	655	1.68	1113	1140	6.9	155.8	7.4	46.6	87.8	3.4		0.7	9.9	4.2	95.8	5.2
90	R	5	19	26	12.19	13	37.46	26	10.49	13	37.44	591	596	1.75	1258	1328	3.3	1186	4.5	673.2	49.6	0.9		2.7	456.7	0.3	99.7	5.9
91	R	7	19	26	10.96	13	30.3	26	12.59	13	30.35	870	874	1.61	1522	1552	5.2	152.4	2	45.1		49.6			65.7	3.3	96.7	4.6
92	R	2	19	26	17.82	13	36.15	26	19.51	13	35.76	647	663	1.7	1734	1804	6.65	162	2.7	10	146	1.3		0.1	1.9	3.9	96.1	5.7
93	R	2	19	26	22.97	13	34.39	26	21.2	13	34.98	692	695	1.83	1925	1955	43.2	83.6	29	12	37.1	0.9			4.6	34.1	65.9	5.2
94	R	9	19	26	22.24	13	28.33	26	23.72	13	28.39	1026	1022	1.45	2127	2200	2.3	64	23.8	12.3	3.6	8.8			15.5	3.5	96.5	3.4
95	R	1	20	26	21.43	13	35.46	26	20.39	13	36	679	664	1.12	45	107	52900	2	1	0.7					0.3	100.0	0.0	5.5

Appendix 17: Station and catch summary for trawls conducted by *FV* Emaguluko and *FV* Southern Aquarius

Summary of station and catch data from Emanguluko, survey trawling.

TowNo	Type	Stratum	Day	START Lat (min)	START Lon (min)	FINISH Lat (min)	FINISH Lon (min)	DEPTH Start	DEPTH Finish	DISTANCE nm	TIME Start	TIME Finish	ORH	OTH	CATCH TOTAL (KG) RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH
RIX																							
1	R	5	2	22 37.8	12 48.6	22 36.0	12 49.0	539	519		4:55	5:25	0.0	79.0	35.9	3.3	15.4				24.4	0.0	100.0
2	R	4	2	22 36.0	12 46.8	22 35.0	12 47.0	621	660		6:45	7:15	0.0	230.0		121.7	19.0	39.3			50.0	0.0	100.0
3	R	6	2	22 35.0	12 42.0	22 33.0	12 42.0	976	985		9:05	9:35	5.0	195.0						107.0	88.0	2.5	97.5
4	R	2	2	22 31.8	12 43.8	22 30.0	12 43.0	740	720		11:30	11:45	12.0	33.0			10.0				23.0	26.7	73.3
5	R	1	2	22 29.0	12 43.2	22 28.0	12 43.0	790	820		15:40	15:55	4200.0	0.0							0.0	100.0	0.0
6	R	2	2	22 27.6	12 40.8	22 25.0	12 41.0	1013	990		17:40	18:10	11.0	82.0	13.0	33.0	10.0	13.0			13.0	11.8	88.2
7	R	6	3	22 27.6	12 39.0	22 25.0	12 39.0	1041	1070		20:40	21:10	9.0	95.3		67.6	6.0	17.7			4.0	8.6	91.4
8	R	2	3	22 25.2	12 40.8	22 24.0	12 41.0	975	945		1:35	1:50	0.4	36.6		6.0	5.3			6.7	18.6	1.1	98.9
9	T	2	3	22 33.0	12 48.0	22 34.0	12 45.0	480	730		9:40	10:45	11.0	150.0		7.9	8.5			118.0	15.6	6.8	93.2
10	T	2	3	22 33.0	12 45.0	22 33.0	12 45.0	620	710		12:05	12:35	11.0	339.0		294.0	32.0				13.0	3.1	96.9
11	T	6	3	22 30.0	12 42.0	22 30.0	12 40.0	810	980		14:10	14:50	245.0	5.0		2.0		1.0		2.0	0.0	98.0	2.0

TowNo	Type	Stratum	Day	START Lat (min)	START Lon (min)	FINISH Lat (min)	FINISH Lon (min)	DEPTH Start	DEPTH Finish	DISTANCE nm	TIME Start	TIME Finish	ORH	OTH	CATCH TOTAL (KG) RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH
FRANKIES																							
12	R	3	4	24 15.0	13 16.0	24 15.0	13 14.0	595	699		14:55	15:25	2.0	198.0		64.0	115.0				19.0	1.0	99.0
13	R	3	4	24 16.0	13 17.0	24 17.0	13 14.0	620	680		16:50	17:20	0.0	222.0	5.0	53.0	130.0				34.0	0.0	100.0
14	R	3	4	24 19.0	13 16.0	24 19.0	13 14.0	720	760		18:50	19:20	0.5	104.5	5.0	38.0	22.0	5.0			34.5	0.5	99.5
15	R	6	4	24 20.0	13 11.0	24 20.0	13 8.0	880	960		20:30	21:00	15.0	165.0	34.5	60.0	6.2	47.1		1.2	16.0	8.3	91.7
16	R	NV	5	24 22.0	13 23.0	24 ?	13 21.0	470	510		0:40	1:10	0.0	94.0		9.0	46.6				38.4	0.0	100.0
17	T	6	6	24 44.0	13 18.0	24 46.0	13 19.0	693			9:35	10:30	17.0	120.7	2.0	2.0	5.2	96.9			14.6	12.3	87.7
18	R	1.1	6	24 39.0	13 23.0	24 37.0	13 24.0	684	684		12:15	12:40	7.3	69.4		16.0	9.9	31.4			12.1	9.6	90.4
19	T	2	6	24 36.0	13 24.0	24 34.0	13 23.0	615	614		15:20	15:55	1.2	114.5		78.7	16.5	4.9			14.4	1.1	98.9
20	R	1.2	6	24 32.0	13 21.0	24 30.0	13 21.0	660	660		17:15	17:45	0.0	66.2	5.9	37.5	28.8	3.7			10.3	0.0	100.0
21	R	6	6	24 32.0	13 19.0	24 30.0	13 19.0	730	720		19:20	19:50	0.9	75.0	9.0	32.5	8.5	3.8			21.2	1.2	98.8
22	T	Out	6	24 30.0	13 13.0	24 29.0	13 13.0	916	916		22:15	22:45	26.5	149.3	7.8	19.4	2.1	103.8			16.4	15.1	84.9
23	T	1.3	7	24 25.0	13 21.0			580			1:04	1:31	0 0	182.0	2.1	9.3	163.9	5.5			1.2	0.0	100.0
24	T	Out	7	24 49.0	13 29.0	24 37 0	13 29 0	625	628		6:00	6:30	0 0	45.0	1.3	11.2	21.4	2.0			9.1	0.0	100.0

TowNo	Type	Stratum	Day	START Lat (min)	START Lon (min)	FINISH Lat (min)	FINISH Lon (min)	DEPTH Start	DEPTH Finish	DISTANCE nm	TIME Start	TIME Finish	ORH	OTH	CATCH TOTAL (KG) RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH
JOHNNIES																							
25	R	0	7	26 9.0	13 32.0	26 8.0	13 32.0	820	810		17:35	18:05	6.5	37.3	3.3	6.6	5.1	7.2			15.1	14.8	85.2
26	R	3	7	26 14.0	13 36.0	26 16.0	13 36.0	670	670		20:15	20:45	3.7	77.7	23.4	24.5	13.9	7.8			8.1	4.5	95.5
27	R	5	7	26. 15.0	13 38.0	26 16.0	13 38.0	580	580		22:05	22:35	1.4	331.2	87.0	87.9	100.3	8.4			47.6	0.4	99.6
28	R	5	7	26 16.0	13 39.0	26 17.0	13 39.0	530	515		23:45	0:15	0.0	182.3	50.2	28.2	90.7	0.0			13.2	0.0	100.0
29	R	6	8	26 15.0	13 31.0	26 17.0	13 31.0	867	881		2:20	2:50	22.1	150.5	28.1	30.4	42.5	13.2			36.3	12.8	87.2
30	R	6	8	26 21.0	13 34.0	26 23.0	13 34.0	736	731		4:35	5:10	210.7	133.4	29.1	19.2	29.9	48.5			6.7	61.2	38.8
31	R	6	8	26 24.0	13 32.0	26 26.0	13 32.0	840	840		7:12	7:43	63.7	65.0	5.1	11.2	6.9	16.3			25.5	49.5	50.5
32	R	6	8	26 25.0	13 33.0	26 26.0	13 33.0	783	780		9:30	10:00	2600.0	28.4	5.9	7.5	0.0	12.8			2.2	98.9	1.1
33	T	0	8	26 28.0	13 30.0	26 30.0	13 30.0	980	980		13:30	14:00	300.0	52.7	1.0	5.4	0.0	29.5			16.8	85.1	14.9
34	T	0	8	26 23.0	13 28.0	26 24.0	13 29.0	1050	1050		16:20	16:55	48.0	154.2	1.8	29.2	5.0	58.1			60.1	23.7	76.3
35	T	0	8	26 22.0	13 30.0	26 24.0	13 30.0	915	915		18:30	19:00	43.3	220.3	16.6	65.6	7.9	75.0			55.2	16.4	83.6
36	T	6	8	26 19.0	13 34.0	26 20.0	13 34.0	750	750		21:05	21:35	2.2	181.6	24.4	74.2	46.8	22.2			14.2	1.2	98.8
37	T	0	8	26 22.0	13 36.0	26 24.0	13 36 0	635	634		23:00	23:30	7000 0	70.0	24.6	27.8	0.0	1.6			16.0	99.0	1 0

TowNo	Type	Stratum	Day	START Lat (min)	START Lon (min)	FINISH Lat (min)	FINISH Lon (min)	DEPTH Start	DEPTH Finish	DISTANCE nm	TIME Start	TIME Finish	ORH	OTH	CATCH TOTAL (KG) RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH
JOHNNIES																							
38	T	0	9	26 37.0	13 28.0	26 37.0	13 28.0	1101	1102		5:15	5:35	13.9	127.2	2.9	0.0	0.8	7.3			116.2	9.9	90.1
39	T	6	9	26 30.0	13 32 0	26 31 0	13 32.0	870	860		9.00	9:30	1453.0	270 0	9 2	86.2	4.6	43.1			126.8	84.3	15.7
40	R	6	9	26 29.0	13 34 0	26 31.0	13 34.0	750	50		11:15	11:45	14.4	132.0	43.6	9.0	19.2	25.0			35.2	9.8	90 2
41	T	0	9	26 37.0	13 32.0	26 38 0	13 32.0	940	950		15:20	15:50	21.0	76 7	17.2	6.1	4.7	7.5			39.2	21.5	78 5
42	R	0	9	26 37.0	13 35 0	26 38.0	13 35.0	780	780		17:40	18:10	6.2	131.0	38.1	64.2	8.7	7.0			13.0	4.5	95.5
43	T	1	9	26 21.0	13 36.0	26 22.0	13 36.0	645	635		21:55	22:15	23677.5	0.0	0.0	0 0	0.0	0.0			0.0	100.0	0.0
44	T	0		25 40.0	13 24.0	25 43 0	13 24.0	1020	1020		16:55	18:20	26.5	169.5	7.4	64.6	1.2	70.0			26.3	13.5	86 5

Appendix 17: Station and catch summary for trawls conducted by *Fv* Emaguluko and *FV* Southern Aquarius

Summary of station and catch data from Southern Aquarius, survey trawling.

TowNo	Type	Stratum	Day	START Lat	START (min)	START Lon	START (min)	FINISH Lat	FINISH (min)	FINISH Lon	FINISH (min)	DEPTH Start	DEPTH Finish	DISTANC nm	TIME Start	TIME Finish	CATCH TOTAL (KG) ORH	OTH	RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH	TEMP
RANKIES																												
96	R	2	20	24	42.3	13	25.0	24	40.9	13	25.0	660	648	1.34	1415	1438	0.0	124.7	0.1	32.6	91.2				0.8	0.0	100.0	5.3
97	R	2	20	24	40.2	13	24.8	24	38.3	13	24.4	645	634	1.92	1554	1628	0.0	268.8	2.5	67.6	190.4				8.3	0.0	100.0	5.5
98	R	2	20	24	33.7	13	21.2	24	32.1	13	21.0	695	684	1.55	1815	1844	2.3	161.4	4.5	23.8	120.4				12.7	1.4	98.6	5.2
99	R	1b	20	24	32.8	13	22.7	24	31.8	13	22.3	617	615	1.03	2032	2051	600.6	60.6	0.8	1.4	58.4				0.0	90.8	9.2	5.5
100	R	2	20	24	31.3	13	23.7	24	29.7	13	23.0	567	566	1.69	2200	2230	0.0	266.2	7.0	17.7	235.3				6.2	0.0	100.0	5.9
101	R	2	20	24	25.6	13	17.5	24	24.4	13	17.3	739	733	1.28	2337	2402	0.3	20.5	3.1	4.3	1.8	2.1			9.3	1.4	98.6	5.1
102	R	1c	21	24	24.4	13	21.2	24	23.3	13	21.2	569	558	1.15	128	148	135.3	167.2	7.6	28.1	121.7	3.5			6.3	44.7	55.3	6.1
103	R	3	21	24	17.8	13	18.5	24	16.4	13	17.9	570	596	1.5	324	352	185.0	98.1	2.2		88.0				7.9	65.3	34.7	6
104	R	3	21	24	17.6	13	14.7	24	16.0	13	14.1	727	720	1.64	522	552	0.3	52.0	6.2	24.1	11.5	0.9			9.3	0.6	99.4	5.2
105	R	3	21	24	15.3	13	13.7	24	14.1	13	12.6	718	735	1.5	718	735	0.3	33.4	2.3	9.5	10.4	1.3		1.1	8.8	0.9	99.1	5.1
106	R	3	21	24	20.2	13	18.2	24	18.6	13	17.6	633	636	1.63	1005	1035	0.3	84.6	3.6	35.7	39.9	1.6			3.8	0.3	99.7	5.8
107	R	1c	21	24	25.0	13	21.4	24	23.3	13	21.4	574	548	1.73	1254	1324	100.8	203.4	7.5	40.9	146.4	1.7			6.9	33.1	66.9	5.8
108	R	1a	21	24	39.7	13	21.5	24	39.3	13	21.5	751	756	0.38	1645	1652	3790.0	1.8				1.8			0.0	100.0	0.0	5
109	R	1a	21	24	38.1	13	22.3	24	37.4	13	22.3	708	696	0.73	1805	1820	465.0	6.5	1.8		0.6	3.1			1.0	98.6	1.4	5.1
110	R	6	21	24	43.1	13	20.8	24	42.0	13	20.2	809	804	1.25	2150	2213	10.2	19.9	1.7	2.7	5.7	1.7			8.1	33.9	66.1	4.7
111	R	1a	21	24	39.8	13	21.6	24	39.0	13	21.4	698	747	0.88	2325	2340	0.0	0.0							0.0	#DIV/0!	#DIV/0!	5.2
112	R	6	22	24	35.0	13	17.5	24	33.5	13	17.1	847	847	1.53	55	125	0.0	70.5	2.9	29.3	18.8	5.7			13.8	0.0	100.0	4.5
113	R	2	22	24	31.9	13	19.8	24	30.4	13	19.1	725	725	1.57	303	333	0.6	74.4	4.7	31.0	27.9	4.9			5.9	0.8	99.2	5.2
114	R	1b	22	24	32.7	13	22.6	24	32.1	13	22.4	624	617	0.65	532	543	97.7	62.8	2.2	21.7	38.3				0.6	60.9	39.1	5.7
115	R	6	22	24	28.2	13	15.0	24	26.7	13	14.4	843	841	1.65	706	736	3.6	72.3	3.8	19.6	42.5	3.2			3.2	4.7	95.3	4.5
116	R	1a	22	24	39.8	13	21.5	24	39.2	13	21.4	740	740	0.48	1052	1100	647.0	4.2	0.4	0.7		3.1			0.0	99.4	0.6	4.9
117	R	1a	22	24	38.1	13	22.31	24	37.28	13	22.16	707	699	0.84	1219	1234	104.0	86.0	1.4	9.9	2.9	4.9			66.9	54.7	45.3	5.1
TowNo	Type	Stratum	Day	START Lat	START (min)	START Lon	START (min)	FINISH Lat	FINISH (min)	FINISH Lon	FINISH (min)	DEPTH Start	DEPTH Finish	DISTANC nm	TIME Start	TIME Finish	CATCH TOTAL (KG) ORH	OTH	RAT	SHA	HAK	OEO	UNI	CDL	OTH	%ORH	%OTH	TEMP
RIX																												
118	T	.	23	22	44.38	12	48.21	22	43	12	47.56	679	689	1.51	0	25	0.0	198.1	2.3	71.5	113.7	1.3			9.3	0.0	100	5.1
119	T		23	22	33.88	12	43.72	22	33.35	12	43.67	829	805	0.33	223	233	150.2	113.8	0.0	103.1	0.0	1.7			9	56.9	43.106	4.5
120	T	Poor	23	22	31.68	12	43.61	22	30.8	12	48.69	770	742	0.91	523	540	5.6	58.6	0.3	51.7	1.0	0.3		0.4	4.9	8.7	91.277	4.9
121	R	1	23	22	29.84	12	42.98	22	28.8	12	43.01	766	768	1	830	849	50.4	438	0.1	375.0	58.4	1.5			3	10.3	89.681	4.8
122	T		23	22	36.91	12	43.49	22	35.3	12	43.37	892	895	1.57	1113	1143	2.5	140.6	0.0	100.4	34.6	1.3			4.3	1.7	98.253	4.3
123	T		23	22	33.54	12	44.16	22	32.81	12	44.16	772	741	0.72	1307	1320	4250.0	100			60.0				40.0	97.7	2.2989	4.9
124	R	1	23	22	30.41	12	43.31	22	29.06	12	42.52	726	781	1.52	1547	1613	12.2	997.8		977.8	0.8				19.2	1.2	98.792	4.7
125	R	2	23	22	27.31	12	45.01	22	25.66	12	44.59	683	703	1.69	1752	1822	0.7	74.8	3.0	57.8	10.3	1.3			2.4	0.9	99.1	5.2
126	R	2	23	22	25.96	12	46.89	22	24.25	12	46.17	549	569	1.83	1937	2007	0.0	62.1	7.8	34.4	18.6	0.5			0.8	0.0	100.0	6.6
127	R	2	23	22	31.58	12	43.43	22	32.85	12	43.44	746	803	1.26	2230	2300	122.1	96.3	4.4	77.0	5.1	2.9			6.9	55.9	44.1	4.9
128	R	2	24	22	33.54	12	46.1	22	34.89	12	46.61	608	696	1.4	140	210	11.1	148.7	7.2	40.6	62.4	31.2			7.3	6.9	93.1	5.8
129	R	2	24	22	33.75	12	43.75	22	33.2	12	43.71	830	798	0.55	330	340	11273.0	19.0			4.8	14.2			0.0	99.8	0.2	4.7
130	R	6	24	22	35.28	12	42.97	22	34	12	42.99	915	915	1.27	526	550	3.6	24.4	0.1	7.6	15.3	1.4			0.0	12.9	87.1	4.3
131	R	2	24	22	34.93	12	44.14	22	36.1	12	44.13	774	814	1.15	809	829	30580.0	13.5		12.5	1.0				0.0	100.0	0.0	4.9
132	R	6	24	22	32.91	12	42.26	22	31.38	12	41.82	942	968	1.57	1245	1315	10.1	109.4	1.4	72.2		11.9			23.9	8.5	91.5	3.8
133	R	2	24	22	31.29	12	44.71	22	29.52	12	44.58	663	659	1.76	1440	1510	1.1	151.8	0.9	59.0	88.2	0.1			3.6	0.7	99.3	5.3

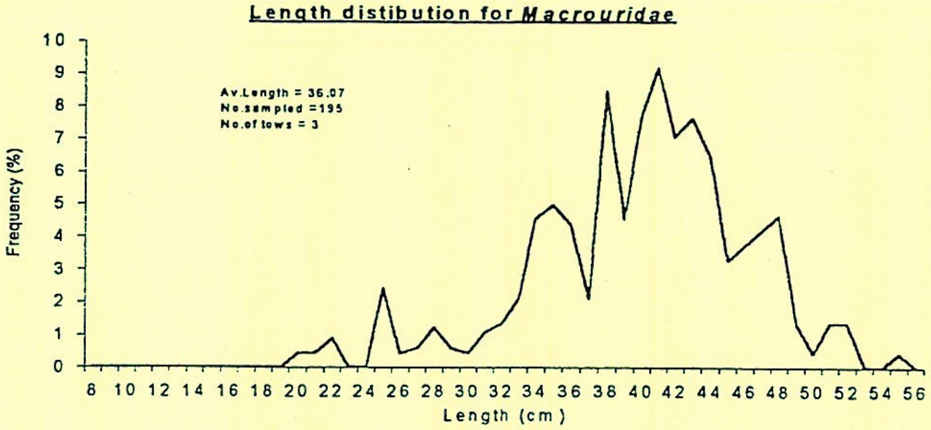
Appendix 18: Station and catch summary for trawls conducted by *RV* Dr. Fridtjof Nansen

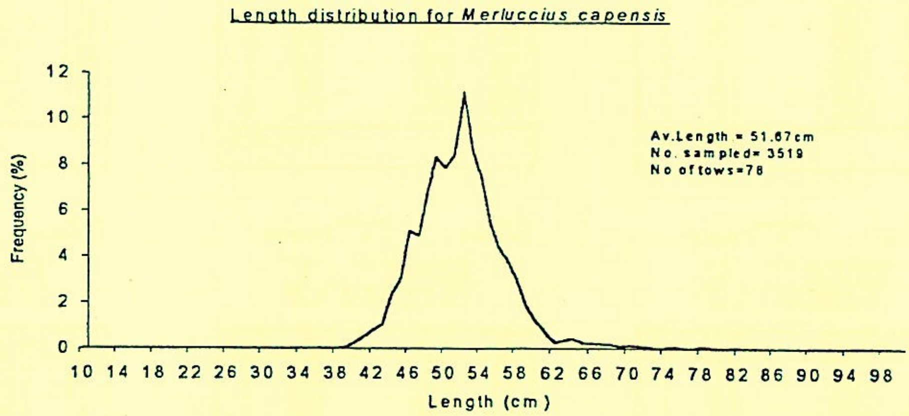
Summary of station and catch data from "Dr Fridtjof Nansen", survey trawling

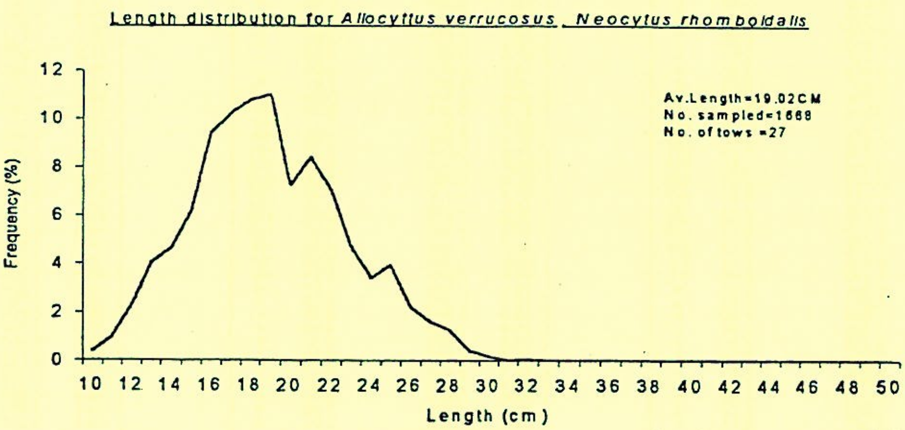
					START					Depth		DIST	TIME		CATCH TOTAL (KG)								
owN	Type	Leg	Statio	Day	Lat		Long		Cours	Start	Finish	ist_n	Start	Finish	ORH	OTH	RAT	SHA	HAK	OEO	UNI	CDL	OTH
1	PT	1	2581	2	22	34	12	49	90	370	350	2	14:53	15:23	0	137.6	0	0	0	0	0	0	137.6
2	PT	1	2582	2	22	33.1	12	50	360	150	150	1.8	16:38	17:09	0	83.7	0	0	0	0	0	0	83.7
3	BT	1	2583	5	24	29.2	13	25.4	170	485	476	2.5	10:07	10:42	0	757.9	134.9	0	530.1	0	0	0	92.9
4	PT	1	2584	5	24	33	13	25	350	450	450	2	15:46	16:16	0	4.8	0	0	0	0	0	0	4.8
5	BT	1	2585	6	24	29.5	13	23.1	345	510	520	1.8	16:03	16:33	0	59.3	0	0	0	0	0	0	59.3
6	PT	1	2586	7	24	37.4	13	21	188	620	600	3.5	00.:45	1:45	0	18.6	0	0	0	0	0	0	18.6
7	BT	1	2587	8	26	29.6	13	34	350	743	742	1.5	13:20	13:50	12	471.7	338.8	25.8	63.5	15			28.6
8	PT	2	2588	15	26	36.6	13	30.8	170	1000	980	?	22:39	22:49	0	11.7	0	0	0	0	0	0	11.7
9	BT	2	2589	15	26	16	13	32	360	834	834	1.7	16:38	17:09	5.6	120.2	43	6	18.2	5.3			47.7
10	BT	2	2590	16	26	24.6	13	35	360	700	712	1.7	12:58	13:28	0	179.9	39.7	2	42.2	16			80
11	BT	2	2591	17	26	21.7	13	33	180	687	709	1.6	10:23	11:40	20000	55	0	0	54.8	0	0	0	0.2
12	BT	2	2592	17	26	21.2	13	35.3	5	670	677	0.7	22:38	22:52	20000	42.4	0	2.7	25.1	0.4	0	0	14.3
13	PT	2	2593	18	26	20.1	13	35.9	160	653	659	0.7	12:51	13:05	0	44.4	0	0	9.8	0	0	0	34.6
14	PT	2	2594	19	24	40.1	13	21.7	330	650	650	0.8	11:32	11:46	0	45.2	0	0	0	0	0	0	45.2
15	PT	2	2595	23	22	47.5	12	32.6	320	560	560	1.1	8:54	9:15	0	197	0	2.1	181	0	0	0	14

Appendix 19: Mean length and weight for bycatch species, as well as length the distribution.

	Mean Length (cm)			Average Weight (kg)		
	Johnnies	Frankies	Rix	Johnnies	Frankies	Rix
Rat	43.5	34.6	38.9	0.46	0.23	0.32
Hake	52.8	50.1	50.5	1.21	1.05	1.03
Oeoe	18.9	23.1	17.5	0.17	0.28	0.28







Appenix 20: No. and biomass of fish per length class (.5cm) calculated from targeted acoustics (Johnies)

Area: Johnies
Coverage: 1 Targeted

Mean sA (m2/nm 7.11
Area (nm2) 335
L-W parameter "a 0.145
L-W parameter "b 2.54

Length cm	Relative frequency	Number (million	iomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.01	1
14.5	0.000	0.01	1
15.5	0.000	0.01	2
16.5	0.000	0.01	3
17.5	0.001	0.04	9
18.5	0.003	0.10	24
19.5	0.007	0.22	59
20.5	0.019	0.64	198
21.5	0.029	0.97	339
22.5	0.061	1.99	785
23.5	0.096	3.16	1389
24.5	0.094	3.10	1516
25.5	0.108	3.54	1918
26.5	0.101	3.33	1985
27.5	0.112	3.66	2404
28.5	0.109	3.59	2577
29.5	0.078	2.55	1999
30.5	0.092	3.04	2593
31.5	0.045	1.47	1362
32.5	0.023	0.76	759
33.5	0.016	0.52	566
34.5	0.004	0.12	141
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	3
38.5	0.000	0.00	0
39.5	0.001	0.02	31
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		32.87	20666

Area: Johnies
Coverage: 2 Targeted

Mean sA (m2/nm 4.73
Area (nm2) 441
L-W parameter "a 0.145
L-W parameter "b 2.54

Length cm	Relative frequency	Number (million	iomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.01	1
14.5	0.000	0.01	1
15.5	0.000	0.01	2
16.5	0.000	0.01	2
17.5	0.001	0.04	8
18.5	0.003	0.09	21
19.5	0.007	0.19	52
20.5	0.019	0.56	174
21.5	0.029	0.85	297
22.5	0.061	1.74	687
23.5	0.096	2.76	1216
24.5	0.094	2.71	1328
25.5	0.108	3.10	1680
26.5	0.101	2.91	1739
27.5	0.112	3.21	2105
28.5	0.109	3.14	2257
29.5	0.078	2.23	1750
30.5	0.092	2.66	2271
31.5	0.045	1.29	1193
32.5	0.023	0.66	665
33.5	0.016	0.46	496
34.5	0.004	0.11	124
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	3
38.5	0.000	0.00	0
39.5	0.001	0.02	27
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		28.78	18098

Area: Johnies
Coverage: 3 Targeted

Mean sA (m2/nm 0
Area (nm2) 36
L-W parameter "a 0.145
L-W parameter "b 2.54

Length cm	Relative frequency	Number (million	iomas tonnes
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.001	0.00	0
18.5	0.003	0.00	0
19.5	0.007	0.00	0
20.5	0.019	0.00	0
21.5	0.029	0.00	0
22.5	0.061	0.00	0
23.5	0.096	0.00	0
24.5	0.094	0.00	0
25.5	0.108	0.00	0
26.5	0.101	0.00	0
27.5	0.112	0.00	0
28.5	0.109	0.00	0
29.5	0.078	0.00	0
30.5	0.092	0.00	0
31.5	0.045	0.00	0
32.5	0.023	0.00	0
33.5	0.016	0.00	0
34.5	0.004	0.00	0
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.001	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		0.00	0

Area: Johnies
Coverage: 4 Targeted

Mean sA (m2/nm 10.5
Area (nm2) 34
L-W parameter "a 0.145
L-W parameter "b 2.54

Length cm	Relative frequency	Number (million	iomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.001	0.01	1
18.5	0.003	0.02	4
19.5	0.007	0.03	9
20.5	0.019	0.10	30
21.5	0.029	0.14	51
22.5	0.061	0.30	118
23.5	0.096	0.47	208
24.5	0.094	0.46	227
25.5	0.108	0.53	288
26.5	0.101	0.50	298
27.5	0.112	0.55	360
28.5	0.109	0.54	386
29.5	0.078	0.38	300
30.5	0.092	0.46	389
31.5	0.045	0.22	204
32.5	0.023	0.11	114
33.5	0.016	0.08	85
34.5	0.004	0.02	21
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.001	0.00	5
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		4.93	3097

Area: Johnies
Coverage: 5 Targeted

Mean sA (m2/nm 18.6
Area (nm2) 9
L-W parameter "a 0.145
L-W parameter "b 2.54

Length cm	Relative frequency	Number (million	iomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.001	0.00	1
18.5	0.003	0.01	2
19.5	0.007	0.02	4
20.5	0.019	0.04	14
21.5	0.029	0.07	24
22.5	0.061	0.14	55
23.5	0.096	0.22	98
24.5	0.094	0.22	107
25.5	0.108	0.25	135
26.5	0.101	0.23	140
27.5	0.112	0.26	169
28.5	0.109	0.25	181
29.5	0.078	0.18	140
30.5	0.092	0.21	182
31.5	0.045	0.10	96
32.5	0.023	0.05	53
33.5	0.016	0.04	40
34.5	0.004	0.01	10
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.001	0.00	2
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		2.31	1452

Area: Johnies
Coverage: 6 Targeted

Mean sA (m2/nm 76.2
Area (nm2) 5
L-W parameter "a 0.145
L-W parameter "b 2.54

Length cm	Relative frequency	Number (million	iomas tonnes
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.001	0.01	1
18.5	0.003	0.02	4
19.5	0.007	0.03	9
20.5	0.019	0.10	32
21.5	0.029	0.15	54
22.5	0.061	0.32	126
23.5	0.096	0.50	222
24.5	0.094	0.50	243
25.5	0.108	0.57	307
26.5	0.101	0.53	318
27.5	0.112	0.59	385
28.5	0.109	0.57	412
29.5	0.078	0.41	320
30.5	0.092	0.49	415
31.5	0.045	0.24	218
32.5	0.023	0.12	121
33.5	0.016	0.08	91
34.5	0.004	0.02	23
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	1
38.5	0.000	0.00	0
39.5	0.001	0.00	5
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		5.26	3306

Appenix 21: No. and biomass of fish per length class (.5cm) calculated from scrutinised acoustics (Johnies)

Area: Johnies
Coverage: 1 Scrutinised

Mean sA (m2/nm2) 8.8
Area (nm2) 335
L-W parameter "a" 0.145
L-W parameter "b" 2.5397

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.01	1
14.5	0.000	0.01	1
15.5	0.000	0.02	3
16.5	0.000	0.02	3
17.5	0.001	0.05	11
18.5	0.003	0.12	30
19.5	0.007	0.27	73
20.5	0.019	0.79	245
21.5	0.029	1.20	420
22.5	0.061	2.46	971
23.5	0.096	3.91	1719
24.5	0.094	3.84	1877
25.5	0.108	4.38	2374
26.5	0.101	4.12	2457
27.5	0.112	4.54	2975
28.5	0.109	4.44	3190
29.5	0.078	3.16	2474
30.5	0.092	3.76	3209
31.5	0.045	1.82	1686
32.5	0.023	0.94	939
33.5	0.016	0.65	700
34.5	0.004	0.15	175
35.5	0.000	0.00	1
36.5	0.000	0.00	0
37.5	0.000	0.00	4
38.5	0.000	0.00	0
39.5	0.001	0.02	38
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		40.68	25878

Area: Johnies
Coverage: 2 Scrutinised

Mean sA (m2/nm2) 5.7
Area (nm2) 441
L-W parameter "a" 0.145
L-W parameter "b" 2.5397

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.01	1
14.5	0.000	0.01	1
15.5	0.000	0.02	2
16.5	0.000	0.02	3
17.5	0.001	0.04	9
18.5	0.003	0.11	26
19.5	0.007	0.23	63
20.5	0.019	0.67	209
21.5	0.029	1.02	358
22.5	0.061	2.10	828
23.5	0.096	3.33	1466
24.5	0.094	3.27	1600
25.5	0.108	3.74	2024
26.5	0.101	3.51	2095
27.5	0.112	3.87	2537
28.5	0.109	3.79	2720
29.5	0.078	2.69	2109
30.5	0.092	3.21	2736
31.5	0.045	1.55	1437
32.5	0.023	0.80	801
33.5	0.016	0.55	597
34.5	0.004	0.13	149
35.5	0.000	0.00	1
36.5	0.000	0.00	0
37.5	0.000	0.00	3
38.5	0.000	0.00	0
39.5	0.001	0.02	33
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		34.69	21810

Area: Johnies
Coverage: 3 Scrutinised

Mean sA (m2/nm2) 11.2
Area (nm2) 36
L-W parameter "a" 0.145
L-W parameter "b" 2.5397

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.001	0.01	1
18.5	0.003	0.02	4
19.5	0.007	0.04	10
20.5	0.019	0.11	34
21.5	0.029	0.16	57
22.5	0.061	0.34	133
23.5	0.096	0.53	235
24.5	0.094	0.52	257
25.5	0.108	0.60	325
26.5	0.101	0.56	336
27.5	0.112	0.62	407
28.5	0.109	0.61	436
29.5	0.078	0.43	338
30.5	0.092	0.51	439
31.5	0.045	0.25	231
32.5	0.023	0.13	128
33.5	0.016	0.09	96
34.5	0.004	0.02	24
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	1
38.5	0.000	0.00	0
39.5	0.001	0.00	5
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		5.56	3498

Area: Johnies
Coverage: 4 Scrutinised

Mean sA (m2/nm2) 26.3
Area (nm2) 34
L-W parameter "a" 0.145
L-W parameter "b" 2.5397

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.01	1
16.5	0.000	0.01	1
17.5	0.001	0.02	3
18.5	0.003	0.04	9
19.5	0.007	0.08	22
20.5	0.019	0.24	74
21.5	0.029	0.36	127
22.5	0.061	0.75	295
23.5	0.096	1.19	521
24.5	0.094	1.16	569
25.5	0.108	1.33	720
26.5	0.101	1.25	745
27.5	0.112	1.38	902
28.5	0.109	1.35	967
29.5	0.078	0.96	750
30.5	0.092	1.14	973
31.5	0.045	0.55	511
32.5	0.023	0.28	285
33.5	0.016	0.20	212
34.5	0.004	0.05	53
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	1
38.5	0.000	0.00	0
39.5	0.001	0.01	12
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		12.34	7758

Area: Johnies
Coverage: 5 Scrutinised

Mean sA (m2/nm2) 23.2
Area (nm2) 9
L-W parameter "a" 0.145
L-W parameter "b" 2.5397

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.001	0.00	1
18.5	0.003	0.01	2
19.5	0.007	0.02	5
20.5	0.019	0.06	17
21.5	0.029	0.08	30
22.5	0.061	0.17	69
23.5	0.096	0.28	122
24.5	0.094	0.27	133
25.5	0.108	0.31	168
26.5	0.101	0.29	174
27.5	0.112	0.32	211
28.5	0.109	0.31	226
29.5	0.078	0.22	175
30.5	0.092	0.27	227
31.5	0.045	0.13	119
32.5	0.023	0.07	67
33.5	0.016	0.05	50
34.5	0.004	0.01	12
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.001	0.00	3
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		2.88	1812

Area: Johnies
Coverage: 6 Scrutinised

Mean sA (m2/nm2) 91.2
Area (nm2) 5
L-W parameter "a" 0.145
L-W parameter "b" 2.5397

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	1
17.5	0.001	0.01	2
18.5	0.003	0.02	5
19.5	0.007	0.04	11
20.5	0.019	0.12	38
21.5	0.029	0.18	65
22.5	0.061	0.38	150
23.5	0.096	0.60	266
24.5	0.094	0.59	290
25.5	0.108	0.68	367
26.5	0.101	0.64	380
27.5	0.112	0.70	460
28.5	0.109	0.69	493
29.5	0.078	0.49	383
30.5	0.092	0.58	496
31.5	0.045	0.28	261
32.5	0.023	0.14	145
33.5	0.016	0.10	108
34.5	0.004	0.02	27
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	1
38.5	0.000	0.00	0
39.5	0.001	0.00	6
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		6.29	3986

Appenix 22: No. and biomass of fish per length class (.5cm) calculated from targeted acoustics (Frankies)

Area: Frankies
Coverage: 1 Targeted

Mean sA (m2/nm2) 3.97
Area (nm2) 407
L-W parameter "a" 0.174
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.01	1
12.5	0.001	0.03	2
13.5	0.002	0.05	5
14.5	0.003	0.06	8
15.5	0.004	0.08	14
16.5	0.003	0.06	11
17.5	0.003	0.07	16
18.5	0.003	0.07	17
19.5	0.003	0.07	19
20.5	0.009	0.19	61
21.5	0.012	0.26	95
22.5	0.016	0.33	137
23.5	0.038	0.80	365
24.5	0.054	1.13	575
25.5	0.104	2.17	1224
26.5	0.096	2.01	1246
27.5	0.145	3.05	2071
28.5	0.158	3.31	2461
29.5	0.117	2.45	1982
30.5	0.130	2.71	2388
31.5	0.056	1.18	1122
32.5	0.031	0.65	671
33.5	0.008	0.17	187
34.5	0.002	0.05	60
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		20.94	14738

Area: Frankies
Coverage: 2 Targeted

Mean sA (m2/nm2) 1.7
Area (nm2) 178
L-W parameter "a" 0.174
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.00	0
13.5	0.002	0.01	1
14.5	0.003	0.01	2
15.5	0.004	0.02	3
16.5	0.003	0.01	2
17.5	0.003	0.01	3
18.5	0.003	0.01	3
19.5	0.003	0.01	4
20.5	0.009	0.04	11
21.5	0.012	0.05	18
22.5	0.016	0.06	26
23.5	0.038	0.15	68
24.5	0.054	0.21	108
25.5	0.104	0.41	229
26.5	0.096	0.38	233
27.5	0.145	0.57	388
28.5	0.158	0.62	461
29.5	0.117	0.46	371
30.5	0.130	0.51	447
31.5	0.056	0.22	210
32.5	0.031	0.12	126
33.5	0.008	0.03	35
34.5	0.002	0.01	11
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		3.92	2760

Area: Frankies
Coverage: 3 Targeted

Mean sA (m2/nm2) 4.52
Area (nm2) 180
L-W parameter "a" 0.174
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass tonnes
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.01	0
12.5	0.001	0.01	1
13.5	0.002	0.02	3
14.5	0.003	0.03	4
15.5	0.004	0.04	7
16.5	0.003	0.03	5
17.5	0.003	0.04	8
18.5	0.003	0.03	8
19.5	0.003	0.03	10
20.5	0.009	0.09	31
21.5	0.012	0.13	48
22.5	0.016	0.17	69
23.5	0.038	0.40	184
24.5	0.054	0.57	289
25.5	0.104	1.09	616
26.5	0.096	1.01	627
27.5	0.145	1.53	1043
28.5	0.158	1.67	1239
29.5	0.117	1.23	998
30.5	0.130	1.37	1202
31.5	0.056	0.59	565
32.5	0.031	0.33	338
33.5	0.008	0.08	94
34.5	0.002	0.03	30
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		10.54	7421

Area: Frankies
Coverage: 4 Targeted

Mean sA (m2/nm2) 0
Area (nm2) 19
L-W parameter "a" 0.174
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.00	0
13.5	0.002	0.00	0
14.5	0.003	0.00	0
15.5	0.004	0.00	0
16.5	0.003	0.00	0
17.5	0.003	0.00	0
18.5	0.003	0.00	0
19.5	0.003	0.00	0
20.5	0.009	0.00	0
21.5	0.012	0.00	0
22.5	0.016	0.00	0
23.5	0.038	0.00	0
24.5	0.054	0.00	0
25.5	0.104	0.00	0
26.5	0.096	0.00	0
27.5	0.145	0.00	0
28.5	0.158	0.00	0
29.5	0.117	0.00	0
30.5	0.130	0.00	0
31.5	0.056	0.00	0
32.5	0.031	0.00	0
33.5	0.008	0.00	0
34.5	0.002	0.00	0
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		0.00	0

Area: Frankies
Coverage: 5 Targeted

Mean sA (m2/nm2) 9.6
Area (nm2) 13
L-W parameter "a" 0.174
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.00	0
13.5	0.002	0.00	0
14.5	0.003	0.00	1
15.5	0.004	0.01	1
16.5	0.003	0.00	1
17.5	0.003	0.01	1
18.5	0.003	0.01	1
19.5	0.003	0.01	1
20.5	0.009	0.01	5
21.5	0.012	0.02	7
22.5	0.016	0.03	11
23.5	0.038	0.06	28
24.5	0.054	0.09	44
25.5	0.104	0.17	95
26.5	0.096	0.16	96
27.5	0.145	0.24	160
28.5	0.158	0.26	190
29.5	0.117	0.19	153
30.5	0.130	0.21	184
31.5	0.056	0.09	87
32.5	0.031	0.05	52
33.5	0.008	0.01	14
34.5	0.002	0.00	5
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		1.62	1138

Area: Frankies
Coverage: 6 Targeted

Mean sA (m2/nm2) 8.1
Area (nm2) 24
L-W parameter "a" 0.174
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass tonnes
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.00	0
13.5	0.002	0.01	1
14.5	0.003	0.01	1
15.5	0.004	0.01	2
16.5	0.003	0.01	1
17.5	0.003	0.01	2
18.5	0.003	0.01	2
19.5	0.003	0.01	2
20.5	0.009	0.02	7
21.5	0.012	0.03	11
22.5	0.016	0.04	16
23.5	0.038	0.10	44
24.5	0.054	0.14	69
25.5	0.104	0.26	147
26.5	0.096	0.24	150
27.5	0.145	0.37	249
28.5	0.158	0.40	296
29.5	0.117	0.29	238
30.5	0.130	0.33	287
31.5	0.056	0.14	135
32.5	0.031	0.08	81
33.5	0.008	0.02	22
34.5	0.002	0.01	7
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		2.52	1773

Appenix 23: No. and biomass of fish per length class (.5cm) calculated from scrutinised acoustics (Frankies)

Area: Frankies
Coverage: 1 Scrutinised

Mean sA (m2/nm2) 5
Area (nm2) 407
L-W parameter "a" 0.1743
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.01	1
12.5	0.001	0.03	3
13.5	0.002	0.06	7
14.5	0.003	0.07	10
15.5	0.004	0.11	17
16.5	0.003	0.07	13
17.5	0.003	0.09	20
18.5	0.003	0.08	21
19.5	0.003	0.08	24
20.5	0.009	0.24	77
21.5	0.012	0.33	120
22.5	0.016	0.42	172
23.5	0.038	1.00	460
24.5	0.054	1.42	724
25.5	0.104	2.74	1541
26.5	0.096	2.53	1569
27.5	0.145	3.84	2608
28.5	0.158	4.17	3100
29.5	0.117	3.08	2496
30.5	0.130	3.42	3008
31.5	0.056	1.48	1413
32.5	0.031	0.82	846
33.5	0.008	0.21	236
34.5	0.002	0.06	75
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		26.37	18561

Area: Frankies
Coverage: 2 Scrutinised

Mean sA (m2/nm2) 2.7
Area (nm2) 178
L-W parameter "a" 0.1743
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.01	1
13.5	0.002	0.01	2
14.5	0.003	0.02	2
15.5	0.004	0.02	4
16.5	0.003	0.02	3
17.5	0.003	0.02	5
18.5	0.003	0.02	5
19.5	0.003	0.02	6
20.5	0.009	0.06	18
21.5	0.012	0.08	28
22.5	0.016	0.10	41
23.5	0.038	0.24	109
24.5	0.054	0.34	171
25.5	0.104	0.65	364
26.5	0.096	0.60	371
27.5	0.145	0.91	616
28.5	0.158	0.99	732
29.5	0.117	0.73	590
30.5	0.130	0.81	710
31.5	0.056	0.35	334
32.5	0.031	0.19	200
33.5	0.008	0.05	56
34.5	0.002	0.01	18
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		6.23	4384

Area: Frankies
Coverage: 3 Scrutinised

Mean sA (m2/nm2) 4.8
Area (nm2) 180
L-W parameter "a" 0.1743
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.01	0
12.5	0.001	0.01	1
13.5	0.002	0.03	3
14.5	0.003	0.03	4
15.5	0.004	0.04	7
16.5	0.003	0.03	6
17.5	0.003	0.04	9
18.5	0.003	0.04	9
19.5	0.003	0.04	10
20.5	0.009	0.10	33
21.5	0.012	0.14	51
22.5	0.016	0.18	73
23.5	0.038	0.43	195
24.5	0.054	0.60	307
25.5	0.104	1.16	654
26.5	0.096	1.07	666
27.5	0.145	1.63	1107
28.5	0.158	1.77	1316
29.5	0.117	1.31	1060
30.5	0.130	1.45	1277
31.5	0.056	0.63	600
32.5	0.031	0.35	359
33.5	0.008	0.09	100
34.5	0.002	0.03	32
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.20	7881

Area: Frankies
Coverage: 4 Scrutinised

Mean sA (m2/nm2) 0
Area (nm2) 19
L-W parameter "a" 0.1743
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.00	0
13.5	0.002	0.00	0
14.5	0.003	0.00	0
15.5	0.004	0.00	0
16.5	0.003	0.00	0
17.5	0.003	0.00	0
18.5	0.003	0.00	0
19.5	0.003	0.00	0
20.5	0.009	0.00	0
21.5	0.012	0.00	0
22.5	0.016	0.00	0
23.5	0.038	0.00	0
24.5	0.054	0.00	0
25.5	0.104	0.00	0
26.5	0.096	0.00	0
27.5	0.145	0.00	0
28.5	0.158	0.00	0
29.5	0.117	0.00	0
30.5	0.130	0.00	0
31.5	0.056	0.00	0
32.5	0.031	0.00	0
33.5	0.008	0.00	0
34.5	0.002	0.00	0
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		0.00	0

Area: Frankies
Coverage: 5 Scrutinised

Mean sA (m2/nm2) 13.5
Area (nm2) 13
L-W parameter "a" 0.1743
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.00	0
13.5	0.002	0.01	1
14.5	0.003	0.01	1
15.5	0.004	0.01	1
16.5	0.003	0.01	1
17.5	0.003	0.01	2
18.5	0.003	0.01	2
19.5	0.003	0.01	2
20.5	0.009	0.02	7
21.5	0.012	0.03	10
22.5	0.016	0.04	15
23.5	0.038	0.09	40
24.5	0.054	0.12	62
25.5	0.104	0.24	133
26.5	0.096	0.22	135
27.5	0.145	0.33	225
28.5	0.158	0.36	267
29.5	0.117	0.27	215
30.5	0.130	0.29	259
31.5	0.056	0.13	122
32.5	0.031	0.07	73
33.5	0.008	0.02	20
34.5	0.002	0.01	6
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		2.27	1601

Area: Frankies
Coverage: 6 Scrutinised

Mean sA (m2/nm2) 3.9
Area (nm2) 24
L-W parameter "a" 0.1743
L-W parameter "b" 2.495

Length cm	Relative frequency	Number (millions	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.001	0.00	0
12.5	0.001	0.00	0
13.5	0.002	0.00	0
14.5	0.003	0.00	0
15.5	0.004	0.00	1
16.5	0.003	0.00	1
17.5	0.003	0.00	1
18.5	0.003	0.00	1
19.5	0.003	0.00	1
20.5	0.009	0.01	4
21.5	0.012	0.02	6
22.5	0.016	0.02	8
23.5	0.038	0.05	21
24.5	0.054	0.07	33
25.5	0.104	0.13	71
26.5	0.096	0.12	72
27.5	0.145	0.18	120
28.5	0.158	0.19	143
29.5	0.117	0.14	115
30.5	0.130	0.16	138
31.5	0.056	0.07	65
32.5	0.031	0.04	39
33.5	0.008	0.01	11
34.5	0.002	0.00	3
35.5	0.000	0.00	0
36.5	0.000	0.00	0
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		1.21	854

Appendix 24: No. and biomass of fish per length class (.5cm) calculated from targeted acoustics (Rix)

Area: Rix
Coverage: 1 Targeted

Mean sA (m2/nm2) 2.96
Area (nm2) 214
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.05	16
21.5	0.011	0.09	31
22.5	0.008	0.06	25
23.5	0.024	0.18	82
24.5	0.037	0.29	142
25.5	0.068	0.52	288
26.5	0.098	0.75	465
27.5	0.153	1.17	787
28.5	0.130	1.00	733
29.5	0.125	0.96	770
30.5	0.140	1.07	940
31.5	0.110	0.84	801
32.5	0.046	0.35	362
33.5	0.017	0.13	142
34.5	0.018	0.13	162
35.5	0.005	0.04	46
36.5	0.004	0.03	45
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		7.65	5827

Area: Rix
Coverage: 2 Targeted

Mean sA (m2/nm2) 8.9
Area (nm2) 109
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.08	24
21.5	0.011	0.13	47
22.5	0.008	0.10	38
23.5	0.024	0.28	125
24.5	0.037	0.44	217
25.5	0.068	0.80	442
26.5	0.098	1.14	697
27.5	0.153	1.80	1205
28.5	0.130	1.53	1123
29.5	0.125	1.46	1179
30.5	0.140	1.64	1440
31.5	0.110	1.29	1227
32.5	0.046	0.53	554
33.5	0.017	0.19	218
34.5	0.018	0.21	248
35.5	0.005	0.05	70
36.5	0.004	0.05	69
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.72	8925

Area: Rix
Coverage: 3 Targeted

Mean sA (m2/nm2) 15
Area (nm2) 43
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.05	16
21.5	0.011	0.09	31
22.5	0.008	0.06	25
23.5	0.024	0.19	83
24.5	0.037	0.29	144
25.5	0.068	0.53	294
26.5	0.098	0.76	463
27.5	0.153	1.19	801
28.5	0.130	1.01	747
29.5	0.125	0.97	784
30.5	0.140	1.09	957
31.5	0.110	0.85	816
32.5	0.046	0.36	368
33.5	0.017	0.13	145
34.5	0.018	0.14	165
35.5	0.005	0.04	47
36.5	0.004	0.03	46
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		7.79	5934

Area: Rix
Coverage: 4 Targeted

Mean sA (m2/nm2) 38.3
Area (nm2) 28
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	1
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.08	26
21.5	0.011	0.15	52
22.5	0.008	0.1[illegible]	42
23.5	0.024	0.31	139
24.5	0.037	0.48	240
25.5	0.068	0.89	488
26.5	0.098	1.26	770
27.5	0.153	1.99	1332
28.5	0.130	1.69	1241
29.5	0.125	1.62	1303
30.5	0.140	1.81	1692
31.5	0.110	1.42	1367
32.5	0.046	0.59	612
33.5	0.017	0.21	241
34.5	0.018	0.23	278
35.5	0.005	0.06	78
36.5	0.004	0.05	77
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		12.96	9866

Area: Rix
Coverage: 5 Targeted

Mean sA (m2/nm2) 33.4
Area (nm2) 28
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.07	23
21.5	0.011	0.13	45
22.5	0.008	0.09	37
23.5	0.024	0.27	121
24.5	0.037	0.42	209
25.5	0.068	0.77	426
26.5	0.098	1.10	672
27.5	0.153	1.73	1162
28.5	0.130	1.47	1083
29.5	0.125	1.41	1137
30.5	0.140	1.58	1388
31.5	0.110	1.24	1183
32.5	0.046	0.52	534
33.5	0.017	0.19	210
34.5	0.018	0.20	240
35.5	0.005	0.05	68
36.5	0.004	0.05	67
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.30	8604

Area: Rix
Coverage: 6 Targeted

Mean sA (m2/nm2) 26
Area (nm2) 28
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.06	18
21.5	0.011	0.10	35
22.5	0.008	0.07	29
23.5	0.024	0.21	94
24.5	0.037	0.33	163
25.5	0.068	0.60	331
26.5	0.098	0.86	523
27.5	0.153	1.35	904
28.5	0.130	1.14	843
29.5	0.125	1.10	886
30.5	0.140	1.23	1080
31.5	0.110	0.96	921
32.5	0.046	0.40	416
33.5	0.017	0.15	163
34.5	0.018	0.15	186
35.5	0.005	0.04	53
36.5	0.004	0.04	52
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		8.80	6697

Appendix 25: No. and biomass of fish per length class (.5cm) calculated from scrutinised acoustics (Rix)

Area:	Rix	
Coverage:	1	Targeted
Mean sA (m2/nm2)	2.96	
Area (nm2)	214	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.05	16
21.5	0.011	0.09	31
22.5	0.008	0.06	25
23.5	0.024	0.18	82
24.5	0.037	0.29	142
25.5	0.068	0.52	288
26.5	0.098	0.75	455
27.5	0.153	1.17	787
28.5	0.130	1.00	733
29.5	0.125	0.96	770
30.5	0.140	1.07	940
31.5	0.110	0.84	801
32.5	0.046	0.35	362
33.5	0.017	0.13	142
34.5	0.018	0.13	162
35.5	0.005	0.04	46
36.5	0.004	0.03	45
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		7.66	5827

Area:	Rix	
Coverage:	2	Targeted
Mean sA (m2/nm2)	8.9	
Area (nm2)	109	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.08	24
21.5	0.011	0.13	47
22.5	0.008	0.10	38
23.5	0.024	0.28	125
24.5	0.037	0.44	217
25.5	0.068	0.80	442
26.5	0.098	1.14	697
27.5	0.153	1.80	1205
28.5	0.130	1.53	1123
29.5	0.125	1.46	1179
30.5	0.140	1.64	1440
31.5	0.110	1.29	1227
32.5	0.046	0.53	554
33.5	0.017	0.19	218
34.5	0.018	0.21	248
35.5	0.005	0.05	70
36.5	0.004	0.05	69
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.72	8925

Area:	Rix	
Coverage:	3	Targeted
Mean sA (m2/nm2)	15	
Area (nm2)	43	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.05	16
21.5	0.011	0.09	31
22.5	0.008	0.06	25
23.5	0.024	0.19	83
24.5	0.037	0.29	144
25.5	0.068	0.53	294
26.5	0.098	0.76	463
27.5	0.153	1.19	801
28.5	0.130	1.01	747
29.5	0.125	0.97	784
30.5	0.140	1.09	957
31.5	0.110	0.85	816
32.5	0.046	0.36	368
33.5	0.017	0.13	145
34.5	0.018	0.14	165
35.5	0.005	0.04	47
36.5	0.004	0.03	46
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		7.79	5934

Area:	Rix	
Coverage:	4	Targeted
Mean sA (m2/nm2)	38.3	
Area (nm2)	28	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	1
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.08	26
21.5	0.011	0.15	52
22.5	0.008	0.11	42
23.5	0.024	0.31	139
24.5	0.037	0.48	240
25.5	0.068	0.89	488
26.5	0.098	1.26	770
27.5	0.153	1.99	1332
28.5	0.130	1.69	1241
29.5	0.125	1.62	1303
30.5	0.140	1.81	1592
31.5	0.110	1.42	1357
32.5	0.046	0.59	612
33.5	0.017	0.21	241
34.5	0.018	0.23	275
35.5	0.005	0.06	78
36.5	0.004	0.05	77
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		12.96	9866

Area:	Rix	
Coverage:	5	Targeted
Mean sA (m2/nm2)	33.4	
Area (nm2)	28	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.07	23
21.5	0.011	0.13	45
22.5	0.008	0.09	37
23.5	0.024	0.27	121
24.5	0.037	0.42	209
25.5	0.068	0.77	426
26.5	0.098	1.10	672
27.5	0.153	1.73	1162
28.5	0.130	1.47	1083
29.5	0.125	1.41	1137
30.5	0.140	1.58	1388
31.5	0.110	1.24	1183
32.5	0.046	0.52	534
33.5	0.017	0.19	210
34.5	0.018	0.20	240
35.5	0.005	0.05	68
36.5	0.004	0.05	67
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.30	8604

Area:	Rix	
Coverage:	6	Targeted
Mean sA (m2/nm2)	26	
Area (nm2)	28	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.06	18
21.5	0.011	0.10	35
22.5	0.008	0.07	29
23.5	0.024	0.21	94
24.5	0.037	0.33	163
25.5	0.068	0.60	331
26.5	0.098	0.86	523
27.5	0.153	1.35	904
28.5	0.130	1.14	843
29.5	0.125	1.10	885
30.5	0.140	1.23	1080
31.5	0.110	0.96	921
32.5	0.046	0.40	416
33.5	0.017	0.15	163
34.5	0.018	0.15	186
35.5	0.005	0.04	53
36.5	0.004	0.04	52
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		8.80	6697

Area: Rix
Coverage: 1 Scrutinised

Mean sA (m2/nm2) 3.36
Area (nm2) 214
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.06	17
21.5	0.011	0.10	35
22.5	0.008	0.07	28
23.5	0.024	0.21	93
24.5	0.037	0.32	161
25.5	0.068	0.59	327
26.5	0.098	0.85	516
27.5	0.153	1.33	893
28.5	0.130	1.13	832
29.5	0.125	1.09	874
30.5	0.140	1.22	1067
31.5	0.110	0.95	910
32.5	0.046	0.40	411
33.5	0.017	0.14	161
34.5	0.018	0.15	184
35.5	0.005	0.04	52
36.5	0.004	0.04	51
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		8.69	6615

Area: Rix
Coverage: 2 Scrutinised

Mean sA (m2/nm2) 8.6
Area (nm2) 109
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.07	23
21.5	0.011	0.13	46
22.5	0.008	0.09	37
23.5	0.024	0.27	121
24.5	0.037	0.42	210
25.5	0.068	0.77	427
26.5	0.098	1.10	673
27.5	0.153	1.74	1164
28.5	0.130	1.47	1085
29.5	0.125	1.41	1139
30.5	0.140	1.58	1391
31.5	0.110	1.24	1186
32.5	0.046	0.52	535
33.5	0.017	0.19	210
34.5	0.018	0.20	240
35.5	0.005	0.05	68
36.5	0.004	0.05	67
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.33	8624

Area: Rix
Coverage: 3 Scrutinised

Mean sA (m2/nm2) 18.8
Area (nm2) 43
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.06	20
21.5	0.011	0.11	39
22.5	0.008	0.08	32
23.5	0.024	0.23	105
24.5	0.037	0.36	181
25.5	0.068	0.67	368
26.5	0.098	0.95	581
27.5	0.153	1.50	1004
28.5	0.130	1.27	936
29.5	0.125	1.22	983
30.5	0.140	1.37	1200
31.5	0.110	1.07	1023
32.5	0.046	0.45	462
33.5	0.017	0.16	181
34.5	0.018	0.17	207
35.5	0.005	0.04	58
36.5	0.004	0.04	58
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		9.77	7437

Area: Rix
Coverage: 4 Scrutinised

Mean sA (m2/nm2) 34.1
Area (nm2) 28
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.07	23
21.5	0.011	0.13	46
22.5	0.008	0.09	38
23.5	0.024	0.28	124
24.5	0.037	0.43	214
25.5	0.068	0.79	435
26.5	0.098	1.13	686
27.5	0.153	1.77	1186
28.5	0.130	1.50	1105
29.5	0.125	1.44	1160
30.5	0.140	1.61	1417
31.5	0.110	1.26	1208
32.5	0.046	0.53	546
33.5	0.017	0.19	214
34.5	0.018	0.20	245
35.5	0.005	0.05	69
36.5	0.004	0.05	68
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.54	8784

Area: Rix
Coverage: 4 Scrutinised

Mean sA (m2/nm2) 34.1
Area (nm2) 28
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.07	23
21.5	0.011	0.13	46
22.5	0.008	0.09	38
23.5	0.024	0.28	124
24.5	0.037	0.43	214
25.5	0.068	0.79	435
26.5	0.098	1.13	686
27.5	0.153	1.77	1186
28.5	0.130	1.50	1105
29.5	0.125	1.44	1160
30.5	0.140	1.61	1417
31.5	0.110	1.26	1208
32.5	0.046	0.53	546
33.5	0.017	0.19	214
34.5	0.018	0.20	245
35.5	0.005	0.05	69
36.5	0.004	0.05	68
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		11.54	8784

Area: Rix
Coverage: 6 Scrutinised

Mean sA (m2/nm2) 24.2
Area (nm2) 28
L-W parameter "a" 0.1214
L-W parameter "b" 2.6001

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.05	16
21.5	0.011	0.09	33
22.5	0.008	0.07	27
23.5	0.024	0.20	88
24.5	0.037	0.31	152
25.5	0.068	0.56	308
26.5	0.098	0.80	487
27.5	0.153	1.25	842
28.5	0.130	1.07	784
29.5	0.125	1.02	824
30.5	0.140	1.15	1006
31.5	0.110	0.90	857
32.5	0.046	0.37	387
33.5	0.017	0.14	152
34.5	0.018	0.14	174
35.5	0.005	0.04	49
36.5	0.004	0.03	48
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		8.19	6234

Appendix 25: No. and biomass of fish per length class (.5cm) calculated from scrutinised acoustics (Rix)

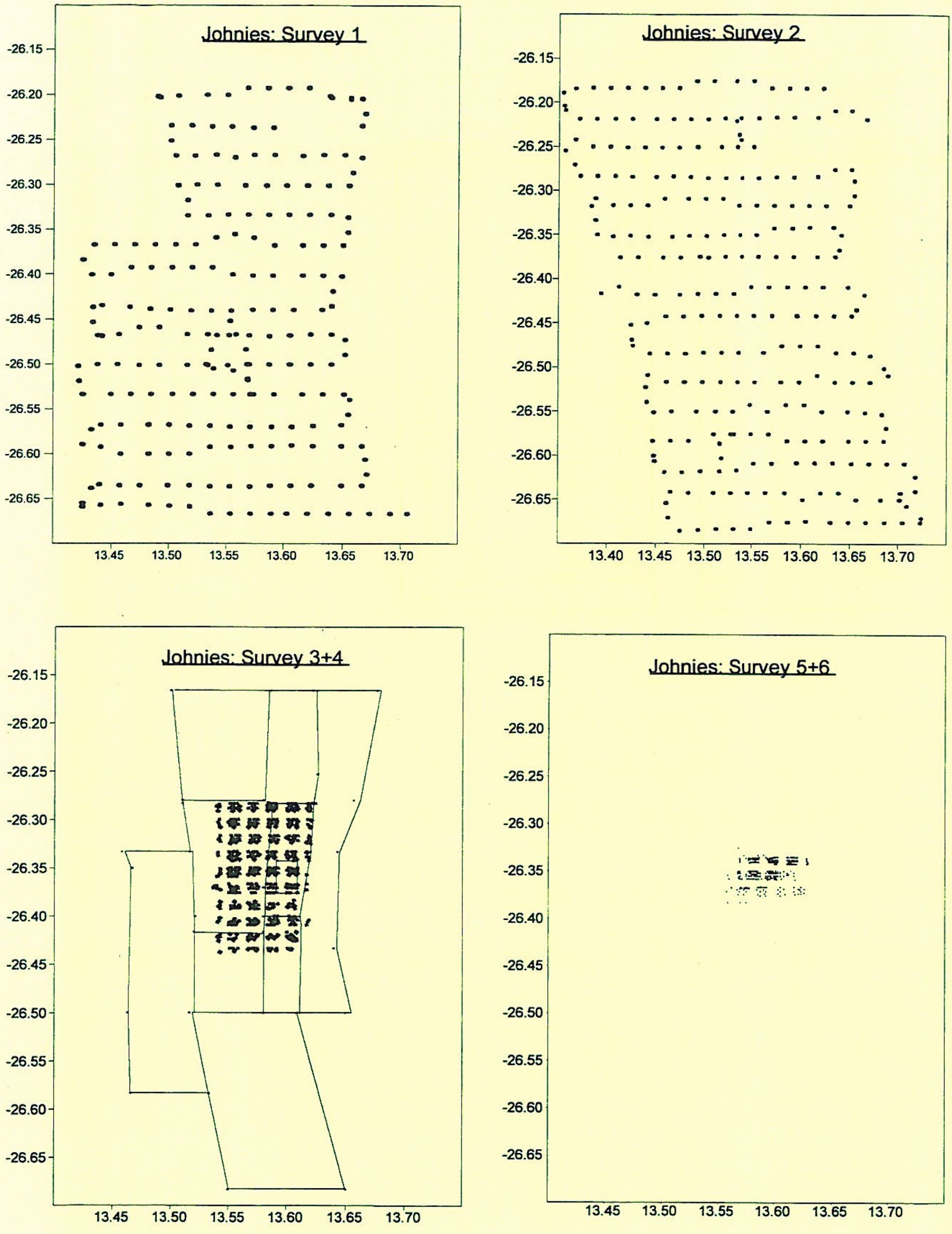
Area	Rix	
Coverage	7	Scrutinised
Mean sA (m2/nm2)	38.9	
Area (nm2)	28	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	1
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.08	28
21.5	0.011	0.15	53
22.5	0.008	0.11	43
23.5	0.024	0.32	141
24.5	0.037	0.49	244
25.5	0.068	0.90	496
26.5	0.098	1.28	782
27.5	0.153	2.02	1383
28.5	0.130	1.71	1261
29.5	0.125	1.64	1324
30.5	0.140	1.84	1617
31.5	0.110	1.44	1378
32.5	0.046	0.60	622
33.5	0.017	0.22	244
34.5	0.018	0.23	279
35.5	0.005	0.06	79
36.5	0.004	0.06	78
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		13.16	10020

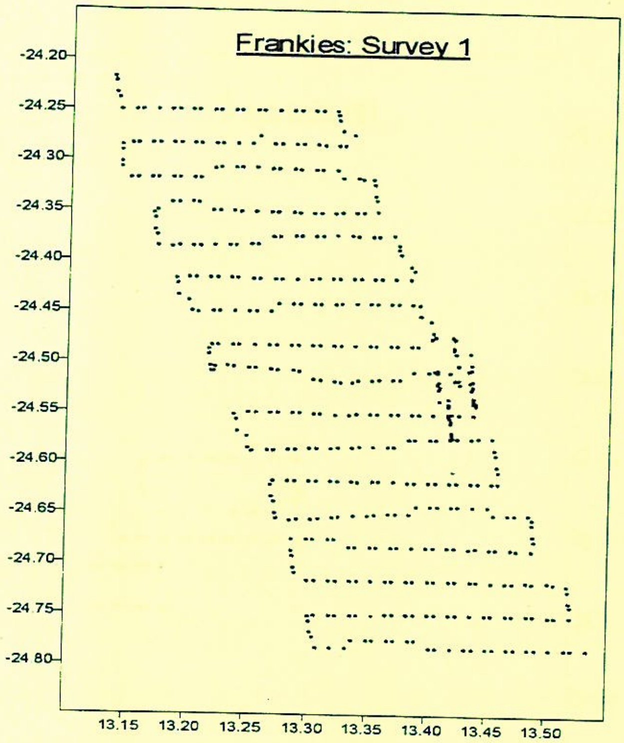
Area	Rix	
Coverage	8	Scrutinised
Mean sA (m2/nm2)	32	
Area (nm2)	28	
L-W parameter "a"	0.1214	
L-W parameter "b"	2.6001	

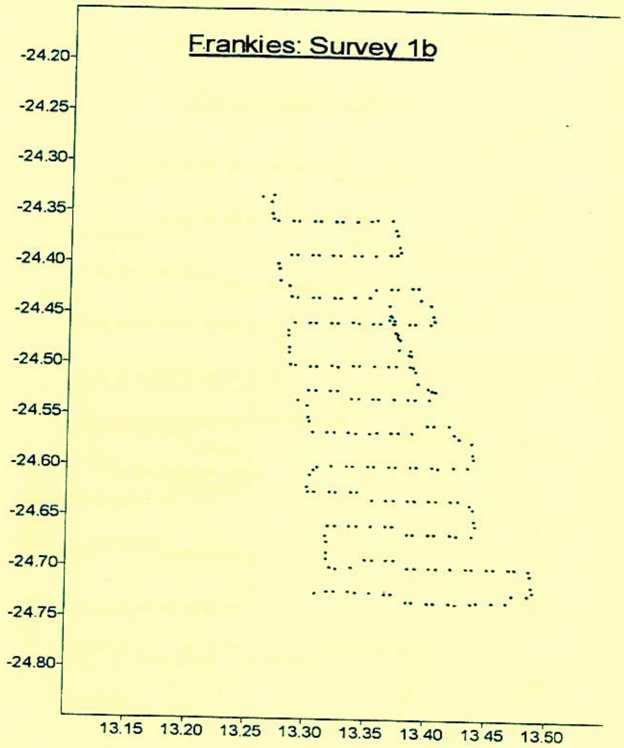
Length cm	Relative frequency	Numbers (millions)	Biomass (tonnes)
4.5	0.000	0.00	0
5.5	0.000	0.00	0
6.5	0.000	0.00	0
7.5	0.000	0.00	0
8.5	0.000	0.00	0
9.5	0.000	0.00	0
10.5	0.000	0.00	0
11.5	0.000	0.00	0
12.5	0.000	0.00	0
13.5	0.000	0.00	0
14.5	0.000	0.00	0
15.5	0.000	0.00	0
16.5	0.000	0.00	0
17.5	0.000	0.00	0
18.5	0.000	0.00	0
19.5	0.000	0.00	0
20.5	0.006	0.07	22
21.5	0.011	0.12	44
22.5	0.008	0.09	35
23.5	0.024	0.26	116
24.5	0.037	0.40	200
25.5	0.068	0.74	408
26.5	0.098	1.06	643
27.5	0.153	1.66	1113
28.5	0.130	1.41	1037
29.5	0.125	1.35	1089
30.5	0.140	1.51	1330
31.5	0.110	1.19	1134
32.5	0.046	0.49	512
33.5	0.017	0.18	201
34.5	0.018	0.19	229
35.5	0.005	0.05	65
36.5	0.004	0.05	64
37.5	0.000	0.00	0
38.5	0.000	0.00	0
39.5	0.000	0.00	0
40.5	0.000	0.00	0
41.5	0.000	0.00	0
42.5	0.000	0.00	0
43.5	0.000	0.00	0
44.5	0.000	0.00	0
		10.83	8243

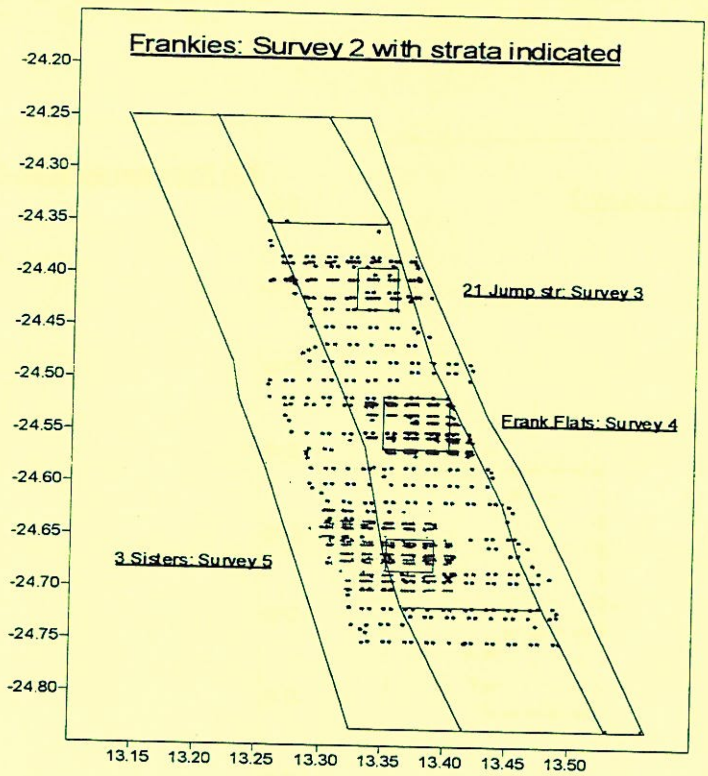
Appendix 26: Transects covered during the survey (Johnies).



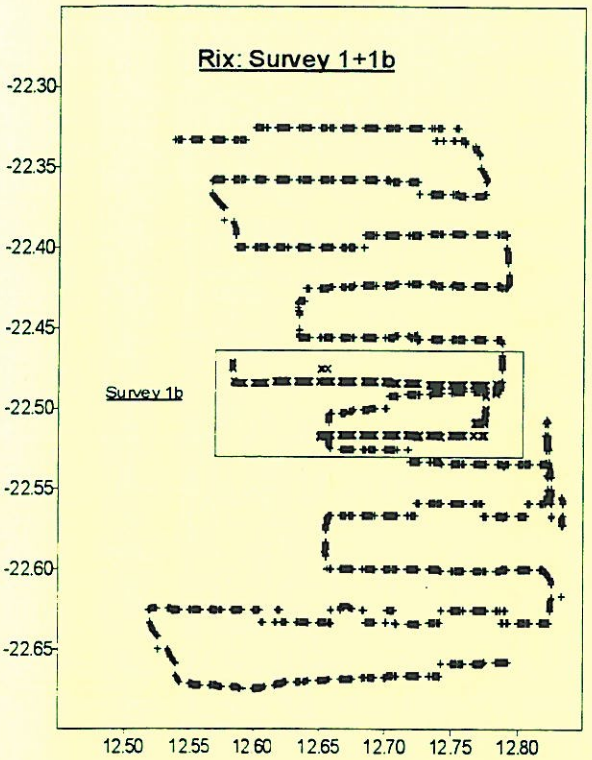
Appendix 27: Transects covered during the survey (Frankies).

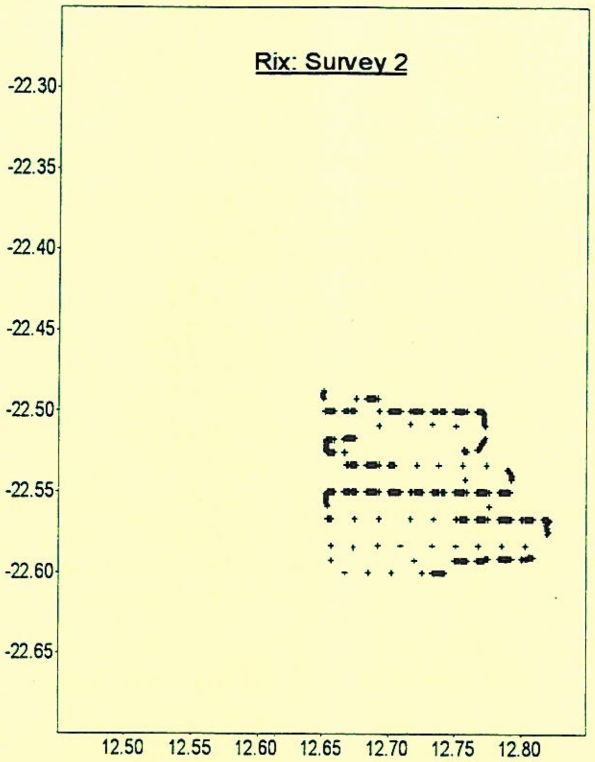


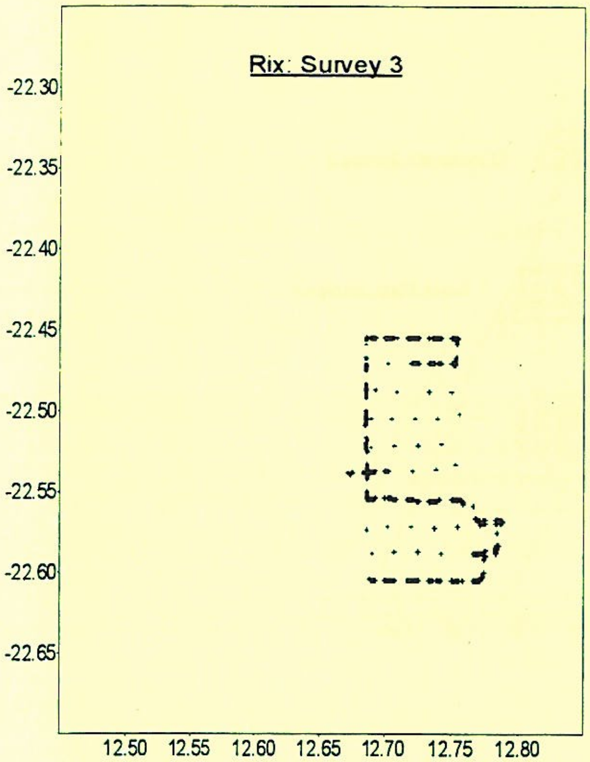


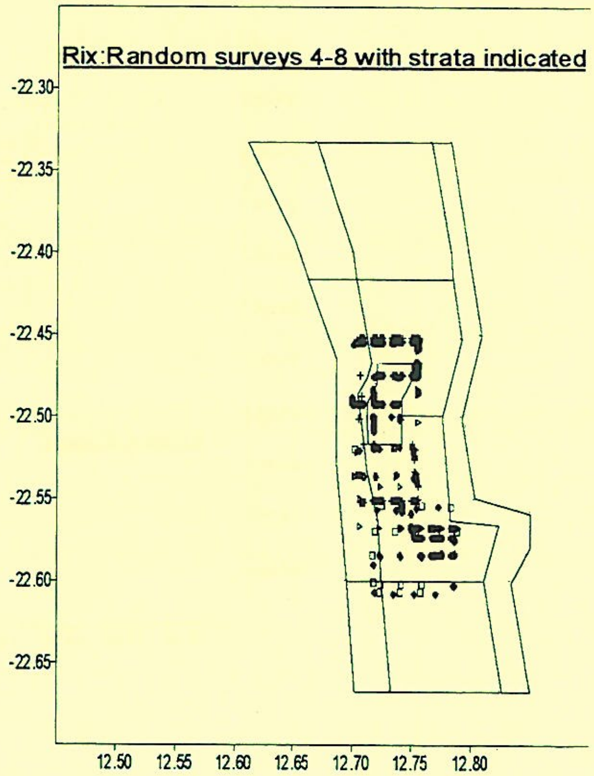


Appendix 28: Transects covered during the survey (Rix).









Appendix 29 Estimation of biomass and variance from acoustic data

This appendix describes the algorithms used for the following calculations:

(1) Estimation of the mean s_A and variance for a stratum or survey, based on the mean S_A values for the survey/stratum transects, and the transect length.

(2) Calculation of the scaling factor used to make a rough correction for differences in the target strength of Orange Roughy and other species when estimating Orange Roughy density in dispersed, mixed-species layers, for the scrutinized acoustic method.

(3) Estimation of Orange Roughy from S_A values and the length distribution of fish in identification trawls for a) clean Orange Roughy catches and b) mixtures of Orange Roughy and other species in the catch

(1) Estimation of mean S_A and variance

The algorithms are based on Eqs. in Jolly and Hampton (1992). For any stratum or survey:

$$\overline{S} = \frac{\sum_{j=1}^{M} L_j (\overline{S})_j}{\sum_{j=1}^{M} L_j}$$

and

$$Var(\overline{S}_A) = \frac{\frac{M}{M-1} \sum L_j^2 \left[(\overline{S})_j - (\overline{S}_A) \right]^2}{\sum_{j=1}^{M} L_j}$$

where $(\overline{S}_A)_j$ = mean S_A for transect j

L_j = length of transect j

M = No of transects in stratum/survey

(2) Estimation of scaling factor F for estimating Orange Roughy density in mixed layers

In any aggregation the number of fish/m^3 (N) can be estimated from:

No of fish/m^3 $\quad N = \frac{S_A}{\overline{\sigma}}$

$\overline{\sigma}$ = mean back-scattering cross section of all fish

$$\bar{\sigma} = \sum_{i=1}^{n} p_i \cdot \bar{\sigma}_i \qquad (1)$$

where

$\bar{\sigma}_i$ = mean back-scattering cross-section of species *i*
p_i = proportion by number of species *i*
n = no of species

Number density of species *i* $N_i = \frac{S_A}{\bar{\sigma}} \cdot p_i$

Weight density of species *i*

$$\rho_i = \frac{S_A}{\bar{\sigma}} \cdot p_i \bar{w}_i \qquad (2)$$

where $\bar{w}_i$ denotes mean weight of species *i*

From (1)

$$\rho_i = \frac{S_A \cdot p_i \cdot \bar{w}_i}{\sum_{i=1}^{n} p_i \cdot \bar{\sigma}_i} \qquad (3)$$

If it is assumed that all targets have the same $\bar{\sigma}$ as roughy, we get a positively biased estimate ρ'_{ORH}:

$$\rho'_{ORH} = \frac{S_A \cdot p_{ORH} \cdot \bar{w}_{ORH}}{\bar{\sigma}_{ORH}} \qquad (4)$$

$\bar{w}_{ORH}$ = mean weight of roughy

p_{ORH} = roughy proportion

$\bar{\sigma}_{ORH}$ = mean back scattering cross-section of roughy

If the other species present have an average back-scattering cross-section $\bar{\sigma}_{oth} = \alpha \bar{\sigma}_{ORH}$, equation 3 becomes for roughy

$$\rho_{ORH} = \frac{S_A \cdot p_{ORH} \cdot \bar{w}_{ORH}}{p_{ORH} \cdot \bar{\sigma}_{ORH} + \alpha (1 - p_{ORH}) \cdot \bar{\sigma}_{ORH}}$$

$$= \frac{S_A \cdot p_{ORH} \cdot \overline{w}_{ORH}}{(\alpha + (1-\alpha) \cdot p_{ORH}) / \overline{\sigma}_{ORH}}$$

i.e. $\rho_{ORH} = F \cdot \rho'_{ORH}$ (from eq. 4)

where

$$F = \frac{1}{(\alpha + (1-\alpha) \cdot p_{ORH})}$$

therefore F is a scaling factor by which the S_A value should be multiplied to give a more correct estimate of Orange Roughy density.

From TS values in Tables 7 and 15 in the 1997 Cruise Report, it seems as if the non-roughy mixtures commonly encountered had $\bar{\sigma}_{oth}$ values about 50 times greater than roughy (i.e. $\alpha \approx 50$), particularly if dominated by swim-bladdered species such as hake, dories and rat-tails.

Illustrative values:

p_{ORH}	$\alpha = 50$	$\alpha = 25$	$\alpha = 10$
	1/F	1/F	1/F
1	1	1	1
0.99	1.49	1.24	1.09
0.95	3.45	2.2	1.45
0.90	5.9	3.4	1.9
0.80	10.8	5.8	2.8
0.70	15.7	8.2	3.7
0.60	20.6	10.6	4.6
0.50	25.5	13.0	5.5
0.40	30.4	15.4	6.4
0.30	35.3	17.8	7.3
0.20	40.2	20.2	8.2
0.10	45.1	22.6	9.1
0.05	47.5	23.8	9.5

Therefore it can be seen that even a small proportion of other (swim bladdered) species will introduce a large positive bias into the roughy density estimate unless differences in TS are taken into account (i.e. the S_A values should not be proportioned solely according to the species composition in the catches.)

(1) Estimation of roughy biomass using length frequency information

a. If no other species present

Roughy Biomass = $B_{ORH} = A * \bar{\rho}_{ORH}$

Where $\bar{\rho}_{ORH}$ = mean weight of roughy/nmile^2

A = survey area in nmile^2

$\bar{\rho}_{ORH}$ is given by:

$$\bar{\rho}_{ORH} = \frac{\bar{S}_A}{(\bar{\sigma}_{kg})_{ORH}} \quad \text{..........(1)}$$

where $(\bar{\sigma}_{kg})_{ORH}$ is the mean roughy scattering cross-section per kg, estimated from the length frequency distribution through the expression:

$$(\bar{\sigma}_{kg})_{ORH} = \frac{\sum_{i=1}^{N} n_i * [(\sigma_{kg})_{ORH}]_i}{\sum_{i=1}^{N} n_i} \quad \text{..........(2)}$$

where $[(\sigma_{kg})_{ORH}]_i$ = scattering cross-section per kg for roughy in length class *i*

n_i = No of roughy in length class *i*

N = No of length classes

$$(\sigma_{kg})_{ORH} = \frac{\sigma_{ORH}}{w} \quad \text{..........(3)}$$

where σ_{ORH} is the scattering cross-section of a Orange Roughy of weight w (kg), which is obtained from the target strength (TS_{ORH}) through the expressions $TS_{ORH} = 20\text{Log}L + C_{ORH}$ and $TS_{ORH} = 10\text{Log}\frac{\sigma_{ORH}}{4\pi}$, giving:

$$\sigma_{ORH} = 4 * \pi * 10^{C_{ORH}/10} * L^2 \quad \text{..........(4)}$$

From (3) and (4):

$$(\sigma_{kg})_{ORH} = \frac{4\pi * 10^{C_{ORH}/10} * L^2}{a_{ORH} * L^{b_{ORH}}}$$

$$= \frac{4\pi * 10^{C_{ORH}/10} * L^{(2-b_{ORH})}}{a_{ORH}} \quad \text{.................................(5)}$$

where a_{ORH} and b_{ORH} are the coefficient and exponent respectively in the roughy weight/length relationship, $w = a_{ORH} * L^{b_{ORH}}$ (w in kg, L in cm).

Eq. (2) then becomes:

$$\left(\bar{\sigma}_{kg}\right)_{ORH} = \frac{4 * \pi * 10^{C_{ORH}/10}}{a_{ORH}} * \frac{\sum_{i=1}^{N} n_i * L_i^{2-b_{ORH}}}{\sum_{i=1}^{N} n_i} \quad \text{...........(6)}$$

where L_i is the midpoint length of length class i.

Substitution in (1) gives the mean weight density (in kg/nmile^2) for the surveyed area, and hence the biomass (in kg) for the area.

Constants needed:

C_{ORH} = -81.0 –1.0 (correction applied in Jan 1998)

= -82.0dB

a_{ORH} =

b_{ORH} =

b. Conversion: $\bar{S}_A$ → Biomass for mixed species

From Eq. (1)

$$\bar{\rho}_{Mix} = \frac{\bar{S}_A}{\left(\bar{\sigma}_{kg}\right)_{Mix}} \quad \text{.................................(7)}$$

$\bar{\rho}_{Mix}$ = mean weight of all fish/nmile^2 in survey

$$\left(\bar{\sigma}_{kg}\right)_{Mix} = \frac{\sum_{j=1}^{M} n_j * \left(\bar{\sigma}_{kg}\right)_j}{\sum_{j=1}^{M} m_j} \quad \text{.....................................(8)}$$

where $\left(\bar{\sigma}_{kg}\right)_j$ = mean scattering cross-section per kg for species j.

m_j = no of fish of species j in pooled sample

M = no. of species present in sample

Strictly, $(\bar{\sigma}_{kg})_j$ for each species should be calculated from the length distribution of species j in the sample, but since these distributions are not available for species other than roughy, and approximation to Eq. (6), viz:

$$(\bar{\sigma}_{kg})_j \approx \frac{4\pi * 10^{c_j/10} * \bar{L}_j^2}{\bar{w}_j} \qquad \text{.......................(9)}$$

has to be used, where c_j is the TS constant for species j, and $\bar{L}_j$ and $\bar{w}_j$ are the mean length and weight of species j.

The weight density for roughy in a mixture is given by:

$$\bar{\rho}_{ORH} = \frac{(W_{tot})_{ORH} * \bar{\rho}_{Mix}}{W_{tot}} = f_{ORH} * \bar{\rho}_{Mix}$$

where $(W_{tot})_{ORH}$ = total weight of roughy in the sample

W_{tot} = total weight of sample

(i.e. $f_{ORH} = \frac{(W_{tot})_{ORH}}{W_{tot}}$ = proportion by weight of roughy in sample)

from Eqs (7), (8) and (9):

$$\bar{\rho}_{ORH} \approx \frac{f_{ORH} * \bar{S}_A * \sum_{j=1}^{M} m_j}{4\pi * \sum_{j=1}^{M} \frac{m_j * 10^{c_j/10} * \bar{L}_j^2}{\bar{w}_j}}$$

For roughy, $\bar{L}_j$ and $\bar{w}_j$ can be obtained directly from the length frequency sample, but for all other species, they may have to be taken from the 1997 data – (Table 8 in 1997 Cruise report).

The c_j values for species other than roughy are given in Table 8 («TS constant») of the '97 Cruise report. i.e.

Hake: -68.0dB

Oreo dories: -68.0dB

Rat-tails:-72.7dB

Sharks: -79.0dB

Note that for roughy, C_{ORH} = -81 – 1.0 = -82 dB

	C-values	σ	K
Roughy	-82.0	$10^{-8} L^2$	10^{-8}
Hake	-68.0	$10^{-5.7} L^2$	$10^{-5.7}$
Dories	-68.0	$10^{-5.7} L^2$	$10^{-6.2}$
Rat-tails	-72.7	$10^{-6.2} L^2$	$10^{-6.8}$
Sharks	-79.0	$10^{-6.8} L^2$	$10^{-6.8}$
Other	-68.0		

<u>Estimation of mean S_A and CV from transects</u>

From survey area:

$$\overline{S}_A = \frac{\sum_{i=1}^{N} L_i * \left(\overline{S}_A\right)_i}{\sum_{i=1}^{N} L_i}$$

$\left(\overline{S}_A\right)_i$ = Mean S_A for transect *i*

L_i = Length of transect *i*

N = No of transects in survey area

$$Var\left(\overline{S}_A\right) = \frac{\frac{N}{N-1} * \sum_{i=1}^{N} (L_i)^2 * \left(\left(\overline{S}_A\right)_i - \left(\overline{S}_A\right)\right)^2}{\left(\sum L_i\right)^2}$$

$$CV = \frac{\sqrt{Var\left(\overline{S}_A\right)}}{\overline{S}_A}$$

Appendix 30 Echosunder settings for the survey and new calibration values after the survey.

The Simrad scientific echo sounder EK 500/38 kHz, was used during the survey for estimation of fish density. The Bergen Echo Integrator system (BEI) logging raw data from the echo sounder, was used to scrutinise the acoustic records, and to allocate integrator data to fish species. All raw data were stored to CD disc, and a backup of the database of scrutinised data, stored. The details of the settings of the 38 kHz echo sounder were as follows:

Transceiver-1 menu

Transducer depth	5.5 m
Absorption coeff.	10 dB/km
Pulse length	medium
Bandwidth	wide
Max. power	2 000 W
Angle sensitivity	21.9
2-way beam angle	-21.0 dB
SV transducer gain	27.48 dB
TS transducer gain	27.72 dB
3 dB Beamwidth	6.8 deg
Alongship offset	-0.05 deg
Athwartship offset	0.14 deg

Display menu

Echogram	1
Bottom range	12 m
Bottom start	10 m
TVG	20 log R
SV Colour minimum	-76 dB
TS Colour minimum	-50 dB

Printer settings

Range	0-250 m, 250-500 m
TVG	20 log R
SV Colour minimum	-64 dB

Bottom detection menu

Minimum level	-45 dB

HYDROGRAPHY

Conductivity, temperature, density, and oxygen were sampled regularly at CTD stations with a Seabird CTD-sonde. The salinity was calculated by a computer.

FISHING GEAR

The small "Åkrehamn" pelagic trawl and "Gisund super" bottom trawl was used for sampling fish.

The bottom trawl had a headline of 31 m, a footrope of 47 m and 20 mm meshsize in the codend with an inner net of 10 mm meshsize. The estimated headline height is 5 m and distance between the wings during towing about 21 m (18m used for swept area calculations). A 20 m constraining rope is mounted on the warps 140 m in front of the trawl doors. The trawl is equipped with a 12" rubber bobbins gear and the Tyborøn 7.8 sqm (1670 kg) trawl doors were used for both trawls. Complete drawings of the trawls used are included.

Annex Records of fishing stations

```
R/V "DR. FRIDTJOF NANSEN"        PROJECT:N1       PROJECT STATION:2581
DATE: 2/ 7/98               GEAR TYPE: PT No: 2  POSITION:Lat    S  2234
           start    stop   duration                      Long    E  1249
TIME  :14:53:00 15:23:00  30  (min)   Purpose code:  1
LOG   :1301.00  1303.00  2.00         Area code    : 2
FDEPTH:     370       350             GearCond.code: 1
BDEPTH:     631       531             Validity code: 3
        Towing dir:  90°  Wire out: 750 m  Speed:   3 kn*10

   Sorted:  19 Kg       Total catch:     137.55    CATCH/HOUR:      275.10
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Maurolicus muelleri	275.10	169292	100.00	8712
Total	275.10		100.00	

```
R/V "DR. FRIDTJOF NANSEN"        PROJECT:N1       PROJECT STATION:2582
DATE: 2/ 7/98               GEAR TYPE: PT No: 2  POSITION:Lat    S  2233
           start    stop   duration                      Long    E  1250
TIME  :16:39:00 17:09:00  30  (min)   Purpose code:  1
LOG   :1307.60  1309.40  1.80         Area code    : 2
FDEPTH:     150       150             GearCond.code: 1
BDEPTH:     456       403             Validity code: 3
        Towing dir: 360°  Wire out: 420 m  Speed:   3 kn*10

   Sorted:  62 Kg       Total catch:      83.70    CATCH/HOUR:      167.40
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Brama brama	77.00	192	46.00	8713
Taractes sp.	47.00	6	28.08	8714
Miscellaneous fishes	43.20		25.81	
Total	167.20		99.8	

```
R/V "DR. FRIDTJOF NANSEN"        PROJECT:N1       PROJECT STATION:2583
DATE: 5/ 7/98               GEAR TYPE: BT No: 1  POSITION:Lat    S  2429
           start    stop   duration                      Long    E  1325
TIME  :10:07:44 10:47:47  35  (min)   Purpose code:  1
LOG   :1655.53  1657.54  2.50         Area code    : 2
FDEPTH:     485       479             GearCond.code: 1
BDEPTH:     485       479             Validity code: 3
        Towing dir: 170°  Wire out:1400 m  Speed:   3 kn*10

   Sorted: 159 Kg       Total catch:     772.38    CATCH/HOUR:     1324.08
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Merluccius paradoxus	908.74	1051	68.63	8715
Trachyrincus scabrus	187.29	423	14.14	8716
Helicolenus dactylopterus	56.09	154	4.24	
Todarodes sagittatus	48.53	139	3.67	
Lophius vomerinus	44.95	9	3.39	
Selachophidium guentheri	27.69	24	2.09	
Coelorinchus fasciatus	25.23	130	1.91	8717
Nezumia micronychodon	18.81	285	1.42	8718
Notacanthus sexspinis	3.26	24	0.25	
Epigonus sp.	1.22	24	0.09	
Photichthys argenteus	0.98	115	0.07	
MYCTOPHIDAE	0.98	122	0.07	
Maurolicus muelleri	0.33	163	0.02	
Total	1324.10		99.99	

```
R/V "DR. FRIDTJOF NANSEN"        PROJECT:N1       PROJECT STATION:2584
DATE: 5/ 7/98               GEAR TYPE: PT No:    POSITION:Lat    S  2433
           start    stop   duration                      Long    E  1325
TIME  :15:46:45 16:17:23  30  (min)   Purpose code:  1
LOG   :1673.37  1675.08  2.00         Area code    : 2
FDEPTH:     450       450             GearCond.code: 1
BDEPTH:     544       528             Validity code: 2
        Towing dir: 350°  Wire out: 750 m  Speed:      kn*10

   Sorted:   1 Kg       Total catch:       4.83    CATCH/HOUR:        9.66
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Lycoteuthis diadema	9.42	840	97.52	
Bathylagus glacilis	0.12	4	1.24	
Maurolicus muelleri	0.08	34	0.83	
Symbolophorus boops	0.04	4	0.41	
Total	9.66		100.00	

```
R/V "DR. FRIDTJOF NANSEN"        PROJECT:N1       PROJECT STATION:2585
DATE: 6/ 7/98               GEAR TYPE: BT No:    POSITION:Lat    S  2429
           start    stop   duration                      Long    E  1323
TIME  :16:03:00 16:33:00  30  (min)   Purpose code:  1
LOG   :1875.00  1876.80  1.80         Area code    : 2
FDEPTH:     510       520             GearCond.code: 1
BDEPTH:     510       520             Validity code: 3
        Towing dir: 345°  Wire out:1500 m  Speed: 35 kn*10

   Sorted:  13 Kg       Total catch:      59.30    CATCH/HOUR:      118.60
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Symbolophorus boops	51.80	5506	43.68	
Lycoteuthis diadema	51.40	4666	43.34	
Photichthys argenteus	10.00	1662	8.43	
MYCTOPHIDAE	3.60	1200	3.04	
Nansenia sp.	1.40	78	1.18	
Lestrolepis intermedia	0.40	6	0.34	
Total	118.60		100.01	

```
R/V "DR. FRIDTJOF NANSEN"        PROJECT:N1       PROJECT STATION:2586
DATE: 7/ 7/98               GEAR TYPE: PT No:    POSITION:Lat    S  2437
           start    stop   duration                      Long    E  1321
TIME  :00:48:05 01:44:17  60  (min)   Purpose code:  1
LOG   :1946.37  1949.82  3.50         Area code    : 2
FDEPTH:     620       600             GearCond.code: 1
BDEPTH:     759       740             Validity code: 1
        Towing dir: 188°  Wire out:1200 m  Speed: 35 kn*10

   Sorted:   2 Kg       Total catch:      18.59    CATCH/HOUR:       18.59
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
MYCTOPHIDAE	11.59	305	62.35	
Photichthys sp.	5.60	1250	30.12	
Dicrolene sp.	1.35	15	7.26	
Lycoteuthis diadema	0.05	5	0.27	
Total	18.59		100.00	

```
R/V "DR. FRIDTJOF NANSEN"        PROJECT:N1       PROJECT STATION:2587
DATE: 8/ 7/98               GEAR TYPE: BT No: 1  POSITION:Lat    S  2629
           start    stop   duration                      Long    E  1334
TIME  :13:20:20 13:49:23  30  (min)   Purpose code:  1
LOG   :2233.65  2235.18  1.50         Area code    : 1
FDEPTH:     743       742             GearCond.code: 1
BDEPTH:     743       742             Validity code: 1
        Towing dir: 350°  Wire out:1800 m  Speed: 31 kn*10

   Sorted:  77 Kg       Total catch:     483.69    CATCH/HOUR:      967.38
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachyrincus scabrus	607.50	538	62.80	8720
Merluccius paradoxus	127.00	122	13.13	8719
Nezumia sp.	70.00	1100	7.24	8721
S H A R K S	51.60	36	5.33	8723
OREOSOMATIDAE	31.60	282	3.27	
Hoplostethus atlanticus	24.00	198	2.48	
APOGONIDAE	20.86	16	2.16	
Notacanthus sexspinis	14.70	136	1.52	
Selachophidium guentheri	7.50	60	0.78	
HISTIOTEUTHIDAE	5.56	16	0.57	
Dicrolene sp.	4.20	60	0.43	
OPHICHTHIDAE	1.36	16	0.14	
CHAULIODONTIDAE	0.90	16	0.09	
NEMICHTHYIDAE	0.60	16	0.06	
Total	967.38		100.00	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2588
DATE:15/ 7/98 GEAR TYPE: PT No: POSITION:Lat S 2636
Long E 1330
start stop duration
TIME :22:39:48 23:48:41 70 (min) Purpose code: 1
LOG :2997.61 2999.87 2.26 Area code : 1
FDEPTH: 550 550 GearCond.code: 1
BDEPTH: 1000 980 Validity code: 1
Towing dir: 170° Wire out:1600 m Speed: 30 kn*10

Sorted: 12 Kg Total catch: 11.73 CATCH/HOUR: 10.05

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
C E P H A L O P O D A	2.66	123	26.47	
Photichthys argenteus	1.64	108	16.32	
Chauliodus sloani	1.29	42	12.84	
Bathylagus glacilis	1.22	27	12.14	
Opostomias micripnis	0.65	3	6.47	
Ceratias holboelli	0.58	1	5.77	
Lampadena sp.	0.53	15	5.27	
S H R I M P S	0.30	50	2.99	
MYCTOPHIDAE	0.18	81	1.79	
Paradiplospinus gracilis	0.18	2	1.79	
Melamphaes microps	0.17	24	1.69	
Nemichthys scolopaceus	0.11	2	1.09	
Stomias boa boa	0.10	3	1.00	
Triplophos sp.	0.08	1	0.80	
Oreosoma atlanticum	0.08	2	0.80	
Melanocetus johnsoni	0.07	1	0.70	
APOGONIDAE	0.07	3	0.70	
NOTOSUDIDAE	0.06	6	0.60	
Anoplogaster cornuta	0.05	1	0.50	
Evermanella balbo	0.03	2	0.30	
Total	10.05		100.03	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2589
DATE:15/ 7/98 GEAR TYPE: BT No: 1 POSITION:Lat S 2616
Long E 1332
start stop duration
TIME :16:38:23 17:09:33 31 (min) Purpose code: 1
LOG :3172.60 3174.39 1.79 Area code : 1
FDEPTH: 834 842 GearCond.code: 1
BDEPTH: 834 842 Validity code: 1
Towing dir: 360° Wire out:1900 m Speed: 30 kn*10

Sorted: 64 Kg Total catch: 128.59 CATCH/HOUR: 248.88

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Nezumia sp.	69.93	1128	28.10	
Hoplostethus melanopus	40.74	821	16.37	
Dicrolene intronigra	37.99	457	15.26	
Merluccius paradoxus	35.13	21	14.12	8725
Coelorinchus braueri	12.33	45	4.95	
Centroscymnus crepidater	11.57	4	4.65	
Hoplostethus atlanticus	10.78	283	4.33	8727
Allocyttus verrucosus *	10.22	108	4.11	8726
HISTIOTEUTHIDAE	4.95	8	1.99	
Trachyscorpia capensis	2.69	2	1.08	
Todarodes sagittatus	2.07	2	0.83	
Photichthys argenteus	1.26	45	0.51	
Halosaurus sp.	1.22	15	0.49	
CARISTIIDAE	1.18	2	0.47	
SERGESTIDAE	1.06	145	0.43	
Selachophidium guentheri	1.03	6	0.41	
MACROURIDAE	0.93	29	0.37	
Bathylagus glacilis	0.77	15	0.31	
Lampanyctodes hectoris	0.68	35	0.27	
CYCLOPTERIDAE	0.66	2	0.27	
Nemichthys scolopaceus	0.60	8	0.24	
Lycoteuthis diadema	0.58	19	0.23	
GEMPYLIDAE	0.45	10	0.18	
Diaphus hudsoni	0.06	6	0.02	
Total	248.88		99.99	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2590
DATE:16/ 7/98 GEAR TYPE: BT No: 1 POSITION:Lat S 2624
Long E 1335
start stop duration
TIME :12:58:03 13:29:15 30 (min) Purpose code: 1
LOG :3343.38 3345.04 1.70 Area code : 1
FDEPTH: 700 712 GearCond.code: 1
BDEPTH: 700 712 Validity code: 1
Towing dir: 360° Wire out:1750 m Speed: 30 kn*10

Sorted: 52 Kg Total catch: 179.93 CATCH/HOUR: 359.86

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Merluccius paradoxus	84.40	88	23.45	8728
Nezumia micronychodon	77.44	520	21.52	
Photichthys argenteus	59.38	896	16.50	
Allocyttus verrucosus *	32.04	412	8.90	8729
Hoplostethus melanopus	16.38	470	4.55	
Todarodes sagittatus	13.36	16	3.71	
Chaceon maritae, female	12.60	22	3.50	
Dicrolene intronigra	11.16	134	3.10	
Notacanthus sexspinis	11.00	24	3.06	
OPISTHOTEUTHIDAE	10.58	16	2.94	
Trachyscorpia capensis	9.10	24	2.53	
Schedophilus huttoni	7.52	6	2.09	
Etmopterus brachyurus	4.00	10	1.11	
Selachophidium guentheri	3.64	22	1.01	
Coelorinchus sp.	1.92	26	0.53	
Lithodes ferox	1.88	6	0.52	
Nemichthys curvirostris	1.50	16	0.42	
Ebinania costaecanarie	0.96	10	0.27	
Coelorinchus innotabilis	0.58	22	0.16	
Neoscopelus macrolepidotus	0.42	6	0.12	
Total	359.86		99.99	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2591
DATE:17/ 7/98 GEAR TYPE: BT No: POSITION:Lat S 2621
Long E 1335
start stop duration
TIME :09:49:13 10:23:09 33 (min) Purpose code: 1
LOG :3419.44 3421.11 1.60 Area code : 1
FDEPTH: 687 709 GearCond.code: 1
BDEPTH: 687 709 Validity code: 1
Towing dir: 180° Wire out:1750 m Speed: 30 kn*10

Sorted: 163 Kg Total catch: 20054.80 CATCH/HOUR: 36463.28

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Hoplostethus atlanticus	36363.64	93425	99.73	
Merluccius paradoxus	99.64	124	0.27	8730
Coelorinchus acanthiger	0.00			
Centrophorus squamosus	0.00			
Todarodes sagittatus	0.00			
Centroscyllium fabricii	0.00			
Etmopterus lucifer	0.00			
Photichthys argenteus	0.00			
Allocyttus verrucosus *	0.00			
Epigonus telescopus	0.00			
Notacanthus sexspinis	0.00			
Nezumia micronychodon	0.00			
Trachyscorpia capensis	0.00			
Coelorinchus matamua	0.00			
Total	36463.28		100.00	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2592
DATE:17/ 7/98 GEAR TYPE: BT No: POSITION:Lat S 2612
Long E 1335
start stop duration
TIME :22:38:17 22:52:54 14 (min) Purpose code: 1
LOG :3476.26 3477.00 0.74 Area code : 1
FDEPTH: 667 676 GearCond.code: 1
BDEPTH: 667 676 Validity code: 1
Towing dir: 5° Wire out:1750 m Speed: 30 kn*10

Sorted: 237 Kg Total catch: 20024.10 CATCH/HOUR: 85817.57

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Hoplostethus atlanticus	85714.28	157650	99.88	
Merluccius paradoxus	107.57	111	0.13	8731
Coelorinchus sp.	0.00			
Ebinania costaecanarie	0.00			
Etmopterus lucifer	0.00			
OREOSOMATIDAE	0.00			
Trachyscorpia capensis	0.00			
Notacanthus sexspinis	0.00			
Coelorinchus matamua	0.00			
Centroscymnus crepidater	0.00			
Selachophidium guentheri	0.00			
Nezumia micronychodon	0.00			
Total	85821.85		100.01	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2593
DATE:18/ 7/98 GEAR TYPE: PT No: POSITION:Lat S 2620
start stop duration Long E 1335
TIME :12:51:05 13:05:25 14 (min) Purpose code: 1
LOG :3559.23 3559.92 0.70 Area code : 1
FDEPTH: 0 0 GearCond.code: 1
BDEPTH: 653 659 Validity code: 1
Towing dir: 160° Wire out:1300 m Speed: 30 kn*10

Sorted: 9 Kg Total catch: 44.44 CATCH/HOUR: 190.46

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
SERGESTIDAE	56.74	9459	29.79	
Merluccius paradoxus	42.00	26	22.05	8732
Todarodes sagittatus	24.00	17	12.60	
Solenocera africana	18.34	1731	9.63	
Photichthys argenteus	15.26	1131	8.01	
Todaropsis eblanae	11.66	754	6.12	
PHOTICHTHYIDAE	9.26	583	4.86	
Neoscopelus macrolepidotus	4.11	206	2.16	
Yarrella blackfordi	4.11	343	2.16	
Nansenia sp.	2.06	69	1.08	
Chauliodus sloani	1.89	86	0.99	
NOTOSUDIDAE	0.51	17	0.27	
Scopelosaurus meadi	0.34	17	0.18	
Glyphus marsupialis	0.17	17	0.09	
Total	190.45		99.99	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2594
DATE:19/ 7/98 GEAR TYPE: PT No: 2 POSITION:Lat S 2440
start stop duration Long E 1321
TIME :11:31:59 11:46:53 15 (min) Purpose code: 1
LOG :3737.73 3738.52 0.80 Area code : 2
FDEPTH: 650 650 GearCond.code: 1
BDEPTH: 746 761 Validity code: 1
Towing dir: 330° Wire out:1350 m Speed: 30 kn*10

Sorted: 7 Kg Total catch: 45.23 CATCH/HOUR: 180.92

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Todarodes sagittatus	51.52	128	28.48	
Yarrella blackfordi	42.40	2960	23.44	
Thysanoteuthis rhombus	31.20	160	17.25	
Macroparalepis macrogeneion	8.64	208	4.78	
Photichthys argenteus	8.48	1104	4.69	
Bathylagus glacilis	8.32	160	4.60	
Trachipterus jacksonensis	7.20	16	3.98	
Lycoteuthis diadema	6.88	336	3.80	
Chauliodus sloani	5.12	96	2.83	
Trichiurus lepturus	2.08	48	1.15	
CARISTIIDAE	1.60	16	0.88	
MALACOSTEIDAE	1.60	16	0.88	
Solenocera africana	1.60	80	0.88	
Diaphus hudsoni	1.60	448	0.88	
SERRIVOMERIDAE	1.48	8	0.82	
Maurolicus muelleri	0.80	64	0.44	
Hoplostethus melanopus	0.40	8	0.22	
Total	180.92		100.00	

R/V "DR. FRIDTJOF NANSEN" PROJECT:N1 PROJECT STATION:2595
DATE:23/ 7/98 GEAR TYPE: PT No: POSITION:Lat S 2233
start stop duration Long E 1247
TIME :08:54:32 09:15:48 21 (min) Purpose code: 1
LOG :4430.13 4431.22 1.10 Area code : 2
FDEPTH: 560 0 GearCond.code: 1
BDEPTH: 590 506 Validity code: 5
Towing dir: 320° Wire out:1150 m Speed: 30 kn*10

Sorted: 197 Kg Total catch: 197.36 CATCH/HOUR: 563.89

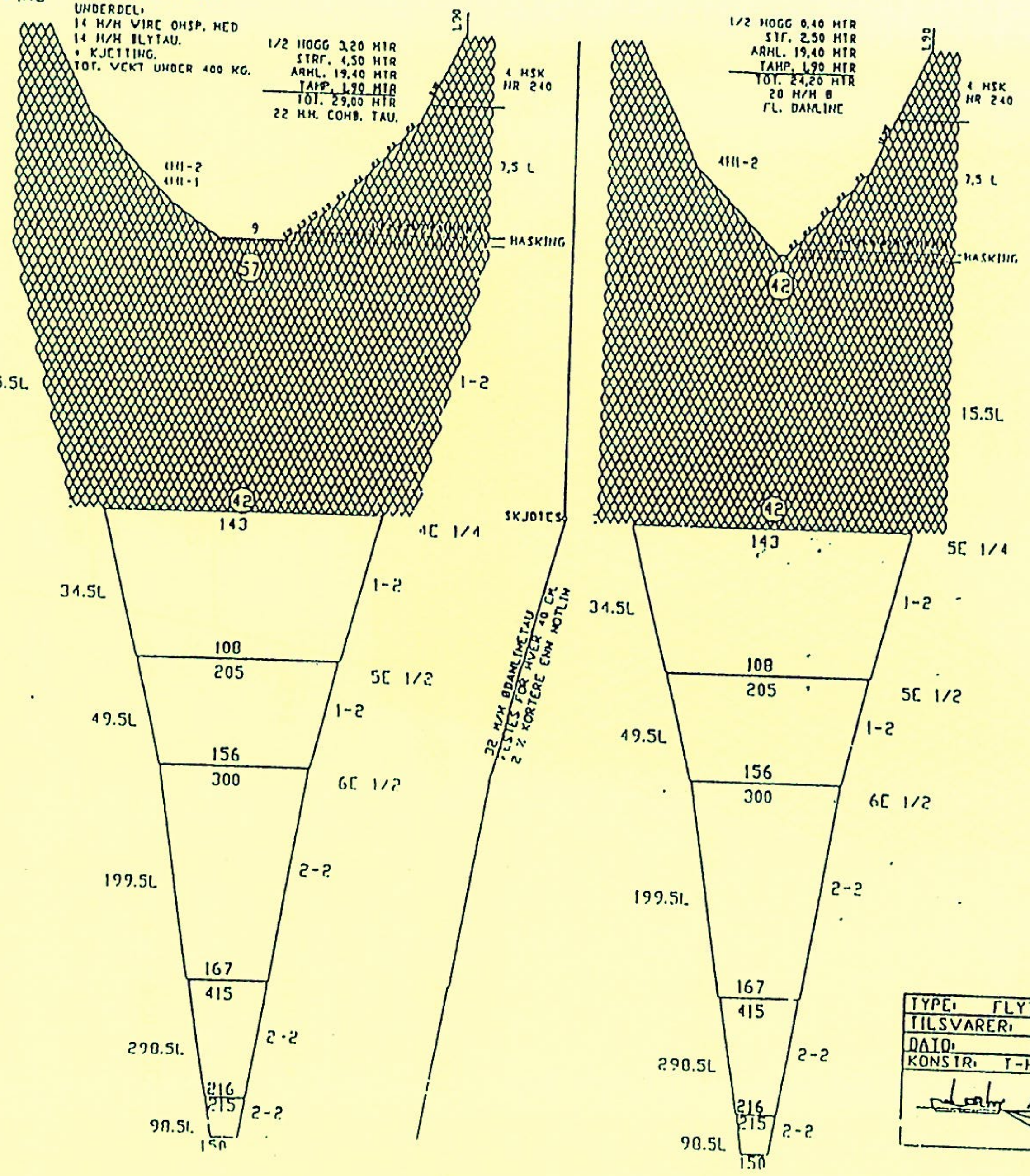
SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Merluccius paradoxus	517.14	529	91.71	8733
Taractichthys longipinnis	18.29	6	3.24	
Trachurus capensis	12.49	26	2.21	8732
Centrophorus squamosus	5.86	3	1.04	
OPISTHOTEUTHIDAE	5.71	3	1.01	
Todaropsis eblanae	4.31	17	0.76	
Lycoteuthis diadema	0.29	6	0.05	
Total	564.09		100.02	

SPECIES	Johnies			Frankies			Rix			
	400-700	700-900	900-1200	400-700	700-900	900-1200	400-700	700-900	900-1200	
Alepocephalus australis	*	*	*		*	*			*	
Allocyttus niger (black oreo)			*							
Allocyttus verrucosus (oreo)	*	*	*				*	*	*	
Anoplogaster cornuta			*							
Antimora rostrata			*							
Astronethes niger	*						*			
Barbourisia rufa							*			
Bassango albescens	*			*						
Bathylagus glacialis										
Bathyraja smithii	*	*	*		*	*	*		*	
Bathyuroconger vicinus			*	*	*	*	*			
Beryx splendens		*								
Brama brama							*			
Caristus groenlandicus		*								
Centrocymnus coelolepis		*	*					*	*	
Centrophorus squamosus							*			
Centrophorus squamosus	*									
Centroscyllium fabricii	*	*	*		*		*	*	*	
Centrosymnus crepidator	*	*	*	*	*		*	*	*	
Cerastius holboeli		*								
Chaceon maritae		*			*					PT 2
Chauliodus sloani		*		*						
Chimaera sp.		*	*							
Coelorinchus aganthiger					*		*	*		
Coelorinchus brauerei	*	*	*			*	*			
Coelorinchus fasciatus	*			*			*			
Coelorinchus matamua	*	*	*	*		*	*			
Cruriraja parcomaculatua	*	*			*		*			
Deania calcea	*	*		*	*	*	*	*	*	
Deania profundorum	*	*		*	*	*	*	*	*	
Diaphus hudsoni		*								
Dicrolene intronigra	*	*	*	*	*		*			PT 2
Ebinania costaecanarie	*	*	*	*			*			
Epigonus denticolatus							*			
Epigonus rebustus?		*								
Epigonus telescopus			*					*		
Etmopterus brahyurus		*								
Etmopterus 'lucifer'	*	*		*			*		*	
Evermannella balbo		*								
Gempylidae		*								PT 2
Glyphus marsiopalis		*								PT 2
Harriotta raleighana ?										
Helicolenus dactylopterus		*					*			
Histioteuthidae		*								
Holosaurus ovenii	*	*			*	*				PT 2
Hoplostesthus menalopus	*	*	*	*	*		*	*		
Hoplostethus atlanticus	*	*	*	*	*		*	*	*	
Hydrolagus sp.		*								
Laemonia globiceps										
Lampadena sp.		*								
Lampanyctus hectoris		*								PT 2
Lamprogrammus exutus				*			*			PT 2
Lepidopus caudatus		*								
Lestrolepis intermedia				*						
Liparididae		*								
Lithodes ferox	*	*		*		*	*		*	PT 2
Lophius vomerinus			*		*		*			
Lycoteuthis diadema	*				*		*			
Macroparalepis	*									
Malacosteidae	*									
Maurolicus muelleri							*			
Melamphae microp		*								
Melanocettus johnsoni		*								PT 2
Merluccius paradoxus	*	*	*	*	*		*	*	*	PT 2
Metelectona ventralis										
Moroteuthis robsoni		*		*	*	*		*	*	
Myctophiddae				*						
Nemicthys scolopaceus	*									
Neocyttus rhomboidalis (oreo)	*	*	*		*		*	*	*	
Neolithodes asperrimus		*	*	*	*		*		*	
Neoscopelus macrolepidotus		*								
Nesorhamphus ingolfianus										
Nezumia leonis	*	*		*	*		*	*		
Notacanthus sexpinis		*	*		*	*	*	*	*	
Notosudidae		*								
Octopoteuthis sicula ?										

Ommastrephidae			*							
Opisthoteuthidae	*	*				*			*	
Opostomias micripinus		*								PT 2
Oreosoma atlanticum		*								PT 2
Pavoraja spinifer										
Photichys argenteus	*				*		*			
Polychelidae					*					
Pseudocyttus maculatus (oreo)										
Raja caudaspinosa			*							
Raja confundens	*		*	*			*			
Raja doutrei	*			*			*			
Raja leopardus	*			*						
Raja ravidula				*						
Raja spinacidermis			*							
Raja springeri								*		
Rhinochimaera atlantica		*	*		*	*			*	
Schedophilus huttoni		*		*	*		*	*		
Scopelosaurus meadi		*								
Selachophidium quentheri	*	*		*	*	*	*			
Sergestid shrimp	*	*								PT 2
Serrivomeridae	*									
Seyliorhinidae	*									
Simenchelys parasiticus										
Solenocera africana	*	*								
Spentruculus grandis			*							
Stomias boa boa		*								
Synaphobranchus kaupi		*	*							
Taractes rubescens							*			
Taractichthys longipinis							*			
Thysanotheuthis rhombus	*									
Todarodes sagittatus	*	*	*		*		*		*	
Todaropsis enblanae	*	*								
Trachipterus jacksonensis	*									
Trachunurus villosu			*							
Trachurus capensis							*			
Trachyrincus scrabus	*	*	*		*	*	*	*		
Trachyscorpia capensis	*	*		*	*		*			
Trichiurus lepturus	*									
Triplophus hemingri		*								PT 2
Yarella blackfordi	*	*		*			*			

F/F Dr. Fridtjof Nansen

MASKER M/M	TRAAD NR.	LENGDE 1 MTR.	MASKER I EVING
1620.0	160	19.4	4
1620.0	160	25.9	4
400.0	40	14.0	4
200.0	32	10.00	4
100.0	24	20.0	4
30.0	12	11.4	4
36.0	10	3.76	4



TYPE: FLYTETRAL 198 MSK X 1620 M/M	
TILSVARER: 4010 X 80	MTR.OMKR: 320
DATO: 23/6 93	TEGN.NR: 510
KONSTR: T-H	SKALA: 0

AKRAMANN TRÅLBØTERI A/S

F/F Dr. Fridtjof Nansen

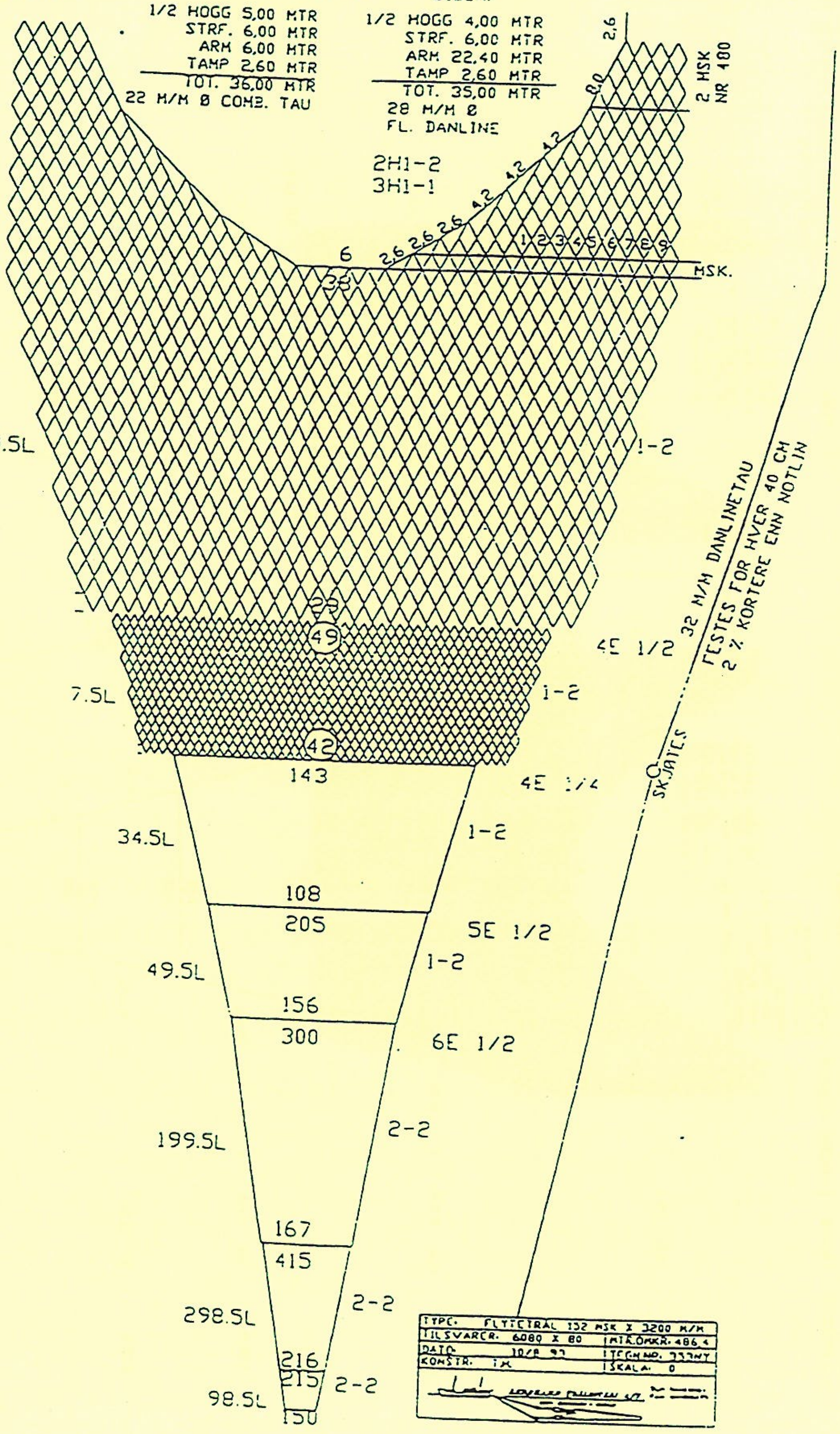
OVER/UNDER/SIDER

OVERDEL:
50 STK 11" PLASTKULER
UNDERDEL
14 M/M WIRE OMSP. MED
14 M/M BLYTAU
+ KJETTING.
TOTAL VEKT UNDER 400 KG.

1/2 HOGG 5,00 MTR
STRF. 6,00 MTR
ARM 6,00 MTR
TAMP 2,60 MTR
TOT. 36,00 MTR
22 M/M Ø COMB. TAU

SIDER.
1/2 HOGG 4,00 MTR
STRF. 6,00 MTR
ARM 22,40 MTR
TAMP 2,60 MTR
TOT. 35,00 MTR
28 M/M Ø
FL. DANLINE

MASKER M/M	TRAAD NR.	LENGDE I MTR.	MASKER I EVING
3200.0	240	22.4	4
3200.0	240	32.0	4
620.0	160	13.0	4
400.0	48	14.0	4
200.0	32	10.00	4
00.0	24	20.0	4
38.0	12	11.4	4
38.0	18	3.76	4



Bottom trawl: High opening shrimp and fish trawl with net headline 31m (floatline), foot-rope 47m, gear with 12 cm diameter roller disks, 40 m sweeps, estimated headline hight 6m and distance between wings during towing 18-20m.