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DEVELOPMENT OF ACOUSTIC METHODS TO SURVEY ORANGE ROUGHY IN THE EASTERN AND SOUTHERN ZONES

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NON TECHNICAL SUMMARY

95/031 Development of acoustic methods to survey orange roughy in the Eastern and Southern Zones

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Objectives

1. To conduct 2-3 acoustic surveys of the orange roughy spawning ground off St. Helens, Tasmania during the peak spawning period (approximately 15-30 July) in 1995.
2. To determine the species composition of acoustic marks through trawl sampling of the acoustic marks and the ensonification of targets with several frequencies.
3. To determine the relative biomass and spawning condition of orange roughy in the Eastern and Southern Zones during the spawning period based upon a survey of selected hills in the Southern Zone that contain the principal concentrations of orange roughy (e.g. Maatsuyker, Pedra Branca, Macca's Hill).
4. To assess the biomass of orange roughy in the area between St. Helens and the Southern Hills through a series of zigzag transects between 700-1200 m and to assess their spawning condition.

Non-technical Summary

Three acoustic surveys were carried out between 17 and 20 July 1996 on the orange roughy spawning ground off St. Helens, Tasmania. A combination of 22 demersal trawls and ensonification with three frequencies (12, 38 and 120 kHz) was used to assess the species composition around the spawning hill. Both methods showed that orange roughy were aggregated on only the north/northwestern half of the hill. Acoustic marks on the south/southwestern sector of the hill were composed predominantly of macrourids (rattails) and deepwater cods. This was the first successful use of multi-frequency acoustics to discriminate among species groups in a deepwater environment and should greatly enhance the resolution of deepwater acoustic surveys. Acoustic estimates of orange roughy biomass on the spawning hill ranged from 5649 - 9706 tonnes, down from 16,777 tonnes in 1993. A survey of the trawl ground off St. Patrick's Head noted a single moderate-sized aggregation on a single transect. If

the school as assumed to be spherical in cross-section, its biomass was 6% the biomass of the largest orange roughy school observed at St. Helens.. The biomass at St. Patrick's Head thus appears to have been a small proportion of the biomass around St. Helens Hill during the survey, but the data were insufficient to derive a biomass estimate from this area with confidence. Acoustic surveys were also carried out on a small hill just north of St. Helens and on the seamounts in the Southern Zone but no significant acoustic marks associated with orange roughy were observed in these areas.

Several changes were made to the methods of analysis. First, the area of the strata comprising the St. Helens hill were re-calculated based on improved bathymetric and GPS data,. Secondly, we changed the method used to account for targets within the deep scattering layers (DSL) that extend across the survey area. A constant fraction of the ensonified targets were previously assumed to belong to the DSL, but this assumption was no longer tenable considering both the decline in orange roughy abundance on the hill and the ~2-fold variation in the abundance of midwater scatterers between surveys in 1996. Acoustic backscattering from areas outside the survey area were now measured for each survey and subtracted from the backscattering observed around the hill itself. These changes were applied retrospectively to biomass estimate from previous orange roughy surveys.

Keywords

Acoustics, orange roughy, biomass assessment, multi-frequency

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1 BACKGROUND AND NEED

1.1 As in Proposal

The orange roughy fishery remains the most valuable sector of the SEF, and there is an urgent need to resolve uncertainties regarding the present state of the resource because it may now be at a critical stage of the fishdown process. The 1994 Stock Assessment Report concluded that there was a 66% probability that Eastern Zone orange roughy were below 30% of virgin biomass if there were two stocks and a 12% probability that the stock was below 20% of prefishery biomass; if there was a single stock in the Eastern & Southern Zones, there was 53% probability that the stock was below 20% of prefishery biomass. The report concluded: "Improved monitoring of this(ese) stock(s) is required to effectively monitor its status in coming years because it is now close to or below the level defined necessary to meet AFMA's objectives. Proposed monitoring of the St. Helens spawning aggregation in 1995 is considered essential." The proposed research will provide the fishery-independent assessment of the orange roughy resource recommended by the SAG. However, due to uncertainties regarding the interpretation of previous acoustic surveys, the present study will focus on developing methods to resolve these uncertainties rather than simply providing a survey to monitor the resource, although the survey will serve that purpose as well.

Stock assessment for the orange roughy that spawns off NE Tasmania is based largely upon a series of acoustic surveys that were conducted annually from 1990-93. The surveys from 1990-92 were part of a FRDC/CSIRO-funded study. The 1993 survey, however, was carried out on an opportunistic basis without external funding and no trawling was carried out to identify the acoustic marks on the spawning ground. Unfortunately the depth distribution of acoustic marks was significantly deeper in the 1993 survey than in previous years, which led to uncertainty regarding interpretation of the survey results. Did these deeper marks simply represent a shift into deeper water of the roughy or were they composed of different species?

A proper assessment of the species composition of acoustic marks is critical to an acoustic survey. It is particularly important in the case of species with low target strengths, such as orange roughy, because the survey estimate is highly sensitive to errors in the species composition. Assessing the species composition of acoustic marks on orange roughy surveys has proven difficult for several reasons:

i. orange roughy appear to be distributed well above bottom but can only be sampled with trawls on the bottom due to avoidance of midwater nets;

ii. orange roughy appear to avoid objects, such as the towed body, at distances of greater than 100 m, so it is difficult to obtain representative samples of the target strength distribution within suspected orange roughy acoustic marks; and

iii. the target strength of orange roughy appears to overlap that of small midwater fishes, such as myctophids, that have swimbladders.

As a result of these factors, the use of our acoustic system's split-beam technology, which enables us to obtain the target strength of individual fish at distances of up to ~100m from the transducer, has not proven as fruitful as originally expected. To resolve this difficulty, we propose to use three frequencies in the July 1995 survey (12, 38, and 120 kHz) rather than the single frequency (38 kHz) used in previous orange roughy surveys. Because fishes of different sizes and swimbladder characteristics resonate differently at different frequencies, the simultaneous use of different frequencies should enable us to discriminate between aggregations composed of, say, large fish without an air-filled swimbladder, such as orange roughy, and small fish with an air-filled swimbladder. Multi-frequency acoustics will be used in conjunction with trawl sampling of acoustic marks.

Another major source of uncertainty in the present orange roughy stock assessment revolves around questions of whether there are one or two stocks in the Eastern and Southern Zones and the total biomass in the combined area. Previous surveys of the orange roughy have been carried out during the winter spawning period in the Eastern Zone and in the summer in the Southern Zone. A combined survey of these two zones during the spawning period will not provide an unequivocal answer to the question of total orange roughy biomass in the region, because Southern Zone orange roughy may migrate to spawn somewhere outside both zones. However a combined survey could provide a conservative estimate of total Eastern and Southern Zone biomass in the absence of information either of a further major spawning area or whether the stocks should be considered distinct based on genetic/chemical/morphological/etc grounds.

2. OBJECTIVES

Objectives

1. To conduct 2-3 acoustic surveys of the orange roughy spawning ground off St. Helens, Tasmania during the peak spawning period (approximately 15-30 July) in 1995.

2. To determine the species composition of acoustic marks through trawl sampling of the acoustic marks and the ensonification of targets with several frequencies.

3. To determine the relative biomass and spawning condition of orange roughy in the Eastern and Southern Zones during the spawning period based upon a survey of selected hills in the Southern Zone that contain the principal concentrations of orange roughy (e.g. Maatsuyker, Pedra Branca, Macca's Hill).

4. To assess the biomass of orange roughy in the area between St. Helens and the Southern Hills through a series of zigzag transects between 700-1200 m and to assess their spawning condition.

3. METHODS

As in Original Proposal

The assessment will be based upon a 15 day cruise from approximately 15-30 July 1995. The cruise will be divided into two segments:

1) A survey of selected hills in the Southern Zone (e.g. the Maatsuyker and Pedra Branca groups, Macca's Hill, and others that are reported to contain concentrations of orange roughy) based upon two orthogonal transects over the summit of each hill, as in CSIRO's two previous surveys of the Southern Zone. At the end of this survey, in transit to the spawning hill, a series of zigzag transects will be carried out between 700-1200 m to search for and sample orange roughy.

2) Two or three surveys of the spawning ground off St. Helens will be conducted through the period of peak spawning (approximately 15-30 July).

The surveys will be carried out using the portable acoustic system aboard a chartered vessel. An orange roughy trawler will be chartered to accompany the survey vessel throughout the survey to trawl on acoustic marks. (Note: It is assumed that quota will be available for charter purposes. Otherwise, the cost of vessel charter would add ~$225,000 to the cost of the project.) The trawl samples will be used to ascertain the species composition of the marks, the size composition of major species within the marks, and the maturity stage composition of orange roughy in all areas. This sampling will specifically address questions regarding 1) the species composition of acoustic marks in deeper water around St. Helens hill; 2) the spawning condition of orange roughy in the Southern Zone, as well as the relative biomass in the Southern and Eastern zones during the spawning season; and 3) the incidence of fish outside the spawning ground and their maturity state.

The species composition of acoustic targets in the water column has been a major uncertainty in the orange roughy acoustic surveys. To address this, a towed body will be modified to contain 12 and 120 kHz transducers, as well as the 38 kHz transducer that is standard in these surveys. Due to the different acoustic resonance of species of different sizes, shapes, and swimbladder types, the use of several frequencies should enhance our ability to discriminate among different species in the survey. The problem of target discrimination has been particularly acute between orange roughy and some of the small midwater fishes containing swimbladders (e.g. myctophids). These two groups appear to have similar target strengths when ensonified with a single frequency but should be separable when viewed with different frequencies.

Although the survey would not commence until July, construction must commence by 1 February of the towed body/electronics package required to conduct a multifrequency acoustic survey. Funding is therefore sought by 1 February 1995 for the acoustics technician and construction costs ($13,000). (Other funding would not need to come on line until 1 July.) If funding cannot be approved by this date, our options are either to conduct a survey using only a single frequency (38kHz), as in previous years, or to construct the towed body in 1995 and delay the survey until July 1996.

3.1 Acoustic Systems Development

3.1.1 Towed Body Design

A major part of the project centred on the development of a multi-frequency towed body to obtain a trawl independent estimate of species composition. To achieve this a new towed body was designed that could accommodate three deep water transducers at 12, 38 and 120 kHz. The specifications are outlined in Table 3.1.1-1. The design of the system can be separated into two parts, Hydrodynamic/Mechanical and Acoustic/Electronics development.

Table 3.1.1-1. Transducer Information for both vessel and towed transducers

Transducer	Manufacturer	Locations	Equivalent Beamwidth	Beamwidth	Type
120Khz	Simrad	Hull	-18.5	11.2	Split
38kHz	Simrad	Hull	-20.7	7.1	Split
12kHz	Simrad	Hull	-13.2	16/17.5	Single
120kHz	Simrad	Towed Body	-20.6	7	Split
38Khz	EDO western	Towed Body	-21.1	6.5	Split
12kHz	MASA	Towed Body	-10	40	Single
38kHz	Simrad	Pole	-20.7	7.3	Split

3.1.1.1 Hydrodynamic / Mechanical

The design of the deep towed body was constrained by several factors. Firstly, it needed to be large enough to house the three transducers and associated electronics. Secondly, it needed to be stable at both low (2 knots) and high speeds (10 knots). The weight of the towed body was required to in the range of 400 – 500 kg to allow for ease of deployment. Also the transducers needed to be mounted so that they were flush with the bottom of the towed body so no window was required. Previous towed systems that had polycarbonate windows were prone to calibration problems at shallow depths.

To satisfy these requirements two major designs were investigated. The first was a wing shaped body that maximised the transducer deployment options and produced a relatively short (1.6 m) and wide (1.0 m) body. The performance of this type of towed body was unknown to us as we had used more traditional torpedo shaped bodies in the past. To gauge the stability performance of this body a half size model was constructed and tested. The tests centered on towing the body at various speeds with a pitch/ roll monitor installed in the model. From these tests it was obvious that the design suffered serious roll problems irrespective of changes made to the tail fin size and towing point positions. This design was discarded for a more traditional approach.

The second shape was a traditional torpedo design that that was 2.4 m long and 0.5 m round and had a flat base for the transducers. We were certain that this type of body would be suitable from past experience but to optimise the design it was necessary to model the tail fin position and size. Given time constraints no model of this design was constructed, instead a full size unit was constructed and this was then tested at the AMC (Australian Maritime College) flume tank with three tail fin sizes.

3.1.1.2 Acoustic / Electronics

The design of the acoustic and electronic system was determined by the following constraints. First the three transducers needed to cover as wide a range as possible yet still operate within the Simrad EK500 frequency range. The 12, 38 and 120 kHz frequencies were chosen as a compromise between cost and frequency separation. The 12 kHz frequency was particularly attractive as comparisons between 12 kHz and 38 kHz vessel mounted echograms in deep water showed marked frequency differences. Secondly, the frequency data needed to be mixed and transmitted up 2700 m of multi-core torque balanced steel armoured cable to the surface. The cable consisted of four twisted shielded pairs and five single conductors.

Design considerations:

- Transmitters needed to be placed in the towed body to overcome cable attenuation.
- Pre-amplifiers required in the towed body for good signal to noise performance.
- Three frequencies to be mixed onto the conductors available, two with split beam mixing and one at single beam mixing.
- Monitoring of towed body movement, circuit voltages and instrument control and interface to CTD instrument.
- Current consumption of the system to be kept to a minimum to avoid large cable voltage drop.
- Cable communication not to interfere with the acoustic signals.

Design Solution:

To overcome the cable attenuation and noise the transmitters and pre-amplifiers were placed in the towed body. A separate transmitter and pre-amplifier module was built for each frequency to ensure the system was modular and individual frequencies could be removed from the system if required. The pre-amplified frequencies were mixed with a summing amplifier and with line drivers communicated up the cable as described by Kloser, 1996. A standard micro controller was used to monitor the pitch/roll, depth and voltages of the system. These data were communicated via a modem to the surface. A modem proved to be the best method of ensuring low contamination of the analogue voltages.

3.2 Acoustic Surveys

3.2.1 Survey Methods and Design

The calibration parameters for the hull mounted and towed transducers are shown in Table 3.2.1-1 along with the bounds of the St. Helens survey area. The areas surveyed are shown in Figures 3.2.1-1 and 3.2.1-2

Table 3.2.1-1. Calibration parameters for hull mounted and towed transducers and area constraints for the St. Helens survey. The towed transducer is assumed to be operating at a mean depth of 500 m. Frequency is 38kHz.

Parameter	Vessel mounted		Towed transducer		Units
Year	1996-1	1996-3	1996-1	1996-3	
Pulse Length	3	3	1	1	ms
Bandwidth	0.3	0.3	3.3	3.3	kHz
Equivalent Beam Angle	-20.7	-20.7	-20.6	-20.6	dB re steradian
Volume reverberation Gain	27.2	27.2	26.5	26.5	
Absorption at a mean depth of 800 m*	9.44 ± .018	9.44 ± .018	9.419 ± 0.018	9.419 ± 0.018	dB km^{-1}
Sound velocity at a mean depth of 800 m**	1497.1 ± 0.5	1497.1 ± 0.5	1492.8± 0.7	1492.8± 0.7	ms^{-1}
Volume reverberation noise at 1 m	-165	-165	-153.6	-153.5	dB re 1uPa at 1m
Absorption correction required at 800 m	0.44	0.44	0.41	0.41	dB
Calibration correction	N/A	N/A	0.39	0.39	dB
Date	17-Jul	20-Jul	17-Jul	20-Jul	
Start Time (hours) local	16:53	2:51	16:53	2:51	
Stop Time (hours)	9:41	15:34	9:41	15:34	
No. of Transects	12	8	8	8	
Weeks from 1 July	3	3	3	3	
Time Spanned	N-D-N	D-N	N-D-N	D-N	

	Min Latitude	Max Latitude	Min Longitude	Max Longitude
Area constrained to	-41.2500	-41.2083	148.7375	148.7833

* For the hull mounted transducer this is the absorption value integrated from 0 to 800 meters whereas for the towed body this is the absorption value integrated from 500 to 800 meters (i.e. the towed body depth + 300 = 800 meters)

** For the hull mounted transducer this is the sound velocity value integrated from 0 to 800 meters whereas for the towed body this is the sound velocity value integrated from 500 to 800 meters (i.e. towed body depth + 300 = 800 meters)

Figure 3.2.1 –1. The hills acoustically surveyed in the Southern Zone in July 1995.

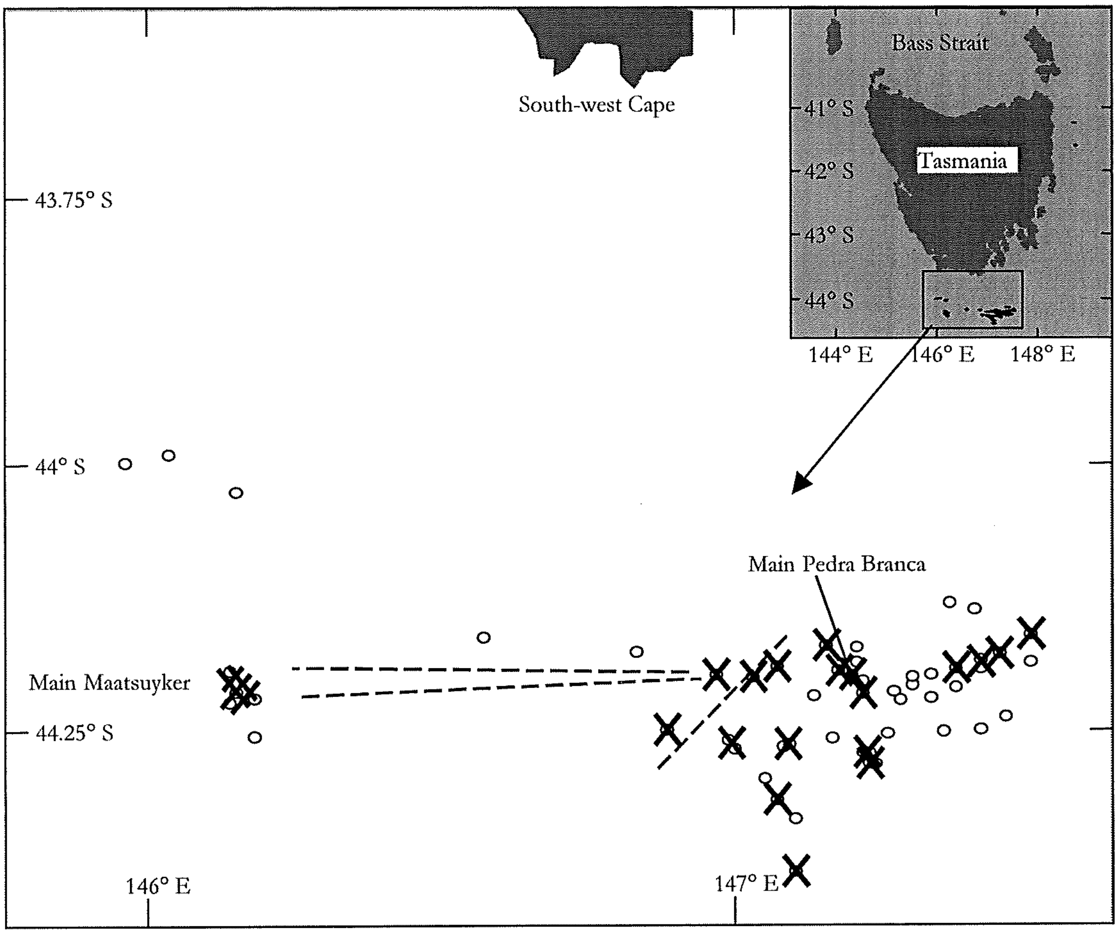
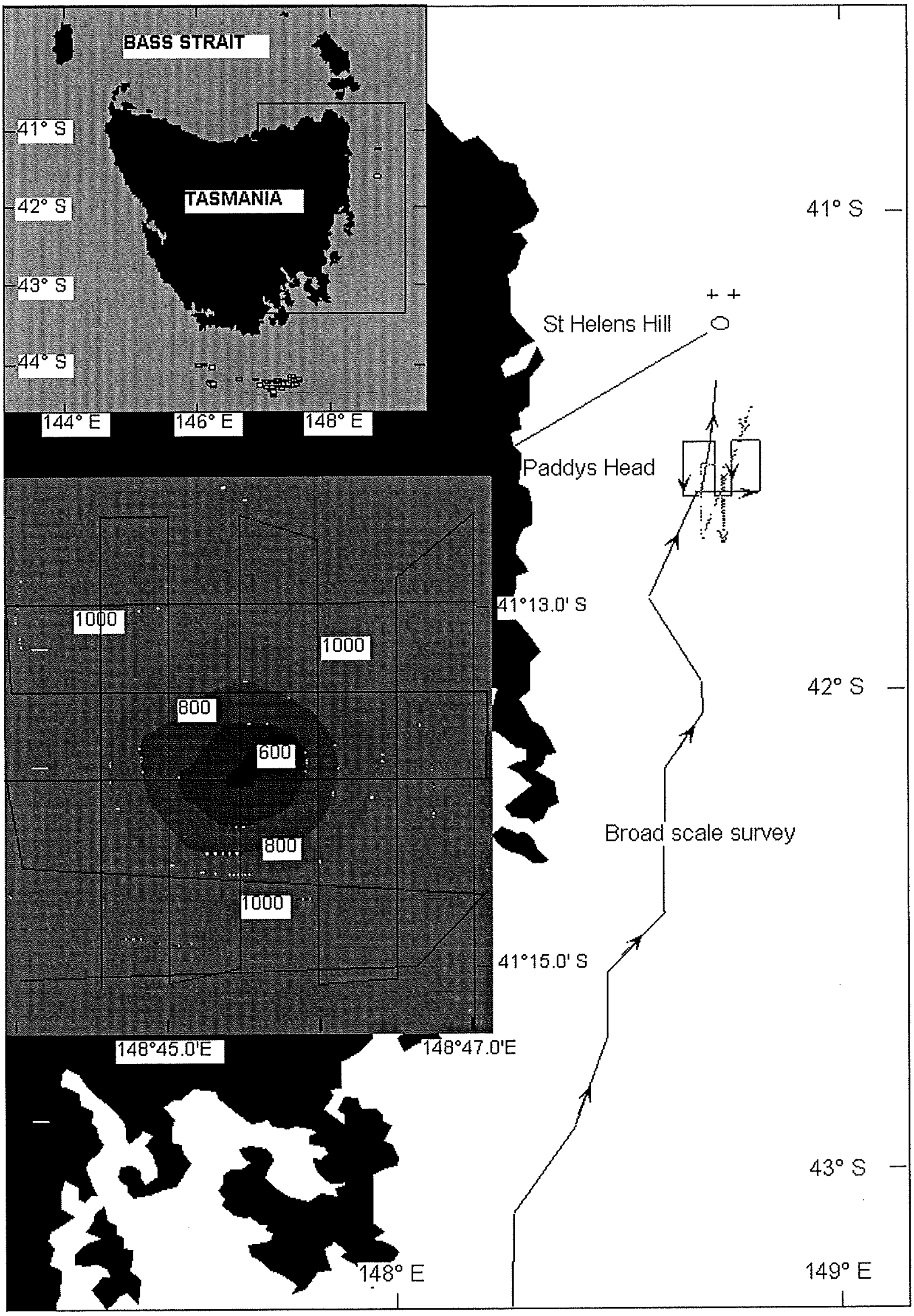


Figure 3.2.1-2. The areas surveyed off eastern Tasmania in July 1995, including St. Helens Hill, St. Patric's Head and the broad-scale coverage between the Eastern and Southern Zones. Inset shows the acoustic transects over St. Helens Hill.



The 1996 acoustic surveys of the St. Helens spawning ground were based on the survey design that has been used consistently in previous surveys of the spawning ground (see Kloser et al. 1996). Surveys have been carried out in the last two weeks of July, which egg surveys and repeat acoustic surveys, as well as patterns of catch from the fishery, indicate is the peak period of spawning (Koslow et al. 1995a, Kloser et al. 1996). North-South and East-West transects across the hill are spaced at 0.5 minute intervals of latitude (0.93 km) and longitude (0.66 km). The N-S transects are occupied on every cruise with a transect sometimes repeated to estimate sampling variability. The E-W transects are occupied on some but not all surveys. The topography of the spawning ground and the survey design are shown in Figure 3.2.1-1.

Because the backscattering density and species composition vary substantially with depth, the transects are stratified by 100 m depth intervals. It was apparent from the trawl and multi-frequency data that the species composition differed by hill sector in the 1996 survey as well. In analyzing the data, the mean acoustic backscattering was estimated by depth and sector strata on each transect and the appropriate species composition applied.

To examine species composition with the multi-frequency acoustics required that the transducer be towed approximately 100 m above the aggregations in order to minimize the flight response from the orange roughy (Koslow et al. 1995b) and maximize the acoustic return from the high frequency (120 kHz) transducer. Due to the steep topography, this could only be achieved by towing the transducer array along constant depth contours. The acoustic array was therefore towed at successive 100 m depth contours. To ensure there was no bias from tow direction, replicate tows were carried out in clockwise and counter-clockwise directions.

The St Patricks Head fishing ground is a small area of trawlable ground south of the spawning ground (Figure 3.2.1-2). The ground was surveyed twice, once on the way to the St. Helens spawning ground and again upon completion of the spawning ground survey. Four transects were carried out on the first survey along the 700-850 m, 850-950, 1000 and 1300 m depth contours. Because orange roughy were only noted at intermediate depths, two transects at 900-1000 and 900-1100 m were carried out across the ground on the second survey.

Zig-zag transects between the 700 m and 1300 m depth contours were carried out between St. Patrick's Head and the Southern Hills fishing ground. Twenty-three hills were surveyed in the Southern Zone (Figure 3.2.1-1, Table 3.2.1-2). Except for the major fishing hills, Maatsuyker and Pedra Branca, which were surveyed with additional transects, all hills were surveyed with two orthogonal (N-S and E-W) transects from their base, over their summit and across the base on the other side.

Table 3.2.1-2. Hills surveyed in the Southern Zone

	Hill name (when available)	Lat (S) degrees	minutes	Long (E) degrees	minutes
1		44	9.3	147	31.22
2		44	10.42	147	28.22
3		44	10.77	147	26.17
4		44	11.23	147	23.37
5		44	9.89	147	10.7
6		44	11.1	147	5.16
7		44	11.6	146	59.2
8	Macka's	44	11.69	147	2.42
9		44	11.42	147	11.3
10		44	11.77	147	12.58
11		44	12.68	147	14.13
12		44	14.73	146	54.13
13		44	15.86	147	0.54

14	Part of Pedra	44	15.7	147	5.77
15	Part of Pedra	44	15.58	147	6.67
16	Sister I	44	16.65	147	14.93
17	Sister II	44	16.02	147	14.27
18	Sams Hill	44	18.68	147	5.03
19	Belinda's Dory hill	44	22.82	147	6.87
20	Main Matt	44	12.93	146	11.45
21		44	12.52	146	9.87
22	Sharks Tooth	43	59.4	145	58.3
23	N.W. Matt.	44	11.35	146	9.27

3.2.2 Calibration methods

The acoustic equipment was calibrated with a standard -33.6 dB, 60 mm copper sphere for the 38 kHz transducer or a 42 mm sphere for all the transducers to obtain the on-axis echo integration constant (Foote 1982). This technique combines the electrical and acoustic constants of the system, such as transmitter power, the transmitting and receiving efficiency of the transducer, and receiver gain. The equivalent beam angle was measured by the manufacturer of the transducer and tests on this value were confirmed for the towed system with a special calibration rig. The split-beam deep-tow transducers were also calibrated from 100 - 700 m to correct for changes with depth in transducer sensitivity and to test for changes in beam pattern (Kloser, 1996). A calibration sphere suspended fore and aft 10 m under the towed body was lowered through the water column. The seawater propagation parameters of absorption and sound velocity were calculated from the formulae of Francois and Garrison (1982) and MacKenzie (1981), respectively, based upon temperature and salinity profiles obtained during the surveys with a Neil Brown conductivity-temperature-depth recorder (CTD).

In late 1996 an error was discovered in the Simrad software that affected the absolute calibration of the instrument. The Simrad software did not take into account the instrument delays and the TVG gain ramp through the target sphere. This was a surprise to many acousticians as Simrad quote the correct research paper that accounts for this change. The calibration error is more pronounced in deep water due to the longer pulse lengths and narrower bandwidths used. Our calibration data have been corrected by the appropriate amount as determined by the pulselength, bandwidth and sphere depth used for each calibration, Table 3.2.2-1.

Table 3.2.2-1. Correction factor required for the vessel mounted and towed 38kHz transducers due to Simrad EK500 TVG software error.

	Correction Factor	
Survey	Hull	Towed Body
SS496-1	1.19	1.12
SS496-3	1.20	1.12

3.2.3 Trawl Methods

The species composition of fish marks around St. Helens Hill, Paddy's Head and hills in the Southern Zone was assessed by targeted trawling. Demersal trawling was carried out by commercial trawlers (*Saxon Progress* at St Helens and Paddy's Head, and *Saxon Onward* in the Southern Zone) under direction of scientists aboard *Southern Surveyor*. Depth-stratified pelagic trawling was carried out by the *Southern Surveyor*. Standard commercial roughy nets were fitted with a 40 mm cod-end liner for the demersal trawling; the Engels 308 pelagic net with the opening/closing MIDOC cod-end system was used for pelagic trawling. Trawls mainly targeted fish marks surveyed with the acoustic body on hills, but around St Helens Hill we also sampled adjacent deep areas that had not been sampled in previous surveys, and in the Southern Zone areas of flat bottom adjacent to hills.

Three scientists aboard the commercial vessels recorded the proportions (numbers and weight) of all species in each catch, measured a representative number of each species, and took biological samples. Pelagic catches were treated similarly, although swimbladder dimensions were also measured and sketched for some species, and length data were taken to permit standard length to total length conversions.

3.2.3.1 Trawl species composition

All catches were sorted and recorded at the species level, but they were subsequently grouped into seven categories for analysis based on a simple classification incorporating fish family and swimbladder type: orange roughy, oreos, sharks, eels, whiptails, morid cods and miscellaneous species. Species catches were not standardised by tow time due to the uncertainty of determining start and end times of bottom contact and effective fishing.

3.3 Data Analysis

3.3.1 Acoustic data collection and quality assurance

A program, ECHO, was used to collect, quality assure and analyse the acoustic data on a SUN workstation (Waring *et. al.*, 1994). The acoustic data were displayed as an echogram with 16 colour levels, each level separated by 3 dB. The dB scale is logarithmic to the base 10, so 3 dB represents an approximate doubling of intensity. The program enabled the user to specify background and spike noise thresholds, correct for calibration and absorption changes, remove bad data, and edit bottom and shadow-zone levels.

Background Sv noise was measured for each survey (Table 3.2.1-1) by obtaining the average Sv value below the bottom signal at 1200 m, where there was no acoustic reverberation signal, and subtracting this value from all Sv data, as described in Kloser (1996). Spike Sv noise occurred at very high values (commonly > -25 dB) due mainly to unsychronised sounders for the vessel-mounted data or occasional high vibration and electrical noise from the deep-tow system. Spike Sv noise greater than the threshold was replaced by the Sv value immediately above in the water column. Large areas of data that were affected by vessel movement for the vessel-mounted transducer or electrical noise for the deep-tow transducer were removed.

Calibration corrections were required on the vessel-mounted and deep-tow transducer data for each survey (see in Table 4.1.1.-2).

Bottom editing was required when the slope of the hill prevented the automatic depth tracking in the Simrad EK500 from predicting the bottom signal. These high-bottom signal values could corrupt the acoustic data, but the acoustic bottom line could be redrawn with a mouse on the ECHO program. The shadow-zone line or true bottom depth was set on the highest acoustic bottom signal; the shadow-zone height was then estimated as the difference between the two lines. Backscattering in the shadow-zone was extrapolated from the mean Sv in the 10 m above it (Kloser, 1996).

3.3.2 Species Composition

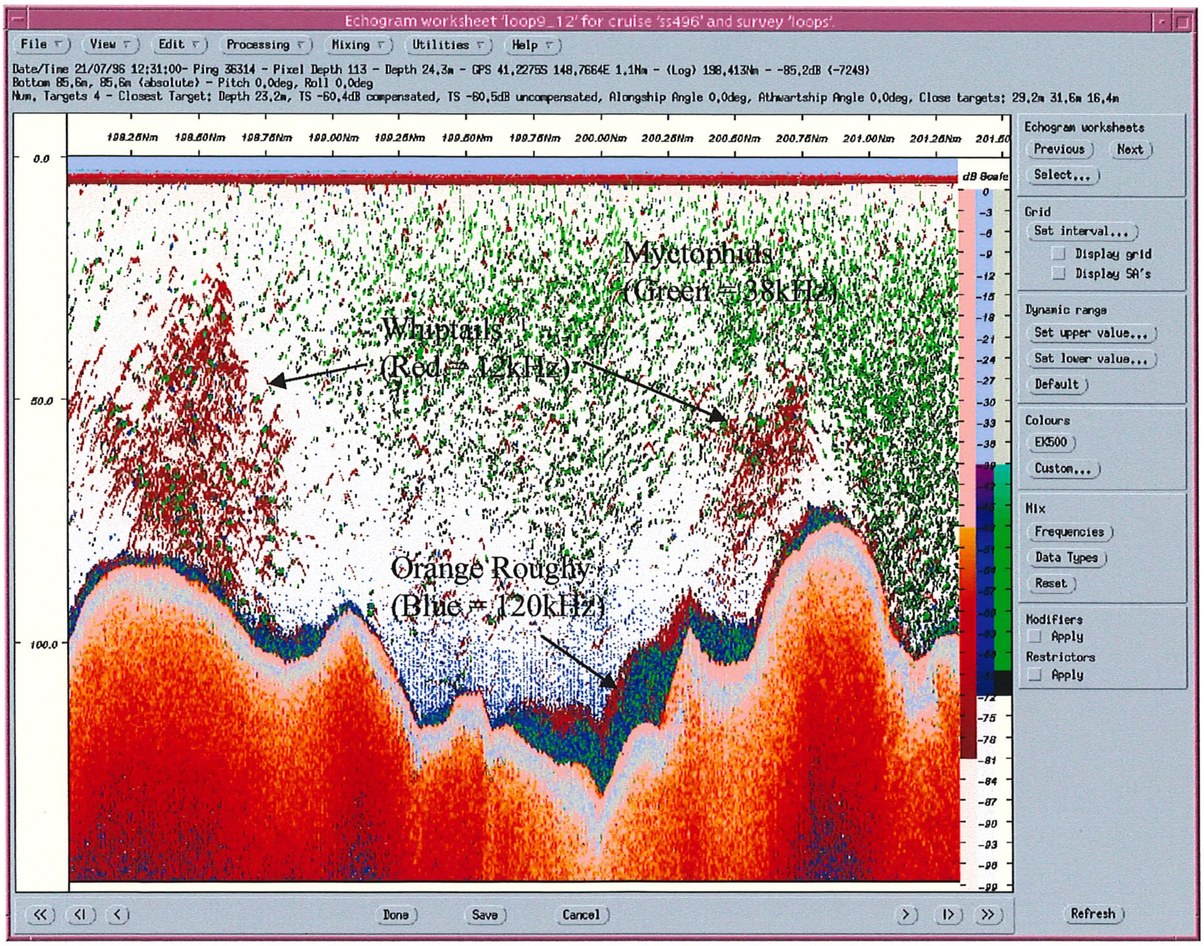
3.3.2.1 Multifrequency Data to Improve Species Composition Estimate

Acoustic surveys of Orange Roughy are very sensitive to error in assessment of species composition (Kloser 1997), because orange roughy have relatively low acoustic reflectance due to a lack of a gas-filled swimbladder. Furthermore, because the target strength of orange roughy is similar to that of small feed fishes (i.e. myctophids) with swimbladders at 38 kHz, it has not been possible to differentiate between these two types of acoustic targets using split beam technology at this frequency. A major potential source of bias may be eliminated, therefore, if such targets can be discriminated using several frequencies.

Species composition around the hill was investigated by following the depth contour of 700 – 900m at a height of 100 m above using the multi-frequency towed body. This survey strategy ensured that all sectors of the hill could be sampled in a timely manner. In all 14 loops around the hill were conducted and the multi-frequency data were logged and processed using the multi-frequency composite colour mixing feature of the ECHO software.

The general approach we have taken to visualise the multi-frequency data is to apply the various corrections for noise, absorption and calibration on each frequency and then mix them according to an algorithm as dictated by the particular application. Presently an empirical mixing of the frequencies has proven most useful in extracting out features of interest. This is achieved by allocating each frequency a unique colour pallet with independent start range and dynamic range. Mixing of the three colours is then displayed as its own mixed pallet or by an algorithm of the individual colours (Figure 3.3.2-1).

Figure 3.3.2-1 Example of mixing three frequencies for a deep-water application.



From Figure 3.3.2-1, the composite colours were mixed to highlight the orange roughy as an even mix of the three frequency colours. The other species at that depth were then highlighted as per the dominant frequency colour. The strong 38kHz signals (blue) have been associated empirically to myctophids that have small gas-filled bladders and are highly reflective at this frequency. The whiptail and morids have much larger swim bladders and have a strong reflectance at 12 kHz and in this example are represented by a strong red colour.

To estimate the relative species composition of orange roughy, whiptails and myctophids, the hill was divided into eight segments. Each segment was visually assessed to estimate the proportion of species according to the colour intensity and area of sector covered by a particular colour, Figure 4.2.3-1.

The species composition around the hill was also investigated by 21 demersal trawl tows conducted from a commercial vessel. The catches were sorted into dominant acoustic categories based on swim bladder and shape characteristics as outlined in section 3.3.2.2.

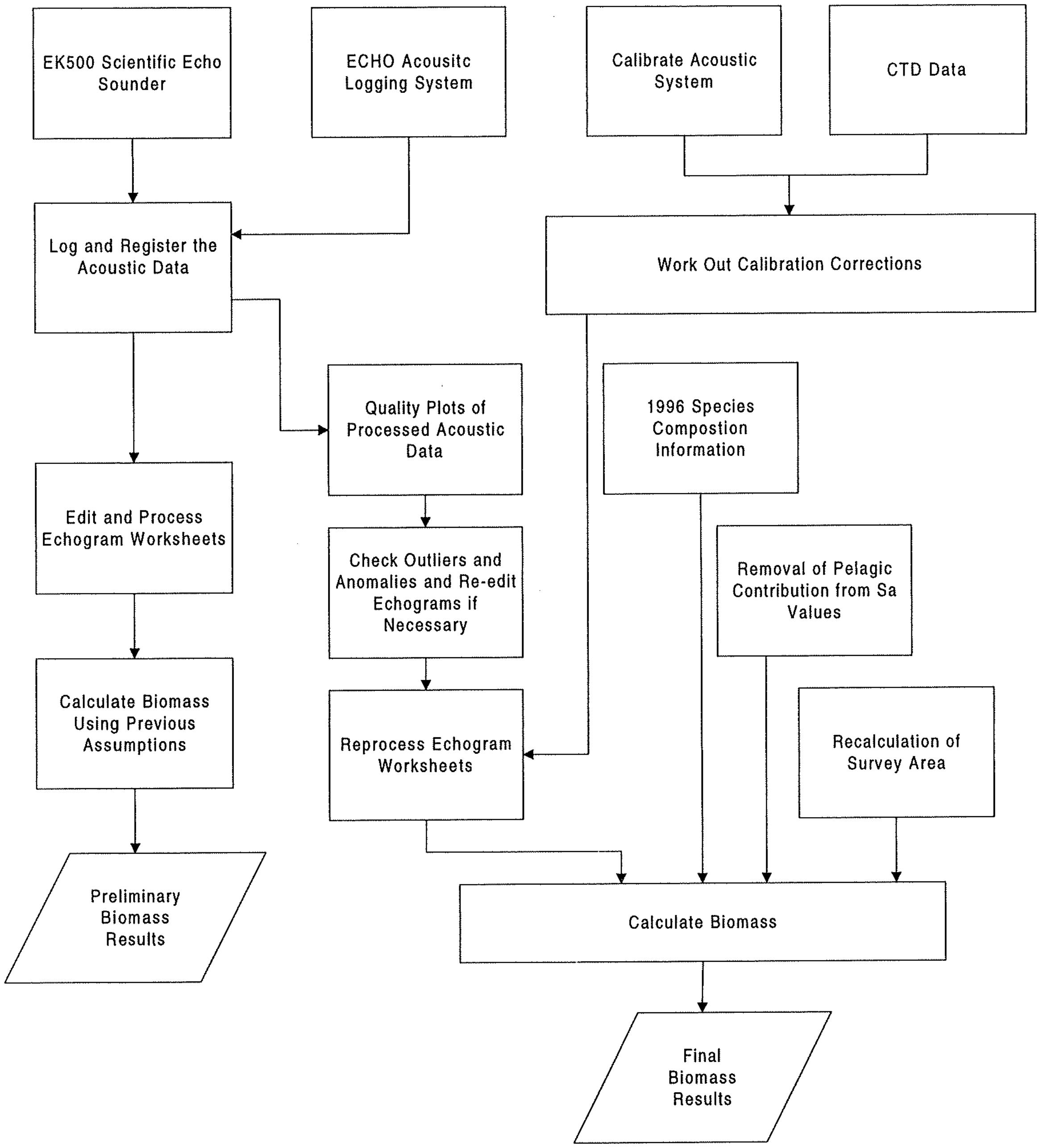
3.3.2.2 Trawl Data for Species Composition Estimates

The species composition for each depth/sector stratum was estimated with data from the depth-stratified demersal trawls carried out as part of the 1996 survey. In combining trawl shots within a stratum, catches were weighted by numbers caught. The data, which were originally enumerated by species, were grouped into eight major functional/taxonomic groups with similar TS values: orange roughy, oreosomatids, sharks, eels, macrourids (whiptails), morid cods, and miscellaneous. In the final data analysis for St. Helens, these were reduced further to the three groups sufficiently abundant to contribute significantly to the assessment: orange roughy, whiptails and morids.

3.3.3 Biomass calculation methods

Figure 3.3.3-1 is a flow chart that gives an overview of how a biomass value is derived from an acoustic survey. These steps help to ensure that we have quality data to produce our biomass assessments. The double handling of the data both at sea and back at the laboratories reduces the possibility of errors.

Figure 3.3.3-1 Block diagram outlining the steps taken to produce biomass estimates.



3.3.3.1 Pelagic removal

In previous years, 1990 - 93, we have applied a combined species composition obtained from both pelagic and demersal trawls (Kloser et al. 1996). This approach was adequate when there was significant backscatter from orange roughy schools but clearly as the biomass of orange roughy decreased the approach became insensitive to changes in orange roughy school size as observed on the echograms. Further, the pelagic layers surrounding the hill were not constant and added a significant contribution to the bottom locked echo integration values at low levels of orange roughy density. To address this we introduced an approach that removed this background pelagic contribution using information about pelagic backscatter away from the hill. The mean pelagic backscatter in 10 m intervals was estimated from several locations around the hill that did not show any backscatter associated to bottom referenced schools. This profile was then used to generate a mean pelagic backscatter profile based on the integrated 0–150 m bottom referenced and greater than 600 m in depth, profiles.

3.3.3.2 Acoustic analysis and Biomass Calculations

The acoustic returns were integrated from 0 to 150 m above the bottom, less than 600 m below the surface and at 0.1 nautical mile length intervals. Due to differences in species composition and levels of echo returns with depth, they were subsequently stratified by 100-meter bottom depth intervals. The calibrated Sv values were summed each ping vertically (d = 1, 75) and averaged horizontally for p pings to give the mean area backscattering coefficient, $S_{A_{ij}}$, for a given segment length of acoustic transect data, i, in a depth interval, j:

$$\overline{SA}_{ij} := \frac{\left[\sum_{p=1}^{m}\left(2\cdot\sum_{d=1}^{75}10^{\frac{S_{vdp}}{10}}\right)\right]}{m}\cdot 4\cdot\pi\cdot 1852^2 \qquad m^2\ \mathrm{n.mile}^{-2} \qquad (1)$$

The area backscatter obtained from the extrapolation into the shadow-zone for the same length of acoustic transect was then added to the values $\overline{S_{A_{ij}}}$.

The weighted arithmetic mean $\overline{S_{A_j}}$ and variance s_j^2 of the $\overline{S_{A_{ij}}}$ values for each depth interval area j were obtained by weighting the $\overline{S_{A_{ij}}}$ values by segment length L_i in n.mile expressed as:

$$\overline{S_{A_j}} = \frac{1}{n} * \sum_{i=1}^{n} W_i * S_{A_i} \quad \text{where} \quad W_i = \frac{L_i}{\overline{L_j}}$$

and $$\sigma_j^2 = \frac{1}{n-1} * \frac{\sum_{i=1}^{n} W_i * (S_{A_i} - \overline{S_{A_j}})^2}{\sum_{i=1}^{n} W_i} \qquad (2)$$

The biomass of a given species (s = 1,*n*) in an area *j* is expressed as a function of the mean backscattering in the region, SA_j (m^2 $n.mile^{-2}$); the proportion (number of individuals) of the species, F_s; their target strength, TS_s in dB; individual fish weight, W_s in kg; and area of the region, Aj, in $n.mile^2$ by:

$$Biomass_{sj} = F_s \times \frac{S_{A_j}}{\sum_{s=1}^{n} (F_s \times 4\Pi \times 10^{\frac{TS_s}{10}})} \times W_s \times A_j \text{ (kg)}$$

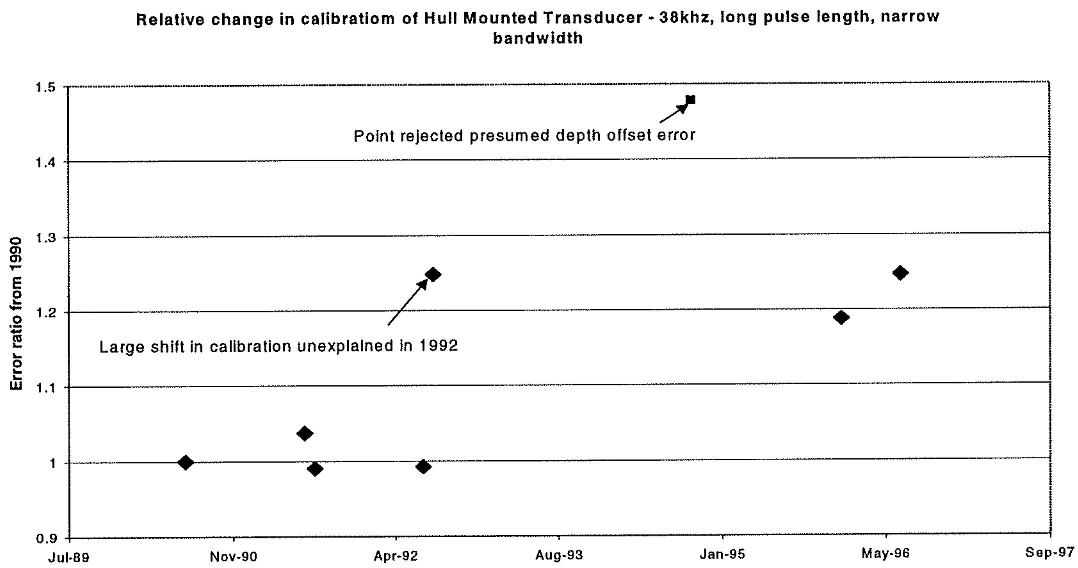
4. DETAILED RESULTS

4.1 Acoustic system

4.1.1 Calibration results and instrument settings

Detailed calibration results are given in Appendix B and outline the transducer specifications and the instrument settings for both the vessel and towed transducers. To summarise the calibration settings Figure 4.1.1-1 below displays the stability of the 38 kHz vessel mounted transducer at one setting over a number of years. The large shift in calibration in 1992 has not been explained and may be due to hardware modifications. The shift in calibration in 1992 has been reproduced in subsequent calibrations and is thus seen as an actual change.

Figure 4.1.1-1. Stability of vessel mounted 38 kHz transducer over a six year period.



The deep-tow transducers are sensitive to depth and a plot of the up and down profiles for the three transducers shows hysteresis in the transducers. The hysteresis of the 38 kHz transducer was documented in Kloser (1996). The results for calibration of the 12kHz, 38kHz and 120kHz transducers presented here (Figures 4.1.3-2,4.1.3-3 and 4.1.3-4) are from one site and investigations are continuing into the transmitter to transducer matching that may be contributing to the hysteresis.

Figure 4.1.1-2 Results of deep water calibrations for the 120kHz transducer.

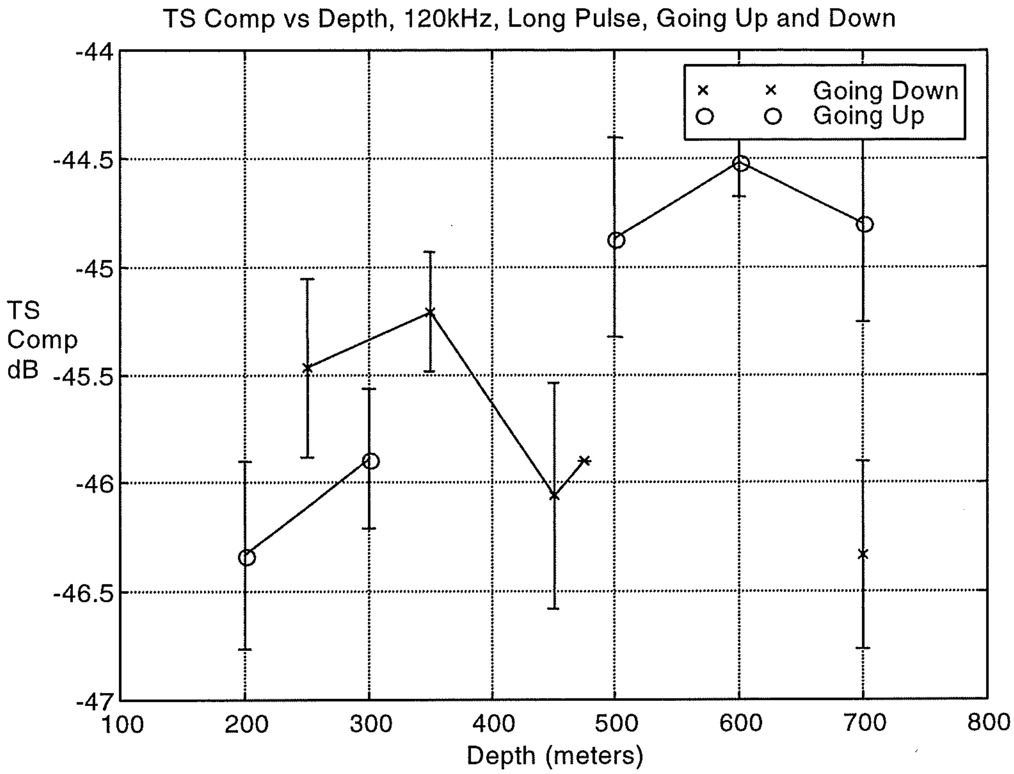


Figure 4.1.1-3 Results of deep water calibrations for the 12kHz transducers

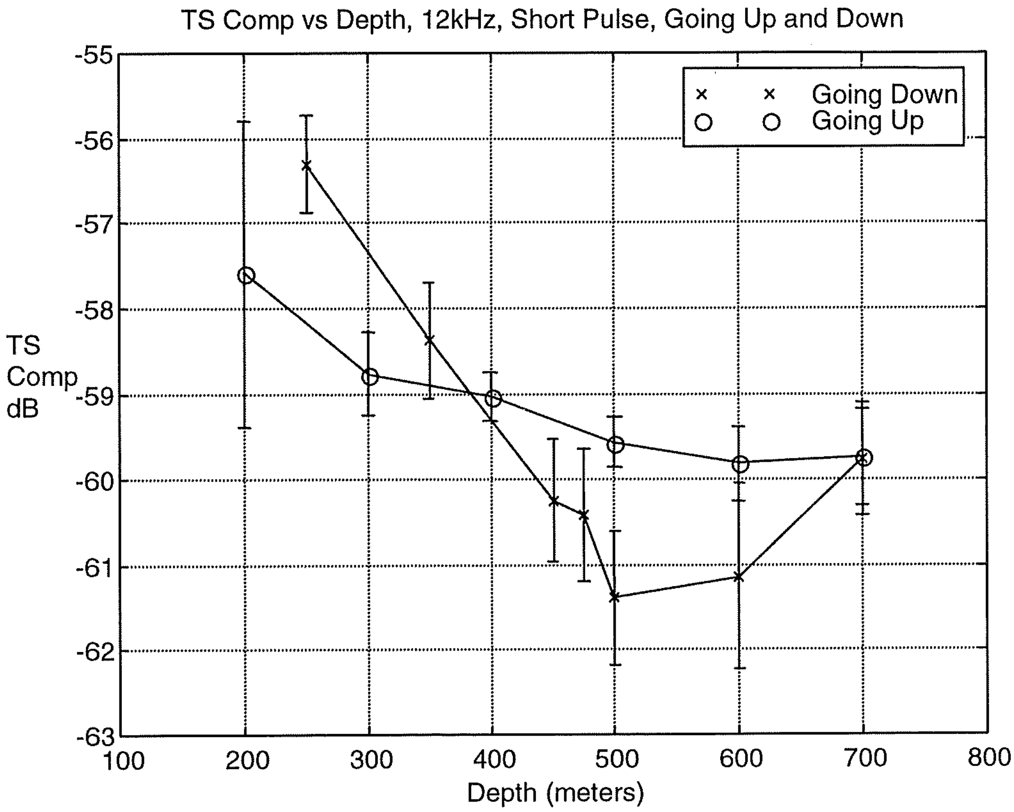
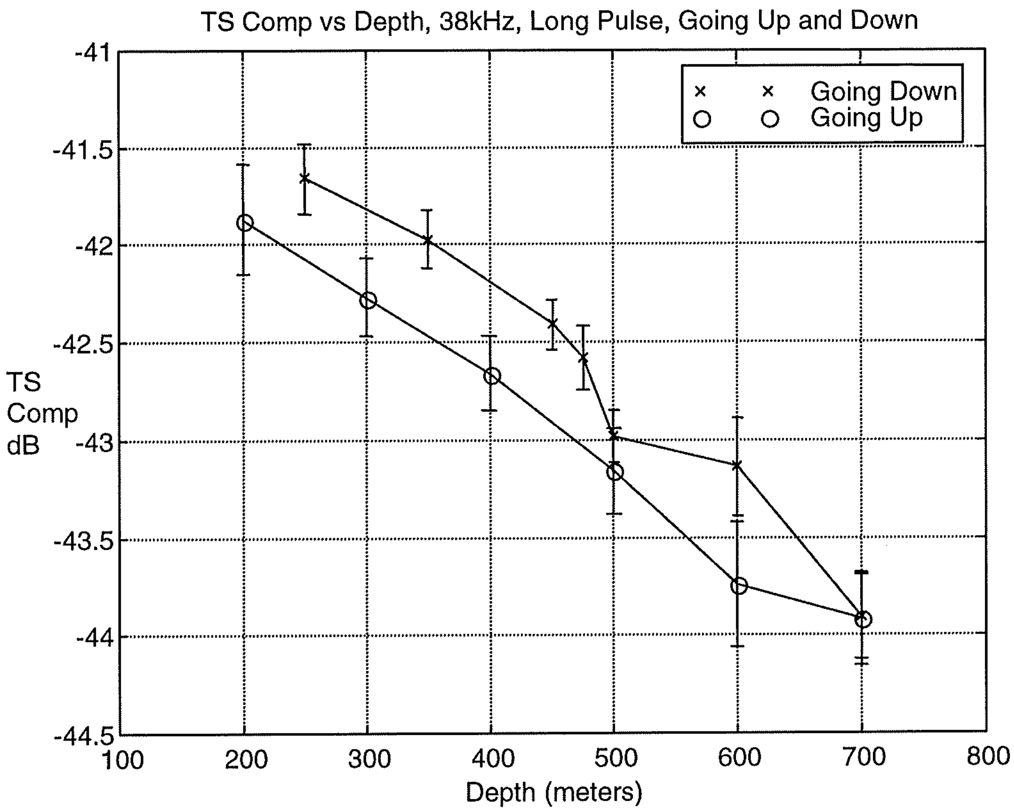


Figure 4.1.1-4 Results of deep water calibrations for the 38kHz transducers



The towed system was calibrated both at sea to a depth of 700 m and in port after the voyage. The calibration at sea measured the change of the on-axis sensitivity due to depth whilst the shallow calibration measured the beam pattern of each transducer. The calibration results are summarised in Appendix B for both the vessel and towed transducers.

Table 4.1.1-1. Summary of Towed Body Surface Calibration Results.

Date	Frequency	Pulse Length	Bandwidth	Depth to Sphere	SVc	TSc
1-Aug-96	38	medium	wide	6.3	29.3	29.1
1-Aug-96	120	medium	wide	6.2	20.5	20.8
1-Aug-96	120	long	narrow	6.1	24.1	23.8

Table 4.1.1-2. Towed Body TS vs Depth Corrections.

EK500 Settings				Surface Calibration Results			Theoretical	Measured		ECHO Settings	
Freq	Pulse Length	Svc_set	TSc_set	Svc	TSc	Sphere Depth	TS Sphere	Slope	Intercept	TS Intercept	Sv Intercept
38	Long	-	-	-	-	-	-42.35	-0.0052	-40.8093	-	-
38	Medium	31.7	31.5	29.3	29.1	6.3	-42.35	-0.00492	-40.2808	2.0692	2.0692
120	Long	23	23	20.5	20.8	6.21	-39.5	-0.00276	-44.5109	-5.01	-4.41
120	Medium	23	23	24.1	23.8	6.15	-39.5	-0.00534	-37.0662	2.4338	3.0338
12	Long	18.5	18.5	no result	no result	no result	-42	0	-62.3	-20.3	-20.3
12	Medium	18.5	18.5	no result	no result	no result	-42	0	-60	-18	-18

Notes:

Svc_set: Sv value as set in EK500

TSc_set TS value as set in EK500

Svc Sv value determined from calibration

TSc TS value determined from calibration

TS Sphere Theoretical value of calibration target sphere

Slope Slope of Depth vs TS relationship

Intercept Intercept with y axis of Depth vs TS relationship

TS Intercept Value that is entered into ECHO software for correction purposes

Sv Intercept Value that is entered into ECHO software for correction purposes

Sv intercept and TS intercept should be set to the identical values if the difference between Sv_set and TS_set is the same as the difference between Svc and TSc calibration results. This is the case for the 38kHz. In this instance

TS Intercept = Intercept – TS Sphere

TS Intercept = -40.2808 - -42.35 = 2.0692 = Sv Intercept

For the 120kHz the Svc and TSc have been set to the same value. For this case for long pulse length:

TS Intercept = -44.5109 - -39.5 = -5.01

but for Sv Intercept Sv Intercept = Intercept – TS Sphere – 2 * (Svc – TSc)

Sv Intercept = -44.5109 - -39.5 - 2*(20.5-20.8)

Sv Intercept = -4.41

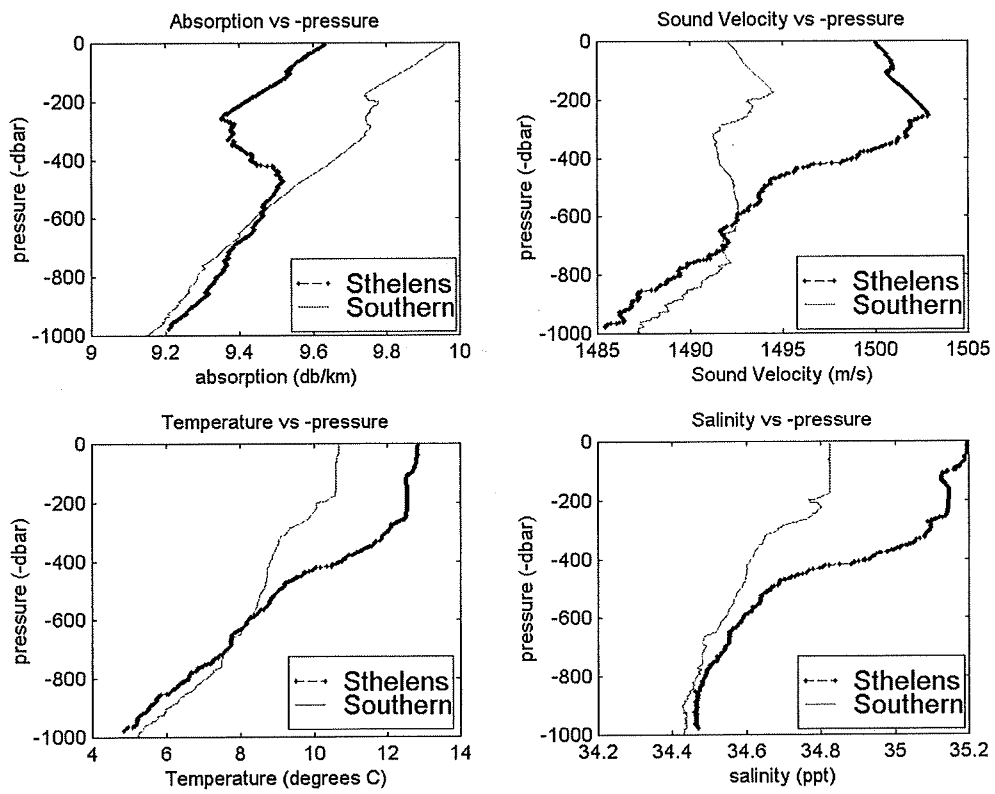
The TS Slope and Sv slope are assumed to be the same so in the ECHO software worksheet calibration table the value of slope from Table 4.1.3.-2 can be entered into both the TS Slope and Sv Slope fields.

12kHz slope and intercept values were not calculated from the plot of TS Comp vs Depth since the plot was not linear. For this frequency the average towed body depth was calculated for all the loops of Sthelens Hill and this depth was used to find the corresponding TS Comp value on the plot of TS Comp vs depth.

4.1.2 Absorption and Sound velocity

The Simrad EK500 was preset at fixed values of absorption and sound velocities throughout the cruise. Corrections on the data were required where the mean absorption and sound velocity differed from the fixed values as determined by CTD casts in the region. In total, six CTD stations were performed during the voyage, three at St Helens Hill and three at the Southern Hills. This data is summarised in Appendix A. Figure 4.1.2-1 shows the differences in the absorption and sound velocity profiles at 38kHz between the St Helens and Southern Hills regions. The mean absorption profiles for a given frequency, integration depth and transducer depth as outlined in Appendix A were entered into the ECHO post processing software during analysis.

Figure 4.1.2-1 Absorption and Sound Velocity Profiles at 38kHz for CTD measurements obtained at St. Helens Hill and the Southern Hills regions.



4.2 Species Composition

4.2.1 Demersal Trawls

In the Eastern Zone, mainly on St. Helens, 26 trawls were completed and 35.1 tonnes of fish taken. Forty-five species of fish were caught,, which were reduced to the seven groups as shown in Tables 4.2.1-1 and 4.2.1-2. Although orange roughy made up 99% of the catch by weight at both St Helens and St Patricks Head, the proportion of orange roughy by numbers on the S/SW sector of St. Helens hill was only 27%, most of the remainder being comprised of macrourids and morids (Table 4.2.1-2).

Table 4.2.1-1 Species caught by demersal trawl in the 1996 St Helens Survey showing species groups used in analysis and total unstandardised numbers

Species	Group	Total nos.	Species	Group	Total nos.
Diastobranchus capensis	E	10	Neocyttus rhomboidalis	O	22
Snipe eel	E	1	Allocyttus niger	O	15
Conger verreaux	E	0	Allocyttus verrucosus	O	2
Eels (2 spp)		11	Oreosoma atlanticum	O	0
Antimora rostrata	MC	0	Psuedocyttus maculatus	O	200
Halargyreus johnsonii	MC	271	Unidentified oreo	O	1
Antimora rostrata	MC	1	Oreos (5 spp)		240
Lepidion microcephalus	MC	0	Hoplostethus atlanticus	OR	21893
Large Cod (Commercial)	MC	0	Etmopterus pusillus	S	19
Morid cods (3 spp)		272	Deania calcea	S	3
Notocanthus sexpinnis	MISC	0	Deania quadrispinosa	S	8
Epigonus robustus	MISC	8	Centroscymnus plunketi	S	6
Epigonus leninmen	MISC	0	Centroscymnus crepidater	S	1
Bathylagidae	MISC	0	Centrophorus squamosus	S	0
Angler Fish	MISC	3	Rhinochimera pacifica	S	3
Idiacanthus atlanticus.	MISC	7	Hydrolagus sp.A	S	0
Alepocephalus (large scale)	MISC	3	Apristurus sp. A	S	2
Alepocephalus (small scale)	MISC	1	Apristurus sp. E	S	1
Chauliodus sloanii	MISC	1	Apristurus sp. D	S	0
Hygophum hansenii	MISC	0	Apristurus sp. C	S	0
Lampanyctus australis	MISC	10	Sharks (8 spp)		43
Persparsia kopua	MISC	0	Coryphaenoides subserrulatus	W	370
Agyropelacus gigas	MISC	1	Coryphaenoides serrulatus	W	37
Photichthys argenteus	MISC	11	Lepidorhyncus denticulatus	W	4
Myctophidae	MISC	11	Caelorinchus fasciatus	W	3
Diretmus sp.	MISC	0	Caelorinchus matamua	W	2
Macruronus novaezelandiae	MISC	2	Caelorinchus innotabilis	W	0
Calamari squid	MISC	1	Caelorinchus australis	W	3
Unidentified Squid	MISC	2	Caelorinchus kaiyomaru	W	1
Pelagic Squid	MISC	2	Macrurus carinatus	W	0
Strawberry Squid	MISC	2	Mesobius antipodum	W	0
Todarodes sp.	MISC	16	Caelorinchus sp.	W	0
Hyperoglyphe antarctica	MISC	1	Ventrofossa nigromaculata	W	0
Beryx splendens	MISC	1	Trachyrincus longirostris	W	0
Tubbia tasmanica	MISC	0	Whiptail (not above)	W	8
Centriscops humerosus	MISC	0	Nezumia loricata	W	0
Trachipteridae arawatae	MISC	0	Whiptails (8 spp)		428
Genypterus sp.	MISC	0			
Miscellaneous (18 spp)		83			

Only orange roughy, whiptails and morid cods were treated in the analysis of St Helens data because they were the dominant groups (Table 4.2.1-2).

Table 4.2.1-2 The numbers and proportions of each species group in Eastern Zone catches

	St Patrick	St. Helens	Isolated hill	St Patrick	St. Helens	Isolated hill
	Tot nos.	Tot nos	Tot nos	Tot wt	Tot wt	Tot wt
No. shots	3	22	1	3	22	1
Hoplostethus atlanticus	196	21685	12	310.7	34126.8	12.34
Oreos (5 spp)	0	22	218	0	20.17	194.3
Sharks (8 spp)	1	39	3	1.15	121.17	5
Eels (2 spp)	0	11	0	0	11.19	0
Whiptails (8 spp)	19	408	1	1.96	62.328	0.13
Morid cods (2 spp)	0	272	0	0	229.19	0
Miscellaneous (18 spp)	1	82	0	0.05	47.925	0
Total	217	22519	234	313.86	34618.773	211.77
% composition by site	St Patrick	St. Helens	Isolated hill	St Patrick	St. Helens	Isolated hill
	Tot nos	Tot nos	Tot nos	Tot wt	Tot wt	Tot wt
No. shots	3	22	1	3	22	1
Hoplostethus atlanticus	90	96	5	99	99	6
Oreos (5 spp)	0	0	93	0	0	92
Sharks (8 spp)	0	0	1	0	0	2
Eels (2 spp)	0	0	0	0	0	0
Whiptails (8 spp)	9	2	0	1	0	0
Morid cods (2 spp)	0	1	0	0	1	0
Miscellaneous (18 spp)	0	0	0	0	0	0

Species compositions were calculated separately for three zones on the hill to correspond with the distinct distribution of acoustic marks. The distribution of trawl stations on the hill, and the relative proportions of orange roughy, whiptails and morids are shown in Figure 4.3.2.2-1

In the Southern Zone, 18 trawls were completed and 1.6 tonnes of fish taken. Fifty-eight species of fish were caught, of which orange roughy made up 44% of catch weight on the hills and 13% on the adjacent flat ground. The large number of species caught was reduced to the seven groups as shown in Table 4.2.1-3.

Table 4.2.1-3 The species caught by demersal trawling in the 1995 Southern Zone Survey showing species groups used in analysis and total unstandardised numbers.

Species	Group	Total nos	Species	Group	Total nos
Diastobranchus capensis	E	440	Neocyttus rhomboidalis	O	80
Snipe eel	E	0	Allocyttus niger	O	180
Conger verreauxi	E	1	Allocyttus verrucosus	O	2
Eels (2 spp)		441	Oreosoma atlanticum	O	94
Antimora rostrata	MC	2	Psuedocyttus maculatus	O	1122
Halargyyreus johnsonii	MC	20	Unidentified oreo	O	0
Antimora rostrata	MC	0	Oreos (5 spp)		1478
Lepidion microcephalus	MC	2	Hoplostethus atlanticus	OR	963
Large Cod (Commercial)	MC	2	Etmopterus pusillus	S	162
Morid cods (4 spp)		26	Deania calcea	S	14
Notocanthus sexpinnis	MISC	1	Deania quadraspinosa	S	30
Epigonus robustus	MISC	148	Centroscymnus plunketi	S	4
Epigonus leninmen	MISC	1	Centroscymnus crepidater	S	0
Bathylagidae	MISC	7	Centrophorus squamosus	S	1
Angler Fish	MISC	0	Rhinochimera pacifica	S	2
Idiacanthus atlanticus.	MISC	0	Hydrolagus sp.A	S	1
Alepocephalus (large scale)	MISC	31	Apristuras sp. A	S	3
Alepocephalus (small scale)	MISC	7	Apristuras sp. E	S	0
Chauliodus sloanii	MISC	1	Apristuras sp. D	S	1
Hygophum hansenii	MISC	0	Apristuras sp. C	S	1
Lampanyctus australis	MISC	19	Sharks (10 spp)		219
Persparsia kopua	MISC	3	Coryphaenoides subserrulatus	W	732
Agyropelacus gigas	MISC	1	Coryphaenoides serrulatus	W	1
Photichthys argenteus	MISC	19	Lepidorhyncus denticulatus	W	64
Myctophidae	MISC	24	Caelorinchus fasciatus	W	5
Diretmus sp	MISC	2	Caelorinchus matamua	W	5
Macruronus novaezelandiae	MISC	3	Caelorinchus innotabilis	W	1
Calamari squid	MISC	2	Caelorinchus australis	W	0
Unidentified Squid	MISC	3	Caelorinchus kaiyomaru	W	7
Pelagic Squid	MISC	0	Macrurus carinatus	W	19
Strawberry Squid	MISC	2	Mesobius antipodum	W	2
Todarodes sp.	MISC	6	Caelorinchus sp.	W	1
Hyperoglyphe antarctica	MISC	0	Ventrofossa nigromaculata	W	2
Beryx splendens	MISC	0	Trachyrincus longirostris	W	2
Tubbia tasmanica	MISC	14	Whiptail (not above)	W	9
Centriscops humerosus	MISC	40	Nezumia loricata	W	1
Trachipteridae arawatae	MISC	1	Whiptails (14 spp)		851
Genypterus sp.	MISC	1			
Miscellaneous (22 spp)		336			

4.2.2 Pelagic trawls

Thirty-five species of pelagic fishes, crustaceans and squids, and six zooplankton groups were caught in the three pelagic trawls at St. Helens (Table 4.2.2-1). The dominant fishes included two lanternfishes— *Diaphus danae* and *Lampanyctus australis*— and the lighthousefish *Photichthys argenteus*. Segestid prawns— mostly *Sergia potens*— and were also abundant.

Large numbers of gelatinous siphonophores were also caught but it was not clear whether these were from near surface depths. The numbers, weights, lengths and swimbladder characteristics of all species were recorded for subsequent analysis and comparison with acoustic data (some summary data included in Table 4.2.2-1).

Table 4.2.2-1. The species caught by pelagic trawling around St. Helens Hill, showing swimbladder type and total unstandardised numbers.

Species	Code	Total numbers	Swimbladder type
Serrivomer beani	75001	1	Long, thin-walled sac
Cyclothone sp.	106000	1	Fat-invested
Photichthys argenteus	106002	25	Large, thick-walled bladder
Argyropelecus gigas	107005	20	Relatively larger, circular bladder
Argyropelecus hemigymnus	107006	2	Relatively larger, circular bladder
Malcosteus niger	110001	6	Absent
Chauliodus sloani	111001	5	Absent
Idiacanthus atlanticus	113002	4	Absent
Persparsia kopua	115001	5	Absent
Lampanyctus sp.	122000	11	Elongate bladder
Diaphus danae	122001	87	Gas-filled bladder
Symbolophorus barnardi	122007	0	Gas-filled bladder, ~=HL
Metelectrona ventralis	122016	3	Rel. large oval bladder
Lampichthys proceros	122017	31	Rel. large oval bladder, ~>HL
Lampanyctus australis	122019	72	Rel. large oval bladder, ~>HL
Diaphus meadi	122036	1	Gas-filled bladder (not confirmed)
Hygophum hanseni	122045	19	Gas-filled bladder (not confirmed)
Lampanyctus ater	122049	1	Large gas-filled bladder
Protomyctophum normani	122067	1	Gas-filled bladder
Taaningichthys bathyphilis	122069	2	Gas-filled bladder (not confirmed)
Electrona paucirastra	122075	1	Gas-filled bladder (not confirmed)
Scopelosaurus sp.	125000	1	Lacking in family (not confirmed)
Cryptosaras couseii	220001	2	Lacking in family (not confirmed)
Macruronus novaezelandiae	227001	1	Large gas-filled bladder
Coryphaenoides subserrulatus?	232016	1	Spongy gas matrix
Diretmus argenteus	254002	7	Gas-filled bladder (not confirmed)
Synagrops (white tail)	311000	1	Gas-filled bladder (not confirmed)
Todarodes sp.	600001	5	Absent
Histioteuthis miranda?	600002	1	Absent
Lycoteuthis lorigera	600003	1	Absent
Cranchia sp.	600004	1	Absent
Sergia potens	700001	24	Absent
Oplophorus novaezelandiae	700002	15	Absent
Acanthephyra sp. (large)	700003	1	Absent
Small prawn species	700004	36	Absent
Amphipod		15	Unclassified, probably absent
Pureulus larva		1	Unclassified, probably absent
Siphonophores		599	Unclassified, probably absent
Salps (Thetys?)		10	Unclassified, probably absent
Salps (dark green)		3	Unclassified, probably absent
Rigid, clear salps		2	Unclassified, probably absent

In the Southern Zone, nine successful pelagic trawl samples of micronekton were taken in deep scattering layers with different acoustic backscatter at 12kHz and 38kHz. Each trawl fished only one layer— typically along a depth horizon of about 25-50 m— for two hours; the shallowest and deepest layers were at 190 m and 750 m. Replicate samples taken in opening/ closing nets in five trawls showed a fairly consistent species composition horizontally along each layer. Samples from four trawls in which the opening/ closing net system did not work properly were contaminated with animals—especially salps and pyrosomes— during the ascent and descent of the gear. However, because the sampling time in the layer was relatively long, these samples identified the dominant species in the targeted layers. Some layers had a distinct species composition, e.g. a very high abundance and dominance of *Photichthys argenteus* in 565-575 m during the day and a mix of only salps and *Protomyctophum normani* in 327-377 m during the day. These catches were used to assess species or species-group recognition in multi-frequency acoustic data.

4.2.3 Species Composition from Multifrequency Acoustics

In total, there were 13 loops around the hill as outlined in Table 4.2.3-1

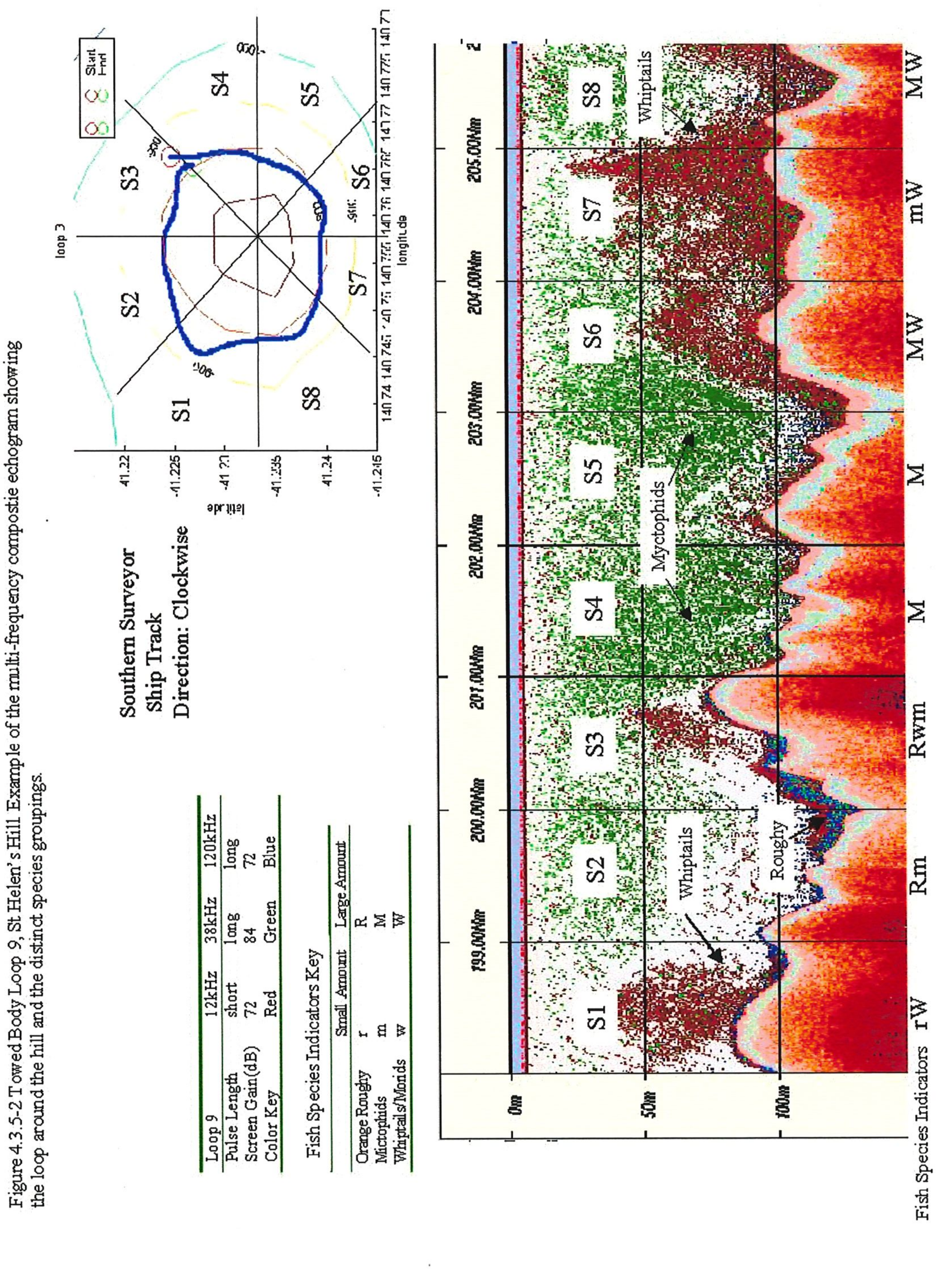
Table 4.2.3-1 Towed Body Loops Around St Helen's Hill.

loop number	Start Time UTC	End Time UTC
1	21-Jul-96 5:23:37 AM	21-Jul-96 6:12:59 AM
2	21-Jul-96 6:12:59 AM	21-Jul-96 7:03:03 AM
3	21-Jul-96 7:03:03 AM	21-Jul-96 7:52:21 AM
4	21-Jul-96 7:52:21 AM	21-Jul-96 8:40:59 AM
5	21-Jul-96 8:40:59 AM	21-Jul-96 9:27:32 AM
6	21-Jul-96 9:27:32 AM	21-Jul-96 10:34:26 AM
7	21-Jul-96 10:34:26 AM	21-Jul-96 11:37:39 AM
8	21-Jul-96 11:37:39 AM	21-Jul-96 12:28:38 PM
9	21-Jul-96 12:28:38 PM	21-Jul-96 1:15:25 PM
10	21-Jul-96 1:15:25 PM	21-Jul-96 2:00:33 PM
11	21-Jul-96 2:00:33 PM	21-Jul-96 2:35:11 PM
12	21-Jul-96 6:03:14 PM	21-Jul-96 6:38:11 PM
13	21-Jul-96 6:38:11 PM	21-Jul-96 7:18:38 PM

The multi-frequency data for each loop were displayed and analysed as outlined in section 3.3.2.1. An example of the analysis for one loop (loop 9) is shown in Figure. 4.2.3-1. This colour Figure shows the ship track for the loop with the bathymetry of the hill as an underlay. For the purposes of the analysis, the hill has been divided into 8 sectors as shown. The composite 12, 38 and 120 kHz (red, green, blue) echogram is also shown for the loop. Each sector has been ascribed a species mixture of myctophids, whiptalis/morids and orange roughy. This mixture was based on the intensity of the colour and the area of coverage.

Results of the multi-frequency analysis were generally consistent with the trawl sampling, insofar as orange roughy were found to be aggregated on the northern and western sectors of the hill with macrourids and morids dominant in southern and eastern segments (Figure 4.2.3-1).

Figure 4.2.3-1. Multi-frequency acoustic data from loop 9 around the St. Helens hill spawning area.



4.3 Biomass

4.3.1 Pelagic removal

Figure 4.3.1-1 shows the backscatter profiles for all the years sampling has been performed on St. Helens Hill and the times during the day that the surveys occurred. It can be seen that the pelagic backscatter more than doubled on cruise SS496-3 for both the hull and the towed body. Figure 4.3.1-2 shows an example of the echograms comparing SS496-1 and SS496-3 data. Clearly, there is a marked change in the height and intensity of the deep scattering layer in survey three of 1996. This pelagic backscatter was subtracted from the total hill backscatter and its effect on the Sa values is seen in Figures 4.3.1-3 and 4.3.1-4. Due to this marked change in pelagic backscatter and the smaller size of the orange roughy schools during survey SS96-3, it is of questionable value.

Figure 4.3.1-1. Pelagic profiles calculated for each acoustic survey from 1991 – 1996 with the associated survey time. Note the very much larger pelagic profile for survey 3 in 1996 when compared to all other years.

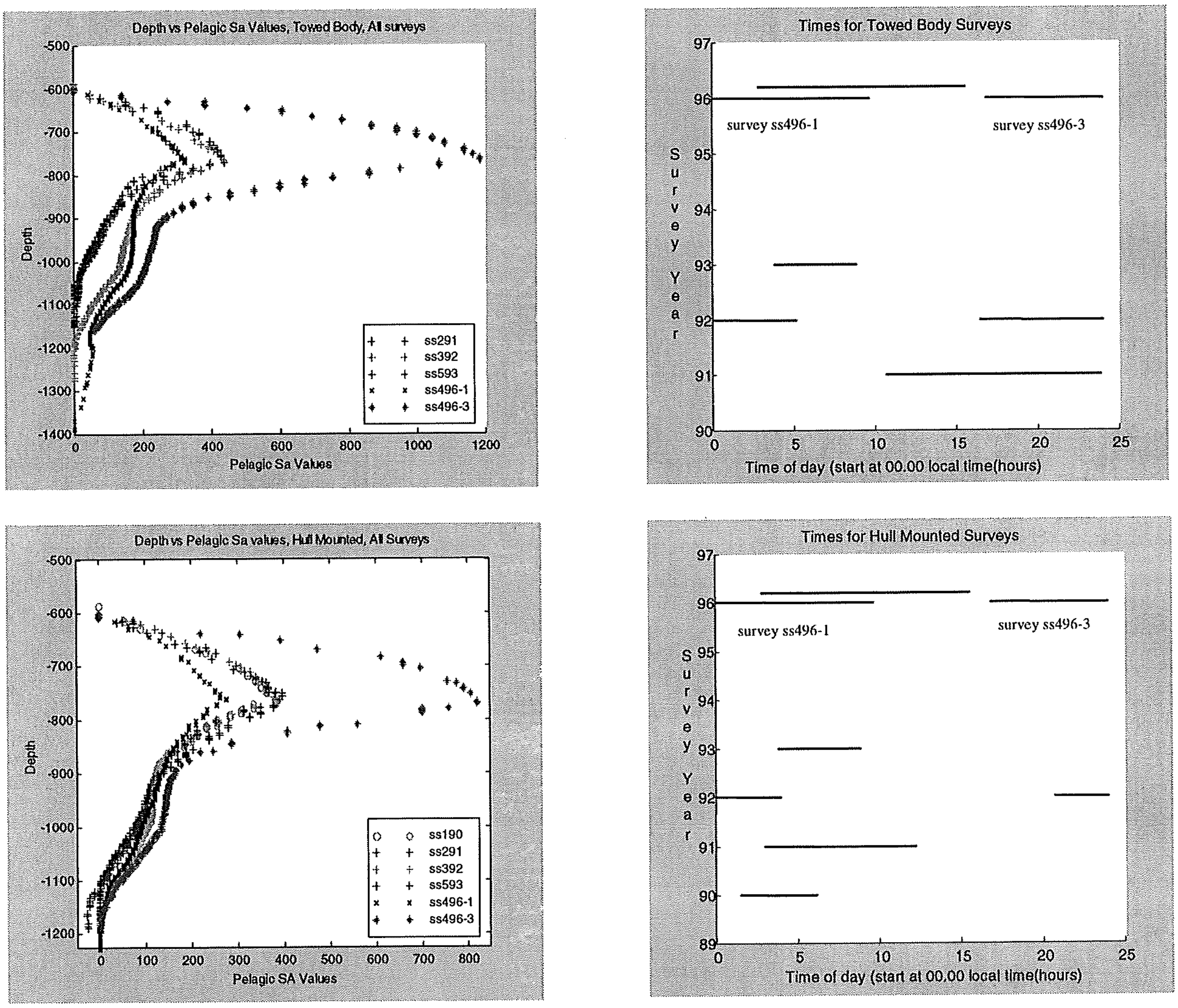
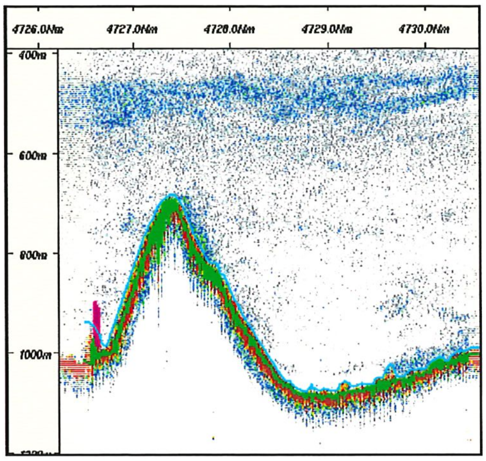
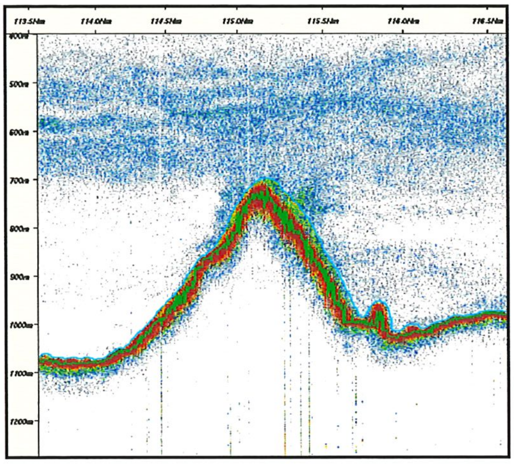


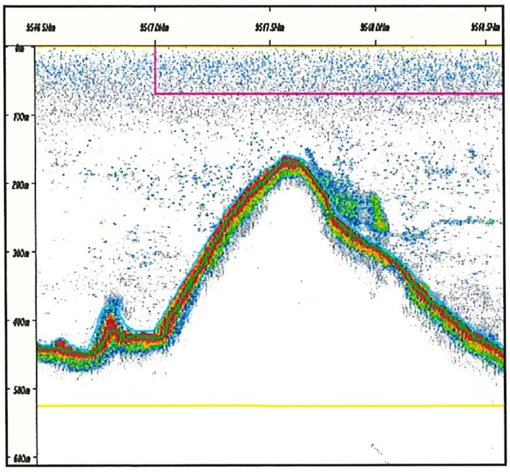
Figure 4.3.1-2. Echograms at 38 kHz from survey one and three in 1996 for both the vessel and towed transducers. Note the greatly increased pelagic backscatter for survey 3 on both the vessel and towed transducer echograms.



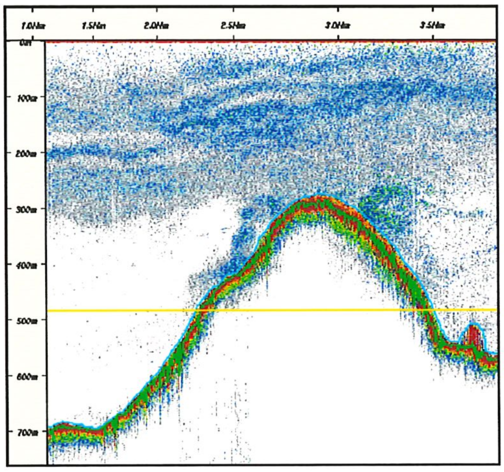
Survey 1 Hull Transect 2
17-Jul -1996 16:53 to 18-Jul 09:41 local time



Survey 3 Hull Transect 3a
20-Jul-1996 02:51 to 15:34 local time



Survey 1 Towed Body Transect 2
17-Jul -1996 16:53 to 18-Jul 09:41 local time



Survey 3 Towed Body Transect 3a 20-Jul-1996 02:51 to 15:34 local time

Figure 4.3.1-3 Survey 1 Sa Values by Depth, With and Without Pelagic Contribution.

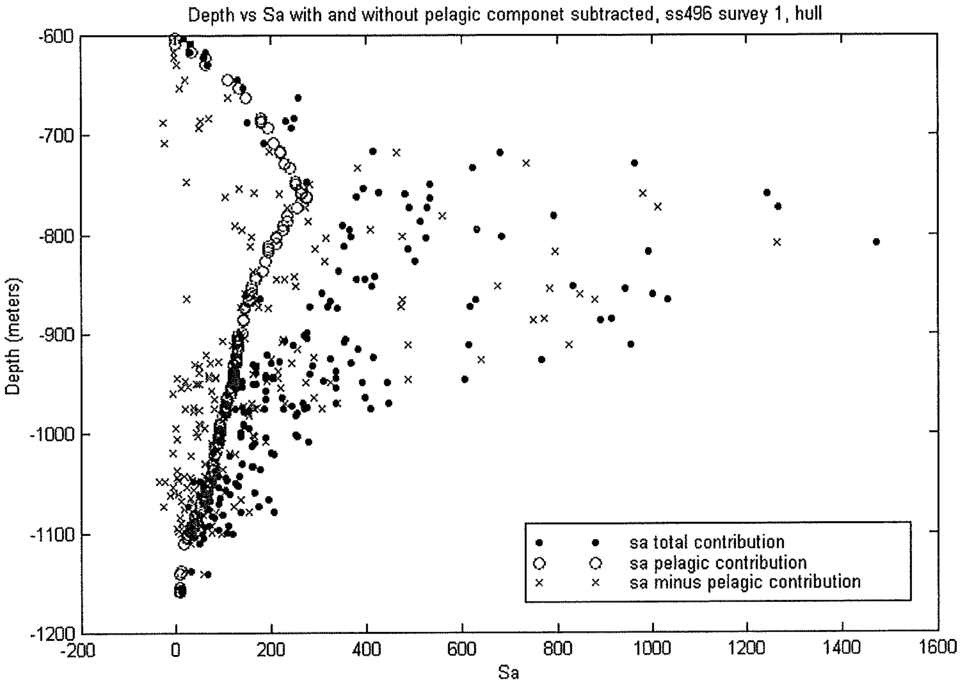
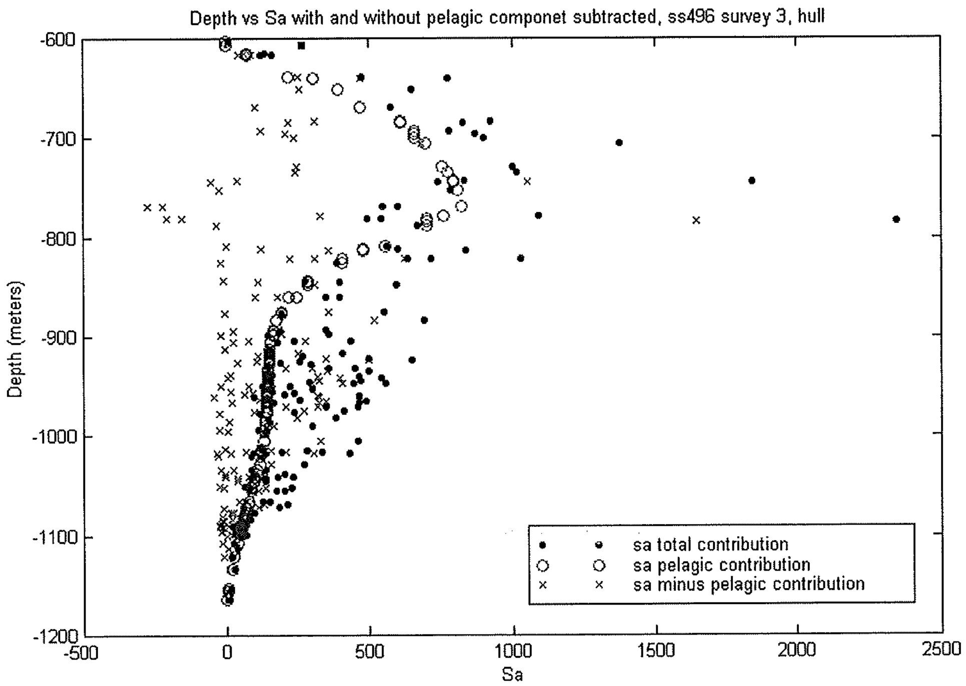


Figure 4.3.1-4 Survey 3 Sa Values by Depth, With and Without Pelagic Contribution.



4.3.2 St Helen's Hill

4.3.2.1 Hill Area Caclulation

The 100 m depth stratified areas of the hill were previously calculated from GPS referenced data in 1990, Kloser 1996, with overall boundaries defined by the extent of coverage of the transects. After reviewing the trawl catches in 1996, the hill was divided into two sectors with areas calculated for each 100-m depth stratified region. The boundaries of the hill, Table 4.3.2.1-1, were also changed to reflect the extent of schools that are associated with orange roughy. Table 4.3.2.1-2 shows the combinations of areas and the changes introduced due to new bathymetric and GPS data. Figure 4.3.2.1-1 shows the transects for the surveys and the NW, SE bounded regions bounded by a line along 41.26S, 148.73E and 41.233S and 148.758E.

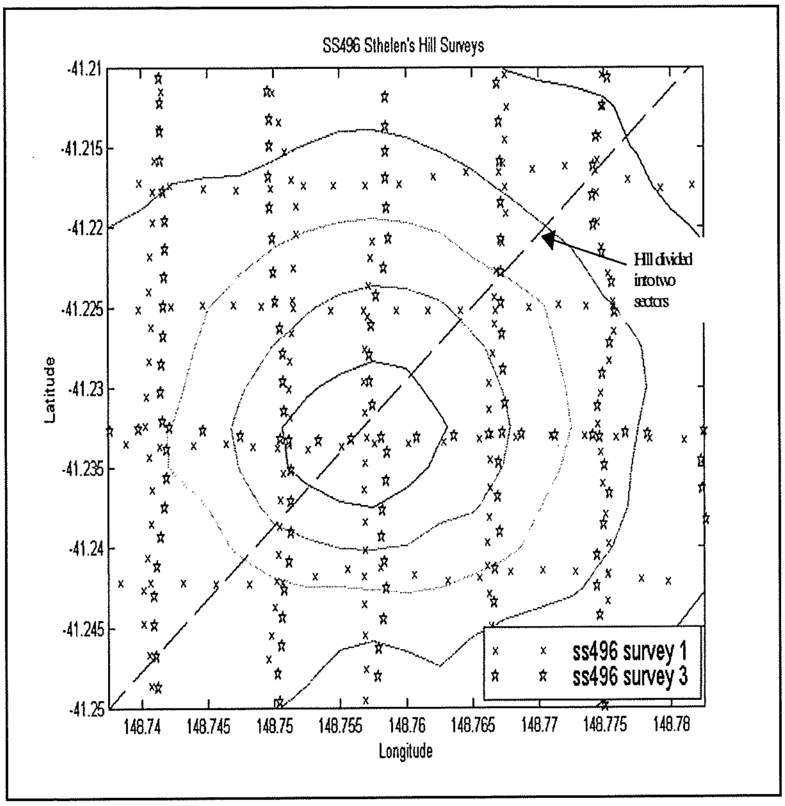
Table 4.3.2.1-1 Changes made to the calculation of the area used for St Helens Hill.

	Min Lat	Max Lat	Min Lon	Max Lon
Area constrained to	-41.2500	-41.2083	148.7375	148.7833

Table 4.3.2.1-2. Summary of Area Calculations Including Changes From Previous Calculations

Depth Region	Old area nm^2	NW region nm^2	SE region nm^2	New area nm^2	% change from old area nm^2
600					
700	0.25	0.15	0.13	0.29	1.15
800	0.45	0.28	0.20	0.49	1.08
900	0.7	0.46	0.33	0.78	1.11
1000	1.9	1.00	0.65	1.64	0.86
1100	2.6	0.90	1.06	1.98	0.76
Total	5.90	2.80	2.37	5.17	0.88

Figure 4.3.2.1-1 The transects and bathymetry used for Sthelens Hill biomass survey.



4.3.2.2 Species Composition

Twenty-two tows were carried out during the 1996 survey of the St. Helens hill, of which 15 contained > 20 fish. These were stratified by 100-m depth intervals and by the two sectors (N/NW and S/SE sectors of the hill). The percentage composition was determined by weighting the catches by total number caught. Table 4.3.2.2-1 summarises the catches for the three acoustically dominant species caught with the demersal trawl being orange roughy, whiptails and morids. Figure 4.3.2.2-1 shows the catch positions and the relative proportions of the dominant species.

Table 4.3.2.2-1. Percent composition of the three dominant species groups from the demersal trawl catch from St. Helens hill stratified by 100 m depth strata and by two hill sectors for depths between 700 and 1000 m. Depth strata between 700 and 900 m were combined in the N/NW sector. TS: target strength.

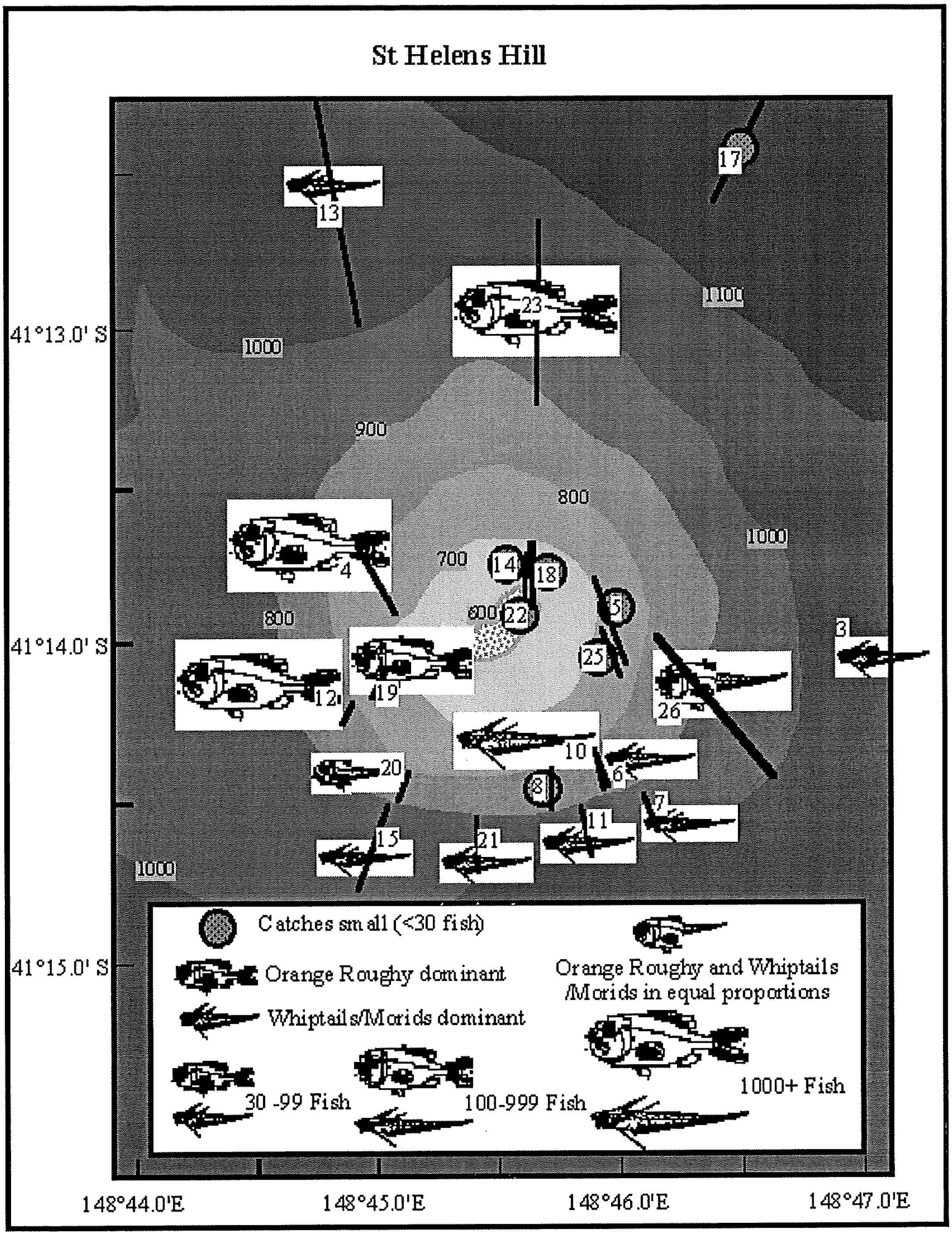
North/North West sector

	Orange Roughy	Whiptails	Morids
Weight (kg)	1.49	0.06	0.4
TS (dB)	-50	-44	-34.6
600-699 m	31.7	43.3	25.1
700-1000 m	99.4	0.2	0.4
> 1000 m	3.5	78.3	14.6

South/South East sector

	Orange Roughy	Whiptails	Morids
600-699 m	31.7	43.3	25.1
700-799 m	16.7	2.8	80.6
800-899 m	13.1	35.8	50.3
900-999 m	30.9	40.4	26.2
> 1000 m	3.5	78,3	14.6

Figure 4.3.2.2-1 Catch Positions and the Relative Proportions of the Dominant Species.



4.3.2.3 Acoustic Data

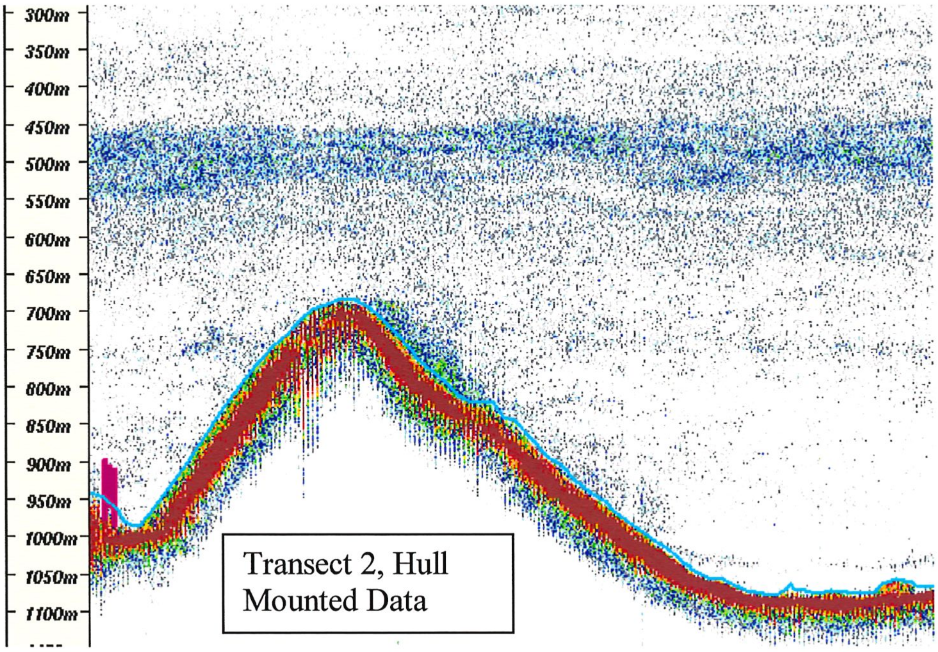
The dates and times of the acoustic surveys carried out on the St. Helens spawning ground and presented here are shown in Table 4.3.2.3-1. The dates are comparable to those on which acoustic surveys were carried out in previous years (1990-93), which ranged from 16 - 26 July (a survey carried out on 30 July 1991 is generally discounted for having missed the peak of spawning).

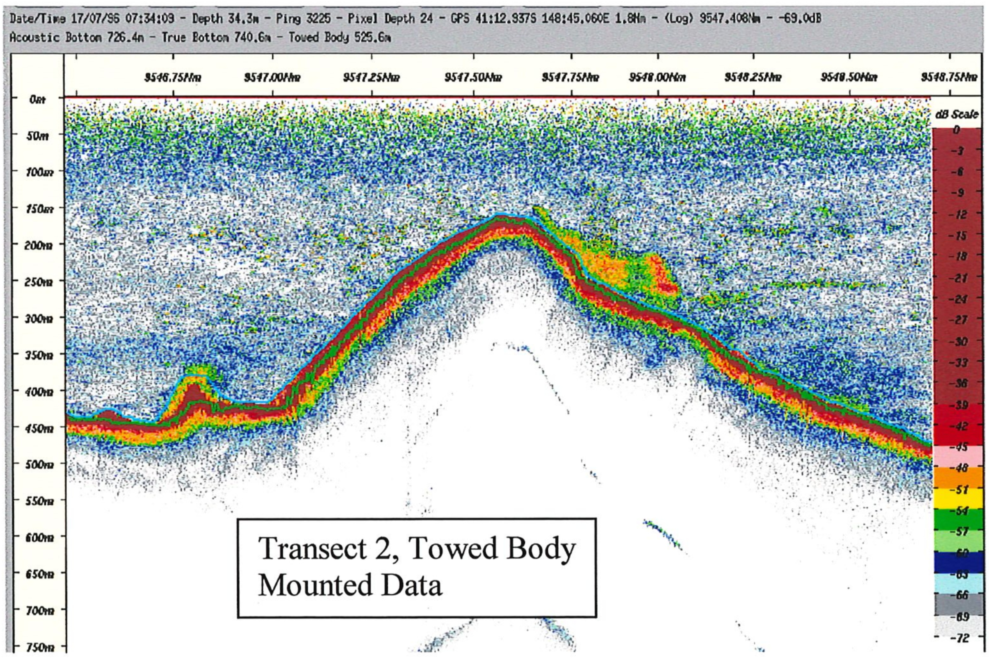
Table 4.3.2.3-1. St Helens acoustic surveys. Dates, times and number of transects. N: Night; D: Day.

	Vessel mounted		Towed transducer	
	1996-1	1996-3	1996-1	1996-3
Date	17-Jul	20-Jul	17-Jul	20-Jul
Start Time (hours) local	16:53	2:51	16:53	2:51
Stop Time (hours)	9:41	15:34	9:41	15:34
No. of Transects	12	8	8	8
Weeks from 1 July	3	3	3	3
Time Spanned	N-D-N	D-N	N-D-N	D-N

The acoustic data for both the vessel and towed transducers were quality checked, adjusted for calibration coefficients and summarised as outlined in section 3.2.2 and 3.3.3. The acoustic data quality for the deep-tow system was far superior than the vessel mounted transducer. Improved school recognition and reduced noise and acoustic shadow zone are clearly observed when using a deep-tow transducer, Figure 4.3.2.3-1. The towed transducer shows the orange roughy schools clear of the bottom whilst the vessel mounted system shows the orange roughy school blending into the bottom echo. The poor data quality from the vessel-mounted transducer greatly reduces our confidence in obtaining a biomass assessment from it as the stock is reduced to very small school sizes.

Figure 4.3.2.3-1 Shows the difference in data quality between the vessel mounted and towed below transducers. The school definition and smaller near seabed interference zone is clearly shown by the distinct school from the towed transducer being well clear of the bottom echo.





The contour plots of the 0.1 nm acoustic backscatter, Figure. 4.3.2.3-2, shows the distribution of acoustic marks as observed from the two vessel mounted and two towed transducer surveys.

These surveys can be compared to previous years assessments by observing the contour plots in Figure. 4.3.2.3-3.

Figure 4.3.2.3-2, shows the distribution of acoustic marks as observed from the two vessel mounted and towed transducer surveys for ss496, surveys 1 and 3

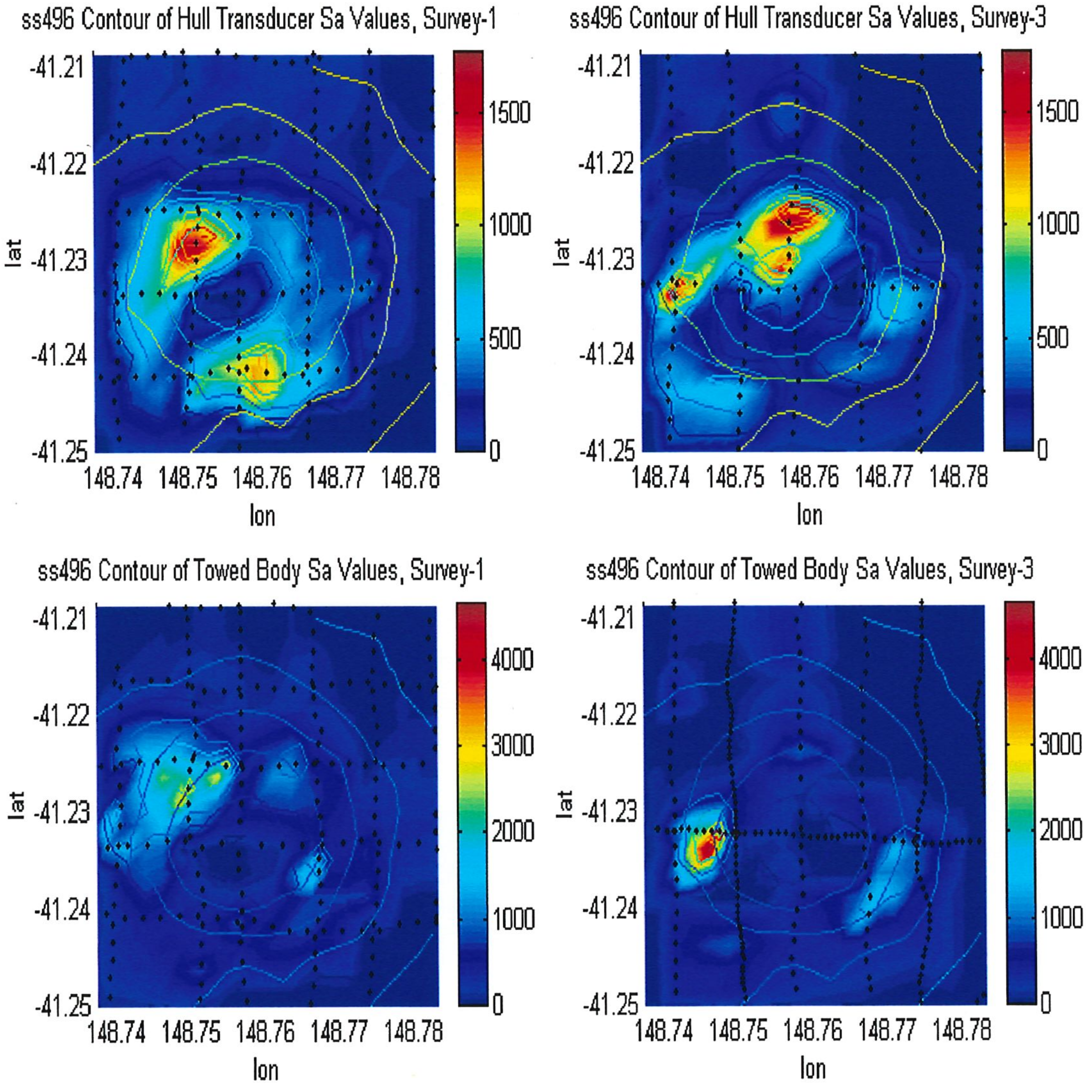
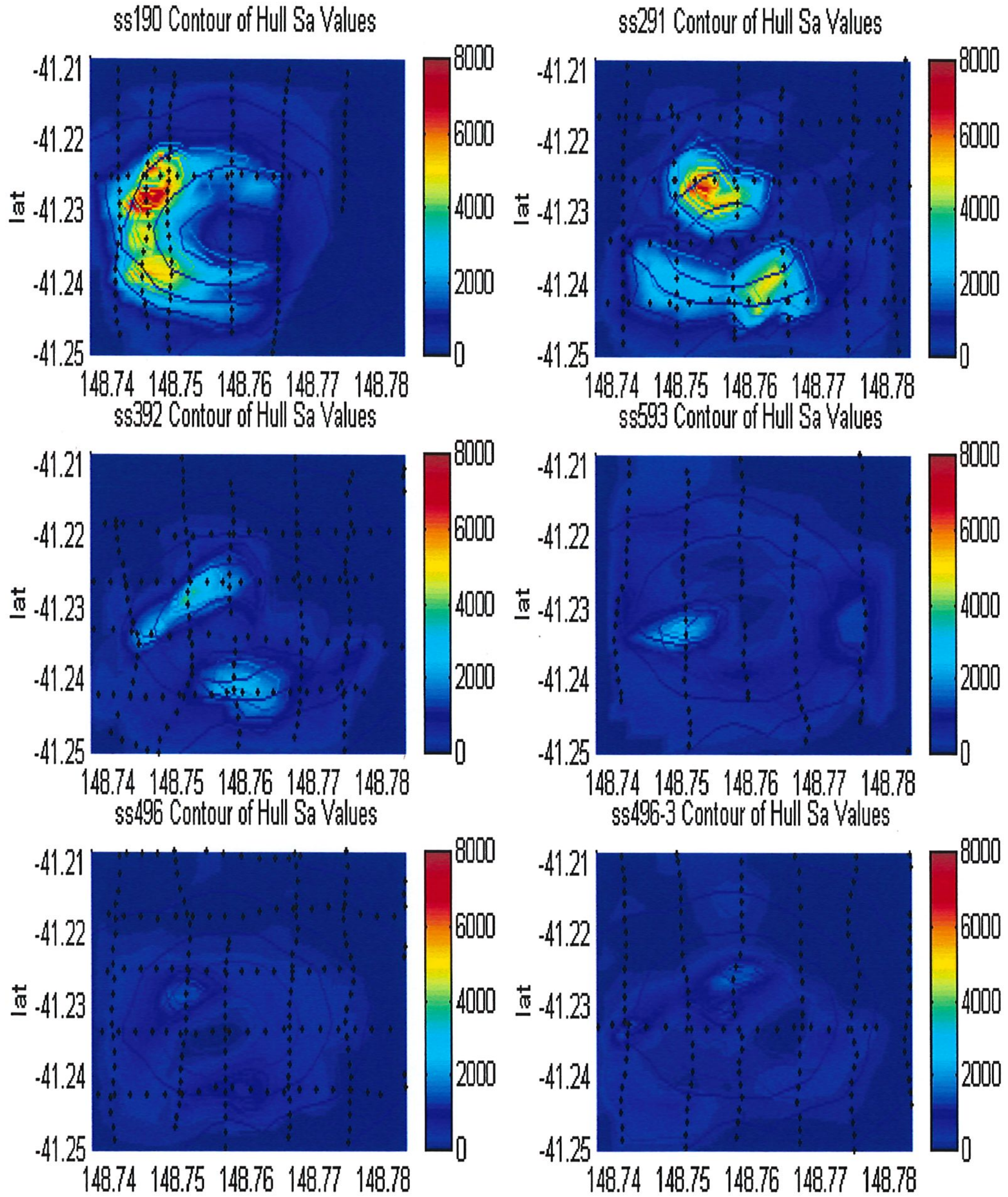


Figure 4.3.2.3-3, shows the distribution of acoustic marks as observed over the last six years.



4.3.2.4 Biomass Assessment

The biomass of orange roughy on St Helens Hill was calculated from the methods as outlined in 3.3.3 using the areas calculated in 4.3.2.1 and the species composition, weight and target strengths as outlined in 4.3.2.2 and the acoustic data in 4.3.2.3. Table 4.3.2.4-1 outlines the summary of the results. The amount of extrapolation caused by the shadow zone for both the vessel and towed transducers is given in Table 4.3.2.4-2.

Table 4.3.2.4-1

Hull Mounted - North + Plus South sectors, Pelagic Component Subtracted, New Species Compositions

	Depth					
	600-699	700-799	800-899	900-1000	>1000	Total
Area(n mile^2)	0.29	0.48	0.78	1.64	1.98	5.17
Sa (m^2) Survey						Mean Sa
1996-1	24	266	432	423	103	1248
1996-3	130	108	362	474	85	1159
Biomass(t)						Total Biomass
1996-1	6	1769	2505	2071	5	6356
1996-3	32	1099	2866	2515	4	6517

Towed Body –North + Plus South sectors, Pelagic Component Subtracted, New Species Compositions

	Depth					
	600-699	700-799	800-899	900-1000	>1000	Total
Area(n mile^2)	0.29	0.48	0.78	1.64	1.98	5.17
Sa (m^2) Survey						Mean Sa
1996-1	56	439	562	529	182	1769
1996-3	-11	63	712	333	98	1194
Biomass(t)						Total Biomass
1996-1	14	2416	3865	3403	9	9706
1996-3	-3	869	4682	96	5	5649

Table 4.3.2.4-2 Summary Table – Percentage Dead Zone for Hull and Towed Body.

	Hull			Towed Body		
Year	North	South	Mean DZ Nth + Sth	North	South	Mean DZ Nth + Sth
1996-1	27	32	29.5	16	17	16.5
1996-3	25	28	26.5	17	19	18

4.3.2.5 Comparison with previous surveys

Two aspects of the 1996 survey relative to prior surveys (1990-93) should be noted: the marked change in species composition and continued decline in biomass on the spawning ground.

Previous acoustic biomass assessments assumed that orange roughy comprised 96-99% of acoustic scatterers (other than myctophids) at depths between 700 and 1000 m. This is a critical assumption: because orange roughy, unlike the dominant morid cods and macrourids, lacks a gas-filled swimbladder, its target strength is relatively low and the estimate of its biomass is very sensitive to changes in estimates of community composition (Figure 4.3.2.5-1). Trawl samples were obtained in 1990-92 (the 1993 survey was carried out opportunistically because the RV *Southern Surveyor* was in transit past the spawning ground at the critical spawning time). However, of the 20 successful trawls carried out to assess species composition between 1990 and 1992, 12 were obtained in 1990 at the peak of the fishery. Of these trawls (none of which were at depths > 1000 m), all but one, which was carried out at < 700 m depth, contained ≥96% orange roughy. This led to the conclusion that the acoustic marks were overwhelmingly composed of orange roughy. In the 1991 and 1992 surveys, trawls at > 1000 m indicated that macrourids and morids were dominant at these depths. Only five research trawls were carried out at lesser depths. Orange roughy was not predominant in all these trawls but entirely dominated the largest shots, so the assumption of orange roughy predominance in all sectors was maintained in the assessment. Was this assumption warranted? Was the change in species composition in the S/SE sector of the spawning ground anomalous in 1996 or was it to be expected as a consequence of the fishdown from 1990 to the present, if one assumes a constant background abundance of macrourids and morids? In fact, a simple model indicates that the transition from the 1990 to 1996 species composition is consistent with the fishdown process.

To construct our best time series for the fishdown of the St. Helens spawning aggregation, we used both the hull-mounted and towed transducer surveys (Figure 4.3.2.5-2). The pelagic layers were excluded from all survey data and the species composition was based on the 1990 and 1996 trawl surveys, the species composition in the intervening years being interpolated from the relative proportion of the stock that was fished down based on available catch data and published estimates of virgin stock size (Kloser et al. 1996). Although the data frm the deep-towed transducer surveys are of higher quality, there was no survey with the towed body in 1990 and the towed-body survey in 1991 was conducted late in the season (30 July) and is therefore of dubious value. It should be noted that the declining trend from the towed body is steeper from 1992 to 1996 than from the hull-mounted transducer. This is believed to reflect the actual state of affairs, due to the combination of the approximately two-fold greater acoustic dead zone in surveys carried out with the hull-mounted transducer and the decreased height of the aggregations as the stock is fished down such that the hull-mounted system is able to detect little that is meaningful at low stock size in recent years

Is the Eastern Zone orange roughy stock continuing to decline? If so this is a matter of great concern, since the stock assessment (Bax 1997) indicates the stock would then likely be at les than 20%of its original size. The industry has argued that a substantial proportion of the spawning stock was at the St. Patrick's Head ground at the time of the survey and that, although no fishing occurred in August (and only a single trawler was on the spawning ground at the time of the survey), that there was a greater body of fish on the hill in early August, a period significantly beyond the period of peak spawning observed in previous years. Acoustic surveys were not carried out previously off St. Patrick's Head and a reliable estimate of the stock in this area cannot be obtained. What could account for a continued decline in the stock?

The TAC has been reduced to the point that the stock should be re-building. However, this assumes an 'average' level of recruitment that has in fact not been observed. Furthermore, Marine Police investigations and successful prosecution of industry for mis-reporting catch in 1993 indicate that actual removals from the stock may be substantially larger than the TACs indicate. This is disputed by the industry (Bax 1997). Clearly it is a matter of some urgency that the status of the stock be clarified.

4.3.3 St Patricks Head

Only one school that appeared to be associated to orange roughy was observed in the two surveys of the area. This school was half the diameter and one-third the intensity of the largest school encountered at St. Helens. The biomass of this school, assuming it was circular, would be 6% of the biomass of the largest school encountered at St Helens Hill (Figure 4.3.3-1). This result indicates a relatively small proportion of orange biomass was off St. Patrick's Head at the time of the survey. However, the result needs to be treated with caution given the single aggregation observed and the limited school identification at St. Patricks Head.

4.3.4 Transects from St Helens to the Southern Zone

Acoustic transects were conducted between St Helens and the Southern Zone. Apart from a school at St Patricks Head no acoustic marks were encountered that could be associated to orange roughy. Hence, no further analysis has been carried out on these data.

4.3.5 Southern Zone

The survey of the Southern Zone was interesting for the complete lack of acoustic scatters around the hills. From visual inspection, none of the hills surveyed had any acoustic marks of note. In particular Main Matt, who is usually very active, was characterised by a complete lack of acoustic marks. Due to the lack of any appreciable acoustic marks, the acoustic data were not processed. The low acoustic biomass is supported by very low catches from the commercial trawls. A summary of the catch from the trawls is given in table 4.2.1-3.

5 BENEFITS

The orange roughy sector of the SEF are the primary beneficiaries of the proposed research. This fishery remains the most valuable component of the SEF. A current stock assessment is required to ensure on the one hand that the maximum sustainable TAC is extracted from the resource and to protect the stock from collapse, on the other hand. Given that each 1000 tonnes of quota has a value of several million dollars, the potential benefit of proper management is considerable.

The full direct benefit of the research will be within the SEF. However, the development of multi-frequency methods of species discrimination in acoustic surveys could significantly improve the stock assessment of other species, for which acoustic surveys are undertaken.

6 INTELLECTUAL PROPERTY

Intellectual Property created from this Project include the results from the acoustic surveys. These results have been incorporated in this Report. While the development of multi-frequency techniques may have commercial applications for species identification and application in future acoustic surveys, if a project is approved to commercialise the multi-frequency method then CSIRO and FRDC will need to negotiate the details regarding commercial exploitation for that project.

7 FURTHER DEVELOPMENTS

This research project has implications in two primary directions, namely for the orange roughy stock assessment and more generically, to improvements in acoustic survey methodology. The present survey indicates that stock size may be significantly lower than was previously believed. This is not accepted by the industry. In view of the many assumptioins underlying the survey and the implications of stock size falling significantly below 20% of its virgin biomass, it will likely be necessary to repeat the survey.

More positively, the ability to use multi-frequency acoustics to discriminate among species groups is a substantial advance. Species composition is probably the most critical and most difficult factor to assess due to the problems in sampling fish without bias, particularly above the bottom. Further research to consolidate these results could lead to a major advance in our deepwater stock assessment capability.

8 STAFF

Name	Skills relevant to project	% year spent on project	
		FRDC	CSIRO
Tony Koslow	Project Leader, survey design and biological interpretation.	7.5	7.5
Rudy Kloser	Acoustics specialist: oversee acoustic surveys, data analysis, multi-frequency system development	12.5	12.5
Alan Williams	Acoustic surveys: biological sampling (length frequency analysis; swimbladder type); relation to acoustics	7.5	7.5
Ian Helmond	Design and development of the multi-frequency towed body	10	5
Alan Poole	Acoustics/electronics technician: maintain and operate acoustic system (50%); construct towed body for multi-frequency acoustics (50%)	50	
Kathy Haskard	Statistical consultant	5	0
Tim Ryan	Data base manager/analyst /programmer: maintain and analyse acoustic data	50	
Mark Lewis	Biological technician. Assistance in field survey	10	
Paul Sakov	Programming ECHO. Development of multi-frequency software tools.	25	
Alex Terauds	Biological technician assistance in field (survey)	10	

9 APPENDIX A

Absorption and Sound Velocity Data

Six CTD stations were performed throughout the cruise, three at St Helens Hill and three at the Southern Hills as per Table 9-1. Absorption and sound velocity profiles were calculated as per 3.2.2, using MatLab scripts which are based on the formulas of Francois and Garrision.

Table 9-1 Location of CTD drops for acoustic surveys at St Helens and the Southern Hills

CTD Number	Location	Date	Time	Lat	Lon	Data File*
1	St Helens	18-Jul-96	0520 hrs (UTC)	41:15.10S	148:45.42E	s496ctd1.txt s496ctd1.dat
2	St Helens	18-Jul-96	0622 hrs (UTC)	41:16.87S	148:45.62E	s496ctd2.txt s496ctd2.dat
4	St Helens	21-Jul-96	2135 hrs (UTC)	41:14.19S	148:52.11E	s496ctd4.txt s496ctd4.dat
5	Southern Hills	25-Jul-96	0032 hrs (UTC)	44:15.26S	146:05.20E	s496ctd5.txt s496ctd5.dat
6	Southern Hills	26-Jul-96	0811 hrs (UTC)	44:12.45S	147:06.94E	s496ctd6.txt s496ctd6.dat
7	Southern Hills	28-Jul-96	2133 hrs (UTC)	44:17.01S	147:19.64E	s496ctd7.txt s496ctd7.dat

- Note: *.txt files contain header information plus ctd raw data, while *.dat files have header information removed and if necessary, gaps filled in with averaged values. The *.dat files are ready for loading into MatLab.

Table 9-2: St Helens Hill. Sound Velocities at Depth Hull Transducer

Depth Below Transducer	Mean Sound Speed	Standard Deviation	Number of CTDs
600	1498.971	0.551	3
700	1498.049	0.559	3
800	1497.159	0.527	3
900	1496.229	0.558	3
1000	1495.404	0.887	2

Table 9-3: St Helens Hill. Sound Velocities at Depth Towed Body Transducer
Towed Body at 450 meters

Depth Below Transducer	Mean Sound Speed	Standard Deviation	Number of CTDs
150	1494.368	0.776	3
250	1493.647	0.765	3
350	1492.888	0.673	3
450	1491.992	0.743	3
550	1491.353	0.996	2

Table 9-4: St Helens Hill Absorptions at depth Transducer : 38khz Hull

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
600	9.469	0.020	3
700	9.461	0.019	3
800	9.447	0.018	3
900	9.430	0.017	3

1000	9.406	0.025	2

Table 9-5: St Helens Hill Absorptions at depth
Towed Body Depth = 450m Transducer : 38khz Towed Body

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
150	9.471	0.023	3
250	9.446	0.022	3
350	9.419	0.018	3
450	9.391	0.018	3
550	9.353	0.021	2

Table 9-6: St Helens Hill Absorptions at depth Transducer : 120khz Hull

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
600	38.615	0.191	3
700	37.780	0.191	3
800	36.976	0.178	3
900	36.184	0.182	3
1000	35.446	0.279	2

Table 9-7: St Helens Hill Absorptions at depth
Towed Body Depth = 450m Transducer : 120khz Towed Body

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
150	34.630	0.258	3
250	33.904	0.248	3
350	33.188	0.215	3
450	32.456	0.228	3
550	31.827	0.291	2

Table 9-8: St Helens Hill Absorptions at depth Transducer : 12khz Hull

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
600	1.225	0.005	3
700	1.232	0.005	3
800	1.239	0.005	3
900	1.247	0.005	3
1000	1.253	0.008	2

Table 9-9: St Helens Hill Absorptions at depth
Transducer depth is 450 meters Transducer : 12khz Towed Body

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
150	1.261	0.007	3
250	1.267	0.007	3
350	1.273	0.006	3
450	1.281	0.007	3
550	1.286	0.010	2

Summary of Southern Hills Sound Velocities and Absorption

Table 9-10: Southern Hills. Sound Velocities at Depth

Depth Below Transducer	Mean Sound Speed	Standard Deviation	Number of CTDs
600	1492.498	0.323	3
700	1492.407	0.215	3
800	1492.301	0.156	3
900	1492.063	0.084	3
1000	1491.708	0.164	3

Table 9-11: Southern Hills. Sound Velocities at Depth. Towed Body

Towed Body Depth = 450 meters

Depth Below Transducer	Mean Sound Speed	Standard Deviation	Number of CTDs
150	1492.400	0.284	3
250	1492.186	0.408	3
350	1492.010	0.434	3
450	1491.608	0.554	3
550	1491.052	0.716	3

Table 9-12: Southern Hills Absorptions at depth Transducer : 38khz Hull

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
600	9.705	0.012	3
700	9.662	0.009	3
800	9.620	0.007	3
900	9.579	0.003	3
1000	9.539	0.001	3

Table 9-13: Southern Hills Absorptions at depth
Towed Body depth is at 450 meters. Transducer : 38khz Towed Body

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
150	9.516	0.007	3
250	9.473	0.011	3
350	9.430	0.011	3
450	9.391	0.013	3
550	9.353	0.014	3

Table 9-14: Southern Hills Absorptions at depth Transducer : 120khz Hull

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
600	36.321	0.117	3
700	35.782	0.081	3
800	35.248	0.061	3
900	34.690	0.031	3
1000	34.112	0.033	3

Table 9-15: Southern Hills. Absorptions at depth.
Towed Body depth is 450 meters Transducer: 120 Khz Towed Body.

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
150	33.967	0.091	3
250	33.409	0.128	3
350	32.878	0.134	3
450	32.296	0.165	3
550	31.688	0.206	3

Table 9-16: Southern Hills Absorptions at depth Transducer : 12khz Hull

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
600	1.281	0.003	3
700	1.281	0.002	3
800	1.281	0.001	3
900	1.282	0.001	3
1000	1.284	0.002	3

Table 9-17: Southern Hills. Absorptions at depth.
Towed Body depth is 450 meters Transducer: 12 Khz Towed Body.

Depth Below Transducer	Mean Absorption	Standard Deviation	Number of CTDs
150	1.277	0.003	3
250	1.278	0.004	3
350	1.279	0.004	3
450	1.281	0.005	3
550	1.286	0.007	3

10 APPENDIX B

Calibration Results

The Simrad EK500 is the main acoustic instrument connected to transducers located on the vessel and on deep water towed transducers. The specifications of the transducers are detailed in Table 10-1.

Table 10-1. Transducer Information

Transducer	Manufacturer	Locations	Equivalent Beamwidth	Beamwidth
120Khz	Simrad	Hull	-18.5	11.2
38kHz	Simrad	Hull	-20.7	7.1
12kHz	Simrad	Hull	-13.2	16/17.5
120kHz	Simrad	Towed Body	-20.6	7
38Khz	EDO western	Towed Body	-21.1	6.5
12kHz	MASA	Towed Body	-10	40
38kHz	Simrad	Pole	-20.7	7.3

Table10-2. Definition of Pulse Length Names for Three Frequencies – Simrad EK500

	Pulse Length (ms)		
Frequency	Short	Medium	Long
12 kHz	1	3	10
38kHz	0.3	1	3
120kHz	.1	.3	1

Table 10-3. Definition of Pulse Length Names for Three Frequencies – Towed Body

	Pulse Length (ms)	
Frequency	Short	Long
12 kHz	1	3
38kHz	.3	1
120kHz	.3	1

Table 10- 4. Definition of Bandwidth Names for Three Frequencies – Simrad EK500

	Bandwidth (kHz)	
Frequency	Wide	Narrow
12 kHz	1.2	0.12
38kHz	3.8	0.38
120kHz	12	1.2

A summary of all the calibration results for the vessel mounted transducers for various combinations of pulse lengths and bandwidths is given in Table 4.

Table 10-5. Summary of Hull Mounted Surface Calibration Results.

Date	Frequency	Pulse Length	Bandwidth	Depth to Sphere	SVc	TSc
Jul-90	38	short	wide	15.3	26.8*	26.8
Jul-90	38	medium	wide	15.4	27.9*	27.9
Jul-90	38	medium	narrow	15.6	27.7*	27.7
Jul-90	38	long	narrow	15.8	27.4*	27.4
Jul-91	38	long	narrow	14.9	27.7	27.3
Aug-91	38	long	narrow	14.9	27.8	27.4
Jul-92	38	long	narrow	14.5	27.8	
Jul-92	38	medium	wide	14	27.6	27.7
Aug-92	38	long	narrow	14.6	27.3	26.9
Oct-94	120	long	narrow	21.09	22.4	
Oct-94	120	medium	wide	21.09	22.6	
Oct-94	38	medium	wide	21.09	27.2	
Oct-94	38	long	narrow	21.09	26.8	
Nov-94	120	medium	wide	19.74	22	22.1
Nov-94	120	short	wide	19.74	22.4	22
Nov-94	120	long	narrow	19.8	22.2	22.2
Jan-96	120	long	narrow	18.96	22.8	22.6
Jan-96	38	medium	wide	18.6	27.3	27.1
Jan-96	38	short	wide	18.7	27	26.4
Jan-96	38	long	narrow	19.5	27.3	26.9
Jan-96	38	long	wide	19.1	27.5	27.4
Jan-96	120	medium	wide	18.96	22.8	22.6
Jan-96	120	short	wide	18.93	23	22.8
Jan-96	12	medium	wide	18.5	13.4	N/A
Mar-96	12	medium	wide	16.5	13.2	N/A
Mar-96	38	medium	wide	17	27.1	
Mar-96	120	long	narrow	17.01	22.6	22.4
Aug-96	12	medium	wide	16.5	13.2	N/A
Jul-96	38	long	narrow	19.2	27.2	26.8

* To compare these 1990 SVc results with other years, 0.35 should be added to these SVc values. This has arisen because the Ideal Beamwidth was set to 20.0 whereas for subsequent years it was set to 20.7

Table 10-6. Summary of Towed Body Surface Calibration Results.

Date	Frequency	Pulse Length	Bandwidth	Depth to Sphere	SVc	TSc
1-Aug-96	38	medium	wide	6.3	29.3	29.1
1-Aug-96	120	medium	wide	6.2	20.5	20.8
1-Aug-96	120	long	narrow	6.1	24.1	23.8

Table 10-7. Towed Body TS vs Depth Corrections.

	EK500 Settings	Surface Calibration Results	Theoretical	Measured	ECHO Settings

Freq	Pulse Length	Svc_set	TSc_set	Svc	TSc	Sphere Depth	TS Sphere	Slope	Intercept	TS Intercept	Sv Intercept
38	Long	-	-	-	-	-	-42.35	-0.0052	-40.8093	-	-
38	Medium	31.7	31.5	29.3	29.1	6.3	-42.35	-0.00492	-40.2808	2.0692	2.0692
120	Long	23	23	20.5	20.8	6.21	-39.5	-0.00276	-44.5109	-5.01	-4.41
120	Medium	23	23	24.1	23.8	6.15	-39.5	-0.00534	-37.0662	2.4338	3.0338
12	Long	18.5	18.5	no result	no result	no result	-42	0	-62.3	-20.3	-20.3
12	Medium	18.5	18.5	no result	no result	no result	-42	0	-60	-18	-18

Notes:

Svc_set:	Sv value as set in EK500
TSc_set	TS value as set in EK500
Svc	Sv value determined from calibration
TSc	TS value determined from calibration
TS Sphere	Theoretical value of calibration target sphere
Slope	Slope of Depth vs TS relationship
Intercept	Intercept with y axis (ie TS) of Depth vs TS relationship
TS Intercept	Value that is entered into echo software for correction purposes
Sv Intercept	Value that is entered into echo software for correction purposes

Sv intercept and TS intercept should be set to the identical values if the difference between Sv_set and TS_set is the same as the difference between Svc and TSc calibration results. This is the case for the 38kHz. In this instance

TS Intercept = Intercept – TS Sphere

TS Intercept = -40.2808 - -42.35 = 2.0692 = Sv Intercept

For the 120kHz the Svc and TSc have been set to the same value. For this case for long pulse length:

TS Intercept = -44.5109 - -39.5 = -5.01

but for Sv Intercept   Sv Intercept = Intercept – TS Sphere – 2 * (Svc – TSc)

Sv Intercept = -44.5109 - -39.5 - 2*(20.5-20.8)

Sv Intercept = -4.41

The TS Slope and Sv slope are assumed to be the same so in the Echo worksheet calibration table the value of slope from Table 12-7 can be entered into both the TS Slope and Sv Slope fields.

12kHz slope and intercept values were not calculated from the plot of TS Comp vs Depth since the plot was not linear. For this frequency the average towed body depth was calculated for all the loops of Sthelen's Hill and this depth was used to find the corresponding TS Comp value on the plot of TS Comp vs depth.

Table 10-8. Instrument settings at commencement of cruise

Cruise	Freq	Date	Transducer Location	Power	absorption set	pulse length	bandwidth	Sv gain	TSc
ss9305	120	15-Jul-93	Hull	no info	no info	long	narrow	22.4	no info
ss9305	38	15-Jul-93	Hull	no info	no info	long	narrow	27.8	no info
ss9405	38	18-Aug-94	Hull	2000	10	medium	wide	27.8	27.4

ss9405	12	18-Aug-94	Hull	4000	1	medium	wide	13.3	13.3
ss9405	120	18-Aug-94	Hull	2000	37	long	narrow	22.4	22.1
ss9511	120	20-Nov-95	Hull	2000	40	long	narrow	22.6	no info
ss9511	38	20-Nov-95	Hull	4000	10	medium	wide	27.8	no info
ss9511	12	20-Nov-95	Hull	2000	1	short	wide	11.7	no info
ss9602	38	16-Apr-94	Hull	no info	9	medium	wide	27.2	27.1
ss9602	12	16-Apr-94	Hull	no info	1	medium	wide	13.3	no info
ss9602	120	16-Apr-94	Hull	no info	43	long	narrow	22.7	22.5
ss9603	38	16-Apr-94	Hull	no info	9	medium	wide	27.2	27.1
ss9603	12	16-Apr-94	Hull	no info	1	medium	wide	13.3	no info
ss9603	120	16-Apr-94	Hull	no info	43	long	narrow	22.7	22.5
ss9604	38	16-Jul-96	Towed Body	2000	9	medium	wide	26.5	26.5
ss9604	38	16-Jul-96	Hull	2000	9	long	narrow	27.2	27
ss9604	12	16-Jul-96	Hull	2000	1	medium	wide	18.5	18.5
ss9604	120	16-Jul-96	Hull	1000	42	long	narrow	22.7	22.5
ss9604	38	17-Jul-96	Towed Body	2000	9	medium	wide	26.5	26.5
ss9604	38	19-Jul-96	Towed Body	2000	9	medium	wide	31.7	31.5
ss9604	12	19-Jul-96	Towed Body	2000	1	medium	wide	18.5*	18.5*
ss9604	120	19	Towed Body	500	42	long	narrow	23	23

notes: Sound Velocity was set to 1498 m s^{-1} for all cruises except for ss9604 Towed Body from 16-Jul-96 to 19-Jul-96 where the EK500_2 was set to 1444 ms^{-1}

* ss9604, 12kHz hull was set to 18.5 while calibration results showed that it should have been set at 13.2

11 APPENDIX C

Matlab Scripts

Biomass

The following scripts are kept at f:/matlab/toolbox/biomass.

bio.m	fuction script to calculate the biomass of the hull mounted data for survey data.
bio_all	macro style m file to run survey_biomass.m for all surveys.
calc_biomass	script to calculate the biomass
contour_bio_layers_hull.m	macro style script to contour up biomass at each integration interval for the six hull mounted surveys from 1990 to 1996.
contour_bio_layers.m	macro style script to contour up biomass at each integration interval for the five towed surveys from 1990 to 1996.
contour_hull_surveys.m	macro style script to contour up Sa values for the six hull mounted surveys from 1990 to 1996.
contour_tb_surveys.m	macro style script to contour up the Sa values for the five towed body surveys from 1990 to 1996.
contour_ss496_surveys.m	macro style script to contour up the hull mounted and towed body Sa value surveys for 1996.
correct_layers.m	function to apply corrections to the layers matrix according to cruise,survey_number and transducer location.
correct_sa.m	function to apply Simrad TVG corrections to the sa values depending in cruise,survey_number and transducer location.
correct_ss190_hull.m	script to 1) set dz height according to the mean of 1991,1992 and 1993 and 2) make corrections for absorption and noise (this was automatically done in ECHO in subsequent years.
correct_tb_position	script to pass corrected towed body positions into the layers matrix
create_bio_layers_tb.m	script to produces a vector of sa values that are attributed only to the roughy contribution. For a given sa value find out what depth range and sector of the survey area it lies in. using the

	appropriate species compostion file, find the proportion of orange roughy in the depth range of our sa value.
create_mat.m	script to create a mat file with all the desired variables for north, south and combined sectors of St Helens Hill.
create_mat_all_surveys	macro style m file to run create_mat.m for all surveys.
decode_layers.m	script to separate out the various variables from the layers matrix.
dz_contribution.m	script to summarize and compare the contribution of the dz to the total Sa. For each survey year load up the biomass_survey_year_survey_num.mat file for each sector calculate the mean sa and mean dz and print to the screen with tab delimiters so that it can be readily imported into excel.
final_plots	script to plot up the final outputs for Sthelens hill surveys.
fixlay	Load a composite echo layer processing file. convert a 0.1 nm log file into a bottom contour file suitable for StHelens.m to perform biomass calculations.
pelagic.m	Estimates the contribution of pelagic biota to the acoustic signal of depth contoured 100 m by 150 m height data.
pelagic_dz.m	Estimates the contribution of pelagic biota to the acoustic signal.of depth contoured 100 m by 150 m height data.
pelagic_sa.m	Estimates the contribution of pelagic biota to the acoustic signal of depth contoured 100 m by 150 m heigh data.
plot_all_ship_tracks.m	script to plot up all the ships tracks for all the surveys includes different color for ships track in northern and southern sectors.
plot_biomass_results.m	script to provide summary plots of the output of survey_biomass.m
plot_pelagic_profiles.m	script to plot up all the pelagic profiles for all surveys.
plot_survey_summaries_hull.m	script to create summary plots of survey data for Sthelens Hill for the surveys ss190 to ss496
remove_nans.m	script to remove rows which contain nans either of mean bottom depth sa or dz sa's
set_area.m	function to set to NaN's any layers.dat values outside a defined area of interest
set_north.m	function to remove any rows in layers that are NOT in the northern sector

set_south.m	function to remove any rows in layers that are NOT in the southern sector.
shiptrack_over_bathy	plot up the contour of the hill bathymetry for ss496 with shiptrack over the top
summary_plot.m	script to take the relevant values in sa_hull.txt and bio_hull.txt and plot out just the total biomass and sa values (with error bars) for all survey years.
summary_plot_tb.m	script to take the relevant values in sa_tb.txt and bio_tb.txt and plot out just the total biomass and sa values (with error bars) for all survey years.
summary_plots.m	script to provide summary plots of biomass and sa's for surveys 1990 to 1996.
summary_results_hull.m	script to summarise results for survey_biomass for all years results are saved in sa_hull.txt and bio_hull.txt.
summary_results_tb.m	script to summarise results for survey_biomass for all years.results are save in sa_tb.txt and bio_tb.txt.
survey_biomass.m	script to calculate the biomass of the hull mounted data for survey data.
survey_biomass_all_surveys	macro style m file to run survey_biomass.m for all surveys.
survey_times_bar_graph.m	script to plot out the time of survey for the surveys from 1990 to 1996.
tb_posn.m	script to calculate lat and lons for the the tb for ss496, sthelens hill
layback.m	script to allow the user work out the layback of the tb by viewing bathymetry plots of tb and hull data for a user specified transect

Biomass/Low_Level_Functions

The following scripts are kept at f:/matlab/toolbox/biomass/Low_Level_Functions.

compsig	Compute the Composition sigma.
l_decode_bottom	Extracts the mean bottom depths at each integration interval of an echo processing file.
l_decode_dz	Extracts the dead zone SA and dead zone heights at each integration interval of an echo processing file.
l_decode_header	Extracts header information from the header file. This describes how the processing of the layers was performed.

l_decode_hills	Builds a list of start and stop indexes for each hill.
l_decode_log	Extracts the vessel log information, and computes the difference between integration intervals, and the total length of each transect.
l_decode_nav	Decode the navigation information from a composite Echo processing file.
l_decode_pings	Decode the number of pings from a composite Echo processing file.
l_decode_sa	Decode the SA information from a composite Echo processing file
l_decode_transects	Decode the identifier information from a composite Echo processing file.
l_depth_partition	Create a vector of indexes.
l_hull_area	Compute an effective area for each contour interval weighting each transect area by the number of transects per hill.
l_strata_area	Compute the mean biomass for each contour level.
l_strata_biomass	Compute the Biomass for each species.
l_strata_mean	Compute the mean value of the parameter x for each strata.
l_strata_sa	Computes the Mean Sa and the variance for each strata.
l_summary	Write summary support of the results
l_trans_area	Compute an effective area for each contour interval. The area is computed as a quadrant of pi/2.
l_weight_sa	Compute the 'weighted' Sa's.
l_weights	Compute the Layer weights for each transects section.

Echo Utilities

The following scripts are kept at f:/matlab/toolbox/echoutil

absorp	- calculates the sound speed and absorption
calerror	- calculates the calibration error from Simrad
noise	- noise refered to 1m
noisecal	- noise refered to 1m in dB re 1 uPa

sa_calc	- calculates the Sa for a given Sv and depth of integration
sserror	- sound velocity error
sv_error	returns the error for vessel and towed transducers
sv	- calculates the Sv for a given Sa and depth of integration
tvg20log	- TVG gain calculation
fish_per_sample_vol.m	convert an sa value into number of fish per sample volume

General

The following scripts are kept at f:/matlab/toolbox/general

nanmax	Maximum value of matrix columns or two matrices, ignoring NaNs
nanmin	Minimum value of matrix columns or two matrices, ignoring NaNs
nanmean	Mean value of matrix columns, ignoring NaNs
nanstd	Standard deviation ignoring NaNs.
nansum	Sum of matrix columns, ignoring NaNs
nanrange	Finds min and max values, ignoring NaNs.
subset	Plot up two variables, x,y. Using the zoom function zoom into the desired area. At this point run subset.m to ouput only x and y data that is associated with the plot currently being view.

12 APPENDIX D

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