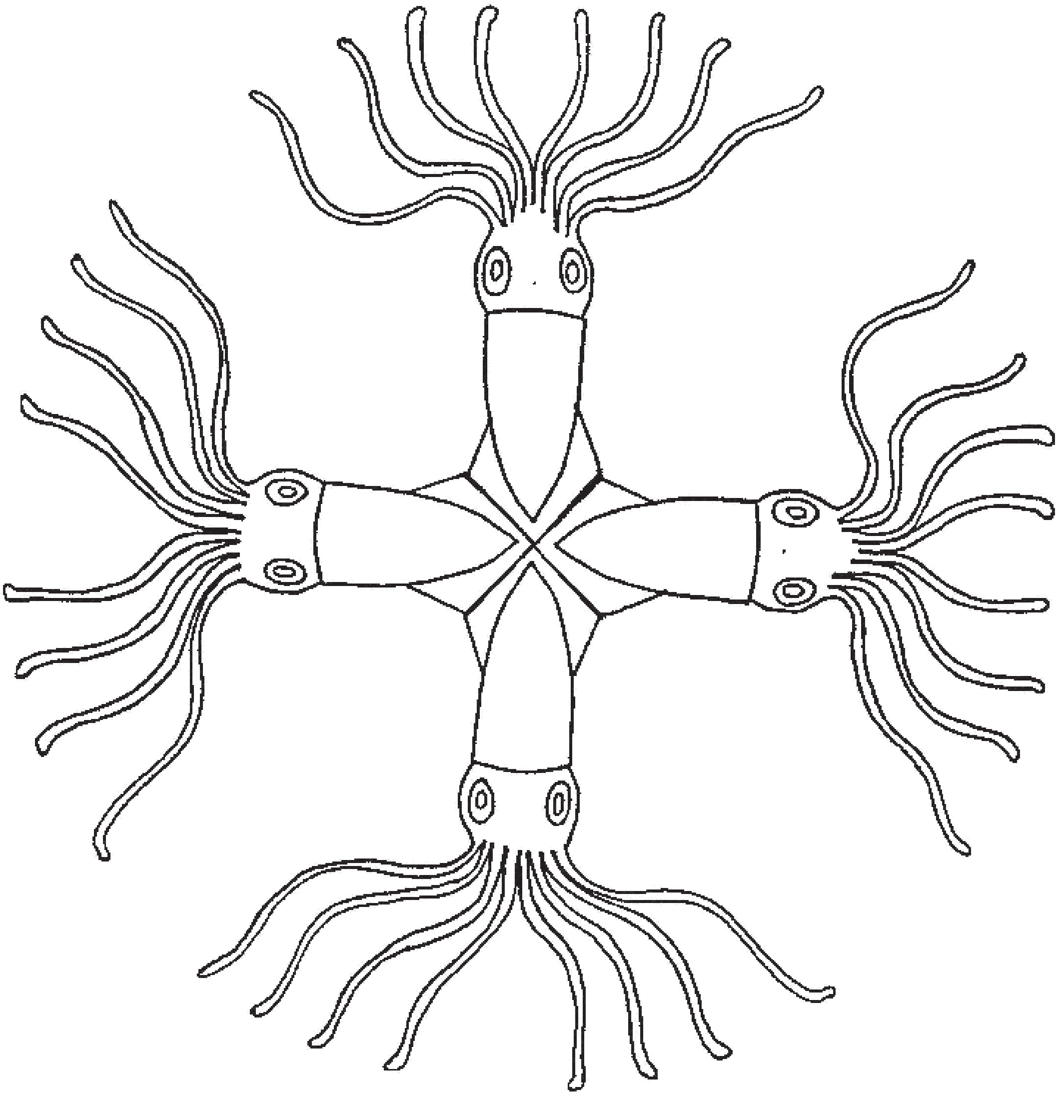
Scientific Report

Fisheries Research Cruise ZDLH1-06-1999



Fisheries Department

Falkland Islands Government

Scientific Report

Fisheries Research Cruise

ZDLH1-06-1999

FPRV Dorada

16 June to 6 July 1999

Fisheries Department

Falkland Islands Government

Stanley

Falkland Islands

Participating scientific staff (alphabetical):	***Principal author of section:***
Alexander Arkhipkin	1, 4.1
Paul Brickle	4.6
Catherine Goss (British Antarctic Survey)	3
Ryszard Grzebielec	2
David Middleton	3, 4.5, editor
Joost Pompert	4.2, 4.3, 4.4
Daniel Poulding	

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Preface

This report describes the activities and results of the research cruise carried out by the Scientific Section of the Falkland Islands Government Fisheries Department during late June and early July 1999. This was the first full research cruise carried out by the Department using the Fisheries Patrol and Research Vessel *Dorada*. Although this was necessarily somewhat of a trial period for the vessel, crew, and scientific staff of the Department, research of a wide-ranging nature was completed successfully.

The scientific report has been produced with the intention of wider circulation than previous FIFD research cruise reports. It is hoped that it will be of interest both to the wider scientific community and to the local fishing industry. One aim has been to produce a report within a reasonably short time period; it should be recognised that analyses of the data are continuing.

We wish to record our thanks to the masters, officers and crew of the *Dorada* for their hard work and enthusiastic participation during both phases of this research cruise.

Summary

The research cruise ZDLH1-06-1999 was conducted on board the Fisheries Protection & Research Vessel *Dorada* (a Polish-built stern trawler) in the beginning of the austral winter (16 June-6 July 1999). The main purpose of the cruise was to investigate the distribution, biological condition and abundance of the second cohort of the squid *Loligo gahi* (Loliginidae) during the feeding period in its principal feeding grounds located in the south-eastern and eastern parts of the Falkland Shelf (the "*Loligo* box"). Additionally, the distribution and size composition of the main by-catch finfish and elasmobranchs, and also parasitic worms infecting squid and skates were also studied.

It was found that the south-eastern and eastern parts of the Falkland Shelf (100-200 m depths) were occupied by a homogenic layer of cold and low-saline waters (mean temperature ~ 6°C and salinity 33.8-33.9‰). Over the continental slope (200-500 m depths), the surface water layers had the same characteristics, whereas near the bottom the temperature was lower (4.5-5.9°C) and salinity was higher (34.0-34.25‰).

Distinctive acoustic traces were observed during a number of trawls that were dominated by a single species, including *Dissostichus eleginoides*, *Loligo gahi* and *Macruronus magellanicus*. Aggregations observed at one station, and believed to be *Loligo gahi*, showed a mean difference in backscattering strength of +5.5dB at 120kHz relative to 38kHz.

Bottom trawl catches were generally low, reflecting quite a low abundance of both *L. gahi* and finfish within the "*Loligo* box". In total, at least 61 species of squid, fish, shellfish and other demersal invertebrates were caught. It was found that *L. gahi* catches varied with depth, being lowest at 100 m and highest at 200 m, with 300-m catches being intermediate in quantity. Small, immature, males and females (< 10 cm DML) tended to occur together at shallow depths (<200 m), and only in some particular regions. Larger squid (>10-11 cm DML) occurred mainly in other regions, and they were segregated by sex and by depth, with females feeding basically deeper (300 m depth) and males feeding shallower (200 m depth). Such a spatial segregation of small and large squid should prevent their competition for food resources and allow a decreased pressure of cannibalism during the feeding period.

Preliminary analysis of the *L. gahi* parasites revealed that generally the squid were clean from any parasitic worms; however, 13% of squid were infected by the trematode worm *Phyllobothrium* spp., and only 6% by the nematode worm *Anisakis simplex*.

Among finfish, the toothfish *Dissostichus eleginoides* was the most abundant. Small toothfish were captured in the shelf waters, and large specimens occurred in colder and more saline slope waters. The dogfish *Squalus avanthias* was most abundant at the southern entrance to Falkland Sound, adult females were either with fertilized eggs or embryos. A total of nine skates and rays species were caught during the cruise; *Bathyraja brachyurops*, *B. albomaculata* and B. *griseocuada* were the most abundant. Parasitological analysis showed that almost all rays and skates were infected by a digenean worm *Otodistomum plunketi* (with prevalence varying from 21 to 100% in the different species).

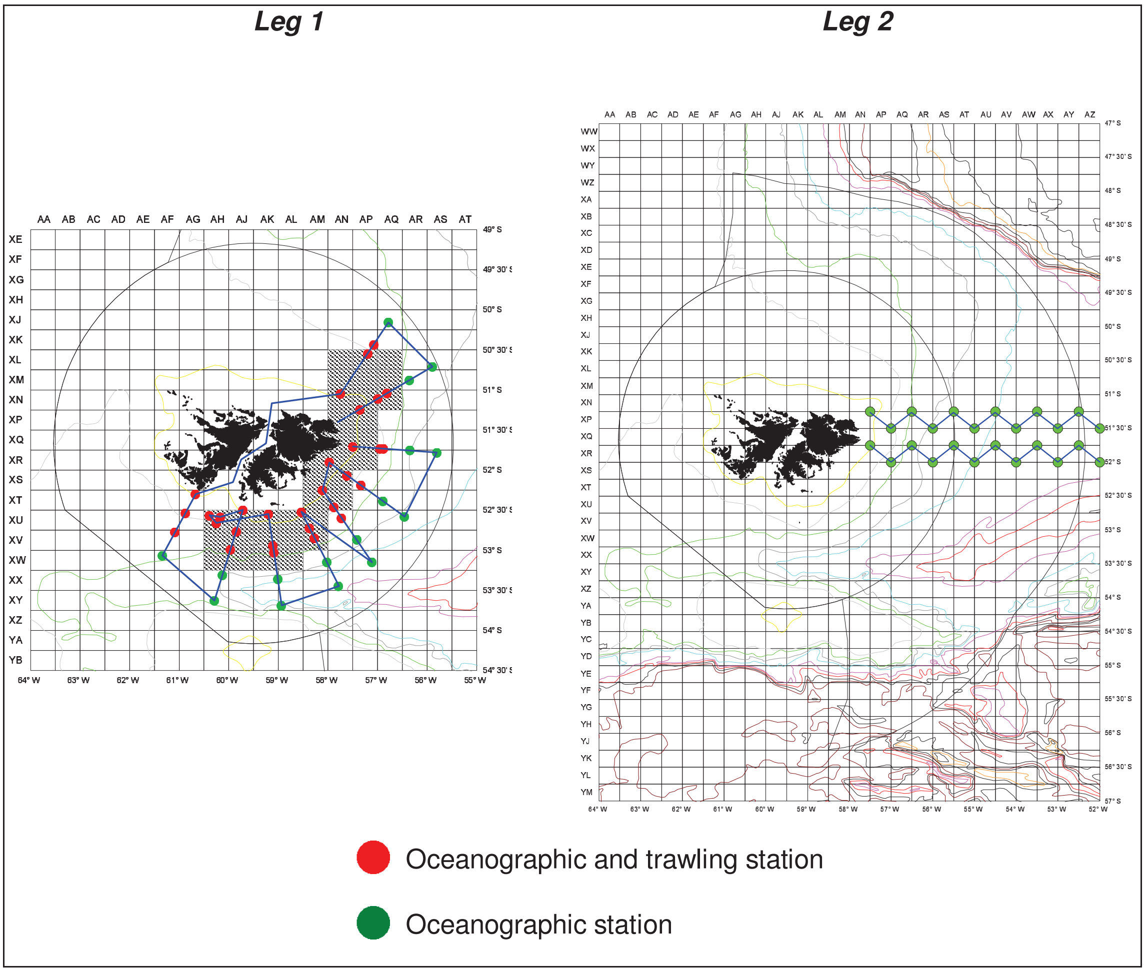
1. Introduction

The Patagonian long-finned squid *Loligo gahi* d'Orbigny occurs in commercial densities on the south-eastern part of the Falkland shelf. It has been suggested that its population structure consists of three broods which are characterised by different growth and maturity rates and spawning times. During its life cycle, *L. gahi* demonstrates ontogenetic migrations to deepwater during the juvenile and immature ontogenetic phases, and to coastal regions in the mature ontogenetic stage for subsequent spawning. We aimed to investigate possible patterns of spatial and vertical distribution of *L. gahi* after the end of the first fishery season for this species (in June) which coincided both with the spawning period of the first cohort and the feeding periods of the second and third cohorts (Hatfield & Des Clers, 1998). For comparative purposes, trawl and oceanographic stations were designed to be on the same transects as in previous research cruises in the "*Loligo* box" carried out by FIFD in 1989-1995.

Region

The surveyed region included a segment of the FICZ (north-eastern, eastern and southern parts) and part of the FOCZ. The planned route and station positions are illustrated in Figure 1.

Figure 1. Planned transects and station positions for the two legs of the cruise. The shaded area on the map for Leg 1 indicates the area licensed for *L. gahi* trawling in the second season 1999.



Cruise objectives

1. To carry out a bottom trawl survey for biological analysis of the second cohort of *L. gahi*.
2. To study oceanographic conditions within the "*Loligo* box" and adjacent waters.
3. To make an acoustic survey of the "*Loligo* box" to investigate the potential of acoustic methods for stock assessment of *L. gahi.*
4. To collect samples of *L. gahi* (as intermediate hosts) and different species of skates and rays (as definite hosts) for a further ecological analysis of their parasites.
5. To trawl for tagged skate and dogfish in grid square XUAH.

Cruise plan

The cruise consisted of two legs:

Leg 1 (16-30 June 1999): Trawl, oceanographic and acoustic survey of the "*Loligo* box".

Leg 2 (3-6 July 1999): Oceanographic survey of the eastern branch of the Falkland Current

The trawl survey included 9 short transects located within the "*Loligo* box", each transect including three half-hour bottom trawl hauls at depths around 100 m, 200 m and 300 m. The acoustic survey was made both at night and in the daytime, attempting to cover all grid squares of the "*Loligo* box".

Vessel characteristics

The cruise was conducted on board the Fishery Patrol/Research Vessel *Dorada* registered in the Falkland Islands.

Table I. Characteristics of the Fisheries Protection and Research Vessel, *Dorada*.

Callsign	ZDLH1
Length	76 m
GRT	2360 t
NRT	708 t
Crew	16 people

Personnel and responsibilities

The following FIFD personnel participated in the cruises:

Dr Alexander Arkhipkin	Chief Cruise Scientist
Paul Brickle	Parasite survey/Trawl survey
Dr Ryszard Grzebielec	Oceanographic survey
Dr David Middleton	Acoustic survey
Joost Pompert	Trawl survey
Daniel Poulding	Trawl survey

Additionally, Dr. Catherine Goss (British Antarctic Survey) participated in the Leg 1 of the Cruise (Acoustic Survey).

Survey design

Leg 1:

The complex survey of the "*Loligo* box" consisted of 9 transects running from the shore on fixed bearings as detailed in Table II.

Table II. Details of transects used in Leg 1, during the "*Loligo* box" survey.

Transect No	*Shoreside Lat/long*	*Bearing*
P9	51°22'S 58°05'W	35°
P8	51°24'S 57°50'W	60°
P1	51°42'S 57°38'W	94°
P2	51°49'S 58°10'W	126°
P3	52°00'S 58°23'W	146°
P4	52°15'S 58°45'W	154°
P5	52°20'S 59°15'W	172°
P6	52°24'S 59°40'W	197°
P7	52°18'S 60°40'W	208°

Each transect included three complex stations (trawls and oceanography) at depths of 80-100; 180-200 and 250-300 m, which were made during the daytime and in the evening, and two oceanographic stations which were situated offshore on the transect at the 500 m and 1000 m depth contours, and were made at night.

Leg 2:

Oceanographic survey of the eastern branch of the Falkland Current consisted of 24 deepwater CTDO stations arranged on four latitudinal transects (see Figure 1). The stations were carried out both at night and in the daytime.

2. Hydrographic survey

Hydrographic data were collected in two periods. In the first period from 16 to 29 June 1999 data were taken within the “*Loligo* box” SE of East Falkland before or after each bottom trawl station and at offshore stations on transects P1-P10 (Figure 2). In the second period from 3 to 6 July 1999 data were collected at stations in the eastern part of FICZ/FOCZ, across the eastern branch of the Falkland Current, on 4 transects H1-H4 (Figure 3).

Figure 2. Oceanographic stations and transects, 16-29 June 1999. Note that this section uses sequential numbering of the CTDO stations. Codes that uniquely identify the stations are shown on Figure 22.

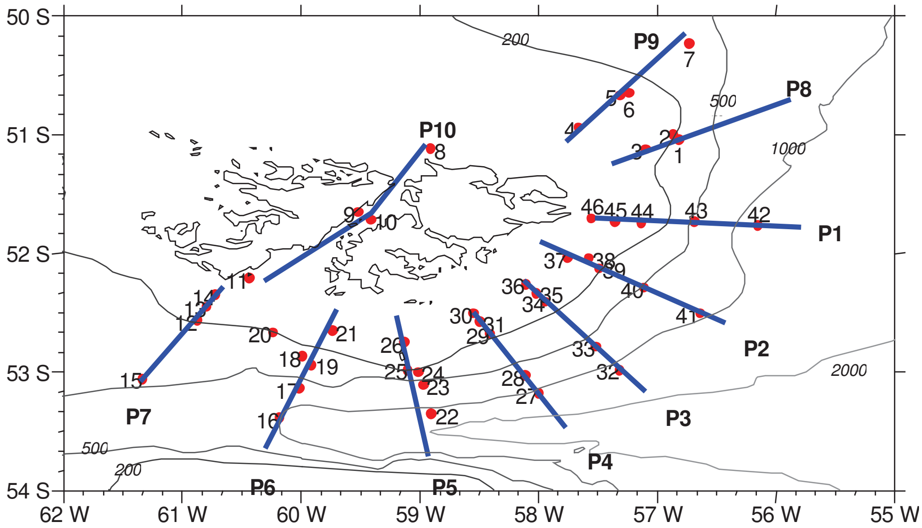
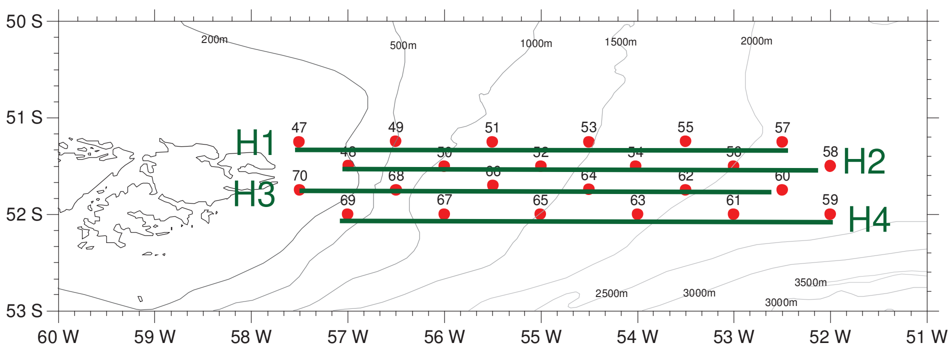


Figure 3. Oceanographic stations and transects across the Falkland Current, 3-6 July 1999.



Method and materials

A CTDO profiler, Sealogger SBE25 (Sea-Bird Electronics Inc.), was deployed at oceanographic stations to obtain depth (m), temperature (°C), salinity (PSU), density (kg m^{-3}) and dissolved oxygen (ml l^{-1}) readings. Deployments of the CTDO profiler were made prior to each trawl and at offshore oceanographic stations on each transect. Speed of deployment was approximately 1 m sec^{-1}. The CTDO was deployed for the first 4 min at 10 m depth to start the pump working and to allow polarizing of the oxygen sensor. It was retrieved to 1 m depth and deployed again either to about 20 m above the bottom (shelf and continental slope complex stations) or down to 1000 m in the open sea.

Temperature was measured directly. Other parameters were derived with Seasoft v. 4.326 software (Sea-Bird Electronics Inc.) from the measured parameters: pressure (db), conductivity (S/m), oxygen current (µA) and oxygen temperature (°C). Directly measured data were recorded in the internal memory of the SBE25 main housing unit during deployment (8 scans per second), and retrieved by the

SBE25 Terminal program 4.234 (Term25) after each cast was completed. Profile readings of both down and up casts were used for calculation of oceanographic variables.

Data quality

The CTDO was calibrated at Sea-Bird Electronics Inc. two months before the start of the cruise, so no additional calibration was performed. All required coefficients were supplied on calibration sheets in the Operating Manual (Anon., 1999a) and on diskette, in text file 0247.con created on 29/03/1999. The dissolved oxygen sensor SBE23B S/N 230788, calibrated on 26 March 1999, unfortunately did not work properly during the cruise so all oxygen data, and data derived from oxygen measurements, were ignored.

Processing raw data

Standard programs from the Seasoft software v.4.326 (Anon., 1999b) were used to process the collected CTDO data according to the following scheme:

1. Transmission of the raw data (file extension HEX) by cable connection from the SBE25 Main Housing Unit to a stand-alone notebook using the terminal program Term25.

The following steps were carried out using either a notebook or desktop PC:

2. Datcnv.exe was used to convert raw the data to pressure, conductivity, oxygen current and oxygen temperature (creating a new file with extension CNV).
3. The Write editor was used to remove recorded data from the first 4 minutes of the cast needed to start the pump and polarizing.
4. Alignctd.exe was run to advance oxygen 3 seconds relative to pressure.
5. Filter.exe low-pass filtered the pressure and conductivity readings.
6. Loopedit.exe was used to mark scans with less than the minimum velocity.
7. Derive.exe computed oxygen concentration from oxygen current, oxygen temperature, temperature and pressure readings.
8. Binavg.exe averaged the data into the desired pressure (depth) intervals.
9. Derive.exe was run again to compute salinity and density.
10. The data was plotted with Seaplot.exe.
11. The plots were checked and, if a mistake or measurement error was apparent, the process was restarted at stage 2 or 3.
12. The final files were saved for further analysis.

Data presentation

Temperature (T), salinity (S) and density from each station were plotted in overlay mode using the Seaplot.exe program and copied via the “clipboard” to the Surfer package (Golden Software, Inc.). Here each plot was annotated with a map showing the station location.

For each transect P1-P10 and H1-H4 contour maps were created with the vertical distribution of temperature and salinity. On the horizontal axis stations were set according to the distance between them, and temperature and salinity were calculated for all grid points using Kriging.

Temperature and salinity contour maps were also built along the 100 m, 200 m, 300 m, 500 m and 1000 m isobaths for transects P1-P9. These were produced using the same settings as previous figures.

Finally horizontal temperature and salinity distributions were estimated using data from all stations from both survey periods. Cross-section at the surface, 50 m, 100 m, 150 m, 200 m, 300 m and at 500 m depth were calculated using a grid spacing of 50 km x 50 km, to match the HO Atlas (Anon., 1990).

Results

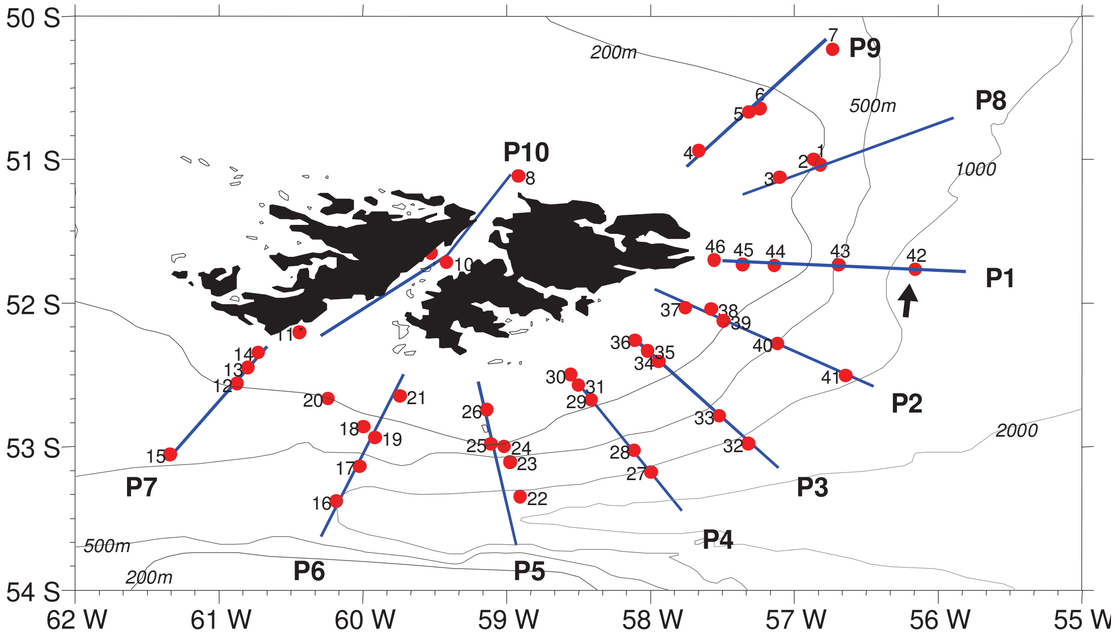
A total of 70 oceanographic stations were measured, comprising 46 stations on the shelf and slope in the "*Loligo* box", and 24 stations in an easterly direction from Berkeley Sound across the Falkland Current.

Figure 4 presents the data obtained from deep-water station 42. In Figure 5 and Figure 6 contours of temperature and salinity are presented using the data from stations 1-46 on transects P1-P10. In the region from the SW limit of the survey area (transect P7) to the NW limit (transect P9) the upper layer of water from the surface to ~250 m depth contains shelf waters. These waters have a temperature above 6° C and salinity below 34 PSU. Their horizontal extent ranged from 40 to 90 km calculated from the nearest station to the coast (excluding transect P1, where this water mass lies deeper, under colder waters). These waters have a greater horizontal extent in the SW (P7) and NW (P9) of the survey area where the continental slope is bigger. The layer of water between ~250 m and ~500/600/700 m, where temperature ranged from 4.5°C to 5.9°C and salinity varied from 34.00 PSU to 34.25 PSU, constituted continental slope water masses (slope waters). Further offshore, starting 10 to 60 km before the last station on a given transect, these waters occupy depths from the surface to ~500/600 m. Below ~500/700 m there are waters with temperature less then 4.5°C and salinity greater than 34.25 PSU. These constitute deep-water masses of the Falkland Current

Figure 7 and Figure 8 present temperature and salinity contours, with the measured points used for interpolation, for transects H1-H4 (stations 47-70). The water masses which were distinguished from transects P1-P9 are also visible in these transects. Shelf waters are just visible on the western edge of these transects. Slope waters with temperatures greater then 4.5°C rise from depths around 600m and reach the surface approximately above the 2000 m isobath. Beyond this border deep-water masses of the ACC occur at the surface.

Figure 9 and Figure 10 present temperature and salinity contours, respectively, at a depth of 300 m.

Figure 4. Temperature, salinity and density at station 42.



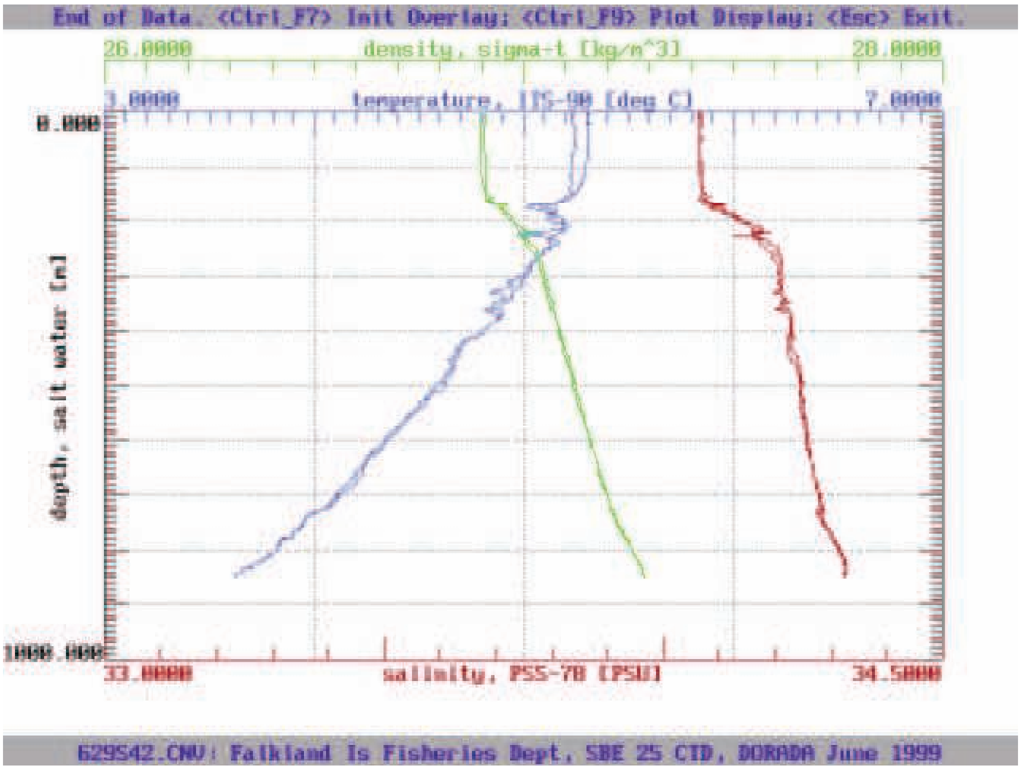


Figure 5. Temperature profiles on transects P1-P10.

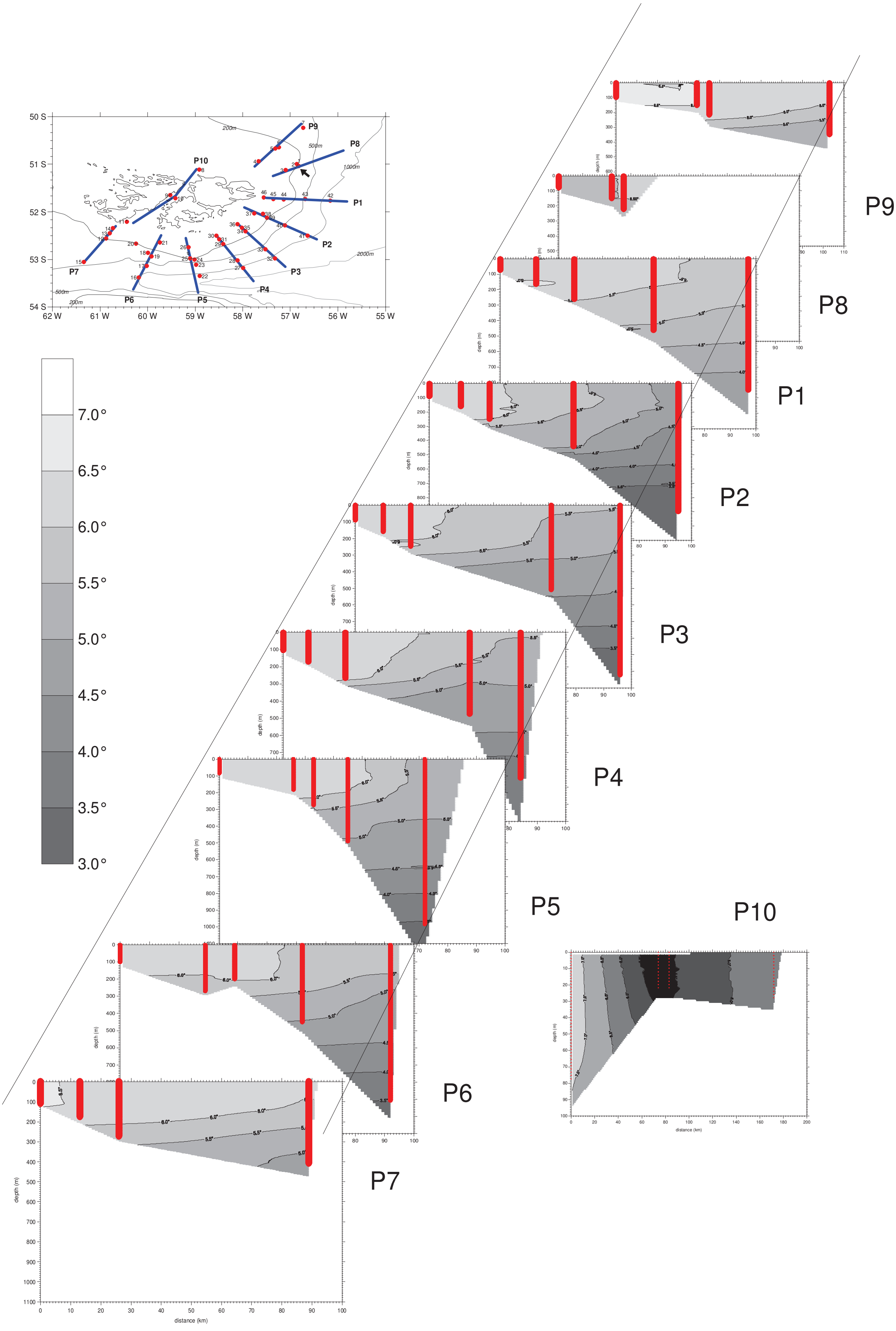


Figure 6. Salinity profiles on transects P1-P10.

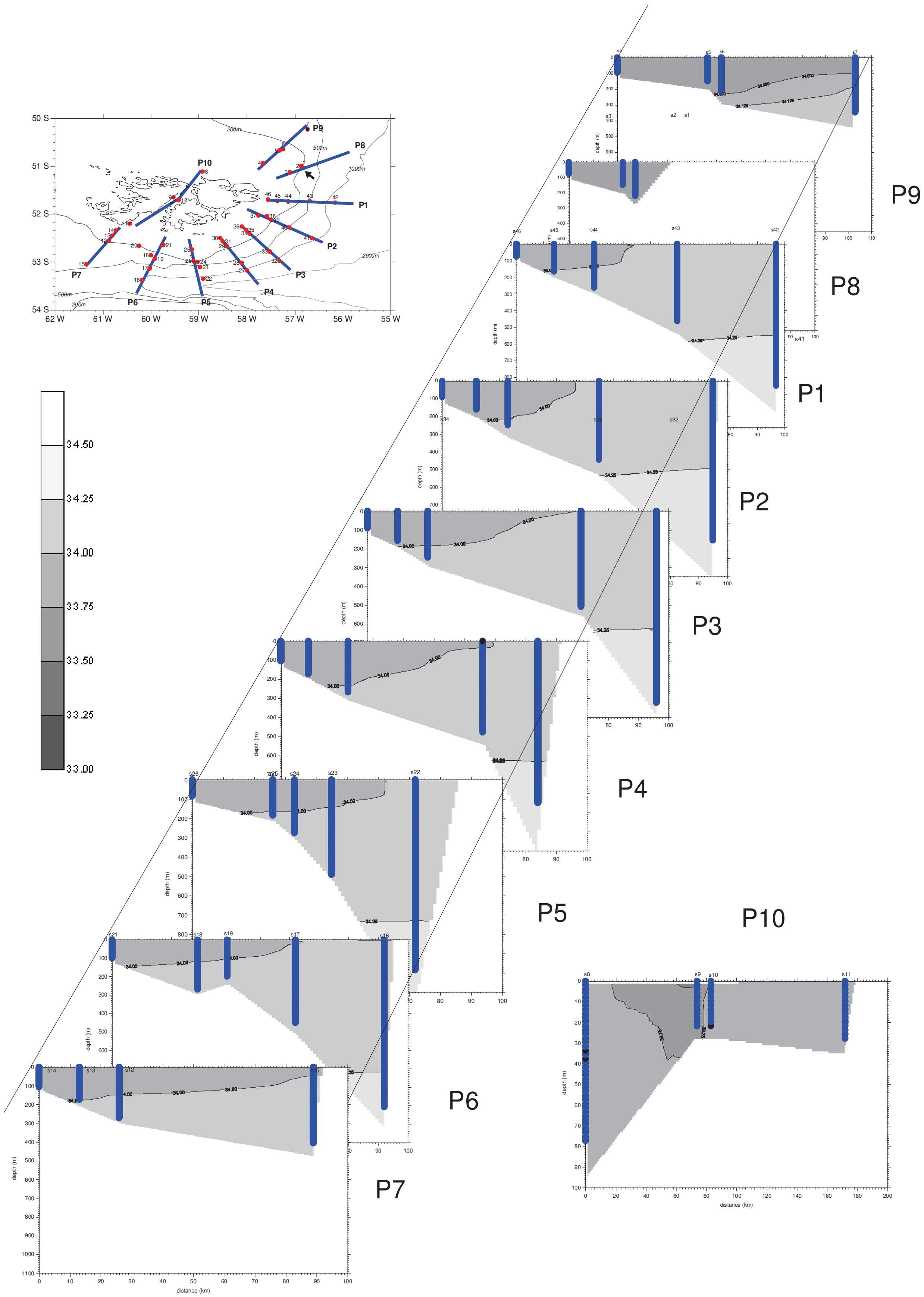


Figure 7. Temperature profiles on transects H1-H4

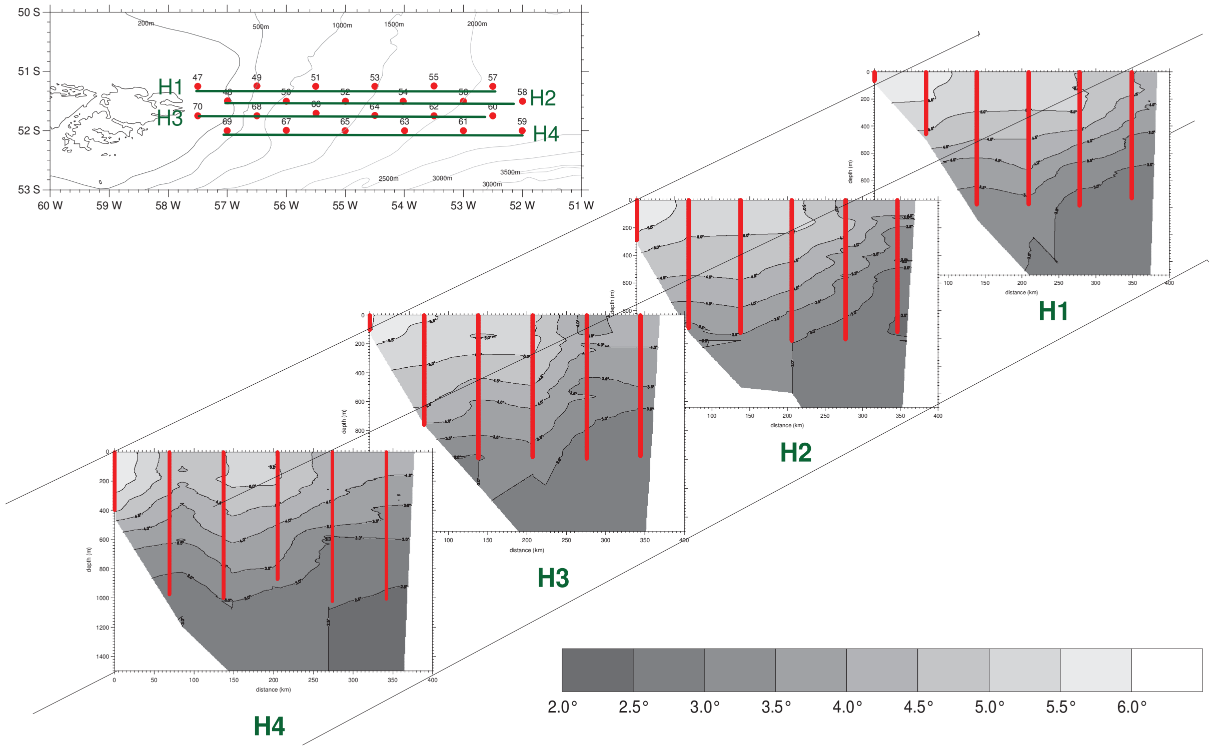


Figure 8. Salinity profiles on transects H1-H4

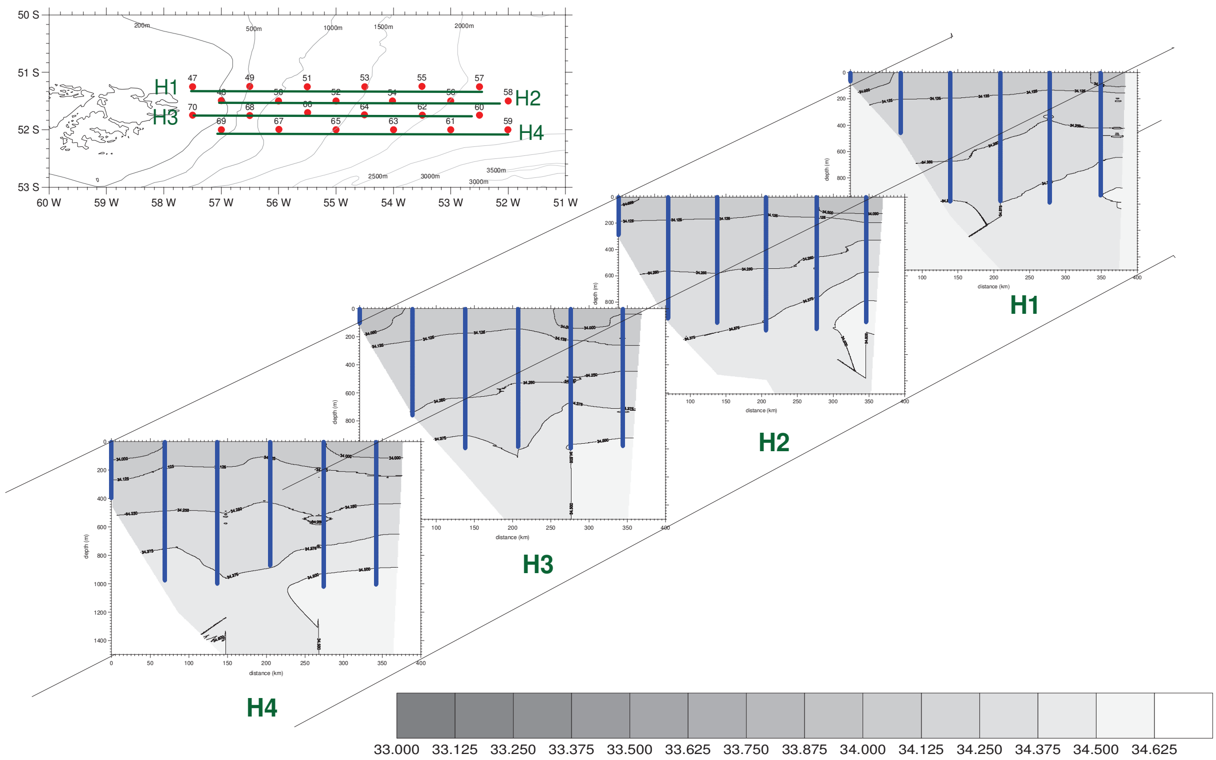


Figure 9. Temperature along the 300 m isobath for transects P1-P9

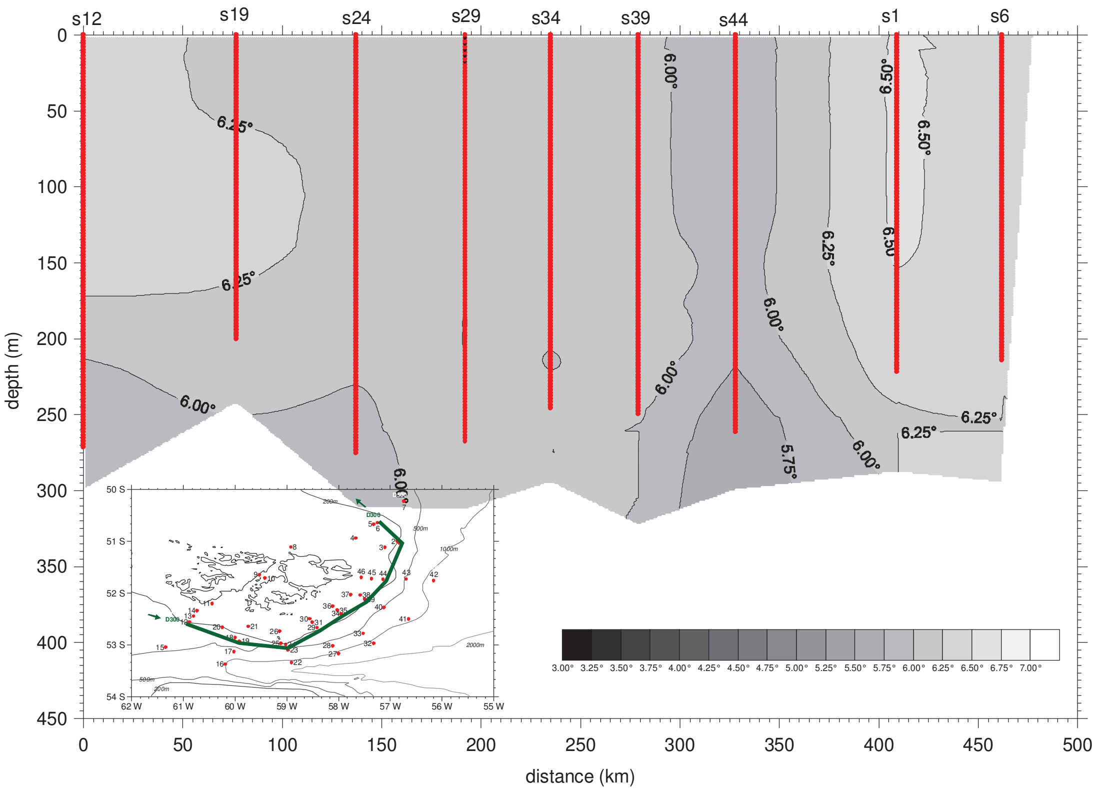
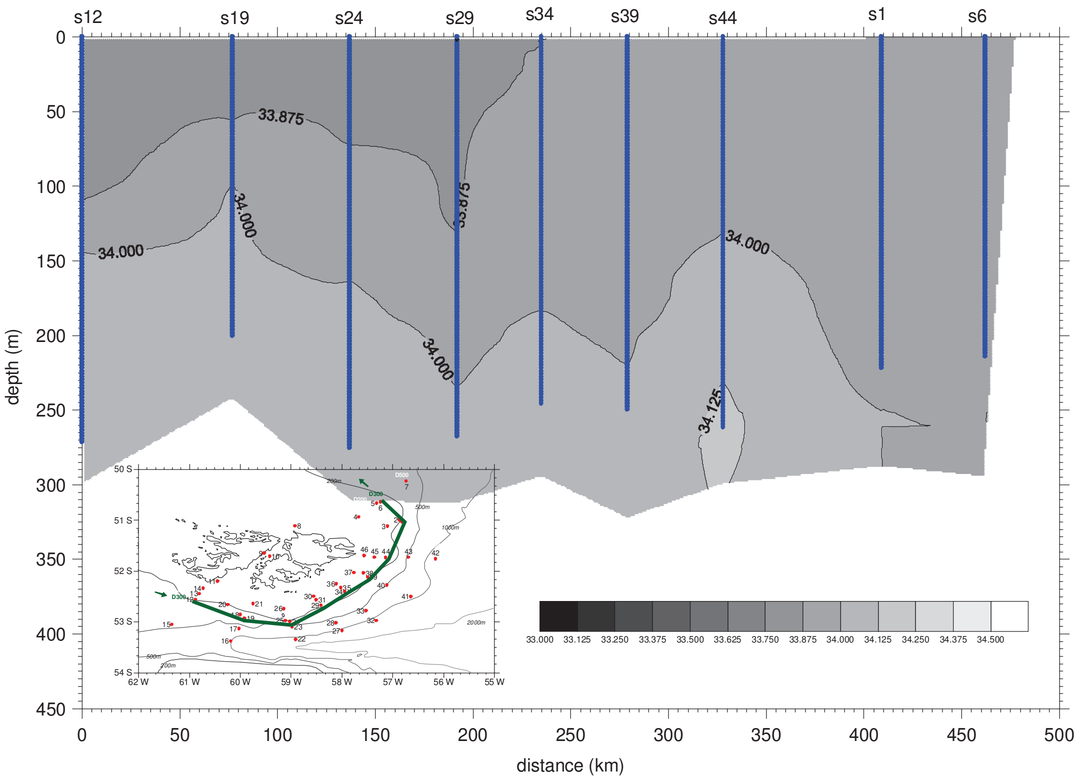


Figure 10. Salinity along the 300 m isobath from transects P1-P9.



3. Acoustic surveying

Introduction

An acoustic surveying component was included in the cruise plan with the aim of carrying out an initial evaluation of the potential of acoustic methods in surveys of the biological resources of the Falklands Fishery Zones, in particular the assessment of stocks of *Loligo gahi*. Specific objectives included:

- To thoroughly test, and become familiar with, the EK500 scientific echo sounder and associated equipment and software (SonarData EchoLog and EchoView and, to a lesser extent, the RoxAnn system).
- To calibrate the EK500 echo sounder using standard targets.
- To use acoustic data from trawl stations to identify marks attributable to specific species and to estimate target strengths of important species.

The time available did not allow for any targeted trawling on specific acoustic marks.

Dr Catherine Goss from the British Antarctic Survey joined the cruise to assist with the acoustic work.

Methods

Equipment and Software

Dorada is equipped with a Simrad EK500 scientific echo sounder with hull mounted split beam transducers operating at 38kHz and 120kHz (Table III).

Table III. Simrad EK500 scientific echo sounder, FPRV *Dorada*: installed transducers

EK500 channel number	*1*	*2*	*3*
Transducer type	ES 38-B	ES 120-7	None installed
Serial number	22047	28907	

Bottom profiling: RoxAnn

The signal from the 38kHz transducer is processed independently by the RoxAnn system unit. RoxAnn data is both displayed and logged by the RoxMap application. The RoxAnn system is also equipped with programs to export the data and graph it in 3D.

Calibration

Introduction

To make quantitative measurements of both single individual target strength and biomass backscattering the EK500 echo sounder must be calibrated. Local conditions of salinity and temperature influence the calibration in addition to instrument factors. For this reason a calibration should be carried out at least once on each research cruise that utilises acoustics. Calibration is accomplished by suspending a reference target (a metal sphere) of known target strength in the echo sounder beam. Choice of calibration site is important: the characteristics of the water mass should be as similar as possible to those of the area to be surveyed (e.g. major freshwater inputs should be avoided), there must be sufficient depth to suspend the calibration spheres approximately 20m beneath the transducers with sufficient additional depth to allow easy distinguishing of the echo from the target and that from the bottom, and the site must be calm and sheltered so that the target can remain in position for the extended periods necessary to carry out the calibration.

The basic calibration method is described in the Simrad EK500 manual (Simrad, 1997) with further background information given by MacLennan & Simmonds (1992, p.68). This information, modified by the experiences of BAS, was used to compile a calibration procedure. This is included for future reference as Appendix 2.1; more detail can be found in the narrative below.

The reference targets were suspended below the ship on monofilament nylon line (0.55mm diameter, 35lb/15.9kg breaking strain) using fishing rods and reels (on loan from BAS). The rods were sufficiently bottom heavy that they remained in place when leant against the ships rails without the need for additional attachment. Positions for the rods were chosen at recognisable sites on the trawl deck walkways, and line lengths calculated with the aid of a docking plan of the vessel.

Calibration narrative

20 June, 1999, 1520h the vessel arrived at the calibration site, Port Albemarle, 52° 12.42' S, 60° 26.22' W, having previously visited, and ruled out, Fox Bay where there was a slight swell that would have made maintaining the sphere in position impossible. The ship anchored in a sheltered part of the outer harbour, to the north of the largest Arch Island, close to shore in around 34m water depth. The swell and wind speed were both negligible throughout the calibration.

A CTDO cast was made so that the sound speed and absorption coefficient could be calculated (see Figure 11). The salinity and temperature from 6 to 20m range was used to calculate average salinity of 33.87‰ and temperature of 6.38°C, which resulted in a sound speed of 1474.9ms^{-1} at 10m depth using Mackenzie's empirical equation (MacLennan & Simmonds, 1992, pp. 43-44). A request was made that all discharges from the vessel would be kept to an absolute minimum, preferably zero, throughout the calibration, but some discharge was seen just below the surface on the port side in the final stages of the calibration.

The EK500 was tested at each frequency using the internal test oscillator; the resulting levels fell within the expected ranges for both frequencies. (See TABLE IV for results).

Three points around the trawl deck had been previously chosen for location of the fishing rods and lines that would be used to suspend the sphere (see Figure 12). A heaving line was passed under the hull, weighted with shackles, from line point A (port), to a point midway between line points B and C (starboard). The first fishing line A was joined to the heaving line at position A, and hauled across to starboard keeping the line loose to avoid snagging on the hull. The first sphere (60mm for calibrating at 38kHz) was immersed in a bucket of weak detergent solution, to minimise bubble formation on the sphere and lines in its immediate neighbourhood, and joined to all three lines on starboard side. All lines were lowered to marks positioned to place the sphere 20m below the transducers (see TABLE V). Marks for placing the sphere at 18m or 15m had also been put in place in case the water depth had been insufficient for 20m.

The sphere was immediately visible in the EK500 TS display window, and was brought onto the axis of the echo sounder beam using three helpers with walkie-talkie radios to control fishing lines. Walkie-talkie radios were not very effective between deck and dry lab, so communications were improved by using the telephone to the bridge where an additional helper relayed messages by radio to the deck helpers.

The EK500 layer settings were adjusted so that the super layer included the sphere, but as little as possible of the water column above and below it. The target strength (TS) of the sphere was measured and then the TS gain set so that the TS of the sphere matched the predicted TS from data supplied with the sphere by Simrad. Data from the narrow layer containing the sphere were integrated for several short integration intervals and printed out. These Sa values were compared with the expected Sa from the sphere and the Sv gain set so that the observed Sa matched that expected. The `lobe` program was run to measure beam characteristics using three helpers on deck with radios to adjust fishing lines to slowly swing the sphere across the entire area of the beam (see TABLE IV for results).

When running `lobe` on a laptop PC an energy saving screen shutdown occurred on several occasions, but each time the program was terminated by any keystroke that was used to restore the screen, and data were lost. The `lobe` program was restarted on an old machine that did not have the energy saving features.

Two of the three lines were freed off and the third hauled in to bring the sphere to the surface. The 60mm sphere was replaced by a second 23mm sphere, and the 60mm was used as a weight to hang about 3m below it. In future cheaper weights could be used for this purpose, and a 5m gap would allow more manoeuvrability. (Although the limited distance below the spheres and the seabed need to be borne in mind when recovering the spheres at the end of the calibration.) TS, Sv gain settings were adjusted for the 120kHz as above, and finally the `lobe` program run for this frequency (see Table IV for results).

The spheres were recovered and all calibration stages complete at 0120h 21 June 1999. Total time, excluding anchoring, was 10 hours.

Figure 11. Temperature and salinity profiles from CTDO cast at EK500 calibration site. Shaded region denotes depth range over which values were averaged for the calculation of sound speed.

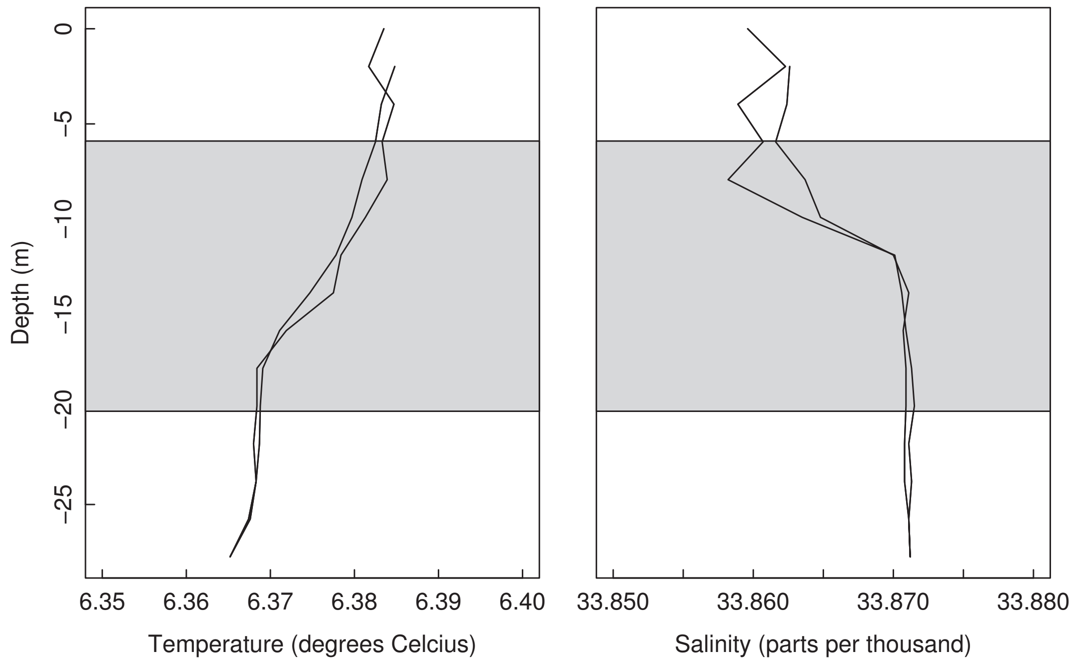


Figure 12. FPRV *Dorada* EK500 scientific echo sounder calibration line positions, July 1999.

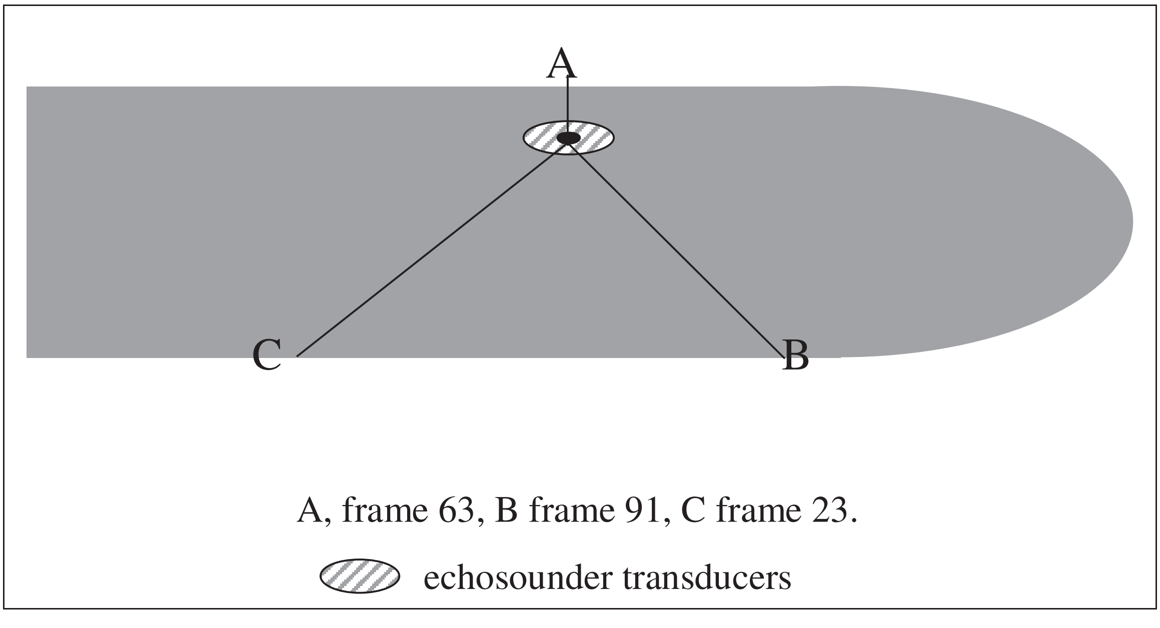


Table IV. FPRV *Dorada* EK500 calibration results, 19 July 1999.

Date	*20/6/99*	*20/6/99*
Time (local)	18:34	22:47
Place	Port Albemarle	Port Albemarle
Software version	5.30	5.30
Frequency	**38**	**120**
Test oscillator	-55.5	-56.0
Water depth	34.5	31.89
Temperature	6.38	6.38
Salinity	33.87	33.87
Sound speed	1474.9	1474.9
Alpha	10.3	33.12
Angle sensitivity along	21.9	21.0
Angle sensitivity athwart	21.9	21.0
Ping rate	0.0	0.0
Transmit power	normal	normal
Max power	4000	1000
Pulse duration	medium 1.0	long 1.0
Bandwidth	wide	narrow
Minimum echo length	0.8	0.8
Maximum echo length	1.6	1.5
Max gain compens.	1.4	1.4
Max phase deviation	2.0	2.0
Sphere TS	-33.62	-40.28
Sphere type	**Cu 60.0**	**Cu 23.0**
Old TS gain	20.00	26.10
Calibrated TS gain	**24.95**	**25.17**
Default 2-way beam	-20.6	-18.0
Range to sphere	21.1	20.79
Old Sv gain	25.00	26.10
Calibrated Sv gain	**24.71**	**25.25**
Lobe results		
TS gain	24.98	25.01
Alongships beam	6.98	7.64
Athwartships beam	6.83	7.34
Alongships offset	-0.17	-0.62
Athwartships offset	-0.05	0.16

Table V. Calibration lines.

Fishing line	*Locations, on trawl deck level*	*Length for 15m depth*	*Length for 18m depth*	*Length for 20m depth*
Port Line A	Space between first and second mess-room windows, counting from the bow	26.99 m	29.93 m	31.91 m
	length to next mark	2.94 m	1.98 m	
Starboard Forward Line B	In line with front of superstructure	33.88 m	36.27 m	37.92 m
	length to next mark	2.39 m	1.65 m	
Starboard Aft Line C	Behind final boat deck support in side alley	37.46 m	39.67 m	41.18 m
	length to next mark	2.21 m	1.51 m	
Vertical height to deck		26.46 m	29.46 m	31.46 m

20 m marks approximately resemble the number 2, 18 m marks resemble the letter B, 15 m marks are a plain rectangle.

Operating procedures

The EK500 and PC logging echogram data were both synchronised to local time (Falklands winter, GMT-5) at the beginning of the cruise, and periodic checks were made to ensure that these times remained close. In future it may be preferable to operate in ZULU (i.e. GMT) to avoid the issue of time zones and daylight saving time changes. This has the added advantage that automated synchronisation of both the EK500 and lab PCs to the time provided by the GPS feed from the bridge would be possible.

Echogram data were logged over the entire cruise track. The echogram information output on the ethernet by the EK500 is limited to 714 depth intervals. Thus for most depths the resolution at which data can be logged is lower than that at which the transducers operate (the sample distance for the ES38-B transducer is 10cm and of the ES120-7 is 3cm). For routine logging (i.e. when trawling was not in progress) the depth range logged was adjusted as required to give maximum resolution possible while displaying the entire water column. However, it became clear during the course of the cruise that this gave insufficient resolution near the bottom at trawl stations when it was hoped to be able to correlate echogram marks with the trawl catch. At later trawl stations the vertical range of the echogram logged was therefore decreased to give greater vertical resolution near the bottom. In these cases a 50m range straddling the bottom was used. The start depth of the logging range is specified relative to the surface, with the result that the starting depth of the logged range sometimes had to be adjusted mid-trawl to take account of changes in depth. A new version of EchoView has been released since the cruise which allows the use of "expanded bottom" data to increase the echogram resolution near the bottom. The EK500 outputs such data for a range relative to the detected bottom with the result that future echogram logging at trawl stations will not need manual adjustment to ensure that high resolution data is logged while trawling.

An EchoView "ev" file was created for each trawl station with marker regions denoting the position at which the net was believed to have reached and left the seabed. These marker positions were corrected to take account of the fact that the ship passed over a particular position some minutes before the trawl sampled this region. These corrections were calculated assuming that vessel speed, and the distance of the trawl behind the ship, remained constant during the trawl. In some cases the trawl was not directly in line with the ship and the area sampled acoustically did not match that sampled by the trawl. In future more detailed logging of the information provided by the Simrad ITI (Integrated Trawl Instrumentation) system should allow acoustic and trawl sampling regions to be calculated more precisely.

Table VI. Constants used in EchoView processing.

	Transducer 1		*Transducer 2*	
	Pre-calibration	Post-calibration	Pre-calibration	Post-calibration
Absorption coefficient (dB/m)	0.0100000	0.0100000	0.0380000	0.0331200
Sound speed (m/sec)	1500.0	1474.9	1500.0	1474.9
Transmitted power (W)	4000.0	4000.0	1000.0	1000.0
Equivalent 2-way solid beam angle	-20.60	-20.60	-18.00	-18.00
SV gain (dB)	25.00	24.71	26.10	25.25
TS gain (dB)	20.00	24.96	26.10	25.17
Wavelength (m)	0.03947	0.03881	0.01250	0.01229
Transmitted pulse length (ms)	1.000	1.000	1.000	1.000
Frequency (kHz)	38	38	120	120
Draft correction (m)	0	0	0	0
Nominal angle (degrees)	6.90	6.90	7.490	7.490

Table VI shows the constants applied in the processing of logged acoustic data with EchoView. Data collected prior to calibration were collected with the pre-calibration constants but processed with the post-calibration constants. Data collected after calibration were logged and processed with the post-calibration constants.

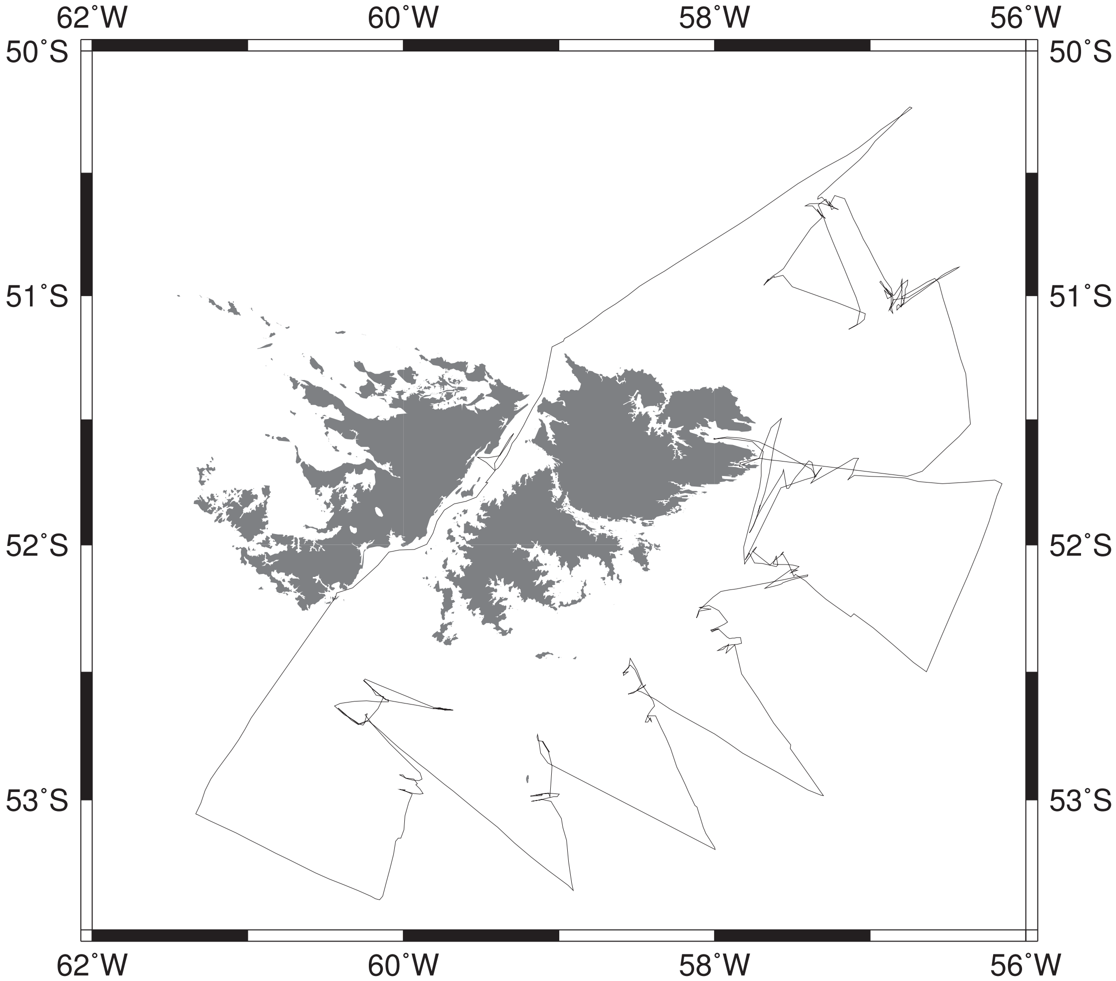
Results

Figure 13 illustrates the track along which acoustic data were collected.

System performance

After some experimentation, two ship sources of acoustic interference were identified. The Furuno echo sounder system on the bridge (Transceiver unit model ETR-10D1, Echo Sounder FE-881 II and colour display FCV-780/782), operating at 28kHz, produces interference at both 38kHz and 120kHz on the EK500. Very much more severe interference at the EK500's 120kHz frequency was produced by the bridge's Furuno Doppler sonar current profiler (model CI-30) which has three beams operating at 130kHz. It is hoped that both these sources of interference can be eliminated by synchronising their pinging with that of the EK500.

Figure 13. Track of FPRV *Dorada* from 16 to 30 June 1999 along which acoustic data were collected.

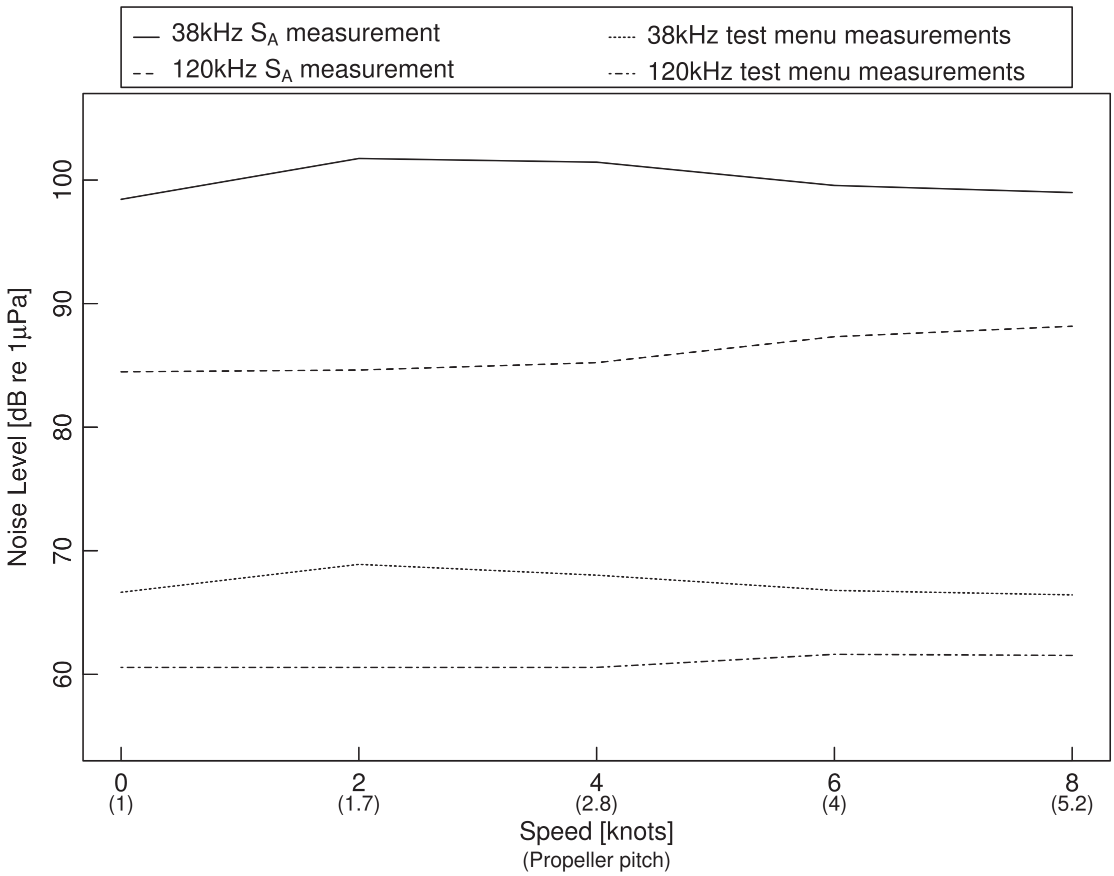


Noise measurements

Measurements of acoustic noise (i.e. noise sources inherent to the ship caused by the propeller etc., as opposed to the sources of interference discussed above) were made between 01:13 and 02:34 on 27/6/99. During this period the bridge echo sounder and Doppler log were turned off. The procedures for noise measurement basically followed those outlined in the Simrad EK500 calibration manual (Simrad, 1997). The main difference arises from the fact that the *Dorada*'s speed is determined entirely by pitch variation; engine and propeller r.p.m are constant. Noise was measured at speeds between 0 and 8 knots. The propeller was clutched in at all times. A fuller set of measurements, including higher speeds, and with the propeller de-clutched should be made in the future.

Noise was calculated using both methods outlined in the Simrad manual (test menu readings and integration of a specific narrow layer), simultaneously for both transducers set for passive listening (i.e. no pinging). The absolute values obtained from the two methods differed somewhat (the reasons for this are unclear at present) but show the same trends (see Figure 14). At 38kHz noise levels are highest at intermediate speeds of 2-4 knots (typical trawling speeds), but fall as speed is increased to rates which would be more likely during an acoustic survey. At 120kHz noise levels are constant below 4 knots after which they rise.

Figure 14. Acoustic noise in front of EK500 transducers as a function of vessel speed, calculated from integration of noise levels in a specified layer over 200 pings, and EK500 Test Menu noise power readings (see Simrad, 1997, p.27-31).



Trawls

Analysis of the acoustic records associated with each trawl station is continuing. Quantitative results are hampered by the interference discussed previously. However, a number of echograms show distinctive marks which are illustrated here.

The largest catch of any commercial species was that of Toothfish, *Dissostichus eleginoides* Smith 1898, at station 14. The echograms associated with this station are shown in Figure 15. Interference from the Furuno echosounder is visible at both frequencies as lines of short pulses. The Doppler log is responsible for the longer lines of interference visible in the 120kHz echogram. The echograms show distinct, but only moderately strong, marks which are approximately 10dB stronger at 38kHz than 120kHz. The marks seen during this trawl were not observed during other trawls. As *D. eleginoides* lack a swimbladder they would not be expected to be especially good acoustic targets.

Some of the most distinctive marks observed on the cruise were those attributed to the Falkland Herring, *Sprattus fuegensis* Jenyns, 1842. These marks were seen in the pelagic zone while the trawl was in progress, and a large catch (209 kg) of very fresh individuals suggests that the net passed through one of these aggregations during hauling. Figure 16 illustrates these marks, using echograms from the period immediately following the trawl because only the region near the bottom was logged during trawling. Some smaller aggregations with similar properties were also observed nearer the bottom during the trawl.

Station 43 yielded a reasonably large (205kg) and reasonably clean (74%) haul of Hoki, *Macruronus magellanicus*, Lönnberg, 1907. Two large marks were observed approximately half way through the trawl, extending 4 - 7m off the bottom. These are illustrated in Figure 17. Note the increased echogram resolution after the 20 minute time marker (see Operating procedures).

Figure 15. Echograms from station 14 at 38kHz (top) and 120kHz (bottom), showing marks believed to be *Dissostichus eleginoides*.

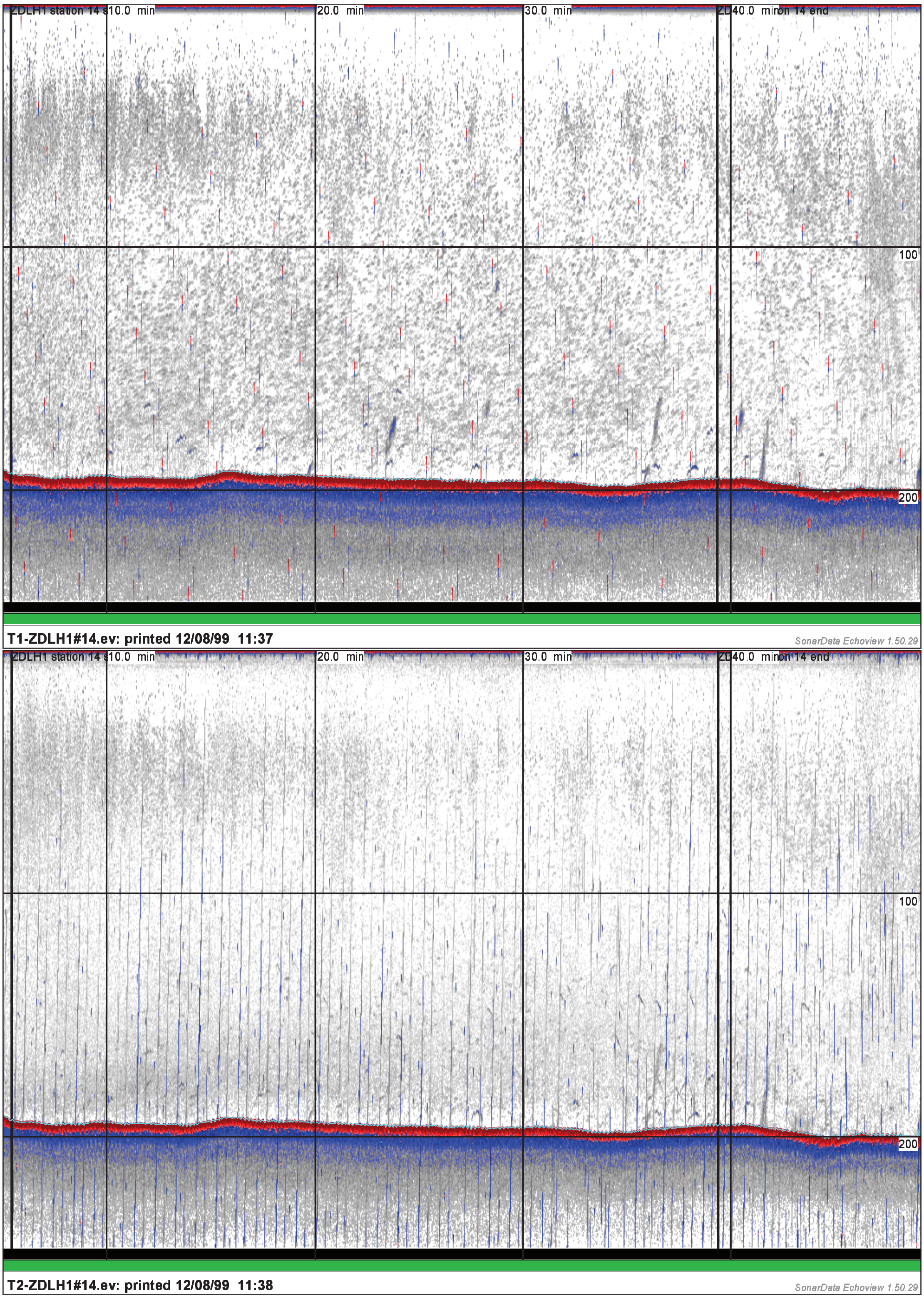


Figure 16. Echograms (38kHz, top, and 120kHz, bottom) from the period following station 38 when pelagic marks likely to be *S. fuegensis*, were observed.

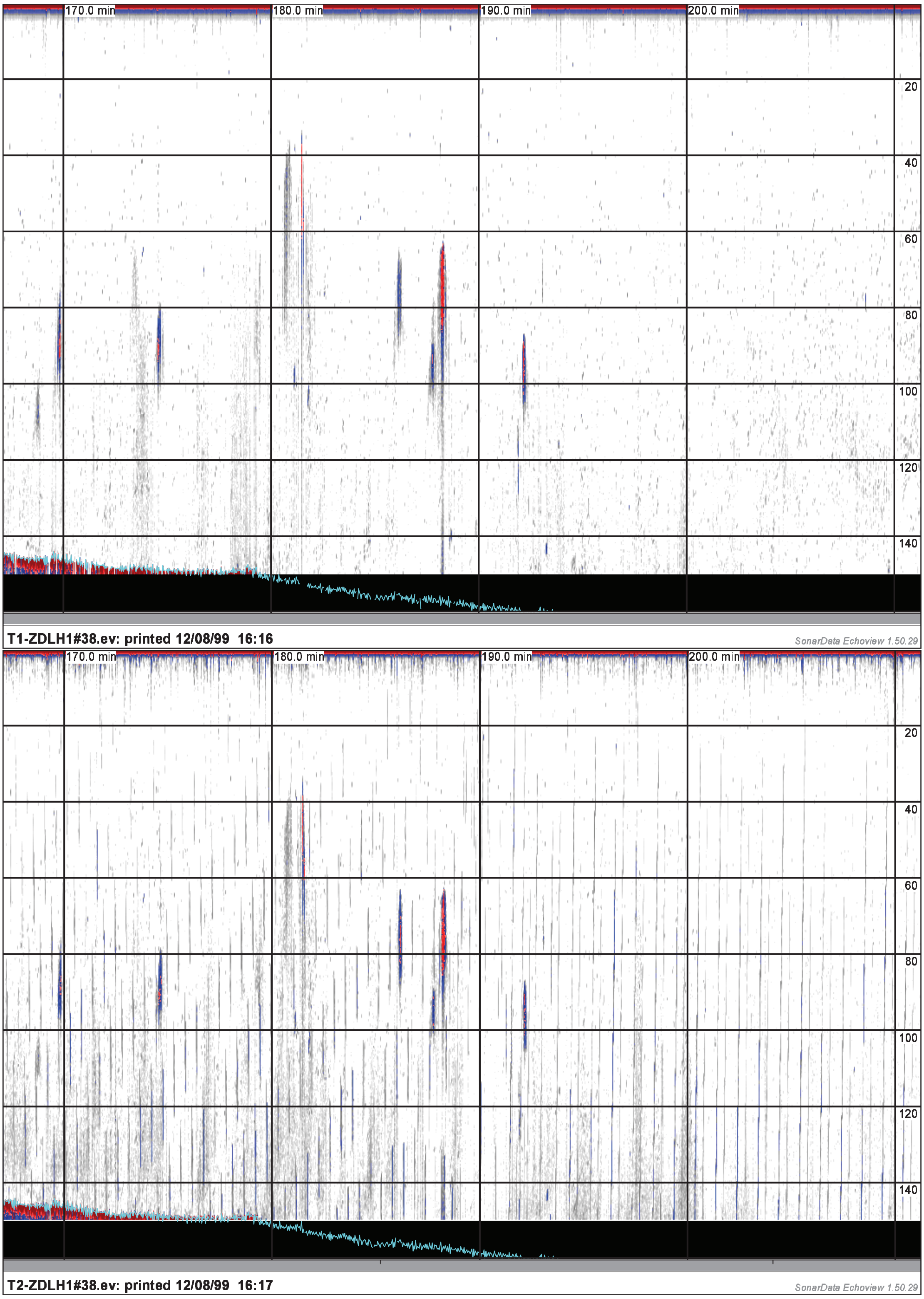
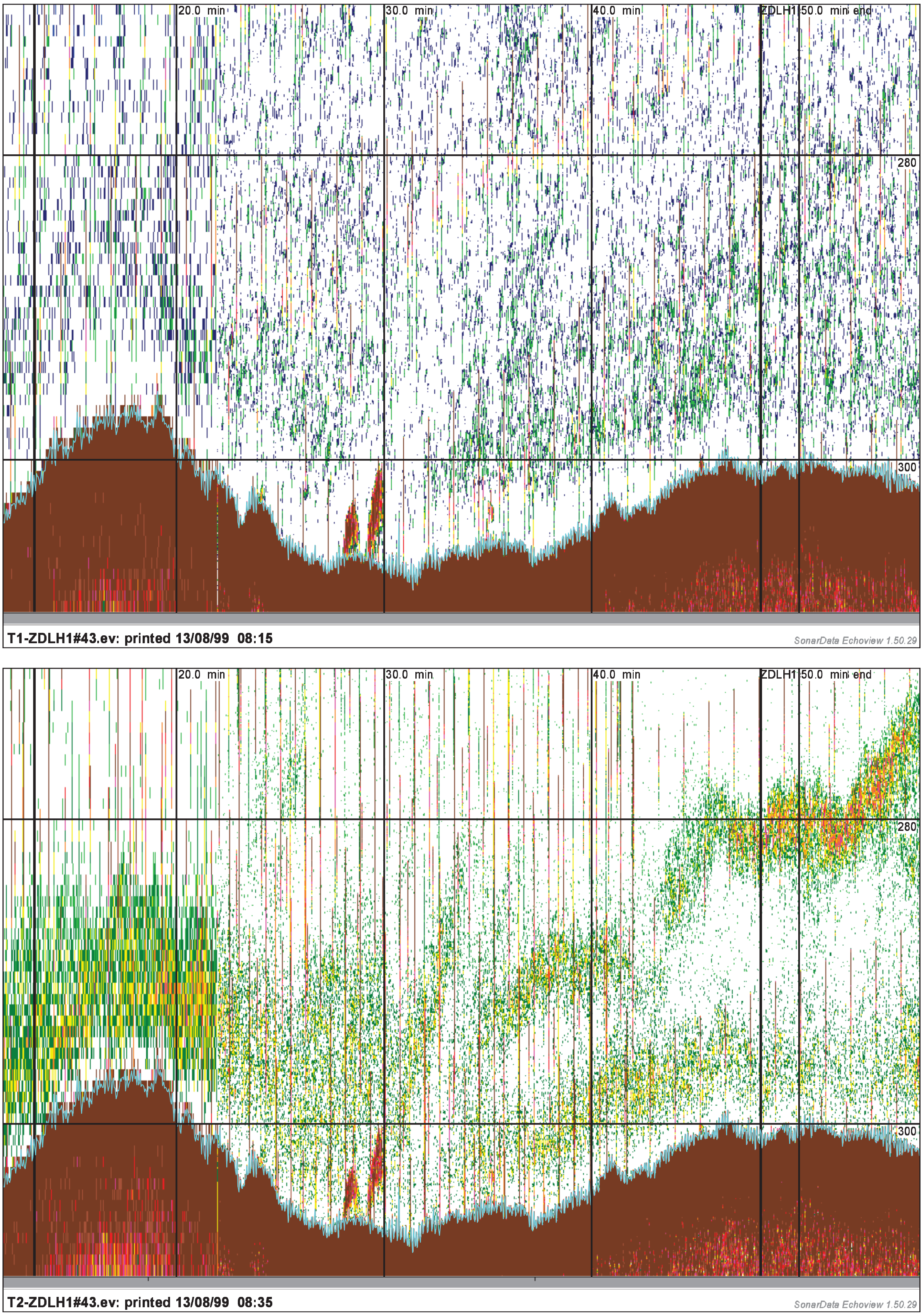


Figure 17. Echograms from station 43 at 38kHz (top) and 120kHz (bottom). A large catch of *Macruronus magellanicus* was taken at this station.



Some interesting, but as yet unexplained, marks were observed during the passage through Falkland Sound. Figure 18 shows the cruise track on the afternoon of 19 June 1999 and the following morning. From shortly after 16:00 local on the 19th a layer of strong acoustic backscattering, extending up to 12 m off the bottom, was visible at both echo sounder frequencies (Figure 19, top, shows the echogram for 38kHz). This layer was essentially continuous over the area surveyed. The following morning, after anchoring in Port Howard, the cruise track covered some of the same area (Figure 18), but the layer was no longer present (Figure 19, bottom). Unfortunately a computer problem meant that acoustic data were not logged between 00:00 and 06:00 on 20th June so it is not possible to say precisely when the layer dispersed. However, these observations suggest that an organism with differing patterns of aggregation during darkness and daylight was responsible. Lobster krill, *Munida gregaria* Fabricius 1793, is one potential candidate.

Figure 18. Section of cruise track through Falkland Sound. Solid line is the track on the afternoon of 19/6/99, dashed line is the track on the morning of 20/6/99. Crosses mark the positions of echograms shown in Figure 19.

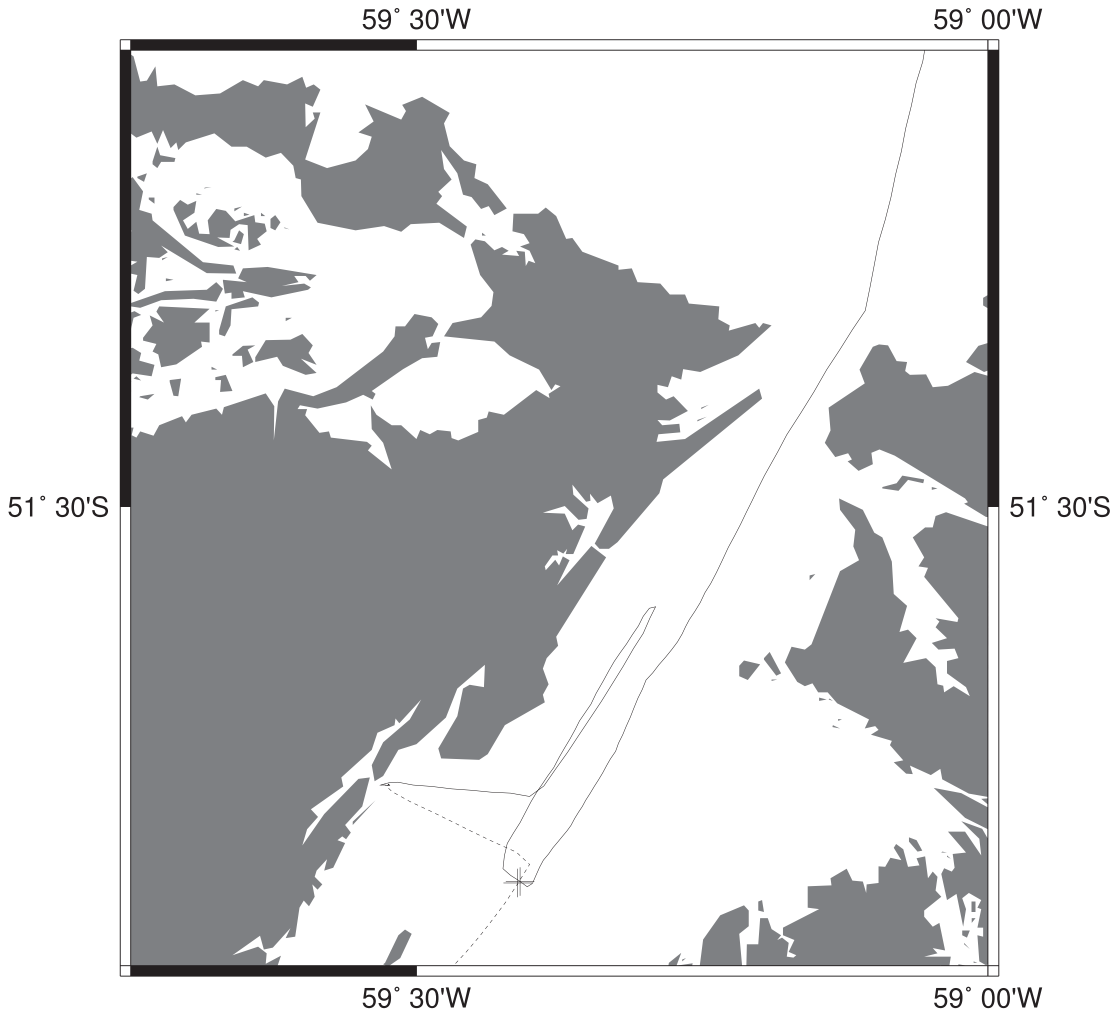
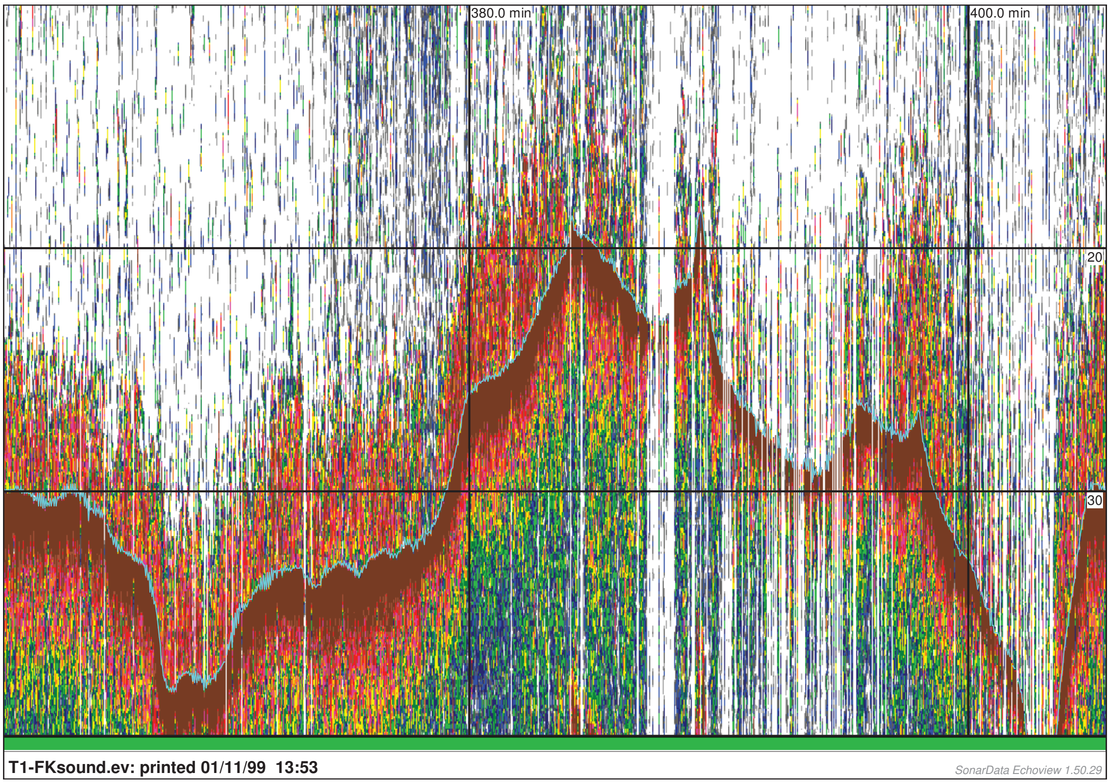
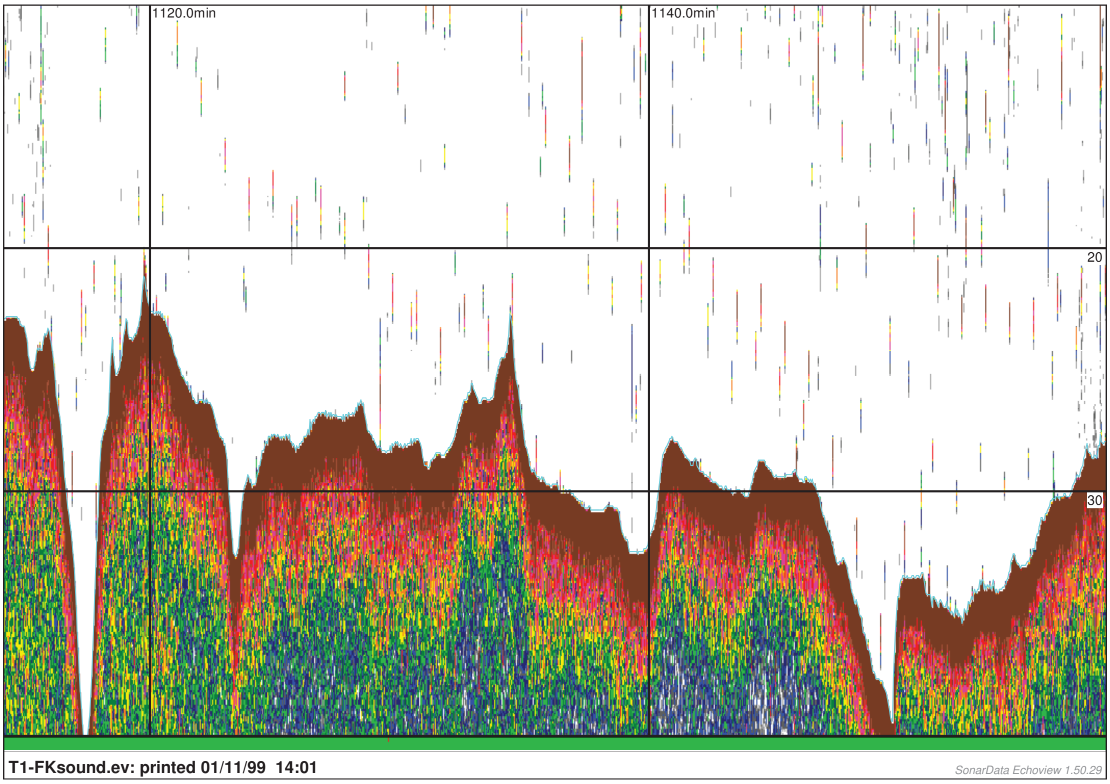


Figure 19. 38kHz echograms from the northern part of Falkland Sound on 19/6/99 and 20/6/99. During darkness (top) and light (bottom).

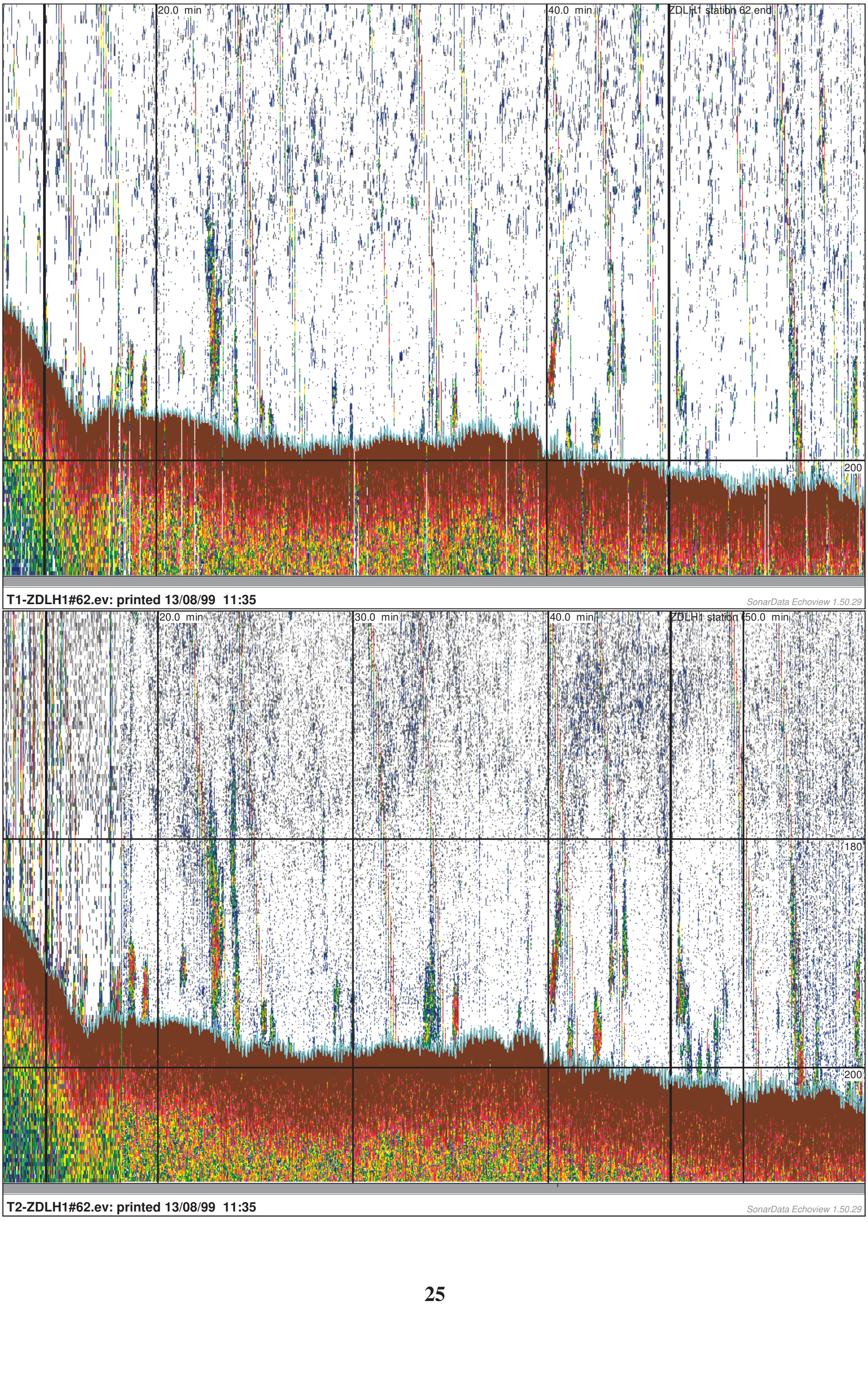




Loligo gahi

The highest catch of *L. gahi* was obtained at station 62. The catch of 71kg was 53% of the total catch; no other species comprised more than 11% of the catch by weight. The echograms from the trawl show a number of aggregations near the bottom (Figure 20). Although the Doppler log was turned off during this trawl (note the decreased interference at 120kHz after about 10 minutes) the acoustic data still contains interference from the bridge echo sounder.

Figure 20. Echograms from station 62 at 38kHz (top) and 120kHz (bottom) showing possible *L. gahi* aggregations.

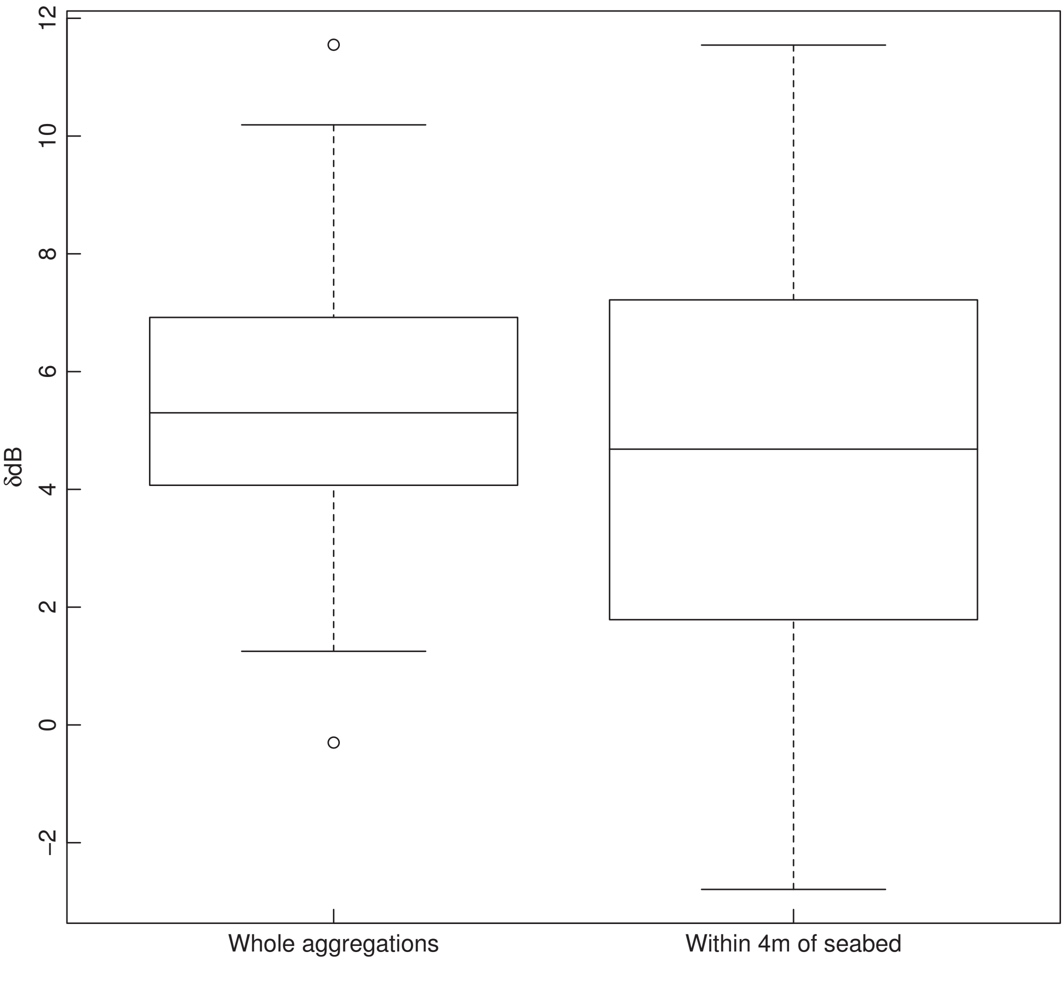


Differences in backscattering strength at 120kHz and 38kHz

The outlines of recognisable aggregations during the period of the trawl were defined by hand, taking care not to include pulses of interference, and the integration results exported for further processing. Two sets of regions were defined, one including whole aggregations, and one including only those parts of aggregations that are within 4m of the bottom (i.e. the area sampled by the trawl). The visual impression that the aggregations show stronger backscattering at 120kHz than 38kHz was confirmed by calculating the difference in mean volume backscattering (Sv) between 120kHz and 38kHz for each region. The distributions of δ dB are illustrated in Figure 21. The distribution is rather wider for the regions confined to within 4m of the seabed, probably as a result of the fact that, for the larger aggregations, the area of highest backscattering strength was more than 4m above the seabed so only the edges of these aggregations were included. Average δ dB is +5.5 dB for complete aggregations and +4.7 dB for aggregations within 4m of the seabed.

Differences in mean volume backscattering strength have been used successfully in the acoustic classification of various organisms (Madureira *et al.* 1993; Goss *et al.* 1998). Antarctic krill (*Euphausia superba* Dana, 1850) shows values of +2 to +12 dB (Madureira *et al.* 1993), and the ommastrephid squid *Martialia hyadesi,* Rochebrune et Mabille 1891, shows values of –3 to +1 dB (Goss *et al.* 1998). A value around +5 dB would therefore seem about right for *Loligo gahi*, as individual size is between those of krill and *M. hyadei*. Further acoustic records, with a more definite attribution to *L. gahi*, are required to confirm this value.

Figure 21. Difference in mean volume backscattering (Sv) at 38kHz and 120kHz for the aggregations visible in the echograms records of station 62. For each region δ dB = mean(Sv at 120kHz) – mean (Sv at 38kHz). Two groups of regions were considered: those defining complete identifiable aggregations, and those parts of aggregations that lie within 4m of the seabed.



Target strength

For quantitative studies of squid number and/or biomass using acoustic techniques it is important to know the acoustic target strength, that is the size of echo that would be expected from an individual of a given size. Split beam echo sounders, such as the EK500, have the capability of measuring the strength of individual targets *in situ*. Measuring target strength *in situ* avoids problems associated with behaviour and orientation that have affected experimental observations of target strength using dead or captive animals, but relies on positive identification of the observed values by, for example, trawling.

The ease with which single targets can be identified is related to depth. At the depths at which most *L. gahi* were caught on the present cruise, the EK500 was not able to identify many single targets. No single targets were identified from the part of the water column sampled by the trawl at station 62.

Other work

Database of acoustic properties

During the course of the cruise work was begun on a database to store information gathered on the acoustic properties of the various species that comprise the fishery in the Falklands Zones.

RoxAnn

Data from the RoxAnn seabed classification system were also logged along the track shown in Figure 13. It was hoped that such data could be used to distinguish between different seabed types in the surveyed region, even if the precise nature of these differences was not investigated using ground truthing procedures. Unfortunately the RoxAnn system unit tended to "crash" fairly frequently. When this occurred the logging application continued recording data, despite the fact that these were now erroneous. The reasons for the poor performance of the system are still being investigated.

It is likely that the data logged can be filtered to remove the sections of bad data. The RoxAnn unit calculates depth independently of the calculation of depth by the EK500 unit. After system failures the recorded depth will have been in error and so these data can be identified by comparison with the bathymetric data logged from the EK500.

Discussion

This research cruise proved a useful test of the Department's capabilities in the area of acoustic surveying. It was especially useful to have carried out a successful calibration of the EK500 echo sounder using standard targets, as we are not aware of this having been done previously around the Falklands coastline and there was some concern as to whether a suitable site could be found. The site eventually chosen proved very suitable and now that both the Department's scientific staff and the crew of the *Dorada* have been through this exercise once it is possible that alternative suitable sites could be found in future if weather conditions so dictate.

The interference problems caused by the bridge echo sounder and Doppler profiler must be solved before quantitative acoustic surveying can be seriously considered. It is hoped that synchronising the pinging of these devices to that of the EK500 will be the required solution, and plans for this work are advancing.

The comparison of acoustic records with trawling samples is greatly aided by detailed information on the actual region trawled. In future it should be possible to log more detailed information from the Simrad Trawl Instrumentation system.

The small catches of *L. gahi* taken during the cruise allow only limited analysis of the potential for using acoustic methods in surveys for this species. Initial results, however, are reasonably encouraging. Further analysis of the data from station 62, using target strength data for related species from the literature, is continuing. In future, targetted trawling on marks believed to be *L. gahi* could aid the acoustic characterisation of this species. Catches from shallower stations would increase the probability of obtaining *in situ* target strength measurements. Pelagic trawling when squid are higher in the water column could also prove useful. A pelagic trawling capability would also be important in any surveying of finfish species.

Appendix 3.1: Equipment detail

The EK500 system box and display are housed in the dry laboratory. There is a direct parallel port connection from the EK500 to a Deskjet 870Cxi A4 cut sheet printer. An ethernet connection to a PC allows acoustic data to be logged with the SonarData Echolog_EK program. This data is available for display and post-processing with EchoView and can be archived to DAT tape. The SonarData EchoConfig_EK program, running on the same PC, allows remote configuration of the EK500, and downloading of configuration settings.

The signal from the 38kHz transducer is also fed to the RoxAnn seabed profiling system box, again housed in the dry laboratory. A serial connection feeds the RoxAnn output to a second PC where it can be logged and displayed with the RoxMap application. Both the EK500 and RoxAnn PC have serial line input of NEMA format GPS information from the bridge. The RoxAnn PC has a direct parallel port connection to a HP Deskjet 1000C A3 printer. All equipment is powered from the dry laboratory uninteruptable power supply.

Echogram logging: EchoView

The EK500 is connected to a HP Brio PC via ethernet as follows: a 1m 15pin D connector drop cable from EK500 ethernet port connects to a CentreCOM 210TS transceiver, which links via a 3m RJ45 crossover cable to a Planet ENW-8300 10 Mbps ethernet card in PC.

Network settings for the EK500 and logging PC are given in the table below. IP addresses were chosen from the Group C address range specified in RFC 1918 (Rekhter *et al*., 1996). The local and remote IP and ethernet addresses must be specified via the EK500 ethernet menu. The EK500 appears to allow the local ethernet address to be changed. This is unusual as such addresses are generally hard coded by the manufacturer and unique to an individual device. The default EK500 ethernet address was used.

The following versions of SonarData software were used: EchoView 1.40.30, EchoLog_EK 1.40.00, and EchoConfig_EK 1.00.02 beta.

Table VII. Network settings for EK500 and HP Brio PC running SonarData software.

	EK500	*HP Brio EchoLog PC*
Ethernet address	08:00:14:51:57:90	00:00:B4:9F:FE:9D
IP address	192.168.1.1	192.168.1.2
Subnet mask		255.255.255.0
UDP broadcast port	2000	401
UDP mode port		403

RoxAnn

Only the ping frequency setting of the EK500 has any great influence on the RoxAnn – the interval between pings needs to be sufficiently long for the second bottom echo to be detectable. RoxAnn data is both displayed and logged by the RoxMap application. The RoxAnn system is also equipped with programs to export the data and graph it in 3D. The RoxAnn system unit simply outputs three values: current depth, and two variables referred to as E1 and E2 which can be used to characterise the current bottom type. E1 is related to the topographical “roughness” of the seabed surface while E2 is related to relative seabed “hardness” (actually acoustic impedance, Marine Micro Systems, 1995). The RoxAnn system unit operates very much as a “black box” – if both green LEDs on the front of the unit are lit this should indicate correct operation.

Appendix 3.2: Calibration procedure

1. Request that all discharges from the vessel be kept to an absolute minimum, preferably zero, throughout the calibration. Carry out CTDO to generate average temperature, salinity and sound speed for the depth range of interest (i.e. transducer depth to sphere depth).
2. While the CTDO is underway, the EK500 can be tested at each frequency using the internal test oscillator. One frequency should be tested at a time, the other must be turned off during the test. The result is recorded so that any change in the system performance will be noted.
3. A heaving line is passed under the hull, weighted with a shackle, from line point A (port), to a point midway between line points B and C (starboard). See Figure 12.
4. Attach line A to heaving line at position A, and haul loosely across to starboard
5. Immerse sphere in bucket of weak detergent solution and join to all three lines on starboard side. Attach weight to hang about 3 m below the sphere if necessary.
6. Lower all lines to marks, positioned to place the sphere 20 m (or 18 m or 15 m if water depth insufficient) below the transducers (see TABLE V in main document).
7. Look for sphere in TS display window, centralise using three helpers with walkie-talkie radios to control fishing lines.
8. Set up a layer to include the sphere but as little as possible of the water column above and below. Make this the super layer. Measure TS of sphere to set TS gain.
9. Integrate over the narrow layer containing the sphere for several short integration intervals (these can be printed out), use Sa to set Sv gain.
10. Run the `lobe` program, using the three helpers with walkie-talkie radios to adjust fishing lines.
11. Free off two of the three lines and haul on the third to bring the sphere to the surface.
12. Repeat from step 5 for the second sphere.
13. If there are any doubts about the validity of the first CTDO for the calibration exercise, carry out a second CTDO.

4. Biological sampling

Trawls were made at 27 stations around East Falkland (see Figure 22 and Table VIII). Hauls were made using a bottom trawl equipped with polyvalent doors, each weighing 1200kg, and a 40 mm liner. 25 stations lay on the previously established transects (P1 – P9) where trawls were carried out at approximately 100, 200 and 300m. At each transect trawl station a 3.7 km (2 nautical miles) trawl was carried out, with an average on-bottom duration of 30 min depending on weather and sea conditions. Two additional trawls (stations 38 and 39) were made in the grid square XUAH with the hope of recapturing previously tagged skate. Towing time for these stations was approximately 90 minutes, and in the second of these trawls (station 39) a "tickler" chain was used.

Biological analysis and processing of the catch

The objectives of the biological sampling programme were to:

1. Accurately weigh all catch and by-catch, and identify to species level, where possible.
2. Collect biological parameters like length-frequency and/or length-weight data from the main catch and a wide variety of by-catch species.
3. Collect parasitological data on *Loligo gahi* and Ray species.
4. Collect samples of juvenile fish for otolith removal ashore.
5. Collect samples of *Loligo gahi* for statolith removal ashore.
6. Collect taxonomic details from selected ray specimens for an ongoing study.
7. Collect Octopus/Eledone species for positive identification by our resident cephalopod specialists.

Catch and by-catch

Weight and percentage figures (kg & %) in this section are noted without decimals (see Tables for greater accuracy).

Table IX shows the catch summary by species for the period of the cruise. A total catch of 15,370kg was the result of a total of 27 trawled stations. By far the most predominant catch was Medusae with 7,047kg or 46% of the total catch, followed by *Dissostichus eleginoides* with 2,628kg or 17% of the total catch.

Identification of the Medusae was not attempted at this stage, as reference material was not available.

Station 14 yielded an exceptionally high catch of both *D. eleginoides* (2,444kg) and Medusae (2,003kg) in only 30 minutes trawling. This catch of *D. eleginoides* made up 93% of the total catch of that species during the observed period. For Medusae, this particular catch made up for 28% of the total catch of that group during the observed period.

The distribution of catch of commercial species and species groups (i.e. those reported to the Fisheries Department in daily catch reports) is illustrated in Figure 23.

Figure 22. Location of trawl stations.

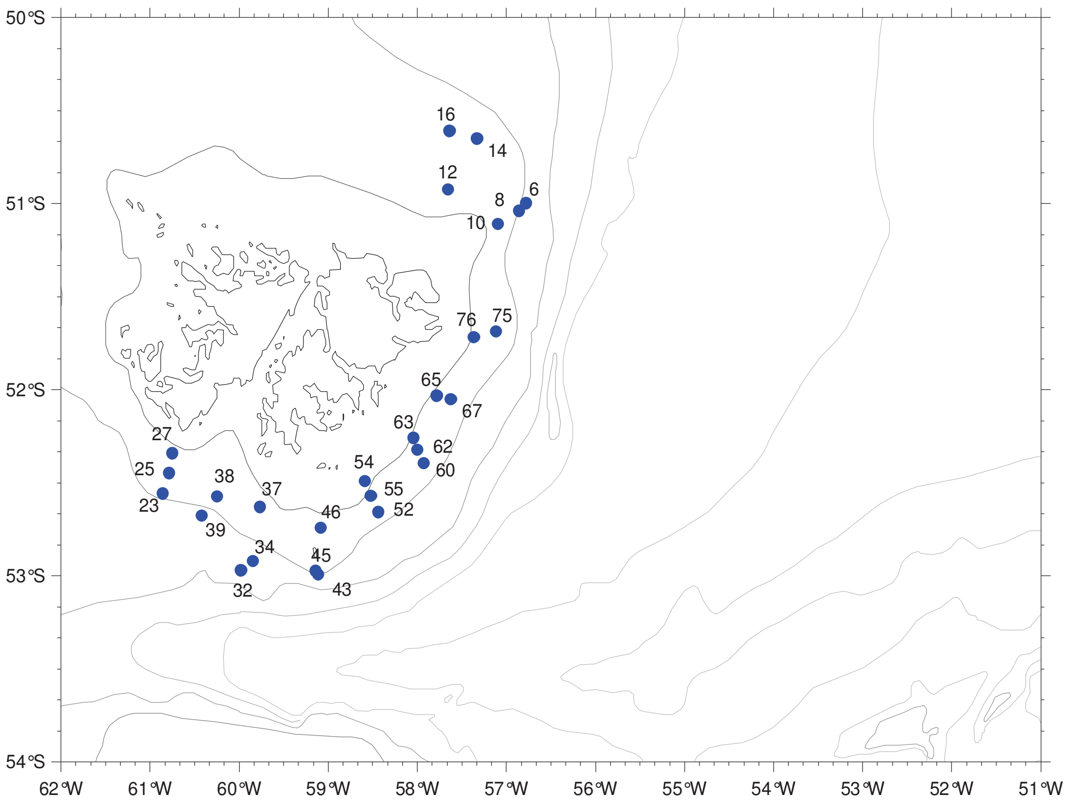


Table VIII. Station details.

Station	*Station Type*	*Date*	*Time*	*Modal Depth*	*Start Latitude*	*Start Longitude*	*End Latitude*	*End Longitude*
5	CTD	17/06/99	10:47	279	51° 2.29' S	56° 49.11' W	51° 2.29' S	56° 49.11' W
6	Trawl	17/06/99	12:09	313	51° 0.95' S	56° 46.70' W	50° 58.88' S	56° 46.67' W
7	CTD	17/06/99	14:42	213	50° 59.96' S	56° 51.88' W	50° 59.96' S	56° 51.88' W
8	Trawl	17/06/99	17:35	206	51° 1.64' S	56° 51.34' W	51° 3.23' S	56° 42.48' W
9	CTD	18/06/99	07:50	114	51° 7.15' S	57° 5.53' W	51° 7.15' S	57° 5.53' W
10	Trawl	18/06/99	08:40	117	51° 7.37' S	57° 5.49' W	51° 6.01' S	57° 2.69' W
11	CTD	18/06/99	12:57	128	50° 56.20' S	57° 39.30' W	50° 56.40' S	57° 39.40' W
12	Trawl	18/06/99	13:50	129	50° 56.26' S	57° 39.30' W	50° 54.75' S	57° 36.42' W
13	CTD	18/06/99	17:25	202	50° 40.30' S	57° 18.90' W	50° 40.30' S	57° 18.90' W
14	Trawl	18/06/99	18:02	197	50° 39.90' S	57° 19.50' W	50° 38.37' S	57° 21.95' W
15	CTD	18/06/99	21:17	297	50° 38.75' S	57° 14.35' W	50° 38.75' S	57° 14.35' W
16	Trawl	18/06/99	22:05	297	50° 37.10' S	57° 38.10' W	50° 36.16' S	57° 18.21' W
17	CTD	19/06/99	03:55	447	50° 13.90' S	56° 43.95' W	50° 13.91' S	56° 43.94' W
18	CTD	19/06/99	14:30	98	51° 10.40' S	58° 57.70' W	51° 10.50' S	58° 57.70' W
19	CTD	20/06/99	07:56	28	51° 29.16' S	59° 31.51' W	51° 39.16' S	59° 31.51' W
20	CTD	20/06/99	09:40	28	51° 45.22' S	59° 27.60' W	51° 45.22' S	59° 27.54' W
21	CTD	20/06/99	15:27	36	52° 12.35' S	60° 26.31' W	52° 12.35' S	60° 26.31' W
22	CTD	21/06/99	09:02	302	52° 33.68' S	60° 52.45' W	52° 33.73' S	60° 52.36' W
23	Trawl	21/06/99	10:04	299	52° 33.69' S	60° 51.45' W	52° 33.43' S	60° 47.41' W
24	CTD	21/06/99	12:44	208	52° 26.97' S	60° 47.83' W	52° 26.95' S	60° 47.77' W
25	Trawl	21/06/99	13:25	202	52° 27.18' S	60° 47.15' W	52° 26.65' S	60° 43.71' W

Table VIII, continued.

26	CTD	21/06/99	18:42	122	52° 20.66' S	60° 43.40' W	52° 20.66' S	60° 43.33' W
27	Trawl	21/06/99	19:31	125	52° 20.92' S	60° 44.86' W	52° 20.30' S	60° 41.65' W
28	CTD	22/06/99	03:09	475	53° 3.30' S	61° 19.50' W	53° 3.30' S	61° 19.50' W
29	CTD	22/06/99	08:52	1035	53° 23.03' S	60° 9.93' W	53° 23.08' S	60° 9.45' W
30	CTD	22/06/99	11:14	516	53° 8.86' S	60° 1.67' W	53° 8.84' S	60° 1.18' W
31	CTD	22/06/99	13:36	298	52° 57.72' S	59° 59.67' W	52° 57.71' S	59° 59.50' W
32	Trawl	22/06/99	14:33	298	52° 58.12' S	59° 58.55' W	52° 58.55' S	59° 54.80' W
33	CTD	22/06/99	16:39	240	52° 56.21' S	59° 54.72' W	52° 56.18' S	59° 54.57' W
34	Trawl	22/06/99	18:27	202	52° 55.08' S	59° 50.55' W	52° 55.46' S	59° 54.67' W
35	CTD	22/06/99	22:26	190	52° 39.94' S	60° 14.41' W	52° 39.88' S	60° 14.23' W
36	CTD	23/06/99	08:07	126	52° 38.86' S	59° 44.46' W	52° 38.82' S	59° 44.37' W
37	Trawl	23/06/99	08:57	126	52° 36.72' S	59° 45.93' W	52° 38.96' S	59° 42.67' W
38	Trawl	23/06/99	12:56	150	52° 32.47' S	60° 14.58' W	52° 36.48' S	60° 7.16' W
39	Trawl	23/06/99	17:12	222	52° 38.86' S	60° 24.98' W	52° 42.41' S	60° 16.49' W
40	CTD	24/06/99	04:30	1000	53° 20.89' S	58° 54.49' W	53° 20.90' S	58° 54.48' W
41	CTD	24/06/99	07:14	526	53° 6.40' S	58° 58.46' W	53° 6.47' S	58° 58.50' W
42	CTD	24/06/99	09:25	311	52° 59.95' S	59° 7.07' W	52° 59.45' S	59° 7.07' W
43	Trawl	24/06/99	10:11	309	52° 59.93' S	59° 6.78' W	52° 59.29' S	59° 2.76' W
44	CTD	24/06/99	12:44	223	52° 58.94' S	59° 6.46' W	52° 58.99' S	59° 6.47' W
45	Trawl	24/06/99	13:36	195	52° 58.73' S	59° 8.51' W	52° 58.30' S	59° 4.82' W
46	Trawl	24/06/99	16:38	112	52° 42.92' S	59° 4.99' W	52° 46.09' S	59° 6.65' W
47	CTD	24/06/99	00:00		52° ' S	59° ' W	52° ' S	59° ' W
48	CTD	24/06/99	18:16	114	52° 44.75' S	59° 8.33' W	52° 44.80' S	59° 8.41' W
49	CTD	24/06/99	23:45	1145	53° 10.85' S	57° 59.73' W	53° 11.26' S	57° 59.77' W
50	CTD	25/06/99	05:05	602	53° 1.85' S	58° 6.78' W	53° 2.10' S	58° 6.77' W
51	CTD	25/06/99	10:08	313	52° 40.89' S	58° 24.67' W	52° 40.94' S	58° 24.71' W
52	Trawl	25/06/99	11:02	270	52° 40.60' S	58° 26.15' W	52° 38.45' S	58° 23.91' W
53	CTD	25/06/99	14:26	132	52° 30.05' S	58° 33.31' W	52° 30.07' S	58° 33.28' W
54	Trawl	25/06/99	15:00	122	52° 30.35' S	58° 35.00' W	52° 28.66' S	58° 32.91' W
55	Trawl	25/06/99	17:29	200	52° 34.81' S	58° 30.99' W	52° 33.68' S	58° 28.08' W
56	CTD	25/06/99	19:11	200	52° 34.35' S	58° 29.99' W	52° 34.32' S	58° 29.89' W
57	CTD	26/06/99	00:24	1118	52° 58.92' S	57° 18.70' W	52° 58.92' S	57° 18.70' W
58	CTD	26/06/99	02:44	563	52° 47.09' S	57° 30.88' W	52° 47.10' S	57° 30.90' W
59	CTD	26/06/99	08:02	295	52° 24.40' S	57° 56.48' W	52° 24.36' S	57° 56.28' W
60	Trawl	26/06/99	08:52	302	52° 23.92' S	57° 55.67' W	52° 23.52' S	57° 51.81' W
61	CTD	26/06/99	13:48	199	52° 20.04' S	58° 0.75' W	52° 20.03' S	58° 0.70' W
62	Trawl	26/06/99	14:27	203	52° 19.85' S	57° 59.94' W	52° 18.91' S	57° 56.71' W
63	Trawl	26/06/99	17:19	123	52° 15.50' S	58° 2.60' W	52° 15.74' S	58° 6.09' W
64	CTD	27/06/99	18:51	121	52° 15.47' S	58° 6.24' W	52° 15.49' S	58° 6.08' W
65	Trawl	28/06/99	13:55	123	52° 2.92' S	57° 46.66' W	52° 1.14' S	57° 44.68' W
66	CTD	28/06/99	15:15	122	52° 1.86' S	57° 45.42' W	52° 1.87' S	57° 45.41' W
67	Trawl	28/06/99	16:21	198	52° 3.86' S	57° 37.12' W	52° 2.36' S	57° 34.43' W
68	CTD	28/06/99	17:53	208	52° 8.27' S	57° 34.47' W	52° 2.19' S	57° 34.42' W
69	CTD	28/06/99	19:19	321	52° 7.39' S	57° 29.41' W	52° 7.25' S	57° 29.28' W
70	CTD	28/06/99	21:43	514	52° 16.96' S	57° 6.78' W	52° 16.75' S	57° 6.53' W
71	CTD	29/06/99	01:10	1113	52° 30.03' S	56° 30.13' W	52° 29.51' S	56° 38.02' W
72	CTD	29/06/99	06:14	1017	51° 45.46' S	56° 9.42' W	51° 45.31' S	56° 9.10' W
73	CTD	29/06/99	09:16	530	51° 44.87' S	56° 41.33' W	51° 44.61' S	56° 41.30' W
74	CTD	29/06/99	11:21	300	51° 44.31' S	57° 8.26' W	51° 44.18' S	57° 8.19' W

Table VIII, continued.

75	Trawl	29/06/99	12:06	325	51° 42.50' S	57° 6.61' W	51° 40.17' S	57° 5.45' W
76	Trawl	29/06/99	14:53	204	51° 44.23' S	57° 21.66' W	51° 42.19' S	57° 19.47' W
77	CTD	29/06/99	16:32	202	51° 43.73' S	57° 21.43' W	51° 43.66' S	57° 21.36' W
78	CTD	29/06/99	21:43	98	51° 42.07' S	57° 33.37' W	51° 42.05' S	57° 33.35' W
79	CTD	03/07/99	14:53	89	51° 14.96' S	57° 30.08' W	51° 14.95' S	57° 30.07' W
80	CTD	03/07/99	17:30	330	51° 29.75' S	56° 59.65' W	51° 29.68' S	56° 59.50' W
81	CTD	03/07/99	19:52	504	51° 14.77' S	56° 30.04' W	51° 14.65' S	56° 29.97' W
82	CTD	03/07/99	22:44	962	51° 30.07' S	56° 0.06' W	51° 30.04' S	55° 59.91' W
83	CTD	04/07/99	01:59	1095	51° 15.04' S	55° 29.81' W	51° 15.03' S	55° 29.72' W
84	CTD	04/07/99	04:55	1356	51° 30.31' S	54° 59.10' W	51° 30.39' S	54° 59.25' W
85	CTD	04/07/99	07:44	1503	51° 14.98' S	54° 30.02' W	51° 15.17' S	54° 30.07' W
86	CTD	04/07/99	10:52	1393	51° 30.10' S	54° 1.07' W	51° 30.04' S	54° 0.81' W
87	CTD	04/07/99	14:03	1857	51° 14.73' S	53° 29.89' W	51° 14.74' S	53° 29.89' W
88	CTD	04/07/99	17:02	2036	51° 30.25' S	52° 59.61' W	51° 30.36' S	52° 59.27' W
89	CTD	04/07/99	19:53	2087	51° 15.07' S	52° 29.77' W	51° 15.13' S	52° 29.44' W
90	CTD	04/07/99	22:47	2173	51° 30.01' S	51° 59.86' W	51° 30.11' S	51° 59.49' W
91	CTD	05/07/99	02:44	2411	51° 59.86' S	51° 59.85' W	51° 59.83' S	51° 59.80' W
92	CTD	05/07/99	05:43	2149	51° 44.98' S	52° 29.33' W	51° 44.98' S	52° 29.31' W
93	CTD	05/07/99	08:36	2165	52° 0.02' S	53° 0.01' W	52° 0.32' S	52° 59.94' W
94	CTD	05/07/99	11:53	1975	51° 44.97' S	53° 29.91' W	51° 45.21' S	53° 29.87' W
95	CTD	05/07/99	15:06	1901	52° 0.13' S	53° 59.28' W	52° 0.13' S	52° 59.27' W
96	CTD	05/07/99	18:29	1617	51° 44.69' S	54° 30.08' W	51° 44.85' S	54° 29.71' W
97	CTD	05/07/99	21:45	1542	52° 0.02' S	54° 0.03' W	52° 0.09' S	55° 59.38' W
98	CTD	06/07/99	01:29	1182	51° 45.41' S	55° 29.56' W	51° 45.50' S	55° 29.70' W
99	CTD	06/07/99	04:40	1206	51° 59.75' S	55° 59.35' W	51° 59.80' S	55° 59.50' W
100	CTD	06/07/99	07:43	770	51° 45.02' S	56° 29.81' W	51° 45.08' S	56° 29.12' W
101	CTD	06/07/99	11:04	460	51° 59.92' S	56° 59.82' W	51° 59.91' S	56° 59.52' W
102	CTD	06/07/99	13:50	135	51° 44.86' S	57° 29.69' W	51° 44.87' S	57° 29.67' W

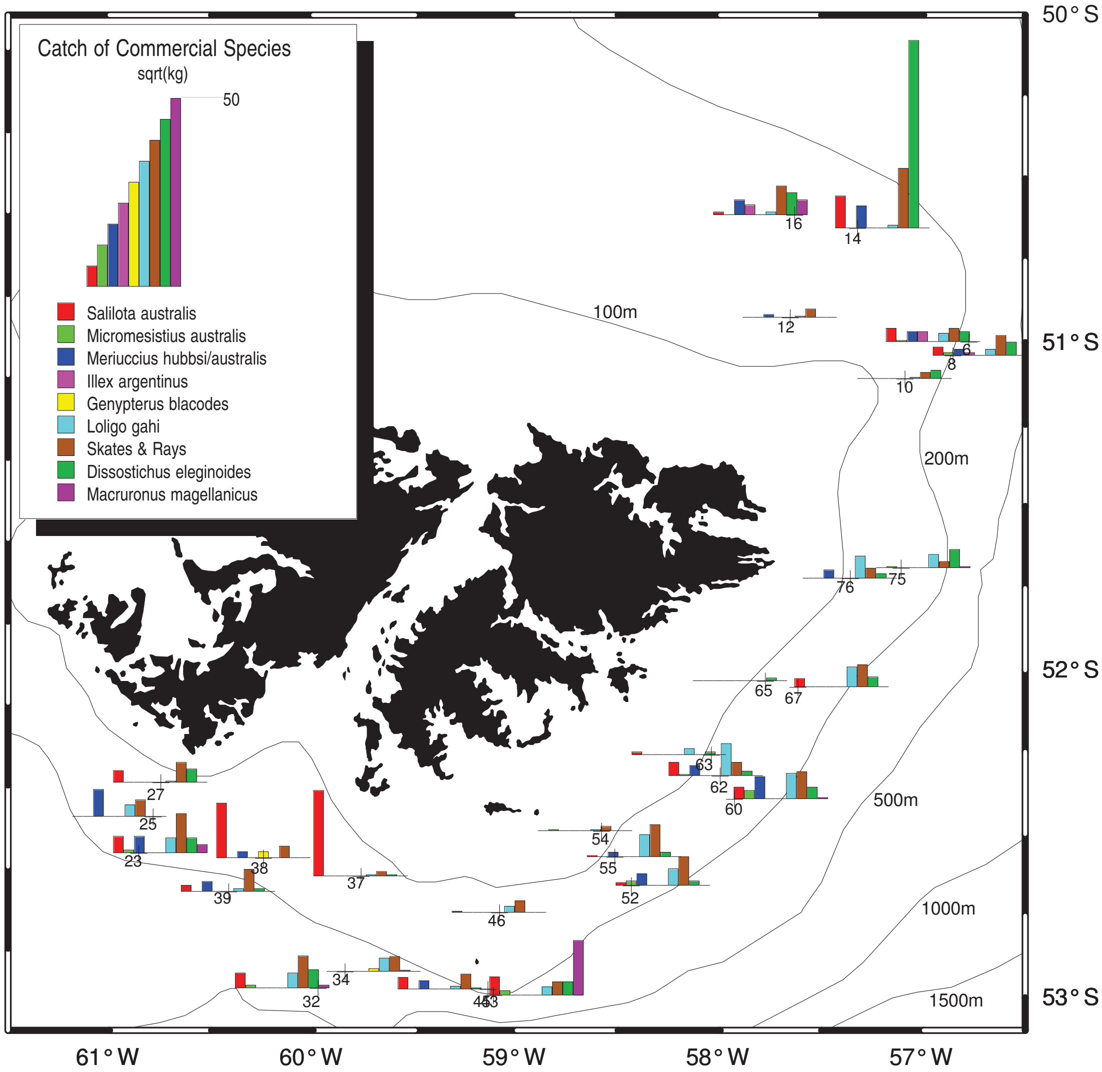
Table IX. Catch summary by species, ZDLH1 16 – 29 June 1999. Percentages are given to two decimal places only.

	Species Name	*Species Code*	*Catch Total (kg)*	*Proportion of Total Catch (%)*	*Sample Total (kg)*
1	MEDUSAE SP.	MED	7,047.74	45.85%	3.00
2	DISSOSTICHUS ELEGINOIDES	TOO	2,628.56	17.10%	418.42
3	SALILOTA AUSTRALIS	BAC	1,367.09	8.89%	174.89
4	NOTOTHENID SPP.	COX	1,343.42	8.74%	0.30
5	BATHYRAJA GRISEOCAUDA	RGR	417.54	2.72%	417.54
6	LOLIGO GAHI	LOL	338.8	2.20%	117.76
7	SQUALUS ACANTHIAS	DGS	261.78	1.70%	94.62
8	BATHYRAJA BRACHYUROPS	RBR	256.17	1.67%	136.77
9	MERLUCCIUS HUBBSI	HAK	230.2	1.50%	87.60
10	MACRURONUS MAGELLANICUS	WHI	228.75	1.49%	54.67
11	SPRATTUS FUEGENSIS	SAR	209.24	1.36%	10.38
12	BATHYRAJA ALBOMACULATA	RAL	173.92	1.13%	104.92
13	COTTOPERCA GOBIO	CGO	158.01	1.03%	5.26
14	SCALLOP	SCA	125.72	0.82%	0.00
15	SPONGES	SPN	125.45	0.82%	0.00
16	UNIDENTIFIED BATHYRAJA	RBZ	101.42	0.66%	67.42
17	SEA URCHIN	UCH	55.22	0.36%	0.16
18	BATHYRAJA MULTISPINIS	RMU	31.8	0.21%	28.80
19	OPHIUROIDEA	OPH	28.24	0.18%	0.34
20	BATHYRAJA SCAPHIOPS	RSC	23.7	0.15%	23.70
21	BATHYRAJA MACLOVIANA	RMC	17.36	0.11%	3.36
22	ANTHOZOA	ANT	16.56	0.11%	0.34
23	ILLEX ARGENTINUS	ILL	16.12	0.10%	16.12
24	SCHROEDERICHTHYS BIVIUS	DGH	14.32	0.09%	3.24
25	ASTEROIDEA	AST	13.88	0.09%	0.06
26	MICROMESISTIUS AUSTRALIS	BLU	12.4	0.08%	1.26
27	ANEMONE	ANM	12.3	0.08%	0.00
28	RAJA DOELLOJURADOI	RDO	10.64	0.07%	4.64
29	PATAGONOTOTHEN RAMSAYI	PAR	9.12	0.06%	4.60
30	GENYPTERUS BLACODES	KIN	9	0.06%	0.00
31	SEBASTES OCULATUS	RED	8.58	0.06%	1.00
32	MERLUCCIUS AUSTRALIS	PAT	8.32	0.05%	2.42
33	ASCIDIACEA	SQT	7.96	0.05%	0.00
34	ILUOCOETES FIMBRIATUS	EEL	7.6	0.05%	0.00
35	PATAGONOTOTHEN TESSELLATA	PTE	6.94	0.05%	0.54
36	MACROURUS CARINATUS	GRC	6.87	0.04%	1.48
37	WHELKS	WLK	6.58	0.04%	0.14
38	OCTOPUS MEGALOCYATHUS	OCM	6.44	0.04%	6.44
39	PSAMMOBATIS SPP.	RPX	4.3	0.03%	3.06
40	UNIDENTIFIED ANIMAL	XXX	4.21	0.03%	1.17
41	COELORHYNCHUS FASCIATUS	GRF	3.64	0.02%	0.00
42	MOROTEUTHIS INGENS	ING	3.58	0.02%	2.12
43	NEOPHYRNICHTHYS MARMORATUS	NEM	2.36	0.02%	0.00
44	ELEGINOPS MACLOVINUS	MUL	1.46	0.01%	0.00
45	MANCOPSETTA MILFORDI	MAM	1.4	0.01%	1.40
46	MANCOPSETTA MACULATA	MMA	1.3	0.01%	1.30
47	PATAGONOTOTHEN GUNTHERI	COG	0.94	0.01%	0.64
48	HOLOTHUROIDEA	HOL	0.9	0.01%	0.00
49	SERIOLELLA POROSA	SEP	0.78	0.01%	0.78
	Continued overleaf				

Table IX, continued.

	Species Name	*Species Code*	*Catch Total (kg)*	*Proportion of Total Catch (%)*	*Sample Total (kg)*
50	OCTOPUS/ELEDONE SPP.	OCT	0.72	0.00%	0.00
51	BRACHIOPOD SPP.	BRP	0.16	0.00%	0.01
52	PARANOTOTHENIA MAGELLANICA	NOW	0.16	0.00%	0.00
53	BENTOCTOPUS SPP.	BEX	0.14	0.00%	0.14
54	COTTUNCULUS GRANULOSUS	COT	0.14	0.00%	0.00
55	CAMPYLONOTUS VAGANS	CAV	0.02	0.00%	0.00
56	SEMIROSSIA PATAGONICA	SRP	0.02	0.00%	0.00
57	CAMPYLONOTUS SEMISTRIATUS	CAS	0.01	0.00%	0.00
58	MUNIDA GREGARIA	MUN	0.01	0.00%	0.00
59	PELTARION SPINOSULUM	PES	0.01	0.00%	0.00
60	POLYCHAETA	POL	0.01	0.00%	0.01
61	SERIOLIS SPP.	SER	0.01	0.00%	0.00
			15,370.04	100.00%	1,786.93

Figure 23. Catch of commercial species (those reported in daily catch reports). Height of bars is proportional to the square root of catch (in kg). Catch weight at stations 38 and 39 was divided by three to scale to equal effort. The crosses on the histogram axis mark the trawl position.



Catches of Red Cod, *Salilota australis* Günther 1878, were next highest by weight although the total was again heavily influenced by just two stations in the south (stations 37 & 38). Skates and Rays, taken as a group as in FIFD catch data, represented the next highest catch total and were caught at most stations. The catch of Rays by species is examined in more detail later in this report. *Loligo gahi* was the fourth highest catch overall, with a total of 338.8kg. Hake, *Merluccius hubbsi* Marini 1933, was caught in small quantities at most stations, while station 43, to the SE of East Falkland, produced a high (> 200kg) catch of *Macruronus magellanicus*.

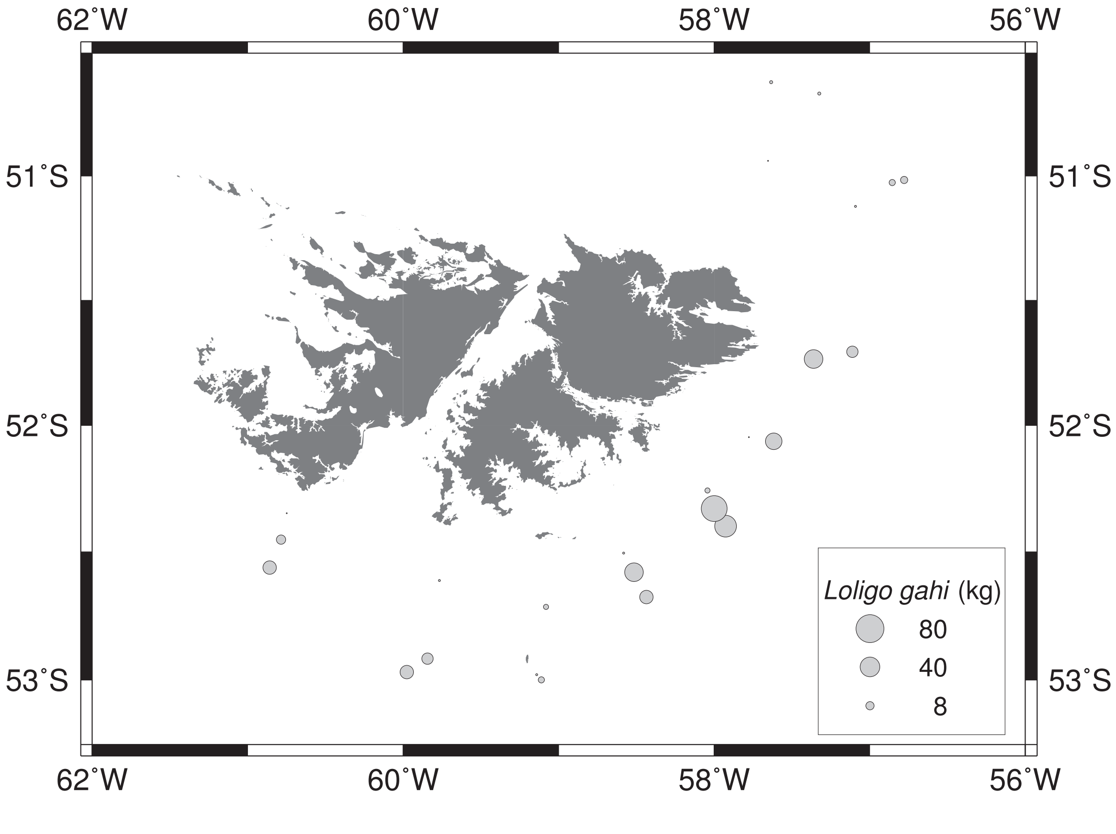
4.1 *Loligo gahi*

Distribution within the "*Loligo* box"

During the survey, catches of *L. gahi* were low in all regions, averaging 13.4 kg per trawl (see Figure 24). The highest catches (both in weight and numbers) were observed on the P3 transect at depths of 200 m (71 kg) and 300 m (47.4 kg). Another high catch (mainly in numbers) was on the P1 transect at 200 m depth. Catches in the north-eastern part of the FICZ were the lowest (mean weight of 1.92 kg).

Catch also varied with depth, being lowest at 100 m (mean 0.87 kg) and highest at 200 m (22.4 kg), with intermediate catches at 300 m (15.9 kg).

Figure 24. Catch of *Loligo gahi* at constant effort bottom trawl stations. Circle size is proportional to the square root of catch weight.



Sex ratio

Sex ratio varied with region and depth. In the extreme transects (P7 and P9) sex ratios were quite similar at 200 m and 300 m depths, with the ratio almost equal on P7 and a slight predominance of males on P9 (Figure 25). On all other transects, sex ratios had the same pattern, with a predominance of females at 300 m depths and predominance of males at 200 m depths. Maximum prevalence of females was observed on the P4 and P1 transects at 300 m depths, and on the P1 transect at 200 m depth. Maximum predominance of males occurred on transects P3 and P8 at 200 m (Figure 25). However, taking into account only abundant samples (>50 animals), sex ratios were almost equal on all transects when data from 200 and 300 m trawls were pooled together (Figure 25). Unfortunately, small numbers of squid caught at 100 m depths prevented proper analysis of sex ratio at these depths.

Maturity

Almost all females in catches were either immature (stage II) or maturing (stage III). Differences in female maturity state between 200 and 300 m catches were not especially apparent (Figure 26). Females were more mature at 300 m depths on the most abundant (in terms of catch) transects, P3 and P1 (Figure 26). The relative number of maturing females was greatest on two transects, P5 and P8 (Figure 26), but this was probably a result of low total catches of *L. gahi* on these transects (Figure 27) implying the absence of large schools of immature females. The number of immature females was greatest on the P3 (both 200 and 300 m depths) and P1 (only 200 m depth) transects. Maturing females were quite abundant, in numbers only, on transect P3 at 300 m depth. The number of mature females was very low (~1% of the total number of females), and they were most numerous in 300 m trawls on transects P7, P6 and P4 (Figure 27).

During the survey, males of all maturity stages were present in catches (Figure 26, Figure 27). They were more mature than females, generally being maturing and mature. The maturity state of males changed with depth (Figure 26); on each transect males were at more advanced maturity stages at 300 m depth than at 200 m depth. Immature males were most numerous on the P3 and P1 transects. Relative number of mature males was the highest on the P5 transect (both depths), and on transect P1 (300 m depth). However, absolute number of mature males was greatest on transects P3 and P4 (200 m depth).

Figure 25. Total catch per trawl of *L. gahi* in weight (A) and in numbers (B), and proportion of females in catches separately for 200 and 300 m depths (C) and pooled for both depths (D). P1 - P9 are the transect numbers (Table II) of the survey, arranged here from SW to NE.

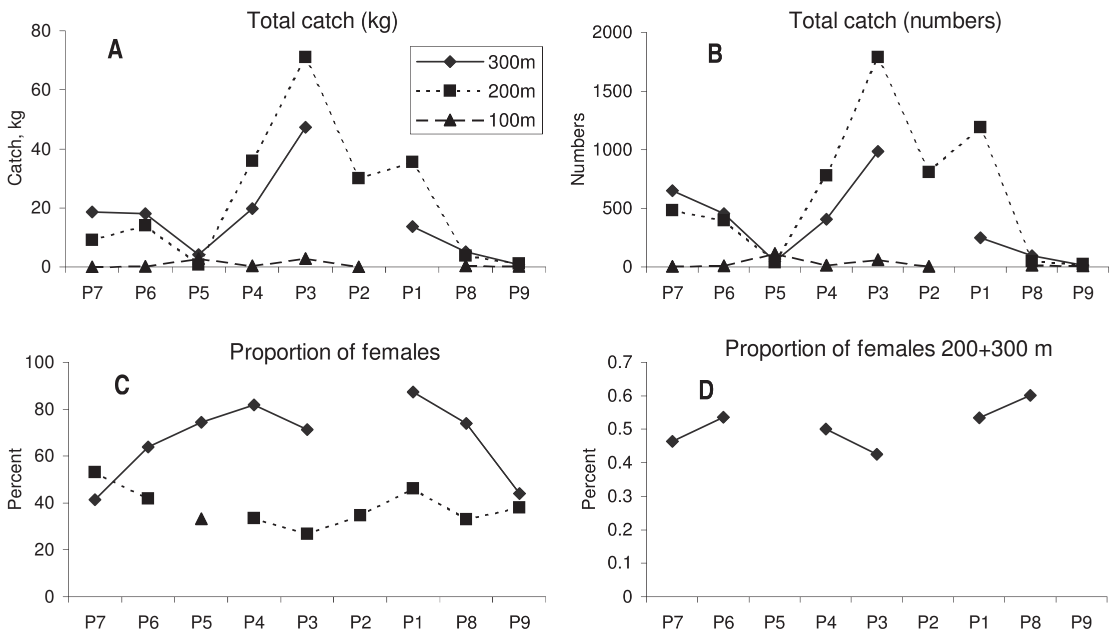
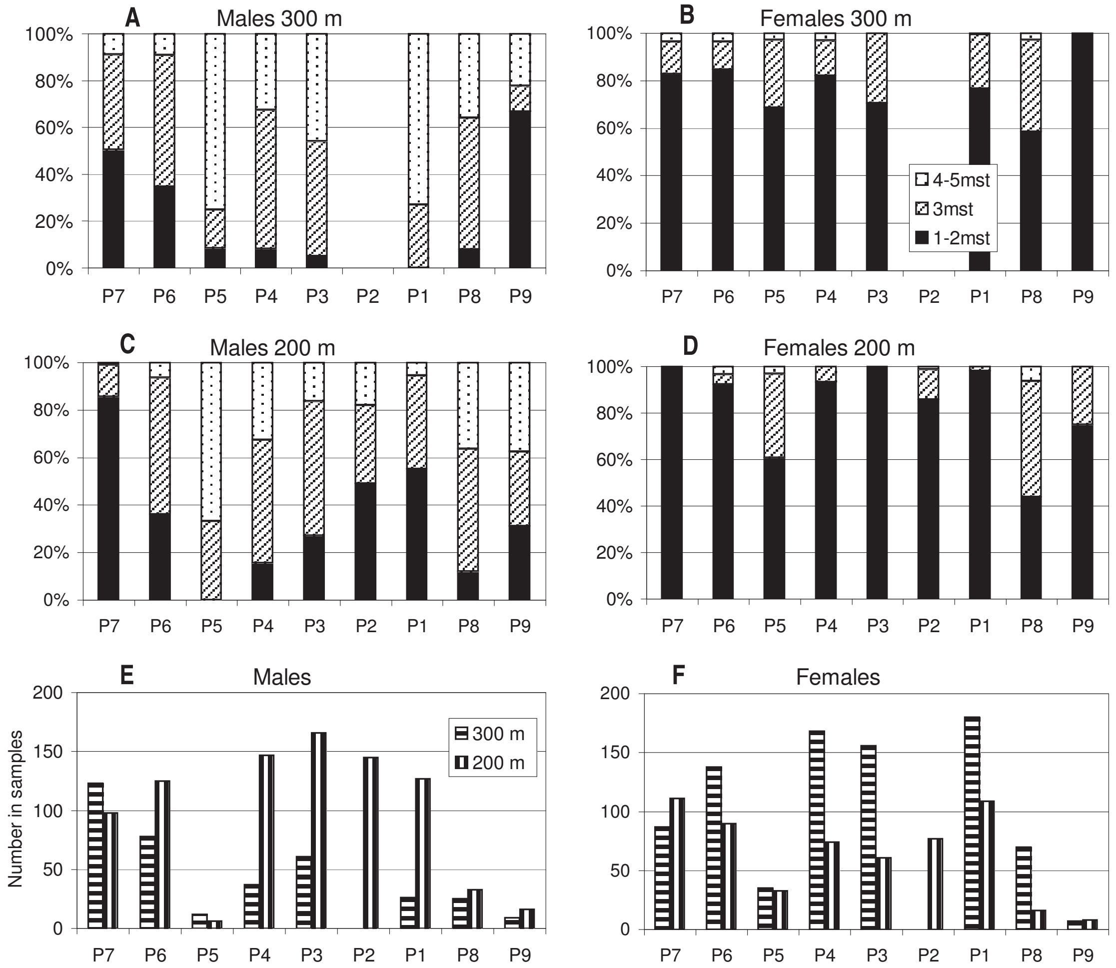


Figure 26. Proportions of males and females at different maturity periods (mst) in 300 m trawls (A, B) and 200 m trawls (C, D), and number of animals in each sample (E, F).



Length-frequency distribution

Length-frequency distributions (LFDs) were analysed separately for each sex, maturity stage and depth (Figure 28, Figure 29). LFDs of immature females were rather narrow on all transects excluding P1 (200 m), and usually consisted of six or seven 1cm length intervals. On each transect, modal sizes of immature females were larger at 300 m depth than at 200 m depth (Figure 28A). Modal length of immature females also varied between transects, being highest on transects P5 and P8, and lowest on transects P7 and P2 (Figure 28A). Differences in modal size of maturing females were not obvious at 200 and 300 m depths probably because of their small number in samples (Figure 28B). LFDs of immature males were also rather narrow, consisting of four to six 1 cm length intervals. Variation in modal size of immature males had the same trend as in immature females; they were largest on transect P8 (unfortunately, no immature males were caught on P5), and smallest on the P7 and P2 transects (Figure 29A). Modal sizes of maturing males were generally larger than those of immature males; variation in their modal size followed the same pattern as in immature males (Figure 29B). The size range of mature males was the greatest. On several transects, their sizes varied from 10 to 28 cm (Figure 29C), and occasional mature males of up to 40cm were found. On each transect, modal size of mature males was greater at 300 m depths than at 200 m depths. Trends in the variation of modal size were not so obvious as in immature and maturing males (probably because of the small number of animals sampled), but an increase in the modal length from P7 to P5 and subsequent decrease from P5 to P3 was distinguishable (Figure 29C).

Figure 27. Numbers in catches of males and females at different maturity stages on each transect.

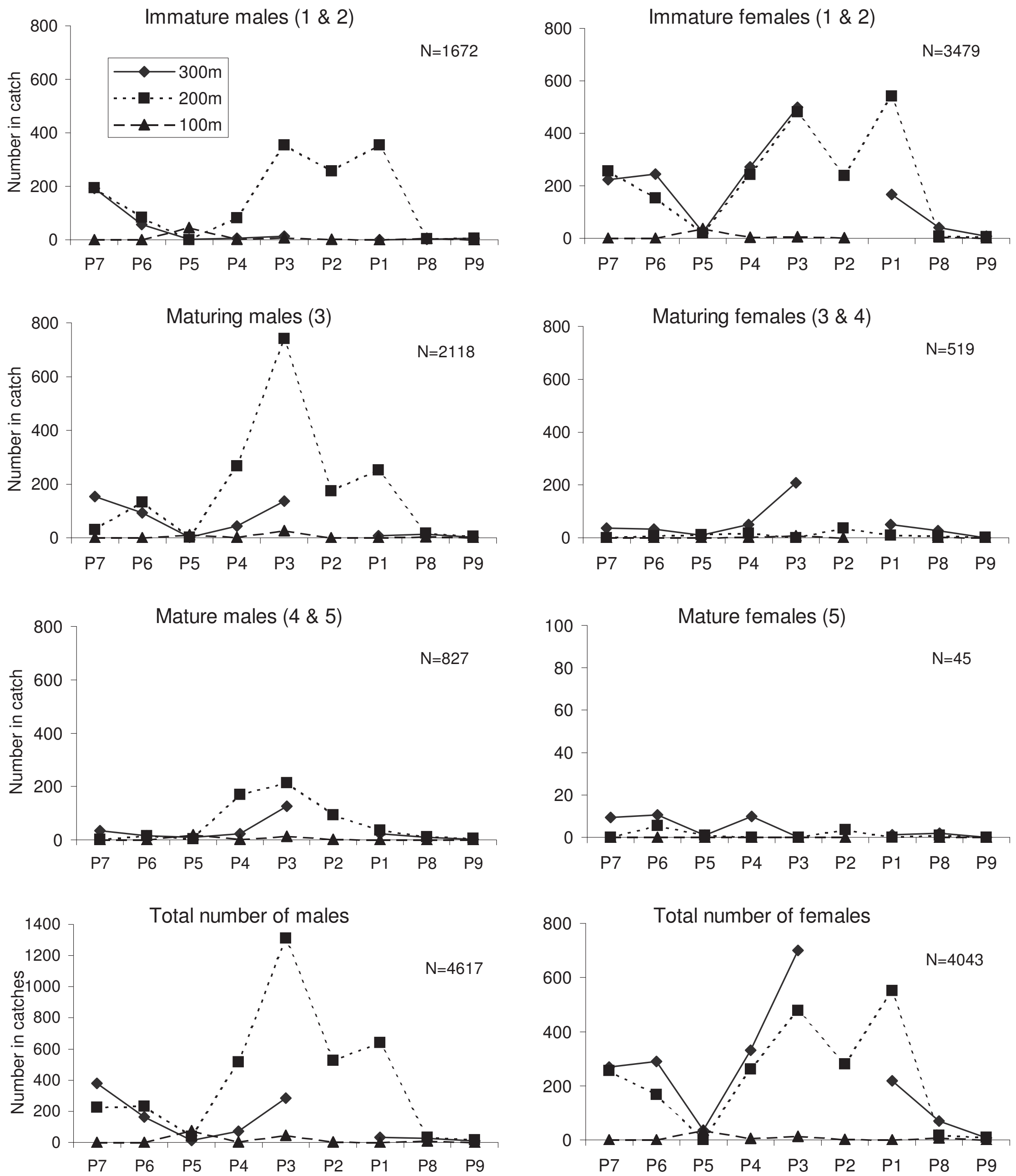


Figure 28. Length-frequency distributions of female *L. gahi* by transect at different depths. A: maturity stages 1 and 2, B: maturity stages 3 and 4. Transects are arranged sequentially from SE to NW. The 1 cm size classes are measured to the nearest centimetre below the actual mantle length (i.e. the 10cm class includes individuals with a dorsal mantle length between 10 and 11 cm). The shade allocated to each size class represents the proportion of individuals, of the total in each depth and maturity stage grouping, that fall in a particular size class. The actual number of individuals used to construct each LFD is given beneath the transect number; these are included to indicate the precision of the LFD rather than the number of individuals present.

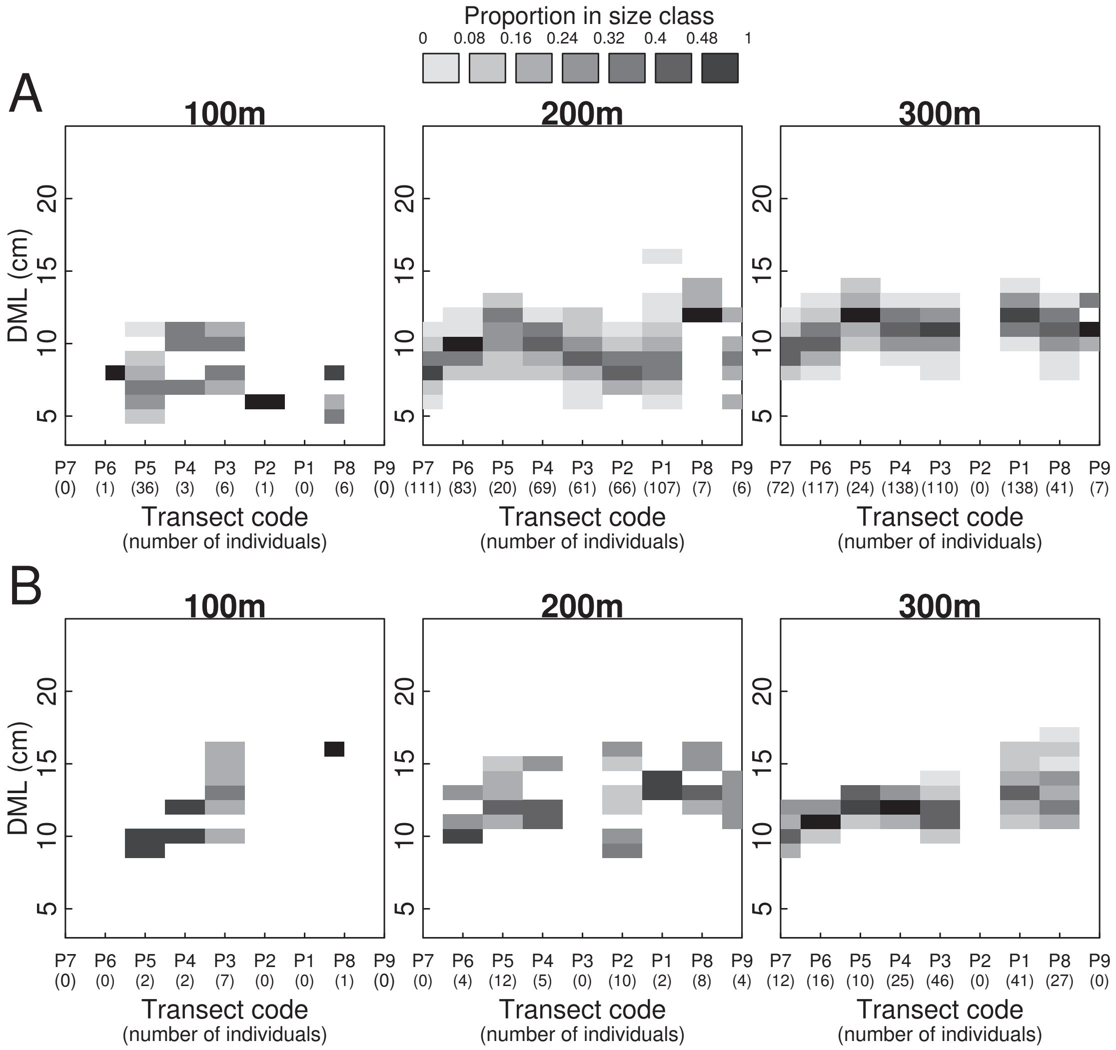
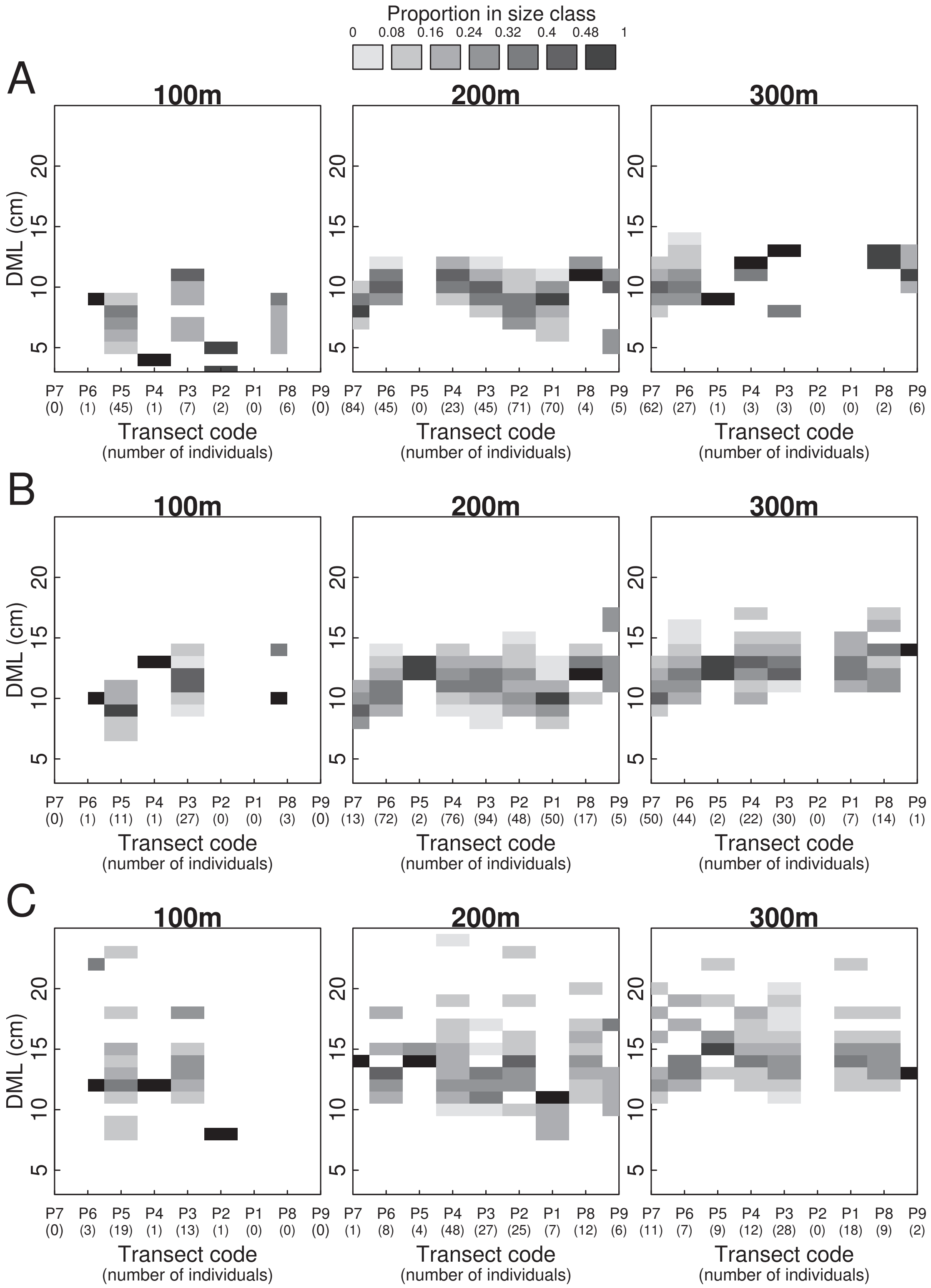


Figure 29. Length-frequency distributions of male *L. gahi* by transect at different depths. A: maturity stages 1 and 2, B: maturity stage 3, C: maturity stages 4 and 5. Transects are arranged sequentially from SE to NW. See Figure 28 for further details. Note that while the size range plotted accounts for the majority of observed individuals, occasional mature males of up to 40cm were found.



General remarks

The survey coincided with the feeding period of the second cohort of *L. gahi*, as established previously (Hatfield, 1992). It has been assumed that, during their feeding, *L. gahi* migrate from shallow coastal waters to deep continental slope waters and that this is reflected in a continuous increase in their size in an offshore direction (Hatfield & Rodhouse, 1994). The same pattern of bathic migrations was revealed during our survey; squid were larger and more mature at 300 m depths than at 200 m depths on each transect. Thorough analysis of length frequencies and sex ratios on different transects and depths has revealed several interesting new patterns in the population structure of *L. gahi*. Small immature males and females (< 10 cm DML) tended to occur together at shallow depths (< 200 m), and only in some particular regions (such as P7 and P1). Larger squid (>10-11 cm DML) were segregated by sex and by depth, with females feeding deeper (300 m depth) and males feeding shallower (200 m depth) (immature females, maturing and mature males, i.e. on the P3 transect). Progress in the modal DML, and the greater occurrence of mature squid at different transects, probably reflect ontogenetic patterns of *L. gahi* migration along the Falkland shelf, but the direction of these migrations is still unclear. For example, squid which moved to deep waters on P2 could either migrate to P5-P4 or to P8. The presence of two regions where small immature squid are prevalent at 200 m depth (P7, Cape Meredith and P2, south of Cape Pembroke) could probably be a result of their offshore migrations from two different inshore spawning sites. It is possible that such a spatial segregation of small and large squid prevents competition for food resources and results in decreased pressure from cannibalism during the feeding period. The prevalence of cannibalism in *L. gahi* is currently under investigation, but has been recorded in other squid species, for example *L. forbesi* (Pierce *et al*., 1994).

4.2 *Dissostichus eleginoides*

During the cruise, a total of 2,628kg of *D. eleginoides* was caught, with 93% (or 2,444kg) caught at just one single station (no. 14). The remainder of the stations yielded catches between 1kg and 34kg. *D. eleginoides* occurred at 81% of the sampled stations. At a number of stations length-weight data was collected for this species, with length-frequency data collected at stations 14, 23, and 55 (Figure 30). The length-weight data is of particular interest (Figure 31), mainly due to the accuracy of the marine adjusted balances used onboard (Scanvaegt). See Figure 31 for the logged length weight relationship.

The samples collected for length frequency purposes at these stations revealed certain clear differences (Figure 30). The results of the sample at station 14 (N=170, Mean Total Length (MTL)=58.51cm) were comparable with the sample at station 23 (N=14, MTL=50.27), but both these were very different from that at station 55 (N=71, MTL=21.61cm) (see Figure 30). Stations 14, 23, and 55 were fished at 197m, 299m and 200m respectively. It seems likely that geographical differences, possibly associated with different water masses, cause congregations of a different size group to be present in certain areas (larger fish in the North and South, juveniles to the Southeast of the Falklands) but these factors are currently not well understood for this species.

Figure 30. Percentage length-frequency distribution for *Dissostichus eleginoides*, ZDLH1 16 – 29/6/99.

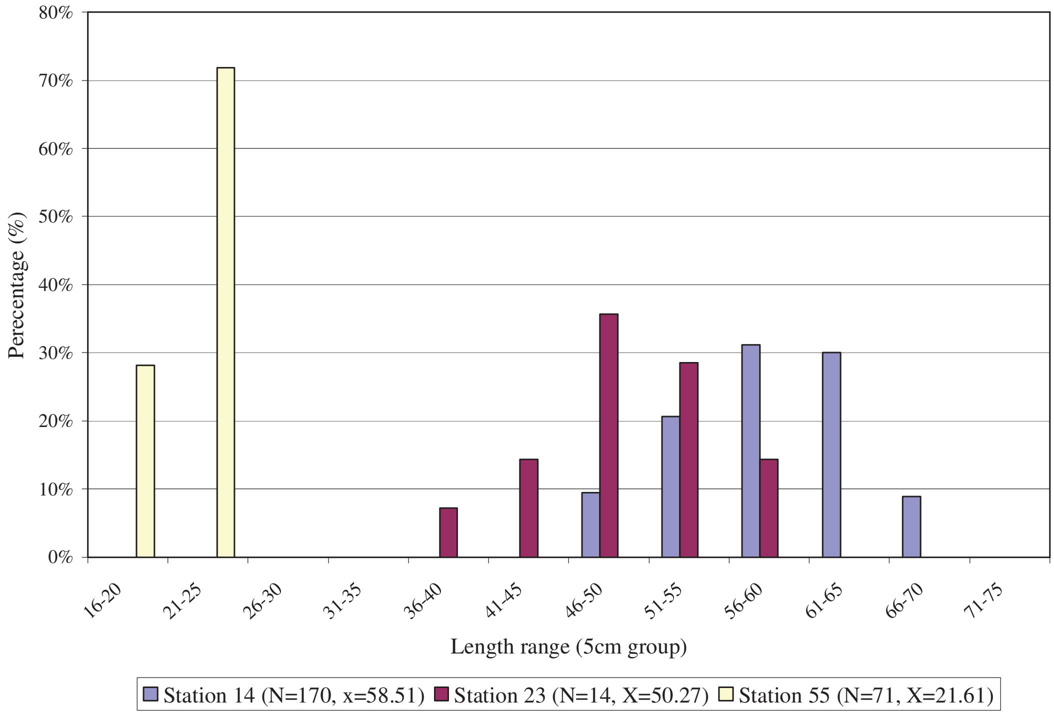


Figure 31. Length weight relationship for *Dissostichus eleginoides*, ZDLH1 16 – 29/6/99.

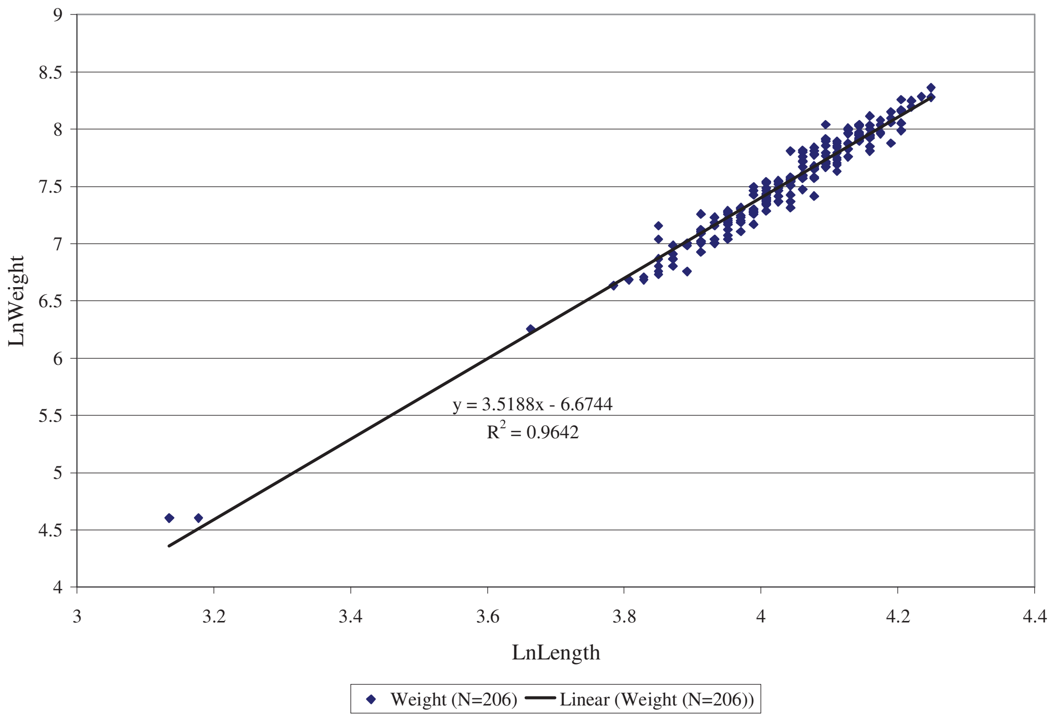
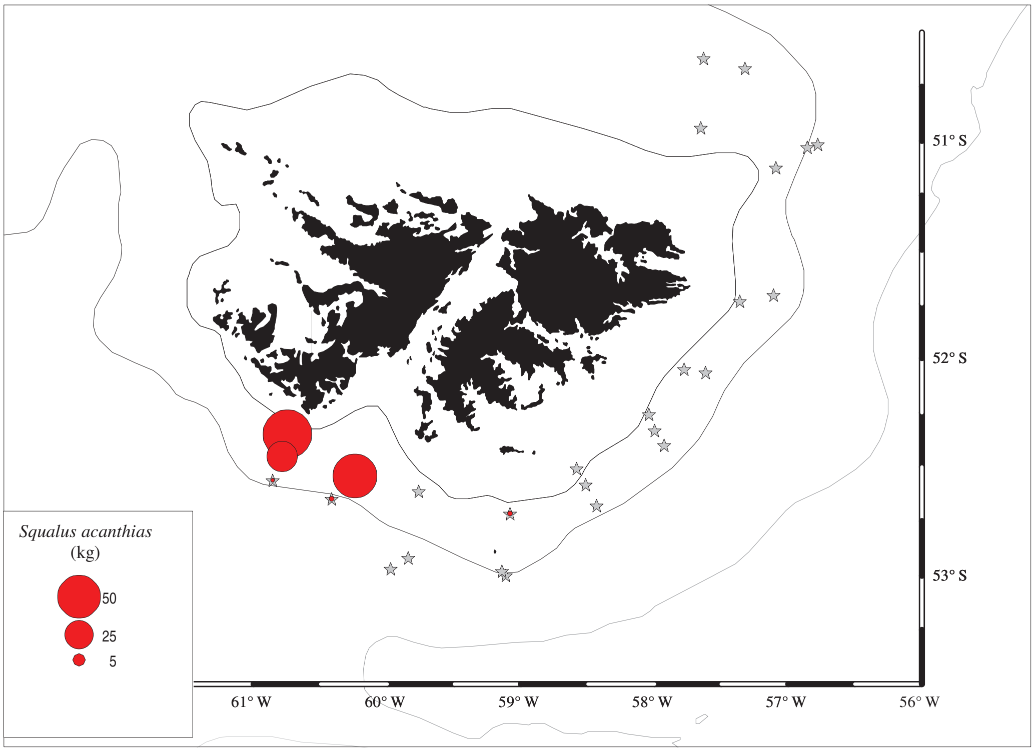
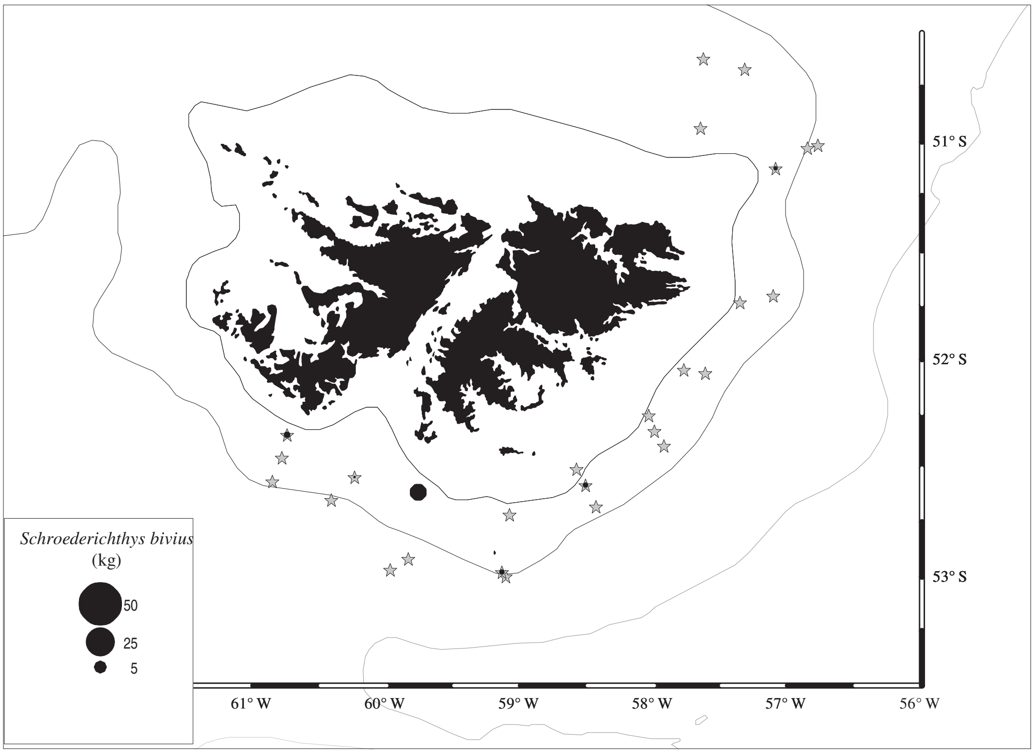


Figure 32. Relative abundance by weight of *Squalus acanthias* (top) and *Schroederichys bivius* (bottom). The stars mark the positions of trawls while catch weight (scaled to equal trawling time) is proportional to the diameter of the coloured circles.

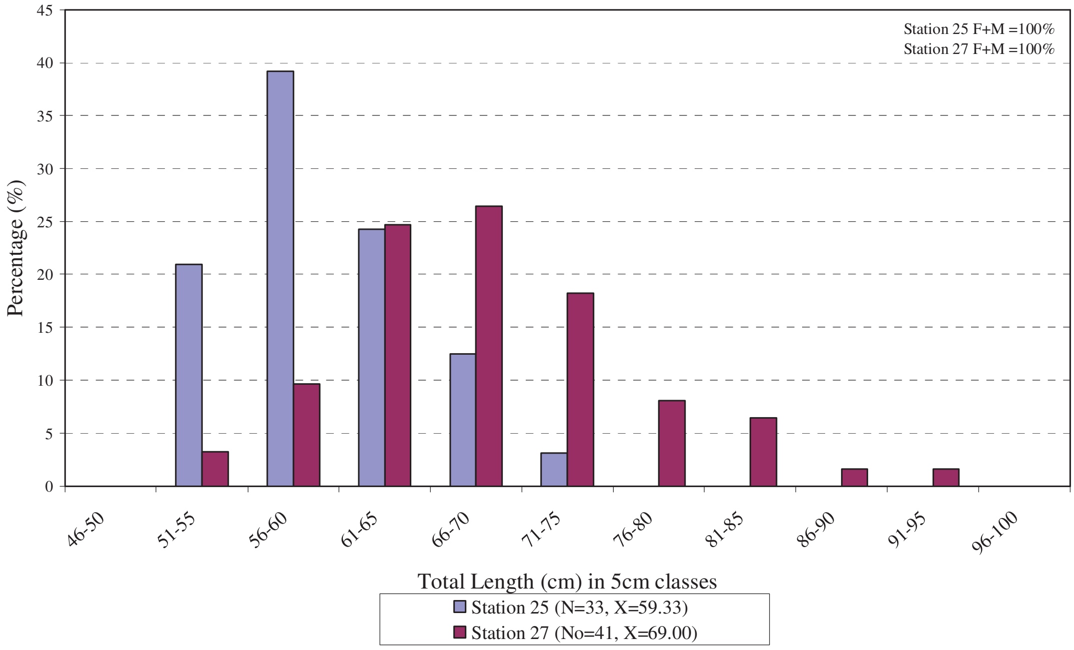




4.3 *Squalus acanthias & Schroederichthys bivius.*

During the cruise, a total of 261kg of *Squalus acanthias* L., 1758, and 14kg of *Schroederichthys bivius* Müller et Henle, 1841, was caught at a limited number of stations. All catches occurred in the southern area, at stations at the Southern entrance to Falkland Sound. See Figure 32 for relative abundance by weight (kg). 98% of the catch for these two species (256kg of *S. acanthias*) was caught at just three stations: 25, 27, & 38. Two samples of *S. acanthias* were analyzed for length/sex/maturity/weight at stations 25 & 27. Figure 33 illustrates the size distribution (by 5cm-length class) for those two stations, which show a distinct difference in modal size of approximately 10cm. The females of adult size contained either well-developed embryos or fertilized and developing oocytes.

Figure 33. Length-frequency distribution for *Squalus acanthias*, ZDLH1 stations 25 and 27.



4.4 Rays and Skates

Table X shows the catch summary of all the ray species during the observed period, resulting in a total catch of 1,037kg for all species combined. The majority of the rays caught comprised of the three species *Bathyraja griseocauda* Norman 1937 (418kg or 40% of the total ray catch), *Bathyraja brachyurops* Fowler 1910 (256kg or 25% of the total) and *Bathyraja albomaculata* Norman 1937 (174kg or 17% of the total). As shown in the table, 74% of the ray catch was sampled for length/weight and length/frequency purposes, with the particular exception of station 14 where 246kg of rays were caught (24% of the total ray catch). This ray catch mainly comprised *B. brachyurops* (119kg), *B. albomaculata* (69kg), and unidentified *Bathyraja* (34kg). This exception is rather unfortunate, as this relatively high proportion would have added substantially to the knowledge of the ray fauna, and in particular of the above three species.

Table X. Ray catch summary by species, ZDLH1 16 – 29 June 1999. Percentages are given to two decimal places only.

Species Name	*Species Code*	*Catch Total (kg)*	*Catch Proportion (%)*	*Sample Total (kg)*	*Discard Total (kg)*	*Not Sampled (kg)*
BATHYRAJA GRISEOCAUDA	RGR	417.54	2.72%	410.43	412.21	7.11
BATHYRAJA BRACHYUROPS	RBR	256.17	1.67%	129.03	256.19	127.14
BATHYRAJA ALBOMACULATA	RAL	173.92	1.13%	104.68	174.52	69.24
UNIDENTIFIED BATHYRAJA	RBZ	101.42	0.66%	74.38	100.52	27.04
BATHYRAJA MULTISPINIS	RMU	31.8	0.21%	19.22	30.52	12.58
BATHYRAJA SCAPHIOPS	RSC	23.7	0.15%	21.02	23.50	2.68
BATHYRAJA MACLOVIANA	RMC	17.36	0.11%	3.36	17.12	14.00
RAJA DOELLOJURADOI	RDO	10.64	0.07%	4.38	10.16	6.26
PSAMMOBATIS SPP.	RPX	4.3	0.03%	0.14	4.3	4.16
RAY TOTAL CATCH	RAY	1,036.85	6.75%	766.64	1,029.04	270.21
						26.06%
TOTAL CATCH		15,370.04	100.00%	1,786.93	15,308.62	

Biological data, Rajidae

Figure 34 and Figure 35 illustrate the distribution of nine species of skate and ray caught during the cruise. The data for both charts has been adjusted to allow accurate CPUE (weight/trawl time and/or number/trawl-time) comparison. All specimens caught were weighed and assessed for size/maturity/weight/presence of parasites except at station 14 where just the catch composition was assessed. Figure 34 shows that the three species *Bathyraja griseocauda*, *Bathyraja brachyurops*, and *Bathyraja albomaculata* occurred in sufficient numbers for biological analyses.

Figure 35 shows that at station 16 a relatively greater number of specimens of *B. griseocauda* than any other station were caught. In comparison with Figure 34 these data suggest that specimens are smaller in the north than in any other region. In order to have sufficient data, all specimens from the north (of 52S) and south (of 52S) were grouped for analysis. The Mean Total Length in the north was approximately 42cm, while in the south this was approximately 88cm. The data suggests that in the northern region, and particularly on the relatively wide continental slope between 100 and 300m immature *B. grideocauda* occur more extensively than elsewhere (Figure 36).

Figure 34. Catch by weight of all Rajidae, ZDLH1 16 - 29 June 1999.

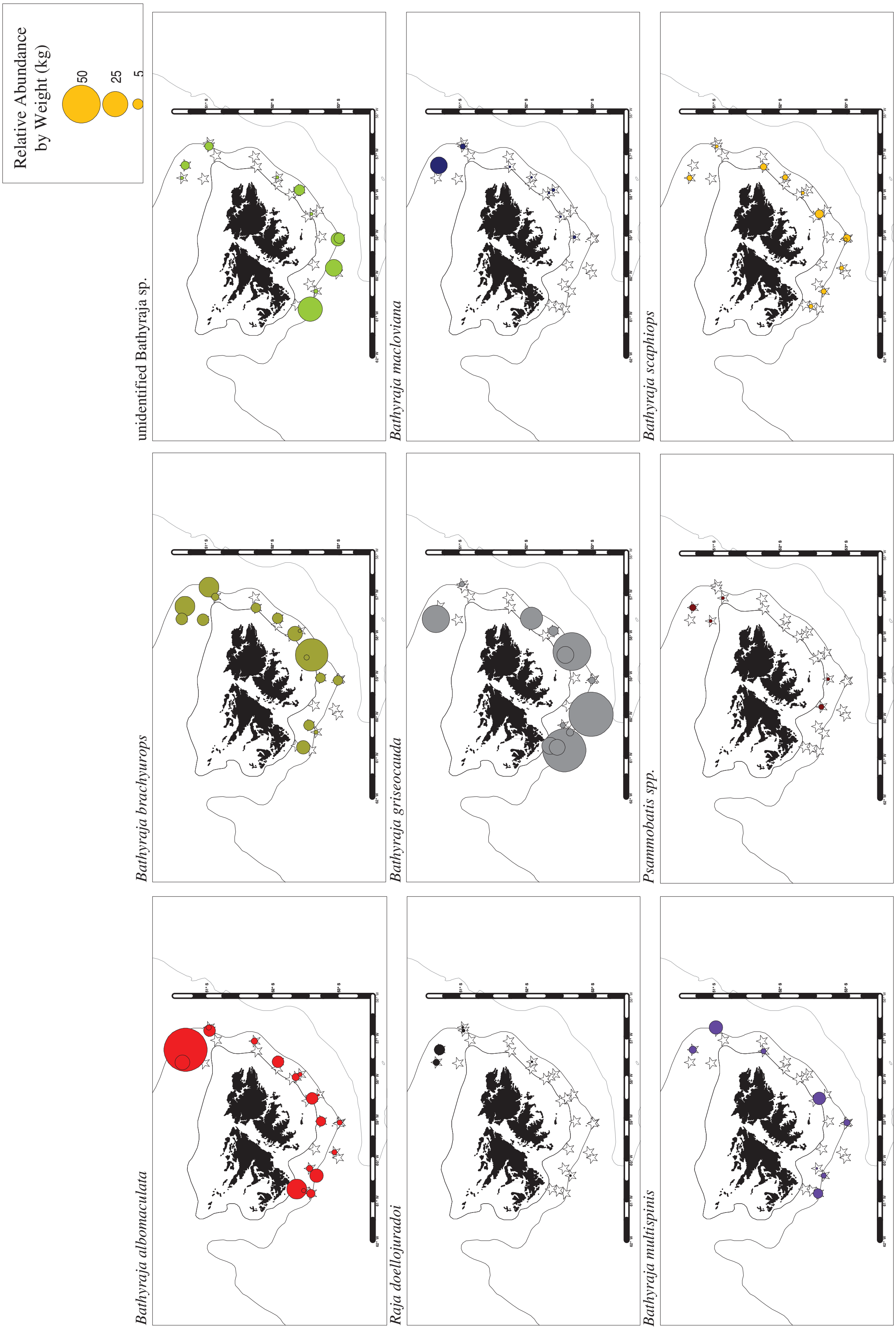
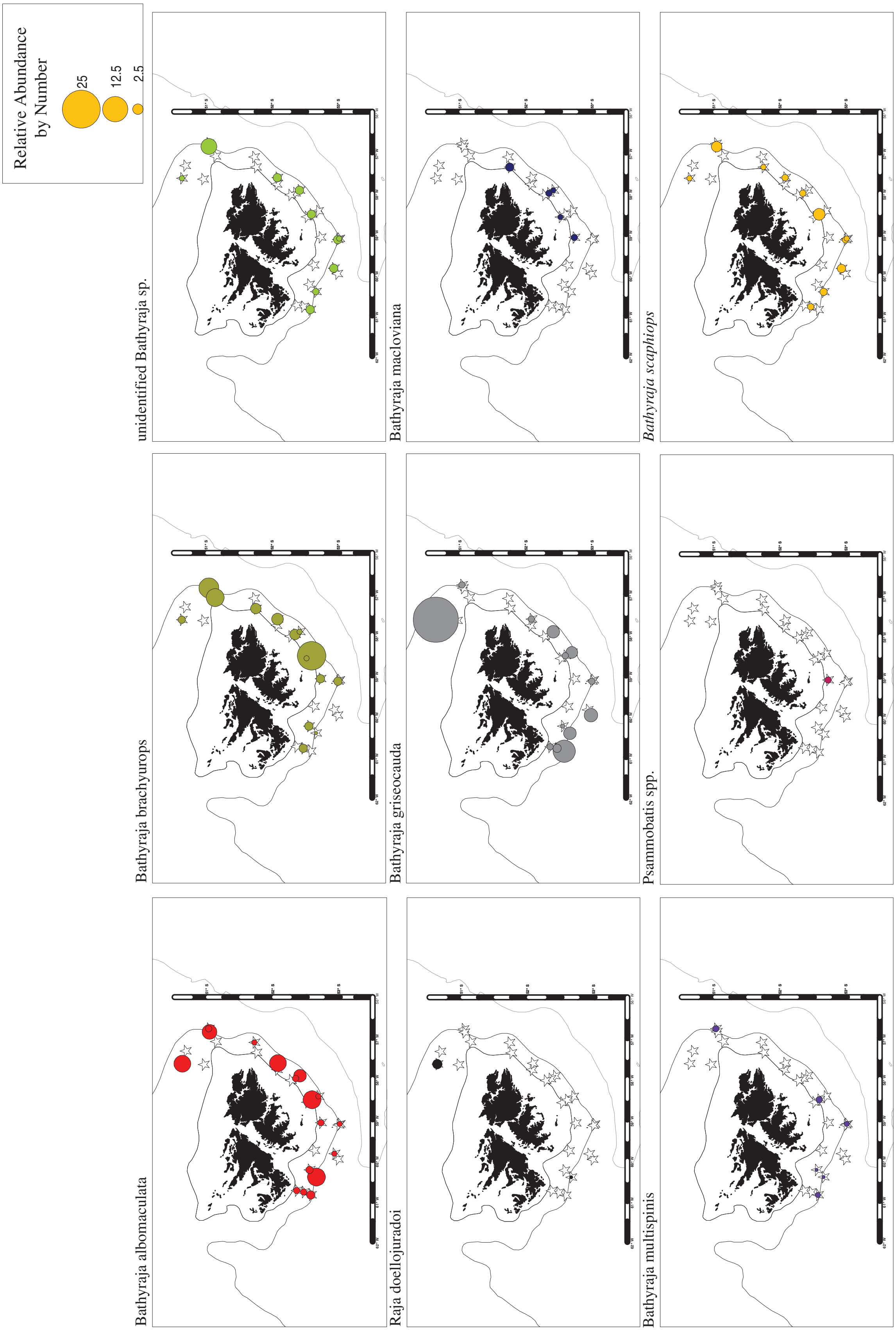


Figure 35. Catch, by number of individuals, of all Rajidae, ZDLH1 16 – 29 June 1999, excluding station 14.



Analysis of the *B. brachyurops* distribution suggests similarly that its juveniles are more abundant in the north. The Mean Total Length in the north was approximately 48cm, while in the south this was approximately 68cm (Figure 37). During past cruises/observed fishing trips vast numbers of juveniles of this species have been caught in a sandy region to the northeast of the Falklands, an area not sampled by this research cruise.

Figure 36. Total length-frequency distribution of *Bathraja griseocauda*, ZDLH1 16 – 29 June 1999.

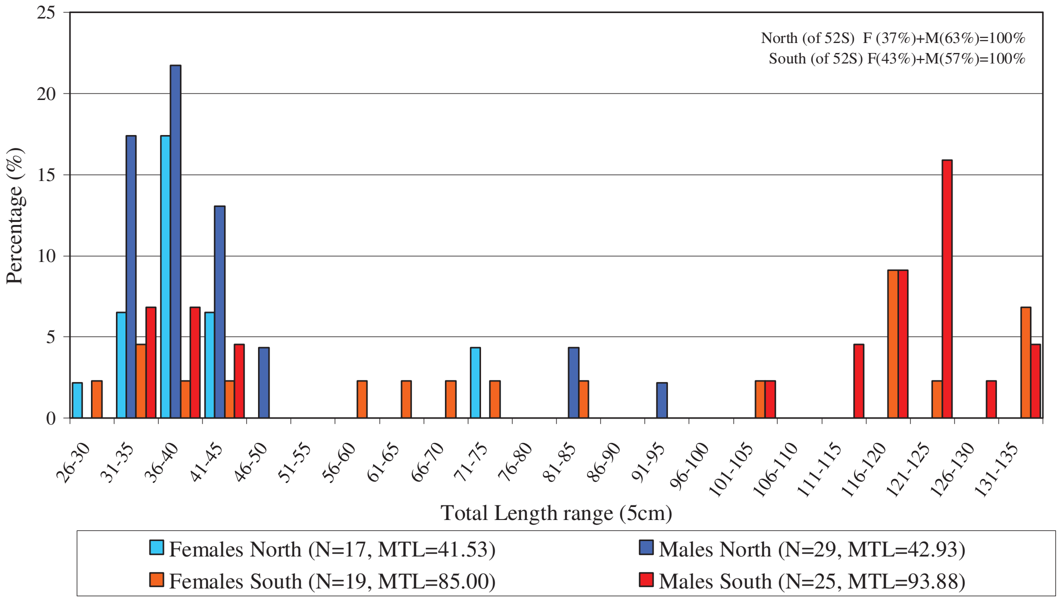
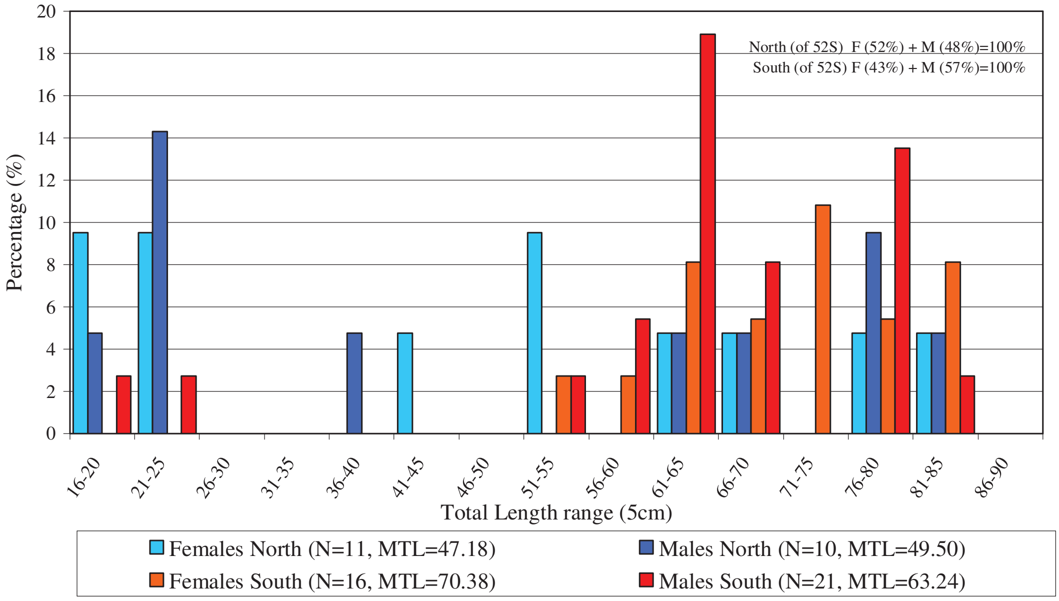


Figure 37. Total length-frequency distribution of *Bathyraja brachyurops*, ZDLH1 16 – 29 June 1999.

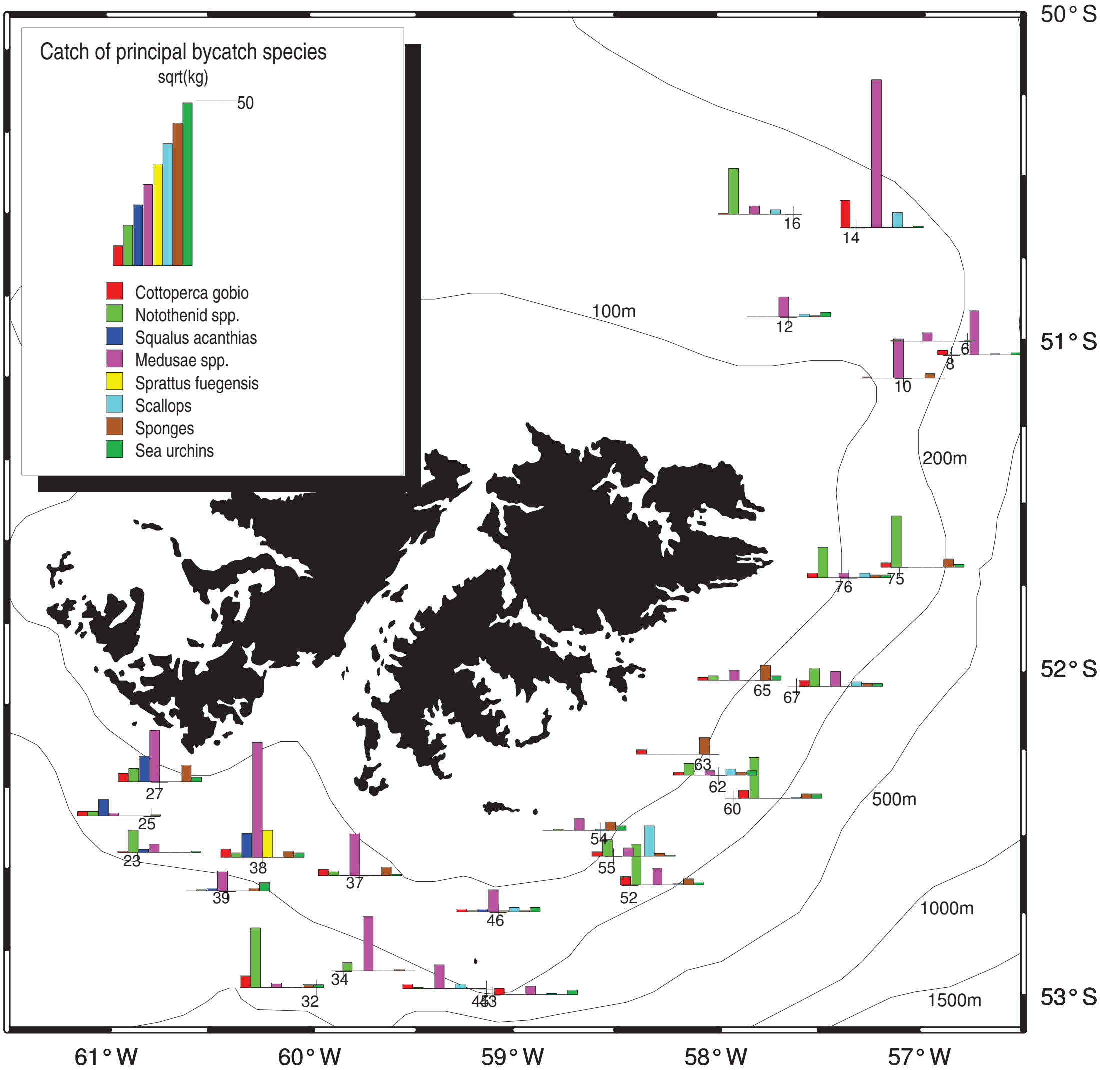


4.5 *Medusae*

The distribution of the major non-commercial species is illustrated in Figure 38. Jellyfish (Medusae spp.) were not only the most abundant non-commercial species, but represented the greatest overall catch at more than seven tonnes. Figure 38 illustrates that jellyfish catches were highest to the SW and NE of East Falkland, and tended to occur mainly on the shelf (i.e. 100 and 200m stations). Notothenid spp. (Rock Cod) were caught, often in quantity, at most stations. Station 38 yielded a high catch of *Sprattus fuegensis* with distinctive acoustic marks (see Figure 16).

It is not currently clear whether Medusae are being caught primarily while the net is on the bottom during trawling, or as it traverses the pelagic zone during shooting and hauling. Figure 39 illustrates that there is not an especially strong relationship between Medusae catch and either trawl time, time spent shooting and hauling, or overall time that the net spends in the water both on the bottom and in the pelagic zone. In addition to the general spatial variability in catch of Medusae observable in Figure 38, Figure 40 illustrates that Medusae catch rate was generally higher at shallower depths (i.e on the shelf) than on the slope and during trawls carried out in darkness (after sunset).

Figure 38. Catch of principal (by catch weight) bycatch species. Height of bars is proportional to the square root of catch (in kg). Catch weight at stations 38 and 39 was divided by three to scale to equal effort. The crosses on the histogram axis mark the trawl position.



The pattern of variation in catch rate with trawl depth and time of day is similar whether catch rate is calculated using actual trawling time (the method used in Figure 40), time spent in the pelagic zone (the sum of shooting and hauling time), or total time that the net is in the water. If a generalised linear model (GLM) is constructed for Medusae catch then trawl depth, darkness/light, and trawling time appear as significant explanatory variables, but time in the pelagic zone does not. Medusae thus appear to be concentrated over the shelf and may undergo diurnal vertical migration in the water column with higher densities near the bottom during darkness.

Figure 39. Medusae catch as a function of trawling time (i.e time the net is on the bottom), time spent in the pelagic zone during shooting/hauling, and overall time (shooting, trawling and hauling). Note that catch is plotted on a logarithmic scale.

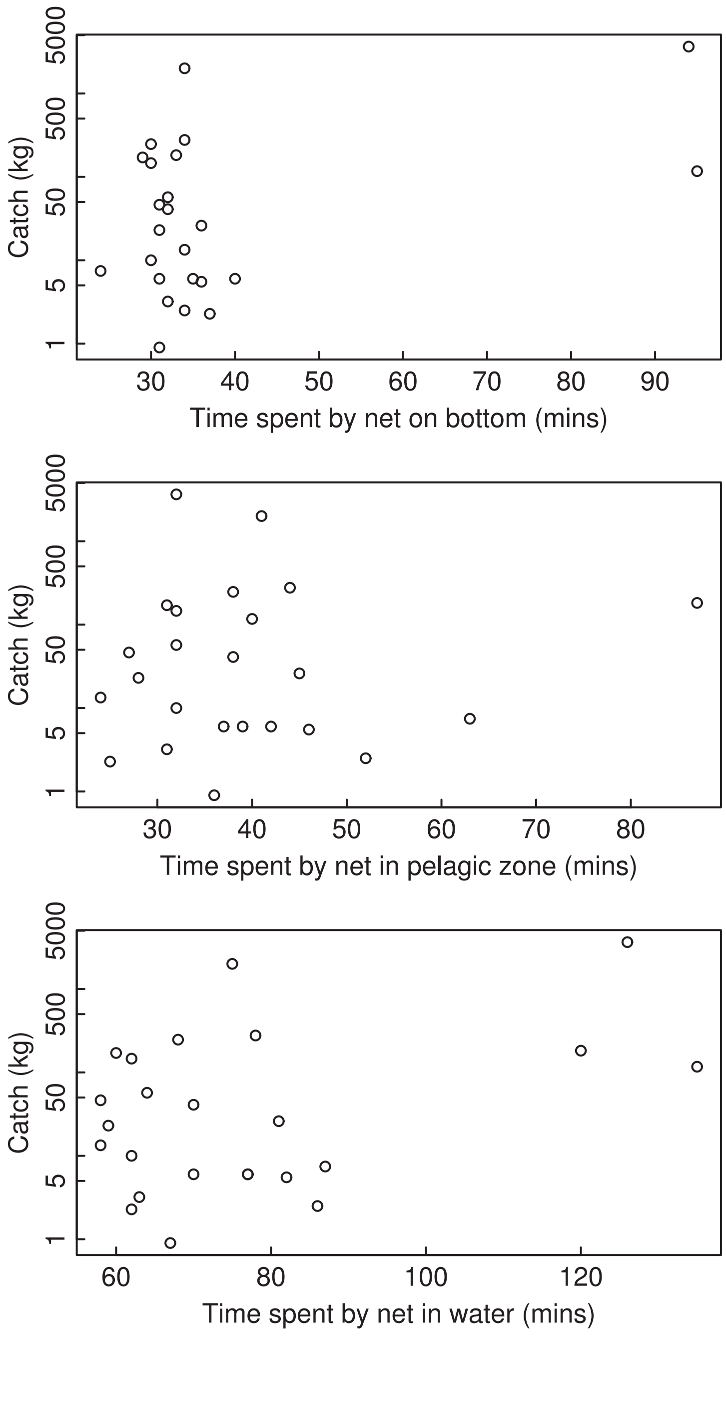
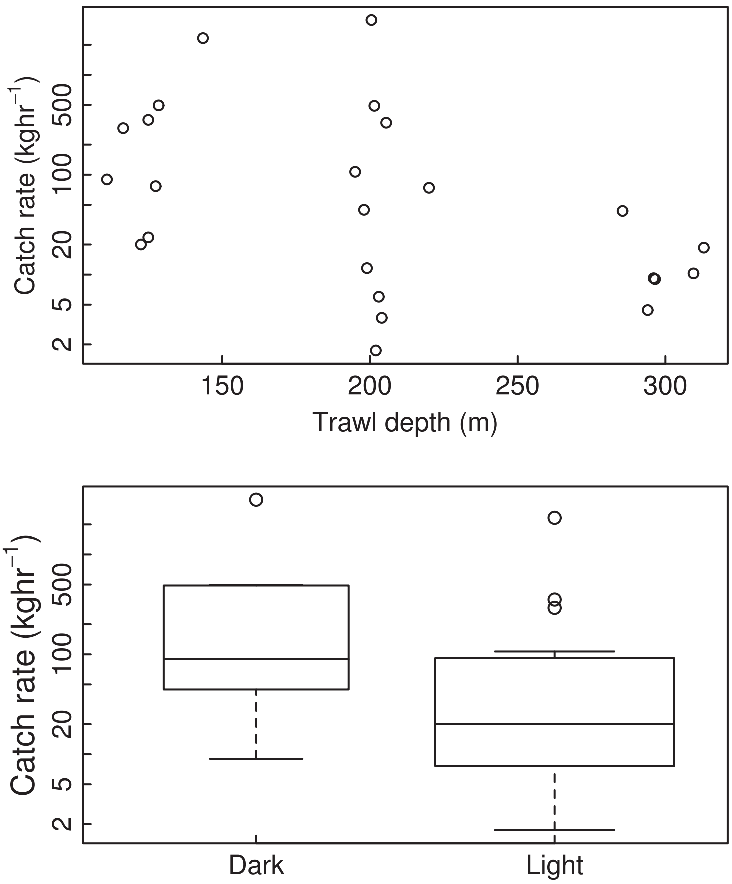


Figure 40. Catch rate of Medusae (kg per hour of trawling time) as a function of trawl depth (the mean of the depths at the start and end of trawling, top), and whether the trawl was before or after sunset (bottom).



4.6 Parasitological studies

4.6.1 The occurrence of *Otodistomum plunketi* Fyfe, 1953 (Digenea: Azygiidae) in Radjids from around the Falkland Islands.

Introduction

The digenean worm *Otodistomum plunketi* has previously been recorded from *Scymnodon plunketi* off New Zealand by Fyfe (1953) and from *Raja longirostris* off the Pacific coast of the former U.S.S.R. by Skrjabin (Skrjabin and Guschanskaja, 1958). Despite the opinions of Dawes (1946, 1947) and Brinkmann (1975), who considered that all of the species of the genus *Otodistomum* of which they were aware were members of the same variable species *Otodistomum velporum*, Gibson and Bray (1977) believe that this species can be distinguished from the other species of the genus (except for *O. pristiophori*, Johnston 1902, and *O. hydrolagi,* Schell 1972) by its geographical location and by the broad shape of its body. *O. pristiophori* has been recorded from *Pristiophorus cirratus* in Australian waters by Johnston (1902) and Woolcock (1935) and from *Psammobatis microps* and *Squatina argentina* in the Atlantic Ocean off northern Argentina by Ostrowski de Nunez (1971). *O. hydrolagi* was recorded from the chimaera *Hydrolagus colliei* off the Pacific coast of the U.S.A. by Schell (1972). *O. plunketi* differs from the other two remarkably similar species in its larger size, wider extra-caecal region of the body, longer uterine field, more posterior position of the gonads and in the absence of a union of the excretory arms in the forebody. For a description of the species see Gibson and Bray (1977). Nothing is known of the life history of *O. plunketi.* Gibson and Bray (1977) suggested that it is similar to the gastric species of the genus, with the exceptions that the encysted metacercariae must penetrate the gut wall in order to grow in the body cavity, and the eggs must presumably be lost through an abdominal pore. Assuming that their life histories are similar to the gastric species of the genus then definitive hosts acquire parasites by feeding on small bony fishes infected with metacercaria.

The purpose of this study was to examine quantitatively the degree of infection by *O. plunketi* in rajids from around the Falkland Islands.

Materials and Methods

During the research cruise a sub-sample of 239 rajids were examined for *O. plunketi.* In addition the rajids' total length, disc width (to the nearest cm below) and weight were noted. They were also sexed and graded according to a FIFD maturity scale. The abdominal cavity and the pericardial cavity were opened, the maturity was assessed and the organs were examined for *O. plunketi* with the aid of a strong light source. Representative samples of *O. plunketi* were collected and fixed in both 99% ethanol and 10% buffered formol saline for the FIFD reference collection. The concepts denoted by the terms prevalence, mean intensity, and mean abundance of infection were defined in accordance with the recommendations of Bush *et. al.* (1997).

Results

The prevalence and mean abundance of parasites in all species was found to be 30.96% and 1.95 respectively. Of the eight species examined *B. multispinus* had the highest mean abundance of *O. plunketi* (see Table XI) while *R. deollojuradai* and *B. scaphiops* had the lowest mean abundance.

Table XI. Prevalence, mean intensity and mean abundance of *O. plunketi*.

Species	*Number Sampled*	*Prevalence %*	*Mean Intensity ±SD*	*Range*	*Mean Abundance*
B.multispinus	5	100.00	50.41 (± 50.82)	8-136	50.41
B. ablomaculata	58	58.62	5.50 (± 2.33)	1-12	1.46
Unidentiied Bathyraja sp.	15	33.33	2.40 (± 1.67)	1-5	0.80
B. brachyurops	49	20.41	2.60 (± 0.84)	1-4	0.53
B. maclovinia	4	25.00	2.00	**	0.50
B. griseocauda	89	21.35	1.58 (± 1.22)	1-6	0.22
B. scaphiops	15	0.00	0.00	**	0.00
R. deollojuradai	4	0.00	0.00	**	0.00

4.6.2 The parasite ecology of *Loligo gahi* in Falkland Islands waters.

Introduction

With one possible exception, adult cestodes have never been reported from cephalopods (Hochberg, 1990). However, a diversity of larval and post-larval stages has been described from decapods and octopods (Dollfus, 1936, 1958; Gayevskaya, 1977, 1978; Naydenova and Zuev, 1978; Stunkard, 1977; Threlfall, 1970 etc.). This diversity indicates that the cephalopods are important as second intermediate or paratenic hosts for cestodes that mature in fishes, and are transferred from host to host through the food chain. Cestode larvae are excellent parasites to use as biological tags for studying trophic interactions in the marine environment. MacKenzie (1987) suggested the use of parasites as biological tags in population studies of invertebrates, particularly crustaceans and cephalopods, would reward further investigation in the future.

Plerocercoids of the genus *Phyllobothrium* occur free or attached in the stomach, caecum and rectum of host cephalopods. Williams (1968) reviewed the genus. The species reported from cephalopods are not well known and the genus needs more study. Most reports simply document the presence and site of infection and list the geographic locality of the collection. Only in the last 20 years have quantitative studies been initiated which address the age, size, sex of the hosts and provide information on the number of hosts examined, percentage of squid infected and the number of parasites recovered from the host (Hochberg, 1990).

Materials and Methods

During the research cruise a total of 168 post-recruit *Loligo gahi* were collected and frozen. Samples were collected randomly throughout the voyage. For each squid the dorsal mantle length (DML) sex and maturity were recorded. The maturities were determined using an established scale (Lipinsky & Underhill, 1995). Each individual was opened longitudinally and given a thorough examination under the dissecting microscope. The ceacum, stomach, rectum and gonads were examined and the number of metazoan parasites per individual were noted.

The concepts denoted by the terms prevalence, mean intensity and abundance of infection are defined in accordance with the recommendations of Bush et al. (1997).

Results

Of the 168 post recruit *Loligo gahi* examined 22 were infected (13.10% prevalence) with a mean abundance of 0.14 (see Table XII).

Table XII. Parasite occurrence in *L. gahi*.

	Phyllobothrium	*A. simplex*
Count	22.00	10.00
Sum	24.00	14.00
Min	1.00	1.00
Max	2.00	3.00
Prevalence	13.10	5.95
Mean Intensity	1.09	1.40
SD	0.29	0.70
Mean Abundance	0.14	0.08

Discussion

This is an on going departmental study and samples from the commercial fleet are currently being examined.

In conjunction with the above study the life cycle of the *Phyllobothrium* sp. found in *Loligo gahi* is being investigated. Juvenile *Phyllobothrium* sp. from *L. gahi* and adult *Phyllobothrium* sp. from radjids were collected and stored in 99% ethanol for DNA analysis. This will be carried out in conjunction with the Natural History Museum, London.

References

Anon. (1990). *South Atlantic Data Atlas*. Hydrographic Office, Marine Science Branch 4, Touton.

Anon. (1999a). *SBE 25 Sealogger CTD Operating Manual*. Sea-Bird Electronics, Inc. Bellevue, Washington, USA.

Anon. (1999b). *CTD Data Acquisition Software Seasoft version 4.326*. Sea-Bird Electronics, Inc., Bellevue, Washington, USA.

Brinkmann, A. Jr. (1975) Trematodes from Greenland. *Meddr Gronland*., **205**, 2-88.

Bush, A. O., Lafferty, K. D., Lotz, J. M. & Shostak, A. W. (1997). Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *J. Parasitol*., **83**, 575-583.

Dawes, A. (1946). The trematoda, with special reference to British and other European forms. Cambridge, 44pp.

Dawes, A. (1947). The trematoda of British fishes. *Ray Society*, **131**. London, 364 pp.

Dollfus, R. P. (1958). Copepodes, Isopodes et Helminths parasites de Cephalopodes de la Mediterranee et de l'Atlantique Europeen. *Faune mar. Pyreneesorientales*, **1**, 61-72.

Dollfus, R. P. (1936). Cestodes des invertebres marins et thalassoides. Pp. 509-539 in C. Joyeux & J.G. Baer, *Faune de France: Cestodes,* **30**, 1-165.

Fyfe, M. L. (1953). *Otodistomum plunketi* n. sp., a large trematode from Lord Plunket's shark, *Scymnodon plunketi* (Waite). *Parasitology (Cambridge),* **43**, 187-190.

Gayevskaya, A. V. (1977). Features of the trematodofauna of cephalopod molluscs. pp 12-17 in *Materials of the Scientific Conferences of the All-Union Helminthological Society, Moscow*, vol 29, Trematoda and Trematozoa.

Gibson, D. I. & Bray, R. A. (1977). The Azygiidae, Hirudinellidae, Ptychogonimidae, Sclerodistomidae and Syncoeliidae (Digenea) of fishes from the northeast Atlantic. *Bull. Br. Nat. Hist. (Zool),* **32,** 167-245.

Goss, C., Rodhouse, P., Watkins, J.L. & Brierley, A.S. (1998). Attribution of acoustic echos to squid in the South Atlantic. *CCAMLR Science*, **5**, 259-271.

Hatfield, E. (1992). Recruitment, demography and growth of the Patagonian squid *Loligo gahi* (d'Orbigny, 1835) in Falkland Islands waters. Ph.D. Thesis, Council for National Academic Awards, London, 146 pp.

Hatfield, E. & des Clers, S. (1998). Fisheries management and research for *Loligo gahi* in the Falkland Islands. *CalCOFI Rep*., **39**, 81-91.

Hatfield, E. & Rodhouse, P. (1994). Migration as a source of bias in the movement of cephalopod growth. *Antarctic Science,* 6 (2), 179-184.

Hochberg, F. G. (1990). Diseases of Marine Animals, Vol III. O. Kinne (ed.). 227pp.

Johnston, S. J. (1902). On a new species of Distomum from the sawfish shark, *Pristiophorus cirratus* Lath. Contributions to a knowledge of Australian Entrozoa, 2. *Proc. Linn. Soc. N.S.W.,* **27**, 326-330.

Lester, R. J. G. (1990). Reappraisal of the use of parasites for stock discrimination. *Aust. J. Mar. Freshwater. Res.*, **41**, 858-864.

Lipinski, M. R. & Underhill, L. G. (1995). Sexual maturation in squid: Quantum or continuum? *S. Afr. J. Mar. Sci.*, **15**, 207-223.

MacLennan, D.N. & Simmonds, E.J. (1992). *Fisheries Acoustics*. Chapman & Hall, London etc.

MacKenzie, K. (1987). Parasites as indicators of host populations. *Int. J. Parasit*., **17**, 345-352.

Madureira, L.S.P., Everson, I. & Murphy, E.J. (1993). Interpretation of acoustic data at two frequencies to discriminate between Antarctic krill (*Euphausia superba* Dana) and other scatterers. *Journal of Plankton Research*, **15**, 787-802.

Marine Micro Systems. (1995). RoxAnn Installation Manual. Marine Micro Systems, Ltd., Aberdeen.

Naydenova, N. N. & Zuev, G. V. (1978). On the helminthfauna of the squid, *Stenoteuthis pteropus* (Steenstrup) in the eastern-central Atlantic. *Biology of the Sea (Kiev),* **45**, 55-64.

Ostrowski de Nunez, M. (1971). Estudios preliminares sobre la fauna parasitaria de algunos elasmobranchquios del litoral bonaerense, Mar del Plata, Argentina. I. Cestodes y trematodes de Psammobatis microps (Gunther) y Zapteryx brevrostris (Muller y Henle). *Physis*, **30**, 425-446.

Pierce, G.J., Boyle, P.R., Hastie, L.C., & Begoña Santos, M. (1994). Diets of squid *Loligo forbesi* and *Loligo vulgaris* in the northeast Atlantic. *Fisheries Research*, **21**, 149-163.

Rekhter, Y., Moskowitz, B., Karrenberg, D., de Groot, G.J. & Lear, E. (1996). *RFC 1918: Address allocation for Private Internets*. Request for Comments 1918 (also Best Current Practice 5), Network Working Group.

Rodhouse, P.G., Symon,C. & Hatfield, E.M. (1992). Early life cycle of cephalopods in relation to the major oceanographic features of the southern Atlantic Ocean. *Marine Ecology Progress Series*, **89**, 183-195.

Schell, S. C. (1972). *Otodistomum hydrolagi* sp. n. (Trematoda: Azgyiidae) from the coelom of the ratfish, *Hydrolagus colliei* (Lay & Bennett, 1839). *J. Parasit*., **42**, 139-140.

Simrad. (1997). *Calibration of the EK 500 / EY 500.* Revision E. Document P2260/E, Simrad AS, Horten, Norway.

Skrjabin, K. I. & Guschanskaja, L. H. (1958). Azygiata La Rue, 1957. Pp. 669-819 in Skrjabin, K. I. (ed.) *Trematodes of animals and man: principles of trematology, 14.* Moscow.

Stunkard, H. W. (1977). Studies on tetraphyllidean and tetrarhynchidean metacestodes from squid taken on the New England coast. *Biol. Bull., Mar. Biol. Lab., Woods Hole*, **153**, 387-412.

Threlfall, W. (1970). Some helminth parasites from *Illex argentinus* (de Castellanos, 1960) (Cephalopoda: Omastrephidae). *Can. J. Zool.,* **48**, 195-198.

Williams, H. H. (1968). The taxonomy, ecology and host specificity of some Phyllobothridae (Cestoda: tetraphyllidea), a critical revision of Phyllobothrium Beneden, 1849 and comments on some allied genera. *Phil. Trans. Roy. Soc. London, series B*, **253**, 231-307.

Woolcock, V. (1935). Digenetic trematodes from some Australian fishes. *Parasitology (Cambridge)*, **27**, 309-331.

Falkland Islands Government,
Fisheries Department,
Stanley,
Falkland Islands
Telephone: +500 27260
Fax: +500 27265
E-mail: fish.fig@horizon.co.fk