JR06:

RRS James Clarke Ross
South Georgia and South Orkneys
Marine Biology (Predator/Prey cruise)
January 1994 - March 1994

Cruise Report

RRS JAMES CLARK ROSS

Predator/prey Cruise: JR06

South Georgia: January - March 1994

Compiled and edited by Martin White: Principal Scientist

Marine Life Sciences Division
British Antarctic Survey
NERC
Madingley Road,
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30 April 1994

Additional data in the form of computer data files resulted from the Cruise and these may be consulted with written permission from the Originator and Division Head, Marine Life Sciences Division.

Contents

1. Introduction

This report contains summary information obtained during the Predator/Prey Cruise (JR06) on RRS *James Clark Ross* to South Georgia during the period 1 January - 9 March 1994.

The primary objectives have been the initiation of the PES Large Scale Monitoring Programme, a study of predator/prey interactions at South Georgia, and Krill distribution and behaviour studies. In addition, studies on microbial biology, secondary production (copepods) and bird flight have been undertaken from the vessel.

The unique feature of the JR06 programme has been the introduction of remote sensing techniques to guide the research during the course of the Cruise. Sea-surface temperature satellite imagery has been used to demonstrate the position of frontal systems, and the near real-time positions of satellite tags attached to predators have been used to indicate the feeding localities as well as the foraging range of key species.

This years' Cruise coincided with a season during which krill were in very low numbers and krill aggregations were almost absent at South Georgia. As a result of this the breeding success of krill dependent predators has been very poor. Similar but not so severe conditions prevailed at the South Shetland Islands while more 'normal' conditions - sufficient to support the land based predators - occurred at the South Orkney Islands. With near-synoptic information from several areas in the Scotia Sea from several research groups - there appears to be an opportunity to pool data and information and so describe the krill abundance and distribution and its effects on the natural predators in more detail than is usually possible.

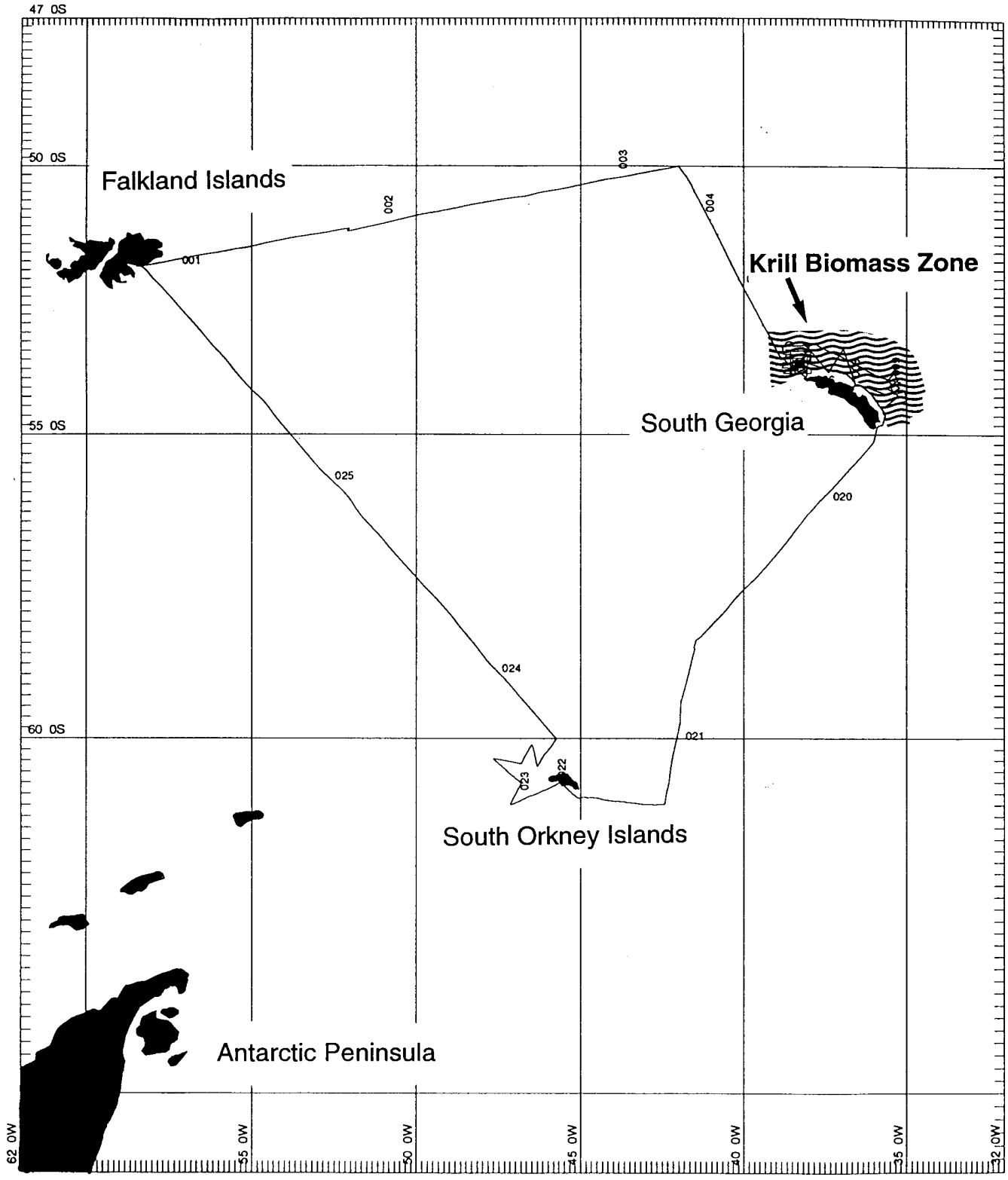
2. Acknowledgments

We acknowledge the enthusiastic support and professionalism of the *RRS James Clark Ross* Officers and Crew - because without this, the research undertaken during the Cruise would not have been possible.

We also gratefully acknowledge the help and support given by members of the Survey at British Antarctic Survey Headquarters, particularly those involved in the Communications, Instrumentation, Computing, Personnel and Logistics sections during the preparation and execution of JR06.

I am most grateful for the help and encouragement offered willing by fellow Participants during the Cruise - which enabled an arduous duty to become a pleasurable task.

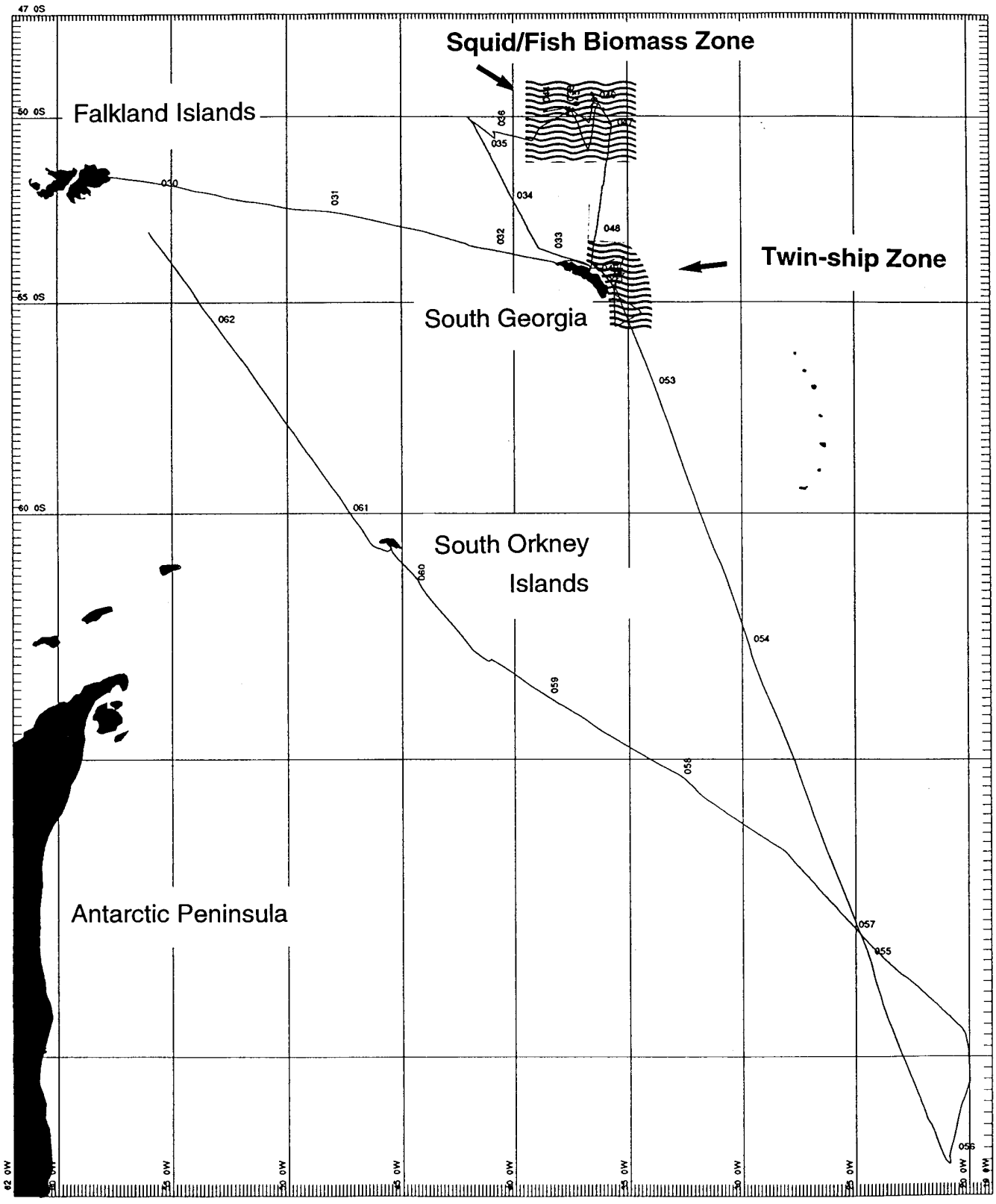
JR06: Leg 1 (1 - 25 Jan 1994)



Ship's track for Leg 1 of JR06 Predator/Prey Cruise

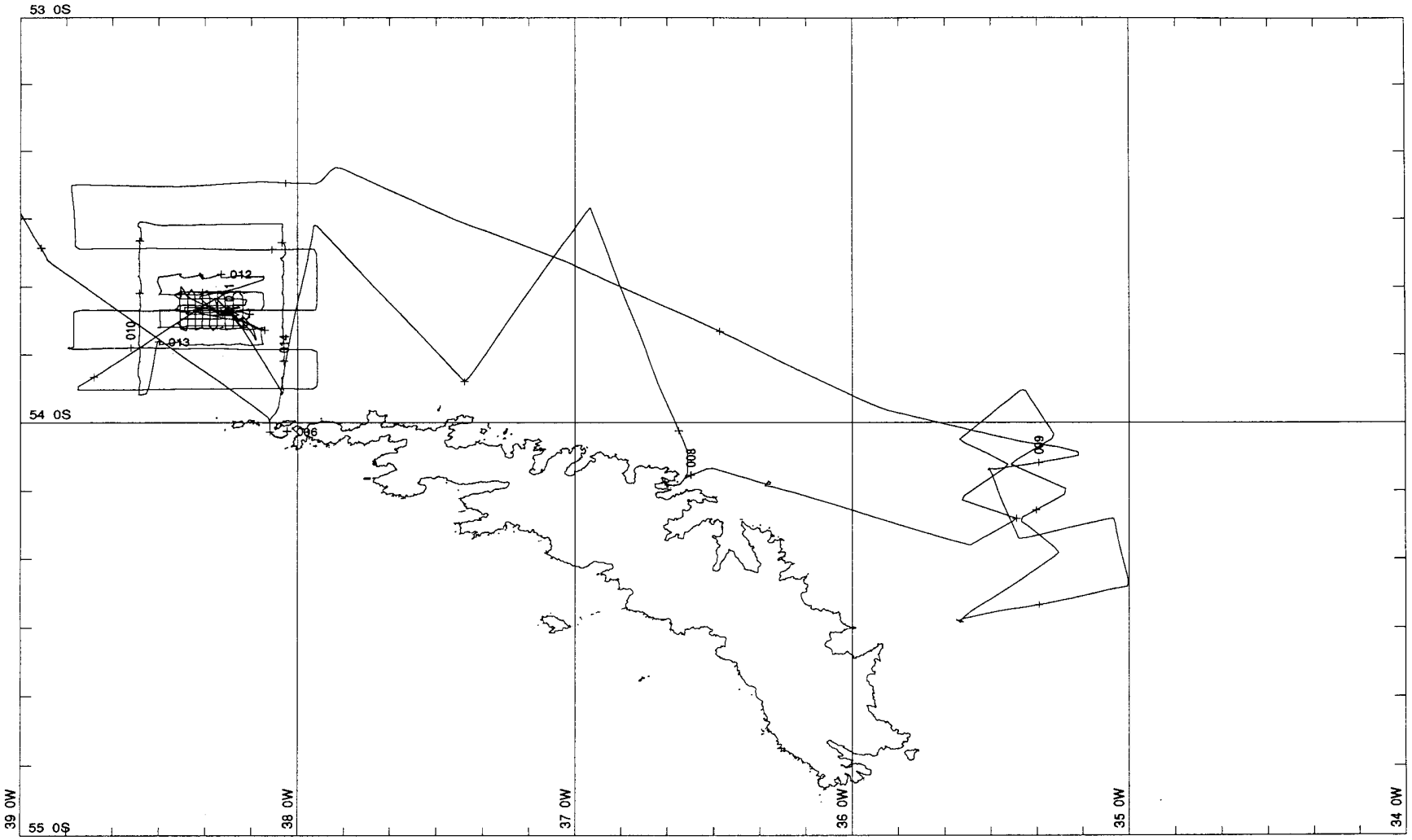
Scaled to fit

JR06: Leg 2 (30 Jan - 4 March 1994)



Ship's track for leg 2 of JR06 Predator/Prey Cruise

Scaled to fit



MERCATOR PROJECTION

SCALE 1 TO 1066620 (NATURAL SCALE AT LAT. -55)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE -55

GRID NO. 1

— Track plotted from gps_trim

Ship's Track around South Georgia

RRS James Clark Ross track during meso-scale and fine-scale studies in Leg 1

5. Summary timetable of phases during Predator/prey Cruise JR06.

28 DEC 94	Join RRS James Clark Ross
29DEC-31DEC94	Mobilisation and fueling
lJAN-3JAN94	Falkland Islands to Maurice Ewing Bank (50s 42W)
3JAN-5JAN94	Maurice Ewing Bank to Willis Islands CTD transect - Leg 1
5JAN-6JAN94	Stewart Strait & Bird Island relief
7JAN-7JAN94	Bird Island to Leith Harbour
7JAN-8JAN94	Leith Harbour for echosounder calibrations
8JAN-9JAN94	Krill search - South Georgia northern shelf
9JAN-10JAN	Willis Islands large-scale search
10JAN- lOJAN	Willis Islands large-scale search to small-scale search (08:23)
lOJAN- lOJAN	Willis Islands small grid E-W
11 JAN- 11 JAN94	Willis Islands FNET transect
11 JAN- 11 JAN94	Willis Islands small grid N-S (until 15:07)
11 JAN- 14JAN94	Willis Islands CTD grid
14 JAN	Krill Biomass Spectrum Multinet series
14 JAN - 15 JAN 94	Willis Islands small acoustic search
15 JAN	Willis Islands acoustic transect
15 JAN - 15 JAN 94	Willis Island clover leaf search for multispecies flock
15 JAN - 17 JAN 94	Krill Biomass Spectrum RMT25 net series
17 JAN - 18 JAN 94	Krill Biomass Spectrum LHPR net series
18 JAN	Krill Biomass Spectrum pelagic midwater trawl series
19 JAN - 19 JAN 94	Leith to Cooper Island
19 JAN - 21 JAN 94	South Georgia to South Orkney Islands
21 JAN - 22 JAN 94	Signy Research Station - Relief
22 JAN - 23 JAN 94	South Orkney krill search
23 JAN - 25 JAN 94	South Orkney Islands to Falkland Islands
26 JAN - 30 JAN 94	Falkland Islands - R&R, crew exchange, refueling and stores
30 JAN - 1 JAN 94	Falkland Islands to Bird Island
1 JAN	Bird Island and Husvik to exchange personnel
lFEB-4FEB94	Maurice Ewing Bank to Willis Islands CTD transect - Leg 2
4FEB-6FEB94	GHA/squid/myctophid search
4FEB-6FEB94	Squid/fish Biomass Spectrum pelagic midwater trawl series
7FEB-9FEB94	Squid/fish Biomass Spectrum RMT25 net series
10FEB	Squid/fish Biomass Spectrum Multinet series
llFEB-12FEB94	Squid/fish Biomass Spectrum LHPR net series
12FEB-13FEB94	Gale! - some gear damage
13 FEB - 15 FEB 94	Squid/fish Biomass Spectrum area physical characterisation
15 FEB - 17 FEB 94	Squid/fish Biomass area to Leith for acoustic calibration
17 FEB	Acoustic calibration and Twin-Ship planning with Africana people
17 FEB - 18 FEB 94	Leith to start of South Georgia krill meso-scale survey
18 FEB - 21 FEB 94	South Georgia krill survey
21 FEB 94	South Georgia krill survey (aborted @ 10.30)
21FEB-24FEB94	South Georgia to 71”s (Save the Bransfield !!)
24 FEB 1 MAR 94	Bransfield to the South Orkney Islands

1 MAR	Cargo relief and cool room checks.
1 MAR - 3 MAR 94	South Orkney Islands to the Falkland Islands
4 MAR - 6 MAR 94	Demobilisation.
9MAR	Disembark from RRS James Clark Ross

Summary

RRS James Clark Ross predator/prey cruise (JR06).

This multi-disciplinary cruise (1 Jan - 5 March 1994) was carried out around South Georgia *(Chief Scientist - Martin White)* with the primary objective of studying the trophic interactions between the major higher predators and both the krill dominated- and fish/squid dominated compartments of the Southern Ocean food web. The predator/prey cruise was a unique opportunity to characterise composition and structure of the marine communities using the full range of oceanographic sampling facilities offered by **RRS James Clark Ross** at the actual localities where predators were feeding as indicated by satellite tag positions (ARGOS); and compare these observations with the actual diet of the breeding birds and seals at colonies investigated from the research station at Bird Island, South Georgia. In addition, the areas studies in detail could be placed in context by reference to the large- and meso-scale oceanography using remote sensed satellite data of sea-surface temperature (ARIES). The programme was divided into two legs comprising four major programme elements - a large scale transect, krill biomass spectrum, squid/fish biomass spectrum and finally a twin-ship krill meso- and fine-scale study with **RV Africana** *(Chief Scientist - Denzil Miller, Sea-Fisheries Research Institute, Cape Town, South Africa).* In addition to the main programme elements there were a number of related projects Eg. Bird flight dynamics, copepod secondary production, microbial community structure and production, and gelatinous plankton studies undertaken during the Cruise. The Cruise participants were drawn from BAS MLS Division, ISG and P&I Sections, Bangor and Bristol Universities, Washington State and Oregon State University - USA, and Alfred-Wegener-Institute - Germany.

Perhaps the most critical biological event that prevailed during the course of the Predator/Prey Cruise was the almost total lack of swarming krill *(Euphausia superba)* in the Scotia Sea and around South Georgia. This resulted in exceptionally low breeding success rates among the bird and seal populations but provided the opportunity to investigate a major component of the Southern Ocean food-web when the ecosystem was under severe biological stress.

Large-scale Transects

The increasing demand for physical and biological data from the Southern Ocean to interpret long-term trends and ground-truth remote sensed data has lead the MLSD Pelagic Ecosystem Study group to initiate a project to routinely collect oceanographic data using the **RRS James Clark Ross** as an underway platform.

In order to characterise the large scale physical, chemical and biological regime of the Scotia Sea during the 1993/4 austral summer a number of transects were undertaken. *(Angus Atkinson, Patricia Gilmour, Alistair Murray, Julian Priddle, Carolyn Symon, Phil Trathan, Peter Ward, Jon Watkins, Cathy Goss, Richard Veit - State University Washington, and Mike Whitehouse).* Four transects were carried out during Leg 1 of the cruise; three of which were opportunistic and comprised underway sampling along tracks determined by BAS logistics. A fourth transect (Maurice Ewing Bank to Willis Islands) was specifically positioned to traverse the sub-Antarctic and Polar Frontal Systems in an area to the north-west of South Georgia shown to be visited by foraging

sea-birds. During Leg 2 of the cruise three transects in addition to the 'biological' transect were undertaken. The requirement to offer emergency support to **RRS Bransfield** at the end of Leg 2 enabled the large-scale transects to be extended to 7 1 "S.

The data have yet to be fully evaluated but preliminary comparison along the Maurice Ewing Bank to Willis Islands transect between legs 1 and 2 showed the correspondence between the surface expression of the Polar Front and that obtained from the uncalibrated CTD casts along this transect is good. The surface expression covers almost half a degree of latitude, rising from a temperature of about 3°C at 5 1 "S to about 6°C at 50" 30's. From the CTD casts the same increase in temperature is observed over the same distance. An important consideration when relating satellite imagery and underway observations to the underlying oceanographic structures. The observations also showed that there had been an overall increase in temperature over the whole length of the transect during the intervening month, and secondly the surface expression of the Polar Front shifted south. This was accompanied by a southerly shift of 'northern' species of sea-birds suggesting a general correlation between sea-bird distribution and the major water masses.

Large scale transect acoustic data was collected during all phases of the Cruise although the quality of the data is not always optimal owing to insuitable weather conditions or high passage speeds. It was possible to see the development of the deep scattering layers on several transects. On the transect to South Georgia this appeared south of the Polar Front as a diffuse layer with quite strong and compact targets embedded within the layer. On the transect from South Georgia to Signy, strong targets were observed in the top 100 m of the water column 50 miles south of Cooper Island. These targets backscattered more strongly at 38 kHz than at 120 kHz and are unlikely to be krill or zooplankton. Approaching Signy the ship ran parallel to the 250 m contour around the South of Coronation Island, many strong targets were detected with acoustic characteristics expected of krill swarms.

Biomass spectrum studies

One of primary scientific goals of the cruise was characterize and study one of two contrasting predator-prey systems - a krill based and a squid/fish based system - and identify these areas by monitoring the foraging activity of two species of albatross fitted with satellite tagging devices at Bird Island, South Georgia, the black-browed albatross (krill predator) and the grey-headed albatross (squid predator). These areas were to be occupied during the first and second legs of the cruise and the respective pelagic communities characterised in terms of species composition and biomass spectra. The purpose being to analyse the food webs supporting the respective predator types. *(Angus Atkinson, Doug Bone, Heather Daly, Emma Hatfield Francesca Pages - A WI, Paul Rodhouse, Phil Trathan, Peter Ward, Jon Watkins, Martin White).*

During Leg 1 the krill biomass spectrum study was undertaken. The 1993/94 season was notably poor for krill predators at Bird Island. Black-browed albatrosses, together with gentoo penguins and fur seals were apparently suffering severe shortages of krill for food and consequent failure to breed. Acoustic searches for krill indications along the north shelf-break of South Georgia failed to locate krill concentrations during Leg 1 and so there was an important opportunity to characterise the pelagic community in the

vicinity of South Georgia in a season when krill densities are low and breeding success of predators was considerably reduced.

Earlier BAS cruises and American data collected during the previous winter cruise on **RS Nathanel T. Palmer** indicated that substantial krill concentrations are normally present to the north of Bird Island and the American data suggested feeding aggregations of seabird predators in the vicinity of a small sea-mount in the region. Acoustic searches in the region revealed a biological layer deflected upwards as a plume from the sea-mount and reaching the surface at a point some 4 nm downstream in the prevailing east current. At this point stronger acoustic targets were identified and subsequent acoustic transects revealed small swarms that were probably krill. Associated shipboard observations on predators showed that there were concentrations of flying seabirds, penguins, fur seals and killer whales in the area.

Preliminary data from the biological sampling programme confirmed that, although present, krill were not available at high densities. The biological layer associated with the sea-mount was composed of copepods, amphipods and small euphausiids and there was a marked absence of gelatinous nektonic forms. Both predatory cnidarians and ctenophores, and suspension-feeding pelagic tunicates (salps) were largely absent from the samples.

The complimentary study of the oceanic squid biomass spectrum during Leg 2 was undertaken at a locality determined by the foraging activity of satellite tagged squid predators - grey-headed albatrosses and a locality just northward of the Polar Front. The biological sampling paralleled that used during Leg 1 and consisted of a suite of net hauls using a variety of nets combined with acoustic and oceanographic observations to characterised the composition and size structure of the pelagic community in the upper 1000m of the water column. Synoptic observations of birds and seals provided the link between land-based marine predators and their food resource. Acoustic visualisation of the biomass in the study area had shown consistent stratification of the pelagic community into 3 main layers at about 50 m, 250-350 m and 5-600 m.

A general description of the communities showed squid, amphipods, euphausiids, myctophid fish and gelatinous zooplankton to be the major components of the upper layer, myctophids and euphausiids comprised the intermediate layer while myctophid fish, decapod crustaceans and the gelatinous zooplanton were the bulk of the deeper layers.

The key achievement was made with the pelagic trawl; catches with which showed that squid of the species (Martialia among others) and size found in albatrosses' diet were located in the study area. Target fishing with the RMT25 demonstrated surprisingly fine scale vertical separation within some layers that could well form the basis of a future research project but could not be examined in detail during period allocated for research during this cruise.

Microbial Studies

A study of microbial production and respiration, using size fractionated high-precision oxygen flux measurements was carried out during the JR06 Cruise (Stephen ***Blight-Bangor University, Julian Priddle Mike Whitehouse).*** The microflora at the 'Krill-

Biomass' and 'Squid/fish Biomass' study sites were studied intensively over periods of approximately one week, and these were was complemented by observations at other times in the Cruise of surface water across the Weddell and Scotia Sea.

At the 'krill biomass' study site, near Willis Islands, phytoplankton was dominated by a bloom of large diatoms, with chlorophyll biomass up to 19 mg m-3. Gross production by the whole community reached 28 µmol 02 dm-3 d-l, of which over 90% was attributed to cells >20 pm. Respiratory activity was concentrated among smaller size fractions - whole community rates varied from 2-3 µmol O2 dm-3 d-l of which up to 60% was in the fraction <0.8 µm The 'squid/fish biomass' site was oceanic, close to the polar front. Here phytoplankton biomass was low, with chlorophyll concentrations <0.75 mg m-3, and nanoplankton predominated. Gross production was around 2.5 µmol 02 dm-3 d-l most of which was associated with the smaller size fractions. respiration rates varied from 0.5-l .O µmolO2 dm-3 d-l.

Over the larger area investigated during JR06, gross production and respiration ranged from 0.6-4.8 and 0.36-1.24 µmol 02 dm-3 d-l respectively. The size-fractionation of these rates varied widely, because of the different communities encountered. For eight sampling localities, 14-88% of gross production and 1597% of respiration were in the fraction <20 pm. This size fraction contained 16-88% of the chlorophyll biomass.

Secondary Production Studies

Experimental work *(Angus Atkinson, Rachael Shreeve, Peter Ward)* concentrated on copepod egg production and grazing studies, whilst field sampling with vertically hauled Z nets (169 hauls) provided material not only for experimental purposes, but also to provide information on mesoplankton composition and abundance at the biomass spectrum stations and on various of the transects run. Double oblique LHPR profiles were also taken to 200 m depth at both biomass spectrum stations, 7 at the krill station on Leg 1 and an abbreviated series of 5 at the squid/fish station on Leg 2.

Copepod Egg Production Studies commenced after crossing the Polar Front. The main study copepod on Leg 1 was *Rhincalanus gigas* which dominated catches in terms of biomass. Small numbers of *Calanoides acutus* and *Calanus propinquus* were also incubated during the first leg. Short term (24hr) incubations in filtered sea-water of randomly selected females indicated that between 60-70% of *R.gigas* females spawned during this period. A number of egg hatching experiments were also undertaken which indicated hatching times of ca. 4-6 days for *R.gigas* and ca. 3-4 days for *C.simillimus* and *C.acutus* at temperatures of around 2°C.

During Leg 2 net sampling and incubations commenced at a station worked at Shag Rocks on the voyage to South Georgia. This time *C.simillimus* was relatively abundant as was *R.gigas* with ca. 30% - 50% of females of the former species producing eggs. During the course of Leg *2 very* few ripe *R.gigas* were found and instantaneous rates of egg production were very low or negligible. During this leg long-term experiments were performed on females of 3 species, *C.simillimus, R. gigas* and *C.propinquus.*

Experiments with *R. gigas* were run for a little over 3 weeks until it became clear that egg production had become negligible and mortality had increased to an unacceptable

level. In the first 14 clays the most productive females produced between 5-8 clutches each at an average of 12-17 eggs female -1 day-l. Overall average clutch size was around 25 eggs which corresponds well to the 33 eggs per clutch obtained from instantaneous measurements carried out during cruise JR03. Observations also appeared to indicate that egg production was fueled by food ingested rather than by mobilisation of lipid.

Similar studies were undertaken on *Calanus propinquus* and C. *simillimus.*

Copepod grazing studies were undertaken to investigate the relationship between copepod size and feeding rate. A secondary objective was to compare diurnal feeding periodicity and vertical migration across the spectrum of copepod body size. Two methods of measuring grazing rate were used. The first was to incubate copepods in natural sea-water for 24 hrs and compare the numbers of food items at the beginning and end of the experiment. Secondly the gut fluorescence method was used to quantify the amount of chlorophyll in the guts of freshly caught copepods. At the biomass spectrum station (Leg 1) 5 incubation experiments were run. A further experiment was run while transecting. The provisional overview is that the principal copepod in terms of biomass, *Rhincalanus gigas,* had low mass specific grazing rates. *Calanus propinquus* and early copepodites of *Metridia gerlachei* had the highest mass specific feeding rates, of those measured. Copepod biomass was heavily dominated by large copepods, and likewise the diatom bloom on which they were feeding was dominated by large diatoms. The copepods were fully capable of ingesting these long colonies.

By contrast during Leg 2 the community was dominated by sub-Antarctic species, with *Calanus simillimus* and *Neocalanus tonsus* comprising most of the biomass.. Their food was much more scarce than at the krill station. Incubation experiments revealed high feeding rates on the larger particles (ciliates and pennate diatoms). This suggests that most of the available chlorophyll was in particles too small to be eaten.

Krill Biology

Krill *(Euphausia superba)* from FNET (foredeck net), multinet and RMT25 hauls have been analysed *(Jon Watkins).* A total of 471 krill were measured from over 500 caught during the week-long biomass spectrum study. The majority of krill were either immature animals with a modal total length of 39 mm or mature adults with a modal total length of 53 mm. Over 25% of these animals were females either about to or just having spawned (stages FA4 & FA5). Just over 11% of the population was juvenile. The relative lack of juvenile krill can be contrasted with the results in January 1982 when the majority of krill were juvenile and the mean size of the sampled population was 30 mm. Krill of mean size 38 mm are most likely to be year 2+ krill while 53 mm krill are likely to year 4+ or 5+. The reasons for the lack of year 1 krill is not clear at present, the abundance of krill (of unknown age/size) at Signy and the apparent lack of juvenile krill at Elephant Island (NOAA Surveyor, Valerie Loeb pers comm) could be due to a recruitment failure from poor survival of larvae last winter. Krill sampled at at South Georgia during Leg 2 had different size structure and maturity stage composition. as krill were generally immature with a modal length of 37 mm. Very few large krill were seen and none appeared to be mature.

Twin Ship studies: RV Africana & RRS James Clark Ross

Two ship operations *(Cathy Goss, Alistair Murray, Jon Watkins)* were designed to investigate processes at both the meso- and fine scale. The first project was to investigate the meso-scale distribution and abundance of acoustically detected organisms, in particular krill, around South Georgia in relation to predator distributions, environmental parameters and bathymetry. The second project was to make a preliminary investigation of the temporal variation of krill swarms, in particular (i) to observe temporal variations in size, shape, density and composition of individual swarms (ii) to determine how long individual swarms maintain their integrity, (iii) to determine the relationship of individual swarms to water structure. Both projects were to be interleaved, thus the survey would be used to find suitable areas for the fine scale work which would then be undertaken before completing the survey.
Much of this study was interupted becasue of the requirement to sail to the assistance of **RRS Bransfield,** however, the first part of the meso-scale studies were completed and the results from the **RV Africana (** *Chief Scientist - DEnzil Miller, Sea-Fisheries Research Institute, South Africa),* which remained at South Georgia rwill be integrated with those from **RRS James Clark Ross** in future.

Sea-bird studies at sea.

The major objective *(Gabrielle Nevitt - State University Orgeon, Emily Silverman and Richard Veit - State University Washington)* to quantify the foraging behaviour by sea-birds in the vicinity of krill patches was disrupted owing to the requirement to provide emergency assistance to the **RRS Bransfield.** Nevertheless, data was collected on 38 feeding flocks. Of these, 21 were associated with acoustic targets that resembled krill, 4 were clearly associated with cetaceans, 4 with carrion (probably penguin carcasses) and 3 appeared to be associated with large gelatinous zooplankton or moribund squid. Thirty-two of the 38 flocks were over the continental shelves of South Georgia and the South Orkney Islands, and the remaining 6 were in the squid biomass study area near the Polar Front. If these flocks were indicative of the situation at South Georgia as a whole, then the 1994 season was characterized by fewer, smaller feeding flocks that each contained a smaller total number of predator species than would be expected during a season of high overall krill abundance, such as 1985-1986. Physical features that seemed to influence the distribution of feeding birds during our study were a warm-core eddy associated with the Antarctic Polar Front, and three seamounts - two on the South Georgia shelf and the third in deep water just south of the Polar Front. The distribution of predator aggregations seemed to be strongly influenced by bottom topography.

Sea-bird behaviour in relation to olfactory cues were conducted during Cruise JR06. These studies concentrated on testing the birds' ability to detect dimethyl sulphide (DMS), a volatile biogenic gas produced by phytoplankton which we hypothesize could serve as an orientation cue for foraging Sea-birds. Preliminary analysis of results clearly showed that the smaller petrels (Wilson's and black-bellied storm petrels, and white-chinned petrels) aggregate to olfactory cues while the larger albatrosses, such as black-browed albatrosses appeared not do so.

In addition, bird flight studies were undertaken using video tape recordings during JR06 and on Bird Island as a sequel to studies undertaken in 1979-1980 (*Colin Pennycuick - Bristol University).* The main objective was to measure wing beat frequencies in flapping flight over the full size spectrum from wilson's petrel to wandering albatross. The second objective was to record and quantify, the soaring manoeuvres used by albatrosses to extract energy from the atmosphere's boundary layer above the surface of the sea. The resultant video tapes contain about 900,000 pictures, which when analysed are anticipated to provide a comprehensive insight of the of Sea-bird flight.

JR06:

RRS James Clark Ross
Predator/Prey Cruise, South Georgia
Marine Biology
January - March 1994

Leg 1: Krill biomass spectrum study

LEG 1 (From Interim Report of activities during Leg 1. Activities for the whole cruise are reported in section about Leg 2)

6. Physical Sciences

6.1 Report on remote-sensing -

by Phil Trathan and Carolyn Symon

Before the start of the cruise Tom Lachland-Cope and Richard Siddons installed OpenWindows and XV on one of the SUN workstations in the data prep room. This was in preparation for any image analysis requirements that were necessary once SST images had been passed to the ship from the ARIES receiving station at Rothera. During the period of the cruise, Richard Siddons based at Rothera, reviewed all incoming images and passed to the ship, via Cambridge, any which he felt provided useful SST information.

As it was not feasible to manipulate the geographic projection of the images, Richard Siddons included geographic coordinates and coastlines within the image; this proved invaluable in their interpretation.

So far 2 images, both from passes on January 11, 1994 have provided reasonable amounts of SST detail for the cruise region to the west and north of South Georgia. The images were from infrared sensors operating at 11 μm. Images in the visible region were also sent for one of these passes. These images provided information along part of the first transect steamed from Maurice Ewing Bank to the Willis Isles, though cloud cover prevented detailed interpretation.

Prior to the cruise, it had been the intention to provide weekly composite images of SST, however, given the prevailing level of cloud cover this was not feasible. If sufficiently cloud free images become available, it is considered that they would be particularly useful in locating the squid biomass spectrum project in the second leg of the cruise.

Problems encountered

Multiple copies of data have been received from Rothera via Cambridge. This is due to problems in the automatic forwarding software running at Cambridge.

Only low quality hardcopy output of images is possible on the ship. A high quality printer would be useful.

6.2 Report on deployment of satellite tags on higher predators -

by Phil Trathan

Tag deployment

During the first leg of the cruise, 3 satellite tags were deployed on Grey-headed albatrosses, 3 on Black-browed albatrosses and 1 on a Fur seal, all from Bird Island. Whilst the cruise was underway, other non-BAS research groups deployed tags on King penguins and Elephant seals.

During the first leg, only a small number of tags were deployed on albatrosses in order to reduce the disturbance to brooding birds. A total of 13 trips were recorded for the albatrosses during the phase, and towards the end of the first leg, tags were recovered and re-deployed on different birds. Deployment on fur seals was limited to 1 tag.

Species	*Ring*	*PTT*	*Start date*	*Start time*	*End date*	*End time*
BBA	1301131	1842	940101	2017	940103	1444
BBA	1301131	1842	940110	0700	-	-
BBA	1301162	1843	940103	0823	940104	0913
BBA	1301162	1843	940106	2043	-	-
BBA	1139956	9132	940103	1451	940110	0652
GHA	1146752	1557	940102	1512	940109	1346
GHA	1146752	1557	940113	1455	940117	2045
GHA	1318292	3244	931231	0932	940102	2338
GHA	1318292	3244	940105	2102	940108	1031
GHA	1318292	3244	940109	0930	940113	1310
GHA	1318291	3246	931230	0930	940102	1652
GHA	1318291	3246	940104	2230	940109	1549
GHA	1318291	3246	940111	0738	940114	0730
FUR	-	2163	940111	1827	-	-

Data handling

During the cruise, Argos data from the tags on the albatross species and on the Fur seal were relayed every weekday from Cambridge by Andy Wood. For the tags on the other predator species, and for all tags at the weekend, data were available via the ARIES receiving station at Rothera. Data handling at Rothera was carried out by Richard Siddons, using BURL software. Data received via Cambridge were loaded into GIS software (PC Arc/Info) and individual plots were made for each predator foraging trip. MAGIC coastlines and GEBCO bathymetry were included in the plots.

Data received via Rothera were used to keep track of individuals during the weekend when data from Cambridge was not available.

Problems encountered

Data transferred by **sendmsg** was not reliably relayed to the correct user-id when it arrived on the ship, this was caused by coloured book protocol messages at the head of the data. Paul Murphy is working on the problem.

Preliminary results

Based on only a very few trips, it appears that the Grey-headed albatrosses are foraging in a very similar pattern to that established last year. Most of the foraging trips were to the north of South

Georgia, but with some birds foraging even further north than anticipated. The remainder of trips were scattered to the south and west of the island. In order to provide a location for the programme in the second leg of the cruise, it will be necessary to amass data on as many trips as possible.

The foraging pattern for the Black-browed albatrosses was very different from that established last year, probably due to the poor krill season. Data from early trips showed that birds were foraging mainly over the shelf, however, data from later trips indicated that the birds were covering a very wide area, much wider than last year. By the end of the first leg, two foraging trips which had started before mid January had not been completed.

6.3 Report on cruise event log -

by Phil Trathan and Alistair Murray

During the course of the cruise all scientific operations were logged by the ship's officers. As this log included exact deployment times as well as a clear narrative of each event, it was decided that this should be used as the basis for the cruise event log. The only necessary modification was for the ship's officers to assign an event number to each operation. As this number was allocated by the bridge it was easily available for individual scientists to use for sample identification and there was little chance of events being miss-numbered.

We are grateful to the ship's officers for extending their procedures and making a copy of the ship's scientific log freely available to us. Daily copies of this log were taken and entered into Oracle. The events were carried out during the first leg of the cruise are given in Annex I.

6.4 Report on cruise tracks -

by Phil Trathan, Bruce Lamden and Graham Butcher

Plots of cruise tracks were produced on a daily basis. Both small scale plots of detailed parts of the ship's track and large scale general plots were produced using the RVS 'C' level software. Plots of individual transects were also produced to help validate the start and end times of the transects. Once validated, the start and end times of each transect were loaded into Oracle. The transects that have been steamed during leg 1 of the Cruise are given in Annex II.:

6.5 Report on scientific instrumentation and logging -

by Phil Trathan, Alistair Murray, Julian Priddle, Bruce Lamden and Graham Butcher

During the course of the cruise a wide variety of instruments were logged to the RVS 'ABC' system. A short logging interval was chosen for most instruments in order to ensure adequate spatial resolution of data and also for ease of merging separate data streams.

Instrument	*Logging interval (seconds)*
Temperature of non-toxic seawater supply	2
Salinity of non-toxic supply	2
Fluorescence of non-toxic supply	2
Wind speed	2
Wind direction	2
Air temperature	2
Humidity	2
Barometric pressure	2
TIR	2
PAR	2
Trimble GPS	2
Transit satnav	120
EM log	2
Doppler log	1
Gyro compass	2
EA500 bathymetry	2
RDI ADCP	300
CTD	-
Down wire net monitor	-
Scientific winches	-
EK500 acoustic sounder	-

Level A

All level 'A' interfaces were configured and logging prior to departure from Stanley.

Level B

Data logging began as we departed from Stanley, so far 6 DC6150 (150MB) tapes have been written and are between 93% and 97% full.

Level C

Level 'C' is performing as usual. At the end of the first leg there was approximately 290 MB of data in the RVS raw-data area. Logging was switched off on January 21, 1994 between 15:54 GMT and 16:28 GMT whilst moored at Signy Island research station, otherwise logging was continuous.

Data not logged to the RVS 'ABC' system

The following data were collected but not logged to the RVS 'ABC' system:

Instrument
Biological net
samples
Bird observations
Microbial studies
Autoanalyser

Problems and points of general note

(1) Non-toxic seawater supply from 6 m

Following a breakdown in the seawater supply on January 15, 1994 at approximately 21:15 GMT the filters on the seawater supply were changed and cleaned on a daily basis. Following the adoption of this practice, there were no further problems.

(2) EA500

The Simrad EA500 echo sounder generated suspect bathymetric data on a number of occasions. The bad data were normally generated in moderate to rough sea conditions, when the ship changed course very quickly, or when a rapid change in sea depth caused the instrument to report a false bottom. The bad data were located by use of the RVS status editor and their status set to 'suspect'. Only data which showed a change in depth of more than 50 m from the adjacent point were edited. A malfunction occurred in the EA500 on January 19, 1994 at 07:44 GMT. So far this problem has not been rectified.

(3) Suspect data

A number of the RVS data streams have all of their data flagged as suspect. This follows from the first entry in the data stream where a bug in the 'restart' software routines flags the data. Further examination of the problem is required.

(4) ADCP

Due to confusion over the possible loan of an Ashtec 3D GPS system, it was not possible to establish accurate headings for use with the ADCP. Use of a 3D GPS is now considered as desirable for accurate analysis of all ADCP data.

Logging from the ADCP occasionally stopped due to bad data being passed from the PC to the RVS level 'C'. When this occurred, it was necessary to initiate a new RVS file.

(5) EK500

The EK500 was logged through the serial port to a locally attached PC during the whole of the cruise. In addition, an experimental link through the Ethernet connection logged data to the RVS 'C' level. This connection provides binary data which requires post-processing in order to provide scientifically useful data. At present the post-processing software has not been tested.

Data was logged to BAS2 rather than BAS1 (Level C) in order to take advantage of the disc space available on that system.

(6) Trimble GPS

GPS coverage was extremely good during the cruise and there were no gaps of more than 10 s. During the first leg there were between 1 and 9 satellites always available, with an arithmetic mean of 3.4.

(7) Gyro compass

A -0.5 degree correction was applied to heading data from the Gyro compass for the generation of bestnav data.

(8) Chlorophyll calibration

To ensure continuous data, hourly checks of the under-way instrumentation were carried out. Log sheets of every check were archived for future reference. The check sheets were also used during the calibration of fluorescence which was carried out as soon as was feasible.

Approximately 280 samples were taken from the non-toxic seawater supply and extracted for chlorophyll estimation. Successful calibration was applied to the through flow fluorometer, using a preliminary classification of transect segments separated on the basis of fluorescence yield. No effects of either light inhibition of fluorescence, or of variable flow rate, were found. It is likely that changes in phytoplankton community composition will be the only significant systematic variable in future calibrations.

6.6 OCEANOGRAPHY -

by Carolyn Symon

Large Scale Transects

In order to characterise the large scale physical, chemical and biological regime of the Scotia Sea during the 1994 austral summer a number of transects were undertaken. Four transects occurred during JR06 leg I; three were opportunistic and comprised underway sampling along tracks determined by BAS logistics, while the fourth was specifically sited across a region of biological interest and included vertical profiling in addition to underway measurements. The four transects are shown in figure 1.

Opportunistic transects:

Transect 1: The Falkland Islands to Maurice Ewing Bank.
Transect 3: South Georgia to Signy Island
Transect 4: Signy Island to the Falkland Islands

These transects were run at a nominal 12 knots and the following data were logged:

EA500 (bathymetry)
ADCP (u, v, z currents over the upper 200/300 m)
Surface water intake (temperature, salinity, fluorescence, nitrate, nitrite, silicate, ammonium)
Meteorological Instruments (PAR, wind speed and direction, air temperature and humidity)
EK500 acoustics at 38 and 120 kHz
Bird observations

A comprehensive suite of measurements were recorded for Transects 1 and 4. Due to poor weather conditions on Transect 3 most of the ADCP and EK500 data are of limited use. In addition, equipment failure meant little nutrient data are available for Transect 3.

Maurice Ewing Bank to South Georgia

A compilation plot of all 1993 satellite tracked albatross locations shows a spread of observations to the north and northwest of South Georgia, with a strongly defined northern limit to the distribution. It is likely that this distribution is associated with the largescale oceanography (principally the subantarctic and polar fronts). Consequently a transect was designed to identify the largescale (major frontal positions) and mesoscale (eddy activity) oceanographic conditions across this region, and was supplemented by biological and chemical data. The orientation of the transect was a compromise between running as normal as possible to the major current flow and the northern limit to the albatross locations.

The transect started at 50°S 42°W on the relatively shallow Maurice Ewing Bank and ran southeast towards the continental shelf west of Bird Island. The transect consisted of 14 CTD stations 35 km apart (which is sufficient to resolve mesoscale variability) and the locations and total water depth at each station are shown in Table 1. The depths of the CTD casts varied; all casts were to at least 1000 m with intermittent profiles to full depth. At each station water samples were taken for chlorophyll analysis at 10, 20, 40, 60, 100, and 200 m. Samples were also obtained at 6 other depths between 200 m and the bottom of the cast; silicate, nitrate, nitrite and ammonium analyses were performed on all 12 water samples. Z-nets were deployed over the upper 200 m at the first three stations and the seventh to tenth of the 14 stations. The transect was also supported by the underway measurements listed in the previous section.

CTD Grid around the Seamount

A CTD grid was undertaken around the Seamount designated as the focus for the biological sampling during leg I. The grid consisted of 6 by 5 array of CTD's spaced 2.5 nm apart. This grid extended mainly over the shelf with the northern section covering part of the shelf break. Owing to poor weather conditions this grid was steamed in a west-east direction rather than the planned north-south direction. An additional onshore-offshore transect was located at each end of the grid, 2.5 nm from the original grid and with the CTD's along the two transects also 2.5 nm apart, and located so as to effectively extend the cover of the first grid.

Data Processing

CTD Data

The majority of the CTD data is stored on the level C system. However, CTD data for events 33, 87, 88, 106, 107, 108, 109, 113, 114, 115, 116, 119 and 120 are not yet on the level C system. These data (which were collected with the EG&G CTD data acquisition software) are currently stored in binary form on magnetic tape and must be converted to a usable form using the EG&G CTD post processing software (back in Cambridge) and then entered onto the level C system. The data on the level C system have been calibrated using the 1993 instrument calibrations and the pressure has been corrected for the 3 to 4 m offset noted on the deck unit when the CTD was at the water surface. These data have not yet been finally corrected using *in situ* corrections. *In situ* temperature has been determined on many CTD casts using three digital reversing thermometers, while salinity samples have been collected from rosette bottles and then analyzed on a Guildline Autosal. The final *in situ* corrections can not be determined until the end of JR06. It is recommended that the *in situ* temperature and salinity corrections determined by IOS for the cruise preceding JR06 should be obtained.

A library file of CTD profiles has been constructed (available in a black ring binder file - c/o AWAM). For each CTD drop there is a plot of temperature against depth, salinity against depth, density against depth and temperature against salinity for the full depth of the profile. **NOTE** these are uncorrected data and are not potential temperature or potential density.

Thermosalinograph Data

Both the temperature sensor and conductivity cell were calibrated prior to the cruise. Water samples were also taken at intermittent times throughout the cruise and analyzed for salinity on a Guildline Autosal. Samples were generally taken at least twice a day and also following any alterations or interruptions to the pumped water supply.

7. Seawater nutrient chemistry -

by Mick Whitehouse

The recently refurbished segmented-flow analyser has performed very well during its first trip to sea, providing detailed underway measurements (logged every 10 secs) which were unattainable with our old system. During Leg 1 a full set of CTD water-bottle and underway measurements were made during the Maurice Ewing Bank - Bird Island transect as well as fine-detail vertical profiles. Further underway measurements were made during the fine-scale survey to the north of Bird Island, on the South Georgia to Signy Transect, during the survey to the west of the South Orkneys and the transect back to the Falklands.

An initial scan of the data shows the predictable change in nutrient concentrations (especially silicate) at the frontal zones, but also great variability in nitrate and ammonium levels over the shelf-break regions around South Georgia and the South Orkney Islands.

8. Microbial Studies -

by Stephen Blight, Julian Priddle and Mick Whitehouse

Following establishment of gear and a number of shake-down experiments, work during the first leg was concentrated on the 'krill biomass spectrum' site near Willis Islands. Most sampling was undertaken at the central waypoint, down current from a sea-mount, but other samples were taken in the course of oceanographic survey transects in the middle of the study. The project commenced with a detailed vertical profile at the main station, where size-fractionated chlorophyll (19 depths 280m to surface), POC and PON (19 depths), inorganic nutrients (19 depths), and Lugol's-preserved taxonomic samples were obtained to characterise the profile. Whole community respiration experiments were established for four depths in the mixed layer and one in the pycnocline, and P-max and thymidine uptake undertaken for 10 m only. This detailed profile was the preface to a series of size-fractionated community production-respiration experiments carried out on subsequent days using water collected from 10 m depth, including sites offshore and inshore from the main station. During the period of the study, a storm suspended operations for a day, and the opportunity was taken to carry out a reduced version of the original vertical profile in order to discover the effects of strong wind-mixing on the microplankton community. Mixing had deepened the mixed layer by 5 m, and appeared to both decrease phytoplankton biomass and shift the size-spectrum slightly towards smaller cells.

The microplankton community was dominated by large-celled organisms. Earlier tests had shown that screening water samples at 200 µm was inadvisable, as this screened out up to 80% of the particulate chlorophyll. The first detailed profile on the main site confirmed that the majority of chlorophyll biomass was in the size fraction >20 µm, with biomass up to 17 mg m-3 over the 55 m-deep mixed layer. Beneath the mixed layer, particles < 20 µm dominated the pigment signal, but pigment degradation was significant. Preliminary examination of preserved samples of microplankton from the mixed layer shows that the phytoplankton was dominated by colonial diatoms such as *Eucampia* (previously encountered in this locality), *Odontella, Thalassiosira* and small *Chaetoceros* spp. The inorganic nutrient analyses showed NO3 , NH4 , SiO3 concentrations of 10, 0.2-0.7 and 15 mmol m-3 in the mixed layer and NO3 and SiO3 of about 30 mmol m-3 at 100 m depth. Ammonium concentrations reached 2 mmol m-3 in the pycnocline, and then decreased to surface values at 200 m depth.

Over all samples carried out at this site, gross community production was 17-33 mmol O2 m-3 d-1 (equivalent to 0.17-0.33 g C m-3 d-1). In all experiments, >50% of production was in the size fraction >200 µm, and <10%ä in the size fraction < 20 µm. Respiration rates were 1.7-6 mmol O2 m-3 d-1 (0.02-0.07 g C m-3 d-1). Respiration was dominated by smaller organisms, with 30-70% being accounted for by the size fraction < 20 µm. Overall, there was consistent net production in the size fraction >20 µm (except in one case), whilst <2 and <0.8 µm showed net respiration. The two vertical profiles showed that bacterial respiration was more-or-less constant through the mixed layer and into the pycnocline, whereas the metabolism of larger organisms dominated in mixed layer waters.

These preliminary results already provide a comprehensive picture of the size-fractionated metabolic activity of the microbial community typical of a dense diatom bloom around South Georgia. They indicate that the overwhelming concentration of phytoplankton biomass in the largest size fractions results in the majority of primary production being concentrated in large particles, presumably available mainly to metazooplankton. heterotrophic activity was mainly carried out by smaller-celled organisms, and the degree to which this was coupled to the primary production was uncertain.

9. Secondary Production Studies: Copepoda -

by Peter Ward, Angus Atkinson and Rachael Shreeve

Experimental work has concentrated again on copepod egg production and grazing studies, whilst field sampling with vertically hauled Z nets has provided material largely for experimental purposes, but also to provide information on mesoplankton composition and abundance at the biomass spectrum station. A series of 7 double oblique LHPR profiles was also taken at this station. The ascent profiles will be used to describe zooplankton abundance and species composition in relation to vertical distribution with particular reference to the distribution of eggs and females. The descent profiles have been frozen and will be used to examine diurnal variation in gut fullness and fluorescence of selected species (see grazing studies). Despite some minor damage to the LHPR during one deployment and the loss of a nose cone and flow meter, the system now works extremely well largely thanks to the efforts of Paul Woodroffe who has successfully interfaced the electro-mechanical side of the system with the DWNM.

Copepod Egg Production Studies:

These commenced as soon as we crossed the Polar Front and gathered enough material to start experiments. The main study copepod has been *Rhincalanus gigas* which has dominated catches in terms of biomass. We had hoped to continue comparative work with *Calanus simillimus* but this species has been extremely rare in catches. Small numbers of *Calanoides acutus* and *Calanus propinquus* have also been incubated.

Short term (24hr) incubations in filtered seawater of randomly selected females has indicated that between 60-70% of *R. gigas* females spawned during this period. Samples of eggs and copepodite stages were also taken and frozen for biochemical analysis. Long term incubations with groups of animals maintained in 2l jars with enriched natural particulates have been less successful. Spawning rates have generally been low in comparison to field data, probably due to 'bottle effects' although as at 21.1.94 numbers of eggs recovered from the jars is increasing. We had hoped to use cultured algae as a source of food to feed these animals to excess but our preferred choice, *Thalassiosira weisflogii*, crashed on the way south and *Dunaniella* sp.(7 μm), has, as we suspected proved unsatisfactory, probably because of its small size. The culturing system does however work extremely well and will be worth developing at Cambridge to grow up some of the larger species.

A number of egg hatching experiments were also undertaken which have indicated hatching times of ca. 4-6 days for *R. gigas* and ca. 3-4 days for *C. simillimus* and *C. acutus* at temperatures of around 2°C.

Copepod feeding studies

A. Atkinson has conducted feeding studies on copepods, with most emphasis being placed on the krill biomass spectrum site. The work was in two parts; firstly to investigate the relationship between feeding rate and copepod size. This involved six incubations of the predominant copepods in ambient seawater. Provisional results from fluorescence analysis indicate that copepodite stage CV of *Calanus propinquus* and early copepodites of *Metridia gerlachei* had the highest mass specific feeding rates. All life stages of *Rhincalanus gigas* were incubated, and highest mass specific feeding rates were among the early copepodites (CI and CII).

The second aspect of the study was to compare diurnal vertical migration and feeding across the copepod body size spectrum. For this a series of closing vertical nets were fished at the site at different times of the day and night, sampling in the 0-75 m and 75-200 m strata. During the diurnal LHPR series, temporal resolution was increased by encompassing 39 net hauls between the 7 LHPR hauls. These, together with the ascent and descent portions of the LHPR tows, will provide a fine scale temporal/spatial picture of zooplankton distribution, feeding and egg production.

10. Acoustic Studies -

by JL Watkins & AWA Murray

Dual frequency (120 and 38 kHz) acoustic data have been collected on all phases of the first leg of JR06. Data have been collected from 120 separate 2 metre layers between 10 and 250 m. Each layer has been logged at two thresholds (-100 and -70 dB) for each frequency. Integration periods have varied from every 6 minutes (equivalent to every nautical mile) on long transects to every minute during net hauls. Data have been collected without the use of Simrad's noise margin setting because this has an unquantifiable effect on the signal passed for processing, however one side effect is that TVG amplified noise is not filtered out either, this has made the job of post-processing and editing the data so much harder.

Large scale transects:

Data have been collected while on passage between Stanley and South Georgia, South Georgia and Signy, Signy and Stanley. The weather has not been optimal for acoustics and the speed of the last two transects has been high (up to 13 knots) when conditions have been suitable. We have seen the development of the deep scattering layers on several transects. On the transect to South Georgia this appeared south of the Polar Front as a diffuse layer with quite strong and compact targets embedded within the layer. On the transect from South Georgia to Signy, strong targets were observed in the top 100 m of the water column 50 miles south of Cooper Island. These targets backscattered more strongly at 38 kHz than at 120 kHz and are unlikely to be krill or zooplankton. Approaching Signy the ship ran parallel to the 250 m contour around the South of Coronation Island, many strong targets were detected with acoustic characteristics expected of krill swarms.

Meso and fine scale surveys:

A zig-zag set of transects along the northern side of South Georgia and a series of smaller scale transects over the shallow bank north of Cape Charlotte did not reveal any krill swarms. However a persistent but diffuse scattering layer was frequently observed, this was hardly detectable at 38 kHz and it is likely to represent a mixed zooplankton community comprising small euphausiids, amphipods and large copepods. A series of surveys north of Bird Island revealed a ridge and a canyon leading off the shelf break. Here a diffuse scattering layer (Figure 1) was found trailing downstream from the ridge. At the edge of the canyon krill swarms were found. Above some of these swarms the echo-sounder detected very small but dense targets, it is thought that these could well have been predators such as penguins or fur seals. Where these very dense targets were found, the swarm or part of the swarm was deeper than the surrounding swarm.

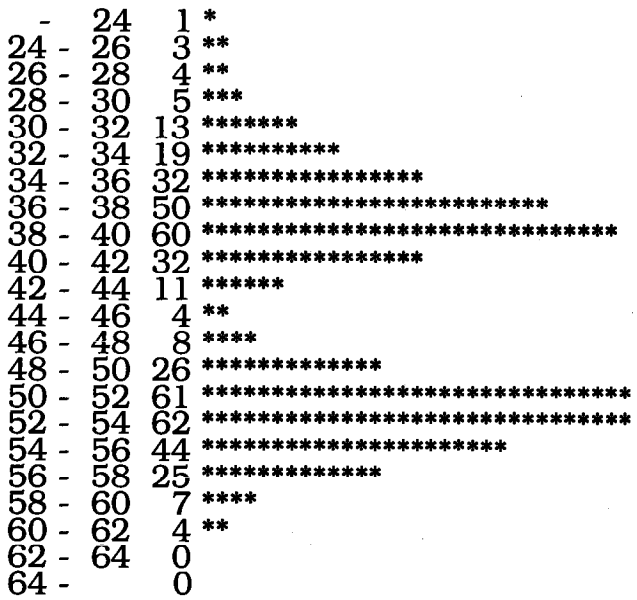
A zig-zag survey to the west and north of Coronation Island, South Orkneys, detected large numbers of dense targets both around the shelf break and over deep water. The shape and relative backscattering at 120 and 38 kHz suggest that these targets were krill.

11. Krill Biology -

by JL Watkins

of 471 krill were measured from over 500 caught during the week-long biomass spectrum study. The majority of krill were either immature animals with a modal total length of 39 mm or mature adults with a modal total length of 53 mm (Figure 2). Over 25% of these animals were females either about to or just having spawned (stages FA4 & FA5). Just over 11% of the population was juvenile. The relative lack of juvenile krill can be contrasted with the results in January 1982 when the majority of krill were juvenile and the mean size of the sampled population was 30 mm. Krill of mean size 38 mm are most likely to be year 2+ krill while 53 mm krill are likely to year 4+ or 5+. The reasons for the lack of year 1 krill is not clear at present, the abundance of krill (of unknown age/size) at Signy and the apparent lack of juvenile krill at Elephant Island (observations from *NOAA Surveyor*, pers comm, Dr Valerie Loeb - January 1994) could be due to a recruitment failure from poor survival of larvae last winter.

Figure 2: Histogram of length of krill sampled from all nets north of Bird Island, Leg 1 JR06



Scale: 1 asterisk represents 2 units.

12. Biomass Spectra of Pelagic Community: Leg 1 -

by Paul Rodhouse, Emma Hatfield & Martin White

One of the scientific goals of the cruise was to identify areas of concentrated foraging activity of two species of albatross fitted with satellite tagging devices at Bird Island, South Georgia, the black-browed albatross (primarily a krill predator) and the grey-headed albatross (primarily a squid predator). These areas were to be occupied during two phases of the cruise and the respective pelagic communities characterised in terms of species composition and biomass spectra. The purpose being to analyse the food webs supporting the respective predator types.

At the time of writing the characterisation of the krill area has been attempted. The 1993/94 season has been notably poor for krill predators at Bird Island. Black-browed albatrosses, together with gentoo penguins and fur seals are apparently suffering severe shortages of krill for food and consequent failure to breed. Acoustic searching for krill indications along the north shelf break of South Georgia failed to locate krill concentrations so this cruise has offered an important opportunity to characterise the pelagic community in the vicinity of South Georgia in a season when krill densities are low and breeding success of predators is considerably reduced.

Earlier BAS cruises (J Watkins *pers comm*) and American data collected during the previous winter (D Veit *pers comm*) indicated that substantial krill concentrations are normally present to the north of Bird Island and the American data suggested feeding aggregations of seabird predators in the vicinity of a small sea mount in the region. Acoustic searches in the region revealed a biological layer arising as a plume from the sea mount reaching the surface at a point some 4 miles downstream in the prevailing east current. At this point stronger acoustic targets were identified and subsequent acoustic transects revealed small targets that were probably krill. Associated shipboard observations on predators showed that there were concentrations of flying seabirds, penguins, fur seals and killer whales in the area.

Samples for characterisation of the biomass spectrum were taken at a fixed station some 4 miles downstream in the prevailing current from the peak of the seamount. Water samples from the CTD rosette were taken for the microbiological component, the vertical Z-net for zooplankton, the RMT25 for micronekton, and the pelagic trawl for the macronekton components of the pelagic community. A CTD survey was carried out to determine the physical dynamics of the system.

Preliminary data from the biological sampling programme confirmed that, although present, krill were not available at high densities. The biological layer associated with the sea mount was composed of copepods and small euphausiids and there was a marked absence of gelatinous nektonic forms. Both predatory cnidarians and ctenophores, and suspension-feeding pelagic tunicates (salps) were largely absent from the samples.

13. BIRD FLIGHT STUDIES -

by Colin Pennycuick

1. I have collected sufficient amounts of video to measure wingbeat frequencies in flapping flight of Wandering and Black-browed Albatrosses, Giant Petrel, White-chinned Petrel, Cape Pigeon, Prion, Wilson's Storm-petrel and unidentified diving petrels. I have insufficient amounts so far on Light-mantled Sooty Albatross, Grey-Headed Albatross and Blue-eyed shag, but should be able to get more material on these species on Bird Island. This information is required partly to test a method for predicting wing-beat frequencies, based on measurements of other species, and partly to work out the power available from the various species' flight muscles. When combined with my earlier flight speed measurements on the same species, this will give a better basis for estimating energy requirements on foraging expeditions. Results will have to await analysis of the video recordings back in Bristol.

2. I have collected video on the soaring manoeuvres of the various species, in the hope of working out where exactly the energy comes from for their soaring flight. This includes all species down to prions, but not storm-petrels, which do not appear to soar to any significant extent. I have also collected direct observations of manoeuvres in relation to wind and swell, which may or may not shed some light on the same problem, when subjected to statistical scrutiny later.

3. The rest of my programme depends on getting in to Bird Island.

Comment on ship's equipment

I need to know the wind strength and direction to make any sense out of my observations, and have been getting this from the "scientific" anemometer on the foremast. The scientific anemometer works, but is not ideally sited. If the wind is from the starboard side, the anemometer is blanked by a spotlight, which is mounted at the same level, besides which the foremast itself disturbs the air flow. A better place would be right at top of the foremast, on one of the two horizontal struts which project aft - preferably the one on the starboard side, as it is further away from the windsock pole. It would be nice to have a backup, but the original ship's anemometer does not work at all. I wonder whether it could be mended. Everything else I need works fine.

LEG 2.

14. Report on Large scale transects -

by Phil Trathan, Carolyn Symon, Patricia Gilmour, Alistair Murray, Julian Priddle, Pete Ward, Jon Watkins and Mick Whitehouse.

In order to characterise the large scale physical, chemical and biological regime of the Scotia Sea during the 1993/4 austral summer a number of transects were undertaken.

Four transects were carried out during Leg 1 of the cruise; three of which were opportunistic and comprised underway sampling along tracks determined by BAS logistics, whilst the fourth was specifically placed to cross a region of biological interest and included vertical profiling in addition to underway measurements. The four transects from Leg 1 are shown in Fig. 1.

During Leg 2 of the cruise, a further 4 transects were carried out. Once again, three of these were opportunistic whilst the fourth was a repeat of the specifically sited transect carried out in Leg 1. The four transects from Leg 2 are shown in Fig. 2.

Opportunistic transects:

Leg 1 Transect 1: The Falkland Islands to Maurice Ewing Bank
Transect 64: South Georgia to the South Orkney Islands
Transect 73: The South Orkney Islands to the Falkland Islands

Leg 2 Transect 110: South Georgia to the Weddell Sea
Transect 112: The Weddell Sea to the South Orkney Islands
Transect 113: The South Orkney Islands to the Falkland Islands

All the opportunistic transects carried out in Leg 1 were run at a nominal 12 knots, whilst in Leg 2 transect 110 was steamed at 15 knots, transect 112 at a speed which varied between 4 and 8 knots and transect 113 at a speed between 10 and 13 knots.

On all transects the following data were logged:

- Simrad EA500 (bathymetry)
- RDI ADCP (u, v, z currents over the upper 200/300 m)
- Non-toxic seawater intake at 6 m (temperature, salinity and fluorescence)
- Meteorological instruments (TIR, PAR, wind speed and direction, air temperature, pressure and humidity)
- Simrad EK500 acoustics at 38 and 120 kHz
- Bird observations

For the transects on Leg 1 (transects 1, 64 and 73), silicate, nitrate, nitrite and ammonium levels were measured from the non-toxic seawater intake; phosphate levels were also measured for 2 of these transects (transects 64 and 73). Following poor weather conditions on transect 64 most of the ADCP and EK500 data were judged to be of limited use and nutrient sampling was discontinued.

Specifically sited transects

Leg 1 Transect 2: Maurice Ewing Bank to the Willis Islands
Leg 2 Transect 74: The Willis Islands to Maurice Ewing Bank

In 1993, Grey-headed and Black-browed albatrosses from Bird Island fitted with satellite tags, were tracked between January and March. Compilation plots of the locations for both albatross species showed a spread of observations to the north and northwest of South Georgia with a clearly defined northern limit to the distribution. It is likely that this distribution is associated with the large scale oceanography (principally the sub-Antarctic and the Polar fronts). Hence, a specifically sited transect was designed to identify the large scale (major frontal positions) and mesoscale (eddy activity) oceanographic conditions across this region. The orientation of the transect was a compromise between running normal to the major current flow and the northern limit of the albatross locations.

The transect was run at the beginning of Leg 1, whilst both species of albatross were brooding chicks and again at the beginning of Leg 2, as the parent birds began to forage in order to feed their chicks. The transect was steamed at a nominal 10 knots, with the ship slowing over the last mile in order to stop at the next station. At the end of each station, the ship travelled back along the transect in order to turn and steam at 10 knots through the just-completed station. The transect was supported by the underway measurements listed in the previous section.

The transect started at 50°S, 42°W on the relatively shallow Maurice Ewing Bank and ran southeast towards the continental shelf west of Bird Island. The transect consisted of 14 CTD stations at 35 km spacing, a resolution sufficient to resolve mesoscale variability. The location of each station and the water depth, is shown in Table 1. The depths of the CTD casts varied; all casts were to at least 1000 m with intermittent profiles to full depth. At each station water samples were taken for chlorophyll determination at 10, 20, 40, 60, 100, and 200 m. Water samples were also obtained at 6 other depths between 200 m and the bottom of the cast. Nutrient analyses for silicate, nitrate, nitrite, phosphate and ammonium were performed on all 12 water samples.

In addition, vertically hauled 'Z' nets were deployed over the upper 200 m at a number of the CTD stations during Leg 1 and at all 14 CTD stations during Leg 2. On Leg 1 a single haul with a 200 μm mesh net was undertaken at stations 1-3, two 200 μm and one 100 μm net hauls were carried out at station 6 and two 500 μm and one 100 μm hauls were carried out at stations 7-10. The larger mesh size used at the later stations was in response to the dense phytoplankton bloom that had blocked the finer meshed nets at some stations and which had also made sorting of live animals difficult. The fine mesh net was still used to collect copepod eggs. On Leg 2 a single deployment of a 200 μm net was undertaken at all 14 stations. The samples were collected in order to assess geographical differences in the reproductive status of several species of copepods which have sub-Antarctic to Antarctic distributions, as well as to provide animals for experimental purposes. An examination of the differences in the reproductive status of several copepod species will be undertaken and the samples will provide an opportunity to characterise catch composition with respect to differences in water masses.

Preliminary results

Data from the opportunistic transects have not yet been examined in detail, and little can be said until the data have been properly validated. Data from the specifically sited transect have been examined at a superficial level but again little can be said at the present time.

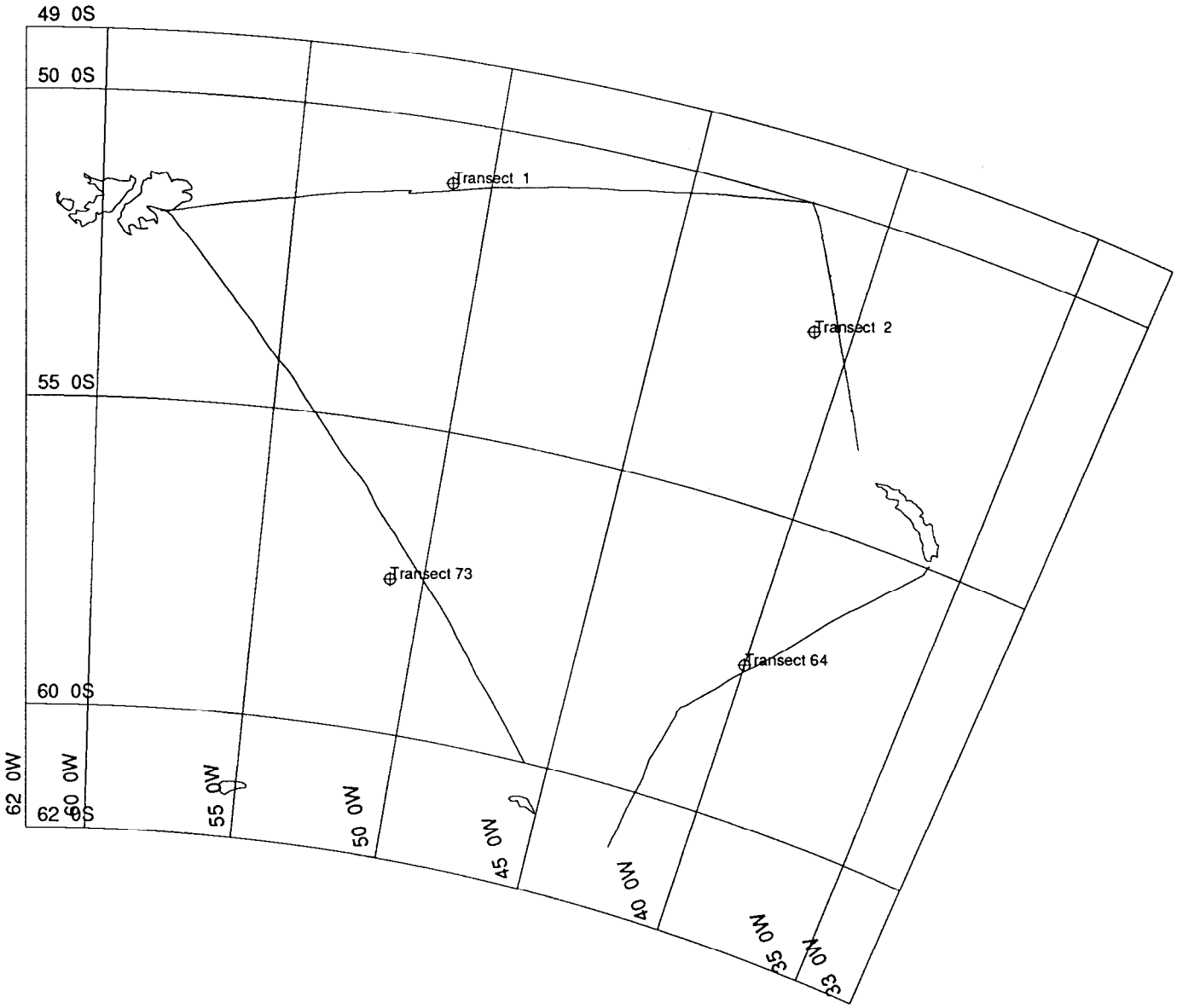
Despite this caution, however, a tentative comparison can be made for the temperature from the non-toxic seawater intake obtained during transect 2 and transect 74. Fig. 3 and Fig. 4 show the surface temperature plotted against latitude for the two transects. Two points are immediately evident; firstly there has been an overall increase in temperature over the whole length of the transect during the intervening month, and secondly the surface expression of the Polar Front appears to have shifted south.

The correspondence between the surface expression of the Polar Front and that obtained from the uncalibrated CTD casts from transect 2 (Fig. 5) is good. The surface expression covers almost half a degree of latitude, rising from a temperature of about 3°C at 51°S to about 6°C at 50° 30_S. From the CTD casts on transect 2, the same increase in temperature is observed over the same distance.

MLSD commitment to Large scale transecting in future years

The large scale transects, in their current format, involve the collection of acoustic data, nutrient chemistry data, fluorescence, temperature, salinity and CTD data. This format already requires a large group of people, therefore, if biological samples from nets are to be collected and if ADCP data, UOR data and remotely-sensed data received at Rothera are also to be utilised, further commitment should be envisaged.

Fig 1



LAMBERTS CONFORMAL CONIC

GRID NO. 1

— Tracl

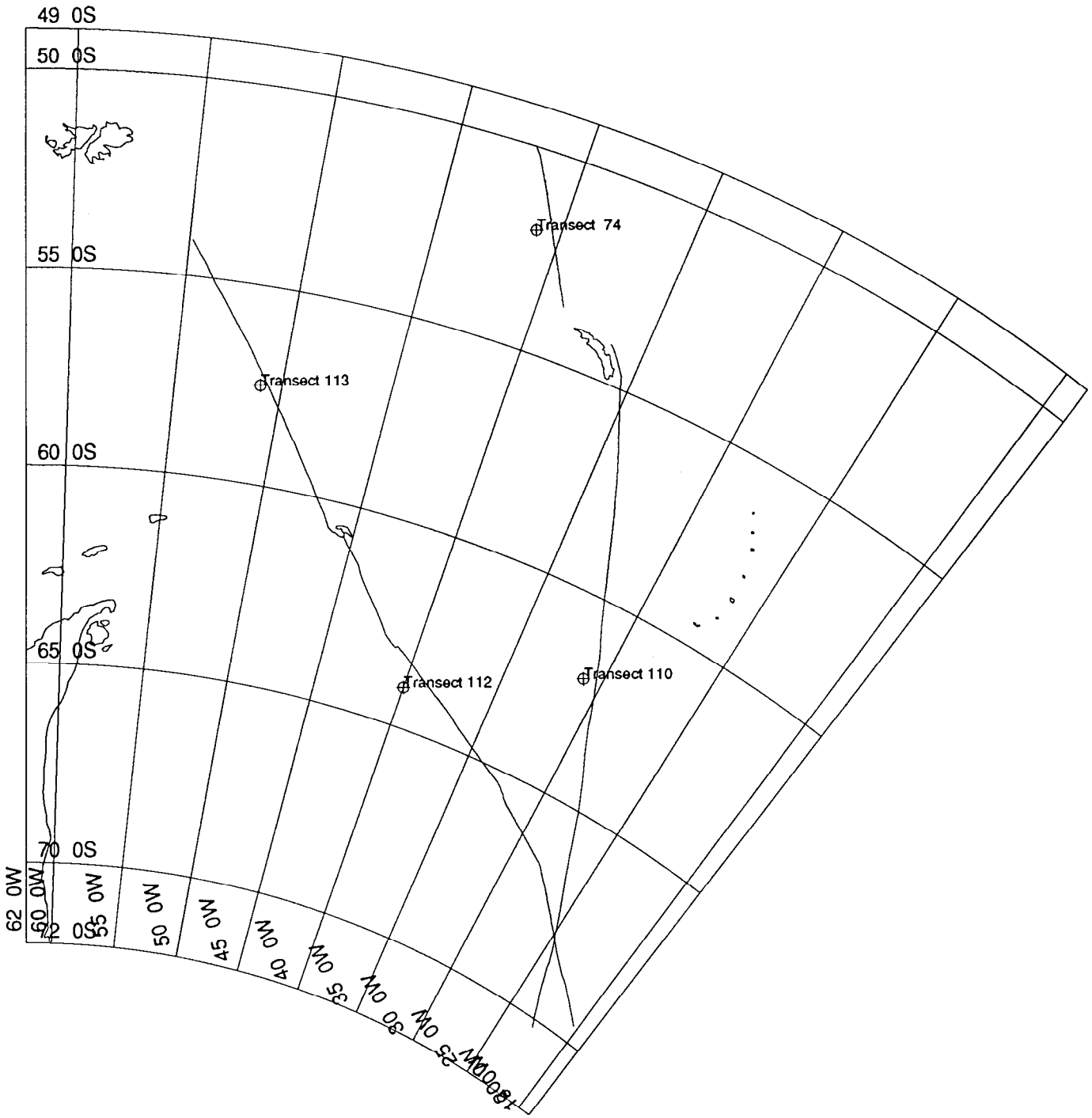
SCALE 1 TO 10000000 (Std Parallels 62S and 49S)

WGS 72 ELLIPSOID

Cruise JCR06: Leg 1 large scale transects

Scaled to fit

Fig 2



LAMBERTS CONFORMAL CONIC

GRID NO. 1

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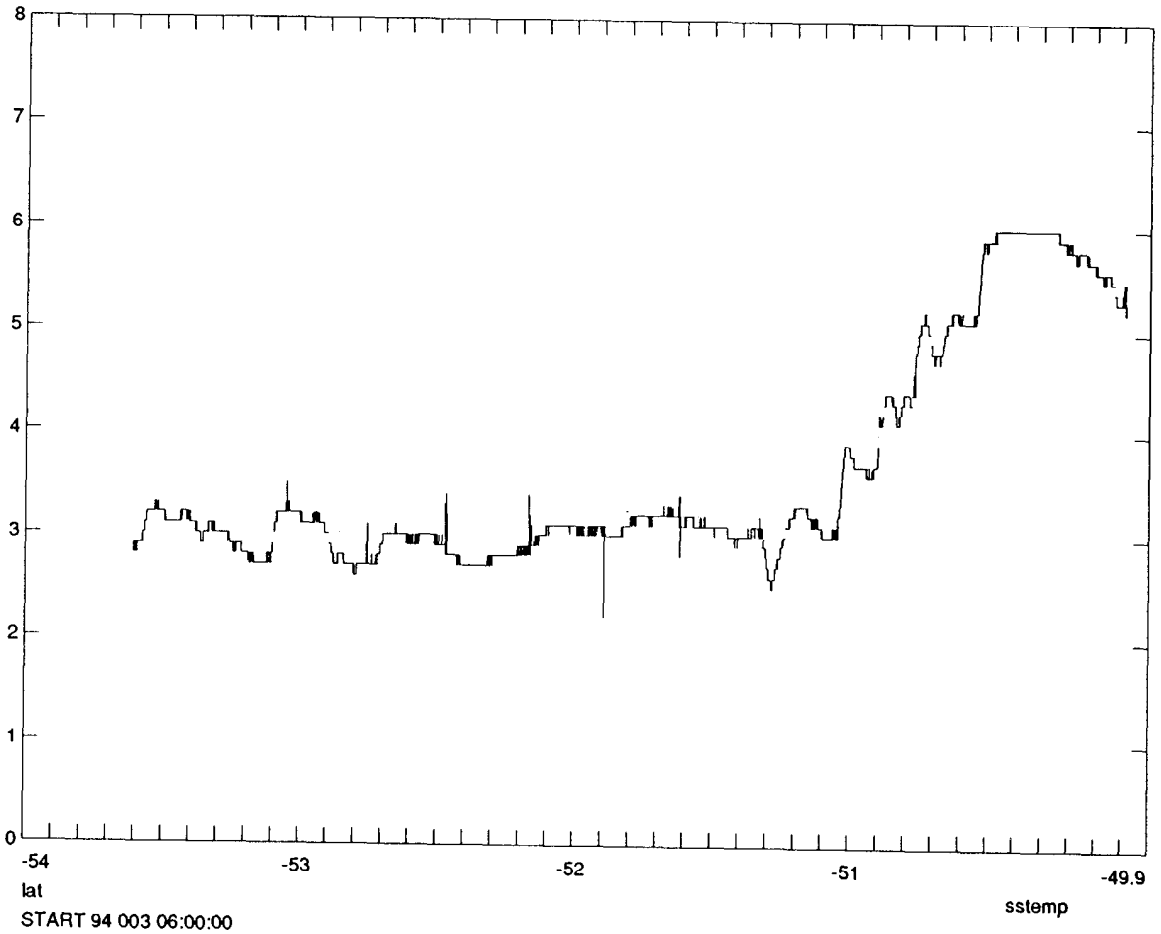
WGS 72 ELLIPSOID

Cruise JCR06: Leg 2 large scale transects

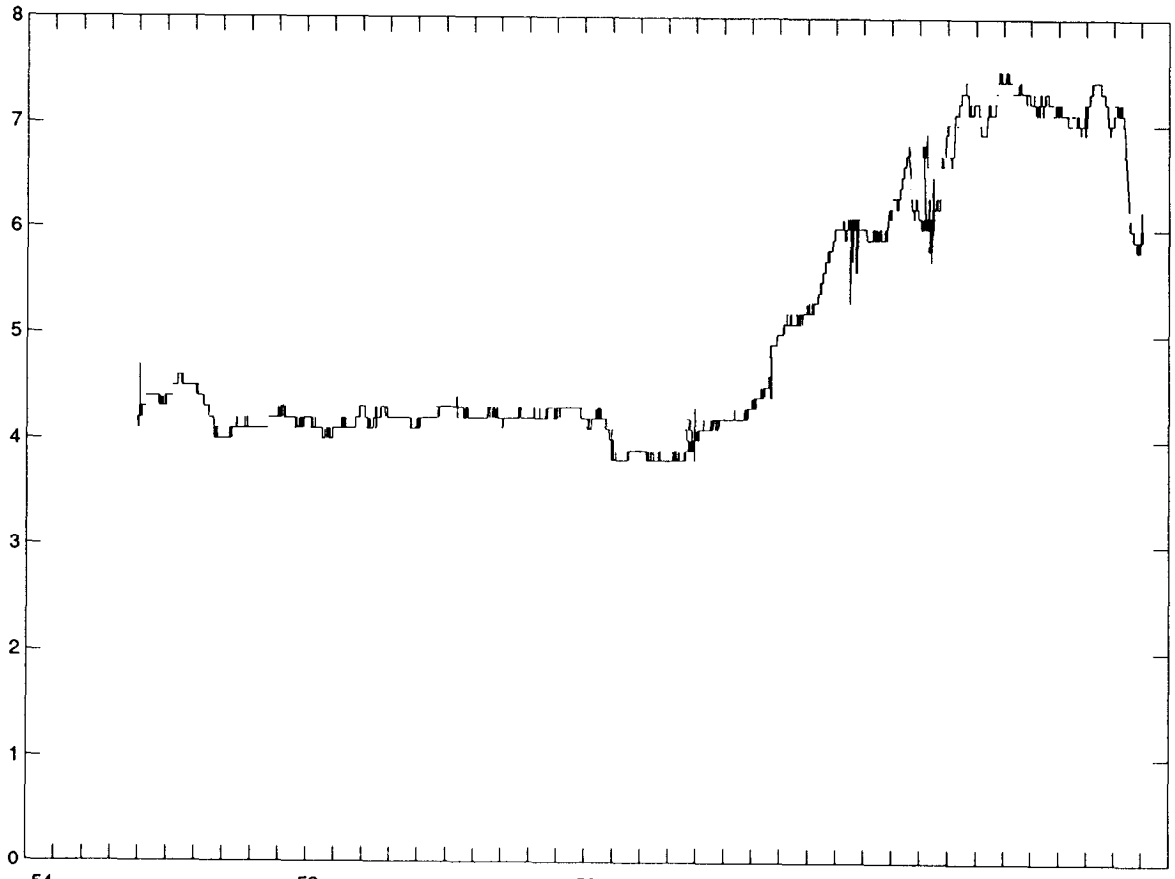
Scaled to fit

Fig 3

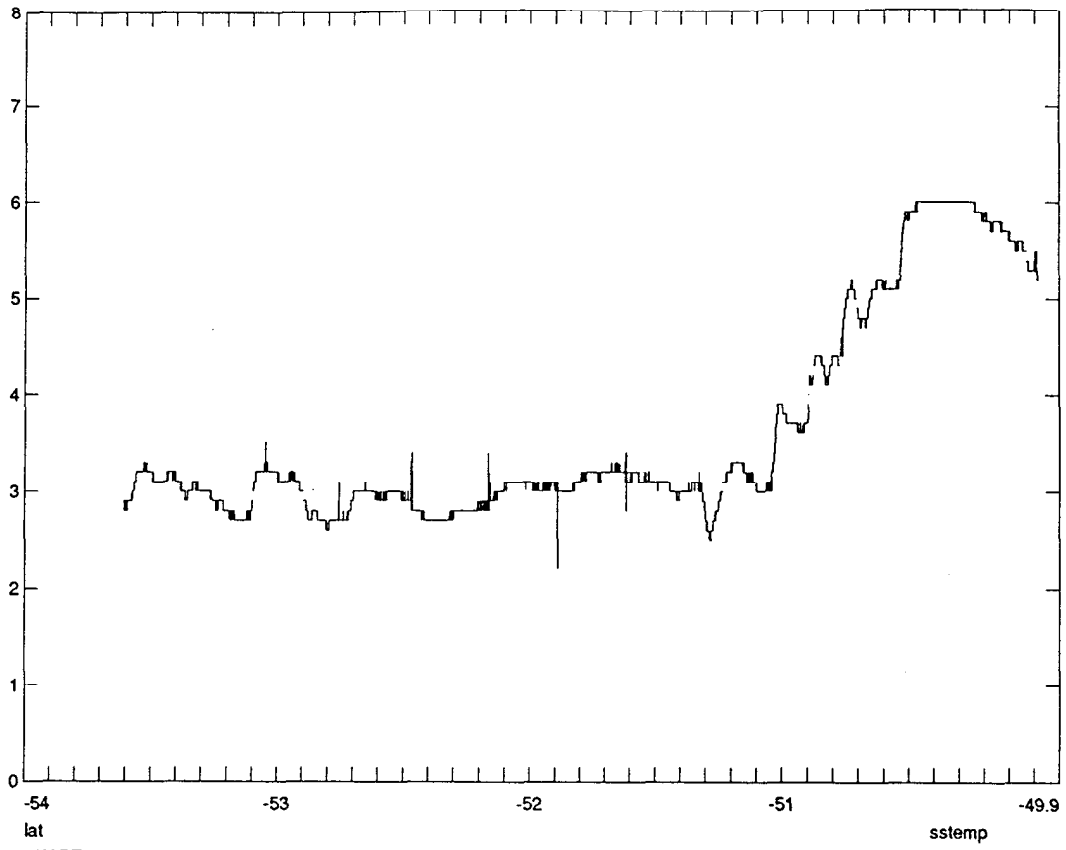


Scaled to fit

Fig 4



Scaled to fit



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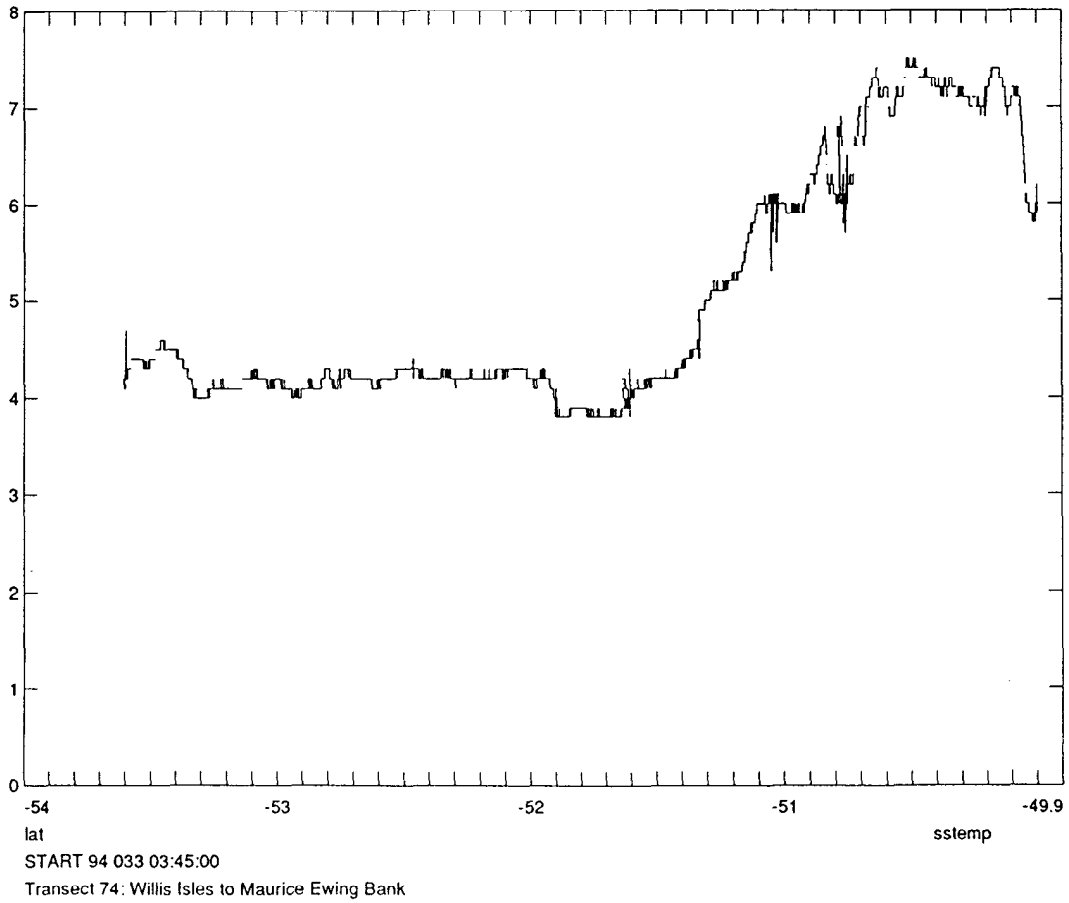


Fig 5 .

Transect 2 and Transect 74

Event Transect 2	Event Transect 74	Latitude	Longitude	Depth (m)	Nominal CTD bottle depths (m)
2	250	50°00′ S	42°00′ W	1646	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
4	248	50°12′ S	41°46′ W	1369	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
6	246	50°29′ S	41°32′ W	1686	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
8	244	50°46′ S	41°18′ W	2357	2000, 1500, 1000, 750, 500, 350, 200, 100, 60, 40, 20, 10
9	242	51°03′ S	41°04′ W	2812	2000, 1500, 1000, 750, 500, 350, 200, 100, 60, 40, 20, 10
10	240	51°20′ S	40°50′ W	3436	3000, 2000, 1000, 750, 500, 350, 200, 100, 60, 40, 20, 10
14	238	51°37′ S	40°36′ W	3713	3000, 2000, 1000, 750, 500, 350, 200, 100, 60, 40, 20, 10
18	236	51°54′ S	40°23′ W	3687	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
22	234	52°11′ S	40°09′ W	3705	3000, 2000, 1000, 750, 500, 350, 200, 100, 60, 40, 20, 10
26	232	52°28′ S	39°54′ W	3714	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
30	230	52°45′ S	39°39′ W	3707	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
31	228	53°02′ S	39°24′ W	3724	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
32	226	53°19′ S	39°09′ W	3604	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10
33	224	53°36′ S	38°54′ W	1154	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20, 10

15. Spatial and temporal variation in phytoplankton biomass

*by **Julian Priddle, Alistair Murray and Phil Trathan***

[Version 2.0 8 March 1994]

Abstract *Particulate chlorophyll a was estimated fluorometrically both continuously on the scientific pumped seawater supply (in vivo fluorescence) and on discrete samples from the same supply and from water bottle profiles (extracted fluorescence). The data comprise continuous underway measurements, supported by nearly 800 discrete samples, and vertical sections along three transects (one of which was repeated) and from the two biomass spectrum sites. Size-fractionated measurements were made for many vertical profiles, and on selected discrete samples from the pumped supply. In all, 1370 chlorophyll extracts were processed.*

Significant spatial variability was evident in both the distribution of phytoplankton biomass and its in vivo fluorescence properties. Two repeat sections from Maurice Ewing Bank to Bird Island showed changes in spatial and temporal distribution of phytoplankton biomass which could be attributed both to changes in hydrography and to seasonal differences in bloom development. Physical characterization in the region of the Polar Front at the 'squid biomass' site indicated complex interleaving of water masses which was reflected to some extent in the chlorophyll distribution.

The ratio of in vivo fluorescence to extracted chlorophyll ('fluorescence yield') was shown to vary over large distance scales. This suggested that there is a link between phytoplankton community composition and the characteristics of in vivo fluorescence. Three experiments using high resolution sampling (5 min. intervals) confirmed that yield varied systematically rather than randomly, and suggested that the observed large-scale patterns were probably representative of biogeographic patterns rather than subsampling of small-scale variability. Some fine-scale pattern could be linked to the proportion of phaeopigment in extracted samples. A diurnal pattern of variability, in which high yield tended to occur frequently at night but seldom during the day, modified large-scale variability.

A further study of size fractionated chlorophyll from underway samples from a large geographic area showed that fluorescence yield was also determined to some extent by the size composition of the phytoplankton community. Large-celled phytoplankton tended to have lower fluorescence yield than nanoplankton communities, although pigment degradation remained the most important factor in determining yield.

Implications for further BAS underway sampling are explored. Because some of the sources of variability in fluorescence yield - especially community composition and diurnal changes - cannot be described adequately on the basis of discrete calibration samples, an adequate calibration of underway in vivo fluorescence cannot be achieved for transects and other heterogeneous data sets. A method for interpolating between discrete measurements using local fluorescence yield values will be developed on the basis of this study.

Introduction

Estimation of particulate chlorophyll *a* is a convenient measure of phytoplankton biomass, which can be automated as *in vivo* measurements on both pumped supplies and *in situ* instrumentation. However, neither the relationship between chlorophyll and carbon biomass, nor the relationship between *in vivo* fluorescence and extractable chlorophyll, are simple. During cruise JR06, we attempted to calibrate *in vivo* fluorescence and use this to build up a picture of spatial and temporal variation of phytoplankton biomass and community composition.

Methods

1. Chlorophyll estimation

1.1 *In vivo* measurements

A Turner Designs through-flow fluorometer was connected to the ship's scientific pumped seawater supply in series with, and downstream from, a Sea Bird Electronics thermosalinograph and a LitreMeter flowmeter. Flow rate through this suite of instruments was of the order 4-8 litres per minute, dependent on the ship's motion and the degree of aeration of the water. The thermosalinograph contains a deadspace of approx. 5 litres, so tends to damp very small scale variability. The fluorometer, thermosalinograph and flowmeter data were logged at 2 second intervals to a dedicated microcomputer using LabWindows software, and thence to the ship's data acquisition system. Discrete samples for calibration were taken from the outflow from the fluorometer. The intake for the seawater supply is in the bottom of the ship's hull, at a nominal depth of 6 m. Under normal circumstances, the supply is drawn through an extensible probe which projects 40 cm from the hull, avoiding turbulence and entrapped bubbles. This probe is withdrawn flush with the hull at speeds over 12 knots and in ice.

1.2 Measurements of extractable chlorophyll

Water samples for chlorophyll analysis were taken from the scientific pumped seawater supply and from water bottles mounted on a CTD-rosette. Samples for whole-community chlorophyll were filtered under low vacuum onto fine glass-fibre filters (Whatman GF/F or Whatman GF/C for some vertical profiles - nominal retentions 0.7 and 1.1 μm respectively). Size fractionations were carried out using 200 and 20 μm nylon mesh (Lockertex) and 2 and 0.8 μm pore-size polycarbonate membrane filters (Poretics). Samples were extracted in 10 ml of 90% acetone (HPLC grade: Rathburn Chemicals) in the dark at approx. 2°C for 24 hours. Fluorescence was measured using a Sequoia-Turner Model 112 benchtop fluorometer, before and after acidification of the extract with dilute hydrochloric acid.

1.3 Calibration and calculation

The benchtop fluorometer was calibrated against a standard prepared from chlorophyll *a* extracted from the cyanobacterium *Anacystis nidulans* (Sigma Chemicals). The standard solution was itself calibrated spectrophotometrically (Strickland and Parsons). Fluorescence before and after acidification was used to derive calibration curves for both chlorophyll and phaeopigment, assuming that phaeopigment = 0.975 chlorophyll (Marker, 1972). These calibrations were used subsequently to calculate chlorophyll and phaeopigment concentrations from pre- and post-acidification values using the solution of simultaneous linear equations outlined by Priddle and Murray (unpublished manual).

The instrument calibration yields two regressions, relating fluorescence to chlorophyll and phaeopigment (acidified chlorophyll) concentrations in the extract. Thus

$$F_c = slope_c\ chl + const_c$$
$$F_p = slope_p\ phaeo + const_p$$

where F is fluorescence, and the subscripts c and p indicate the parameters of the chlorophyll and phaeopigment regressions respectively. The initial fluorescence of the sample, F_B, is a mix of fluorescence from unknown proportions of chlorophyll and phaeopigments, thus

$$F_B = F_c + F_p = slope_c\ chl + const_c + slope_p\ phaeo + const_p$$

where chl and phaeo are unknown. Acidification converts the chlorophyll to a known amount of phaeopigment which is 0.975 of the original chlorophyll mass. Thus the fluorescence after acidification can be considered as the combination of two phaeopigment fluorescences as follows

$$F_A = (slope_p.0.975)chl + slope_p\ phaeo + const_p$$

Subtraction of the two equations allows us to solve for chlorophyll, because the contribution from the original phaeopigment in the sample remains constant and cancels out. Thus

$$F_B - F_A = slope_c\ chl - (slope_p.0.975)chl + const_c$$

Rearranging, this gives

$$chl = (F_B - F_A - const_c)/ (slope_c - (slope_p.0.975))$$

Phaeopigment is then calculated by substituting the value of chlorophyll concentration in the extract into the equation for F_B -

$$phaeo = (F_B - (slope_c\ chl + const_c + const_p)) /slope_p$$

Study Sites

Phytoplankton biomass samples were collected more-or-less continuously during cruise JR06, both from the scientific pumped seawater supply and from water collected using the CTD-rosette system. Since descriptions of these sites are given elsewhere in this report, they are simply listed below.

1. Transects
1.1 Maurice Ewing Bank to Bird Island (14 CTD stations, repeated)
1.2 Polar Front transects (two transects of 10 and 11 CTD stations respectively)
1.3 South Georgia to South Orkney Islands (underway measurements only)
1.4 South Orkney Islands to Falkland Islands (underway measurements only, repeated)
1.5 South Georgia to Weddell Sea (underway measurements only)
1.6 Weddell Sea to South Orkney Islands (underway measurements only)

2. 'Fixed sites'

2.1 Willis Islands - neritic biomass spectrum site (krill)
2.2 Polar Frontal Zone - oceanic biomass spectrum site (squid-myctophid)

Results

1. Vertical profiles on transects (include underway measurements)

1.1 Maurice Ewing Bank to Bird Island - repeat transects

The first transect from Maurice Ewing Bank to Bird Island was carried out on 3-5 January. Chlorophyll concentrations at the northern end of the section were low - usually less than 1 mg m^{-3} in the mixed layer which was 40-50 m deep. Close to the Polar Front, a sub-surface chlorophyll maximum of 2.5 mg m^{-3} was observed at 40 m depth. A dense phytoplankton bloom was associated with the front, with chlorophyll concentrations of around 9 mg m^{-3}. South of the front, chlorophyll concentrations were again low but increased towards Bird Island, and the section ended in a dense bloom close to and on the shelf, where concentrations reached 14 mg m^{-3}. The traces of sea surface temperature and underway *in vivo* fluorescence show clearly the bloom slightly to the south of the Polar Front (Fig. 1a). However, fluorescence does not provide a good representation of phytoplankton biomass at the southern end of the transect - an apparent decline in fluorescence corresponds to only a slight decrease in particulate chlorophyll biomass. Significant changes in fluorescence yield are discussed below (4)

The transect was repeated on 2-4 February, this time running from south to north. The dense bloom which had characterised the southern end of the transect on the first leg, and had been encountered during the neritic biomass spectrum study, persisted. Maximum chlorophyll biomass was around 8 mg m^{-3}. This decreased rapidly to values of around 3 mg m^{-3}. There was no bloom associated with the Polar Front. North of the Polar Front, a sub-surface chlorophyll maximum was encountered, which became more shallow at the extreme northern end of the section. Monitoring of the surface seawater using the pumped supply showed that the surface expression of the front was approximately 50 km south of its earlier position (Fig. 1b). *In vivo* fluorescence agreed with the vertical profile data in showing no bloom associated with the front. However, as in the earlier transect, it failed to reflect the pattern of chlorophyll distribution at the southern end of the section.

1.2 Polar Front transects

Two sections across the Polar Front, to the east of the Maurice Ewing Bank sections, were carried out to provide a physical context for the squid-myctophid biomass spectrum study. The western transect, run first, crossed the surface expression of the Polar Front. Phytoplankton biomass was slightly elevated to the south of this, although chlorophyll concentrations in the mixed layer never exceeded 1.5 mg m^{-3}. The eastern section also transected the Polar Front, but its southern end extended into a complex mixing zone. Here, phytoplankton biomass reached its maximum of around 3 mg m^{-3} in a sub-surface maximum at the penultimate station on the transect. Along the remainder both transects, phytoplankton biomass was uniformly low.

2.1 South Georgia to South Orkney Islands
2.2 South Orkney Islands to Falkland Islands
2.3 South Georgia to Weddell Sea
2.4 Weddell Sea to Falkland Islands

3. Size-fractionated biomass studies at study sites

3.1 Willis Islands neritic site

A single detailed vertical profile was undertaken to characterize the site. This consisted of water samples at 10 m intervals to 120 m, thence more widely separated samples to close to the bottom (280 m). Size fractionation was restricted to >20 μm and 0.7-20 μm. The great majority of the chlorophyll biomass occurred within the mixed layer at depths <60 m, and the >20 μm fraction contained around 90% of the biomass, with concentrations up to 17 mg m^{-3} (Fig. 2). Small maxima in phaeopigment occurred in both size fractions in the pycnocline.

Subsequent size-fractionation studies on water samples from 10 m depth indicated that significant proportions of chlorophyll were contained in the size fractions 20-200 μm and >200 μm. This was consistent with the composition of the phytoplankton community, which was dominated by large colonial diatoms such as *Eucampia* and *Odontella.* However, the very high biomass found during the initial profile gradually declined to around 6 mg m^{-3} a week later. Vigorous mixing following a storm late in the study period did not appear to be responsible for further decline in biomass despite a deepening of the mixed layer.

Samples were taken underway during a small-scale physical survey of the study area, and from two CTD casts - one on the coastal side of the grid and a second on the seaward side. Phytoplankton biomass was higher on the nearshore side of the area, but size- and species-composition appeared to be similar.

3.2 Polar Front oceanic site

The phytoplankton community at this oceanic site contrasted strongly with that at the Willis Islands site. A corresponding vertical profile showed that biomass was very much lower, with maximum concentrations less than 1 mg m^{-3}, and that nearly all of this was < 20 μm (Fig. 3). Phaeopigment comprised the majority of the pigment in the >20 μm fraction. Microscopic examination of the microplankton community confirmed that the majority of cells were small - diatoms were scarce but small dinoflagellates and cryptomonads relatively abundant.

Further samples taken at this site continued to show a pattern of low biomass dominated by small cells.

4. Experimental studies on fluorescence yield

4.1 Large-scale variability of yield - three case studies

Fluorescence yield - the ratio of *in vivo* fluorescence to extracted chlorophyll *a* - provides a convenient variable with which to describe changes in fluorescence which are independent of phytoplankton biomass. This is crucial in establishing instrument calibration, and its direct use is discussed below. The variable also contains information on phytoplankton community

characteristics and physiology. Fluorescence yield has been calculated for all calibration samples in this study (n = 793), and complete analysis of the data has not yet been undertaken. Here we review three contrasting case studies - two transects and a local site.

4.1.1 Transect 2 - Maurice Ewing Bank to Bird Island (samples 1-62: Fig. 4a)

This transect crossed the Polar Front, spanning different water masses. Phytoplankton biomass (extracted chlorophyll *a*) showed two maxima, one associated with the Polar Front (samples 26-29) and a second region of high biomass at the southern end of the transect close to and on the South Georgia shelf. Fluorescence yield showed a very different behaviour - it was high to the north of the Polar Front and low to the south. This appeared to be consistent with the presence of two different communities with differing fluorescence characteristics. A single regression of chlorophyll on fluorescence provided poor prediction of biomass, but two separate regressions for the two communities offered better calibration.

4.1.2 South Georgia shelf (samples 63-153: Fig. 4b)

The majority of samples in this batch were obtained at the Willis Islands study site (see 3.1 above), but the study was preceded by a survey which covered most of the northern shelf of the island and extended to the shelf break at the eastern end. Although chlorophyll biomass was variable, fluorescence yield was quite consistent. The exception to this pattern is a small group of samples from the eastern end of the shelf (76-78 and 88-94). These had significantly higher yield. By excluding these samples, an effective calibration for the entire suite of samples was possible.

4.1.3 Transect 112 - Weddell Sea to South Orkney Islands (samples 607-731: Fig. 4c)

As with Transect 2, this section exhibited large-scale variability in both phytoplankton biomass and fluorescence yield. The pattern was more complex, and includes passage through ice and then across the Weddell Sea. Despite this complexity, it is clear that yield varied systematically along the transect, but that calibration of the entire dataset by a single regression of chlorophyll on fluorescence would not be possible.

4.2 Possible effects of incident radiation

In the ocean, *in vivo* fluorescence varies with incident radiation, since chlorophyll which is in an excited state through photosynthetic photon capture is not available for the analogous process of fluorescence. This property is well documented, and may be responsible for the observation of diurnal pattern in underway fluorescence observations (e.g. Weber and El-Sayed 1985). The effect is the basis of the 'pump-probe' fluorometer (Falkowski) which uses repeat measures of fluorescence to estimate photosynthetic rate *in situ*.

Determination of the possible influence of incident radiation on *in vivo* fluorescence for the ship's pumped seawater supply is an important factor in instrument calibration. Both total incident radiation (TIR) and photosynthetically active radiation (PAR) were logged continuously using the same data acquisition system which records fluorescence. Fluorescence yield was plotted against incident radiation for each batch of underway calibration samples (ten batches, variable number of samples in each). For both TIR and PAR , high fluorescence yield was found only at low irradiance or at night. However, low yield occurred over all irradiances. The pattern was more or less marked between batches (Fig. 5).

The existence of an irradiance-linked variation in fluorescence yield is surprising. We have been unable to estimate directly the transit time between the hull intake and the fluorometer, but calculations suggest that it is likely to be of the order of 1 min. (Simon Wright, pers comm). This appears to be long in comparison with the likely timescale over which chlorophyll molecules would relax to their ground state and be available for fluorescence. Previous tests on other vessels with similar pumped supplies, using DCMU-enhancement of fluorescence, have failed to demonstrate light-inhibition (JP unpublished observations from *John Biscoe* and *Newton* cruises). The effect noted here may not be the short-lived photochemical process described above, but may be a longer-scale phenomenon linked to diurnal cycles in phytoplankton physiology. It clearly needs to be incorporated into the calibration of the underway fluorometry.

4.3 Effects of flow rate

Bidagare et al. (19??) demonstrated that *in vivo* fluorescence varies with the rate of water flow through the flow-cell. At low flow rates, fluorescence increases slightly with flow as the instrument 'sees' more fluorescing cells. However, past a critical flow rate, *in vivo* fluorescence declines. The underlying cause of this phenomenon is the finite time taken for the photochemical process of fluorescence - the time taken for the chlorophyll molecule to enter the excited state by absorbing a photon and then to return to the ground state by emitting a photon in fluorescence. If the cells are moving through the fluorometer too fast, there is insufficient time to complete this process, and fluorescence yield declines correspondingly.

Again, we have plotted the relationship between fluorescence yield and flow rate for individual batches of samples. This demonstrates that there is no significant relationship between fluorescence and flow rate, or at least that such a relationship is insignificant in relation to other sources of variability in yield. This also tends to confirm that the link between fluorescence yield and irradiance is caused by a process with a longer 'memory' than simple light inhibition.

4.4 Fine-scale sampling

Despite the apparently systematic pattern of variation in fluorescence yield along transects, and its local consistency, it was impossible to exclude finer-scale variability as a contributory factor. In order to address this problem, a series of high-resolution time series was collected. Because of the high 'cost' of such sampling in terms of both time and materials, it was only possible to undertake this on three occasions, each for two hours at intervals of five minutes.

Results of these time series are presented in Figs 6a-c. In the first series, logged underway (*in vivo*) fluorescence was low but increased gradually over the sampling period. Fluorescence yield varied between 20-30, but did not change with increasing *in vivo* fluorescence. The proportion of phaeopigment in the extracted samples was high at the start of the series, and decreased approximately as *in vivo* fluorescence increased. Examination of the traces of yield and phaeopigment suggests that some of the variability of yield may be caused by sample-to-sample differences in pigment degradation.

In vivo fluorescence was very much higher and showed no overall trend during the second time series, although a series of spikes occurred throughout the sampling period. Fluorescence yield was slightly higher, varying between 30-40, but again was relatively stable and showed no

variability in relation to *in vivo* fluorescence, except for one high value (Fig. 6b). Again, sample-to-sample changes in pigment degradation appeared to be mirrored in variability in yield.

In the third series, *in vivo* fluorescence was both low and stable, varying from 8 to 11. Fluorescence yield varied from 30-65 - much greater than in the other two series. Some of this variability parallels that in the pigment degradation, especially in the later part of the series (Fig. 6c).

Overall, variability in fluorescence yield was less than that found in large-scale series, suggesting that the latter is a real biogeographic pattern rather than the sampling of small-scale variability. Pigment degradation is likely to be the major determinant of local variation in fluorescence yield.

4.5 Size-fractionation studies

In the last part of cruise JR06, size-fractionation was carried out on discrete samples every four hours (n = 65). This part of the survey started on the South Georgia shelf, but it consists mainly of samples taken on passage between South Georgia and the Weddell Sea, and the Weddell Sea and the Falkland Islands. Thus it covered a very wide biogeographic area, including communities in pack ice regions.

Principal Components Analysis (PCA) was used to provide an initial assessment of the variability in the dataset. Six variables were included - fluorescence yield, the proportion of extracted chlorophyll in the size fractions >20 μm and 2-20 μm, and the proportions of phaeopigment in the whole community ('Degr all') and in the two separate size fractions ('Degr >20 μm' and 'Degr 2-20μm' respectively). The correlation matrix (Table 1) shows that yield was correlated strongly with the proportion of phaeopigment, especially in the whole community. It was correlated negatively with the proportion of chlorophyll in the larger size fraction. For both size fractions, the proportion of phaeopigment was negatively correlated with the contribution of that size fraction to the total extractable chlorophyll.

Table 1. Pearson product-moment correlation coefficients for the six variables used in the multivariate analysis of fluorescence yield and size-fractionated pigment.

Variable	Yield	Prop >20 μm	Prop 2-20 μm	Degr >20 μm	Degr 2-20μm
Yield					
Prop >20 μm	-0.247				
Prop 2-20 μm	-0.029	-0.067			
Degr >20 μm	0.222	-0.852	-0.241		
Degr 2-20μm	0.362	-0.291	-0.717	0.567	
Degr all	0.570	-0.410	-0.343	0.617	0.766

Variable	PC 1	PC 2	PC 3
Yield	0.538	-0.103	0.793
Prop >20 μm	-0.651	0.671	0.264
Prop 2-20 μm	-0.501	-0.763	0.287
Degr >20 μm	0.836	-0.369	-0.349
Degr 2-20μm	0.865	0.422	-0.049
Degr all	0.880	0.062	0.254
Cum var	53%	76%	92%

PCA was effective in describing the variability in the dataset, and indicates the overall contribution of both pigment degradation and the size-distribution of particulate chlorophyll to fluorescence yield. The composition of the first three principal components is presented in Table 2. The first principal component (PC 1) explains half of the total variance. Loadings of the variables indicate that fluorescence yield was related to the proportion of pigment degradation, but was also related negatively to the proportion of pigment in the micro- and nanoplankton size fractions. This is supported by the intuitive impression that large-celled phytoplankton communities, such as those encountered in the Willis Islands study site during Leg 1, have lower fluorescence yield than nanoplanktonic communities of corresponding biomass. The most extreme example was encountered at the South Orkney Islands shelf at the ends of transects 112 and 113. Here, *in vivo* fluorescence was low but extracted chlorophyll in the >20 μm size fraction was high - fluorescence yields for these samples were 2.2 and 3.3 respectively.

This analysis is only a preliminary demonstration, and further work on this dataset will be carried out in Cambridge. A second PCA based on yield and size fractions calculated on the basis of total pigment rather than chlorophyll was equivocal. Irradiance data should be included to simulate the observed diurnal effects.

Discussion

1. Is spatial variability real or random?

The collection of routine samples from the through-flow system was designed to enable simple calibration of the underway *in vivo* fluorescence. Large-scale variability implies that single consistent regressions of extracted chlorophyll with fluorescence will not provide effective calibration on large surveys. In contrast, local sites are more consistent. The results of the three short time-series indicate that the variance over small time- and distance-scales is less than that at larger scales. This in turn implies that large-scale variability in fluorescence yield is systematic and reflects, to a great extent, differences in the phytoplankton community. Other sources of variability identified in this study are diurnal changes (large scale) and effects of phaeopigment on *in vivo* fluorescence (?small scale).

2. Can spatial variability be attributed to easily-measured properties of the phytoplankton community?

The variability in fluorescence yield has been shown to derive from three sources. Of these, the proportion of phaeopigment is measured easily as part of the routine analysis of discrete samples.

The diurnal variation, which is evident in some series of samples, is aliased by irradiance, but the underlying physiological mechanism is unclear and is likely to remain so. Size fractionation of particulate chlorophyll is a very useful addition to the analysis of discrete samples, although it increases the investment of both time and material resources in the calibration of underway fluorometry. On this cruise, size-fractionated measurements were made at four-hourly intervals. It is unclear whether significant benefit would arise from more frequent analyses.

The next step would be to involve more detailed analysis of community composition. This would involve either conventional microscopic counts or image analysis. Both involve a tremendous increase in the amount of effort required to calibrate samples, and it is very much a moot point whether even selective sampling would produce an improved dataset.

3. Implications for future underway monitoring

3.1 Calibration of underway *in vivo* fluorescence

Plans for a series of large-scale transects underline the need for high quality underway data. The study undertaken on this cruise provides the basis for a calibration method which can be used to provide effectively-calibrated chlorophyll biomass estimates, and provide further implicit information on the phytoplankton community.

Because of the complexity of the spatial and temporal variation in fluorescence yield, we have rejected the option of calibrating the through-flow fluorometer by simple regression, using the discrete samples as calibration points for the continuous measurement. This practice inevitably means that transects and other large-scale surveys must be split into subsets to achieve acceptable levels of correlation. In turn, this implies local discontinuities where one calibration stops and the next applies. Our study of transects across fronts has shown that these transition regions are complex, and that water masses and their respective phytoplankton communities are interleaved, making the 'on-off' application of fluorescence calibrations even more inappropriate.

An alternative approach is to use the discrete samples as individual data points, and use the underway fluorescence to interpolate between them. Because of the statistical complications in this process, design of the method has not been undertaken during the cruise and will be addressed on our return.

3.2 Resources and protocol

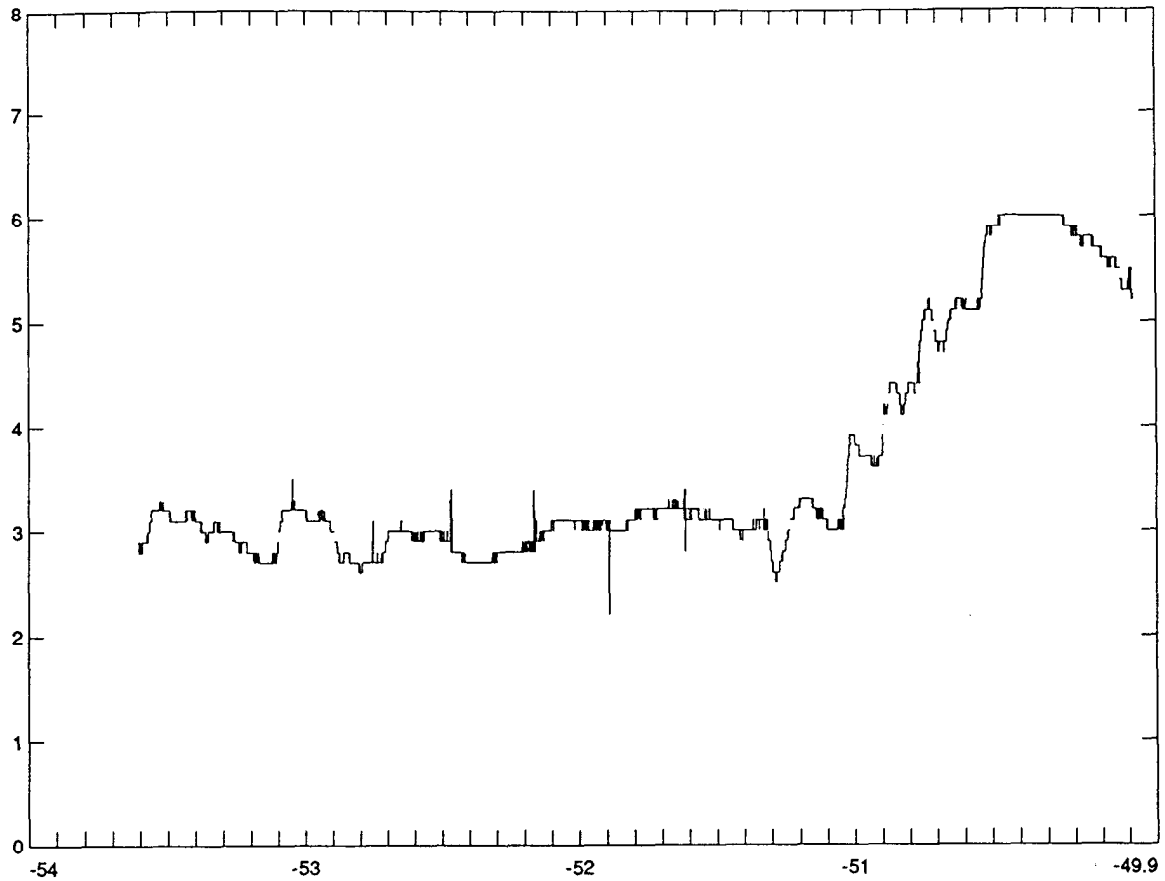
The collection of discrete samples carried out during the final three transects (112-114) is probably close to the optimum needed for both an effective underway dataset and a description of large-scale phytoplankton community variation. This is very much more intensive than was envisaged originally, and means that both more materials are needed and that chlorophyll calibration represents a major investment of two people's time during a cruise.

A protocol for chlorophyll estimation and ancillary tasks has been prepared by JP and AWAM. This already requires some modification, but should be a useful guide for most PES cruises. However, experience on this cruise suggests that calibration of the type needed for transect studies will be a specialist task.

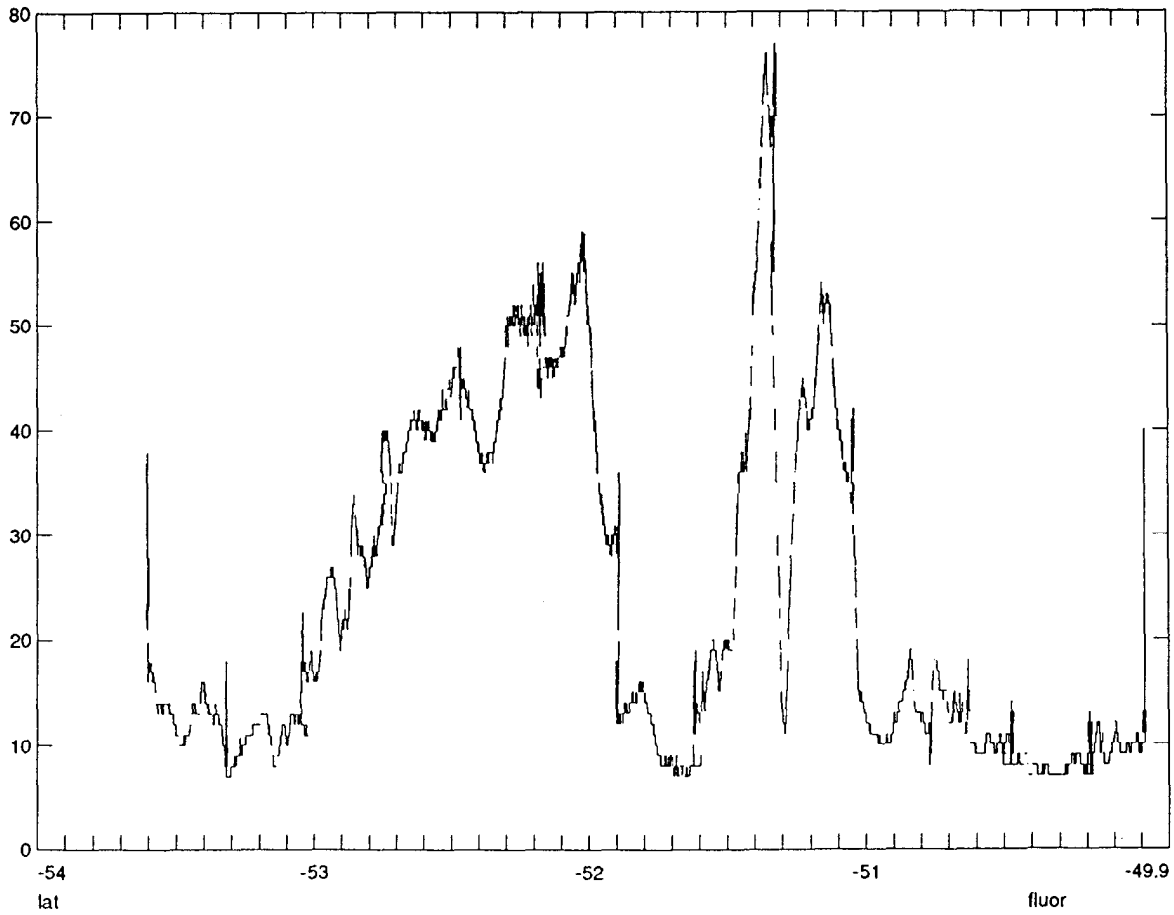
Acknowledgements

We are grateful to all of our colleagues who helped by collecting calibration samples and maintaining records. Particular thanks are due to Heather Daly, who assisted with the high-resolution time series measurements, to Simon Wright for maintaining the pumped seawater supply, and to Paul Woodroffe for his hard work on both the instrumentation and the data logging.

Fig 1a

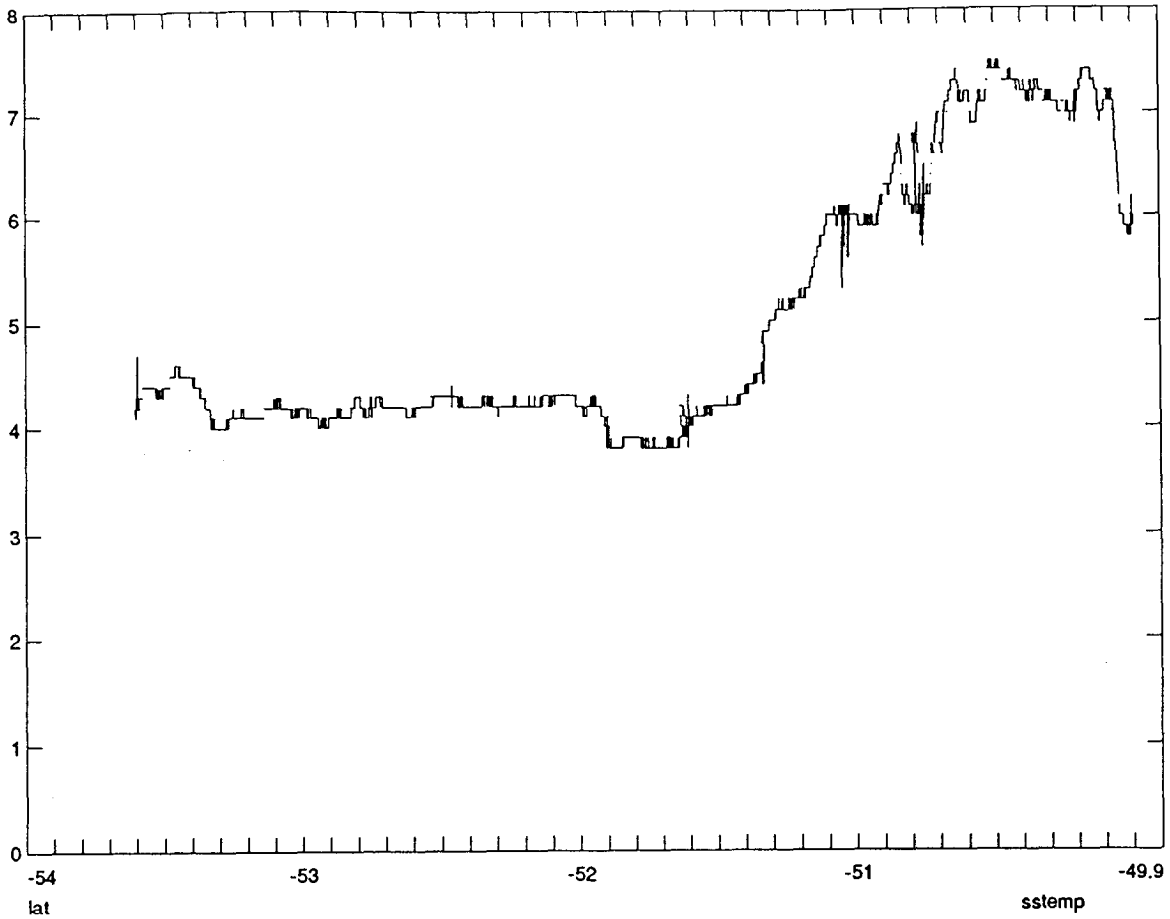


START 94 003 06:00:00
Transect 2: Maurice Ewing Bank to the Willis Isles



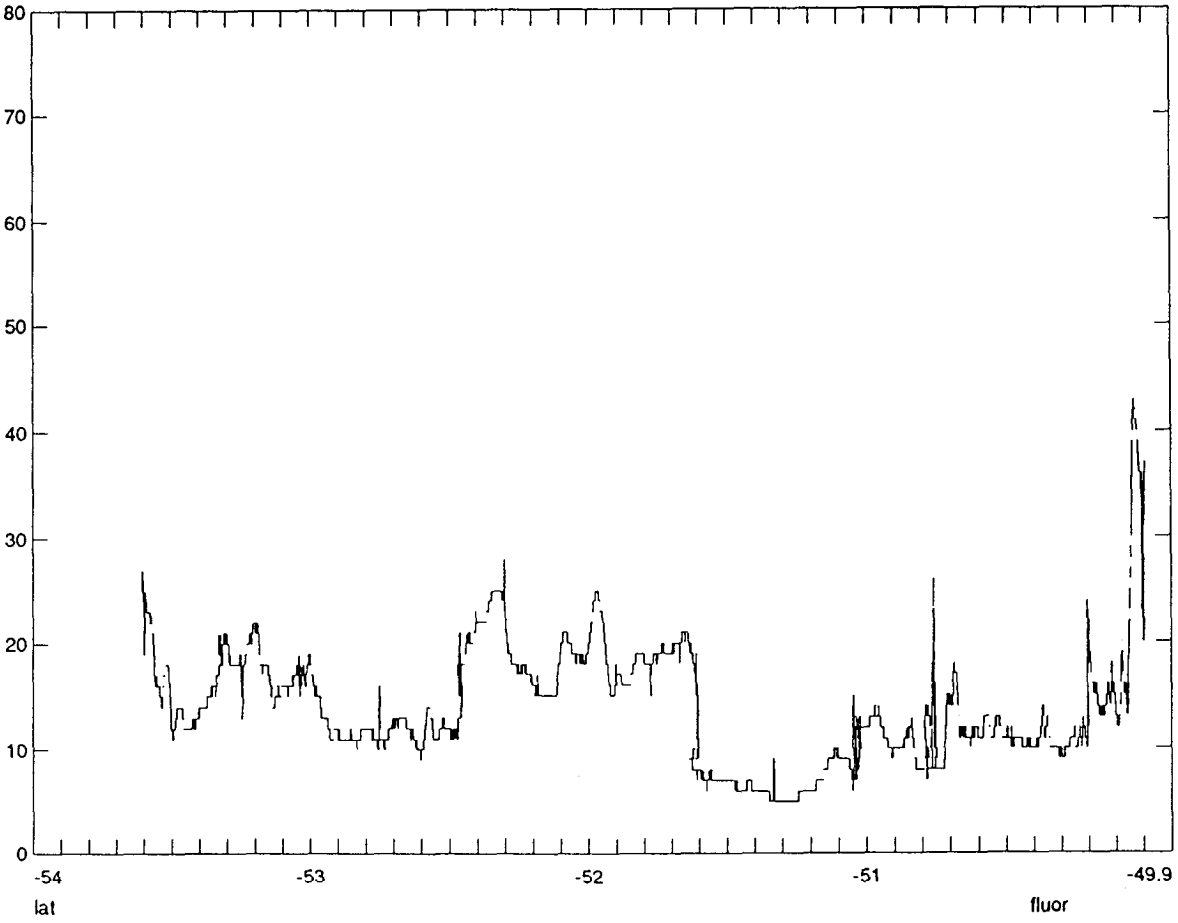
START 94 003 06:00:00
Transect 2: Maurice Ewing Bank to the Willis Isles

Fig 1b



START 94 033 03:45:00

Transect 74: Willis Isles to Maurice Ewing Bank



START 94 033 03:45:00

Transect 74: Willis Isles to Maurice Ewing Bank

Fig 2

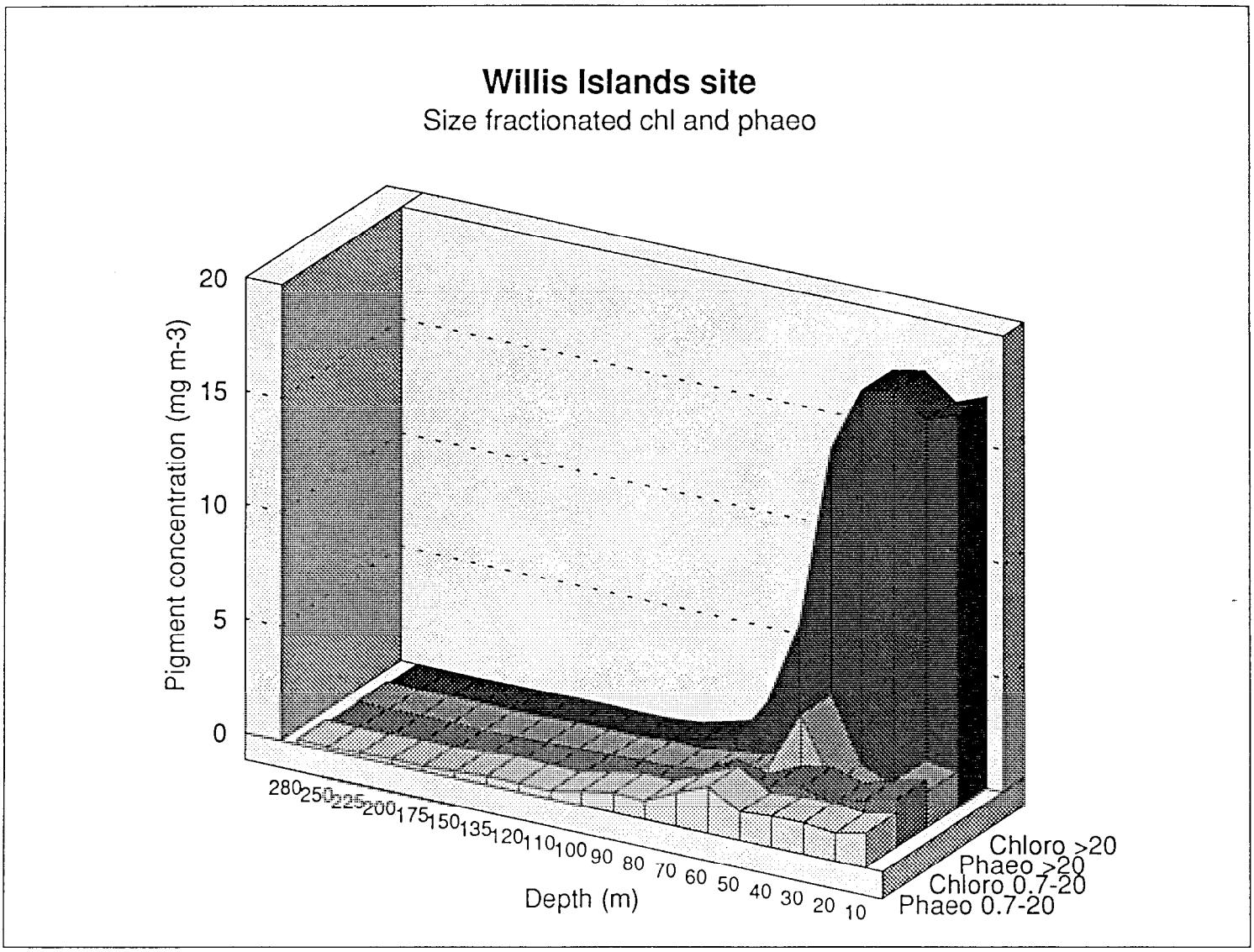
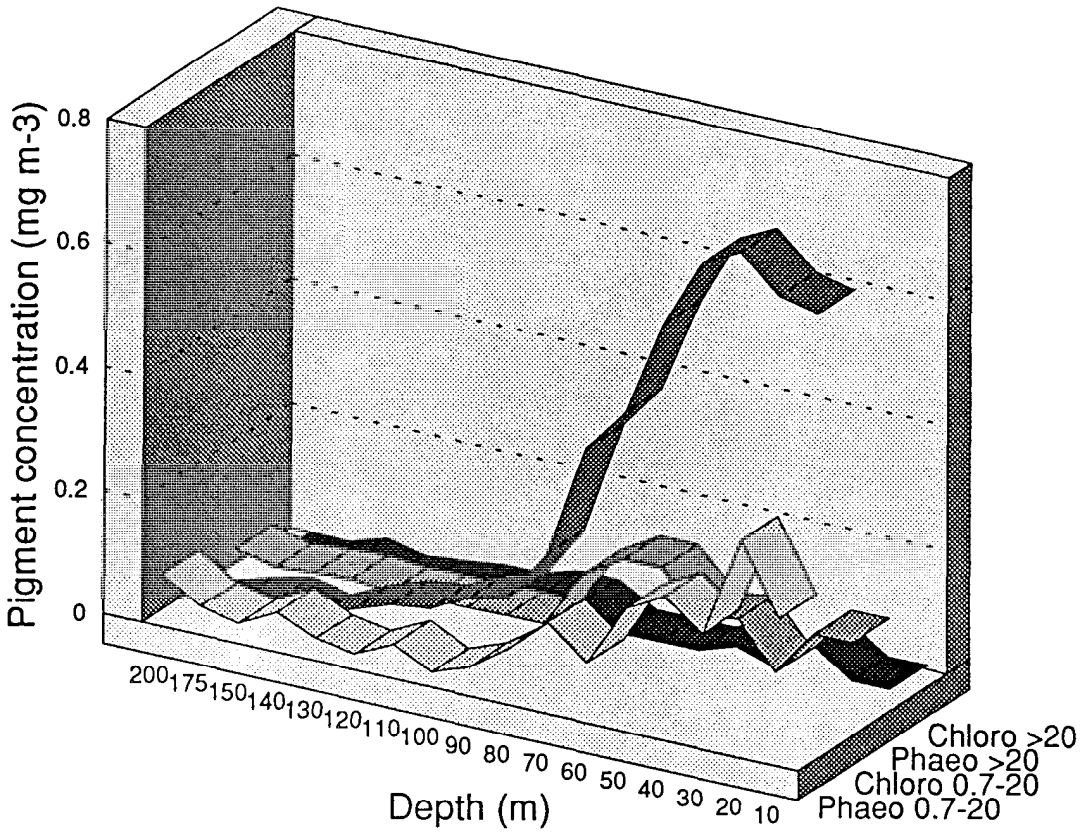

Willis Islands site
Size fractionated chl and phaeo
Pigment concentration (mg m-3)
0
5
10
15
20
Depth (m)
280 250 225 200 175 150 135 120 110 100 90 80 70 60 50 40 30 20 10
Chloro >20
Phaeo >20
Chloro 0.7-20
Phaeo 0.7-20

Fig 3


Squid biomass spectrum site
Size fractionated chl and phaeo
Pigment concentration (mg m-3)
0.8
0.6
0.4
0.2
0
200 175 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
Depth (m)
Chloro >20
Phaeo >20
Chloro 0.7-20
Phaeo 0.7-20

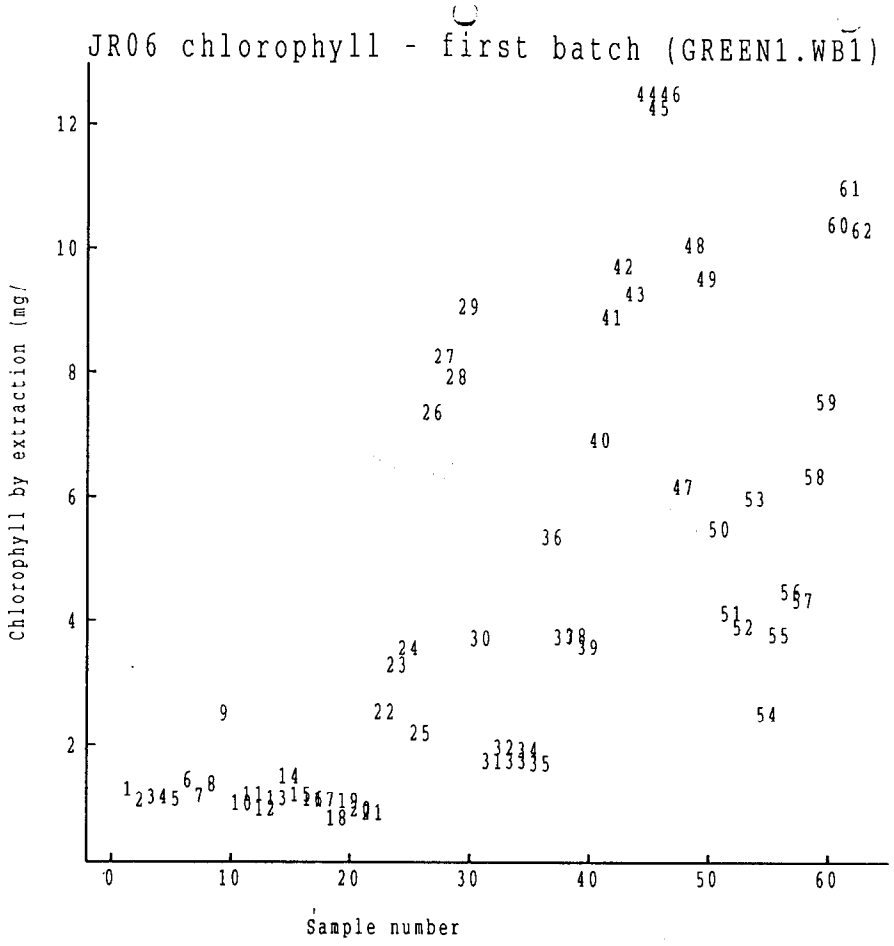
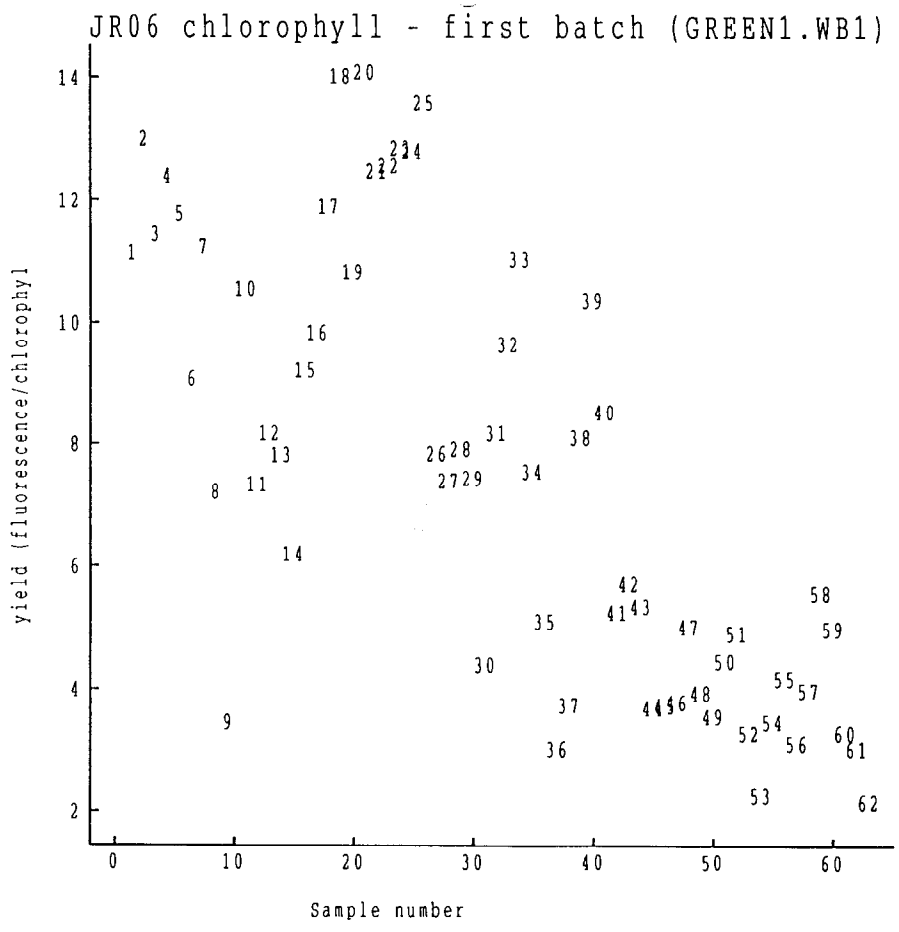

JR06 chlorophyll - first batch (GREEN1.WB1)
Chlorophyll by extraction (mg/
Sample number

Fig 4a


JR06 chlorophyll - first batch (GREEN1.WB1)
yield (fluorescence/chlorophyl
Sample number

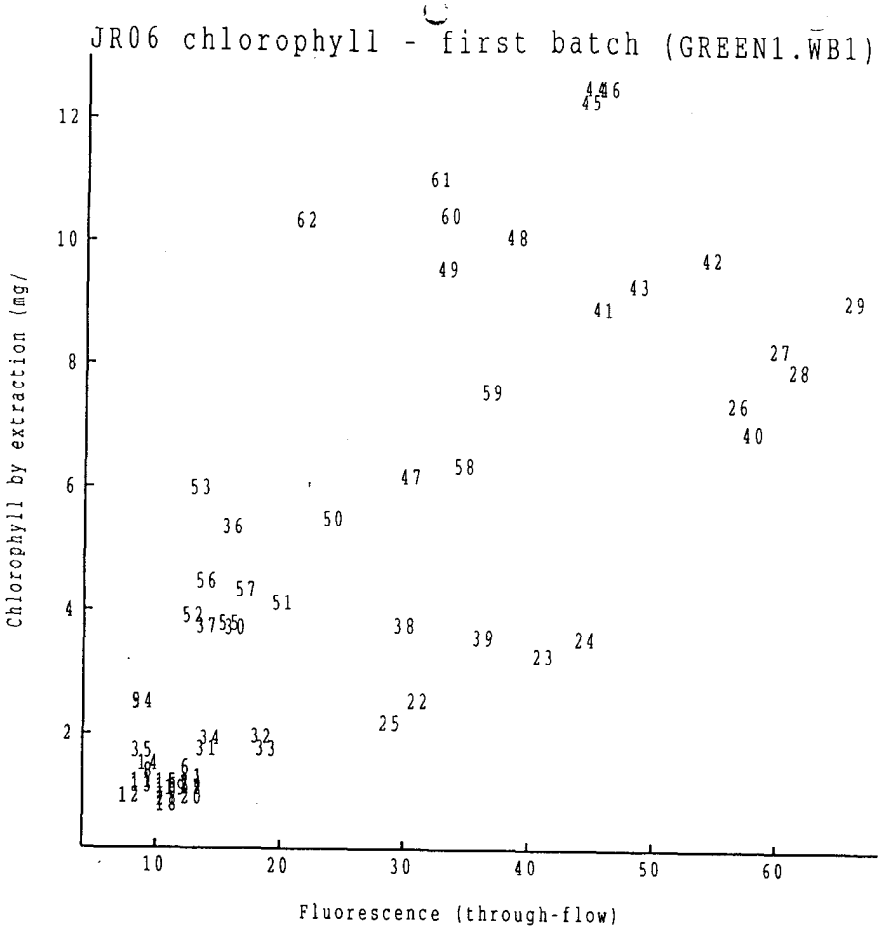
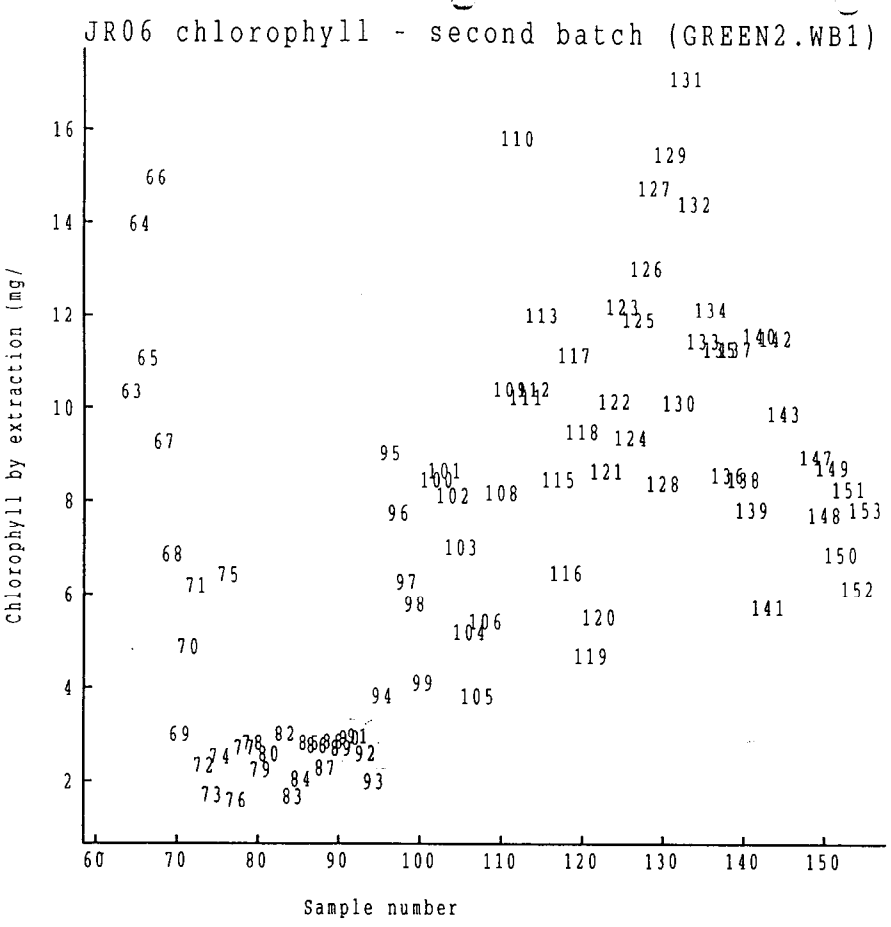

JR06 chlorophyll - first batch (GREEN1.WB1)
Chlorophyll by extraction (mg/
Fluorescence (through-flow)
12
10
8
6
4
2
10
20
30
40
50
60

Fig 4a

Fig 4b


JR06 chlorophyll - second batch (GREEN2.WB1)
Chlorophyll by extraction (mg/
Sample number

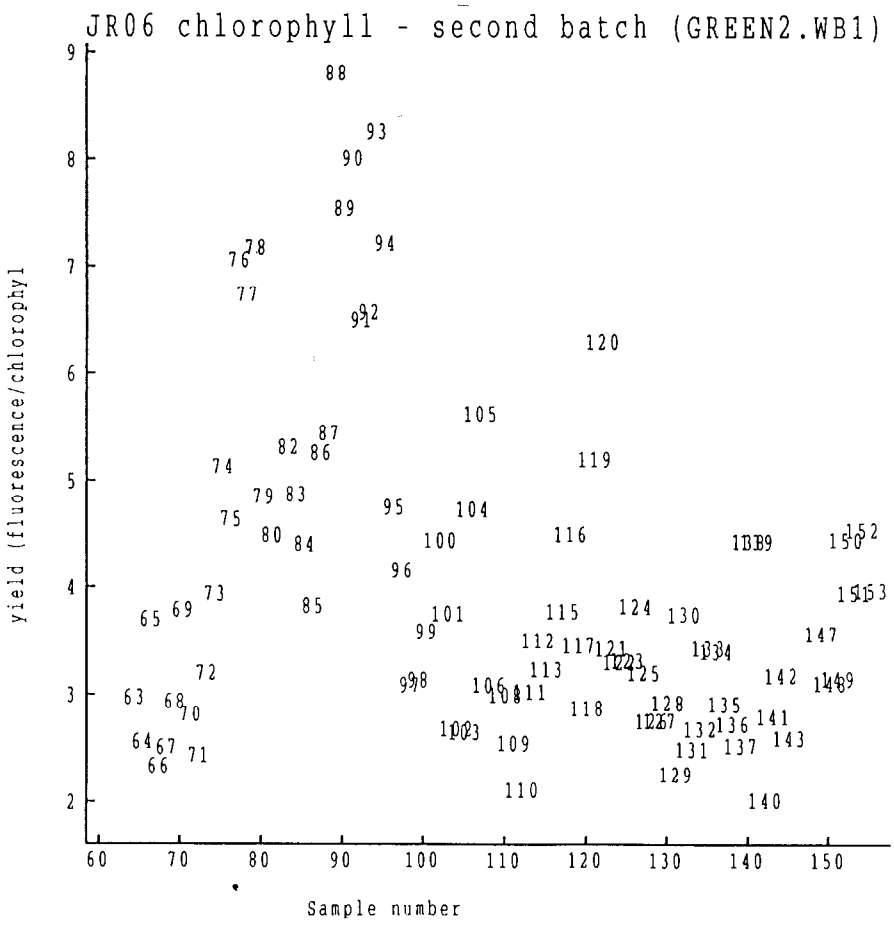

JR06 chlorophyll - second batch (GREEN2.WB1)
yield (fluorescence/chlorophyl
Sample number

Fig 4b

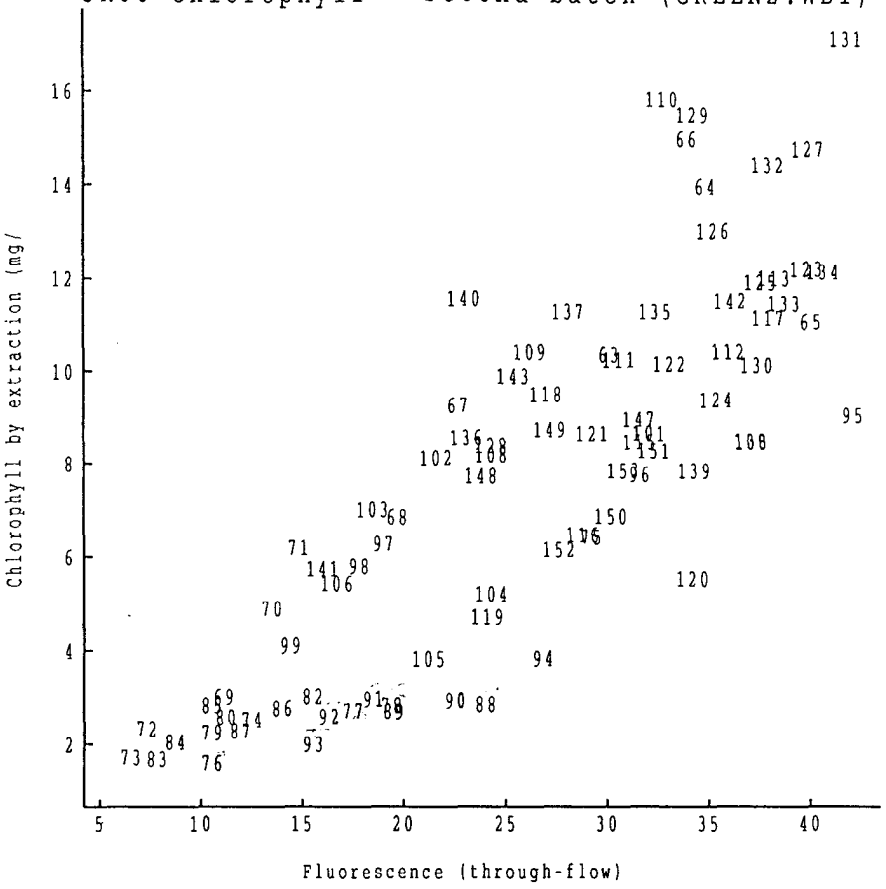
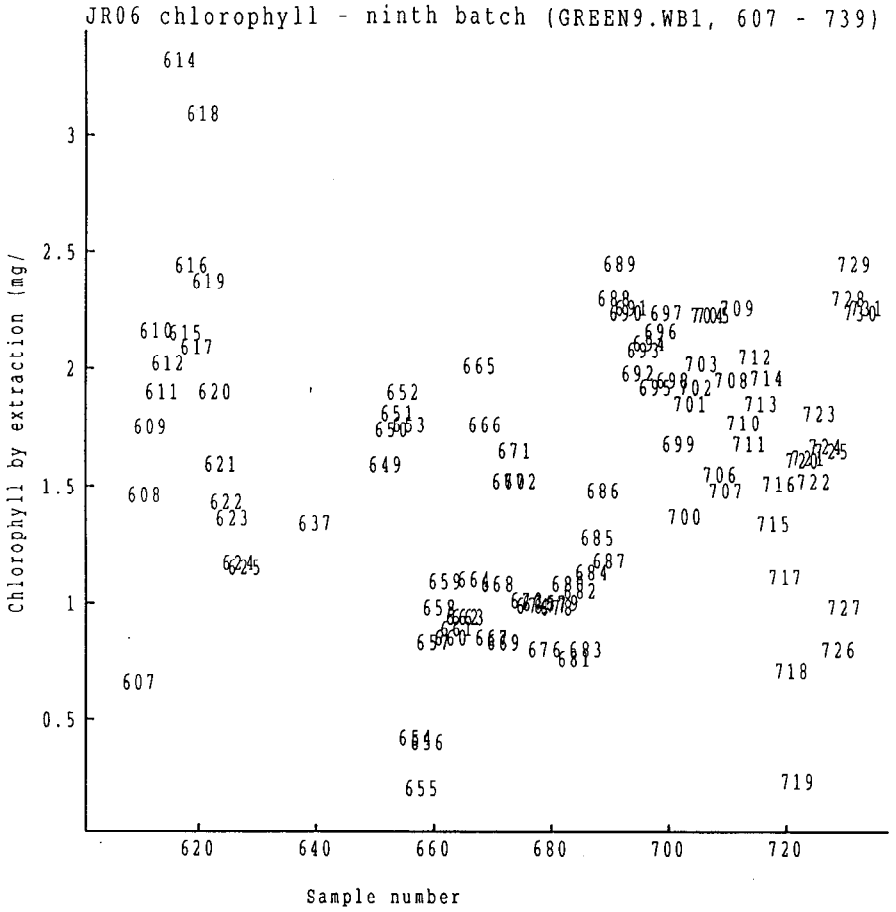

JR06 chlorophyll - second batch (GREEN2.WB1)
Chlorophyll by extraction (mg/
Fluorescence (through-flow)
2
4
6
8
10
12
14
16
5
10
15
20
25
30
35
40

Fig 4c


JR06 chlorophyll - ninth batch (GREEN9.WB1, 607 - 739)
Chlorophyll by extraction (mg/
Sample number

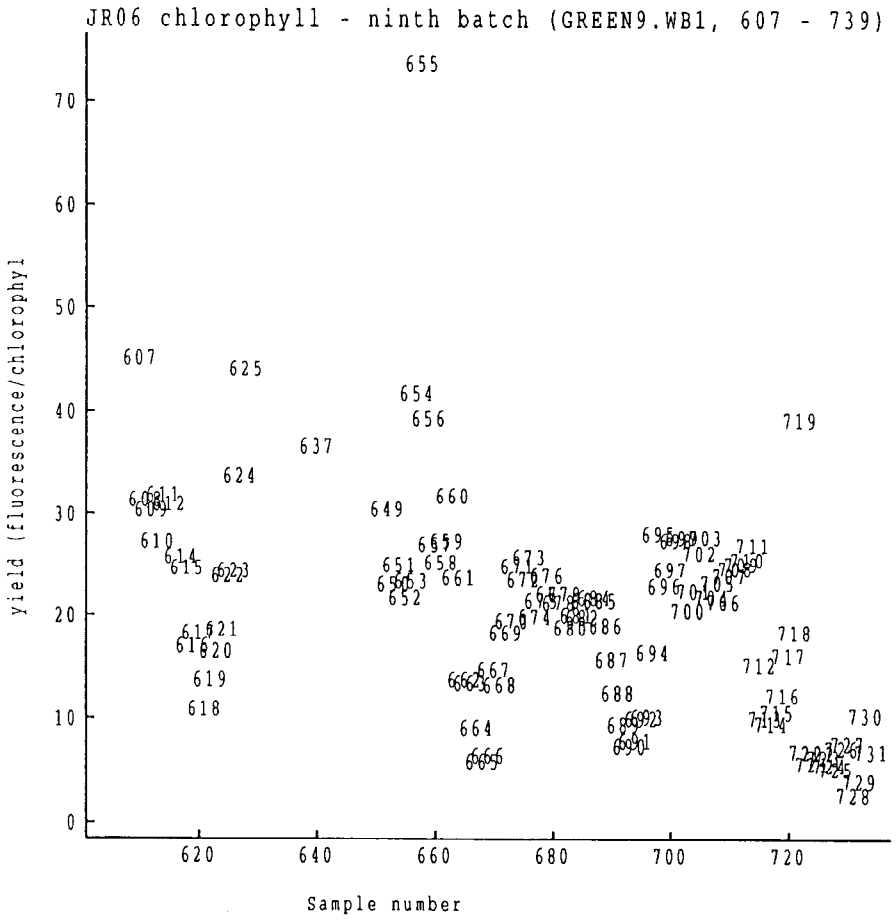

JR06 chlorophyll - ninth batch (GREEN9.WB1, 607 - 739)
yield (fluorescence/chlorophyl
Sample number

Fig 4c .

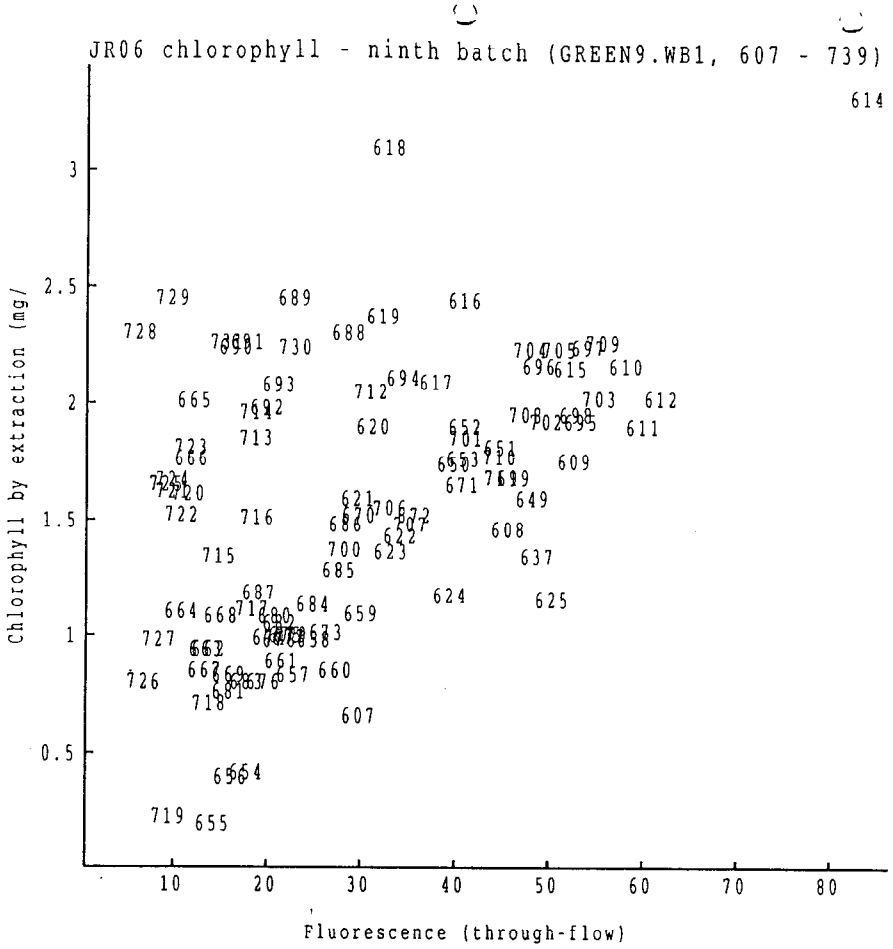
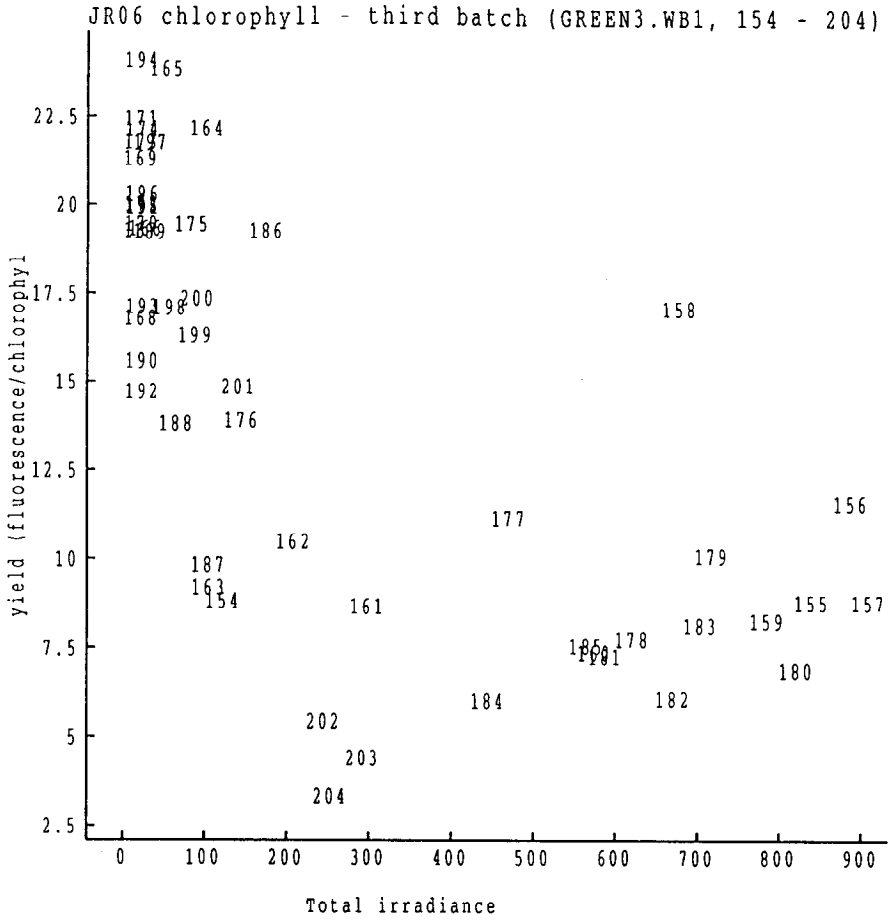

JR06 chlorophyll - ninth batch (GREEN9.WB1, 607 - 739)
Chlorophyll by extraction (mg/
Fluorescence (through-flow)
0.5
1
1.5
2
2.5
3
10
20
30
40
50
60
70
80

Fig 5


JR06 chlorophyll - third batch (GREEN3.WB1, 154 - 204)
yield (fluorescence/chlorophyl
Total irradiance

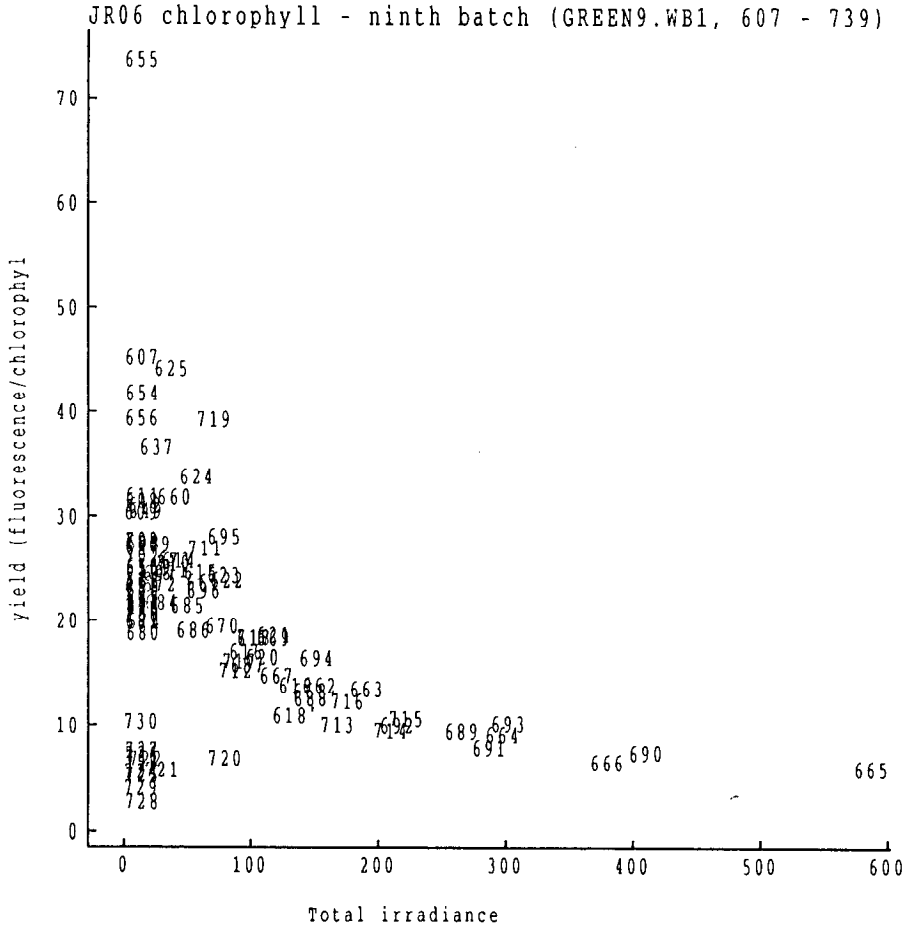

JR06 chlorophyll - ninth batch (GREEN9.WB1, 607 - 739)
yield (fluorescence/chlorophyl
Total irradiance

Fig 6a

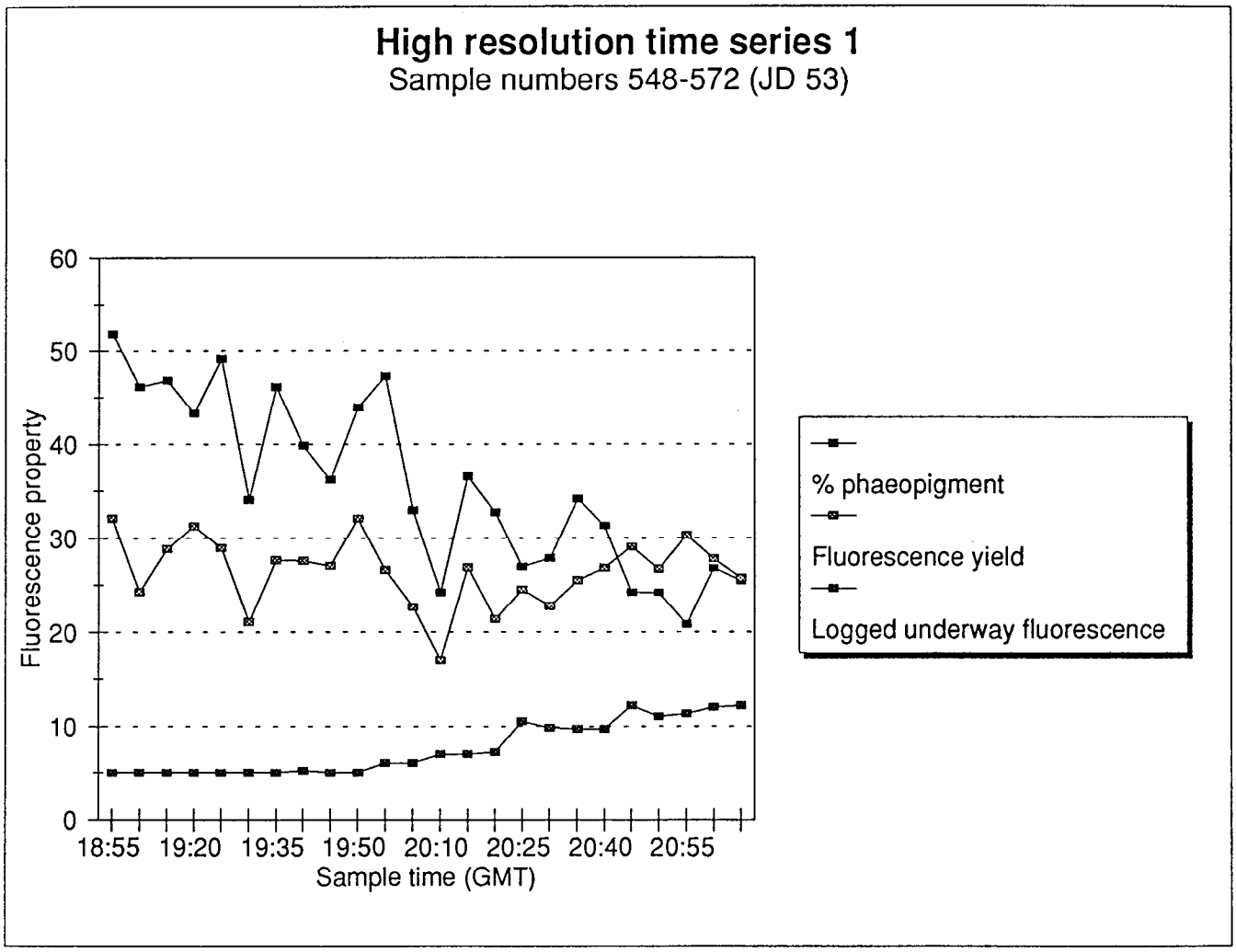

High resolution time series 1
Sample numbers 548-572 (JD 53)
Fluorescence property
60
50
40
30
20
10
0
18:55
19:20
19:35
19:50
20:10
20:25
20:40
20:55
Sample time (GMT)
% phaeopigment
Fluorescence yield
Logged underway fluorescence

Fig 6b

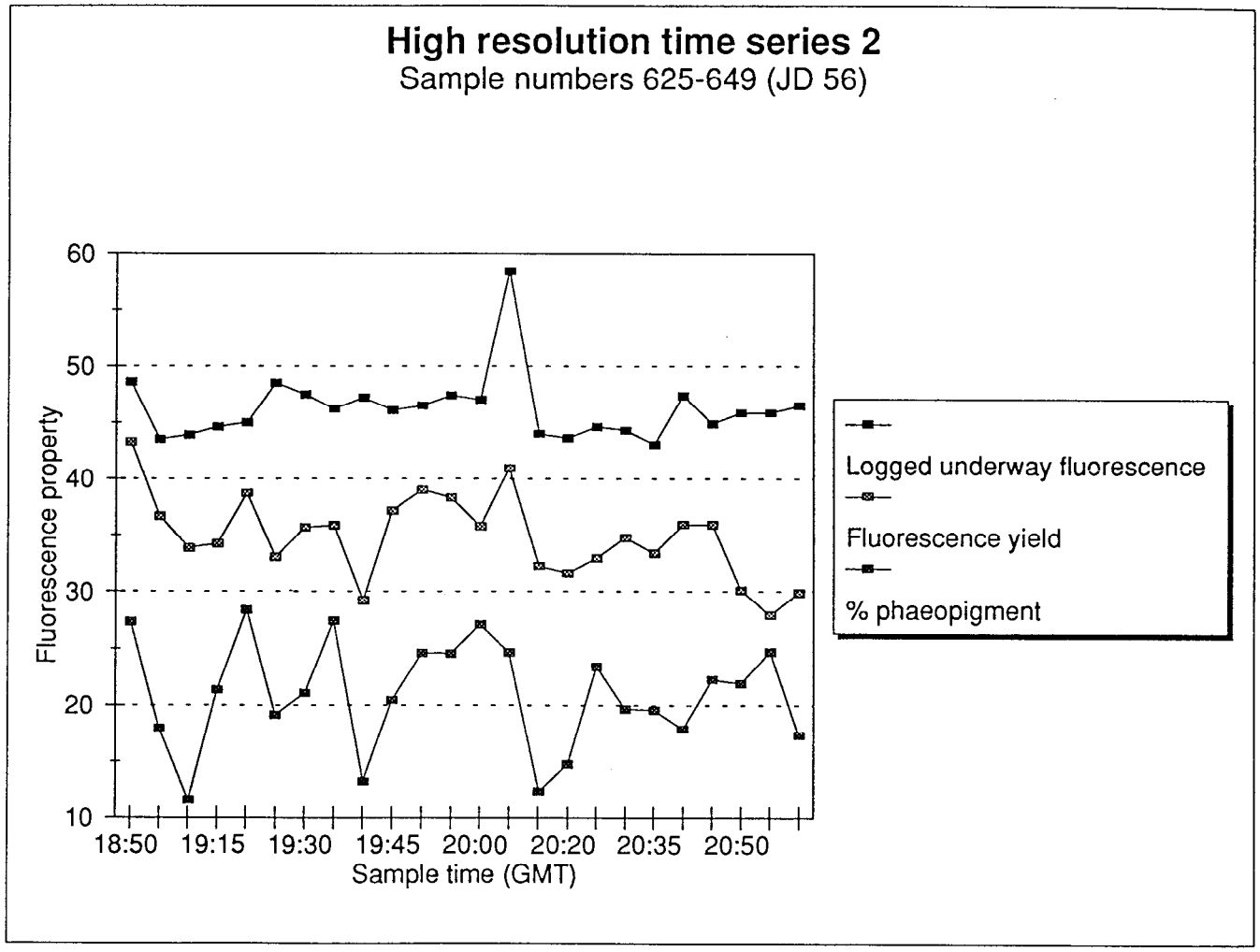
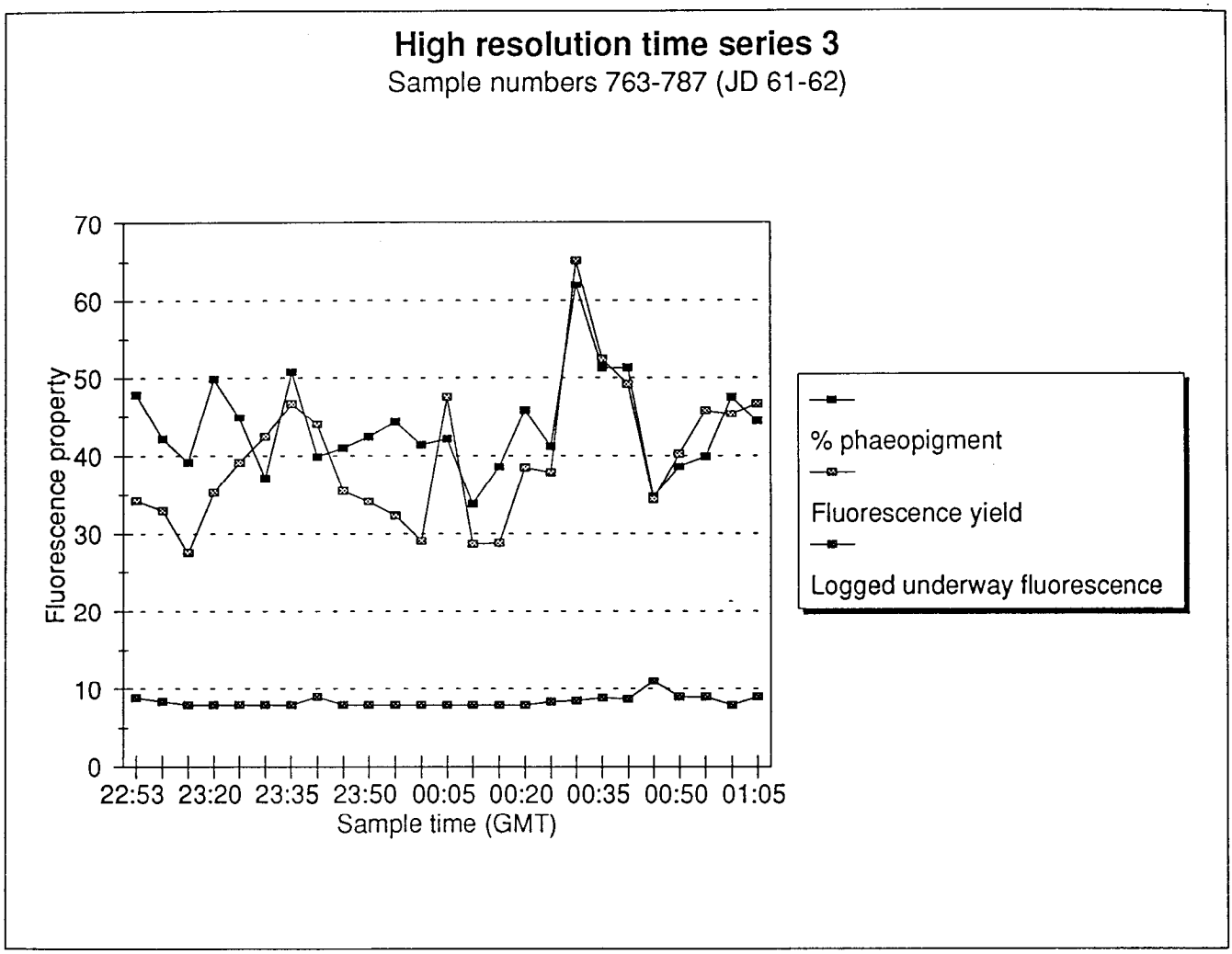

High resolution time series 2
Sample numbers 625-649 (JD 56)
Fluorescence property
60
50
40
30
20
10
18:50
19:15
19:30
19:45
20:00
20:20
20:35
20:50
Sample time (GMT)
Logged underway fluorescence
Fluorescence yield
% phaeopigment

Fig 6c


High resolution time series 3
Sample numbers 763-787 (JD 61-62)
Fluorescence property
70
60
50
40
30
20
10
0
22:53
23:20
23:35
23:50
00:05
00:20
00:35
00:50
01:05
Sample time (GMT)
% phaeopigment
Fluorescence yield
Logged underway fluorescence

16. Oceanography of the krill biomass spectrum area and the squid biomass spectrum area

by Carolyn Symon, Patricia Gilmour and Phil Trathan

As part of the biomass spectrum project, an area around each of the biological study sites was sampled so as to resolve mesoscale and fine scale physical processes. The design for the characterisation was different for the separate study sites, with a fine scale grid adopted for the krill site and mesoscale transects for the squid site.

Grid covering the krill study site

A CTD grid was undertaken around the seamount designated as the focus for the krill biomass study area during Leg 1. The grid consisted of a 6 by 5 array of CTDs spaced at 2.5 nm. This spacing is sufficiently close to describe the fine scale physical characteristics around the seamount. All CTD casts were to near bottom, with the grid extending mainly over the shelf, but with the northern section covering part of the shelf break.

Owing to poor weather conditions the grid was steamed in a west-east direction rather than the planned north-south direction which would have been normal to the major current flow. An additional onshore-offshore pair of transects were located at the outer edge of the grid. These were situated 2.5 nm from the grid, with the CTDs within the transects also at 2.5 nm spacing. The transects were located so as to effectively extend the cover of the grid. Fig. 1 shows the layout of the grid and the two transects.

Due to the closeness of the CTD casts, it was not feasible to take bottle samples for analysis of nutrient chemistry or for chlorophyll determination. Similarly, the close spacing of the grid also prevented the ship from maintaining a constant speed, making it impractical to carry out detailed acoustic data collection.

Large scale transect and mesoscale transects at the squid study site

Ideally, to describe the physical characteristics of the squid study site, a number of fine scale transects should have been steamed normal to the major current flow, however, there was only sufficient time available to carry out two such transects. Therefore, to supplement the characterisation of the squid study site, the planned repeat of the large scale transect from Maurice Ewing Bank to the Willis Islands was brought forward in the cruise schedule, and then steamed in a south-east to north-west direction (transect 74).

The two fine scale transects (transects 83 and 85; Fig. 2) were shorter than transect 74 and were designed to describe the mesoscale and fine scale physical characteristics of the squid biomass area determined from the predator and acoustic observations carried out in Leg 2. Transect 83 was specifically designed to include the netting waypoint where biological net samples were collected, whilst transect 85 was designed to include a seamount, outside the netting area, but where large numbers of squid-feeding predators had been observed. The orientation of both transects was a compromise between running normal to the Polar Front and the local bathymetry. Given the general current flow, it would have been advantageous to have carried out transect 85 before transect 83, however this was not logistically practical.

Transect 83 consisted of 10 CTD stations at 10 km spacing whilst transect 85 comprised 11 stations at the same spacing. This is sufficient to resolve meso- to fine scale variability. The depths of the CTD casts varied; all casts were to at least 1000 m with intermittent profiles to full depth. At each station water samples were taken for chlorophyll determination at 20, 40, 60, 100, and 200 m. Water samples were also obtained at 6 other depths between 200 m and the bottom of the cast. Nutrient analyses for silicate, nitrate, nitrite, phosphate and ammonium were performed on all 11

water samples. The transects were run at a nominal 10 knots in order to facilitate collection of acoustic data.

XBTs (T7: range 760 m) were deployed approximately half way between the CTD stations, that is, 15 minutes after the ship passed through the previous CTD station on the way to the next. XBTs were also deployed every 15 minutes on passage from transect 83 to transect 85 (transect 84). This transect crossed the major current flow in an oblique direction, but nevertheless added extra coverage for the area. Additional XBTs were also deployed at 15 minute intervals at the end of transect 85 on the way to South Georgia. The XBTs effectively extended the transect with temperature profiles, south of the Polar Front.

In addition to the characterisation at each station the following data were logged between stations:

- Simrad EA500 (bathymetry)
- RDI ADCP (u, v, z currents over the upper 200/300 m)
- Non-toxic seawater intake at 6 m (temperature, salinity and fluorescence)
- Meteorological instruments (TIR, PAR, wind speed and direction, air temperature pressure and humidity)
- Simrad EK500 acoustics at 38 and 120 kHz
- Bird observations

Opportunistic CTD casts

Opportunistic CTD casts were taken in the krill biomass study area and in the squid biomass study area. These were principally to support microbiological studies undertaken during the cruise.

Data Processing

CTD data

The majority of the CTD data for Leg 1 and all the data for Leg 2 have been transferred onto the RVS Level 'C' system. However, CTD data for events 33, 87, 88, 106, 107, 108, 109, 113, 114, 115, 116, 119 and 120 are not yet on the Level 'C'. These data are currently stored in binary form on magnetic tape and must be converted to a usable form using the EG & G CTD post-processing software before being entered onto the Level 'C'. The data on the Level 'C' have been calibrated using the 1993 instrument calibrations and the pressure has been corrected for the 3 to 4 m offset noted on the deck unit when the CTD was at the water surface. These data have not yet been finally corrected using *in situ* corrections. *In situ* temperature has been determined on the CTD casts using digital reversing thermometers, 3 thermometers were used during Leg 1 and two during Leg 2 (one stopped functioning).

In situ temperatures using the reversing thermometers were taken on all the CTD casts for the transects. Appendix 3 shows the *in situ* temperatures from the EG & G software, the temperature from the reversing thermometers and the temperature from the Level 'C'. The thermometers, the EG & G software and the Level 'C' system should tally, however, there are clear discrepancies.

The Level 'C' system was calibrated using the calibration file provided by IOS for the WOCE cruise preceding cruise JR06, however, it is uncertain whether the EG & G system had also been calibrated. The pressures shown in Appendix 3 are taken from the EG & G software and correspond to the pressures at which the CTD bottles were fired. For comparison, the corresponding temperature is shown from the reversing thermometers, from the EG & G software and from the Level 'C'. The reading from the Level 'C' has been corrected for the 3 db (3 m) offset noted on the deck unit; for example, for Event 33, 303.2 db has been corrected to 306.2 db. It is strongly recommended that the calibration of the EG & G and the Level 'C' is checked.

Salinity samples were taken from all bottles at the beginning and end of the CTD transects. These samples were processed on the Guildline Autosal. Log sheets of the results (including associated event numbers) have been archived. Salinity values have not yet been calculated. Appendix 4 shows the bottle data from the EG & G software for transects 74, 83 and 85, giving the pressure at which the bottles were fired, and the *in situ* temperatures and salinities at those pressures. Event numbers are noted, for ease of reference.

The final *in situ* corrections to temperature and salinity can not be determined until the data are processed in Cambridge. It is recommended that the *in situ* temperature and salinity corrections determined by IOS for the WOCE cruise preceding JR06 should be obtained.

A library file of CTD profiles has been constructed, for each CTD drop there is a plot of temperature against depth, salinity against depth, density against depth and temperature against salinity for the full depth of the profile. It should be noted that these are uncorrected data and are not potential temperature or potential density.

XBT data

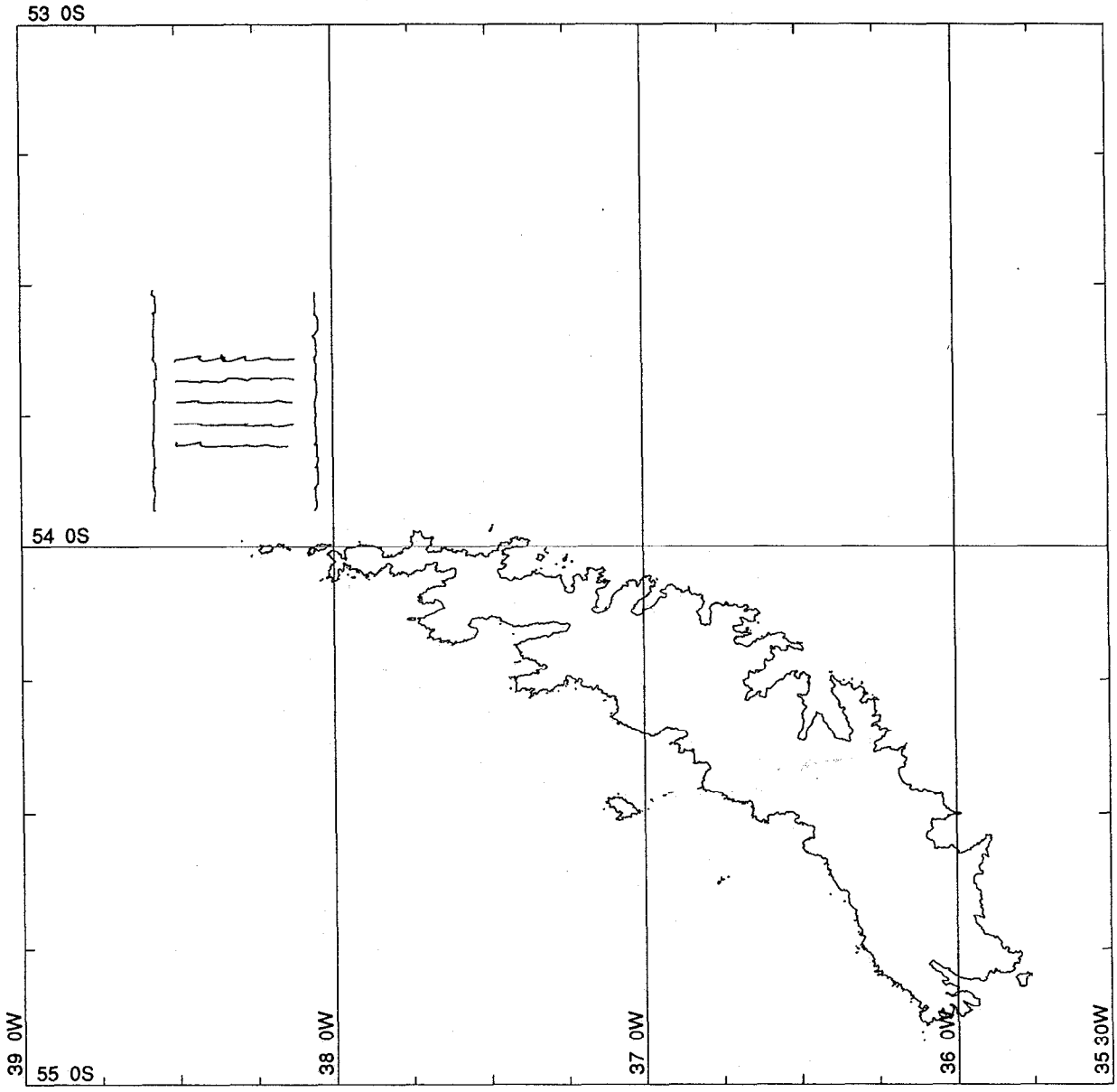
The XBT data were logged onto an attached PC running the Sippican MK9 XBT software. All data were archived onto disc. On return to Cambridge, the data require to be plotted using the MK9 post-processing software. In future a neans of processing these data at sea and transferring the results to the level 'C' must be implemented.

Thermosalinograph Data

Water samples for salinity were taken twice a day from the non-toxic seawater supply. The samples were processed on the Guildline Autosal. A problem was noted with the Autosal when it was in *standby* mode between samples; the nature of this was that the digital display cycled at intermittent periods. The problem was solved by switching the Autosal off and on again, but seemed to recur and may have been related to the stability of the ship, to electrical interference or to the temperature in the laboratory.

The Guildline Autosal results have been archived, and on return to Cambridge the salinity values should be calculated.

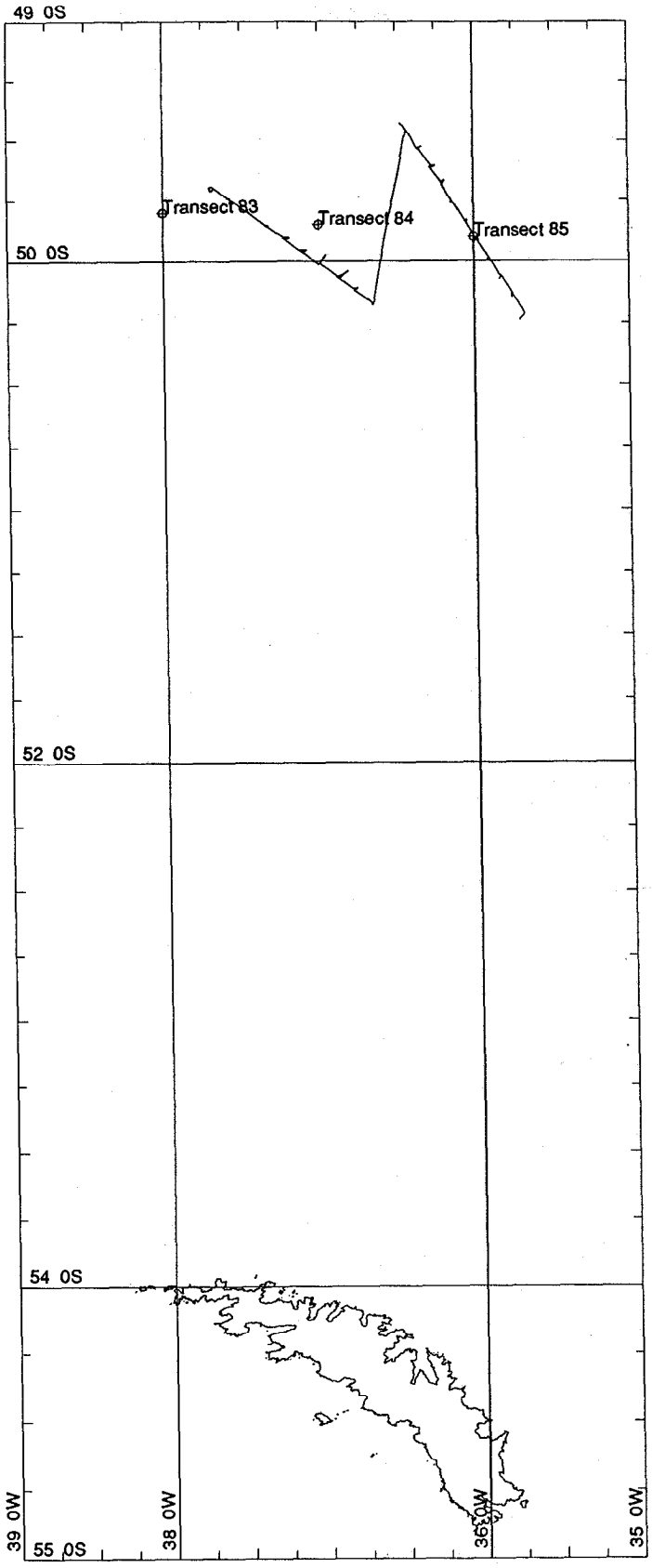
. Fig 1



Leg 1: Physical grid for krill biomass study

Scaled to fit

Fig 2



MERCATOR PROJECTION

SCALE 1 TO 2000000 (NATURAL SCALE AT LAT. -50)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE -50

GRID NO. 1

— Track plotted from gps_trim

Leg 2: Physical transects for squid biomass study

Scaled to fit

Transect 83

Event	Latitude	Longitude	Depth (m)	Nominal CTD bottle depths (m)
325	49° 42′ S	37° 41′ W	5030	4500, 3000, 1500, 1000, 500, 350, 200, 100, 60, 40, 20
328	49° 45′ S	37° 34′ W	5047	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
334	49° 48′ S	37° 27′ W	5059	4500, 3000, 1500, 1000, 500, 350, 200, 100, 60, 40, 20
336	49° 51′ S	37° 20′ W	5069	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
338	49° 54′ S	37° 13′ W	5075	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
340	49° 58′ S	37° 07′ W	5064	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
342	50° 01′ S	37° 00′ W	5034	4500, 3000, 1500, 1000, 500, 350, 200, 100, 60, 40, 20
344	50° 04′ S	36° 53′ W	4997	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
347	50° 07′ S	36° 46′ W	5012	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
352	50° 10′ S	36° 39′ W	3910	4000, 2500, 1500, 1000, 500, 350, 200, 100, 60, 40, 20

Transect 85

Event	Latitude	Longitude	Depth (m)	Nominal CTD bottle depths (m)
366	49° 27′ S	36° 26′ W	5018	4500, 3000, 1500, 1000, 500, 350, 200, 100, 60, 40, 20
370	49° 32′ S	36° 21′ W	4906	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
372	49° 36′ S	36° 17′ W	4884	3000, 2000, 1000, 750, 500, 350, 200, 100, 60, 40, 20
375	49° 41′ S	36° 12′ W	4537	3000, 2000, 1000, 750, 500, 350, 200, 100, 60, 40, 20
377	49° 46′ S	36° 08′ W	2944	3000, 2000, 1000, 750, 500, 350, 200, 100, 60, 40, 20
379	49° 50′ S	36° 03′ W	4130	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
381	49° 55′ S	35° 59′ W	4859	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
383	49° 59′ S	35° 54′ W	4822	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
385	50° 04′ S	35° 50′ W	4771	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
387	50° 08′ S	35° 45′ W	4657	1000, 800, 600, 500, 400, 300, 200, 100, 60, 40, 20
389	50° 13′ S	35° 40′ W	4343	4500, 3000, 1500, 1000, 500, 350, 200, 100, 60, 40, 20

17. Report on remote-sensing

by Phil Trathan and Carolyn Symon

Before the start of the cruise, essential computer software (OpenWindows and XV) was installed on one of the SUN workstations (BAS3) in the data prep room. This was carried out before the ship sailed in preparation for any image analysis requirements that would be necessary once SST images had been passed to the ship from the ARIES receiving station at Rothera. Throughout the period of the cruise, scientists based at Rothera, reviewed all incoming SST images and passed to the ship any which were considered to provide useful information. Images were transferred via Cambridge, using scheduled data transfers.

Prior to the cruise, it had been the intention to provide weekly composite images of SST, however, given the prevailing level of cloud cover in the cruise region, this was not feasible. Images from individual satellite passes were therefore sent to the ship and in total 13 were received.

As it was not feasible to manipulate the geographic projection of the images, geographic coordinates and coastlines were included within the image; this proved invaluable in their interpretation.

A number of images have provided detailed SST data for the cruise areas to the west and to the north of South Georgia. These images were from infrared sensors operating at 11 μm; images in the visible spectrum were also sent for a few of the satellite passes. Though cloud cover prevented detailed interpretation of a large proportion of each image, the images contained information relevant to parts of the large scale transect steamed between Maurice Ewing Bank and the Willis Islands and to the GHA/ squid/ myctophid study.

Images received just after the large scale transect was steamed during Leg 2 and during the physical characterisation of the GHA/ squid/ myctophid study area included large areas of cloud-free sea. These images will provide interesting comparisons with the temperatures obtained from the ship's non-toxic seawater supply and with environmental data-loggers fitted to foraging predator species. One image taken on February 14, 1994 at 19:50 GMT is shown in Fig. 1. At that time the ship was occupying a CTD station located at 49° 27'S, 36° 26'W as part of the physical characterisation of the GHA/ squid/ myctophid study.

Objectives

The object of receiving satellite data whilst at sea was essentially to help in adaptive cruise planning. Due to the prevailing weather conditions, this proved not to be feasible, however, given the potential contribution that SST images can supply, all future cruises should make use of this facility. For future cruises, a direct link to Rothera for image transfer would be advantageous.

Post cruise processing of SST images will provide a wider context for much of the work undertaken during the cruise.

Problems encountered

Multiple copies of data were received from Rothera via Cambridge. This was due to problems in the automatic forwarding software running at Cambridge.

Only low quality hardcopy output of images was possible on the ship. A networked high quality colour printer is essential.

Acknowledgements

We are very grateful for the help and support provided by Tom Lachlan-Cope and Richard Siddans who provided advice and assistance throughout the project.

18. Report on cruise event log

by Phil Trathan and Alistair Murray

During the course of the cruise all scientific operations were logged by the ship's officers. As this log included exact gear deployment times as well as a clear narrative of each event, it was decided that this should be used as the basis of the cruise event log. The only necessary modification was for the ship's officers to assign an event number to each operation. As this number was allocated by the bridge it was easily available for individual scientists to use for sample identification and there was little chance of events being miss-numbered.

We are grateful to the ship's officers for extending their procedures and making a copy of the ship's scientific log freely available to us. Daily copies of this log were taken and entered into Oracle. The events carried out during the cruise are listed in Annex II & III, positions for the start and end of each event are listed in Annex IV.

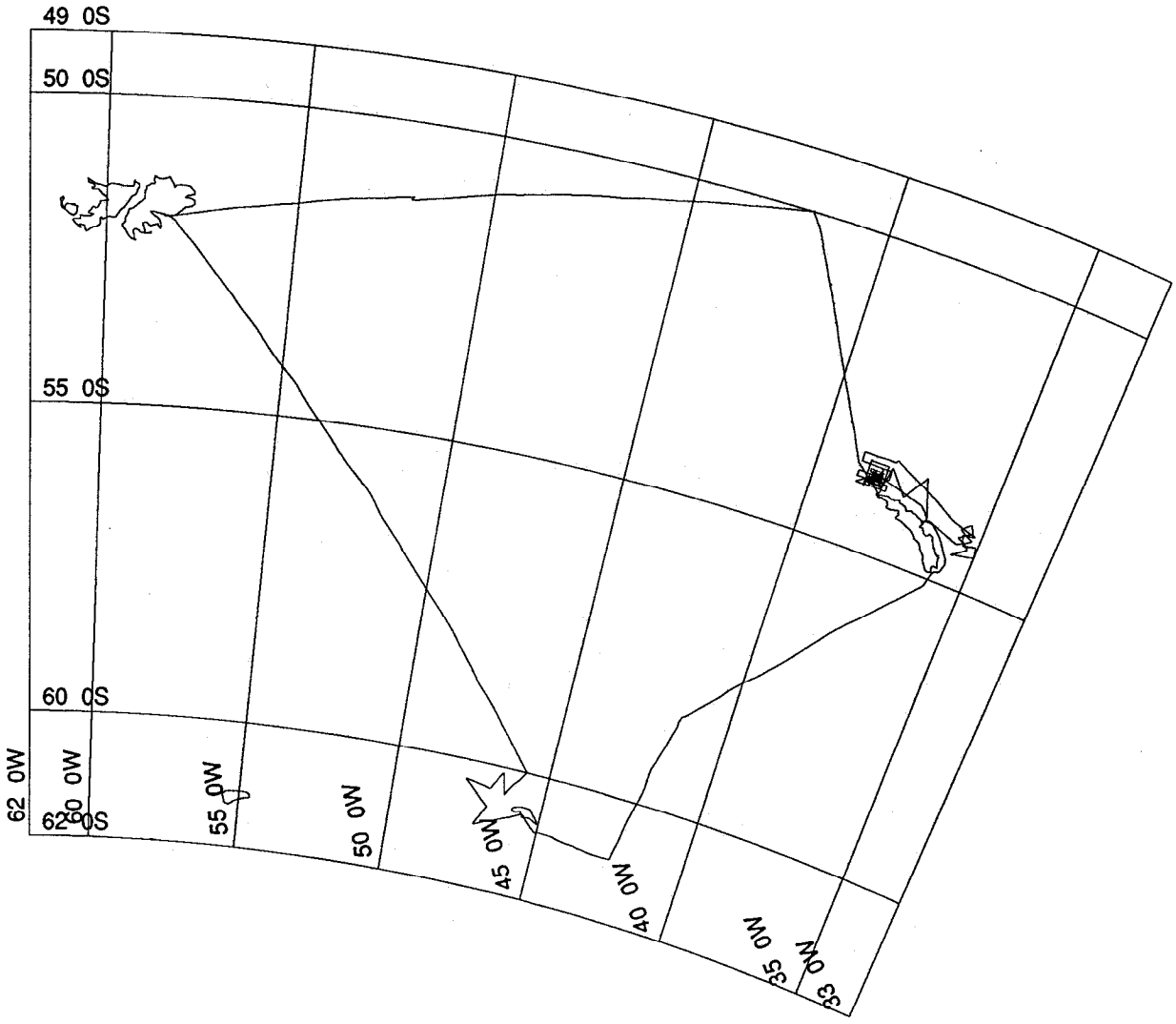
19. Report on cruise tracks

by Phil Trathan, Graham Butcher and Bruce Lamden

Plots of cruise tracks were produced on a daily basis. Both small scale plots of detailed parts of the ship's track and large scale general plots were produced using the RVS Level 'C' software. Plots of individual transects were also produced to help validate the start and end times of the transects. Once validated, the start and end times of each transect were loaded into Oracle. All transects steamed, are listed in Annex I, positions for the start and end of each transect are listed in Annex V.

Plots of the cruise track for Leg 1 and for Leg 2 are shown in Fig. 1 and Fig. 2.

. Fig 1



LAMBERTS CONFORMAL CONIC

SCALE 1 TO 10000000 (Std Parallels 62S and 49S)

WGS 72 ELLIPSOID

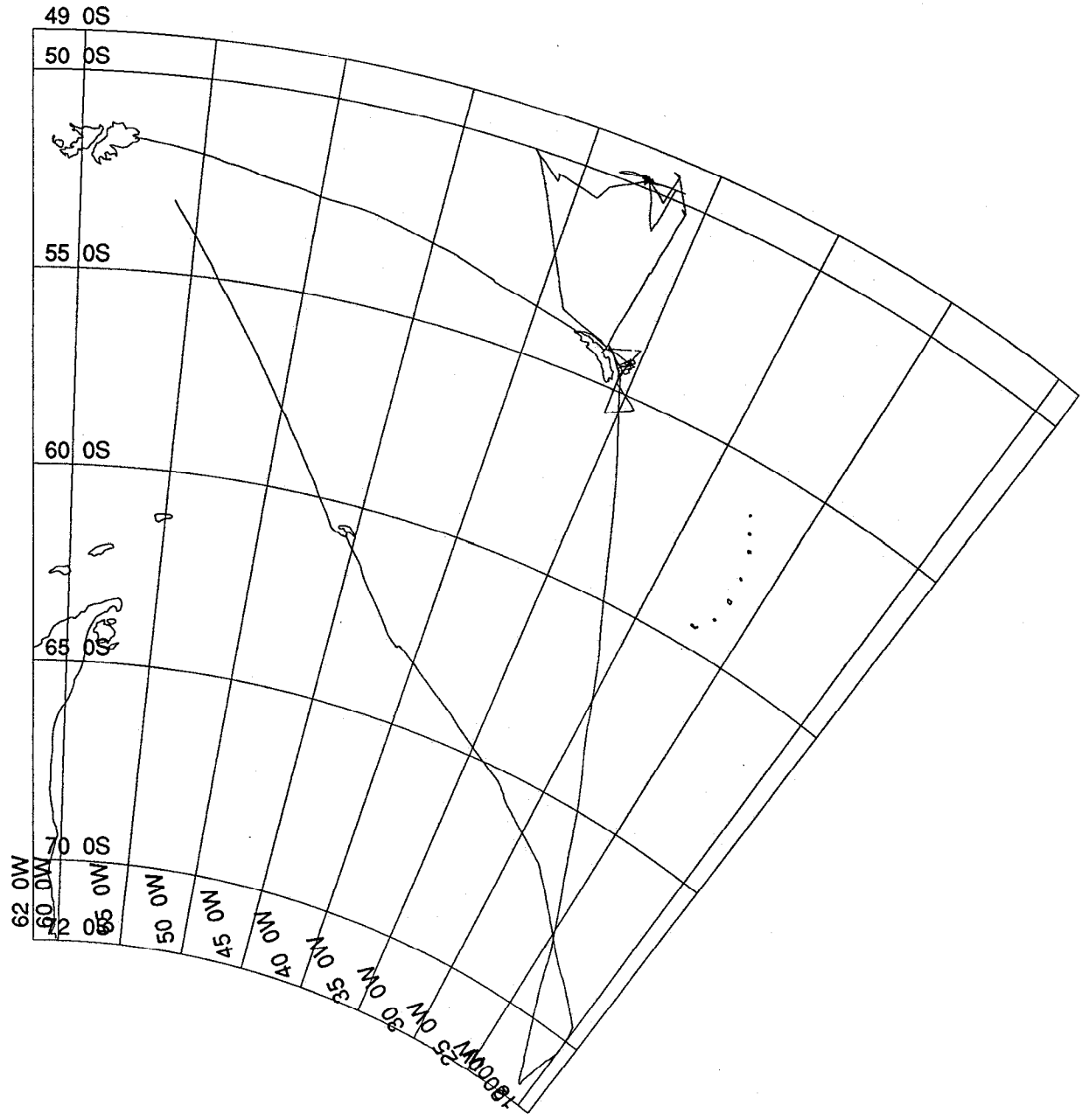
GRID NO. 1

— Track

Cruise JCR06: Leg 1

Scaled to fit

Fig 2



LAMBERTS CONFORMAL CONIC

GRID NO. 1

SCALE 1 TO 15000000 (Std Parallels 72S and 49S)

WGS 72 ELLIPSOID

Cruise JCR06: Leg 2

Scaled to fit

20. Report on scientific instrumentation and logging

by Phil Trathan, Alistair Murray, Julian Priddle, Bruce Lamden and Graham Butcher

During the course of the cruise a wide variety of instruments were logged to the RVS 'ABC' system. A short logging time interval was chosen for most instruments in order to ensure adequate spatial resolution of data and also for ease of merging separate data streams.

Instrument	Logging interval (seconds)
Temperature of non-toxic seawater supply	2
Salinity of non-toxic supply	2
Fluorescence of non-toxic supply	2
Wind speed	2
Wind direction	2
Air temperature	2
Humidity	2
Barometric pressure	2
TIR	2
PAR	2
Trimble GPS	2
Transit satnav	120
EM log	2
Doppler log	1
Gyro compass	2
Simrad EA500 bathymetry	Synchronised to EK500
RDI ADCP	300
Down wire net monitor	2
Flying fish environmental data sampler	2
CTD	-
Scientific winches	-
Simrad EK500 acoustic sounder	-

The first 10 instruments in the table are commonly referred to as the 'oceanlogger'.

Level 'A'

All Level 'A' interfaces were configured and logging prior to departure from Stanley at the start of the cruise.

Level 'B'

Data logging began as the ship departed from Stanley at the start of the cruise. During Leg 1, 6 DC6150 (150 MB) tapes, between 93% and 97% full, were written. During Leg 2, 8 tapes were used. Level 'B' logging was switched off during the mid cruise break, from January 26 to January 29, 1994.

Level 'C'

At the end of Leg 1 there were approximately 290 MB of data in the RVS raw-data area, Leg 2 generated a further 315 MB. Logging was switched off on January 21, 1994 between 15:54 GMT and 16:28 GMT whilst moored at Signy Island base and during the mid cruise break from January 26 to January 29, 1994, otherwise logging was continuous. Logging was finally switched off at the end of the cruise as the ship steamed north of Burdwood Bank; this was to allow adequate time for data archiving. The following backups were taken at the end of the cruise.

Filesystem	Method	Media	Location
/rvs/raw_data	dump	DC6150 (4 tapes)	Cambridge
/rvs/pro_data	dump	DC6150	Cambridge
/home2	dump	DC6150 (5 tapes)	Cambridge
/home	dump	DC6150	Cambridge
/home	tar	DC6130	cambridge
/rvs	dump	DC6150	Cambridge
bas1 all	dump	Exabyte	JCR
bas2 all	dump	Exabyte	JCR
bas3 all	dump	DC6130	JCR
/rvs (all directories)	tar	Exabyte	Cambridge
/home2/ek500/data	tar	Exabyte	Cambridge
/home2/ek50/data (not ping by ping data)	tar	DC6150	Cambridge
/rvs/raw_data/adcp	tar	DC6150	Cambridge
/rvs/raw_data (miscellaneous)	tar	DC6150	Cambridge
/rvs/pro_data	tar	DC6150	Cambridge
/home2/rvs/work	tar	DC6150	Cambridge

The following rvs data streams are included in the backup-set:

Filename	Raw/Pro	Records	Size (MB)
adcp	raw	885056	120.38
bas_ctd	raw	339002	11.54
dop_log	raw	2733506	43.75
em_log	raw	2222583	22.24
flfish	raw	1769	0.19
gps_trim	raw	2514095	176.00
gyro	raw	2519322	25.20
netmon	raw	92137	9.22
oceanlog	raw	2329090	177.02
sim500	raw	608405	17.05
transit	raw	27438	0.61
winch	raw	29836	1.38
bestdrf(Leg 1)	pro	72205	2.03
bestdrf2(Leg 2)	pro	93648	2.63
bestnav(Leg 1)	pro	72325	3.77
bestnav2(Leg 2)	pro	94435	4.92
capechar	pro	86952	2.45
chloro	pro	727851	11.66
dwnm	pro	88748	8.89
ocean	pro	279458	21.25
proctd	pro	338883	27.80

Data not logged to the RVS 'ABC' system

The following data were collected but not logged to the RVS 'ABC' system:

Instrument
Biological net samples
Bird observations
Microbial studies
Autoanalyser
XBT casts
Chlorophyll vertical profile and underway samples
Salinity vertical profile and underway samples

Problems and points of general note

(1) Non-toxic seawater supply from 6 m

Following a breakdown in the seawater supply on January 15, 1994 at approximately 21:15 GMT the filters on the seawater supply were changed and cleaned on a daily basis. Following the

adoption of this practice, there were no further problems. The date and times of filter changes were:

Date	Time	Date	Time	Date	Time	Date	Time
15/01/94	19:00	29/01/94	16:30	12/02/94	16:15	26/02/94	--:--
16/01/94	15:12	30/01/94	09:40	13/02/94	11:35	27/02/94	10:45
17/01/94	14:10	31/01/94	--:--	14/02/94	21:05	28/02/94	15:10
18/01/94	08:20	01/02/94	--:--	15/02/94	13:10	01/03/94	14:30
19/01/94	08:52	02/02/94	16:30	16/02/94	16:50	02/03/94	12:55
20/01/94	14:30	03/02/94	20:47	17/02/94	21:15		
21/01/94	Signy	04/02/94	--:--	18/02/94	13:50		
22/01/94	20:50	05/02/94	20:40	19/02/94	15:30		
23/01/94	10:30	06/02/94	19:00	20/02/94	10:50		
24/01/94	16:40	07/02/94	15:40	21/02/94	15:45		
25/01/94	Stanley	08/02/94	16:15	22/02/94	16:10		
26/01/94	Stanley	09/02/94	16:25	23/02/94	15:50		
27/01/94	Stanley	10/02/94	16:20	24/02/94	In ice		
28/01/94	Stanley	11/02/94	16:25	25/02/94	16:00		

(2) EA500

The Simrad EA500 acoustic sounder was synchronised with the EK500 scientific sounder, causing the ping interval to be dependent upon the exact water depth.

The EA500 generated suspect bathymetric data on a number of occasions. The bad data were normally generated in moderate to rough sea conditions, when the ship changed course very quickly, or when a rapid change in sea depth caused the instrument to report a false bottom. The bad data were located by use of the RVS status editor and their status set to 'suspect'. Only data which showed a change in depth of more than 50 m from the adjacent point were edited. All cruise data have now been 'crudely' despiked.

A malfunction occurred in the EA500 on January 19, 1994 at 07:44 GMT which was rectified on February 3, 1994 at 18:34 GMT.

(3) Suspect data

A number of the RVS data streams from the oceanlogger PC had all of their data flagged as suspect. This followed from the first entry in the data stream where a bug in the software flagged the data as suspect when the first value sampled caused a 'jump' of more than the allowed increment from the default value. The flag was never reset and was propagated throughout the whole file. Further investigation of the problem is required.

(4) RDI ADCP

Due to confusion over the possible loan of an Ashtec 3D GPS system, it was not possible to establish accurate headings for use with the ADCP. Use of a 3D GPS is now considered as desirable for accurate analysis of all ADCP data.

Logging from the ADCP occasionally stopped due to bad data being passed from the PC to the RVS Level 'C'. When this occurred, it was necessary to initiate a new RVS file. This problem, though a frequent occurrence during Leg 1, was not evident in Leg 2 and is thought to be associated with incorrect user modification of the ADCP setup profile.

(5) Simrad EK500

The Simrad EK500 was logged through one of the serial ports to a locally attached PC during the whole of the cruise. The JR02/JR03 version of the software was used although modifications had been redquested but not made. In addition, an experimental link through the Ethernet connection logged data to the Level 'C'. This connection provided binary data which requires post-processing in order to provide usable data. At present the post-processing software has not been tested.

Data were logged to BAS2 rather than BAS1 (Level 'C') in order to take advantage of the disc space available on that system. This was particularly important whilst ping by ping data was logged during a short period in February 1994 (see table below).

The following EK500 data files were collected:

Filename	Period covered	Size (MB)	Comment
ek500.dat	Jan 02	0.13	
ek5001.dat	Jan 02 - Jan 05	3.51	
ek5002.dat	Jan 05 - Jan 16	12.99	EK500 failed
ek5003.dat	Jan 17 - Jan 21	4.83	
ek5004.dat	Jan 21 - Jan 25	4.28	End of Leg 1
ek5005.dat	Jan 29 - Feb 12	23.24	Start of Leg 2
ek5006.dat	Feb 12 - Feb 13	8.51	
ek5007.dat	feb 13 - Feb 15	3.59	
ek5008.dat	Feb 15 - Feb 17	5.73	
ek5009.dat	Feb 17 - Feb 20	377.12	Includes ping by ping data
ek50010.dat	Feb 20 - Feb 20	117.86	Ping by ping data
ek50011.dat	Feb 20 - Mar 01	2.33	
ek50012.dat	Mar 01 - Mar 03	1.15	End of cruise

(6) Trimble GPS

GPS data from the Trimble 4000 DL receiver were logged at 1 second intervals from 18:07 on December 12, 1993 until the ship sailed. The standard errors for latitude and longitude were 0.00021° and 0.00036° respectively over a 24 hour period. These errors are equivalent to 23 m and 65 m respectively. There was no appreciable correlation between the latitude and longitude values nor was there any evidence for a trend over time.

There was were no gaps in satellite coverage of more than 10 s during Leg 1 and only two gaps during Leg 2, both less than 30 s. However, there were times when the number of available satellites fell below the number required for accurate geographic location. The maximum number of satellites available did not exceed 9, but the arithmetic mean was only 3.4 during the first part of the cruise and 2.7 during the second.

On February 18, 1994 around 20:00 GMT, GPS coverage was extremely poor, and wild jumps were recorded for the cruise track.

(7) Gyro compass

More than 20 hours heading data were collected at 2 second intervals whilst the ship was tied up alongside FIPASS before the start of the cruise. Conditions were very windy (30 - 40 knots) so some ship movement is likely to have occurred. The mean heading was 98.94° with standard deviation 0.175° (CV = 0.18%). There was a correlation of 0.56 with time and a clear linear trend. Linear regression accounted for 32% of the variance of the data giving an estimated linear drift of 0.0173°. This cannot be extrapolated over the whole cruise as it is likely to be a cyclic phenomenon (precession) and will also vary with latitude.

An astronomical sighting was taken on December 12, 1993 at 22:07 GMT in order to determine the gyro compass error and this gave a bias of 0.5°. A -0.5° correction was applied to heading data from the gyro compass for the generation of bestnav data.

Subsequent astronomical sightings showed gyro compass errors up to +3.0 degrees. As gyro compasses are liable to precession, a 3D GPS receiver would enable daily checks to be made, so leading to higher quality navigational and scientific data. See table of observed gyro errors kindly supplied by the Ships' Navigating Officer.

(8) Chlorophyll calibration

Throughout the cruise hourly water samples were extracted for chlorophyll determination in order to calibrate the through-flow fluorometer. During Leg 1 and Leg 2 respectively, approximately 280 and 500 samples were taken from the non-toxic seawater supply. Full details of the extraction and calibration methods are detailed elsewhere in the cruise report.

(9) Thermosalinograph calibration

Both the temperature sensor and conductivity cell were calibrated prior to the cruise. Water samples from the non-toxic seawater supply were also taken at frequent intervals throughout the cruise and analyzed for salinity on a Guildline Autosal against standard seawater. Samples were normally taken at least twice a day and often following any alterations or interruptions to the non-toxic seawater supply.

A problem was noted with the Autosal when it was in *standby* mode between samples; the nature of this was that the digital display cycled at intermittent periods. The problem was solved by switching the Autosal off and on again, but seemed to recur depending upon the stability of the ship, upon electrical interference and upon the temperature in the laboratory.

21. Seawater nutrient chemistry -

by Mick Whitehouse & Julian Priddle

Inorganic seawater nutrients were measured during cruise JR06 to help identify water masses, to characterise frontal zones and study sites, and in conjunction with microbial research.

Measurements were made with a Segmented Flow Analyser (upgraded and fully refurbished during summer 1993), which performed most satisfactorily during its first Antarctic field season. Fine-scale measurements of nitrate, nitrite & ammonium - nitrogen, orthophosphate and silicate were made which had been unattainable with MLSD's previous analytical system. During transects, the non-toxic seawater supply was analysed continuously and measurements were logged to a PC every 10 seconds which will allow integration with other underway instrumentation. Discrete CTD water bottle samples were analysed using the same analytical system when the ship was stationary. Thus detailed horizontal and vertical profiles were obtained.

On the first leg of the cruise, horizontal and vertical profiles were measured along the Maurice Ewing Bank transect. Similar measurements were made during a fine-scale survey north of Bird Island. Fine-scale vertical profiles were measured in support of microbial studies and further underway analyses were undertaken during the South Georgia to Signy transect, the survey to the west of the South Orkneys and the transect between the South Orkney Islands and Falkland Islands.

During the second leg of the cruise, CTD water bottle samples were analysed along the repeat transect over the Maurice Ewing Bank. Fine-scale CTD profiles were measured at the squid biomass site in conjunction with microbial studies and all samples from CTD water bottle casts during the squid biomass physical characterisation were analysed for inorganic nutrients.

An initial scan of the data revealed substantial change in the nutrient concentrations (especially silicate) in the frontal zones and considerable variation in the nitrogenous nutrients around the shelf-break regions at South Georgia and around the South Orkneys. The fine-scale vertical profiles (particularly at the squid biomass site) showed complex nutrient variability in the water column with ammonium and nitrite maxima at the bottom of the mixed-layer underlying surface waters depleted of the other nutrients.

A full analysis and assessment of all the nutrient data collected will be undertaken during summer 1994.

22. MICROBIAL ECOLOGY: A size-fractionated study of production, respiration and community composition -

by *Stephen Blight, Julian Priddle and Mick Whitehouse*

Abstract. *A study of microbial production and respiration, using size-fractionated high-precision oxygen flux measurements, was carried out in the Southern Ocean during January-March 1994. Two sites were studied intensively over periods of approximately one week, and this was complemented by a wide-ranging study of surface water in the Weddell and Scotia Seas.*

At the first site, near Willis Islands, South Georgia, the phytoplankton was dominated by a bloom of large diatoms, with chlorophyll biomass up to 19 mg m^{-3}. Gross production by the whole community was up to 28 µmol O_2 dm^{-3} d^{-1}, of which over 90% was attributable to cells >20 µm. Respiratory activity was concentrated in the smaller size fractions - whole community rates varied from 2-3 µmol O_2 dm^{-3} d^{-1} of which up to 60% was in the fraction <0.8 µm.

The second main site was oceanic, close to the Polar Front. Here phytoplankton biomass was low, with chlorophyll concentrations <0.75 mg m^{-3}, and nanoplankton predominated. Gross production was around 2.5 µmol O_2 dm^{-3} d^{-1} most of which was associated with the smaller size fractions. Respiration rates varied from 0.5-1 µmol O_2 dm^{-3} d^{-1}.

Over the larger area of the transect surveys, gross production and respiration ranged from 0.6-4.8 and 0.36-1.24 µmol O_2 dm^{-3} d^{-1} respectively. The size-fractionation of these rates varied widely, because of the different communities encountered. For the eight sampling locations, 14-88% of gross production and 15-97% of respiration were in the fraction <20 µm. This size fraction contained 16-88% of the chlorophyll biomass. Overall, the metabolic activity of the small-celled microbiota appeared to be relatively constant, despite the wide range of environmental conditions encountered during the study. However, both biomass and activity of microplankton varied considerably.

Introduction

Microbial production forms the basis of the pelagic food web, and is the primary process whereby carbon is fixed and subsequently exported from the euphotic zone to deep water. Contrary to early conclusions on the productivity of the Southern Ocean, it is now known that overall primary production is low (see El-Sayed, 1984), leading to a surplus of inorganic nutrients in the euphotic zone. However, some areas are characterised by very dense phytoplankton blooms (Priddle et al. 1992) although the high inorganic nutrient pools are rarely exhausted. These blooms are typically dominated by large diatoms, and form part of the stereotyped Antarctic planktonic food-chain - the diatoms being grazed by krill, which in turn are fed upon by baleen whales. At the other extreme, and possibly more representative of the Southern Ocean as a whole, are microbial communities which are characterised by small-celled flagellates, with a high proportion of heterotrophic microbes.

Against this background, an understanding of the relationship between production and recycling by the microbial community, and its size structure and composition is essential if we are to understand the dynamics of the Antarctic marine planktonic ecosystem. The present study is based on the use of high precision oxygen flux measurements to estimate microbial production and respiration. Measurements have been made on microbial communities across a wide geographic area, from north of the Polar Front to the south-eastern Weddell Sea, and have used size-fractionation to identify the relationship between oxygen flux and community composition.

Materials and methods

Sample Collection.

A rosette fitted with twelve 10 dm^{-3} Niskin water bottles was deployed to collect the water, except for the large-scale study where samples were taken from the ship's non-toxic pumped seawater supply (nominal depth 6 m). For the vertical profiles subsamples for nutrient chemistry and particulate organic carbon (POC), particulate organic nitrogen (PON) and chlorophyll *a* determination were taken directly from each Niskin. For the depths at which oxygen incubations were performed the remaining water was drained through silicon tubing into 10 dm^{-3} aspirators. Care was taken to exclude air bubbles. For the fractionations eight Niskin bottles were triggered at 10 m, six of these were used to fill a 50 dm^{-3} aspirator and one was used to fill a 10 dm^{-3} aspirator. The 10 dm^{-3} aspirator was used for whole community incubations and the 50 dm^{-3} aspirator for the <200, <20, <2 and <0.8 µm incubations. The size fraction POC/PON and chlorophyll *a* concentrations were determined using the water remaining in aspirators once the oxygen bottles had been filled.

Size fractionation. A reverse flow filtration system (Williams and coworkers 1993) was used to perform the fractionations. Meshes with nominal pore sizes of 200 and 20 µm, and polycarbonate membranes with 2 and 0.8 µm size pores were used as the filters. All fractionations were performed at 3-4°C in a constant temperature room and were completed within 2 hours of the water coming on board.

Oxygen flux measurements. Dissolved oxygen concentrations were determined by Winkler titrations using a microcomputer-based system with a colorimetric endpoint detector. All size fraction subsamples other than the <2 and <0.8 µm fractions were incubated in 100 cm^3 glass stoppered bottles. For the <2 and <0.8 µm size fractions 50 cm^3 glass stoppered bottles were used in order to minimise the volume of water filtered. All incubations were performed for 24 ±0.5 hours in either light or dark deck incubators. Near *in situ* temperatures were maintained by circulating near surface seawater through the incubators.

Tritiated thymidine incorporation. ^{3}H-methyl thymidine (final concentration 5 nanomolar) was added to 10cm^3 subsamples and 1.5 - 2 hour incubations performed. Thymidine incorporation was halted by addition of formaldehyde (1% final concentration). The DNA was precipitated using the method of Robarts and Wicks (1987) except the phenol/chloroform wash step was not performed. The filters were dissolved in minivials containing 4 cm^3 of Optiphase scintillation cocktail and counted on a Beckman LS 6000SC scintillation counter. Counts were converted to actual nuclear disintegrations by use of a quench curve generated by the external standard method.

Results and Discussion

The study was divided into two components. Intensive investigations of microbial production were carried out at two sites - one nearshore and one oceanic. These two studies were complemented by a series of experiments carried out on passage in the Scotia and Weddell Seas.

1. Fine-scale studies

1.1 Willis Islands grid - a nearshore site

1.2.1 Study site

The study site (Fig. 1) was selected for an investigation of the biomass size-spectrum in a krill-dominated plankton community. It was centered on a sea-mount at the shelf edge, and samples for

microbial studies were taken from a fixed station a few km downcurrent from the sea-mount, in a water depth of approximately 300 m. As part of the physical characterisation of the site, two N-S transects were worked and microbial production was measured at an offshore and a shelf station.

At the central station in the study area, the mixed layer was approximately 50 m deep, with a gradual temperature gradient to 100 m. Temperature in the mixed layer was 2.5°C, decreasing to 1°C at the base of the pycnocline. In the course of the week-long occupation of this site, wind mixing increased the mixed layer depth. By the end of the study, and following a day of particularly strong winds, the mixed layer was approximately 60 m deep, with a steepened temperature gradient in the upper part of the pycnocline to 80 m depth. The temperature in the mixed layer had increased to 3°C. Inorganic nutrient concentrations within the mixed layer, measured in a profile at the start of the microbial study were approximately 10 mmol m^{-3} NO_3, 15 mmol m^{-3} SiO_3 and 1.75 mmol m^{-3} PO_4. Concentrations increased through the pycnocline, to 30, 35 and 2.25 mmol m^{-3} respectively. There was a strong peak in ammonium concentration in the pycnocline, reaching 1.75 mmol m^{-3} at 60 m depth (Fig. 2).

Phytoplankton biomass was high - up to 19 mg m^{-3} chlorophyll *a* in the mixed layer. Blooms of this magnitude have been found at sites close to the location of the present study on previous BAS cruises (Priddle, unpublished data). The large proportion of particulate chlorophyll was in the size fraction >20 µm. A slight peak in phaeopigment in the pycnocline may indicate a concentration of grazing activity. During the course of the study, phytoplankton biomass declined, but was still high. Detailed size fractionation was consistent with the domination of the phytoplankton community by large cells and colonies. Preliminary examination of Lugol's-fixed samples showed that the phytoplankton contained diatoms known to typify blooms in this location (Priddle, unpublished data). Dominant taxa were *Eucampia antarcticum, Odontella weissflogii, Chaetoceros curvisetum, C. socialis, Thalassiosira tumida* and *Corethron ?inerme.* These are all colonial, and mostly large-celled, diatoms. Heterotrophic microplankton were also dominated by relatively large taxa, mainly large dinoflagellates and ciliates.

1.1.2 Results

See Table I for a summary of CTD casts and measurements made.

1.1.2.1 Vertical profiles

The first vertical profile conducted on JD 11 showed the mixed layer to be 50 m deep. Within this layer WC (whole community) chlorophyll *a* concentrations and respiration rates were approximately 19 mg m^{-3} and 3 µmol O_2 dm^{-3} d^{-1} respectively (Fig.3). Almost 90% of the chlorophyll *a* was accounted for by >20 µm phytoplankters. Near surface (10 m) WC gross production and thymidine incorporation (TI) rates were 28.6 µmol O_2 dm^{-3} d^{-1} and 2.76 pmol dm^{-3} h^{-1} respectively. Within the pycnocline (70 m sample), the WC chlorophyll *a* concentration and respiration rate were 21 and 33% of their respective mixed layer values.

The second vertical profile conducted on JD 16 showed the mixed layer to have deepened to 60 m, presumably a consequence of the previous days storm. Mixed layer WC chlorophyll *a* concentrations and respiration rates were approximately half their respective values on JD 11 (Fig. 3). This decline was due to a decrease in micro-and mesophytoplankton (>200 µm) abundance. The WC TI rate from 10 m was approximately 15% of that measured for the first profile. Size fractionation showed 31 and 100% of the WC respiratory activity at 10 and 80 m respectively to be attributable to the <0.8 µm size fraction. The <0.8 µm size fractions obtained from 10 m and 80 m accounted for 61% and 119% of the WC TI rates respectively.

1.1.2.2 Size-fractionated production

Two detailed size fractionations were performed at the main Willis Islands site on JD's 14 and 17. The mixed layer depth was 45 m with evidence of surface warming on JD 14, the whole community chlorophyll *a* concentration was 9.08 mg m^{-3}, less than half the amount measured on JD 11. In contrast, whole community gross production seemed to change little with a value of 28.63 µmol O_2 dm^{-3} d^{-1}. The reason for this increase in the specific rate of gross production is not clear. Mesophytoplankton appeared to dominate, with only 40% of gross production and 32% of chlorophyll *a* residing in the <200 µm fraction; the nanophytoplankton (<20 µm) community was small accounting for 3% of gross production and 10% of chlorophyll *a* (Fig. 4). In contrast whole community respiratory activity seemed to be dominated by the smallest size fractions with 60% residing in the <0.8 µm fraction (Fig. 5). The WC respiration rate was approximately 160% of that measured on JD 11.

For the JD 17 fractionation the mixed layer depth was 60 m. The WC chlorophyll *a* concentration had declined to 6.45 mg m^{-3}, 71% of the JD 14 concentration (Fig. 4). This decrease was due to a reduction in the mesophytoplankton community (Fig. 4). WC gross production was 20.02 µmol O_2 dm^{-3} d^{-1}, 70% of the JD 14 rate (Fig. 4). The whole community respiration rate was 1.97 µmol O_2 dm^{-3} d^{-1}, 39% of the JD 14 value (Fig. 5). This substantial fall off in WC respiration rate was due to a decline in the respiratory activity of the <0.8 µm size fraction. The respiration rate for the <0.8 µm size fraction was 3.12 µmol O_2 dm^{-3} d^{-1} on JD 14 and only 0.37 µmol O_2 dm^{-3} d^{-1} on JD 17, 12% of the JD 14 rate (Fig. 5). The WC and <0.8 µm TI rates were both approximately 0.24 pmol dm^{-3} h^{-1}, 9% of the JD 11 rate.

Size fractionations were performed at an offshore and onshore site on JD 13. At the offshore site the mixed layer depth was approximately 50 m, whereas the water column was homogeneous at the onshore station (water column depth 113 m). Measurements showed chlorophyll *a* concentrations and gross productivity to be greater in all the size fractions for the offshore site (Fig. 4) with values being less than half of those encountered at the main Willis Islands site on JD 11. Although whole community respiratory activity was slightly greater for the offshore site, for both the <200 and <20 µm size fractions respiratory activity was greater onshore (Fig. 5). Consequently the net autotrophic nanoplankton community present offshore was replaced by a net heterotrophic nanoplankton community onshore.

1.2 Polar Front grid - an oceanic site

1.2.1 Study site

As with the site at Willis Islands, this study site was chosen for an investigation of biomass size spectrum - here in an community characterised by squid and myctophids. The site was located at 49°48'S, 37°26'W, slightly to the north of the Polar Front (Fig. 1). Mixed layer depth varied between 50 and 60 m. This was probably associated with the dynamic nature of the water movement in the vicinity of the front, rather than wind-forcing. A consistent pattern of highly variable salinity structure was found within the pycnocline. Mixed layer temperature was 6.5°C throughout the study. Inorganic nutrient concentrations were measured in a single detailed profile at the start of the study. Silicate concentrations in surface water were low, whereas nitrate levels were higher than at the Willis Islands site. For both nutrients, there were two transition gradients - first a rapid increase in concentration at the top of the pycnocline, and then a second and more gradual increase at a depth of 150 m. Peak values of both ammonium and nitrite occurred in the pycnocline (Fig. 6).

Phytoplankton biomass was low. Particulate chlorophyll concentration in the mixed layer did not exceed 0.75 mg m^{-3}, and nearly all of this was in the size fraction <20 µm. Further more detailed size fractionation measurements showed that nearly half of the chlorophyll biomass was in cells <2 µm. Preliminary microscopic examination of fixed samples confirmed that biomass was very low and consisted largely of small dinoflagellates and cryptomonads. The few diatom taxa were

small cells, such as small *Nitzschia* spp and *Thalassionema*. A wide variety of heterotrophic microplankton were found in these samples. These included small ciliates which have been shown to feed mainly on bacteria at offshore sites near South Georgia (R. Leakey, pers comm.).

1.2.2 Results

See Table II for a summary of the CTD casts and measurements made.

1.2.2.1 Vertical profiles

A vertical profile was performed on both JD's 39 and 41. The profile on JD 39 showed the mixed layer depth to be 45 m. WC chl a concentrations and respiration rates were approximately 0.7 mg m^{-3} and 0.47 µmol O_2 dm^{-3} d^{-1} respectively (Fig. 7), essentially all the chlorophyll *a* resided in the <20 µm fraction. Whole community gross production and TI rates for a subsample from 10 m were 1.6 µmol O_2 dm^{-3} d^{-1} and <1 pmol dm^{-3} h^{-1} respectively.

On JD 41 the mixed layer depth was 65 m. WC chlorophyll *a* concentrations and respiration rates were approximately 0.82 mg m^{-3} and 0.8 µmol O_2 l^{-1} d^{-1} respectively (Fig. 7), again virtually all the chlorophyll *a* was associated with the <20 µm size fraction. WC gross production for a 10 m subsample was 2.55 µmol O_2 dm^{-3} d^{-1}.

1.2.2.2 Size-fractionated production

Of the five fractionations that were performed, three were at the study site. The remaining two were conducted in the Polar Frontal Zone (PFZ) south of the Polar Front.

The three fractionations at the study site were conducted on JD's 38,40 and 42. Both phytoplankton biomass and plankton community metabolic activity seemed to increase slightly during this time. For all five fractionations all the chlorophyll *a* resided in the <20 µm size fraction.

The mixed layer depth on JD 38 was 45 m. WC gross production, respiration rates and chlorophyll *a* concentrations were 2.2, 0.5 µmol O_2 dm^{-3} d^{-1} and 0.72 mg m^{-3} respectively (Figs 4 & 5). The WC and <0.8 µm TI rates were 0.85 and 0.59 pmol dm^{-3} h^{-1} respectively.

The mixed layer depth on JD 40 was 55 m. WC gross production, respiration rates and chlorophyll *a* concentrations were 2.5, 0.8 µmol O_2 dm^{-3} d^{-1} and 0.76 mg m^{-3} respectively (Figs 4 & 5). Approximately 29% and 28% of the WC respiratory activity was attributable to the <2 and <0.8 µm size fractions (Fig. 5). Gross production in the <2 µm size fraction was not measurable. The WC and <0.8 µm TI rates were 1.2 and 0.7 pmol dm^{-3} h^{-1} respectively.

The mixed layer depth on JD 42 was 45 m. WC gross production, respiration rates and chlorophyll *a* concentrations were 2.7, 1.0 µmol O_2 dm^{-3} d^{-1} and 0.81 mg m^{-3} respectively (Figs 4 & 5). Approximately 34% and 33% of the WC respiratory activity was attributable to the <2 and <0.8 µm size fractions (Fig. 5). Gross production in the <2 µm size fraction was not measurable.

The mixed layer depth for both fractionations performed just to the south of the front was 50 m. The WC chlorophyll *a* concentrations were 55 and 56 mg m^{-3} for JD's 45 and 46 respectively (Fig. 4). The WC gross production rate was higher for the JD 46 fractionation with a value of 2 µmol O_2 dm^{-3} d^{-1}, the rate for JD 45 was 1.2 µmol O_2 dm^{-3} d^{-1} (Fig. 4). WC respiration rates were similar for both fractionations with values of approximately 0.6 µmol O_2 dm^{-3} d^{-1} (Fig. 5). Approximately 40-45% and 12-20% of the WC respiratory activity for both fractionations was attributable to the <2 and <0.8 µm size fractions respectively (Fig. 5). Picophytoplankton accounted for 25% on JD 45 and 5% on JD 46 of the WC gross production rate (Fig. 4). The WC

TI rate were 1.2 and 0.8 pmol dm^{-3} h^{-1} for JD's 45 and 46 respectively. For both fractionations approximately 40-50% of the WC TI rate was attributable to the <0.8 μm size fractions.

1.3 Comparison of the two sites

The two sites showed an obvious difference in phytoplankton community structure, biomass and activity. At the Willis Islands site phytoplankton biomass and activity was dominated by a mesophytoplankton bloom. This bloom was characterised by high levels of biomass and gross production with the magnitude of both showing considerable variability over the course of the study. In contrast the oceanic site situated to the north of the Polar Front was characterised by a nanophytoplankton-dominated community. This community exhibited low levels of biomass and activity and showed little variability with time. Nanophytoplankton gross productivity was in fact broadly similar for both the sites. These observations are consistent with the general hypothesis that much of the variability in phytoplankton abundance is due to micro- and mesophytoplankton `blooms', with nano- and picophytoplankton communities remaining largely invariate (see Kiorbee 1993, Riegman 1993).

2. Large-scale study

The non-toxic pumped seawater supply was used during Julian Days 53-58 to sample plankton communities over a wide ranging area (Sites P1-P8: Fig. 1). The methods used were the same as those employed at the two biomass sites.

2.1 Results

The results of the oxygen incubations are shown in Fig. 8.
WC gross production ranged from 0.6-4.8, WC net production from -0.28-3.75, WC respiration from 0.36-1.24 μmol O_2 dm^{-3} d^{-1}. On average 56% (range 14-88, n=8) and 56% (range 15-97, n=8) of WC gross productivity and respiratory activity resided in the <20 μm size fraction respectively. The WC chlorophyll *a* concentration ranged from 0.17-2.15 mg m^{-3}. On average 57% (range 16-88, n=8) of this chlorophyll a resided in the <20 μm size fraction. WC TI rates ranged from 0.02-1.6 pmol dm^{-3} h^{-1}.

Conclusion

The two biomass sites and final large scale study have allowed different plankton communities to be studied. Plots of WC vs <20 μm size fraction rates of gross production, net production and respiration (Fig. 8) show whole community metabolic activities to be substantially greater at the Willis Islands site. The Oceanic site to the north of the polar front and the large scale study are characterised by low levels of metabolic activity with little overall variability. Considering the <20 μm size fraction only, it can be seen that this fractions metabolic activities vary little throughout the cruise except for the respiratory activity of event 149. This respiratory peak was due to microorganisms <0.8 μm, almost certainly predominantly heterotrophic bacteria. Only two net heterotrophic nanoplankton (<20 μm) communities were encountered on the cruise. The first was the onshore station of the Willis Islands study, which is consistent with the general phenomenon of respiration rates increasing offshore-onshore. The second was Event 149 where there appeared to be a heterotrophic bacterial `metabolic bloom'. Only once, the first sampling point of the large scale study (P1), was the whole community net heterotrophic.

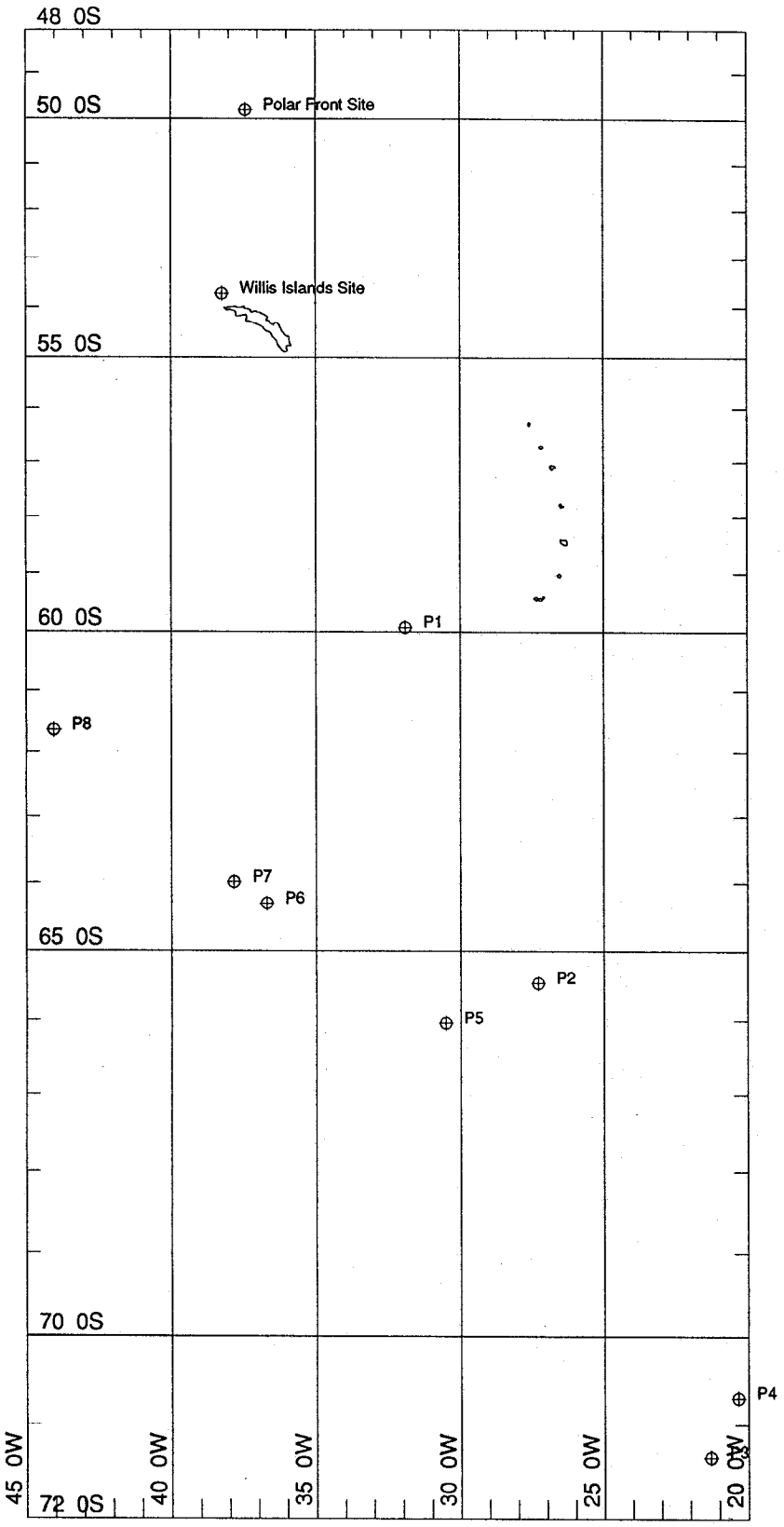
Sample Code (Julian Day)	Mixed Layer Depth and Temperature	CTD Cast Details	Measurements Made
74 (11)	50m & 2.6°C	2 consecutive casts made. Cast 1 - 12 depths (280-80m), cast 2 - 7 depths (70-10m).	Nutrient, POC/PON & Chl concentrations for all 19 depths. Oxygen incubations for 5 depths (70,50,40,20 & 10m). WC TI rate for 10m. Preserved subsamples for later microscopy for 12 depths (120-10m).
101 (12)	30m & 2.8°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Oxygen incubations, WC TI rate. Preserved subsamples for later microscopy.
124 (13)	40m & 3.5°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200 & <20μm). Preserved subsamples for later microscopy
134 (13)	Completely Mixed (Inshore) & 2.3°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200 & <20μm). Preserved subsamples for later microscopy.
149 (14)	45m & 3.3°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <20, <2 & <0.8μm). Preserved subsamples for later microscopy.
162 (16)	60m & 3.3°C	1 cast made - 8 depths (120-10m)	POC/PON & Chl concentrations for all 8 depths. Oxygen incubations for 4 depths (WC & <0.8 for 10 & 80m, WC only for 30 & 60m). WC & <0.8μm TI rates for 10 & 80m. Preserved subsamples (oxygen depths only) for later microscopy.
179 (17)	60m & 3°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <20, <2 & <0.8μm). WC & <0.8μm TI rates. Preserved subsamples for later microscopy.
425 (51)	50m & 3.1°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <20, <2 & <0.8μm). Preserved subsamples for later microscopy.

Table I: CTD casts and measurements made at the Willis Islands site.
Wherein POC denotes particulate organic carbon; PON denotes particulate organic nitrogen, Chl denotes chlorophyll *a*; WC denotes whole community and TI denotes thymidine incorporation.

Sample Code (Julian Day)	Mixed Layer Depth and Temperature	CTD Cast Details	Measurements Made
259 (38)	45m & 6.5°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <20μm). WC & <0.8μm TI rates. Preserved subsamples for later microscopy.
276 (39)	40m & 6.5°C	2 consecutive casts made. Cast 1 - 12 depths (500-110m), cast 2 - 10 depths (120-10m).	POC/PON & Chl concentrations for all depths. Oxygen incubations for 3 depths (40,20 & 10m), WC TI rate for 10m. Preserved subsamples (oxygen depths only) for later microscopy.
285 (40)	55m & 6.5°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <20, <2 & <0.8μm). WC, <2 & <0.8μm TI rates. Preserved subsamples for later microscopy.
300 (41)	65m & 6.5°C	1 cast made - 4 depths (70-10m)	POC/PON & Chl concentrations and oxygen incubations for all 4 depths. Preserved subsamples for later microscopy.
305 (42)	45m & 6.5°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <20, <2 & <0.8μm). Preserved subsamples for later microscopy.
349 (45)	50m & 5.5°C	1 cast made - 8 depths (120-10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <20, <2 & <0.8μm). WC & <0.8μm TI rates. Preserved subsamples for later microscopy.
374 (46)	50m & 5.5°C	1 cast made - 1 depth only (10m)	POC/PON & Chl concentrations. Size fractionated oxygen incubations (WC, <200, <2 & <0.8μm). WC & <0.8μm TI rates. Preserved subsamples for later microscopy.

Table II: CTD casts and measurements made at the Polar Front Site.
Wherein POC denotes particulate organic carbon; PON denotes particulate organic nitrogen, Chl denotes chlorophyll *a*; WC denotes whole community and TI denotes thymidine incorporation.

. Fig 1



MERCATOR PROJECTION

GRID NO. 1

SCALE 1 TO 11160558 (NATURAL SCALE AT LAT. -60)

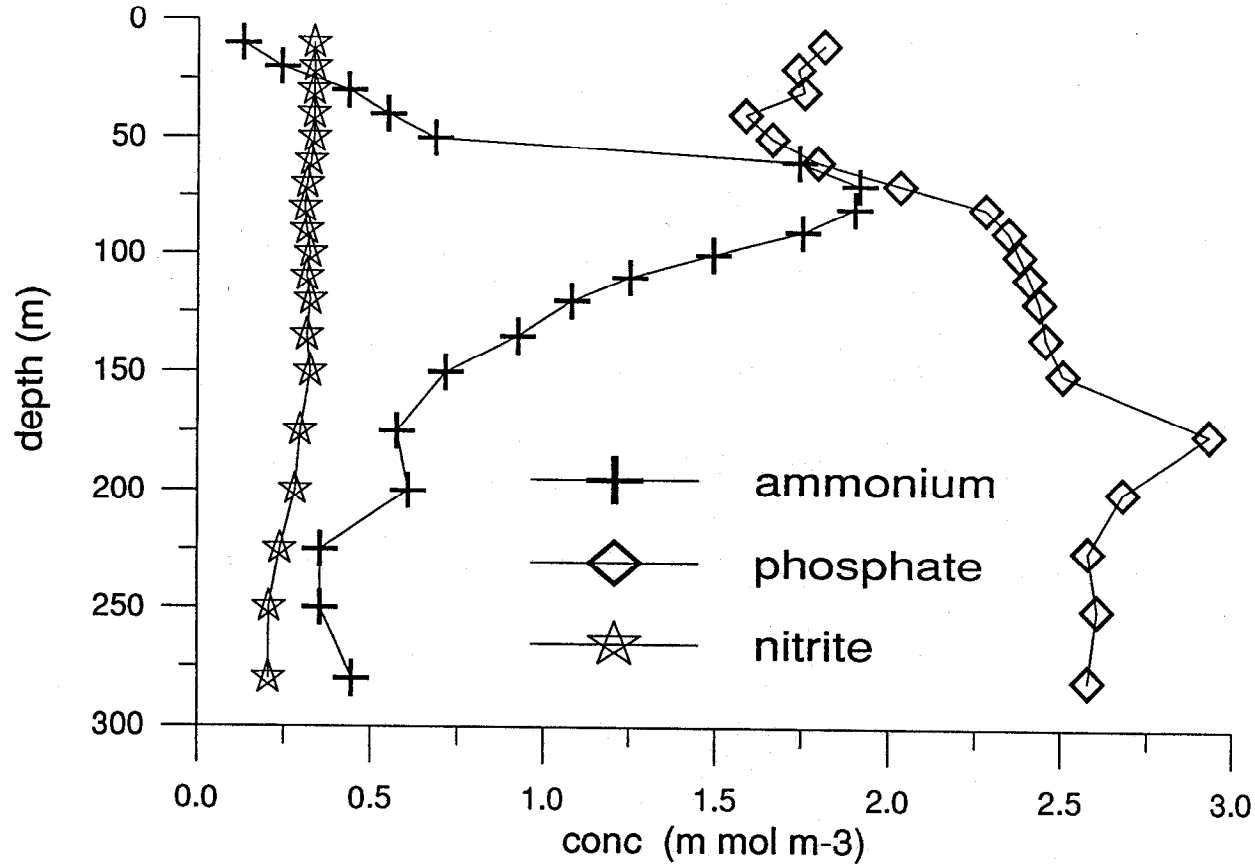
INTERNATIONAL SPHEROID PROJECTED AT LATITUDE -60

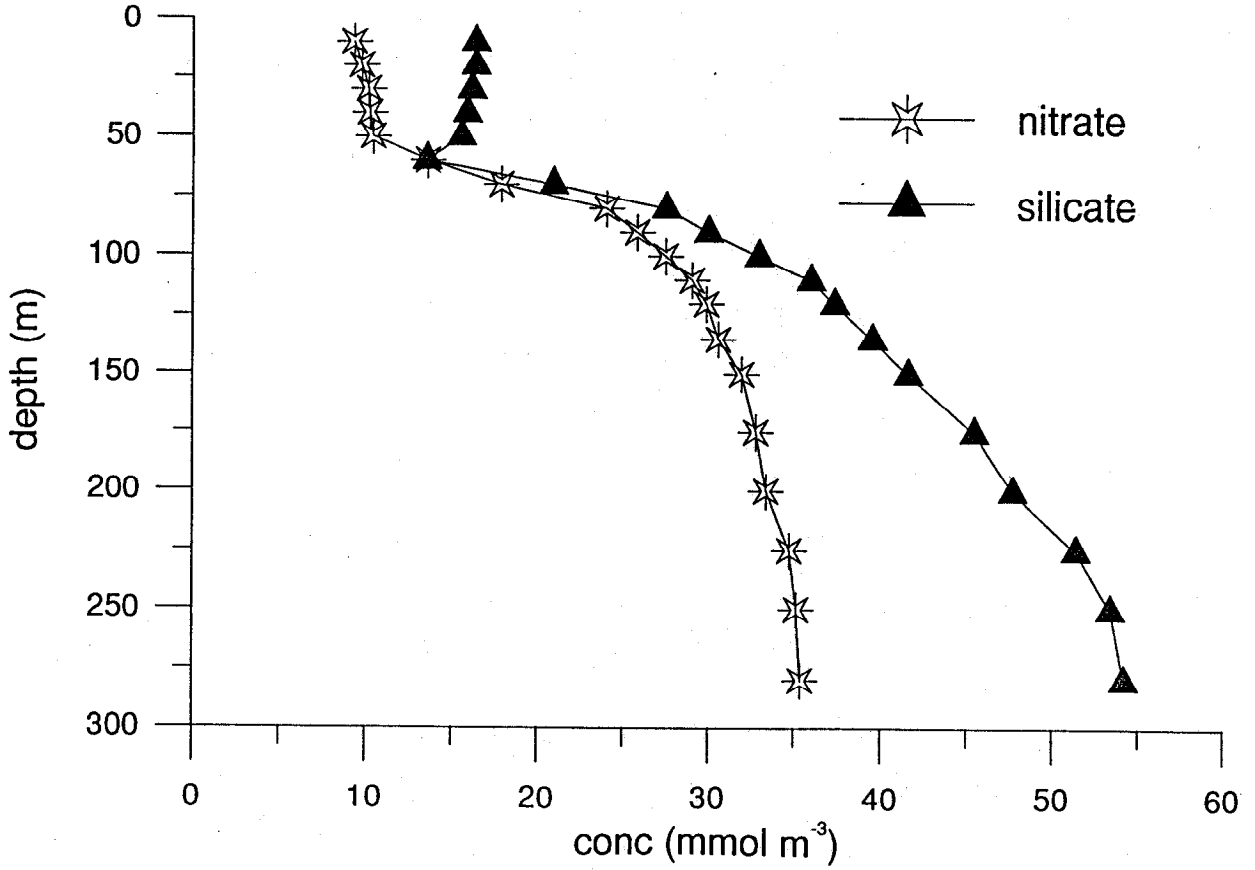
BAS Cruise JR06 - Microbiology Sampling Sites

Scaled to fit

$+Si:NO_3.7+$

Fig 2


depth (m)
0
50
100
150
200
250
300
0.0
0.5
1.0
1.5
2.0
2.5
3.0
conc (m mol m-3)
ammonium
phosphate
nitrite


depth (m)
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200
250
300
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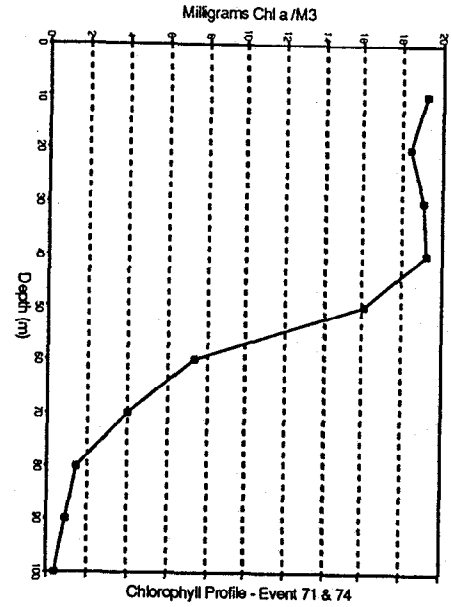
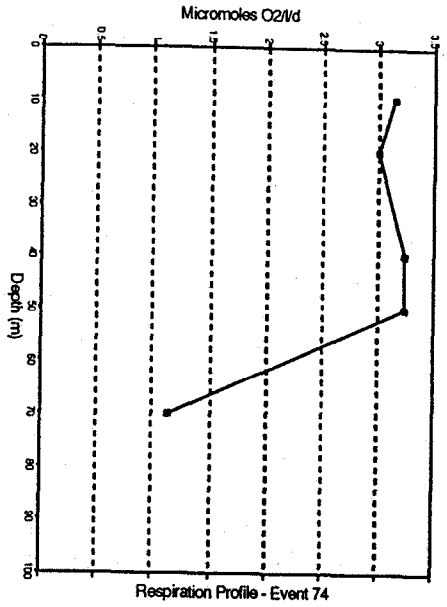
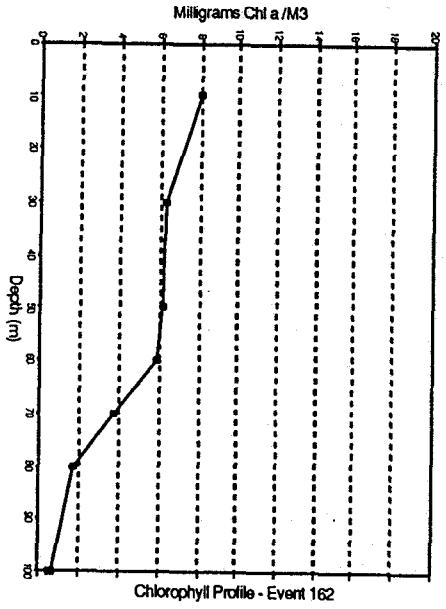
10
20
30
40
50
60
conc (mmol m-3)
nitrate
silicate


Milligrams Chl a /M3
Depth (m)
Chlorophyll Profile - Event 71 & 74


Micromoles O2/l/d
Depth (m)
Respiration Profile - Event 74


Milligrams Chl a /M3
Depth (m)
Chlorophyll Profile - Event 162

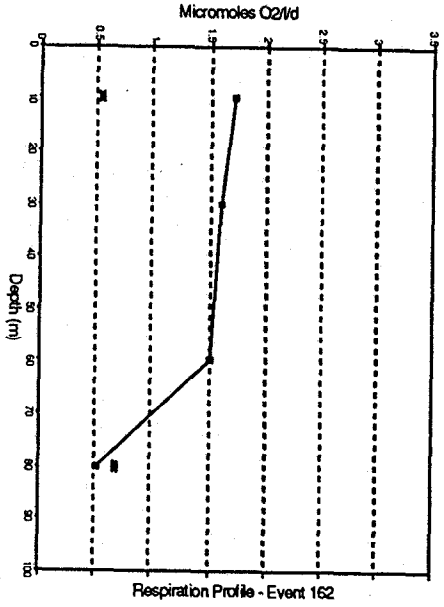
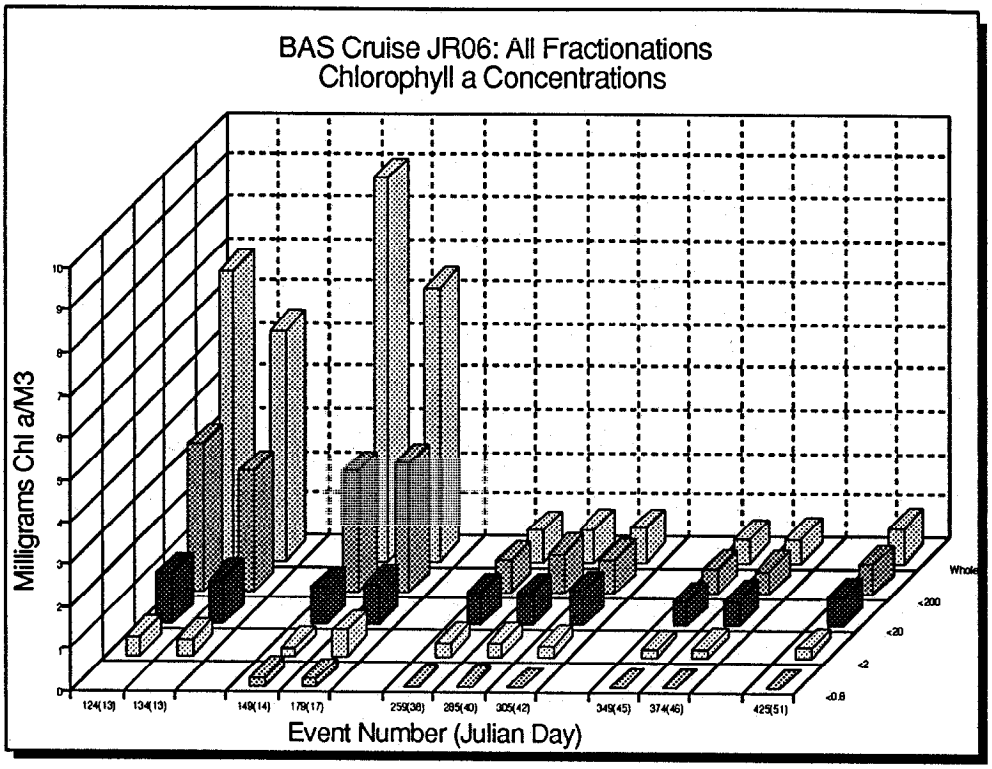

Micromoles O2/l/d
Depth (m)
Respiration Profile - Event 162

Fig 3


BAS Cruise JR06: All Fractionations
Chlorophyll a Concentrations
Milligrams Chl a/M3
Event Number (Julian Day)
124(13)
134(13)
149(14)
179(17)
259(38)
285(40)
305(42)
349(45)
374(46)
425(51)
Whole
<200
<20
<2
<0.8

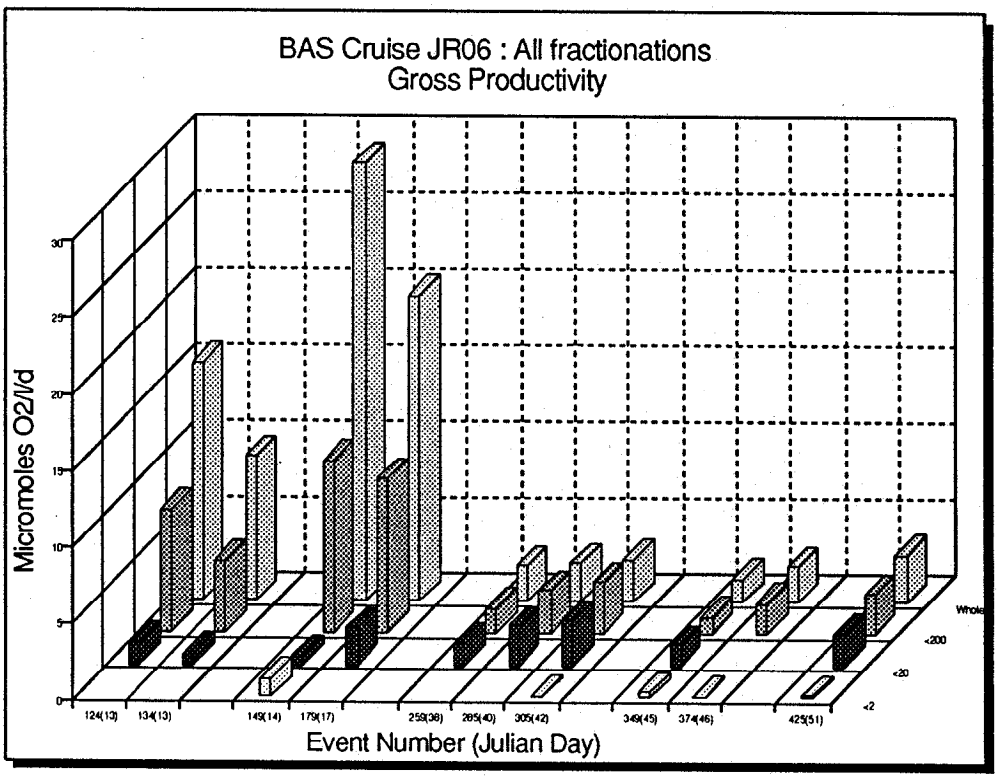
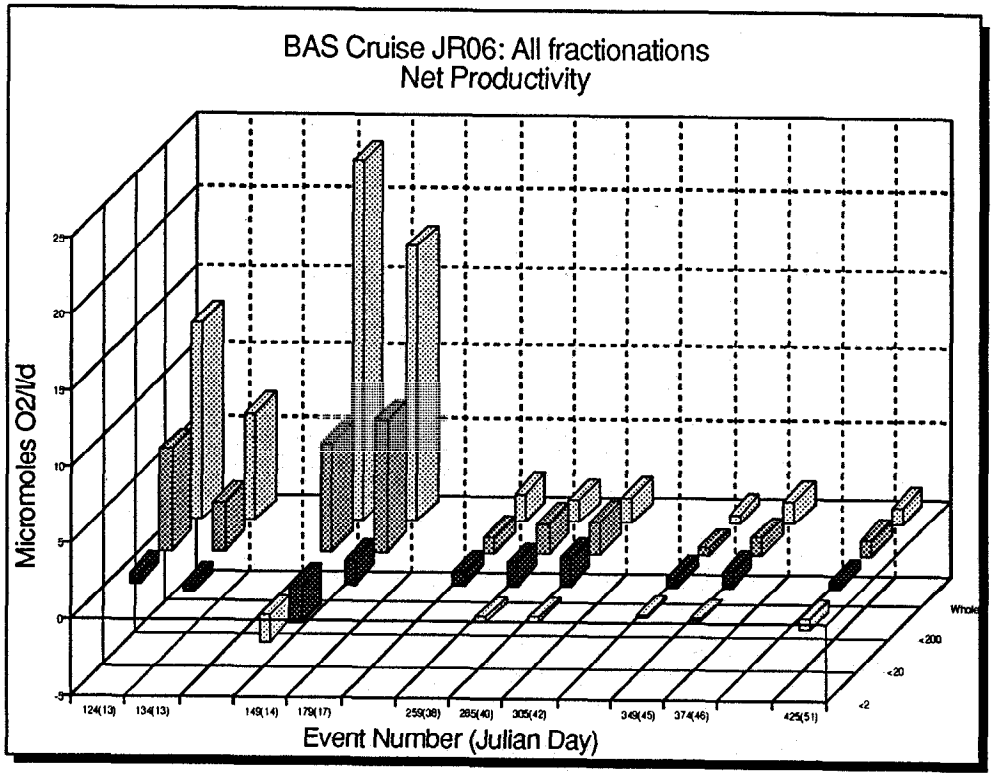

BAS Cruise JR06 : All fractionations
Gross Productivity
Micromoles O2/l/d
Event Number (Julian Day)
124(13)
134(13)
149(14)
179(17)
259(38)
285(40)
305(42)
349(45)
374(46)
425(51)
Whole
<200
<20
<2

Fig 4


BAS Cruise JR06: All fractionations
Net Productivity
Micromoles O2/l/d
25
20
15
10
5
0
-5
124(13)
134(13)
149(14)
179(17)
259(38)
285(40)
305(42)
349(45)
374(46)
425(51)
Whole
<200
<20
<2
Event Number (Julian Day)

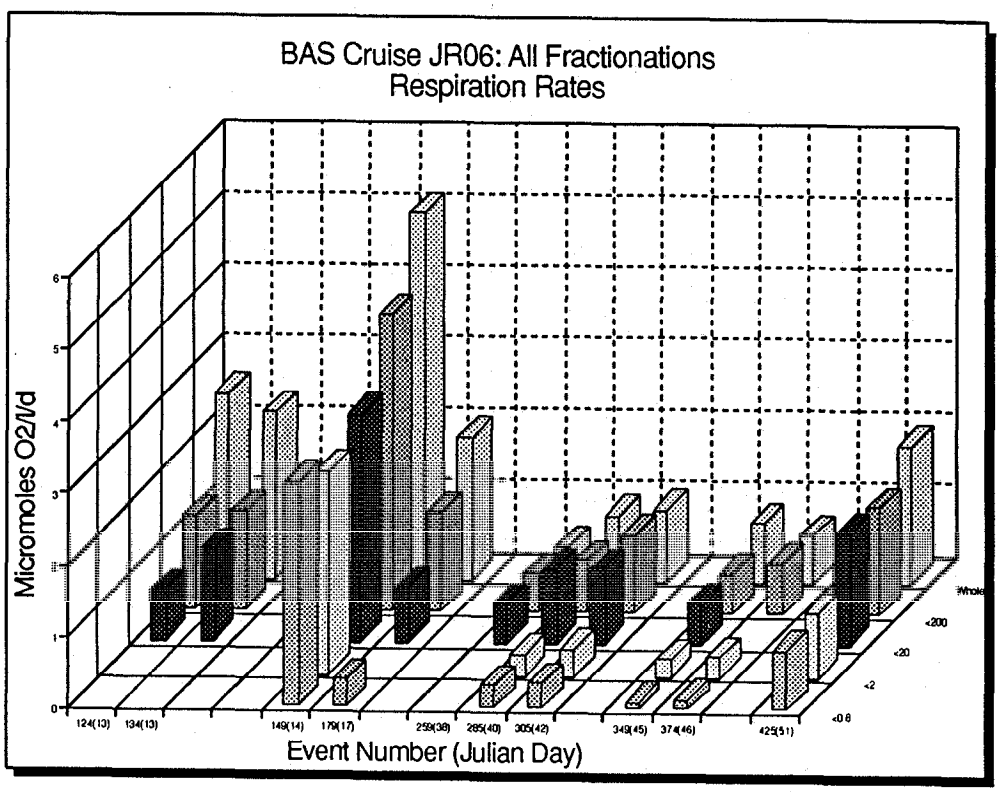
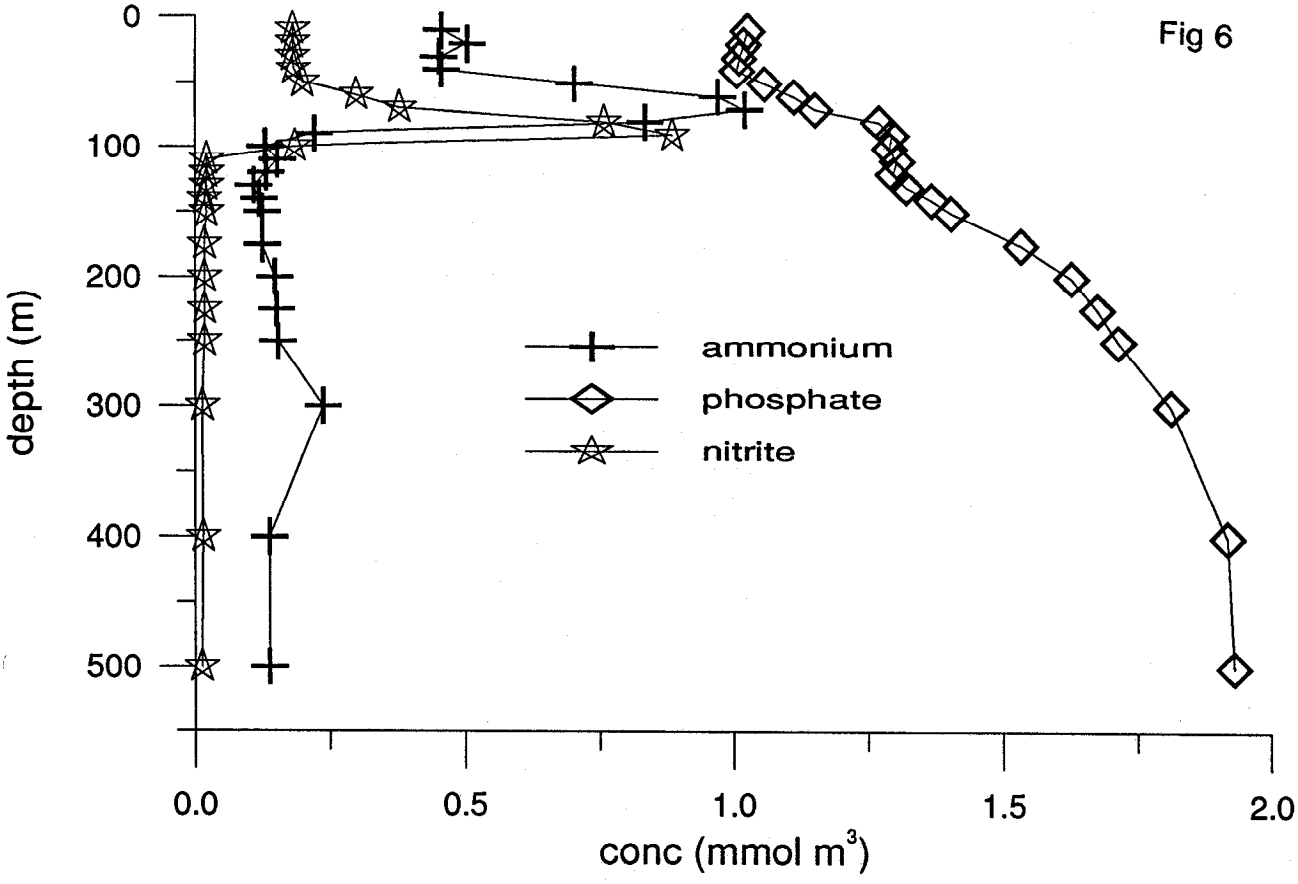
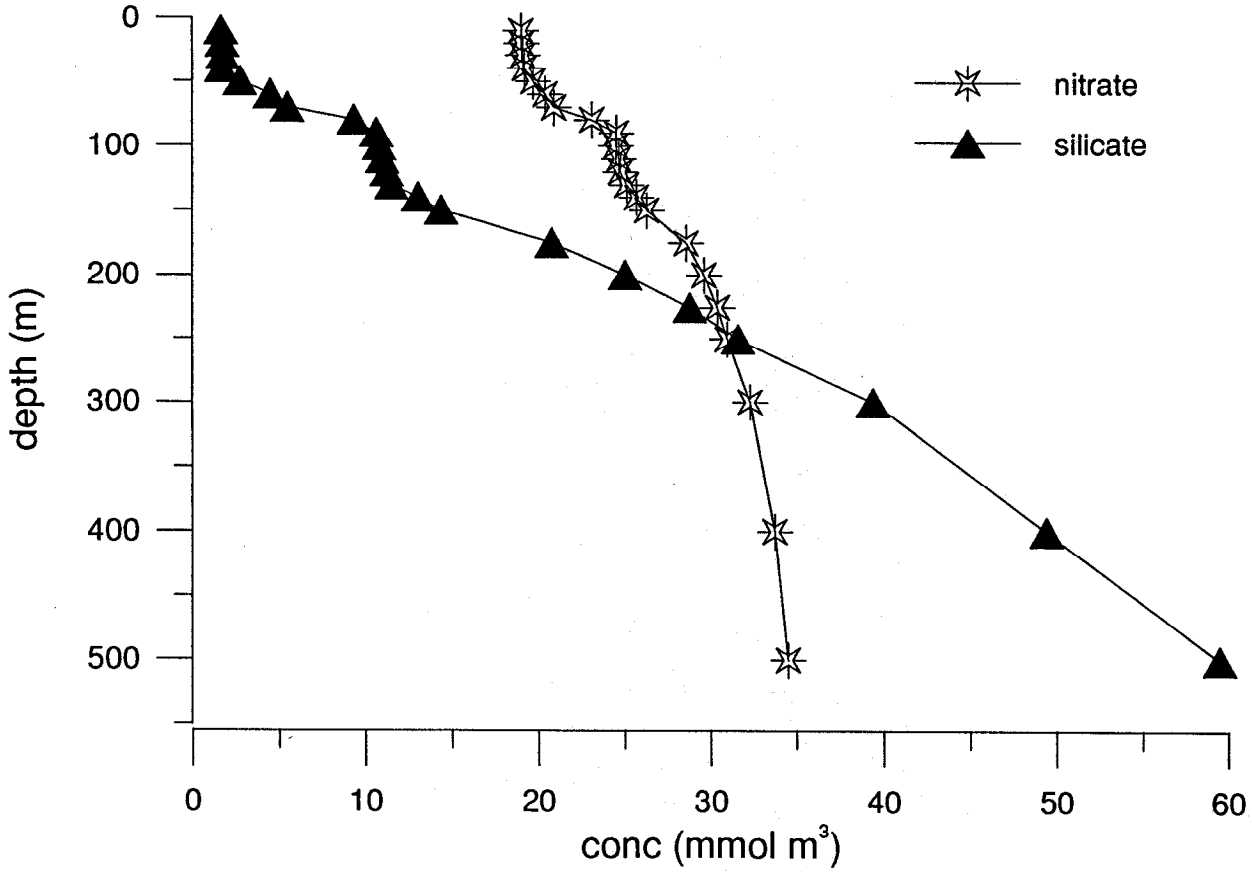

BAS Cruise JR06: All Fractionations
Respiration Rates
Micromoles O2/l/d
6
5
4
3
2
1
0
124(13)
134(13)
149(14)
179(17)
259(38)
285(40)
305(42)
349(45)
374(46)
425(51)
Whole
<200
<20
<2
<0.8
Event Number (Julian Day)

Fig 5

Fig 6


depth (m)
0
100
200
300
400
500
ammonium
phosphate
nitrite
0.0
0.5
1.0
1.5
2.0
conc (mmol m^3)


depth (m)
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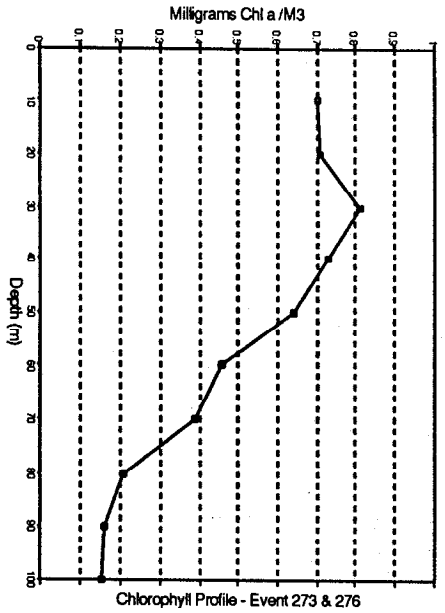
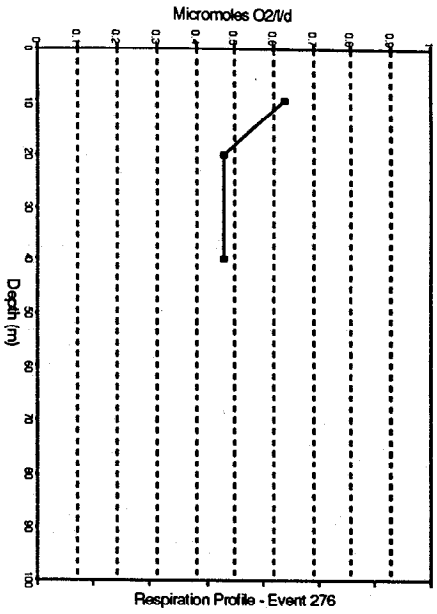
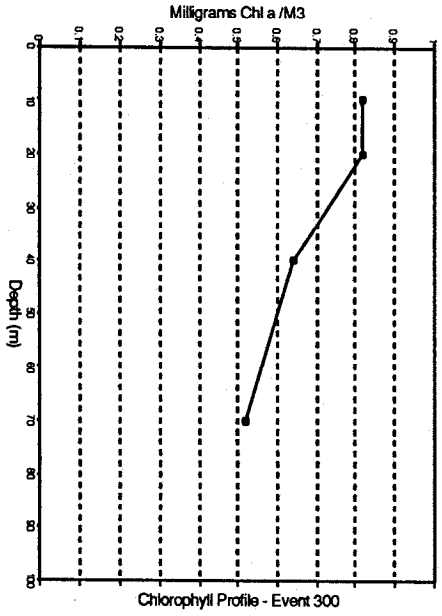
100
200
300
400
500
nitrate
silicate
0
10
20
30
40
50
60
conc (mmol m^3)


Milligrams Chl a /M3
Depth (m)
Chlorophyll Profile - Event 273 & 276


Micromoles O2/l/d
Depth (m)
Respiration Profile - Event 276


Milligrams Chl a /M3
Depth (m)
Chlorophyll Profile - Event 300

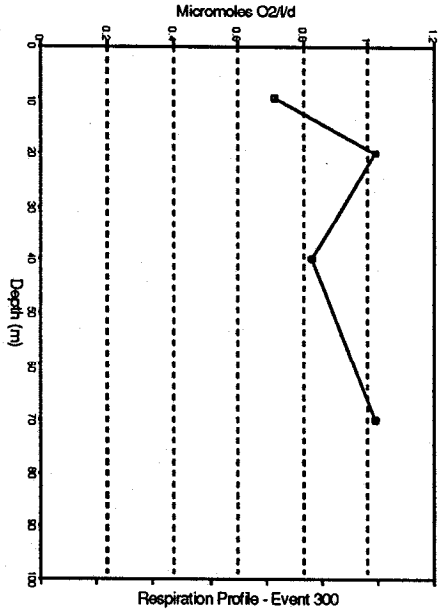
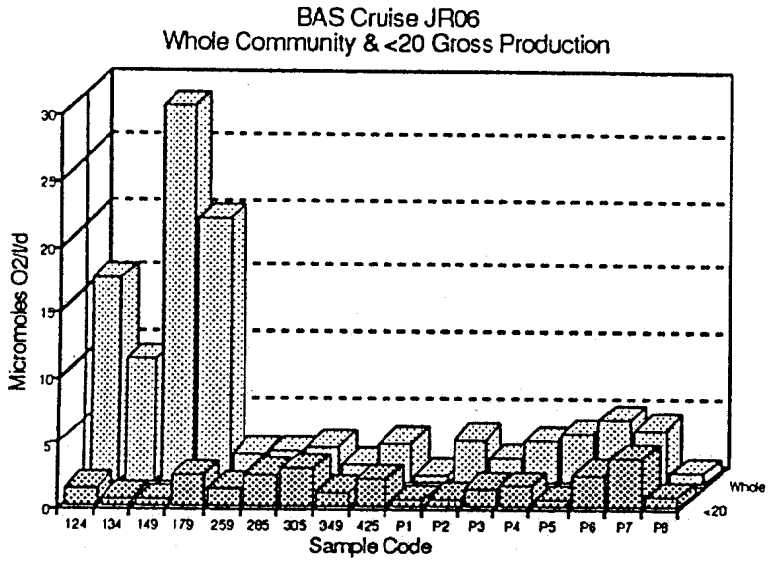
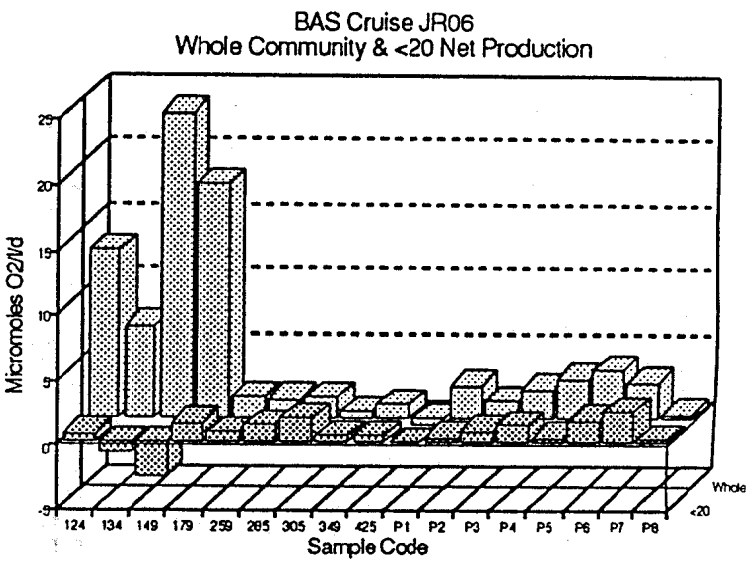

Micromoles O2/l/d
Depth (m)
Respiration Profile - Event 300

Fig 7


BAS Cruise JR06
Whole Community & <20 Gross Production
Micromoles O2/l/d
30
25
20
15
10
5
0
124 134 149 179 259 285 305 349 425 P1 P2 P3 P4 P5 P6 P7 P8
Whole
<20
Sample Code


BAS Cruise JR06
Whole Community & <20 Net Production
Micromoles O2/l/d
25
20
15
10
5
0
-5
124 134 149 179 259 285 305 349 425 P1 P2 P3 P4 P5 P6 P7 P8
Whole
<20
Sample Code

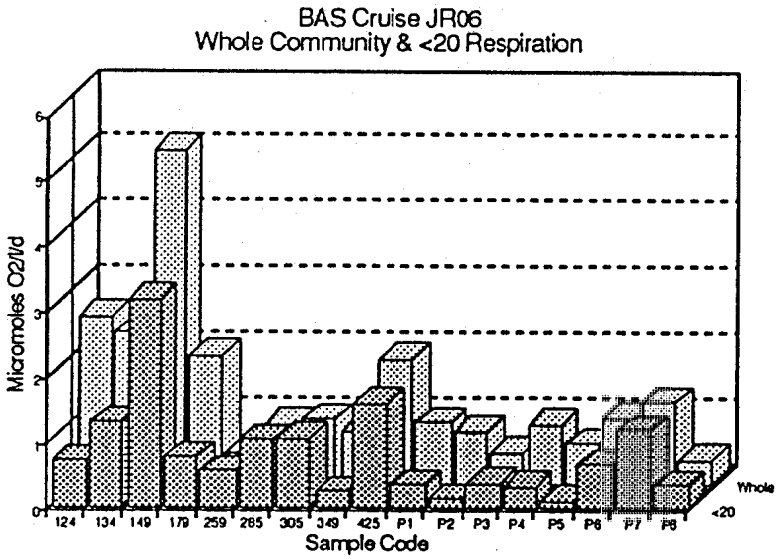

BAS Cruise JR06
Whole Community & <20 Respiration
Micromoles O2/l/d
6
5
4
3
2
1
0
124 134 149 179 259 285 305 349 425 P1 P2 P3 P4 P5 P6 P7 P8
Whole
<20
Sample Code

Fig 8

23. Secondary Production Studies -

by Peter Ward, Angus Atkinson, Rachael Shreeve

Summary:

Experimental work again concentrated on copepod egg production and grazing studies, whilst field sampling with vertically hauled Z nets (169 hauls) provided material not only for experimental purposes, but also to provide information on mesoplankton composition and abundance at the biomass spectrum stations and on various of the transects run. Double oblique LHPR profiles were also taken to 200 m at both biomass spectrum stations, 7 at the krill station on leg 1 and an abbreviated series of 5 at the squid station on leg 2. The ascent profiles will be used to describe zooplankton abundance and species composition in relation to vertical distribution with particular reference to the distribution of eggs and females. The descent profiles have been frozen and will be used to examine diurnal variation in gut fullness and fluorescence of selected species (see grazing studies). During the first series the LHPR system sustained some minor damage which accounted for the loss of a nose cone and flow meter. However during the second series it was effectively written off for the remainder of the cruise. Five of a projected series of 8 hauls had been completed before deteriorating weather forced us to abandon its use. The system was left lashed down in place on the afterdeck. Later in the day, with the vessel hove to in a force 10/11, waves broke over the stern and swamped the gear which resulted in distortion of the frame such that it will be of no further use. The coarse recorder box was also damaged and although the motor and gearing were left intact the perspex box was broken. This should however be repairable. To get the system operational again we will need to purchase a new frame, nose cones and flow meters, as well as meeting the cost of repairing the recorder box. I will cost this on return to the UK. It is worth noting that before its demise the system was working extremely well, largely thanks to the efforts of Paul Woodroffe who had successfully interfaced the electro-mechanical side of the system with the DWNM. On the first leg the loss of the 38 cm inlet diameter nose cone meant that we had to use our spare which only has a 20 cm diameter inlet and accordingly samples only about 25% of the volume taken in by the larger one. This was not a problem at the krill biomass station where quantities of zooplankton were sufficient to provide strong signals on the gauzes. However, at the squid station, catches were extremely low although it was clear that the majority of the plankton was in the top 50 m.

Copepod Egg Production Studies (Peter Ward Rachael Shreeve)

These commenced as soon as we crossed the Polar Front and gathered enough material to start experiments. The main study copepod on leg 1 was *Rhincalanus gigas* which dominated catches in terms of biomass. We had hoped to continue comparative work with *Calanus simillimus* but this was not possible until the start of leg 2 when it became much more abundant in catches. Small numbers of *Calanoides acutus* and *Calanus propinquus* were also incubated during the first leg.

Leg 1

Short term (24hr) incubations in filtered seawater of randomly selected females indicated that between 60-70% of *R. gigas* females spawned during this period. Samples of eggs and copepodite stages were also taken and frozen for biochemical analysis. Long term incubations with groups of animals maintained in 2l jars with enriched natural particulates were less successful. Spawning rates were generally low in comparison to field data, probably due to 'bottle effects'. We had hoped to use cultured algae as a source of food to feed these animals to excess but our preferred choice, *Thalassiosira weisflogii*, crashed on the way south and *Dunaliella* sp.(7 μm), has, as we suspected, proved an unsatisfactory food source for *R. gigas*, probably because of its small size. The culturing system does however work extremely well and will be worth playing with in Cambridge to grow up some of the larger species.

A number of egg hatching experiments were also undertaken which indicated hatching times of ca. 4-6 days for *R. gigas* and ca. 3-4 days for *C. simillimus* and at temperatures of around 2°C.

Leg 2

Net sampling and incubations commenced at a station worked at Shag Rocks on the way in to South Georgia. This time *C. simillimus* was relatively abundant as was *R. gigas* with ca. 30% - 50% of females of the former species producing eggs. During the course of the second leg very few ripe *R. gigas* were found and instantaneous rates of egg production were very low or negligible.

On this leg long-term experiments were performed on females of 3 species, *C.simillimus, R. gigas* and *C. propinquus*, the former species being obtained directly from net hauls during the course of the second leg, whilst ripe *R. gigas* taken on the first leg and which had been maintained in groups, were set up individually, numbers being supplemented by the few ripe females taken in the early net hauls of the second leg. Female *C. propinquus* were entirely drawn from the first leg. All females were maintained at temperatures ranging from ca. 3-4.5°C.

Food was supplied daily in the form of ambient seawater enhanced with either phytoplankton concentrated via filtration through a 20 micron sieve (*R. gigas*) or with a standard concentration (> 300 µg l-1)of *Dunaliella* sp. culture (*C. simillimus* and *C. propinquus*). In the case of *R. gigas* it was impossible to supply a standard ration. Chlorophyll levels had fallen dramatically since the first leg to near winter levels in many parts of the area and with the ship moving from station to station we had to accept that the food supply would be variable. Lugols samples and chlorophyll determinations were made on each days supply of natural food and the multisizer used to determine culture concentrations, so that a standard ration could be provided for *C. simillimus* and *C. propinquus*. Chlorophyll determinations were also made on the culture. At the end of the experiments females were frozen for biochemical analysis.

Rhincalanus gigas

Just over 30 females were maintained in 2l jars set up on the grazing wheels or in 1.5l jars. Experiments were run for a little over 3 weeks until it became clear that egg production had become negligible and mortality had increased to an unacceptable level. In the first 14 days the most productive females produced between 5-8 clutches each at an average of 12-17 eggs female - 1 day-1. Overall average clutch size was around 25 eggs which corresponds well to the 33 eggs per clutch obtained from instantaneous measurements carried out during cruise JR03. Although we experienced difficulties with this species, data do show that they are capable of producing eggs at the same sorts of rates reported for other polar and non-polar species. Observations also appeared to indicate that egg production was fueled by food ingested rather than by mobilisation of lipid. Egg producers invariably produced more faecal pellets than those that didn't spawn, although this wasn't quantified. Similarly despite having appreciable reserves of lipid, many females stayed in a reproductively immature state. No attempt was made to measure grazing rates of individuals. Maintenance in 2l jars mean't that significant rates of particle depletion would have been difficult to demonstrate.

Calanus propinquus

12 females were maintained in 500 ml polythene beakers for a period of 28 days. Again, after a period of approximately 12 days egg production tailed off and mortality increased. The most productive females produced between 4-6 clutches each in 12 days at an average of ca.18 eggs female-1 day-1. Overall, average clutch size was 39 eggs, very close to the mean clutch size of 37.3 eggs reported for this species from the Weddell Sea (Kosobokova in press). During the twelve day period reported on here, female's diet was only supplemented by small amounts of culture. Subsequently, despite the addition of greater quantities, egg production tailed off for all but one female which responded by increasing its output. All females accepted the culture as food as evidenced by the great number of faecal pellets produced. However a question must remain as to its ability to provide sufficient nourishment for this species given the falling rates of egg production seen in the majority of females.

Calanus simillimus

Of the three species maintained we were most successful with this one. Two-three long term experiments were started at different times during the course of leg 2, the longest continuing for 24 days. Females were maintained in a mixture of 125 ml or 250 ml polyethylene pots and fed culture daily. During the first 8 days of the longest experiment egg production averaged 10 eggs female-1 day-1 (average clutch size 16.25 eggs) with a mean of 60% of the population spawning day-1. At this point the culture crashed and for three days females were fed exclusively at ambient seawater concentrations (enhanced) until a new culture became established. Egg production fell to 4 eggs female-1 day-1 (mean clutch size 7 eggs) and continued at this level to the end of the experiment, despite re-introduction of the culture. Immediately following the demise of the culture the percentage of females spawning per day fell from 60% to around 40-45% for 4 days although then quickly climbed back to a mean of 63%. Placement of the females in filtered seawater for 2 days had no measurable effects either in terms of clutch size or the proportion of females spawning. It appeared that in this experiment the frequency of clutch production was relatively stable whereas clutch size was less so, indicating that egg production might be a two stage physiological process (see Peterson 1988).

The second experiment ran for 15 days. Initially 35 females were set up and treated as described above. After 8 days females that had failed to spawn at all were removed and frozen for biochemical analysis. The remaining 19 females increased egg production over the remaining 7 days of the experiment from 2.8 to 6.7 eggs female-1 day-1. The mean clutch size also increased from 4.9 to 8.7 eggs.

In the final experiment 35 females that had been taken for the purposes of producing eggs for biochemical analysis were removed from ambient seawater after 7 days and set up in culture. The experiment was run for a further 7 days. Average egg production rates ranged from 1.17 - 3.64 female-1 day-1 while average clutch size stayed fairly constant at 4-6 eggs. The proportion of the population spawning ranged from 20% on the first day to between 45% and 60% on subsequent days.

By way of comparison the egg production rates of *C.simillimus*, derived from 24 hour incubations (instantaneous rates) on leg 2 averaged 7 egg female-1 day-1 and the mean clutch size was 15.6 eggs. In the first experiment average egg production and clutch size initially paralleled instantaneous rates although later halved. In the second average egg production though initially low increased to around the instantaneous rates largely through an increased proportion of females spawning each day (ca.60%-75% cf an average instantaneous rate of ca.45%) as clutch size remained static at approximately half that of the instantaneous figure. In the third experiment both expressions of egg production were well below the instantaneous estimates. Clearly then there is variability in the performance of batches of individuals maintained under identical conditions. This almost certainly relates to physiological condition and past reproductive history. The data sets will be examined in this light and related to geographical location, species population structure at the time of capture and any significant biochemical differences.

Copepod grazing studies (A. Atkinson)

Objective and methods

The main objective was to continue an investigation into the relationship between copepod size and feeding rate. A secondary objective was to compare diurnal feeding periodicity and vertical migration across the spectrum of copepod body size. Two methods of measuring grazing rate were used. The first was to incubate copepods in natural seawater for 24 hrs and compare the numbers of food items at the beginning and end of the experiment. Secondly the gut fluorescence method was used to quantify the amount of chlorophyll in the guts of freshly caught copepods. These values were then combined with gut throughput times, determined from 30 min. starvation experiments, to provide estimates of feeding rate.

Results

Leg 1

Most study emphasis was placed on the krill biomass spectrum station, where 5 incubation experiments were run. A further experiment was run while transecting. Only one of the incubation experiments has been analysed so far, but an indication of relative grazing rates was provided by comparing the total amount of chlorophyll in the incubation water at the beginning and end of the experiment, using the Turner fluorometer. The provisional picture is that the principal copepod in terms of biomass, *Rhincalanus gigas,* had low mass specific grazing rates. *Calanus propinquus* and early copepodites of *Metridia gerlachei* had the highest mass specific feeding rates, of those measured. Copepod biomass was heavily dominated by large copepods, and likewise the diatom bloom on which they were feeding was dominated by large diatoms, with many colonies of *Odontella* spp. and *Corethron* spp. being over 1 mm long. The copepods were fully capable of ingesting these long colonies.

It was not possible to use the gut fluorescence method to measure grazing at the biomass station, because I could not separate copepods and their food for the starvation experiments, However, we obtained extensive coverage of diurnal feeding periodicity with 39 stratified vertical net hauls and 7 LHPR tows within a 24 h period.

Leg 2

Again, most study emphasis was placed on the squid biomass station, with 5 bottle incubations performed there, plus a further two near South Georgia. In contrast to the krill biomass site, the community was dominated by subantarctic species, with *Calanus simillimus* and *Neocalanus tonsus* comprising most of the biomass. Also small copepods, such as *Oithona* spp. were much more numerous. Their food was much more scarce than at the krill station, and mainly comprised nanoplanktonic flagellates, pennate diatoms and ciliates. Cell counts have been made on one of the incubation experiments, and these revealed high feeding rates on the larger particles (ciliates and pennate diatoms). The small species and stages (*Oithona* spp., *Clausocalanus laticeps* and early copepodites of *Calanus simillimus*) appeared to have higher mass specific feeding rates than the older copepodites of *Calanus simillimus* and *Neocalanus tonsus*. Feeding rates were also measured for each experiment by measuring the decrease in chlorophyll (in cells > 1 um) during the incubation. Overall feeding rates on cells > 1 μm was low, in contrast to the microscope results. This suggests that most of the available chlorophyll was in particles too small to be eaten.

The gut fluorescence/gut evacuation method was also used to estimate feeding rates. Fifteen gut evacuation experiments were run at different times of day and night, and the descent profiles from the LHPR tows was frozen for fluorescence analysis. These will provide a picture of diurnal vertical migration and feeding, as well as provide an independent measure of feeding rate in relation to copepod size.

24. Underway acoustic studies -

by JL Watkins, AWA Murray & C Goss

Introduction

On this cruise acoustic observations have been carried as part of most projects undertaken over a range of different time and space scales. Acoustics have been carried out on all the large scale transects covering the passages between Stanley, South Georgia, Signy and the Weddell Sea. Acoustics have provided a key surveying tool for the medium-scale biomass spectra studies and also fine-scale coverage of individual net hauls. Finally acoustics have been a key component of the dedicated krill work undertaken in conjunction with the RS *Africana*. More details of these individual projects are provided in the relevant sections. Here we discuss general points of relevance to all acoustic studies undertaken on this cruise.

All work has utilized the Simrad EK500 system with split beam sounders working at 120 and 38 kHz. In addition during the second leg some data have been collected with the newly installed 200 kHz single beam transducer. This is the third cruise of James Clark Ross on which acoustic data have been collected, however logging and data validation techniques are still being developed and so are discussed in detail in this report.

Calibration

Two calibrations sessions using standard target spheres in accordance with ICES and BAS protocols have been carried out during the cruise. Calibration narratives, results and comparisons with previous calibrations are given in appendix I.

Operational settings

The EK500 system is an extremely complex system and as a result the options available on the menus are extremely numerous. In many cases, however, once the machine is calibrated and set up only a small number need be regularly altered. These generally comprise depth range settings, layer settings and printer and display settings. Lists of settings in use are available from JLW and a standard setup file has been created for future use.

Since cruise JR03 (January 1993) several major changes have been made to operational settings:
First the use of the noise margin has been disabled by setting *operation menu/ noise margin - 0 dB*. The noise margin is designed to allow the recording of signal that is a set number of dB above the background noise level. Although Simrad describe their algorithm as *quite robust*, a single level applies to all depths and frequencies. Additionally it is possible that the background level of noise may be raised in areas with targets covering a large depth range. Therefore after consultation with John Simmonds (Head of Acoustics Group, SOFAD, Aberdeen) we decided that it would be better not to use this facility.
Second, two thresholds have been logged consistently through out the cruise. A -100 dB threshold (the minimum allowed) should allow as far as possible for the noise level to be assessed and removed during post-processing. A -70 dB threshold will only allow relatively strong signals to pass through for integration and as a result the integrated output from the EK500 should be suitable for general analysis.

Logging

Output from the EK500 has been logged as colour printout and to computer. Two systems have been operated to log the data to computer. Data from all transects and events have been recorded through a LabWindows program (EKlog94) running on an IBM PS/2 386 computer. This machine is connected to the EK500 via serial port number one. Data held on the IBM were backed up to 80 Mbyte DC2080 tapes using EZTAPE version 3.1. Data were also recorded continuously over the LAN to BAS2 Sun workstation.

In both cases the data require considerable processing before they can be used. These processes are described in the next section.

Processing

1) *Data logged through EKlog94* For each dataset the program writes three files. Files with a .dat suffix contain the data stream exactly as it is sent out from the EK500. Files with a .cnv suffix contain formatted data with each record containing date, time, top depth, bottom depth, Sv for 38 kHz, Sv for 120 kHz, (Sv for 200 kHz). Finally files with a .cmt suffix contain commands and comments sent to and from the machine during a logging session. CNV files are loaded onto the VAX computer and run through a suite of GENSTAT programs. EKREAD.G5 reads the data file, writes a formatted output file which contains addition fields of decimal time and threshold, and finally creates a GENSTAT backing store file for further processing. EKUNI.G5 reads the backing store file and creates an output file suitable for plotting in UNIRAS. EKDESC.G5 also reads from the backing store and then produces summary statistics for different thresholds and frequencies. EKENV.G5 produces a plot of the minimum and maximum Sv values for each layer while EKHIST.G5 produces histograms of Sv .

Once a file has been processed through the GENSTAT programs it can be viewed in UNIMAP as a colour 2-D dot plot and compared with the colour printout. The UNIMAP data editor has been used to change the values of suspect data directly on the contour plot to a large integer (about 1000). The next step will be to write a program to read the edited UNIRAS file, pick out the times and depths where suspect data have been flagged (with values >500) and then modify the data file so that suspect records are tagged appropriately.

One unexpected problem we have encountered this trip is that all of the .cnv files contain a duplicate reset at the end. In addition many files contain 3 resets from a previous session at the beginning of the file, some of the data in these resets is spurious. This is likely to be caused by data being buffered in either the PC or the EK500. In a few files blocks of data from different files have been incorporated into the file. It is not known why this happened but when the hard disk was examined with Norton Disk Doctor it was found to be very fragmented, this may have had some effect. The result of these problems is that a preliminary examination and edit is required before the file is sent for further processing. Summary tables showing state of data editing and processing of acoustic files collected on cruise are held by JLW and are freely available.

2) *Data logged through LAN to SUN* This will eventually be the preferred way of logging the data but this cruise a working set of programs to decode the binary output has not been available. Development of these programs has continued in Cambridge during the cruise and several versions have been tested. At present there is no way of processing this data.

Problems

Ping rate, false bottom and real bottom detection - the rate at which the sounders fire (or ping) can either be left to the EK500 (ping rate = 0 means that it pings as fast as possible) or can be specified by the user. If ping rate = 0 is used then the number of pings per minute depends on the water depth or the maximum bottom setting. A fixed ping rate is desirable for several reasons (i) each reset will have the same number of pings which is desirable for statistical reasons (ii) display and paper trace will run at a constant speed and so targets of similar size and shape will look the same. Unfortunately during integration resets and over deep water the ping rate needs to be longer than in shallow water. A ping rate of 1.5 to 2 seconds is necessary to avoid ping interval warnings every time the integrator sends data to the PC. In addition at fast and medium ping rates (less than 2 seconds), the 38 kHz sounder can pick up false bottom indications. These occur when the bottom return from ping one is picked up during ping two. Thus a false bottom shallower than the real bottom appears. Such false bottom echoes can occur over water depths from about 500-1500 m. One solution is to decrease the ping rate to somewhere between 3 & 5 seconds, thus the sounder does not ping again until all possible returns from the previous ping have died away. An alternative solution is to set a very deep maximum depth (2500-3000 m) which has a similar effect. Unfortunately there are two undesirable effects that occur with either of the above solutions. First the slow ping rate gives less resolution than a medium rate of 1.5 second. Secondly there is an

effect on the averaging interval for each layer. The effect of averaging interval is discussed in detail in the next section.

Averaging interval - if integrator tables are printed out then for each main layer in each reset an 'averaging layer thickness' is produced. This should be the difference between the top and the bottom of each layer unless the layer is intersected by bottom or transmitter pulse (Simrad manual P2259E/O page:5). However, under many conditions the values in the 120 kHz tables are smaller than those in the 38 kHz table. On pelagic layer settings only one set of parameter values consistently produced averaging intervals which corresponded to the expected difference: ping rate = 0, minimum bottom depth 250 m, maximum bottom depth 500 m. Other settings of any of these parameters produced a smaller averaging interval on 120 kHz (or both 120 and 200 kHz if 3 sounders operating), at times the averaging interval for an expected 50 m layer was less than 20 m. **This adversely affects the Sv values produced by EKlog94.** While it will be possible to compensate for data collected when integration tables were printed out, there are some data sets where such information was not collected.

Acoustic 'dropout' - on some of the long transects extensive and continuous deep layers were observed with the 38 kHz sounder. Under certain conditions these layers were interrupted by blank streaks from the surface to the bottom of the sounder range. Once alerted to the presence of these blank streaks both the current display and other printouts could be examined and similar streaks recognized. During a streak the 38 kHz sounder loses the bottom, for a number of pings the depth is displayed as 0.0 m. There appears to be some connection with the surface noise layer, blanks occurring with noise spikes in the top 10 m. Thus it is likely that these blanks are due to aeration under the hull. These streaks or acoustic 'dropout' always appeared to affect 38 kHz records more than 120 kHz records. **This adversely affects the Sv values logged.** The streaking is particularly noticeable in rough weather and when the ship changes course, however, some examples have been found when towing nets at 3-4 knots under quite moderate conditions.

An initial fax to Simrad was most unhelpful. Simrad could only suggest we try something we had told them in our original fax that we had already tried. Now that we have a much more extensive set of observations this problem will need to be followed up. Interestingly Aberdeen use their 38 kHz sounder in a towed body because it works better there while the 120 kHz sounder works better in the hull.

Required action after cruise

1) Problem solving - contact Simrad about averaging of layer thickness
- investigate ways to reduce blank streaking including use of towed bodies

2) Data logging - continue development of level C data logging so that on next cruise we do not have to use PC and all associated problems

3) Data processing - develop/commission data editing software to allow GUI/mouse editing of data
- prioritize data processing and analysis

Preliminary results

Dual frequency (120 and 38 kHz) acoustic data have been collected on all phases of JR06. Usually data have been collected from 120 separate 2 metre layers between 10 and 250 m. Each layer has been logged at two thresholds (-100 and -70 dB) for each frequency. Integration periods have varied from every 6 minutes (equivalent to every nautical mile) on long transects to every minute during net hauls. For some of the transects and net hauls on leg 2 integration to 500 m was undertaken. In addition during the second leg 200 kHz data was also collected during the joint ship work with Africana. Only data from the first leg have been validated so far, some preliminary findings are given below.

1) Large scale transects: - data have been collected while on passage between Stanley and South Georgia, South Georgia and Signy, Signy and Stanley. The weather has not always been optimal for acoustics and the speed of some of the transects has been high (up to 13 knots) when

conditions have been suitable. It has been possible to see the development of the deep scattering layers on several transects. On the transect to South Georgia this appeared south of the Polar Front as a diffuse layer with quite strong and compact targets embedded within the layer. On the transect from South Georgia to Signy, strong targets were observed in the top 100 m of the water column 50 miles south of Cooper Island. These targets backscattered more strongly at 38 kHz than at 120 kHz and are unlikely to be krill or zooplankton. Approaching Signy the ship ran parallel to the 250 m contour around the South of Coronation Island, many strong targets were detected with acoustic characteristics expected of krill swarms.

2) Meso and fine scale surveys on leg 1: - a zig-zag set of transects along the northern side of South Georgia and a series of smaller scale transects over the shallow bank north of Cape Charlotte did not reveal any krill swarms. However a persistent but diffuse scattering layer was frequently observed, this was hardly detectable at 38 kHz and it is likely to represent a mixed zooplankton community comprising small euphausiids, amphipods and large copepods. A series of surveys north of Bird Island revealed a ridge and a canyon leading off the shelf break. Here a diffuse scattering layer (Figure 1) was found trailing downstream from the ridge. At the edge of the canyon krill swarms were found. Above some of these swarms the echo-sounder detected very small but dense targets, it is thought that these could well have been predators such as penguins or fur seals. Where these very dense targets were found, the swarm or part of the swarm was deeper than the surrounding swarm.

A zig-zag survey to the west and north of Coronation Island, South Orkneys, detected large numbers of dense targets both around the shelf break and over deep water. The shape and relative backscattering at 120 and 38 kHz suggest that these targets were krill.

25. Appendix I: Acoustic Calibration of Simrad EK500 echo-sounder.

Two separate acoustic calibrations have been carried at Leith Harbour, South Georgia, this cruise. The first took place on 7 January 1994 after the first two transects to the island had been undertaken. The second took place on 17 February 1994 as a joint calibration with RS Africana prior to the two ship krill survey around South Georgia. Each calibration is described below and the results along with results from previous calibrations of the EK500 system are shown at the end of this appendix.

Calibration narrative, 7 January 1994.

Ship anchored in Leith Harbour with the stern tied to the mooring buoy. A CTD cast was completed by 1100 (local) and from three selected depths (6, 16, 30 m) the salinity (33.0, 33.5, 33.6%) and temperature (2.8, 2.0, 1.6oC) were averaged to give a sound velocity of 1457 ms-1.

At 1130 (local) the 60 mm copper sphere was deployed under the 38 kHz transducer using the standard 3 line setup detailed in the MLSD calibration protocols document. As expected the sphere was observed on the echo-sounder screen but no sign of it was observed in TS Detection-1 Menu on the EK500. Over 4 hours of swinging the sphere through amounts varying between inches and metres failed to centre the sphere. Each time the sphere approached the centre of the transducer it disappeared from the TS Detection-1 Menu display for minutes at a time, when the sphere did appear it was only for a fleeting moment. At first we assumed that the sphere was in a side lobe. However, further investigation revealed a pattern, the sphere gave reasonably compensated TS values near the edge of the beam in the port forward quadrant, but very poor values in other areas. Finally this lead to the conclusion that not all the quadrants of the sounder were working. At this point we jiggled the wires on the transducer cable at the back of the system box. This immediately produced an image of the sphere near the centre of the target circle. Upon centering the sphere the expected TS for a 60 mm copper sphere appeared in the TS window (-33.7 dB).

Given the lateness of the hour (1730 local) and the similarity of this TS value with previous calibration values (see appendix 2), we decided to change to the 23 mm copper sphere to calibrate the 120 kHz sounder rather than undertake the Sv calibration of the 38 kHz sounder.

The 23 mm sphere with the 60 mm copper 2 metres underneath was suspended under the 120 kHz transducer. The observed target strength was a lot higher than expected (-30 rather than -40 dB). This resulted in a change of TS transducer gain from 18.9 to 23.6 dB. The integration of the sphere produced a corresponding change in Sa transducer gain from 18.6 to 22.9 dB.

Initial calculations of the new TS and Sv transducer gain were complicated because the sphere TS for a 30 mm sphere was used initially. Thus on leaving Leith the values entered were respectively 21.3 and 21.1 dB. On finding the correct TS chart for the 23 mm sphere the correct values were calculated (23.6, 22.9 dB). Given the large difference between the results for this calibration and those from previous calibrations at Leith (24/1/93) and Potter Cove (31/10/92) the TS and Sa transducer values were changed back to their pre-calibration values, at least until the results were confirmed by the second calibration expected to take place in mid-February.

Calibration narrative, 17 February 1994

Ship arrived in Leith Harbour at 0630, we anchored in 45 m of water near the whaling station because RS Africana was tied up to the buoy. The sea was calm and there was no wind. The tungsten carbide sphere was in place under the 120 kHz sounder by 0730 (local). Prior to anchoring the ship deployed heaving lines under the bow and around the accommodation, thus sphere rigging was quickly and easily carried out. While awaiting the CTD a test of the effect of averaging interval on Sa was conducted (for more details see main acoustic report). Files

9404810_.cnv, 9404811_.cnv & 9404811a.cnv contain data with different combinations of bottom settings giving averaging intervals equating to the layer thickness or only proportions of the layer thickness.

Salinity and temperature values every 2 m to 30 m taken from a CTD cast after breakfast were averaged to obtain the sound speed of the water under the hull. Once the TS and Sv transducer gains had been calculated, the Simrad LOBE program was run on the PS2 PC to map the beam. Some problems were experienced in getting this program to restart if the menu was re-entered without completely quitting first. The results from this calibration produced TS & Sv transducer gain settings between 2 and 1 dB lower than the calibration at the beginning of the cruise. Both 1994 calibrations produced settings substantially higher than those obtained in previous years. However, the longitudinal offset of about -0.78 degree has remained constant.

The same 38.1 mm tungsten carbide sphere was then positioned under the 38 kHz transducer. By this time the wind had started to blow and the ship lying to one anchor was sailing this way and that so that the sphere disappeared from the target window for long periods. Due to the position of the Africana it was not possible to use the buoy to tie to, however, the second anchor was deployed and this stabilized the ship sufficiently to allow calibration to proceed. The calibration resulted in a 2.5 dB shift in TS transducer gain! This was unexpected because the last 3 calibrations of the 38 kHz transducer had shown a variation of only 0.2 dB.

Finally the 15 mm sphere was deployed for the first 200 kHz calibration. To stabilize the small sphere the 60 mm copper sphere was hung underneath it on a 2 m piece of nylon monofilament. To help find the centre of this single beam transducer, the sphere was centred on the 120 kHz display initially, then the sphere moved until the maximum target strength value was obtained.

There was not enough time to repeat the 120 and 38 kHz calibrations using the Simrad copper spheres. It is recommended that at sufficient time (min. 24 hours) should be allocated to undertake a comprehensive calibration prior to the next cruise. The new calibration settings were entered into the EK500 via the setup file held in ***** on the IBM PS2.

Calibration summary and recommendations

During this cruise two calibrations have been carried out but unfortunately this has demonstrated a fair degree of variation. There is now a problem in deciding which settings should be used for the various parts of the cruise.

The fishing rods work well and the marks now allow consistent positioning of the sphere. However, the requirement to swing the sphere using radios to direct two people adjusting the line lengths is time consuming and inefficient. We should make up some simple motor-driven system to alter the lines directly from the UIC.

A very complete calibration using all the spheres and all pulse lengths should be carried out before the sounder is next used. Ideally this should be done in the UK on sea trials and also at the beginning of the next cruise. It is essential that we build up a data base as quickly as possible so that we can assess system stability.

Summary of 120 kHz calibrations for RRS James Clark Ross EK500 echo-sounder

Date	19 Aug 92	31 Oct 92	24 Jan 93	7 Jan 94	17 Feb 94
Place	Manacles	Potter Co.	Leith, SG	Leith,SG	Leith, SG
Water depth	47 m	36 m		50 m	47 m
Sea temp		-1.2		2.1	3.1
Salinity		33.4		33.37	33.77
Sound velocity		1442 m/s	1458 m/s	1457 m/s	1461 m/s
Absorption coefficient				27.99	
Angle sensitivity	17.0	15.7	15.7	15.7	15.7
Ping interval	0.0	0.0	0.0	0.0	0.0
Transmit power	Normal	Normal	Normal	Normal	Full
Max. power	1000 W	1000 W	1000 W	1000 W	1000 W
Pulse duration	Short	Medium	Long	Long	Long
Bandwidth	Narrow	Wide	Auto	Narrow	Auto
TS of sphere		-39.8[1]	-40.3	-40.3	
Default TS transducer gain			18.9	18.9	18.9
Measured TS		48.0	-41.9	-30.8	-34.4
Calibrated TS transducer		**18.9**	**18.1**	**23.6**	**21.6**
Calibrated TS					-39.7
Default equiv. 2-way beam		-18.3	-18.3	-18.3	-18.3
Trans. data 2-way beam					
Depth to sphere		20.5	20.9	20.3	19.1
Default Sv transducer gain			18.6	18.6	18.6
Theoretical Sa		725	620	661	852
Measured Sa		94	443	4909	3601
Calibrated Sv transducer		**18.6**	**17.9**	**22.9**	**21.7**
Calibrated Sa					
Default -3 dB beam width		9.3		9.3	9.3
Calibrated -3 dB beam		9.32			11.9
Longitudinal offset		-0.78			-0.74
Transversal offset		0.28			0.00

Summary of 38 kHz calibrations for RRS James Clark Ross EK500 echo-sounder

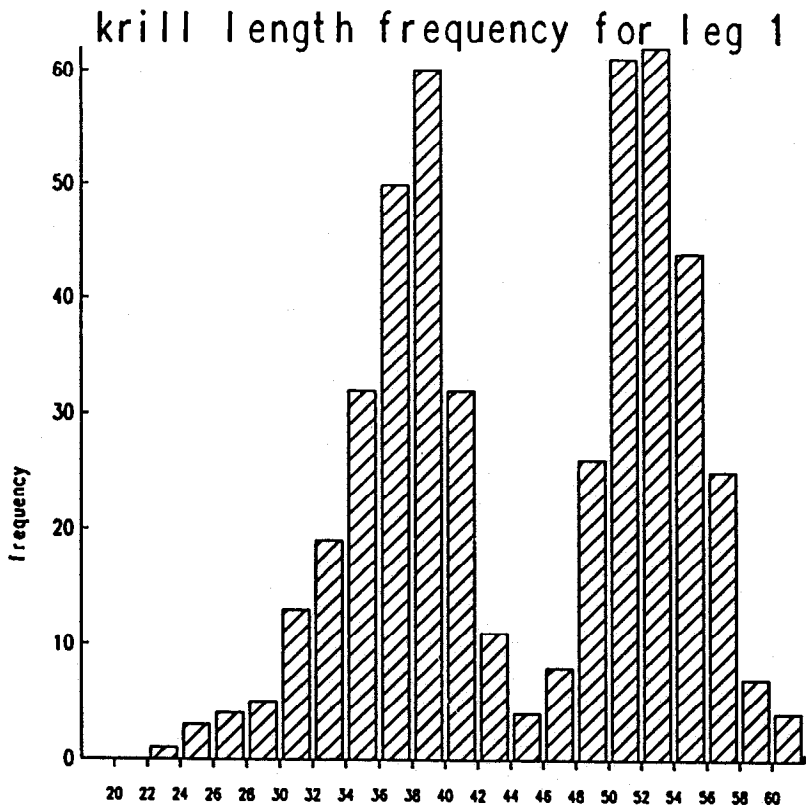
Date	19 Aug 92	31 Oct 92	24 Jan 93	7 Jan 94	17 Feb 94
Place	Manacles	Potter Co.	Leith, SG	Leith,SG	Leith, SG
Water depth	47 m	36 m		50 m	47 m
Sea temp		-1.2		2.1	3.1
Salinity		33.4		33.37	33.77
Sound velocity		1442 m/s	1458 m/s	1457 m/s	1461 m/s
Absorption coefficient				27.99	
Angle sensitivity	21.9	21.9	21.9	21.9	21.9
Ping interval	0.0	0.0	0.0	0.0	0.0
Transmit power	Normal	Normal	Normal	Normal	Full
Max. power	2000 W	2000 W	2000 W	2000 W	2000 W
Pulse duration	Short	Medium	Medium	Medium	Medium
Bandwidth	Wide	Wide	Auto	Auto	Auto
TS of sphere	-33.6	-42.2[1]	-33.7	-33.7	-42.2[1]
Default TS transducer gain		26.9	23.8	23.6	23.6
Measured TS		-48.1	-33.6	-33.7	-37.0
Calibrated TS transducer	**26.9**	**23.8**	**23.8**	**23.6**	**26.2**
Calibrated TS					-42.2
Default equiv. 2-way beam		-20.7	-20.7	-20.7	-20.7
Trans. data 2-way beam	-20.8	-20.8	-20.8	-20.8	-20.8
Depth to sphere	17.9	21.1	20.8	20.1	18.7
Default Sv transducer gain		26.5	23.8	23.6	23.6
Theoretical Sa		685	4993		852
Measured Sa		200	4536		2596
Calibrated Sv transducer	**26.5**	**23.8**	**23.6**		**26.0**
Calibrated Sa					
Default -3 dB beam width	7.3	7.3	7.3	7.3	7.3
Calibrated -3 dB beam	7.0	7.27			6.86[2]
Longitudinal offset	-0.2	0.03			-0.21
Transversal offset	0.0	-0.27			0.11

26. Krill Biology -

by JL Watkins

Krill from FNET (foredeck net), Multinet and RMT25 hauls have been analysed. A total of 471 krill were measured from over 500 caught during the week-long biomass spectrum study. The majority of krill were either immature animals with a modal total length of 39 mm or mature adults with a modal total length of 53 mm (Figure 2a). Over 25% of these animals were females either about to or just having spawned (stages FA4 & FA5). Just over 11% of the population was juvenile. The relative lack of juvenile krill can be contrasted with the results in January 1982 when the majority of krill were juvenile and the mean size of the sampled population was 30 mm. Krill of mean size 38 mm are most likely to be year 2+ krill while 53 mm krill are likely to year 4+ or 5+. The reasons for the lack of year 1 krill is not clear at present, the abundance of krill (of unknown age/size) at Signy and the apparent lack of juvenile krill at Elephant Island (NOAA Surveyor, pers comm) could be due to a recruitment failure from poor survival of larvae last winter.

On the second leg of the cruise no krill were caught until the start of the twin ship work with Africana. A single targetted net haul with the Multinet sampled three swarms in 8 nets, each net fishing for 1.5 mins. A total of 72 litres of krill were taken from the nets. Krill from each net were frozen for analysis in Cambridge. In addition 100 were measured for a quick assessment of the population structure. The length frequency of krill caught on the second leg is quite different from that on leg 1 (Figure 2b). Krill were generally immature with a modal length of 37 mm. Very few large krill were seen and none appeared to be mature. However, catches from Africana after we left to rescue the Bransfield contained mature adults. Further analysis of the situation will therefore await until data from the 2 cruises can be compared in detail.


krill length frequency for leg 1
frequency
0
10
20
30
40
50
60
20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60

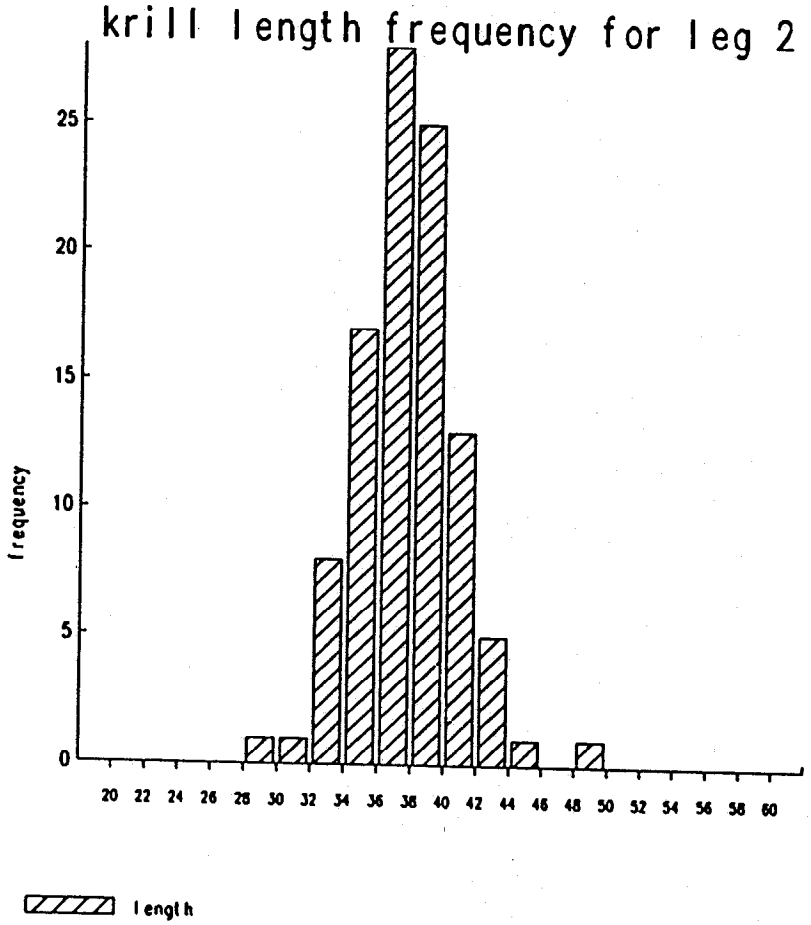

krill length frequency for leg 2
frequency
0
5
10
15
20
25
20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
length

Fig 1

27. Twin Ship studies: Africana & JCR -

by JL Watkins

Introduction

Two ship operations were designed to investigate processes at both the meso- and fine scale. The first project was to investigate the meso-scale distribution and abundance of acoustically detected organisms, in particular krill, around South Georgia in relation to predator distributions, environmental parameters and bathymetry. The second project was to make a preliminary investigation of the temporal variation of krill swarms, in particular (i) to observe temporal variations in size, shape, density and composition of individual swarms (ii) to determine how long individual swarms maintain their integrity, (iii) to determine the relationship of individual swarms to water structure. Both projects were to be interleaved, thus the survey would be used to find suitable areas for the fine scale work which would then be undertaken before completing the survey.

Meso-scale survey

Prior to the start of the joint survey, we set up a grid on the south side of the island (Figure 3) which was undertaken by Africana while JCR completed transects from the squid biomass spectrum area. Both ships then met at Leith Harbour for an acoustic calibration exercise and discussion of science plans.
Survey plan (Figure 3) consisted of approximately 600 n.miles steaming for each ship. Both ships started their respective surveys at 0500 on 18 February off Cooper Island. However, conditions were acoustically bad with a very strong wind and short, sharp chop, within 1 hour both ships were effectively hove-to. Both ships therefore relocated to transects within the lee of South Georgia; during the day JCR completed transects 4&5 while Africana completed transects D&E. Overnight the ships returned to be off Cooper Island by first light, a number of krill-like targets were seen on the echo-sounder between Stromness and Cape Charlotte. A few krill were caught in the FNET deployed at this time. Africana also found krill in this area and caught over 400 litres of krill in their commercial krill trawl. At the morning radio schedule with Africana we agreed to return to the 'Cape Charlotte' bank to try some fine-scale work after completing the Cooper Island transects.

On 19 February conditions were suitable to undertake the triangular sets of transects off Cooper Island (transects 1-3 & A-C). During the morning JCR stopped to observe an aggregation of birds sitting on the water. However, nothing was seen on the sonar except strong targets in the right position to be bow-thruster disturbance. Transects were finished by 2300 (Z) and ship made its way to Charlotte Bank. Three small swarms were detected on the sounder over the shelf-break. The ship was successfully manoeuvred over the swarms while towing the Multinet and over 70 litres of krill caught.

On 20 February both ships worked surveys over the Charlotte bank to characterize the area prior to picking on most suitable spot for krill swarm observations. A number of krill swarms were seen and also several aggregations of penguins and fur seals. A very fine scale grid with ships steaming alternate transects two miles apart was set up for the afternoon. If a suitable aggregation was picked up by either ship then the survey would stop and fine scale observations start immediately. By late afternoon neither ship had found anything on the echo-sounder.

Ships therefore spent the night relocating to start of transects 6 & F. An FNET during the evening caught only *Themisto gaudicaudi*. The following morning transect 6 was started under far from ideal conditions. After one hour even at a speed of 6-7 knots 38 kHz was unable to find the bottom less than 150 m under the hull. At 1000 (Z) both ships were hove-to, while we considered possibility of putting into Cumberland Bay and comparing survey results we received instructions to head for the Weddell Sea. By 1045 (Z) ship was making all speed towards Cooper Island and beyond.

Fine-scale study

No suitable aggregations for temporal observations of krill swarms were found in the time available to JCR although the first part of the study, fine-scale characterization, was undertaken (see above).

Conclusions

Although JCR was unable to complete the meso-scale survey, Africana finished both survey tracks and so many of the objectives of the meso-scale study have been achieved. Africana also attempted some fine-scale observations using their ski-boat and the portable echo-sounder hired from OceanScan as the second vessel. Some acoustic data was obtained on DAT tape.

In the light of the limited experience gained, to undertake this type of work in the future a number of modifications to equipment are necessary.
(1) The sonar is a powerful tool which complements the EK500 system. However, it is very difficult to use without the true north facility, this interface should be provided as soon as possible. In addition there is significant interference from the Sonar on the EK500, the synchronization of these two systems should be investigated. The present position of the sonar in the UIC is useless for any coordinated acoustic observation programme, some way of repositioning the sonar for biological cruises must be found.

Figure 1: Willis Island sea mount study: acoustic data collected on transect 32 on 10 January 1994 showing plume of zooplankton flowing off top of sea mount down stream towards the east

Figure 2: Krill length frequency data (krill length measured to nearest mm below). (a) krill caught on leg 1 of cruise and (b) krill caught on leg 2 of cruise

Figure 3: Planned survey tracks for twin ship study. Westerly tracks allocated to James Clark Ross were eventually completed by Africana

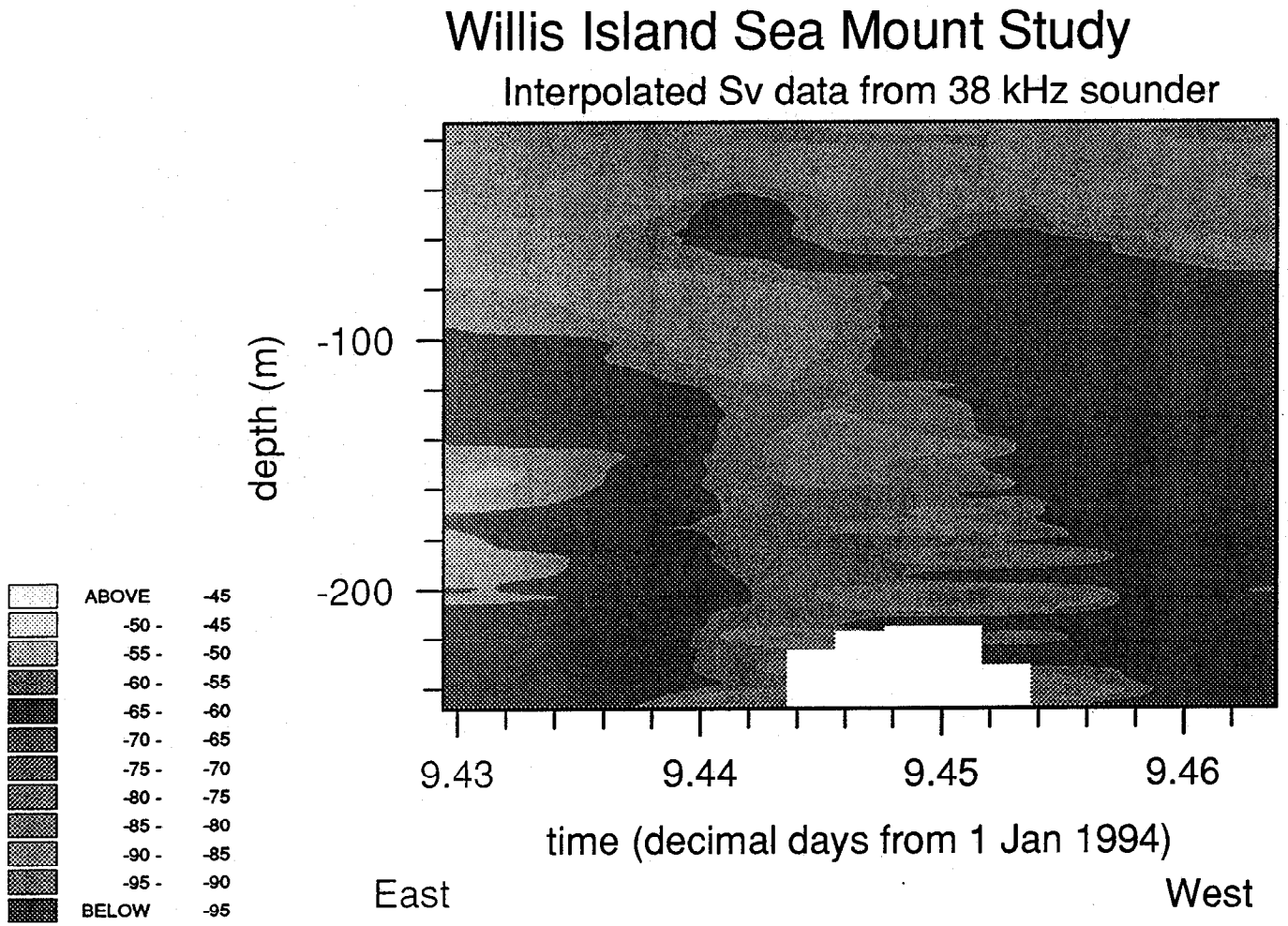
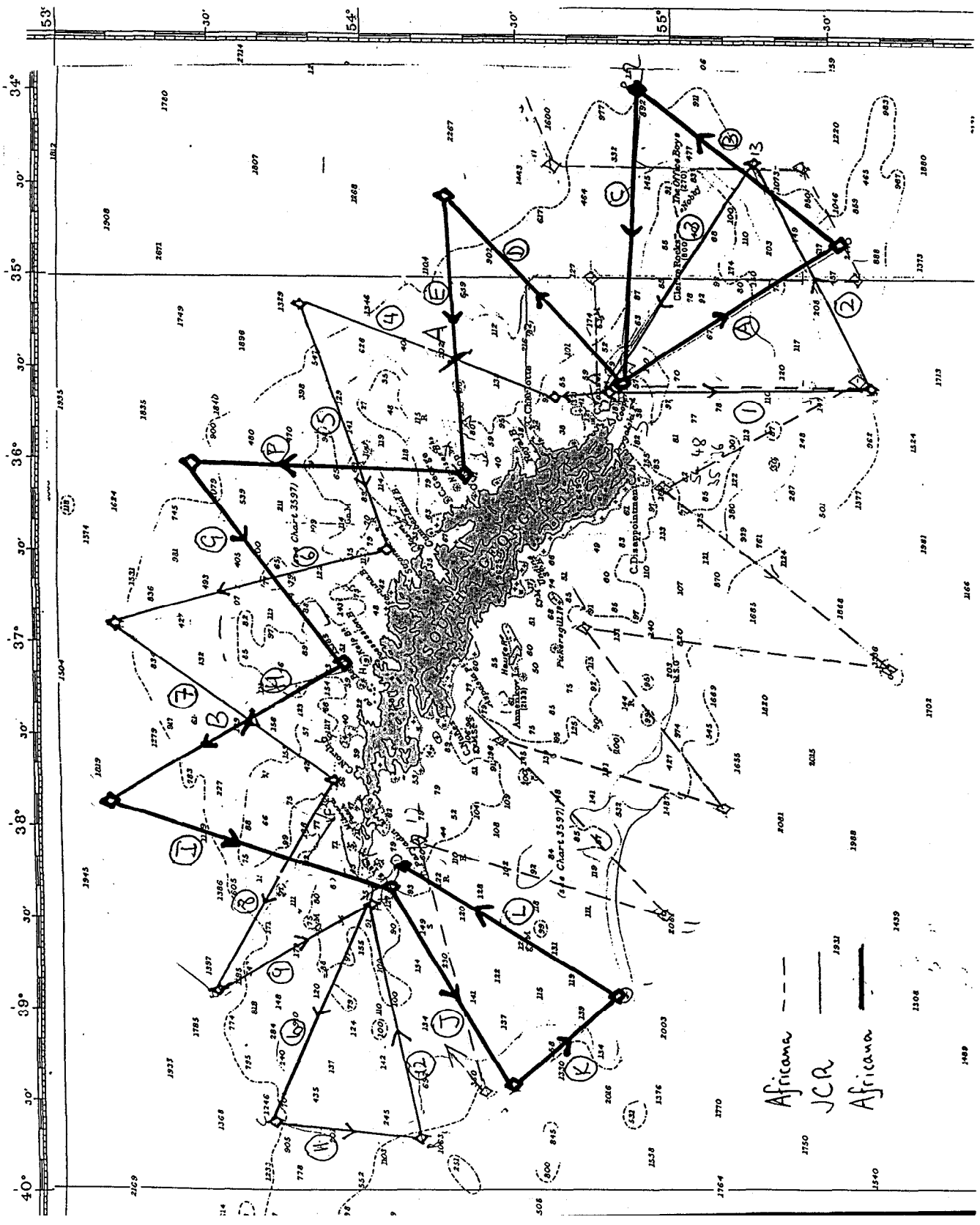

Willis Island Sea Mount Study
Interpolated Sv data from 38 kHz sounder
depth (m)
-100
-200
9.43
9.44
9.45
9.46
time (decimal days from 1 Jan 1994)
East
West
ABOVE -45
-50 - -45
-55 - -50
-60 - -55
-65 - -60
-70 - -65
-75 - -70
-80 - -75
-85 - -80
-90 - -85
-95 - -90
BELOW -95

Fig 2

Fig 3



28. Squid/fish Biomass Spectrum Study

by Emma Hatfield, Heather Daly, Francesc Pages, Paul Rodhouse, and Martin White.

The Squid/fish biomass spectrum study was located in an area to which squid/fish predators were consistently flying. The potential region within which the study could be undertaken covered 1000's km^2 and so to place the detailed sampling activity in a relevant area the foraging behaviour of the squid predators was used to locate 'hot-spots' and thereby select a region that was consistently frequented for studies of the squid/myctophid community . During the early part of JR06, satellite-tagged grey-headed albatrosses from breeding colonies on Bird Island were followed by plotting their daily positions. These observations indicated that a locality to the north of South Georgia near to the Polar Front was a favoured locality by squid predators. Immediately prior to the squid biomass spectrum study, the positions of tagged albatrosses were plotted at 4 hr intervals to focus the area for the detailed investigation. Two of the tagged ablatrosses remained within a relatively small area adjacent to the Polar Front and this was selected for the study.

The planned biological work consisted of a suite of net hauls using a variety of nets combined with acoustic and oceanographic observations to characterise the composition and size structure of the pelagic community in the upper 1000m of the water column. Synoptic observations of birds and seals provided the link between land-based marine predators and their food resource. Acoustic visualisation of the biomass in the study area had shown consistent stratification of the pelagic community into 3 main layers at about 50 m, 250-350 m and 5-600 m.

The net haul series started well - greatly assisted by the down-wire-net-monitor (DWNM) working on both the '10 tonne' and '30 tonne' conducting cables. Day and night deployments were completed with the pelagic trawl and the RMT 25. The pelagic trawl was used to sample the water-column down to 1000m with double oblique hauls; the RMT25 was deployed down to 1000m in 200 m layers to provide more detailed information about the vertical stratification of the nekton assemblages. To sample smaller components of the size spectrum the Multinet, LHPR and vertical zooplankton net (300 micron) were deployed. The vertical zooplankton net series was completed but both the LHPR and Multinet sample series were abbreviated by heavy weather. Biomass sampled with the Multinet was small and the abundance of animals low - suggesting that the organisms were more dispersed and of larger mean size at this oceanic location in comparison with those examined at the more neritic 'krill biomass spectrum' site studied during Leg I.

The key achievement was made with the pelagic trawl; catches with this midwater trawl showed that squid of the species (mainly *Martialia*) and size found in albatrosses' diet were located in the study area. Target fishing with the RMT25 demonstrated surprisingly fine scale vertical separation within some layers that could well form the basis of a future research project but were not able to be examined in detail during the period allocated for research in this cruise.

A general description of the communities in relation to the acoustic layers observed showed squid, amphipods, euphausiids, myctophid fish and gelatinous zooplankton to be the major components of the upper layer, myctophids and euphausiids comprised the intermediate layer while myctophid fish, decapod crustaceans and the gelatinous zooplankton comprised the bulk of the deeper layers.

Bird observations were maintained throughout daylight hours to provide information about the distribution and behaviour of the top predators. These at first were disappointing because no major feeding aggregations were observed and the general abundance levels were low. Nevertheless, the satellite tagged albatrosses remained in the area revealing the importance of the polar frontal zone to their feeding performance in the 1993/94 summer season and the nature of their foraging behaviour. One observation of special note was a large flock of ≈100 grey-headed- and ≈200 black-browed albatrosses that moved past the ship accompanying a school of pilot whales. Pilot whales are also squid predators and so it seems likely that such associations will be favourable to the avian predators by offering enhanced feeding opportunities.

In parallel with the core study work, copepod studies and microbial work continued successfully - providing opportunities to compare and contrast observations and experiments with the 'krill' study area during Leg I.

The Squid/fish biomass spectrum phase of the cruise was completed by the oceanographic and hydro-acoustic 'grid', this took the form of two near parallel N-S transects with stations at 10 km intervals positioned to cross the mass flow and frontal system at right angles.

29. Ichthyological studies during Predator/prey Cruise JR06 -

by Martin White

Fish are a key component of the marine pelagic ecosystem; as larval and juvenile notothenioids in neritic shelf water and myctophids in the open ocean. These comprise a significant part of the diet of many seal, seabird, toothed cetacean and squid species in the Southern Ocean. Studies on fish were undertaken during the JR06 Cruise on the *RRS James Clark Ross* to South Georgia as part of the investigation of predator/prey interactions between the shore-based marine predators and the pelagic marine assemblages at locations where the birds and seals were actively feeding. In addition, studies were carried out to investigate the role of mesopelagic fishes as predators of the zooplankton community, and material was also collected for age and growth determination in fish during the pelagic phase of their life-history.

The main objectives during the cruise were:-

1. *Species occurrence and size structure.*
To determine size structure and species composition of fish at the 'Krill' and 'Squid' biomass spectrum study sites by identifying all fish collected from the routine samples and determining their size and vertical distribution patterns.

2. *Relative abundance and vertical distribution.*
To determine the natural abundance levels and spatial distributions of fish to determine the potential trophic interactions with to higher predators by collecting reference material (whole specimens and otoliths) from the fish occurring at the biomass spectrum study sites.

3. *Diet*
To investigate the trophic interactions between fish and their prey by collecting reference material (stomach contents) so that the diet of the dominant fish species at the study sites can be related to the zooplankton communities.

4. *Proximate composition*
To examine the potential energy provision by fish in the diet of predators by collecting whole organism samples so that the energy composition and proximate composition values can be determined for key species.

5. *Age and growth patterns*
To undertake a comparative development study of the early development of Nototheniids by collecting samples of the pelagic phases *Notothenia rossii* and other related species of for an age and growth study.

6. *Functional morphology*
To collect samples of *Lepidonotothen larseni* as part of a comparative study of the development of locomotory structures in Antarctic fish.

7. *Genetics*
To collect samples of tissue for a study of phyletic affinity among selected demersal species that have widely distributed but apparently isolated populations.

Methods

The Pelagic midwater trawl, RMT25, and Multinet were nets were used to sample zoonekton in the water column to 1000m, 1000m and 600m respectively during daylight and after-dark. Fish in the near-surface layer are not usually accessible to nets towed astern of a vessel. because they are displaced by the propeller wash. To complete the vertical series collection and include near-surface species, samples were collected using a 1m frame-net towed from the foredeck of *RRS James*

Clark Ross. A 3m Agassiz dredge was used to collect samples of juvenile and adult demersal fish on the shelf at South Georgia.

All fish were extracted from net samples collected during station keeping at the 'Krill' and 'Squid' stations. Specimens were identified to species level wherever possible and individual standard length measured using digital calipers as soon as possible after capture. In addition, the morphology and size of fish from each net were recorded by photocopying whole specimens in a transparent plastic tray. Representative examples of species were preserved in buffered 4% formaldehyde solution or 75% alcohol. Material retained for age and growth studies were preserved in 70% alcohol and those for studies of otolith morphology, gut contents and proximate composition were frozen at -20°C.

It was not possible to collect samples for studies of functional morphology and genetics because these were planned for the latter part of Leg 2 and this phase was disrupted by the need to assist RRS Bransfield in the Weddell Sea.

Summary observations

Some 650 fish, mainly larval and post-larval nototheniids, were collected at the 'Krill Station' whereas nearly 2650 fish specimens, most myctophids, were collected at the 'Squid Station'. Table I shows the groups and species of fish that were collected from net samples at the two biomass spectrum sites. The fish assemblages at the two sites were obviously different in diversity and species composition. The 'Krill Station' over the northern continental shelf at South Georgia comprised 18 species from 7 families; the Notothenioid species predominated. At the 'Squid Station' diversity was approximately double with at least 36 species from 17 families occurring. The composition differed; oceanic and mesopelagic groups predominated, while the nototheniids were absent except for pelagic fingerlings of *Paranotothenia magellanica* collected in the neuston.

Myctophids were most abundant beyond the continental shelf/slope junction although they also occurred in neritic water as larval stages advected over the shelf (*Electrona antarctica*), species with a shallow vertical distribution patterns (*Protomyctophum bolini)* or species that have bentho-pelagic distributions such as *Gymnoscopelus nicholsi.* Although 36 species were represented at the 'Squid Station', myctophids overwhelming dominated the catches in terms of numbers and biomass, *Bathylagus antarcticus* was the only other non-myctophid fish that significantly contributed to the biomass in samples.

The most complete sampling of the vertical distribution patterns occurred at the 'Squid Station' and here distinct vertical stratification of species and biomass was evident (Fig 1). The greatest biomass occurred at depths of 200-400m corresponding to the intermediate of three layers visualised by the EK500 acoustic system. Target fishing in the deeper acoustic layer revealed distinct vertical stratification. Sequential nets vertically separated by just 25m in this layer produced samples with different species and size classes of myctophids.

Initial comparisons between the fish species occurring at the predator feeding sites and food being returned to the breeding colonies by the avian predators (material and information provided from Bird Island by John Croxall and Keith Reid, showed good correspondence. Due to the lack of aggregations of krill in the 1993/94 season at South Georgia, the anomalous conditions appeared to be accommodated by species switching to alternative prey and ranging more widely for their food. (John Croxall & Peter Prince, pers comm). The 'Squid Station' was located in and to the north of the Polar Front and so collections of fish included sub-Antarctic species. These 'northern' species also occurred in the diet of seabirds sampled at Bird Island. The exact nature of the predator/prey interactions and analysis of the modifications to foraging behaviour during 1993/94 will be the subject of detailed investigation later in the year at Cambridge.

Table I Families and Species of fish occurring at Biomass Spectrum Stations

Krill (Shelf) Station		Squid (Ocean) Station
Nototheniidae	(5)	(1)
Notothenia rossii		*Paranotothenia magellanica*
Gobionotothen gibberifrons		
Lepidonotothen larseni		
Trematomus hansoni		
Dissostichus eleginoides		
Channichthyidae	(1)	(0)
Champsocephalus gunnari		
Bathydraconidiae	(2)	(0)
Parachaenichthys georgianus		
Racovitzia glacialis		
Myctophidae	(7)	(16)
Electrona antarctica		*Electrona antarctica*
Electrona carlsbergi		*Electrona carlsbergi*
		Electrona subaspera
Protomyctophum bolini		*Protomyctophum bolini*
Protomyctophum choriodon		*Protomyctophum choriodon*
		Protomyctophum andriashevi
		Protomyctophum parallelum
		Protomyctophum tenisoni
Gymnoscopelus nicholsi		*Gymnoscopelus nicholsi*
Gymnoscopelus bolini		*Gymnoscopelus bolini*
		Gymnoscopelus fraseri
		Gymnoscopelus braueri
		Gynnoscopelus piabilis
Krefftichthys anderssoni		*Krefftichthys anderssoni*
		Lampanychtus achirus
		Symbolophorus boops
Photichthyidae	(0)	(1)
		Vinciguerria sp.
Microstomatidae	(0)	(1)
		Nansenia antarctica
Bathylagidae	(0)	(2)
		Bathylagus antarcticus
		Bathylagus sp.
Paralepididae	(0)	(1)
		Notolepis coatsi
Scopelarchidae	(0)	(1)
		Benthabella elongatum
Gonostomatidae	(0)	(2)
		Cyclothone microdon
		Cyclothone pallida

Melamphiadae	(0)	(2) *Poromitra crassiceps* *Sio nordenskjoldii*
Stomatidae	(0)	(2) *Borostomias antarcticum* *Stomias gracilis*
Nemichthyidae	(0)	(1) *Nemichthys* sp.
Chiasmodontidae	(0)	(1) *Chiasmodon* sp.
Macrouridae	(0)	(1) *Cyanomacrurus pirei*
Moridae	(0)	(1) *Halygyreus* sp.
Centrolophidae	(0)	(1) *Icichthys australis*
Platytroctidae	(0)	(1) *Normichthys yahganorum*
Gempylidae *Paradiplospinus gracilis*	(1)	(1) *Paradiplospinus gracilis*
Muraenolepidae *Muraenolepis microps*	(1)	(0)
Zoarcidae *Melanostigma gelatinosum*	(1)	(0)
Families	7	17
Species	18	36+

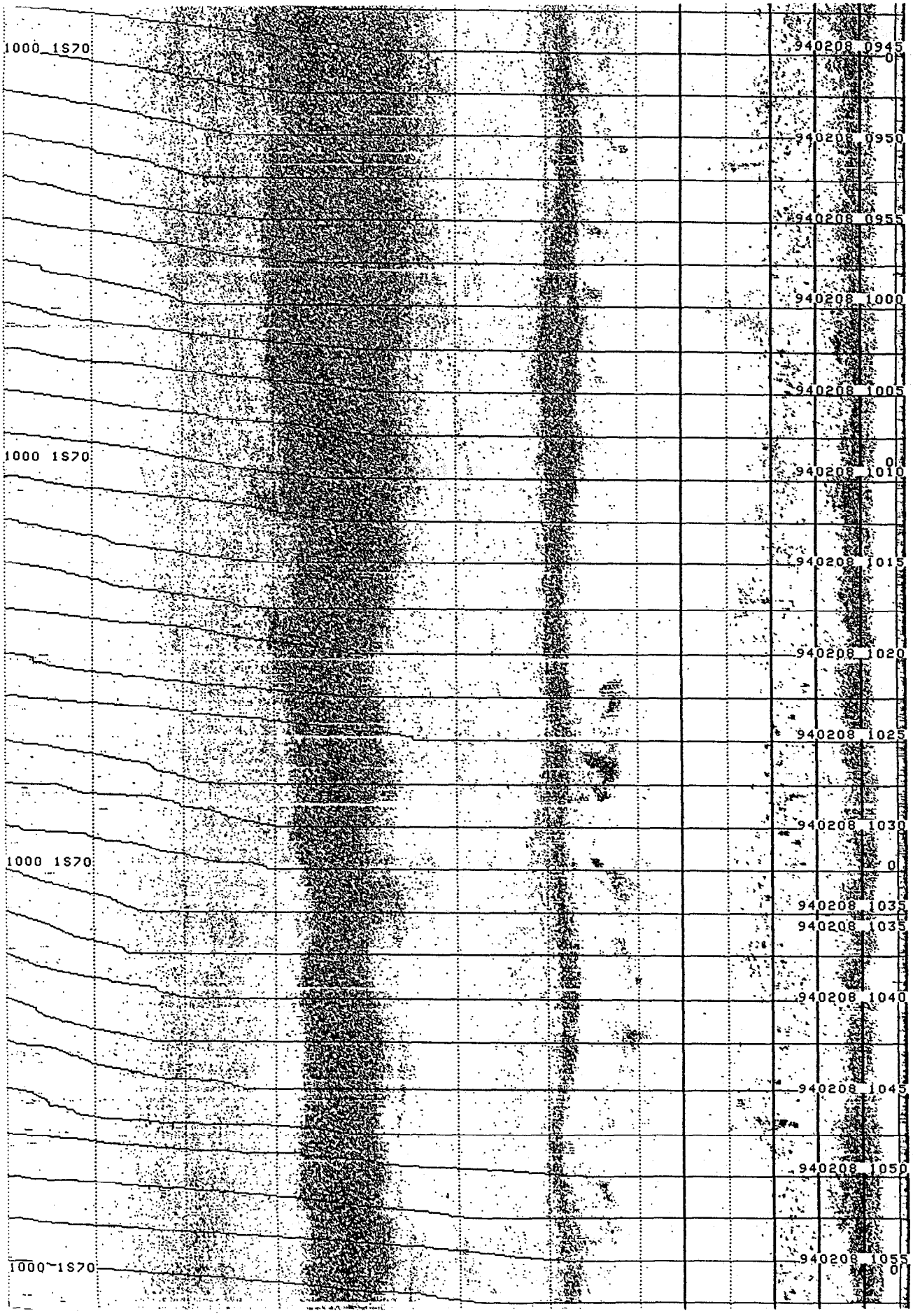


Fig 1. Analog acoustic image of multiple scattering layers present at 'Squid/fish' Biomass Spectrum study site.

(Simrad EK500 echosouder, 38kHz, 0–1000m, 8 Feb 1994)

30. THE GELATINOUS MACRO- AND MEGAPLANKTON COLLECTED DURING THE JCR 06 CRUISE (FEBRUARY 1994): SOME PRELIMINARY RESULTS

by Francesc Pagès

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Introduction

The knowledge of the Southern Ocean zooplankton communities has increased notably in the last decade. Most of the results show that krill and copepods comprise the key groups. However, other groups may be key organisms in certain areas.
The gelatinous zooplankton is doubtless the component of the zooplankton community less reported in the Antarctic literature. However, the few available data indicate that sometimes gelatinous zooplankton is not an anecdotal component of the Antarctic zooplankton community. Gelatinous organisms rarely occur near a krill swarm but when krill is absent, might arise in a wide variety of forms and show different life strategies. Only the salps have received some attention probably due to their great abundance in spring and summer around the Antarctic Peninsula, coincident in time and space with quite research cruises. The scattered data on the abundance and distribution of the gelatinous zooplankton in the Southern Ocean suggest that this group may play a significant role in the pelagic food chain at some spatio-temporal scales. Hauls made using different gears (IKMT, RMT 1+8M, Pelagic Trawl) sometimes have collected large quantities of gelatinous organisms that showed that they were the principal component of the macroplankton and/or nekton. According to this premise, the gelatinous zooplankton has been considered a potential key assemblage in the Southern Ocean and has been integrated into the **Pelagic Ecosystem Studies** program.

Objectives

The objective was to characterise the gelatinous zooplankton community in the area surveyed during the second leg of the JCR 06 cruise. Several aspects were studied in order to gain a better understanding of the role played by this zooplankton community in the Antarctic pelagic ecosystem: species composition, abundance, small and medium spatial distribution, biomass, biotic associations and gut content.

Material and methods

The material examined was collected by different gears deployed during the cruise (RMT 25, the Multinet H-AMPS, the Pelagic Trawl and the F-net). Most of the specimens studied were collected by the RMT25 and Pelagic Trawl nets. The biovolume of the fresh zooplankton was calculated immediately after each haul by measuring the volume of seawater displaced in a measuring cylinder. The bigger zooplankters (including the gelatinous ones) were immediately sorted to characterise the size-spectrum. Later the gelatinous components of the remainder were also sorted. All the gelatinous forms were pooled to calculate their biovolume and percentage in the whole sample. All the specimens were classified to specific level according to the present knowledge about the systematics of the gelatinous zooplankton in the Southern Ocean.

Taxonomic composition

The taxonomic groups collected were medusae (16 species), siphonophores (5 sp.), ctenophores (3 sp.), salps (1 sp.) and nemerteans (1 sp.). Most of the species have been already recorded in the Southern Ocean. However, three species of medusae and one ctenophore could not be identified and they require further examination after the cruise.

Distribution and Abundance

Plankton samples were collected during the transect from South Georgia to the area located north of the Polar Front, selected to carry out the biological program. The samples were collected from 200 m depth to the surface using a Z-net (75 cm mouth diameter, 200 mesh-size). The examination of these samples indicated a very low abundance of gelatinous organisms. The salp *Salpa thompsoni* Foxton 1961, was the most outstanding absentee as it is a common and abundant species in the area in spring and summer when the phytoplankton bloom occurs. For instance, it was very abundant in 1993 (AWA Murray *pers. comm.*). North of the Polar Front, the RMT25 and H-AMPS hauls only caught a few specimens of both stages scattered along the water column. The abundance of each species at each haul could not be known before finish this report as the flow of water filtered by the RMT25 was still being calculated. Nevertheless, medusae was the most abundant and conspicuous gelatinous group in the samples collected by the RMT25 north of the Polar Front. They were collected at almost all hauls and at all depths. As always, they occurred in low numbers than contrasted with their relative high biomass. The scyphomedusa *Periphylla periphylla* (Peron & Lesueur 1810) and the anthomedusa *Calycopsis borchgrevinki* (Browne 1910) were the only species collected at all depth ranges, between 1000 m and the sea surface. *P. periphylla* occurred between 200 and 1000 m during daylight but large specimens were collected at surface at night.

The rest of gelatinous organisms were mainly collected below 200 m. *Atolla wyvillei* Haeckel 1880 and *Atolla chuni* Vanhoeffen 1902 were always caught between 400 and 1000 m but they occurred only by night in the 400-600 m depth range. This suggests an upward migration of these mesopelagic medusae at nighttime.

The trachymedusae *Halicreas minimum* Fewkes 1882 and *Crossota brunnea* Vanhoeffen 1902 co-occurred in the same hauls. They showed the same vertical distribution and both increased in abundance from 400 m -its upper layer- to 1000 m. At station 279 two hauls were made between 800 and 1000 m lasting one hour each. However, a significant increase in abundance was observed on the second haul (1854-1954 local time). This suggests an upward migration from waters deeper than 1000 m, where probably both species have bigger populations.

Rosacea plicata (Bigelow 1911) was the only common siphonophore. Most specimens aggregated between 400 and 600 m. Each specimen is formed by two definitive nectophores and a long stem that carries different structures (i.e. gastrozooids and tentacles). It is worthwhile to take into account that each specimen extends its stem and tentacles several centimeters, covering a large area. Although the densities were low, it appears that this siphonophore was one of the main predators in the 400-600 depth range.

The other cnidarian species were collected in very low densities, mostly between 400 and 1000 m. A few specimens of the deep-water nemertine *Pelagonemertes rollestoni* were collected at stations 271 (4 spec.) and 279 (8 spec.). All were captured in the 600-800 m depth range.

Small-scale distribution

The distribution of the organisms collected by the RMT25 and H- AMPS nets suggests that some species were located in narrow depth ranges. These distributions occurred mainly between 300 and 600 m depth. The above mentioned siphonophore *R. plicata* was one of the most evident examples. However, the data lead one to believe that more small-scale distributions took place. For instance, only one ctenophore was caught at station 289 between 300 and 350 m whereas they

were the dominant organisms in the 375-400 depth range. This distinct vertical distribution appears to have been caused by a discontinuity in the temperature.
Small-scale distributions were not so clear between 600 and 1000 m. Some rare species only occurred in the 600-800 or 800-1000 m depth ranges but their low densities do not permit go further.

Biomass

Gelatinous groups occurred almost always in the 22 RMT25 hauls made. They were absent only in two hauls that collected 7 and 35 ml of zooplankton, both at 50 m depth. They constituted the predominant component (more than 50% wet biomass) in 8 hauls that encompassed all depth ranges sampled. The most important contributor to the gelatinous wet biomass was doubtless the scyphomedusae *P. periphylla*. Some individuals measured more than 30 cm in diameter and 1 litre in biovolume. This species achieved a considerable biomass in two Pelagic Trawl hauls made at nighttime in the upper layers. The first (station 257) collected 8 specimens that measured 2 litres in displacement volume but in addition, an uncertain number of broken specimens measured approx. 8 litres. Nevertheless, the highest wet biomass was collected by the Pelagic Trawl at station 367 where 60 large specimens (X=30.32 cm in diameter, SD=7.75) were caught and their wet biovolume was approximately 72 litres.
Other species that contributed but to a lesser extent were the scyphomedusa *A. wyvillei* (600-1000m), the trachymedusae *C. brunnea* and *H. minimum* (800-1000 m), and the siphonophore *R. plicata* (400-600 m). Of note are two specimens of *Aequorea* sp. (20 cm in diameter and 950 ml in biovolume each, St. 277, 800- 1000 m) and one specimen of *Stygiomedusa gigantea* (Browne 1910) (52 cm in diameter, St. 252, 0-500 m). This specimen measured 4000 ml in wet biovolume despite the four thick, long and ribbon-like oral arms being missing. According to its diameter (Larson, 1986), the oral arms should have attained at least 10 meters in length, therefore the biomass should have been bigger.
The biovolume contributed by the other gelatinous species can be considered negligible. Nevertheless large ctenophores (up to 15 cm in length) comprised most part of the sample biovolume at stations 289 (375-400m, *Beroe* sp.) and 422-423 (surface, *Beroe cucumis* Fabricius 1780) respectively.

Biotic associations

The observations made after each haul did not indicate evident biotic associations although there was one exception. At station 270 (200-400 m depth), the 4460 ml wet biomass collected was mostly due to two large specimens of *P. periphylla* measuring 30 and 35 cm in diameter respectively. The only conspicuous organism caught in the same haul was a single specimen of the rare centrolophid *Icichthys australis* (Haedrich, 1966) (identified by MG White) that measured 90 mm in total length. The family Centrolophiidae comprises several species associated to gelatinous organisms. Although neither bite signs were observed in *P. periphylla* nor the stomach content of *I. australis* was examined, the co-occurrence of both species suggests an association between them.

Gut content

The stomach content of the individuals of some medusae species was examined in order to deduce their food preferences and elucidate their predatory behaviour. The species were chosen according to their abundance (*P. periphylla*) or by having a stomach morphology (*C. brunnea, A. chuni* and *C. borchgrevinki*) that could retain the preys during the gear trawling.
All the specimens of the above mentioned species were analyzed but no distinct preys were observed. The gastric cirri of *P. periphylla* sometimes had attached small but unidentifiable particles. Some specimens of *A. chuni* had copepods into the stomach and even one specimen of

the large ostracod *Gigantocypris* but they were not partially digested. The other medusae always showed empty stomachs

Predators

A few observations about some predators of gelatinous macrozooplankton were made in the vicinity of South Georgia. For instance, a group of almost 20 albatrosses were observed foraging on a large reddish medusae (R.R. Veit & M.G. White *pers. comm.*) which probably was a specimen of the scyphomedusa genus *Desmonema* Moreover, a great number of specimens of *Notothenia rossii* collected by **M.V. Cordella** on the South Georgia shelf, had the stomach plenty of ctenophores (C. Goss *pers. comm.*). Ctenophores were the overwhelmingly dominant zooplankters in some F-net hauls made in the area.

Conclusions

The results support the premise that gelatinous zooplankton is sometimes the main component of the macrozooplanktonic/nektonic community in the Southern Ocean. This contrasts with the fact that this group has been continuously neglected in the Antarctic food chain models. Such omission is partially attributable to the difficulties in identifying and quantifying the medusae, siphonophores and ctenophores when conventional gears are used. Also, the omission is due to the problems in studying their diet and feeding behaviour from material collected by plankton nets. Unfortunately, such difficulties were also found during this cruise. However, the results obtained -specially those about wet biomass- leads one to believe that gelatinous zooplankton may have a substantial role in the Antarctic pelagic ecosystem,

During daylight, gelatinous organisms were almost always absent in the epipelagic community near the Polar Front but they were abundant between 400 and 1000 m depth. At night, they were prominent throughout the water column and were the group with the higher biomass in the 0-200 and 800-1000 m depth ranges. This was due to the occurrence of big specimens of *P. periphylla* at such depths. This species was distributed between 200 and 1000 m during daytime but specimens bigger than 10 cm in diameter were only collected below 600 m. This suggests that specimens caught in the surface at night probably initiated an upward migration at dusk. Why this scyphomedusa migrated to the upper layers at night remains unknown. It is worthwhile to note that *P. periphylla* only occurs at surface waters in the Southern Ocean although it is a deepwater species widely distributed in all the oceans except the Arctic. Besides the lack of results on its diet and feeding behavior, this carnivorous organism may be an important secondary consumer in the Southern Ocean as other pelagic scyphozoans in other areas.

The few observations on gelatinous zooplankton obtained near South Georgia indicate that this group may also be important in neritic waters. The scyphomedusa *Desmonema glaciale* and some ctenophores can show high densities and biomass around this island (Ward, 1989) but little is known about their ecology. Diving observations on *D. glaciale* made at Signy Island (White & Bone 1972), showed that this medusa is a benthopelagic predator. Both gelatinous organisms are abundant around South Georgia and they appear to be common preys for some higher predators (seabirds and fishes) when krill populations are depleted as happened during the cruise.

In summary, gelatinous macrozooplankton but particularly medusae show relative high biomasses in the vicinity of the Polar Front and probably in other oceanic areas of the Southern Ocean. However little is known about their reproduction, feeding, biotic associations and small-scale distribution. It would be very interesting to deepen on these aspects in order to establish their importance in the Antarctic pelagic ecosystem. Doubtless, the carnivorous gelatinous zooplankton deserve to be inserted in the Antarctic trophic models. This interest extends to species inhabiting neritic waters.

References

Larson, R.J., 1986. Pelagic Scyphomedusae (Scyphozoa: Coronatae and Semaeostomeae) of the Southern Ocean. Antarct. Res. Ser., 41:59-165.

Ward, P. 1989. The distribution of zooplankton in an Antarctic fjord at South Georgia during summer and winter. Antarct. Sci., 1: 141-150.

White, M.G. & D.G. Bone, 1972. The interrelationship of *Hyperia galba* (Crustacea, Amphipoda) and *Desmonema gaudichaudi* (Scyphomedusae, Semaeostomae) from the Antarctic. Br. Antarct. Surv. Bull., 27: 39-49.

31. Satellite tracking of higher predators -

by P.A.Prince, P.N.Trathan, R.Veit and M. J Whitehouse

During the second leg of the cruise 4 satellite PTTs were deployed on Grey-headed Albatrosses foraging to feed their chicks at Bird Island. In addition two PTTs were deployed on King Penguins at Husvik.

As a contribution towards the Squid Biomass spectrum project it was our intention to identify a body of water in which the higher predators might be feeding.

In order to achieve this objective it was decided to use:-
1) Satellite tagged higher predators to identify a broad area in which predator prey activity might occur.

2) Using a combination of acoustic and direct observations of higher predators select a way point for the Biomass spectrum.

3) While this project was being carried out direct observations of the numbers and variety of birds and mammals seen along the transect would be recorded.

4) In the event of any feeding activity being observed, video film would be taken for later analysis of feeding methods being deployed by the various predators.

RESULTS

Fig 1 shows the foraging range of Grey-headed Albatrosses determined from 935 locations received by the satellite (see table 1 for summary data from leg 1 & 2) During the period of this work all the locations were obtained during late January and in February. From the location data we received it was clear that the Grey-headed Albatrosses tended to concentrate to the North of South Georgia in the region of the Polar Front. Fig 2 shows the area with the densest number of localities in this region. The King Penguin locations and the way point selected for the Biomass spectrum are also shown. Table 2 shows the range and percentage composition of avian predators observed during the work period.

CONCLUSIONS

The concept of using satellite tagged higher predators is a realistic approach to locating natural resources. The biomass spectrum project caught a range of prey that have been identified previously, and during this work as forming a significant contribution to the diets of avian predators foraging from Bird Island, South Georgia.

However, feeding activity was not observed during the work period. Therefore it was not possible to carry out one of our objectives. Nevertheless, significant associations between deep diving predators such as Pilot Whales and Albatrosses were observed providing an indication at least on how surface feeding birds such as Albatrosses might be able to obtain their food.

Table 1. No of recorded positions for satellite tagged species, whilst foraging away from Bird Island (uncalibrated data).

Species	Leg	Positions
Grey-headed albatross	Leg 1	354
Grey-headed albatross	Leg 2	935
King penguin	Leg 2	13 ???
Black Browed albatross	Leg 1 and Leg 2	439

Table 2. Trips recorded by individuals marked with satellite tags during cruise JR06

Leg 1 (Uncalibrated data)

Spp	Ring	PTT	Trip start		Trip end	
BBA	1301131	1842	940103	0823	940104	0913
BBA	1301131	1842	940106	2043	940123	1327
BBA	1301162	1843	940101	2017	940103	1444
BBA	1301162	1843	940110	0700	-	-
BBA	1139956	9132	940103	1451	940110	0652
GHA	1146752	1557	940102	1512	940109	1346
GHA	1146752	1557	940113	1455	940117	2057
GHA	1318292	3244	931231	0932	940102	2338
GHA	1318292	3244	940105	2102	940108	1031
GHA	1318292	3244	940109	0930	940113	1310
GHA	1318291	3246	931230	0930	940102	1652
GHA	1318291	3246	940104	2230	940109	1549
GHA	1318291	3246	940111	0738	940114	0730
FUR	-.	2163	940111	1827	940112	1825

Leg 2 (Uncalibrated data)

Spp	Ring	PTT	Trip start		Trip end	
GHA	5092172	1842	940126	1701	940201	1044
GHA	5092172	1842	940201	1052	940212	1430
GHA	5092172	1842	940212	1442	-	-
GHA	1139899	1557	940126	1328	-	-
GHA	1318294	3244	940126	1511	940131	1622
GHA	1318294	3244	940131	1644	940208	0829
GHA	1318294	3244	940208	0840	-	-
GHA	1318275	3246	940124	1524	940129	2001
GHA	1318275	3246	940129	2014	940205	2036
GHA	1318275	3246	940205	2058	-	-
KPN	0000061	2162	940208	0900	-	-
KPN	0000192	2160	940210	1030	-	-
KPN	0000198	2384	940216	1900	-	-

Table 3. Proportional abundance (percentage of total) of seabird species in squid biomass spectrum area.

Prion, sp.	0.28
Great Shearwater	0.24
Soft-plumaged Petrel	0.19
Grey-headed Albatross	0.05
Black-browed Albatross	0.05
White-chinned Petrel	0.04
Wandering Albatross	0.04
Sooty Albatross	0.02
Pediunker	0.01

Northern Giant-Petrel
Southern Giant-Petrel
Thin-billed Prion
Atlantic Petrel
Little Shearwater
Wilson's Storm-Petrel
Black-bellied Storm-Petrel
White-bellied Storm-Petrel
Grey-backed Storm-Petrel
Leach's Storm-Petrel
Diving-Petrel, Sp.
Brown Skua

Fig 1

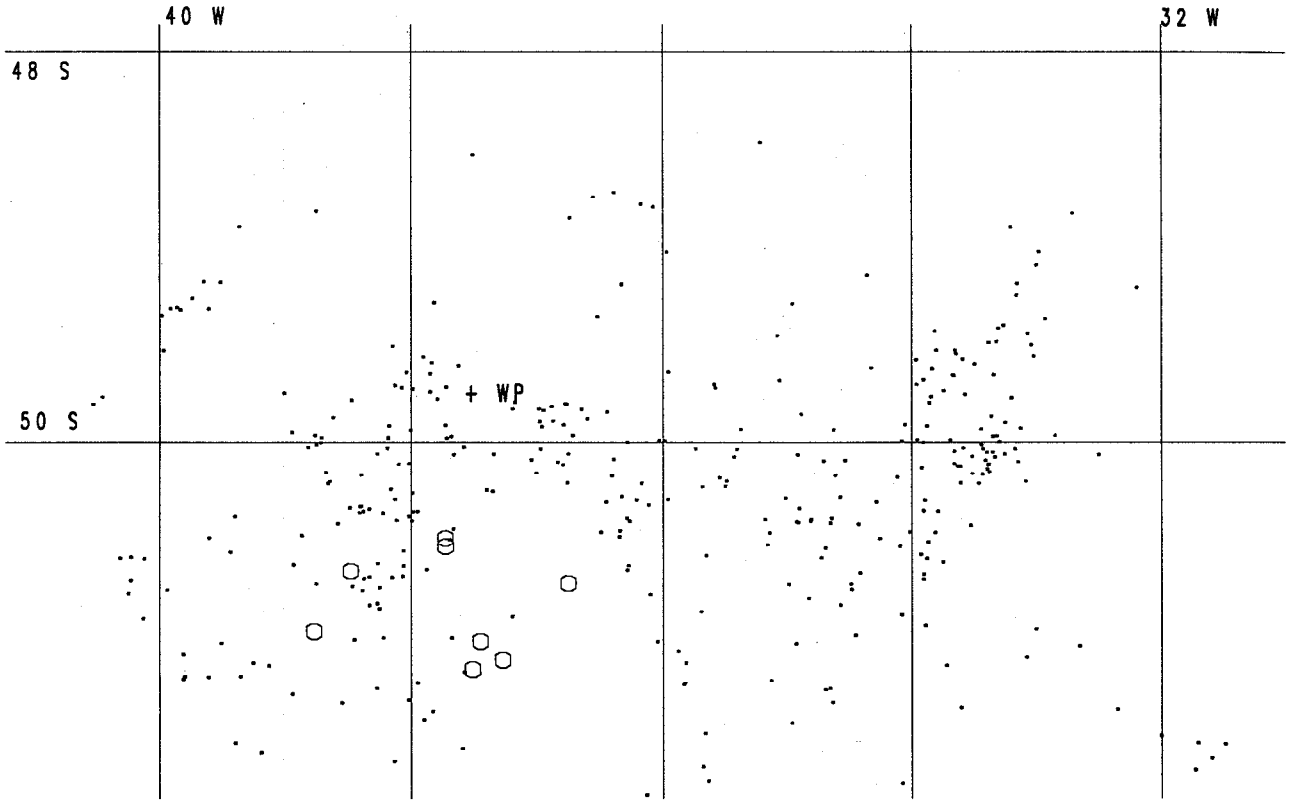
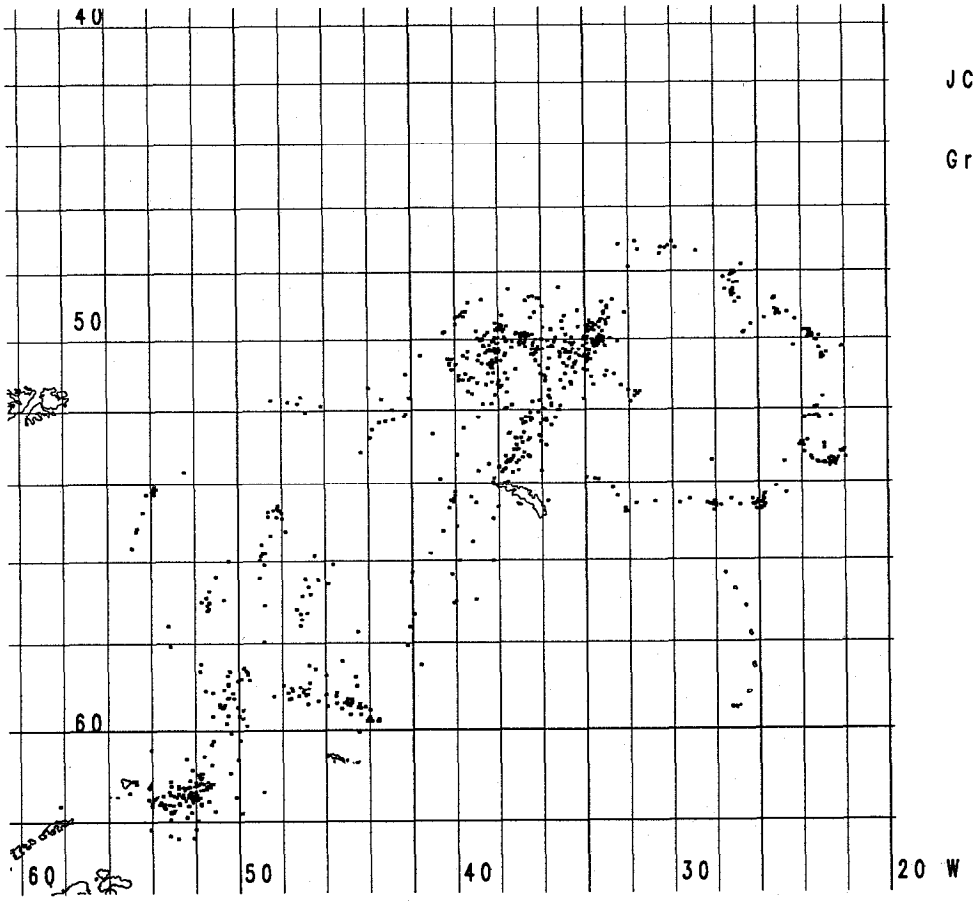


Fig 2



JCR06: Leg 2

Grey-headed albatro

32. Foraging Ecology of Seabirds -

by Richard R. Veit, Gabrielle A. Nevitt and Emily D. Silverman

Our first objective during JR06 was to quantify foraging behaviour of seabirds. Because we were subsequently invited to participate in an analysis of large scale oceanographic patterns within the Scotia Sea, we also quantified distributional patterns of seabird communities during transects between Stanley and South Georgia. Our primary objective involved three main components: 1) quantifying the spatial distribution and composition of feeding flocks, 2) analyzing bird spacing along transects to determine whether birds use cooperative search strategies, and 3) measuring densities of birds around South Georgia with respect to krill distribution and abundance. An additional objective was to examine the role of olfaction as a sensory modality important to foraging birds.

To meet our primary objective, we measured bird abundance and behaviour while strip transects were being conducted around South Georgia. We noted and recorded the composition and characteristics of all feeding flocks we encountered. To meet our second objective, we conducted experiments to test the hypothesis that birds respond to volatile aromatics associated with krill and phytoplankton. We measured the accumulation of birds to scented slicks and changes in upwind flight behaviour in response to scented aerosols. These experiments will be completed during the second legs of the cruise.

Data collection on our first two objectives will continue throughout the second leg of the cruise. Overall, bird densities and feeding flock activity were lower than usual summer levels around South Georgia. Of the 23 mixed species flocks we observed, 15 may have had birds feeding on krill, while eight of the flocks were observed to be feeding on other prey, such as dead penguins. Results from the olfactory experiments clearly show a differential response by four petrel species to krill and phytoplankton derived odours. Our broadscale analysis of seabird assemblages revealed weak evidence of southward dispersal of Subantarctic and Subtropical species: small numbers of Great Shearwaters, Broad-billed Prions, Soft- plumaged Petrels and White-bellied Storm-Petrels were seen on the transect between Stanley and South Georgia, and a Broad-billed Prion landed aboard the ship at the shelf-break north of the Willis Islands. We found no particular concentration of birds in the vicinity of the Polar Front, nor was there evidence of a change in species composition across this front.

33. Predator-Prey Interactions -

by Richard R. Veit, Gabrielle A. Nevitt, Peter A. Prince, Emily D. Silverman, and Michael J. Whitehouse

I. Seabirds and Krill

Sampling of diets and assessment of juvenile mortality of fur seals and seabirds at Bird Island (Prince, Croxall, et al.) revealed the 1993-1994 season to be the worst on record in terms of availability of krill to these predators. As might be expected given this evidence from predators ashore, transects conducted by the James Clark Ross during JR06 yielded few aggregations of feeding birds, and little other evidence of birds or seals feeding upon krill.

However, we were able to locate a small number of feeding flocks of birds, and the flocks that we did find were tightly associated with small and dense patches of krill. For example, on one transect that crossed the southern edge of Charlotte Bank on 18 February , we recorded a spatial correlation of +0.39 between Macaroni Penguin density and estimated krill abundance (Fig. 1). In 1986, when krill was much more abundant, correlation between penguins and krill was on the order of 0.1-0.2. This suggests that during times of krill scarcity, predators may be more likely to remain in the vicinity of a krill patch once the patch has been found, rather than moving on in search of another "better" patch.

Our major objective - quantification of foraging behavior by seabirds in the vicinity of krill patches - was to have been carried out during the final 12 days of the cruise. Since nine of those days were cut from the scientific program in order to give emergency assistance to the R.R.S. Bransfield, our ability to sample foraging flocks was curtailed. Nevertheless, we managed to collect data on 38 feeding flocks. Of these 38 flocks, 21 were associated with acoustic targets that resembled krill, 4 were clearly associated with cetaceans, 4 with carrion (probably penguin carcasses) and 3 appeared to be associated with large gelatinous zooplankton or moribund squid. Thirty-two of the 38 flocks were over the insular shelves of South Georgia and the South Orkney Islands, and the remaining 6 were in the squid biomass study area near the Polar Front. If these flocks were indicative of the situation at South Georgia as a whole, then the 1994 season was characterized by fewer, smaller feeding flocks that each contained a smaller total number of predator species than would be expected during a season of high overall krill abundance, such as 1985-1986.

II. Seabirds and Physical Oceanography

In addition to exploring a direct link between vertebrate predators and their prey, we also investigated how physical processes in the ocean might influence distributions of predators indirectly, by stimulating hydrographic conditions conducive to the formation of prey aggregations. Physical features that seemed to influence the distribution of feeding birds during our study were a warm-core eddy associated with
the Antarctic Polar Front, and three seamounts - two on the South Georgia insular shelf and the third in deep water just south of the Polar Front.

The warm-core eddy was identified by infra-red satellite imagery, and was situated near the center of an area frequented by two satellite-tagged Grey-headed Albatrosses. Although we never actually witnessed the capture of prey by Grey-headed Albatross, we did find a pod of about 100 Long-finned Pilot Whales that was attended by approximately 300 albatrosses, including 75 Grey-headed Albatrosses. Since pilot whales feed almost exclusively upon squids, it seems likely that the albatrosses were following the pilot whales in order to benefit from the discovery of squid by the whales. During our initial sampling of the Squid Biomass region, we traversed what proved to be the southern boundary of the warm-core eddy. The surface temperature dropped by about 1o C across this boundary. We observed 15 feeding flocks of Great Shearwaters, Soft-plumaged Petrels, and Prions within 30 NM to the south of this boundary, and none to the north within the eddy (Fig. 2).

The distribution of predator aggregations seemed to be strongly influenced by bottom topography. Seamounts on the South Georgian shelf may affect bird foraging by influencing the formation of krill aggregations, to which birds then aggregate. In support of previous

surveys, we found that the probability of encountering a krill swarm increased over steep bathymetric gradients, such as the slopes of seamounts. Many of the aggregations of birds that we encountered were situated within 5 NM of two seamounts - one to the north of Willis Islands and the other to the north of Royal Bay.

III. Seabirds and Olfaction

Although the olfactory acuity of procellariiform seabirds has been suspected , little is known about how these birds use their keen sense of smell, or what specific odors these birds can detect. As part of our study of seabird foraging, we conducted experiments designed to test the olfactory sensitivities of seabirds to potential volatile substances occurring naturally over Antarctic waters. This set of studies concentrated on testing the birds' ability to detect dimethyl sulfide (DMS), a volatile biogenic gas produced by phytoplankton which we hypothesize could serve as an orientation cue for foraging seabirds. We presented birds with DMS-scented oil slicks (200 mM concentration) paired with nonscented control slicks. Our aim was to produce a plume of odor emanating from the slick which approximated DMS concentrations at near natural concentrations (nanomolar range). Ten paired slicks were deployed in random order from the stern of the vessel. Observers standing on the stern end of the afterdeck recorded numbers and species of new arrivals to slicks. A bird was counted as showing interest in the slick if it 1) flew upwind directly over the slick within approximately 1 M of the surface, 2) alighted or 3) pattered on the slick. Observers had no knowledge as to the nature of the slick being tested (i.e., scented vs. nonscented).

Preliminary analysis of our results clearly shows that both storm petrels (Wilson's and Black-bellied) and White chinned Petrels aggregate to DMS scented slicks faster and in greater numbers than they do to nonscented slicks (Figs. 3 and 4). Interestingly, Black-browed albatrosses, which are thought to be largely visual foragers, responded in equal numbers to both scented and nonscented slicks (Fig. 5). Responses of other birds to DMS have not yet been analyzed.

Figure Legends

Fig. 1. Distribution of Macaroni Penguins (1a) and krill swarms (1b) in the vicinity of Charlotte Bank, 18 February 1994.

Fig. 2. Distribution of feeding flocks of Great Shearwaters, Soft-plumaged Petrels and Prions with respect to the southern boundary of a warm-core eddy near the Antarctic Polar Front 5 February 1994. (temperature front was crossed at 1800 - 1900)

Fig. 3. Preliminary analysis of responses of storm petrels to DMS and nonscented slicks. Data are summed for ten scented and ten nonscented slicks and normalized to the largest number of storm petrels observed during a single time interval (100% response = 114).

Fig. 4. Preliminary analysis of responses of white chinned petrels to DMS and nonscented slicks. Data are presented as in figure 3. (100% response = 55).

Fig 5. Preliminary analysis of responses of Black-browed albatrosses to DMS and nonscented slicks. Data are presented as in figure 3 (100% response = 38).

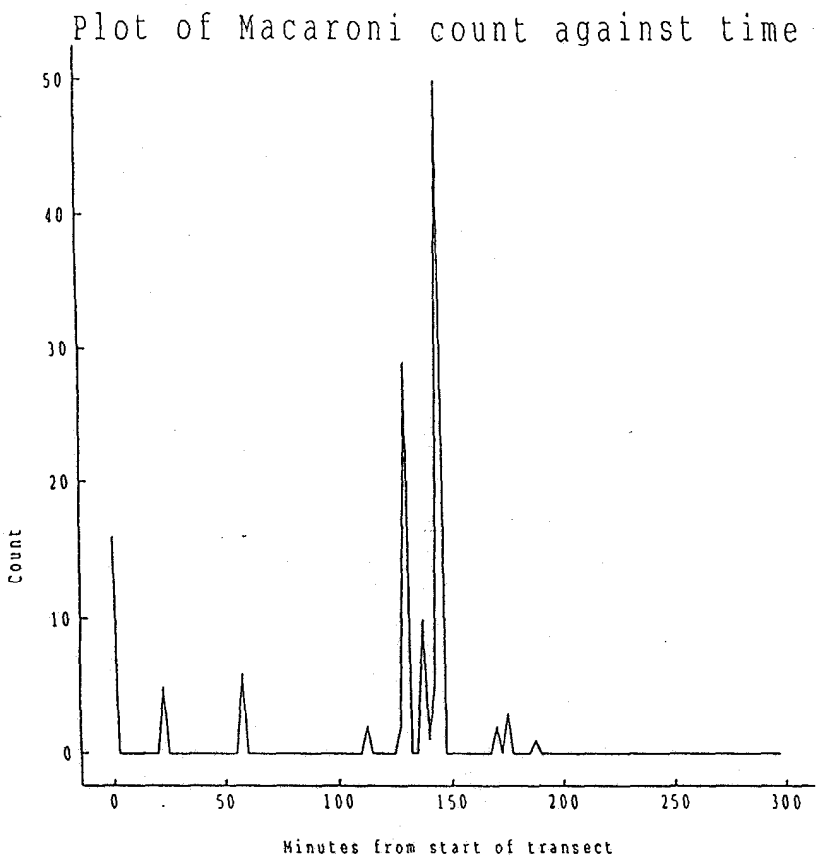

Plot of Macaroni count against time
Count
50
40
30
20
10
0
0
50
100
150
200
250
300
Minutes from start of transect
Macs against time

Fig 1a

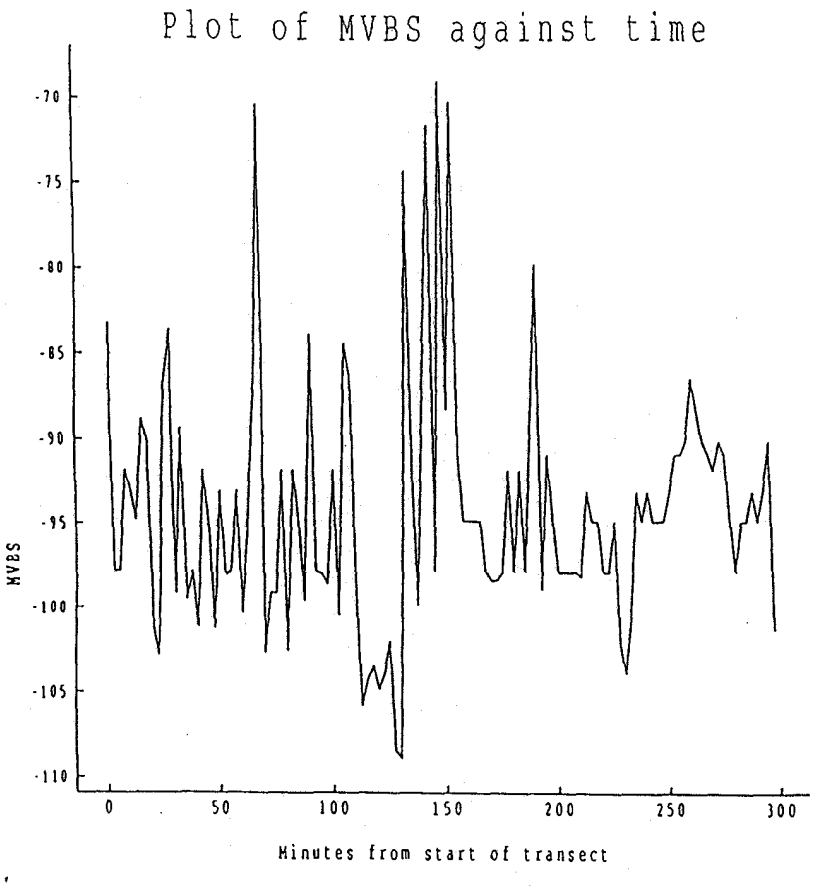

Plot of MVBS against time
MVBS
-70
-75
-80
-85
-90
-95
-100
-105
-110
0
50
100
150
200
250
300
Minutes from start of transect
MVBS against time

Fig 1b

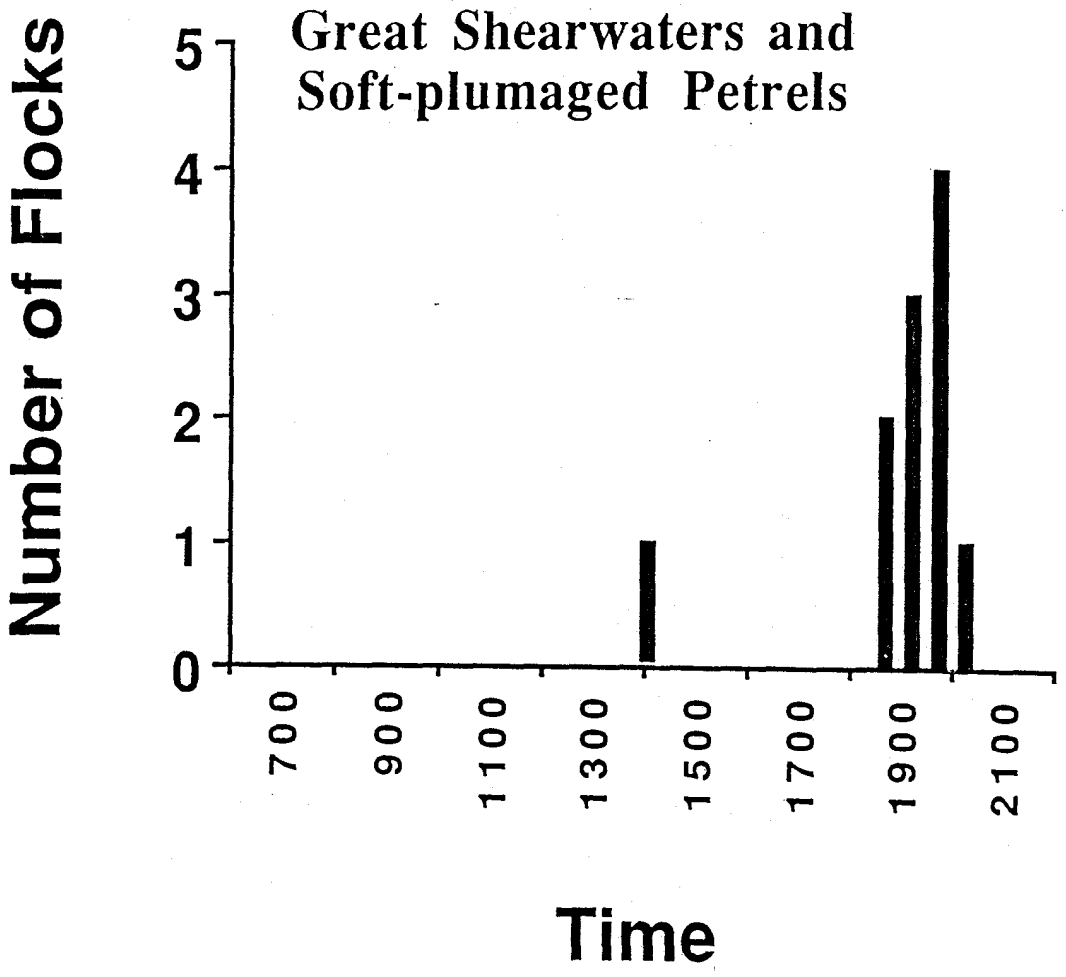

Great Shearwaters and
Soft-plumaged Petrels
Number of Flocks
0
1
2
3
4
5
700
900
1100
1300
1500
1700
1900
2100
Time

Fig 2

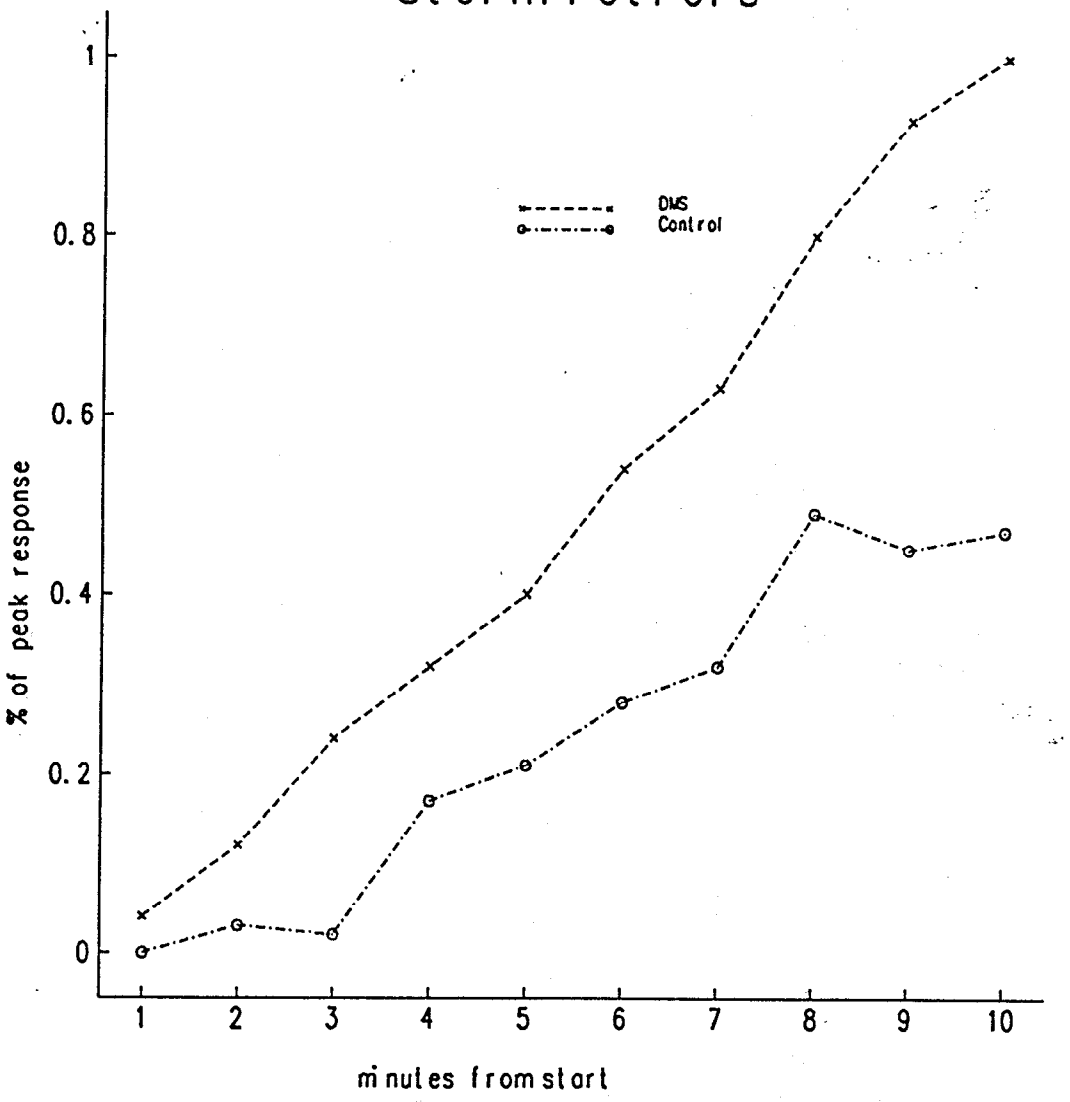

Storm Petrels
DMS
Control
% of peak response
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
10
minutes from start

Fig 3

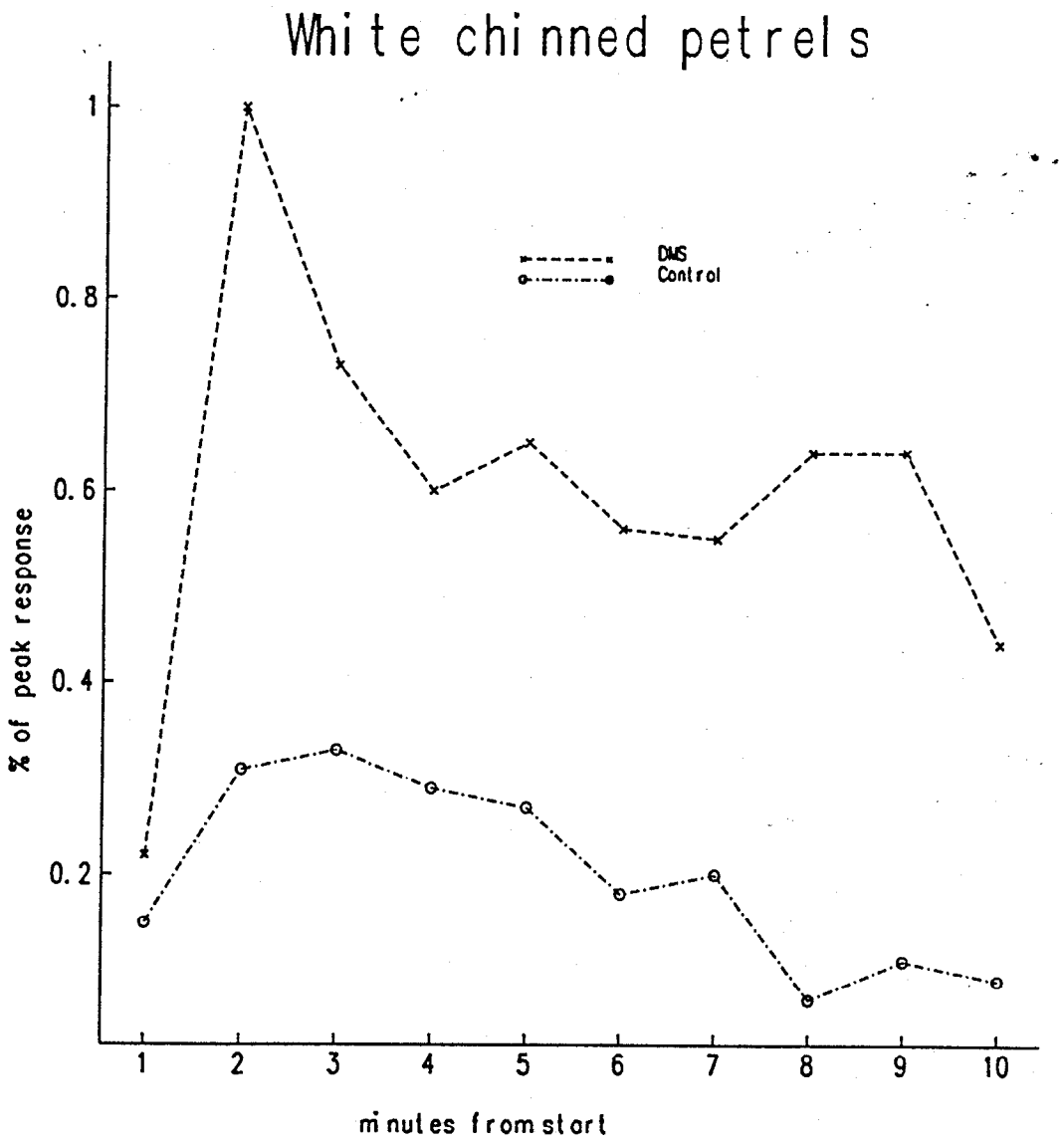

White chinned petrels
DMS
Control
% of peak response
1
0.8
0.6
0.4
0.2
1
2
3
4
5
6
7
8
9
10
minutes from start

Fig 4

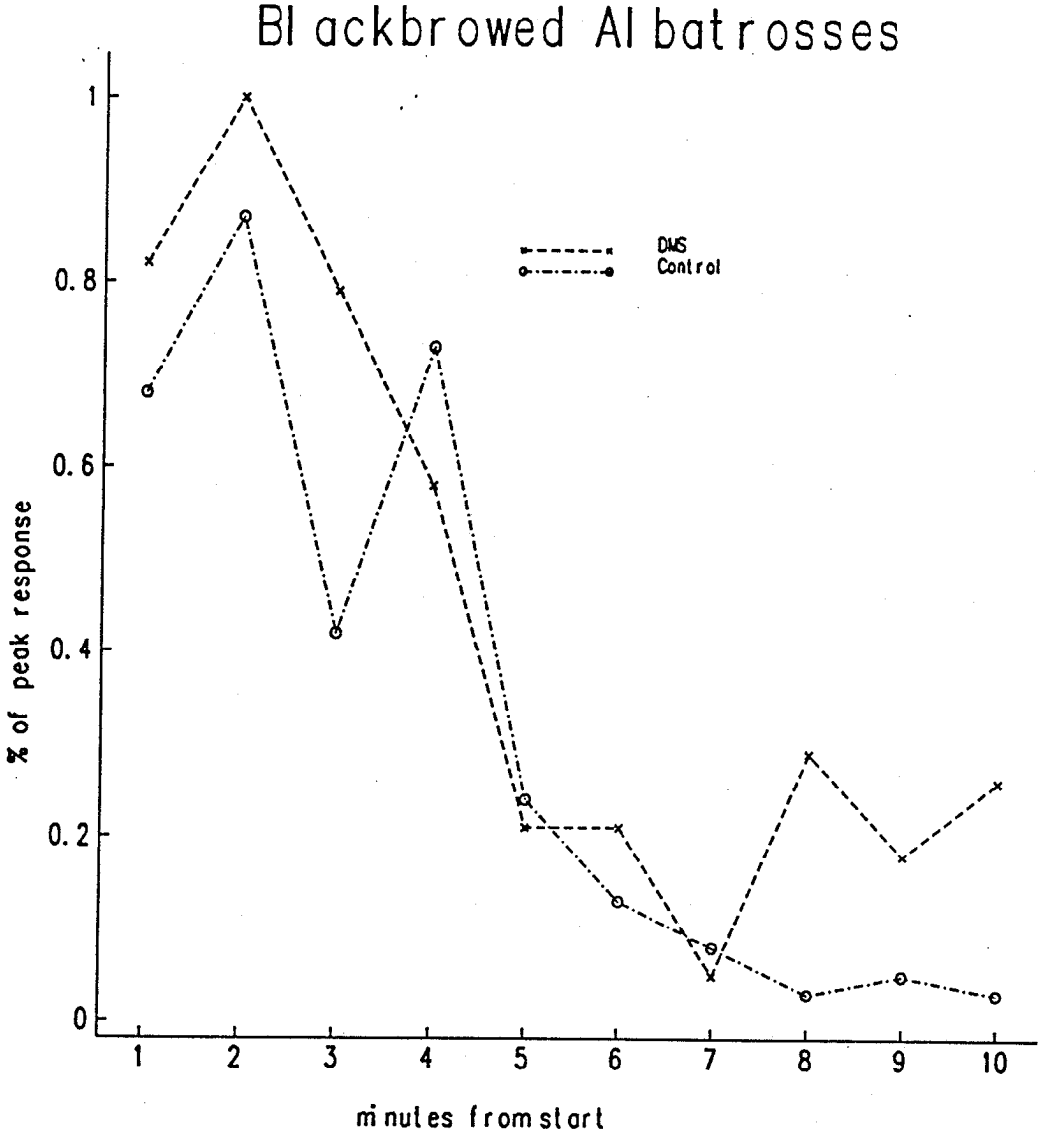

Blackbrowed Albatrosses
DMS
Control
% of peak response
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
minutes from start

Fig 5

34. Bird Flight Observations -

by Colin Pennycuick

This was a follow up to my first trip to Bird Island in 1979-1980, when I measured flight speeds of a range of procellariiform species, from Wanderers to Wilson's Storm Petrels. This time I spent January 1994 on the JCR (the first leg of the Predator-Prey Cruise), and February ashore on Bird Island, whence I was extracted by HMS Norfolk. My main activity was shooting video on the same species as before, with these new objectives:

1. To measure wing beat frequencies in flapping flight. This is a crucial quantity for determining the power output of the flight muscles, and ultimately an essential ingredient in calculations of general energetics. I now have a method for predicting it, which I wanted to test on the same set of species, whose speeds I studied earlier. I also got video on diving petrels, which are interesting because of their convergence on alcids.

2. To record, and if possible quantify, the soaring manoeuvres used by albatrosses to extract energy from the atmosphere's boundary layer above the surface of the sea. Nobody doubts that albatrosses soar over the sea, but exactly how they do it is far from clear. I have so far identified some manoeuvres to be analysed from the tapes, in all species from albatrosses down to prions. I am not sure about storm petrels until I have analysed the tapes.

3. To analyse certain manoeuvres seen last time on Bird Island, to do with slope soaring in strong winds, and with slow flight and landing.

So far (late March) I have been through the tapes and made field-numbered copies for analysis. The tapes contain about 900,000 pictures, many of which will have to be inspected one at a time, so the analysis is going to take a while.

Thanks to the Bird Island team, I obtained many new wing measurements on birds which were caught and released, and also dissected a number of specimens which had been found dead, and frozen prior to my arrival. I obtained especially comprehensive measurements from 3 Black Browed Albatross specimens, which will be used in a computer simulation of flapping flight now being constructed at Bristol. We will be able to compare albatrosses with swans, and eventually with other birds also. Some frozen wings were brought home, and will be used to study the structure and strength of the bones.

I am extremely happy with the scientific haul from this expedition, which will keep me busy at my computer for quite a long time. Eventually I hope to feed back some information and insights, which can be used in wider studies of bird energetics. Meanwhile, I would like to thank BAS for taking me along, and all those on the JCR and at Bird Island who made my trip so enjoyable, as well as productive. I am also most grateful to the Royal Society for a research grant which provided the video equipment, and covered my fare to Stanley.

35. Cruise report for cruise JR06 for Gear Section -

by D.G.Bone.

The following gears were used during the cruise.

1. 'F' Net.

2. 'Z' Net.

3. H-AMPS.

4. RMT 25.

5. LHPR.

6. Commercial Pelagic trawl.

In addition a towed body carrying instruments alone was tested, a pump sampler was assembled ready for use but not used due to the early termination of the cruise. An RMT8 system was also on board and partly assembled to act as backup for the H-AMPS or for catching quantities of Krill for experimental purposes.

Down Wire Net Monitor.

This was our second season with the DWNM, after its successful introduction last season,(Cruise JR03). A number of changes were made in the light of the experience gained, owing to the time commitments of DGB and PW it had not been possible to test some of these changes with the relevant hardware prior to the cruise, this situation was made worse by PW falling ill at the start of the cruise when some of this testing would otherwise have been carried out. This led to some difficulties during the first leg of the cruise but virtually all the problems had been overcome by the start of the second leg or were sorted out soon afterwards.

There were two major advances of note.

Firstly, the introduction of a fluorometer and an altimeter to the system. The former was a new instrument purchased this year which worked without problem, the latter we had last season but were unable to use then due to a power supply problem. Owing to the bulk of the unit it has only been possible to fit it to the H-AMPS frame and even so it seems to be accident prone suffering damage to its electrical connector twice! For a short period however it did work well.

Secondly, the operation of the system down the 10 kilometre Co-ax Cable. This was done to bring the advantages of the DWNM in to play with the RMT25 which requires the extra strength of the co-ax over the 'Biological wire'.

Details of gear operation.

'F'net.

This uninstumented net is used from the 'Scientific' Effer crane located at the break of the Foc's'le, this was is fitted with an integral winch that was furnished with conducting cable. This cable has a large minimum bend radius requiring a large diameter towing block, during the cruise the wire jumped the sheave and forced its way between sheave and frame. This resulted in the frame being strained and frequent repeats of the incident. To overcome this the Conducting cable was removed and replaced by plain wire requiring only a simple small diameter block.

The damaged block will be strengthened and refurbished during refit under the direction of the ships staff. The conducting cable is being returned to Cambridge for storage until it is required.

'Z' Nets.

These uninstrumented nets are operated from the side gantry using plain wire on an unistrumented auxiliary winch. Their operation will be covered by Peter Ward.

Horizontal Antarctic Multiple Plankton Sampler.

Although it was used with success last Season this net is still under development and a number of changes were made in the operation of the cod-end release between cruises, in addition the method of control by the DWNM was changed, all these changes had some unforeseen knock on effects which took time to iron out.

At the end of the first haul the net was recovered at too high a ship speed resulting in it going broadside on and suffering damage, notably to the net itself and the altimeter the connector of which was broken by being caught up in torn net. Later in the first leg fatigue cracks appeared in the welded joints securing the cross members of the aluminium frame.

The frame was repaired ashore during the mid cruise break in the Falklands and the whole sampler performed well in the second leg in spite of being further damaged during a force 11 gale.

Further design changes are planned to eliminate the newly highlighted and some pre existing problems with this potentially very good sampler.

RMT25.

Prior to this cruise the net had only been used from the ship during Trials in the Bay of Biscay.

Few problems were experienced with handling the net but on the first leg the DWNM was not set up to operate on the large Co-ax cable necessitating the use of our old acoustic monitor which provided plenty of the frustrations which stimulated us to look for a better system and develop the DWNM. When used in relatively shallow water and especially near steep slopes the command system has a strong tendency to deafness.

For the second leg the DWNM was operating on the Co-ax cable and no problems were experienced with the net.

LHPR.

This was towed on the 'biological wire' and controlled through the DWNM. For further details see section by Pete ward. And storm damage below.

Pelagic trawl.

This is a commercial size net, intended for midwater fishing for mackerel. It was used here in an attempt to capture squid which form the prey of Grey headed Albatrosses in particular. We have no instrumentation for this net, the only method of finding its fishing depth is to follow it on the Scanning sonar. See below.

The net is deployed from a hydraulically driven net drum and towed on 26mm diameter warps from twin hydraulic winches computer controlled to ensure even warp length.

A total of six hauls were made, two over relatively shallow water during Leg 1, and four more over deep water during Leg 2.

The winches, built to commercial fishing standards cannot be run very slowly for any prolonged period so it is not possible to do deep slow oblique hauls in the manner that many scientific nets are fished. For this reason the warp was paid out in a series of steps, usually 1-300M at a time.

The deepest haul was to a depth of 7-800M, requiring 1500M of warp. Hauling back from this depth caused overheating in the hydraulic pumps so this also was done in a series of steps.

No serious problems were encountered in handling the net, but deployment and recovery were not done in the short time that would be expected on a commercial vessel!

Once the doors are deployed and the net spreads the drag becomes very large, slowing the ship down considerably. While the net is being paid out speed is kept to around three knots but before the doors are deployed the speed needs to be brought up to about 5 knots to prevent dropping to too low a speed when the net opens. in most cases the 'aimed for' towing speed while fishing was around 3.5 knots.

As mentioned earlier, the Furuno scanning sonar was used to determine the nets depth. This was not as easy as might be expected, the net some 200M long and 100M across separated from the doors by 100M sweeps presented a rather diffuse target to the sonar and it was difficult to know which part of the net was causing the strongest reflection. In order to overcome this the beam tilt angle giving the most frequent or strongest response was determined, using this angle and the known slant distance (from wire out etc.) the depth was determined by trigonometry. At best however this was only a rule of thumb.

In terms of total catch and catch of target species the quantities caught were ludicrously small (never was so much deployed against so many to catch so few!) In fact no substantial acoustic targets were seen during any net hauls, most of the sound scatterers were small enough to pass through 90% of the meshes of this net.

We were successful however in catching a small number of Squid of the target species (Martialia sp.?), these were virtually all taken from the meshes of the front, herding, portion of the net rather than from the cod-end itself. It is a characteristic of squids of this group that they try to get out through the sides of the net rather than swim within it until tired as fish would do.

Instrument Package Test.

A towed body, purchased many years ago and found to be unsuitable for its original purpose, was adapted to carry the DWNM instrumentation with a view to using it as an undulating oceanographic instrument platform on future cruises. This was tested by towing on the 'Biological Wire', The results were encouraging, due to slippage in the drive to the tail plane angle adjustment, undulation was not possible but the body proved to be stable at 10 knots and to achieve a depth of 80M at the same speed, this was better than expected.

Winches and wires.

'Biological' Winch and wire.

These worked well, apart from the tension, wire out and rate sensor assembly, this was a known problem that it was not possible to sort out in the last refit. Work is now in hand to move these from their position on the wire between the spurling pipe and the towing block and fit them close to the spooling gear where their support will be independent of wire tension. this should remove most of the problems of exposure to the weather and physical damage due to rapid changes in wire tension when the ship pitches with gear near to the surface.

Co-ax cable and 30 tonne traction winch.

This is the first time that any use has been made of the above cable and the first time that this group has made extensive use of the 30 tonne traction winch.

No problems were experienced with the winch system that affected our operation. (a seized hydraulic pump had potential to limit our operations but did not do so.)

As the cable had not been used before there was no electromechanical termination in existence for it. A termination was designed by D.G.Bone and manufactured in Cambridge prior to the cruise.

Mechanical termination is achieved by potting the previously cleaned, splayed and trimmed armour wires into a conical stainless steel sleeve using a proprietary epoxy based compound, (WireLock). Electrical termination is achieved by crimping the cable conductors to those of an underwater connector (Electro Oceanics type single pin, 2 x 6.5 amp contact female in line connector). This joint is waterproofed by overlaying with heavy duty, mastic lined, heat shrink tubing.

The above assembly is slid into a heavy stainless steel body (placed on the cable prior to mechanical termination) where the potted sleeve is locked in place by Grub screws to prevent rotation. The body attaches directly to the gear via a clevis arrangement that allows articulation in two directions but no rotation. The first termination done was tested by lifting one of the Pelagic Trawl Otter Boards (doors) which was two tons in weight.

After hauls to 1000M depth, requiring 2000M plus wire out some 'birdcaging' was seen in the outer armour just above the termination, initially this was thought to be due to a problem with the termination and this was re-done. Examination of the cut off termination did not reveal any faults and when the same thing occurred with the new termination the cause was sought elsewhere.

The outer layer of armour wires were found to be loose right back through the traction winch, and on the storage drum it was possible push a thumb nail between the strands. Having discovered this, the gear (RMT25) was disconnected and the termination rotated several times so as to 'wind up' and remove the pronounced bird cage just above the termination. The wire was wrapped with tape for a distance of 300mm in case a reoccurrence should allow the loose wires to damage the epoxy

termination. There is no opportunity for the termination to rotate while using the RMT25 and no further problem was seen.

A full description of the Termination, together with instructions for carrying out the procedure are being prepared by DGB and will be lodged on the ship in due course.

At present the Biological wire is terminated in an essentially similar way using a body supplied with the ship by GeoAcoustics of Great Yarmouth. The style of the termination body is not very suitable for the gears that we use and it is intended to acquire a termination of similar style to that for the Co-ax but sized for the Biological wire.

The armour wires of both these cables are very highly tempered which makes then brittle and likely to break at a tight bend, especially if physically damaged. For this reason the Co-ax termination will be adapted to take a stiff rubber bend restrictor. Such a restrictor has already been made and fitted to the Biological wire.

A further point worth noting with regard to both of these cables and the CTD is that with use the lubricant material incorporated in the cable when it is laid up has been drying out and working its way out of the cables, it may be necessary to find a material to replace this in order to prolong their life .

Storm Damage.

During Leg 2 we experienced a force 11 gale with waves to an estimated 50 feet in height. The LHPR was the gear in use when the weather became too bad to continue working and the sampler was left lashed down on deck under the gantry, a position that we expected to be as safe as any with the vessel 'hove to', but as the waves increased in height they began to break over the stern bulwark and eventually wrecked the LHPR frame.

Under these conditions the area further forward and on the port side is slightly safer, when the large net drum is not on deck the best position would be close against the superstructure. BUT NOWHERE WOULD BE ENTIRELY SAFE.

Logistics.

There is no doubt Containers are the way to go but we do a good pallet truck and proper ramps for bringing things out of the container.

36. ISG Electronics cruise report JR06 -

by Paul Woodroffe & Vsevelod Afanasyev

General

A difficult first half of the cruise was fortunately superseded by considerable success on leg 2 - the difference being the opportunity to implement modifications and repairs whilst the ship was stationary at Signy and Port Stanley - as opposed to the excessive work load for the available time during mobilisation.

CTD

The MKIII CTD has performed faultlessly this season. Unfortunately the same cannot be said of the RVS CTD level A, purchased last year at considerable cost, which has a tendency to suddenly stop transmitting data to the level B. This has required us to restart CTD casts on more than one occasion. Normally, one would be aware of the lack of data due to the Level B alarm sounding, however, as the CTD level A causes almost continuous alarms during normal operation, it was often ignored.

The new rosette system was set up after something of a struggle due to lack of experience and instructions from General Oceanics. The system has worked well though we have uncovered one or two bugs, the most serious resulting in the loss of one of the bottle caps, which have a tendency to unscrew themselves. Fortunately there were two spares in the kit which came with the system. The reluctance to close bottles, exhibited during leg 1, was largely solved when the cable was re-terminated. A change required for the next cruise is the modification of the General Oceanics frame, which is far too light and had to be ballasted with about 200Kg of extra weight. Additionally the bottles need transit cases - the cardboard boxes will not last another trip.

EK500

We started by installing V3.01 of the software. Subsequently a problem was noticed which we were not able to solve and it was thought that this problem may have been due to a bug in this version of the software. A plan to convert the system back to the old software version was abandoned as we would have been unable to use the new 200KHz transceiver as planned.

Additionally the EA500 sounder in the wheelhouse blew up, during leg 1, but we were able to fix it, eventually, despite proper technical documentation been unavailable.

Down Wire Net Monitor

Leg 1 was an uphill struggle with the DWNM, due to lack of time to prepare and test what is a complicated system. Fortunately the respite of the mid season break gave me a chance to completely disassemble the underwater and deck units. Subsequently the system performed very well on leg two with the various net systems - including the RMT25 on the 10Km ROV wire. On passage Weddell to Signy, we tried the system in a modified tow fish body which yielded excellent results - with the possibility of us having our own undulator setup.

OceanLogger

The OceanLogger produced excellent results throughout both legs with the previous years thermosalinograph problems being unapparent.

There is a software bug which flags most of the data as suspect in the SMP message but this should be resolved for the next cruise.

Other Equipment

The Furuno sonar requires a visit from the service agents as the display is unreadable in the UIC room.

The ADCP has, as usual, worked without fault.

The PC based XBT system worked well.

37. Computing report -

by Graham Butcher

1. Initial problems

On arrival, it was discovered that the JCR's Scientific and Messaging Computer Systems were not as expected. Two possible reasons for this were :

1. The previous Scientific Cruise had been non BAS and a formal Computing Section handover had not been arranged.
2. The previous Radio Officer, who had a significant involvement in the ship's computing, had previously been working on a logistics only BAS ship, with different computing objectives.

The problems encountered are best summarised as follows :

1. Two Terminal Servers not working
2. VAX user disk 85% full
3. Messaging Software radically altered.
4. Data Transfer Software needed attention
5. The ship's Modem needed reconfiguring
6. PC Print and File services not performing correctly
7. Most PCs had games and software of unknown origin on them and things like mice disabled.
8. The Radio Officer's PC had been swapped with a Scientific one, causing problems with networking, naming and confidentiality. The new Radio Officer found that most of his files had disappeared.
9. Two out of six printing devices were not working.
10. Plotting pens and holders for the Zeta A0 plotter, had been mislaid.

All of these problems were solved or resolved at various times during the Cruise.

2. Security Issues

At the start of the Cruise a formal backup strategy was set up for the PCs, the ABC logging System, the VAX and the Oracle Database. A calendar for 1994 giving information about which tape to use for the whole year was produced. This ensures that VAX, PC and Oracle files can be recovered for at least 2 weeks after any kind of loss (accidental deletion, for example). The ABC System was covered by daily backups of the Sun, BAS1 and additionally by archiving of all level B tapes. More details of the strategies are given below.

PCs	-	Daily backup of all network drives. (usually called M:)
		Weekly backup of all hard-disks (C: drives)
		Weekly virus checking
		Weekly hard-disk integrity checking
Oracle Database	-	Daily incremental exports
		Weekly full exports
		All export files preserved for duration of the Cruise
		Operating System Backups, weekly with Db shutdown
		All redo log files preserved for the duration of the Cruise.

VAX - Daily incremental backups (tape re-cycled after 2 weeks)
Weekly full backups (tape recycled after 3 weeks)
Weekly Standalone Backups of the System Disk (System shutdown for 20 minutes to ensure clean copy)

3. Network Issues

During the Summer sea trials all the PC network cards were upgraded to 16 bit. This produced significant networking performance improvements, most noticed when the PCs are rebooted.

Poor performance still occurs on the PC JRPS, in the far corner of the UIC room. This sometimes results in printing failure. The reason is probably overloading of the single ethernet segment on that area. This same segment carries all level B to C and Sim500 traffic.

The multi-port repeater in the computing office will accommodate up to six more ethernet segments. If these were used the chance of collisions would be reduced and performance would be improved. A future strategy might be to separate Scientific and non Scientific traffic onto different segments.

A problem that came to light during this Cruise was that the ship has too many serial ports (suitable for printers and dumb terminals) and too few ethernet network ports. This problem was most noticeable in the UIC room where two PCs had to share one port.

4. Level C Data Processing

During MLSD and STAP Cruises last season a disk area was created that was common to both the VAX and Suns. This year the area was extended to include PCs. There were two immediate benefits from this setup :

1. New UNIX (C shell) scripts were developed using familiar (VAX) editors and change control and immediately tested under a UNIX environment. Printing out of text files also seemed to work best via the VAX (with two way information flow between host and printer)
2. When the Tektronics printing PC failed, colour prints could still be produced by routing via an adjacent Viglen PC, using this common area.

The Sun, UNIX scripts that were produced were of three types. Firstly work was started on producing management utilities so that new users, for example could be added and removed in a standard way, producing a more unified system.

Secondly, 5 scripts were produced to reduce the amount of typing required to process level C data. Quite often a single command is carried out on a whole series of start and end times which are created from another process. The scripts produced helped by taking their input from files rather than typed in data. All five could be run interactively or as a single command line. Their functionality can be summarised as follows :

1. A script that takes multiple start and end times (in an input file) applies them to a user specified command (with parameters) and produces multiple output files.
2. The same as 1, but producing a single concatenated output file.
3. The same as 1. but takes multiple (start) times only in an input file and a user specified command to produce a single output file.
4. A specific case of 3. Takes a list of times in a input file to give a list of the ship's positions in an output file.
5. A text processing utility to handle columnar data.

Thirdly the ship's officer's found it useful to have level C data displayed in real time on the Bridge and in the Control room. Two scripts were produced that firstly ascertained the time in RVS format and subtracted ten minutes before displaying their data. The first version, used on the Bridge displayed wind speed and direction (relative to the ship). The second script, used in the ship's control room, displayed sea temperature, air temperature, salinity, direction of travel, latitude and longitude. Both displays were designed to give roughly ten minutes of information on screen at a time so that trends could be detected.

5. Recommendations

a) Colour printer - A necessary requirement. In spite of having 3 colour output devices on the ship (HP7475 A3 plotter, Zeta A0 plotter and Tektronics screendump printer) we still lack the capability of producing good hard copy colour graphics. This was mentioned in the last 2 Cruise reports. A colour postscript printer would be ideal but would be expensive to run. The quality of a colour inkjet printer is almost as good and much cheaper to run so that might be the best buy.

b) More disk space - Requirement for disk space is increasing almost as quickly as requirement for more processing power. Now that a SCSI interface has been installed on the VAX the door is open to more competitively priced devices. This extra space could easily be accessed by Suns and PCs.

c) More time allowed for people supporting Cruises to set up - Along with this, if the same people were made responsible for satisfying the requirements of the Cruise, accountability would be simplified.

d) Formal handover - A lot of the early problems were caused by lack of information about what happened on the previous (non BAS) Cruise.

e) More use of double sided printing (A4) - This could be achieved simply by having the printer drivers for the 2250 laser printer and setting the default to double sided within each application (such as WordPerfect)

f) Better use of the graphics capabilities of the Suns - This is beginning to happen already with applications such as UNIRAS and AVS already ported. In the future it will not be necessary run all applications locally on workstations. Optimum performance will be achieved by spreading processing over a distributed environment.

g) Better use of the "spare" VAX - This could be running Ultrix or OSF-1 giving a better gateway than exists at present. It could also help with the BAS migration policy (to UNIX). Alternatively it could be clustered with the existing VAX giving better continuity of service in the event of hardware failure.

h) Better management of individual user accounts on Suns (as opposed to level C type users) - at present it appears that new users on the VAX are better catered for in terms account management.

i) Better Oracle setup - A large amount of Oracle disk space was unused during JR06 because the Oracle files had been set up to fill the whole of disk 2. With the way Oracle works (it can only expand and not shrink) it might have been more prudent to start with smaller files and expand as needed. Additionally disk space had to be used on disk 1 to accommodate the daily exports (part of normal database management). The size of the database at the end of the Cruise amounted to about 50,000 blocks out of 650,00 available.

j) The shortage of network ports in the UIC room should be addressed immediately - if necessary using the short term solution of a "Black Box" expander device.

38. Photography -

by Chris Gilbert

The objectives of the photographer on the second leg of the 1994 Predator prey cruise was to obtain broadcast quality video and 35mm transparencies of shipboard marine science and the support of that science.

Net and instrumentation deployment

RMT25		LHPR	Pelagic trawl
Multinet		CTD	Agassiz trawl
F NET	XBT		
Z Net	Flying fish		

Both night and daytime deployments of the above were filmed. (video and 35mm transparencies). This included the UIC room computer controls, winch controls and winch room. The results of the deployment, whether it was a catch, water sample or data was followed through into the laboratory or computer room. It will
be possible to edit a workable video sequence from any one of the deployments.

Laboratories, computer room and scientific workshop.

(i) Sorting, recording and preserving catches from the RMT 25 Multinet, LHPR, Agassiz trawl, Pelagic trawl and F net.
(ii) Sorting Copepods and setting up an egg production experiment.
(iii) Collecting and analysing water samples from CTD casts and the under way system.
(iv) Data analysis in the data preparation room including the VAX and printer.
(v) Acoustic search and target fishing.
(vi) Repair of the Down wire net monitor in the scientific workshop.

Specimen photography

A system was set up in the explosives room off the scientific hold to photograph living and recently dead specimens. It consisted of a copystand with 35mm camera supported on three pallets, and a dexian frame supporting glass trays of varying sizes. Black card was use to prevent reflections and create a black background. (darkfield)
The specimens were illuminated by a series of 4 Mecablitz CL45-3 flash units run off mains power. Two CL45-3's were supported by lighting stands and used as reflected illumination, one set to half power as the main light and one set to a quarter power as a fill. Two CL45-3's, also set to a quarter power, were used as transmitted illumination supported on wooden blocks on the floor. With this system it was possible to have a combination of reflected and transmitted illumination depending on the type of specimen. For example;

(a) Octopus and squid were photographed with two reflected and one transmitted flash units.

(b) Copepods were photographed with two transmitted flash units.

General photography

(i) Video documentation of JCR going to the assistance of Bransfield.
(ii} Video of JCR engine room and engine control room.
(iii)Video of general scenery and wildlife.
(iv) Video of waste and cargo movement at Stanley.
(v) m transparencies of waste removal from Signy and general Signy base photographs.

Observations

(i) Night deployment. The lighting on the afterdeck and side gantry area was sufficient to video night time deployment, however 9db gain was required as the nets were entering the water and also as the catch was collected from the Multinet.
(ii) The ventilation on the JCR is very noisy and is a serious problem when recording sound. Most sequences will need to be dubbed.

39. Bathymetric data from RRS James Clark Ross

Collected during British Antarctic Survey Marine Life Science cruise JR06 (1/Jan/94 - 3/Mar/94)

Cruise JR06 started and ended at Stanley, Falkland Islands, visiting the Maurice Ewing Bank, South Georgia, Signy Island (South Orkneys) and the Weddell Sea. A cruise track is shown in the attached figure. The boundaries of the region steamed are (SW limit) 71° 34.0'S 38° 28.3'W to (NE limit) 49° 21.3'S 19° 21.3'W. Throughout the cruise bathymetric data were collected using a Simrad EA500 12 kHz echo sounder with a hull-mounted transducer at 6 m depth, and GPS data were collected from a Trimble 4000 DL receiver. Data collection was continuous except for the period 07:44 GMT 19/Jan/94 to 18:34 GMT 3/Feb/94 due to a malfunction in the EA500.

The Simrad EA500 bathymetric sounder was synchronised with the EK500 bioacoustic sounder, causing the ping interval of the former to be dependant upon the settings of the latter. Thus soundings are obtained at somewhat irregular intervals. GPS data were logged at 2 second intervals throughout the cruise.

The EA500 generated suspect bathymetric data on a number of occasions. The bad data were normally generated in moderate to rough sea conditions, when the ship changed course very quickly, or when a rapid change in sea depth caused the instrument to report a false bottom. These bad data were located by use of an interactive graphical data status editor and their status set to 'suspect'. Only data which showed very obvious spikes were edited.

There were no gaps in satellite coverage of more than 10 s during January and only two gaps during February/March, both less than 30 s. However, there were times when the number of available satellites fell below the number required for accurate geographic location. The maximum number of satellites available did not exceed 9, but the arithmetic mean was only 3.4 during the first part of the cruise and 2.7 during the second. On 18/Feb/94, around 20:00 GMT for about three hours, GPS coverage was extremely poor, and wild jumps were recorded for the cruise track. These data have been flagged as suspect.

The other important settings on the EA500 sounder are shown in the table below. The default sound velocity of 1470.6 m/s has been used in the soundings. Depths (excluding all suspect data) which correspond to logged GPS positions have been subsampled every 10 records. This should give adequate resolution but, if desired, the British Antarctic Survey could provide the full data set (this would be best supplied in UNIX file format on a magnetic tape). Please address all communications regarding these data through the navigating officer of RRS James Clark Ross.

There are two files of data, bathy1.dat and bathy2.dat, respectively from the two periods of data collection detailed above. The format of the files is as follows:

1 = year, 2 = julian day, 3 = GMT, 4 = latitude, 5 = longitude, 6 = depth (m)

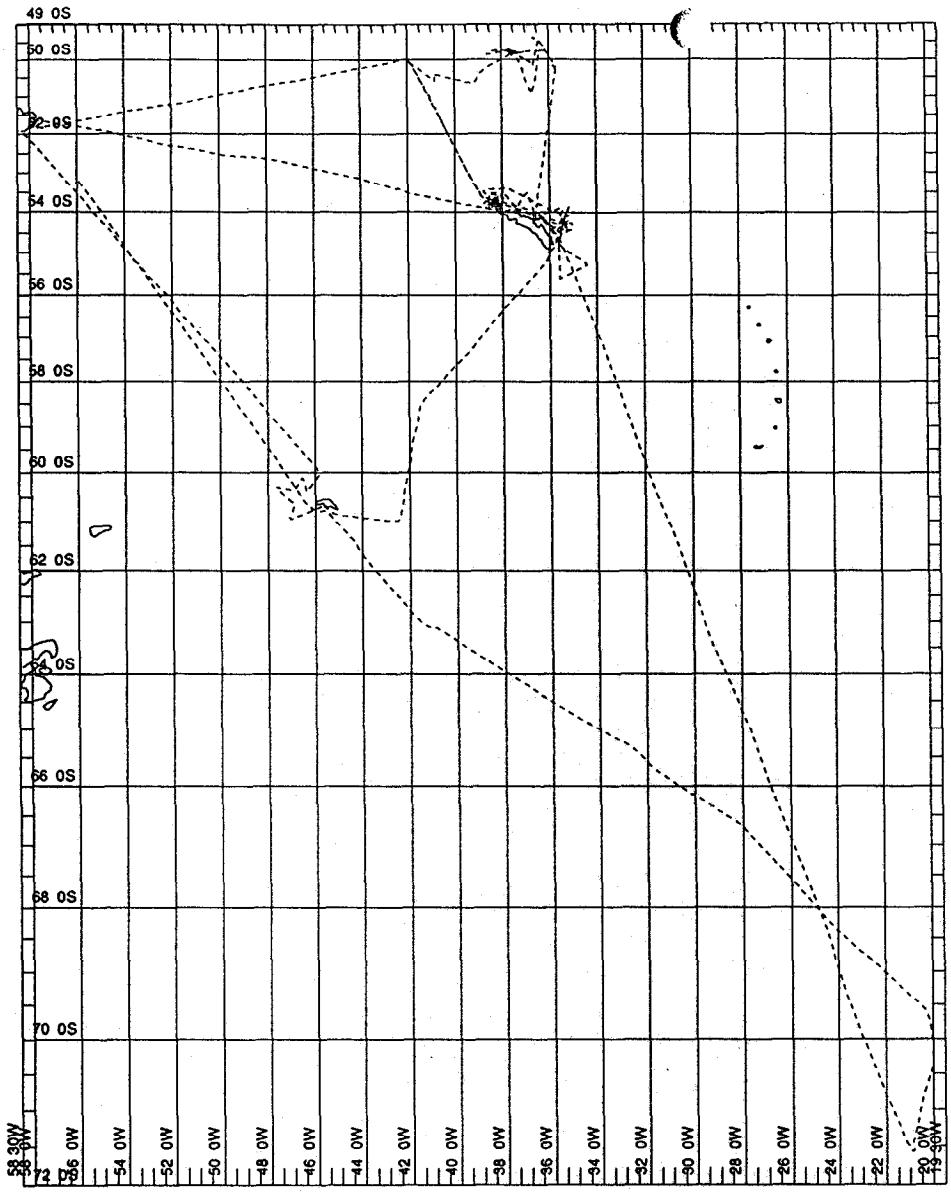
```
1  2   3           4           5           6
94 001 00:01:04    51 49.35S   57 21.37W   246.4
```

Instrument settings for Simrad EA500 12kHz echo sounder on cruise JR06

MENU	SETTING
OPERATION MENU/ PING MODE	EXT. TRIG.
OPERATION MENU/ TRANSMIT POWER	NORMAL
OPERATION MENU/ NOISE MARGIN	0 dB
TRANSCEIVER MENU/ ABSORPTION COEFF	1 dB/km
TRANSCEIVER MENU/ PULSE LENGTH	LONG
TRANSCEIVER MENU/ BANDWIDTH	AUTO (=NARROW)
TRANSCEIVER MENU/ MAX POWER	4000W
TRANSCEIVER MENU/ ANGLE SENSITIVITY	26.9
TRANSCEIVER MENU/ 2-WAY BEAM ANGLE	-12.0 dB
TRANSCEIVER MENU/ Ss TRANSDUCER GAIN	13.3 dB
BOTTOM DETECTION MENU/ MINIMUM DEPTH	0
BOTTOM DETECTION MENU/ MAXIMUM DEPTH	5000
BOTTOM DETECTION MENU/ MINIMUM LEVEL	-50 dB
SOUND VELOCITY MENU/ PROFILE TYPE	ABSOLUTE
SOUND VELOCITY MENU/ DEPTH UPPER	0
SOUND VELOCITY MENU/ DEPTH LOWER	1000
SOUND VELOCITY MENU/ VELOCITY MIN.	1400 m/s
SOUND VELOCITY MENU/ VELOCITY MAX.	1600 m/s

Alistair W A Murray (on behalf of the navigating officer of RRS James Clark Ross)
(British Antarctic Survey,
High Cross,
Madingley Road,
Cambridge,
CB3 0ET)

9/Mar/94



MERCATOR PROJECTION

GRID NO. 1

SCALE 1 TO 12400620 (NATURAL SCALE AT LAT. -60)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE -60

-- Track plotted from gr

Cruise JR06 - RRS James Clark Ross

JR06:

RRS James Clark Ross
Predator/Prey Cruise, South Georgia
Marine Biology
January - March 1994

Annexes I-IV

ANNEX I - Oceanographic transects undertaken during Predator/prey cruise

Transect	Phase	Start time	End time	Description
0001	01	01 JAN 94 00:01	03 JAN 94 05:45	Falkland Is to Maurice Ewing Bank (50S 42W)
0002	01	03 JAN 94 05:56	05 JAN 94 19:27	Maurice Ewing Bank - Willis Islands CTD
0003	01	05 JAN 94 19:27	05 JAN 94 23:01	Stewart Strait (South for Bird Island relief)
0004	01	07 JAN 94 00:20	07 JAN 94 03:06	Stewart Strait (North after Bird Island relief)
0005	02	07 JAN 94 03:06	07 JAN 94 08:47	Bird Island to Leith Harbour
0006	02	07 JAN 94 08:47	07 JAN 94 12:18	Bird Island to Leith Harbour
0007	02	08 JAN 94 00:20	08 JAN 94 05:22	Krill search
0008	02	08 JAN 94 05:22	08 JAN 94 09:19	Krill search
0009	02	08 JAN 94 09:24	08 JAN 94 10:07	Krill search
0010	02	08 JAN 94 10:10	08 JAN 94 10:46	Krill search
0011	02	08 JAN 94 10:50	08 JAN 94 11:29	Krill search
0012	02	08 JAN 94 11:34	08 JAN 94 12:12	Krill search
0013	02	08 JAN 94 12:12	08 JAN 94 12:52	Krill search
0014	02	08 JAN 94 12:52	08 JAN 94 16:00	Krill search
0015	02	08 JAN 94 17:00	08 JAN 94 19:15	Krill search
0016	02	08 JAN 94 19:15	08 JAN 94 20:04	Krill search
0017	02	08 JAN 94 20:14	08 JAN 94 21:17	Krill search
0018	02	08 JAN 94 21:29	08 JAN 94 22:17	Krill search
0019	02	08 JAN 94 23:37	09 JAN 94 00:27	Krill search
0020	02	09 JAN 94 02:00	09 JAN 94 11:17	Krill search
0021	03	09 JAN 94 11:37	09 JAN 94 14:41	Willis Islands large search
0022	03	09 JAN 94 14:41	09 JAN 94 15:33	Willis Islands large search
0023	03	09 JAN 94 15:35	09 JAN 94 18:30	Willis Islands large search
0024	03	09 JAN 94 18:40	09 JAN 94 19:22	Willis Islands large search
0025	03	09 JAN 94 19:27	09 JAN 94 22:27	Willis Islands large search
0026	03	09 JAN 94 22:28	09 JAN 94 22:55	Willis Islands large search
0027	03	09 JAN 94 23:17	10 JAN 94 02:15	Willis Islands large search
0028	03	10 JAN 94 02:18	10 JAN 94 02:49	Willis Islands large search
0029	03	10 JAN 94 02:55	10 JAN 94 05:44	Willis Islands large search
0030	03	10 JAN 94 06:00	10 JAN 94 08:12	Large search to Willis Islands small search
0031	03	10 JAN 94 08:23	10 JAN 94 09:08	Willis Islands small grid EW
0032	03	10 JAN 94 09:18	10 JAN 94 10:03	Willis Islands small grid EW
0033	03	10 JAN 94 10:13	10 JAN 94 10:59	Willis Islands small grid EW
0034	03	10 JAN 94 11:10	10 JAN 94 12:00	Willis Islands small grid EW
0035	03	10 JAN 94 12:09	10 JAN 94 12:55	Willis Islands small grid EW
0036	03	10 JAN 94 13:04	10 JAN 94 13:55	Willis Islands small grid EW
0037	03	11 JAN 94 01:44	11 JAN 94 03:46	Willis Islands FNET transect
0038	03	11 JAN 94 04:02	11 JAN 94 05:36	Willis Islands FNET transect
0039	03	11 JAN 94 09:37	11 JAN 94 10:04	Willis Islands small grid NS
0040	03	11 JAN 94 10:15	11 JAN 94 10:43	Willis Islands small grid NS
0041	03	11 JAN 94 10:53	11 JAN 94 11:21	Willis Islands small grid NS
0042	03	11 JAN 94 11:40	11 JAN 94 12:05	Willis Islands small grid NS
0043	03	11 JAN 94 12:08	11 JAN 94 12:35	Willis Islands small grid NS
0044	03	11 JAN 94 12:44	11 JAN 94 13:16	Willis Islands small grid NS
0045	03	11 JAN 94 13:25	11 JAN 94 13:51	Willis Islands small grid NS
0046	03	11 JAN 94 14:01	11 JAN 94 14:30	Willis Islands small grid NS
0047	03	11 JAN 94 14:41	11 JAN 94 15:07	Willis Islands small grid NS
0048	03	11 JAN 94 22:00	12 JAN 94 04:00	Willis Islands CTD grid
0049	03	12 JAN 94 05:00	12 JAN 94 09:30	Willis Islands CTD grid
0050	03	12 JAN 94 10:00	12 JAN 94 13:48	Willis Islands CTD grid
0051	03	12 JAN 94 15:00	12 JAN 94 19:00	Willis Islands CTD grid
0052	03	12 JAN 94 20:00	13 JAN 94 00:01	Willis Islands CTD grid

Transect	Phase	Start time	End time	Description
0053	03	13 JAN 94 01:43	13 JAN 94 14:31	Willis Islands CTD transect
0054	03	13 JAN 94 16:15	14 JAN 94 01:22	Willis Islands CTD transect
0055	03	14 JAN 94 20:45	14 JAN 94 21:58	Willis Islands small acoustic search
0056	03	14 JAN 94 21:58	14 JAN 94 22:18	Willis Islands small acoustic search
0057	03	14 JAN 94 22:18	14 JAN 94 23:35	Willis Islands small acoustic search
0058	03	14 JAN 94 23:35	15 JAN 94 00:20	Willis Islands small acoustic search
0059	03	15 JAN 94 11:25	15 JAN 94 11:48	Willis Islands acoustic transect
0060	03	15 JAN 94 11:51	15 JAN 94 13:23	Willis Islands acoustic transect
0061	03	15 JAN 94 13:25	15 JAN 94 13:53	Willis Islands acoustic transect
0062	03	15 JAN 94 21:09	15 JAN 94 22:51	Willis Is. clover leaf search for multispecies
0063	04	19 JAN 94 12:19	19 JAN 94 17:00	Leith to Cooper Island
0064	04	19 JAN 94 17:00	21 JAN 94 06:00	S Georgia to South Orkney Islands - part 1
0065	04	21 JAN 94 06:00	21 JAN 94 12:07	S Georgia to South Orkney Islands - part 2
0066	05	22 JAN 94 20:45	23 JAN 94 01:23	South Orkney krill search
0067	05	23 JAN 94 01:32	23 JAN 94 03:43	South Orkney krill search
0068	05	23 JAN 94 03:47	23 JAN 94 06:49	South Orkney krill search
0069	05	23 JAN 94 06:52	23 JAN 94 09:11	South Orkney krill search
0070	05	23 JAN 94 09:14	23 JAN 94 11:06	South Orkney krill search
0071	05	23 JAN 94 11:10	23 JAN 94 13:11	South Orkney krill search
0072	05	23 JAN 94 13:15	23 JAN 94 16:16	South Orkney krill search
0073	06	23 JAN 94 16:23	25 JAN 94 23:59	South Orkney Islands to Falkland Islands
0074	07	02 FEB 94 03:45	04 FEB 94 13:00	Maurice Ewing Bank - Willis Islands CTD
0075	08	04 FEB 94 14:17	04 FEB 94 19:00	GHA/squid/myctophid search
0076	08	04 FEB 94 22:02	05 FEB 94 06:55	GHA/squid/myctophid search
0077	08	05 FEB 94 07:00	05 FEB 94 09:25	GHA/squid/myctophid search
0078	08	05 FEB 94 09:25	05 FEB 94 15:40	GHA/squid/myctophid search
0079	08	05 FEB 94 15:50	05 FEB 94 21:20	GHA/squid/myctophid search
0080	08	05 FEB 94 21:40	05 FEB 94 22:55	GHA/squid/myctophid search
0081	08	05 FEB 94 23:00	06 FEB 94 06:00	GHA/squid/myctophid search
0082	08	06 FEB 94 06:03	06 FEB 94 14:15	GHA/squid/myctophid search
0083	08	13 FEB 94 09:17	14 FEB 94 15:48	GHA/squid/myctophid physical characterisat
0084	08	14 FEB 94 15:52	14 FEB 94 19:40	GHA/squid/myctophid physical characterisat
0085	08	15 FEB 94 03:00	16 FEB 94 03:50	GHA/squid/myctophid physical characterisat
0086	08	16 FEB 94 08:00	17 FEB 94 09:00	GHA/squid/myctophid to Leith for calibration
0087	09	17 FEB 94 23:00	18 FEB 94 08:00	Leith to start of South Georgia krill survey
0088	09	18 FEB 94 08:00	18 FEB 94 09:00	South Georgia krill survey (leg 1 aborted)
0089	09	18 FEB 94 13:09	18 FEB 94 18:00	South Georgia krill survey (leg 4)
0090	09	18 FEB 94 18:04	18 FEB 94 23:14	South Georgia krill survey (leg 5)
0091	09	18 FEB 94 23:20	19 FEB 94 03:09	South Georgia krill survey
0092	09	19 FEB 94 06:00	19 FEB 94 08:50	South Georgia krill survey
0093	09	19 FEB 94 08:54	19 FEB 94 14:00	South Georgia krill survey (leg 1)
0094	09	19 FEB 94 14:04	19 FEB 94 18:05	South Georgia krill survey (leg 2)
0095	09	19 FEB 94 18:15	19 FEB 94 22:46	South Georgia krill survey (leg 3)
0096	09	19 FEB 94 22:50	20 FEB 94 03:30	South Georgia krill survey
0097	09	20 FEB 94 07:28	20 FEB 94 09:55	South Georgia krill survey
0098	09	20 FEB 94 09:55	20 FEB 94 10:24	South Georgia krill survey
0099	09	20 FEB 94 10:24	20 FEB 94 13:01	South Georgia krill survey
0100	09	20 FEB 94 13:05	20 FEB 94 13:33	South Georgia krill survey
0101	09	20 FEB 94 13:33	20 FEB 94 16:40	South Georgia krill survey
0102	09	20 FEB 94 17:00	20 FEB 94 18:10	South Georgia krill survey
0103	09	20 FEB 94 18:15	20 FEB 94 19:15	South Georgia krill survey
0104	09	20 FEB 94 19:15	20 FEB 94 19:40	South Georgia krill survey
0105	09	20 FEB 94 19:40	20 FEB 94 20:40	South Georgia krill survey
0106	09	20 FEB 94 20:40	20 FEB 94 21:05	South Georgia krill survey
0107	09	20 FEB 94 21:05	20 FEB 94 22:00	South Georgia krill survey
0108	09	21 FEB 94 04:00	21 FEB 94 09:42	South Georgia krill survey

Transect	Phase	Start time	End time	Description
0109	09	21 FEB 94 09:42	21 FEB 94 10:10	South Georgia krill survey (leg 6 aborted)
0110	10	21 FEB 94 11:00	24 FEB 94 08:00	Save the Bransfield !!
0111	10	25 FEB 94 00:55	25 FEB 94 09:30	Out of the ice
0112	10	25 FEB 94 10:00	01 MAR 94 07:08	Edge of the ice to the South Orkney Islands
0113	10	01 MAR 94 16:00	03 MAR 94 07:00	South Orkney Islands to the Falkland Islands

ANNEX II - Event log, Leg 1

Event	Activity	Start time	End time
0001	CTD	01 JAN 94 18:30	01 JAN 94 19:05
0002	CTD	03 JAN 94 06:40	03 JAN 94 08:17
0003	ZNET	03 JAN 94 08:40	03 JAN 94 08:56
0004	CTD	03 JAN 94 11:19	03 JAN 94 12:23
0005	ZNET	03 JAN 94 12:31	03 JAN 94 12:51
0006	CTD	03 JAN 94 15:45	03 JAN 94 16:43
0007	ZNET	03 JAN 94 17:04	03 JAN 94 17:20
0008	CTD	03 JAN 94 19:53	03 JAN 94 21:30
0009	CTD	04 JAN 94 00:13	04 JAN 94 02:05
0010	CTD	04 JAN 94 04:45	04 JAN 94 07:00
0011	ZNET	04 JAN 94 07:15	04 JAN 94 07:32
0012	ZNET	04 JAN 94 07:36	04 JAN 94 07:53
0013	ZNET	04 JAN 94 08:00	04 JAN 94 08:22
0014	CTD	04 JAN 94 10:48	04 JAN 94 12:55
0015	ZNET	04 JAN 94 13:05	04 JAN 94 13:23
0016	ZNET	04 JAN 94 13:25	04 JAN 94 13:44
0017	ZNET	04 JAN 94 13:47	04 JAN 94 14:17
0018	CTD	04 JAN 94 16:46	04 JAN 94 17:41
0019	ZNET	04 JAN 94 17:50	04 JAN 94 18:05
0020	ZNET	04 JAN 94 18:08	04 JAN 94 18:24
0021	ZNET	04 JAN 94 18:28	04 JAN 94 18:54
0022	CTD	04 JAN 94 21:10	04 JAN 94 23:26
0023	ZNET	04 JAN 94 23:40	04 JAN 94 23:59
0024	ZNET	05 JAN 94 00:02	05 JAN 94 00:24
0025	ZNET	05 JAN 94 00:30	05 JAN 94 00:52
0026	CTD	05 JAN 94 03:33	05 JAN 94 04:39
0027	ZNET	05 JAN 94 04:53	05 JAN 94 04:55
0028	ZNET	05 JAN 94 05:30	05 JAN 94 05:54
0029	ZNET	05 JAN 94 05:58	05 JAN 94 06:28
0030	CTD	05 JAN 94 08:35	05 JAN 94 09:45
0031	CTD	05 JAN 94 11:54	05 JAN 94 12:52
0032	CTD	05 JAN 94 15:17	05 JAN 94 16:15
0033	CTD	05 JAN 94 18:19	05 JAN 94 19:05
0034	ZNET	08 JAN 94 01:15	08 JAN 94 01:31
0035	ZNET	08 JAN 94 01:34	08 JAN 94 01:50
0036	ZNET	08 JAN 94 01:54	08 JAN 94 02:20
0037	CTD	08 JAN 94 15:02	08 JAN 94 15:36
0038	ZNET	08 JAN 94 15:40	08 JAN 94 16:00
0039	ZNET	08 JAN 94 16:05	08 JAN 94 16:20
0040	ZNET	08 JAN 94 16:24	08 JAN 94 16:49
0041	ZNET	08 JAN 94 22:32	08 JAN 94 22:50
0042	ZNET	08 JAN 94 22:51	08 JAN 94 23:00
0043	ZNET	08 JAN 94 23:02	08 JAN 94 23:15
0044	ZNET	09 JAN 94 00:40	09 JAN 94 00:59
0045	ZNET	09 JAN 94 01:03	09 JAN 94 01:23
0046	ZNET	09 JAN 94 01:26	09 JAN 94 01:47
0047	ZNET	10 JAN 94 15:35	10 JAN 94 15:55

Event	Activity	Start time	End time
0048	ZNET	10 JAN 94 16:00	10 JAN 94 16:13
0049	ZNET	10 JAN 94 16:21	10 JAN 94 16:36
0050	ZNET	10 JAN 94 16:41	10 JAN 94 16:47
0051	MNET	10 JAN 94 18:25	10 JAN 94 18:44
0052	MNET	10 JAN 94 21:21	10 JAN 94 23:08
0053	ZNET	11 JAN 94 00:05	11 JAN 94 00:24
0054	ZNET	11 JAN 94 00:26	11 JAN 94 00:42
0055	ZNET	11 JAN 94 00:51	11 JAN 94 00:59
0056	FNET	11 JAN 94 01:44	11 JAN 94 02:04
0057	FNET	11 JAN 94 02:06	11 JAN 94 02:28
0058	FNET	11 JAN 94 02:31	11 JAN 94 02:54
0059	FNET	11 JAN 94 02:59	11 JAN 94 03:23
0060	FNET	11 JAN 94 03:26	11 JAN 94 03:46
0061	FNET	11 JAN 94 04:02	11 JAN 94 04:23
0062	FNET	11 JAN 94 04:25	11 JAN 94 04:45
0063	FNET	11 JAN 94 04:49	11 JAN 94 05:10
0064	FNET	11 JAN 94 05:14	11 JAN 94 05:36
0065	ZNET	11 JAN 94 06:16	11 JAN 94 06:34
0066	ZNET	11 JAN 94 06:38	11 JAN 94 06:45
0067	ZNET	11 JAN 94 06:50	11 JAN 94 07:06
0068	ZNET	11 JAN 94 07:12	11 JAN 94 07:27
0069	ZNET	11 JAN 94 07:35	11 JAN 94 07:49
0070	ZNET	11 JAN 94 07:54	11 JAN 94 08:08
0071	CTD	11 JAN 94 15:43	11 JAN 94 16:22
0072	ZNET	11 JAN 94 16:29	11 JAN 94 16:35
0073	ZNET	11 JAN 94 16:36	11 JAN 94 16:52
0074	CTD	11 JAN 94 17:20	11 JAN 94 17:55
0075	ZNET	11 JAN 94 18:04	11 JAN 94 18:31
0076	ZNET	11 JAN 94 18:43	11 JAN 94 18:59
0077	ZNET	11 JAN 94 19:02	11 JAN 94 19:10
0078	ZNET	11 JAN 94 19:12	11 JAN 94 19:30
0079	MNET	11 JAN 94 19:50	11 JAN 94 20:27
0080	CTD	11 JAN 94 22:00	11 JAN 94 22:14
0081	CTD	11 JAN 94 22:47	11 JAN 94 23:01
0082	CTD	11 JAN 94 23:41	12 JAN 94 00:02
0083	CTD	12 JAN 94 00:59	12 JAN 94 01:33
0084	CTD	12 JAN 94 02:07	12 JAN 94 02:53
0085	CTD	12 JAN 94 03:28	12 JAN 94 04:25
0086	CTD	12 JAN 94 04:52	12 JAN 94 05:24
0087	CTD	12 JAN 94 06:03	12 JAN 94 06:24
0088	CTD	12 JAN 94 06:57	12 JAN 94 07:12
0089	CTD	12 JAN 94 07:42	12 JAN 94 08:04
0090	CTD	12 JAN 94 08:32	12 JAN 94 08:51
0091	CTD	12 JAN 94 09:19	12 JAN 94 09:33
0092	CTD	12 JAN 94 10:02	12 JAN 94 10:21
0093	CTD	12 JAN 94 10:50	12 JAN 94 11:12
0094	CTD	12 JAN 94 11:43	12 JAN 94 12:03

Event	Activity	Start time	End time
0095	CTD	12 JAN 94 12:28	12 JAN 94 12:40
0096	CTD	12 JAN 94 13:09	12 JAN 94 13:25
0097	CTD	12 JAN 94 13:50	12 JAN 94 14:13
0098	CTD	12 JAN 94 14:41	12 JAN 94 14:58
0099	CTD	12 JAN 94 15:32	12 JAN 94 15:47
0100	CTD	12 JAN 94 16:25	12 JAN 94 16:41
0101	CTD	12 JAN 94 17:14	12 JAN 94 17:31
0102	CTD	12 JAN 94 18:04	12 JAN 94 18:21
0103	CTD	12 JAN 94 18:48	12 JAN 94 19:11
0104	CTD	12 JAN 94 19:35	12 JAN 94 19:52
0105	CTD	12 JAN 94 20:22	12 JAN 94 20:32
0106	CTD	12 JAN 94 21:02	12 JAN 94 21:14
0107	CTD	12 JAN 94 21:43	12 JAN 94 21:58
0108	CTD	12 JAN 94 22:30	12 JAN 94 22:43
0109	CTD	12 JAN 94 23:15	12 JAN 94 23:29
0110	ZNET	12 JAN 94 23:41	12 JAN 94 23:55
0111	ZNET	13 JAN 94 00:01	13 JAN 94 00:15
0112	ZNET	13 JAN 94 00:20	13 JAN 94 00:39
0113	CTD	13 JAN 94 01:52	13 JAN 94 02:04
0114	CTD	13 JAN 94 02:29	13 JAN 94 02:44
0115	CTD	13 JAN 94 03:17	13 JAN 94 03:30
0116	CTD	13 JAN 94 03:58	13 JAN 94 04:12
0117	CTD	13 JAN 94 04:40	13 JAN 94 04:55
0118	CTD	13 JAN 94 05:21	13 JAN 94 05:38
0119	CTD	13 JAN 94 06:08	13 JAN 94 07:05
0120	CTD	13 JAN 94 07:36	13 JAN 94 08:39
0121	CTD	13 JAN 94 09:08	13 JAN 94 10:29
0122	CTD	13 JAN 94 11:03	13 JAN 94 11:47
0123	CTD	13 JAN 94 13:00	13 JAN 94 14:30
0124	CTD	13 JAN 94 16:21	13 JAN 94 17:40
0125	CTD	13 JAN 94 18:05	13 JAN 94 18:59
0126	CTD	13 JAN 94 19:34	13 JAN 94 20:03
0127	CTD	13 JAN 94 20:32	13 JAN 94 20:43
0128	CTD	13 JAN 94 21:08	13 JAN 94 21:18
0129	CTD	13 JAN 94 21:42	13 JAN 94 21:54
0130	CTD	13 JAN 94 22:18	13 JAN 94 22:34
0131	CTD	13 JAN 94 22:57	13 JAN 94 23:13
0132	CTD	13 JAN 94 23:44	13 JAN 94 23:58
0133	CTD	14 JAN 94 00:25	14 JAN 94 00:39
0134	CTD	14 JAN 94 01:05	14 JAN 94 01:22
0135	ZNET	14 JAN 94 02:50	14 JAN 94 02:56
0136	ZNET	14 JAN 94 02:59	14 JAN 94 03:14
0137	MNET	14 JAN 94 04:06	14 JAN 94 04:31
0138	MNET	14 JAN 94 06:35	14 JAN 94 08:00
0139	MNET	14 JAN 94 09:28	14 JAN 94 10:50
0140	ZNET	14 JAN 94 13:06	14 JAN 94 13:24
0141	ZNET	14 JAN 94 13:29	14 JAN 94 13:44

Event	Activity	Start time	End time
0142	ZNET	14 JAN 94 13:46	14 JAN 94 14:03
0143	ZNET	14 JAN 94 14:13	14 JAN 94 14:35
0149	CTD	14 JAN 94 15:13	14 JAN 94 15:38
0150	ZNET	14 JAN 94 15:50	14 JAN 94 15:59
0151	ZNET	14 JAN 94 16:01	14 JAN 94 16:18
0152	ZNET	14 JAN 94 16:27	14 JAN 94 16:45
0153	ZNET	14 JAN 94 16:50	14 JAN 94 16:56
0154	MNET	14 JAN 94 17:57	14 JAN 94 19:40
0155	FNET	14 JAN 94 20:00	14 JAN 94 20:08
0156	FNET	15 JAN 94 00:32	15 JAN 94 00:54
0157	FNET	15 JAN 94 01:03	15 JAN 94 01:24
0158	FNET	15 JAN 94 01:28	15 JAN 94 01:52
0159	RMT25	15 JAN 94 03:10	15 JAN 94 05:00
0160	RMT25	15 JAN 94 07:00	15 JAN 94 08:40
0161	RMT25	16 JAN 94 12:21	16 JAN 94 14:09
0162	CTD	16 JAN 94 15:31	16 JAN 94 16:02
0163	ZNET	16 JAN 94 16:08	16 JAN 94 16:16
0164	ZNET	16 JAN 94 16:19	16 JAN 94 16:35
0165	ZNET	16 JAN 94 16:38	16 JAN 94 16:55
0166	RMT25	16 JAN 94 17:56	16 JAN 94 20:00
0167	RMT25	17 JAN 94 00:21	17 JAN 94 02:01
0168	RMT25	17 JAN 94 02:59	17 JAN 94 05:15
0169	LHPR	17 JAN 94 07:33	17 JAN 94 08:08
0170	ZNET	17 JAN 94 09:11	17 JAN 94 09:17
0171	ZNET	17 JAN 94 09:19	17 JAN 94 09:35
0172	ZNET	17 JAN 94 09:38	17 JAN 94 09:53
0173	ZNET	17 JAN 94 09:57	17 JAN 94 10:13
0174	LHPR	17 JAN 94 11:16	17 JAN 94 11:47
0175	ZNET	17 JAN 94 12:19	17 JAN 94 12:26
0176	ZNET	17 JAN 94 12:39	17 JAN 94 12:47
0177	ZNET	17 JAN 94 12:50	17 JAN 94 12:59
0178	ZNET	17 JAN 94 13:01	17 JAN 94 13:17
0179	CTD	17 JAN 94 14:25	17 JAN 94 14:50
0180	LHPR	17 JAN 94 15:20	17 JAN 94 16:36
0181	ZNET	17 JAN 94 17:35	17 JAN 94 17:43
0182	ZNET	17 JAN 94 17:46	17 JAN 94 18:01
0183	ZNET	17 JAN 94 18:03	17 JAN 94 18:11
0184	ZNET	17 JAN 94 18:14	17 JAN 94 18:20
0185	ZNET	17 JAN 94 18:23	17 JAN 94 18:27
0186	LHPR	17 JAN 94 19:30	17 JAN 94 19:58
0187	ZNET	17 JAN 94 20:50	17 JAN 94 20:57
0188	ZNET	17 JAN 94 20:58	17 JAN 94 21:14
0189	ZNET	17 JAN 94 21:51	17 JAN 94 21:57
0190	ZNET	17 JAN 94 22:00	17 JAN 94 22:14
0191	ZNET	17 JAN 94 22:17	17 JAN 94 22:32
0192	ZNET	17 JAN 94 22:34	17 JAN 94 22:48
0193	ZNET	17 JAN 94 22:44	17 JAN 94 22:51

Event	Activity	Start time	End time
0194	LHPR	17 JAN 94 23:27	18 JAN 94 00:03
0195	ZNET	18 JAN 94 00:55	18 JAN 94 01:00
0196	ZNET	18 JAN 94 01:06	18 JAN 94 01:20
0197	ZNET	18 JAN 94 01:55	18 JAN 94 02:01
0198	ZNET	18 JAN 94 02:03	18 JAN 94 02:19
0199	LHPR	18 JAN 94 02:46	18 JAN 94 03:20
0200	ZNET	18 JAN 94 03:44	18 JAN 94 03:51
0201	ZNET	18 JAN 94 03:54	18 JAN 94 04:09
0202	LHPR	18 JAN 94 05:15	18 JAN 94 05:48
0203	ZNET	18 JAN 94 06:17	18 JAN 94 06:25
0204	ZNET	18 JAN 94 06:29	18 JAN 94 06:45
0205	ZNET	18 JAN 94 07:28	18 JAN 94 07:34
0206	ZNET	18 JAN 94 07:37	18 JAN 94 07:52
0207	LHPR	18 JAN 94 08:45	18 JAN 94 09:15
0208	ZNET	18 JAN 94 10:00	18 JAN 94 10:07
0209	ZNET	18 JAN 94 10:09	18 JAN 94 10:26
0210	ZNET	18 JAN 94 11:03	18 JAN 94 11:10
0211	ZNET	18 JAN 94 11:12	18 JAN 94 11:30
0212	ZNET	18 JAN 94 11:34	18 JAN 94 11:49
0213	ZNET	18 JAN 94 14:02	18 JAN 94 14:08
0214	ZNET	18 JAN 94 14:11	18 JAN 94 14:28
0215	ZNET	18 JAN 94 14:34	18 JAN 94 14:51
0216	PMT	18 JAN 94 16:54	18 JAN 94 18:07
0217	AGSZ	18 JAN 94 19:28	18 JAN 94 20:30
0218	PMT	18 JAN 94 23:46	19 JAN 94 01:20

ANNEX III - Event Log, Leg 2

Event	Activity	Start time	End time
0219	CTD	31 JAN 94 19:10	31 JAN 94 19:30
0220	ZNET	31 JAN 94 19:37	31 JAN 94 19:47
0221	ZNET	31 JAN 94 19:51	31 JAN 94 20:01
0222	TRAK	31 JAN 94 20:05	31 JAN 94 20:17
0223	MNET	01 FEB 94 19:30	01 FEB 94 20:25
0224	CTD	02 FEB 94 03:45	02 FEB 94 04:49
0225	ZNET	02 FEB 94 04:55	02 FEB 94 05:10
0226	CTD	02 FEB 94 07:35	02 FEB 94 08:37
0227	ZNET	02 FEB 94 08:47	02 FEB 94 09:05
0228	CTD	02 FEB 94 11:23	02 FEB 94 12:25
0229	ZNET	02 FEB 94 12:30	02 FEB 94 12:45
0230	CTD	02 FEB 94 15:29	02 FEB 94 16:31
0231	ZNET	02 FEB 94 16:39	02 FEB 94 16:58
0232	CTD	02 FEB 94 19:21	02 FEB 94 20:20
0233	ZNET	02 FEB 94 20:25	02 FEB 94 20:45
0234	CTD	02 FEB 94 23:12	03 FEB 94 01:19
0235	ZNET	03 FEB 94 01:28	03 FEB 94 01:45
0236	CTD	03 FEB 94 04:35	03 FEB 94 05:34
0237	ZNET	03 FEB 94 05:57	03 FEB 94 06:12
0238	CTD	03 FEB 94 08:30	03 FEB 94 10:35
0239	ZNET	03 FEB 94 11:11	03 FEB 94 11:29
0240	CTD	03 FEB 94 14:06	03 FEB 94 16:16
0241	ZNET	03 FEB 94 16:28	03 FEB 94 16:45
0242	CTD	03 FEB 94 19:00	03 FEB 94 20:32
0243	ZNET	03 FEB 94 20:40	03 FEB 94 20:59
0244	CTD	03 FEB 94 23:18	04 FEB 94 00:56
0245	ZNET	04 FEB 94 01:00	04 FEB 94 01:18
0246	CTD	04 FEB 94 03:59	04 FEB 94 05:02
0247	ZNET	04 FEB 94 05:06	04 FEB 94 05:21
0248	CTD	04 FEB 94 07:32	04 FEB 94 08:35
0249	ZNET	04 FEB 94 08:42	04 FEB 94 09:02
0250	CTD	04 FEB 94 11:36	04 FEB 94 12:36
0251	ZNET	04 FEB 94 12:50	04 FEB 94 13:12
0252	PMT	04 FEB 94 19:04	04 FEB 94 21:20
0253	PMT	06 FEB 94 15:31	06 FEB 94 17:45
0254	ZNET	06 FEB 94 20:59	06 FEB 94 21:14
0255	ZNET	06 FEB 94 21:16	06 FEB 94 21:23
0256	ZNET	06 FEB 94 21:25	06 FEB 94 21:33
0257	PMT	06 FEB 94 23:32	07 FEB 94 01:30
0258	ZNET	07 FEB 94 03:28	07 FEB 94 03:37
0259	CTD	07 FEB 94 06:44	07 FEB 94 07:14
0260	RMT	07 FEB 94 10:46	07 FEB 94 13:23
0261	FNET	07 FEB 94 12:00	07 FEB 94 12:30
0262	RMT	07 FEB 94 15:04	07 FEB 94 18:47

Event	Activity	Start time	End time
0263	FNET	07 FEB 94 15:49	07 FEB 94 16:20
0264	RMT	07 FEB 94 20:36	08 FEB 94 00:17
0265	FNET	07 FEB 94 21:14	07 FEB 94 21:45
0266	ZNET	08 FEB 94 01:42	08 FEB 94 01:46
0267	ZNET	08 FEB 94 01:49	08 FEB 94 02:05
0268	ZNET	08 FEB 94 02:07	08 FEB 94 02:14
0269	RMT	08 FEB 94 04:35	08 FEB 94 07:21
0270	RMT	08 FEB 94 08:55	08 FEB 94 11:36
0271	RMT	08 FEB 94 13:06	08 FEB 94 16:05
0272	FNET	08 FEB 94 13:12	08 FEB 94 13:40
0273	CTD	08 FEB 94 16:57	08 FEB 94 17:43
0274	ZNET	08 FEB 94 17:45	08 FEB 94 18:02
0275	ZNET	08 FEB 94 18:05	08 FEB 94 18:12
0276	CTD	08 FEB 94 18:19	08 FEB 94 18:50
0277	RMT	08 FEB 94 19:50	08 FEB 94 23:59
0278	FNET	08 FEB 94 20:03	08 FEB 94 20:29
0279	RMT	09 FEB 94 01:32	09 FEB 94 05:27
0280	FNET	09 FEB 94 05:47	09 FEB 94 06:17
0281	ZNET	09 FEB 94 07:58	09 FEB 94 08:20
0282	ZNET	09 FEB 94 08:22	09 FEB 94 08:30
0283	RMT	09 FEB 94 09:22	09 FEB 94 12:30
0284	RMT	09 FEB 94 13:56	09 FEB 94 15:11
0285	CTD	09 FEB 94 16:20	09 FEB 94 16:47
0286	ZNET	09 FEB 94 16:50	09 FEB 94 16:57
0287	ZNET	09 FEB 94 16:58	09 FEB 94 17:14
0288	ZNET	09 FEB 94 17:17	09 FEB 94 17:34
0289	RMT	09 FEB 94 19:10	09 FEB 94 21:15
0290	RMT	09 FEB 94 22:13	09 FEB 94 23:15
0291	MNET	10 FEB 94 01:03	10 FEB 94 04:28
0292	FNET	10 FEB 94 04:42	10 FEB 94 05:17
0293	ZNET	10 FEB 94 06:11	10 FEB 94 06:16
0294	ZNET	10 FEB 94 06:19	10 FEB 94 06:44
0295	ZNET	10 FEB 94 06:48	10 FEB 94 06:55
0296	ZNET	10 FEB 94 06:58	10 FEB 94 07:18
0297	MNE	10 FEB 94 08:11	10 FEB 94 11:40
0298	FNET	10 FEB 94 12:08	10 FEB 94 12:45
0299	MNET	10 FEB 94 15:04	10 FEB 94 19:03
0300	FNET	10 FEB 94 16:00	10 FEB 94 16:40
0301	CTD	10 FEB 94 21:00	10 FEB 94 21:20
0302	ZNET	10 FEB 94 21:27	10 FEB 94 21:47
0303	ZNET	10 FEB 94 21:50	10 FEB 94 22:10
0304	ZNET	10 FEB 94 22:12	10 FEB 94 22:18
0305	CTD	11 FEB 94 19:02	11 FEB 94 19:25
0306	LHPR	11 FEB 94 20:00	11 FEB 94 20:32
0307	ZNET	11 FEB 94 21:30	11 FEB 94 21:50
0308	ZNET	11 FEB 94 21:56	11 FEB 94 22:02

Event	Activity	Start time	End time
0310	ZNET	11 FEB 94 22:40	11 FEB 94 22:47
0311	LHPR	12 FEB 94 00:13	12 FEB 94 00:46
0312	ZNET	12 FEB 94 01:05	12 FEB 94 01:28
0313	ZNET	12 FEB 94 01:35	12 FEB 94 01:41
0314	LHPR	12 FEB 94 02:09	12 FEB 94 02:42
0315	ZNET	12 FEB 94 03:29	12 FEB 94 03:48
0316	ZNET	12 FEB 94 03:51	12 FEB 94 03:59
0317	ZNET	12 FEB 94 04:04	12 FEB 94 04:22
0318	ZNET	12 FEB 94 04:28	12 FEB 94 04:34
0319	LHPR	12 FEB 94 05:12	12 FEB 94 05:41
0320	ZNET	12 FEB 94 06:17	12 FEB 94 06:34
0321	ZNET	12 FEB 94 06:37	12 FEB 94 06:42
0322	LHPR	12 FEB 94 07:14	12 FEB 94 07:42
0323	ZNET	12 FEB 94 08:33	12 FEB 94 08:40
0324	ZNET	12 FEB 94 08:42	12 FEB 94 08:59
0325	CTD	13 FEB 94 09:17	13 FEB 94 12:15
0326	XBT	13 FEB 94 12:51	13 FEB 94 12:54
0327	XBT	13 FEB 94 13:06	13 FEB 94 13:09
0328	CTD	13 FEB 94 13:25	13 FEB 94 14:20
0329	XBT	13 FEB 94 14:54	13 FEB 94 14:57
0330	XBT	13 FEB 94 15:10	13 FEB 94 15:13
0331	ZNET	13 FEB 94 15:24	13 FEB 94 15:32
0332	ZNET	13 FEB 94 15:34	13 FEB 94 15:52
0333	ZNET	13 FEB 94 15:54	13 FEB 94 16:01
0334	CTD	13 FEB 94 16:30	13 FEB 94 19:28
0335	XBT	13 FEB 94 19:57	13 FEB 94 20:00
0336	CTD	13 FEB 94 20:25	13 FEB 94 21:21
0337	XBT	13 FEB 94 21:55	13 FEB 94 21:58
0338	CTD	13 FEB 94 22:25	13 FEB 94 23:26
0339	XBT	14 FEB 94 00:16	14 FEB 94 00:19
0340	CTD	14 FEB 94 00:46	14 FEB 94 01:46
0341	XBT	14 FEB 94 02:30	14 FEB 94 02:33
0342	CTD	14 FEB 94 02:50	14 FEB 94 05:48
0343	XBT	14 FEB 94 06:35	14 FEB 94 06:38
0344	CTD	14 FEB 94 06:59	14 FEB 94 08:52
0345	XBT	14 FEB 94 09:30	14 FEB 94 09:33
0346	XBT	14 FEB 94 09:40	14 FEB 94 09:43
0347	CTD	14 FEB 94 10:07	14 FEB 94 11:10
0348	XBT	14 FEB 94 11:45	14 FEB 94 11:48
0349	CTD	14 FEB 94 12:06	14 FEB 94 12:18
0350	ZNET	14 FEB 94 12:24	14 FEB 94 12:40
0351	ZNET	14 FEB 94 12:43	14 FEB 94 12:59
0352	CTD	14 FEB 94 13:08	14 FEB 94 15:48
0353	XBT	14 FEB 94 16:24	14 FEB 94 16:27
0354	XBT	14 FEB 94 16:30	14 FEB 94 16:33
0355	XBT	14 FEB 94 16:45	14 FEB 94 16:48
0356	XBT	14 FEB 94 17:00	14 FEB 94 17:03

Event	Activity	Start time	End time
0357	XBT	14 FEB 94 17:15	14 FEB 94 17:18
0358	XBT	14 FEB 94 17:30	14 FEB 94 17:33
0359	XBT	14 FEB 94 17:45	14 FEB 94 17:48
0360	XBT	14 FEB 94 18:00	14 FEB 94 18:03
0361	XBT	14 FEB 94 18:15	14 FEB 94 18:18
0362	XBT	14 FEB 94 18:30	14 FEB 94 18:33
0363	XBT	14 FEB 94 18:45	14 FEB 94 18:48
0364	XBT	14 FEB 94 19:00	14 FEB 94 19:03
0365	XBT	14 FEB 94 19:15	14 FEB 94 19:18
0366	CTD	14 FEB 94 19:45	14 FEB 94 22:38
0367	PMT	14 FEB 94 23:38	15 FEB 94 01:40
0368	XBT	15 FEB 94 03:18	15 FEB 94 03:21
0369	XBT	15 FEB 94 03:30	15 FEB 94 03:33
0370	CTD	15 FEB 94 04:07	15 FEB 94 05:06
0371	XBT	15 FEB 94 05:37	15 FEB 94 05:40
0372	CTD	15 FEB 94 06:14	15 FEB 94 08:21
0373	XBT	15 FEB 94 08:51	15 FEB 94 08:54
0374	CTD	15 FEB 94 09:20	15 FEB 94 09:30
0375	CTD	15 FEB 94 09:47	15 FEB 94 11:50
0376	XBT	15 FEB 94 12:25	15 FEB 94 12:28
0377	CTD	15 FEB 94 12:49	15 FEB 94 14:49
0378	XBT	15 FEB 94 15:14	15 FEB 94 15:17
0379	CTD	15 FEB 94 15:43	15 FEB 94 16:36
0380	XBT	15 FEB 94 17:06	15 FEB 94 17:09
0381	CTD	15 FEB 94 17:39	15 FEB 94 18:37
0382	XBT	15 FEB 94 19:10	15 FEB 94 19:13
0383	CTD	15 FEB 94 19:39	15 FEB 94 20:30
0384	XBT	15 FEB 94 20:57	15 FEB 94 21:00
0385	CTD	15 FEB 94 21:20	15 FEB 94 22:10
0386	XBT	15 FEB 94 22:37	15 FEB 94 22:40
0387	CTD	15 FEB 94 23:01	15 FEB 94 23:55
0388	XBT	16 FEB 94 00:32	16 FEB 94 00:35
0389	CTD	16 FEB 94 01:15	16 FEB 94 03:50
0390	XBT	16 FEB 94 07:32	16 FEB 94 07:35
0391	XBT	16 FEB 94 07:37	16 FEB 94 07:40
0392	XBT	16 FEB 94 08:00	16 FEB 94 08:03
0393	XBT	16 FEB 94 08:17	16 FEB 94 08:20
0394	XBT	16 FEB 94 08:32	16 FEB 94 08:35
0395	XBT	16 FEB 94 08:50	16 FEB 94 08:53
0396	XBT	16 FEB 94 09:08	16 FEB 94 09:11
0397	XBT	16 FEB 94 09:25	16 FEB 94 09:28
0398	XBT	16 FEB 94 09:39	16 FEB 94 09:42
0399	XBT	16 FEB 94 09:55	16 FEB 94 09:58
0400	XBT	16 FEB 94 10:10	16 FEB 94 10:13
0401	XBT	16 FEB 94 10:25	16 FEB 94 10:28
0402	XBT	16 FEB 94 10:40	16 FEB 94 10:43
0403	XBT	16 FEB 94 10:55	16 FEB 94 10:58

Event	Activity	Start time	End time
0404	XBT	16 FEB 94 11:10	16 FEB 94 11:13
0405	XBT	16 FEB 94 11:25	16 FEB 94 11:28
0406	XBT	16 FEB 94 11:40	16 FEB 94 11:43
0407	XBT	16 FEB 94 11:55	16 FEB 94 11:58
0408	XBT	16 FEB 94 12:10	16 FEB 94 12:13
0409	XBT	16 FEB 94 12:25	16 FEB 94 12:28
0410	XBT	16 FEB 94 12:40	16 FEB 94 12:43
0411	XBT	16 FEB 94 12:55	16 FEB 94 12:58
0412	XBT	16 FEB 94 13:10	16 FEB 94 13:13
0413	ZNET	17 FEB 94 05:13	17 FEB 94 05:30
0414	ZNET	17 FEB 94 05:32	17 FEB 94 05:50
0415	AGSZ	17 FEB 94 06:12	17 FEB 94 07:10
0416	FNET	19 FEB 94 03:25	19 FEB 94 03:57
0417	FNET	19 FEB 94 04:34	19 FEB 94 05:06
0418	ZNET	20 FEB 94 01:07	20 FEB 94 01:25
0419	ZNET	20 FEB 94 01:28	20 FEB 94 01:45
0420	ZNET	20 FEB 94 01:47	20 FEB 94 01:55
0421	MNE	20 FEB 94 04:42	20 FEB 94 05:08
0422	FNET	20 FEB 94 05:18	20 FEB 94 05:49
0423	FNET	20 FEB 94 06:03	20 FEB 94 06:29
0424	ZNET	20 FEB 94 16:53	20 FEB 94 17:01
0425	CTD	20 FEB 94 23:45	21 FEB 94 00:28
0426	ZNET	21 FEB 94 00:37	21 FEB 94 00:56
0427	ZNET	21 FEB 94 01:00	21 FEB 94 01:18
0428	FNET	21 FEB 94 03:34	21 FEB 94 04:06
0429	UOR	28 FEB 94 11:40	28 FEB 94 14:12

ANNEX IV: Event position and time (negative value indicates °S and °W)

Event	Start time	Start Lat	Start Long	End time	End Lat	End Long
0001	94001183000	-51.226990	-52.048937	94001190500	-51.227983	-52.053363
0002	94003064000	-49.997180	-41.992322	94003081700	-49.988787	-41.977703
0003	94003084000	-49.988222	-41.982850	94003085600	-49.986193	-41.981813
0004	94003111900	-50.197160	-41.767815	94003122300	-50.188640	-41.759515
0005	94003123100	-50.186837	-41.757028	94003125100	-50.183953	-41.758237
0006	94003154500	-50.476435	-41.529247	94003164300	-50.471065	-41.527477
0007	94003170400	-50.469282	-41.527065	94003172000	-50.468155	-41.527493
0008	94003195300	-50.768452	-41.299900	94003213000	-50.759658	-41.285150
0009	94004001300	-51.050002	-41.056128	94004020500	-51.040080	-41.027432
0010	94004044500	-51.331187	-40.831710	94004070000	-51.324953	-40.813540
0011	94004071500	-51.323805	-40.808445	94004073200	-51.320800	-40.802667
0012	94004073600	-51.320462	-40.801492	94004075300	-51.318583	-40.796883
0013	94004080000	-51.317283	-40.796178	94004082200	-51.314772	-40.794375
0014	94004104800	-51.618017	-40.607648	94004125500	-51.615455	-40.601553
0015	94004130500	-51.613985	-40.597408	94004132300	-51.615940	-40.599798
0016	94004132500	-51.616275	-40.600563	94004134400	-51.618675	-40.602058
0017	94004134700	-51.619065	-40.601990	94004141700	-51.622022	-40.603160
0018	94004164600	-51.900158	-40.385023	94004174100	-51.893442	-40.391132
0019	94004175000	-51.892290	-40.394320	94004180500	-51.891847	-40.396970
0020	94004180800	-51.891538	-40.397362	94004182400	-51.890988	-40.399948
0021	94004182800	-51.890683	-40.400202	94004185400	-51.890223	-40.405727
0022	94004211000	-52.182942	-40.158003	94004232600	-52.166390	-40.164562
0023	94004234000	-52.163975	-40.163032	94004235900	-52.162403	-40.166570
0024	94005000200	-52.162153	-40.168150	94005002400	-52.159907	-40.171637
0025	94005003000	-52.159407	-40.171017	94005005200	-52.157212	-40.176060
0026	94005033300	-52.464777	-39.896162	94005043900	-52.463760	-39.890608
0027	94005045300	-52.463438	-39.888938	94005045500	-52.463695	-39.888942
0028	94005053000	-52.464973	-39.889125	94005055400	-52.466333	-39.886420
0029	94005055800	-52.466518	-39.887045	94005062800	-52.468723	-39.882057
0030	94005083500	-52.751887	-39.652867	94005094500	-52.754138	-39.635000
0031	94005115400	-53.038523	-39.406523	94005125200	-53.047318	-39.396852
0032	94005151700	-53.319360	-39.154123	94005161500	-53.321412	-39.137445
0033	94005181900	-53.602618	-38.903037	94005190500	-53.603842	-38.896355
0034	94008011500	-54.147085	-36.294675	94008013100	-54.146123	-36.293882
0035	94008013400	-54.145867	-36.294722	94008015000	-54.144637	-36.297177
0036	94008015400	-54.144143	-36.298828	94008022000	-54.141948	-36.303055
0037	94008150200	-54.487257	-35.611128	94008153600	-54.485877	-35.602353
0038	94008154000	-54.486190	-35.600797	94008160000	-54.485568	-35.599270
0039	94008160500	-54.485245	-35.600582	94008162000	-54.485157	-35.602780
0040	94008162400	-54.484533	-35.603620	94008164900	-54.482630	-35.609023
0041	94008223200	-54.114812	-35.510418	94008225000	-54.114110	-35.509450
0042	94008225100	-54.114110	-35.508968	94008230000	-54.114063	-35.509277
0043	94008230200	-54.114322	-35.508020	94008231500	-54.114417	-35.504283
0044	94009004000	-54.074827	-35.182437	94009005900	-54.073208	-35.184985

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0046	94009012600	-54.072103	-35.186872	94009014700	-54.070748	-35.189990
0047	94010153500	-53.725855	-38.249625	94010155500	-53.727323	-38.252492
0048	94010160000	-53.727418	-38.253252	94010161300	-53.727032	-38.257175
0049	94010162100	-53.727840	-38.256908	94010163600	-53.728137	-38.259030
0050	94010164100	-53.728225	-38.260413	94010164700	-53.728438	-38.262260
0051	94010182500	-53.769250	-38.138817	94010184400	-53.759270	-38.168488
0052	94010212100	-53.790848	-38.156538	94010230800	-53.698418	-38.289560
0053	94011000500	-53.723177	-38.246378	94011002400	-53.722215	-38.244703
0054	94011002600	-53.722737	-38.243863	94011004200	-53.721912	-38.245438
0055	94011005100	-53.724838	-38.241802	94011005900	-53.724340	-38.243338
0056	94011014400	-53.718437	-38.235382	94011020400	-53.717208	-38.264342
0057	94011020600	-53.717422	-38.267493	94011022800	-53.718447	-38.298903
0058	94011023100	-53.717455	-38.303497	94011025400	-53.716902	-38.333600
0059	94011025900	-53.717007	-38.340055	94011032300	-53.717577	-38.372567
0060	94011032600	-53.717830	-38.376700	94011034600	-53.717242	-38.405717
0061	94011040200	-53.734198	-38.395037	94011042300	-53.734230	-38.354390
0062	94011042500	-53.734613	-38.350768	94011044500	-53.736108	-38.313735
0063	94011044900	-53.736323	-38.305983	94011051000	-53.737047	-38.268892
0064	94011051400	-53.737355	-38.261120	94011053600	-53.737423	-38.220982
0065	94011061600	-53.728793	-38.245377	94011063400	-53.728753	-38.246863
0066	94011063800	-53.728553	-38.248027	94011064500	-53.728135	-38.249185
0067	94011065000	-53.727395	-38.249588	94011070600	-53.727308	-38.251150
0068	94011071200	-53.727020	-38.252078	94011072700	-53.726942	-38.253120
0069	94011073500	-53.728837	-38.252370	94011074900	-53.729878	-38.250653
0070	94011075400	-53.730055	-38.250838	94011080800	-53.730022	-38.250860
0071	94011154300	-53.722302	-38.250070	94011162200	-53.718303	-38.254040
0072	94011162900	-53.718263	-38.255248	94011163500	-53.718025	-38.256467
0073	94011163600	-53.718075	-38.256660	94011165200	-53.717303	-38.260952
0074	94011172000	-53.726980	-38.251737	94011175500	-53.731255	-38.262240
0075	94011180400	-53.732390	-38.263983	94011183100	-53.734722	-38.269842
0076	94011184300	-53.734870	-38.272890	94011185900	-53.734868	-38.276918
0077	94011190200	-53.735107	-38.277575	94011191000	-53.734972	-38.279233
0078	94011191200	-53.734773	-38.280180	94011193000	-53.735255	-38.282233
0079	94011195000	-53.728310	-38.297023	94011202700	-53.702217	-38.340610
0080	94011220000	-53.641852	-38.124812	94011221400	-53.640900	-38.121890
0081	94011224700	-53.638545	-38.201468	94011230100	-53.638365	-38.198462
0082	94011234100	-53.639115	-38.277362	94012000200	-53.636200	-38.275843
0083	94012005900	-53.638610	-38.351233	94012013300	-53.637508	-38.342270
0084	94012020700	-53.639217	-38.425713	94012025300	-53.635173	-38.419045
0085	94012032800	-53.644220	-38.503163	94012042500	-53.652748	-38.505707
0086	94012045200	-53.683082	-38.498908	94012052400	-53.685675	-38.500738
0087	94012060300	-53.684140	-38.420583	94012062400	-53.685113	-38.418698
0088	94012065700	-53.683785	-38.344552	94012071200	-53.683542	-38.344383
0089	94012074200	-53.684327	-38.273757	94012080400	-53.683397	-38.270063
0090	94012083200	-53.682605	-38.197863	94012085100	-53.682743	-38.194540
0091	94012091900	-53.682475	-38.126222	94012093300	-53.682730	-38.124630
0092	94012100200	-53.724630	-38.133880	94012102100	-53.724870	-38.130187

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0093	94012105000	-53.724683	-38.203507	94012111200	-53.724412	-38.198852
0094	94012114300	-53.725970	-38.280720	94012120300	-53.725788	-38.275838
0095	94012122800	-53.724153	-38.351930	94012124000	-53.723047	-38.349230
0096	94012130900	-53.723870	-38.431843	94012132500	-53.721695	-38.428423
0097	94012135000	-53.724855	-38.500688	94012141300	-53.723625	-38.496457
0098	94012144100	-53.767085	-38.502773	94012145800	-53.767360	-38.504223
0099	94012153200	-53.768088	-38.419305	94012154700	-53.768988	-38.419452
0100	94012162500	-53.765940	-38.344730	94012164100	-53.767078	-38.344528
0101	94012171400	-53.767553	-38.276127	94012173100	-53.769517	-38.278905
0102	94012180400	-53.767498	-38.194750	94012182100	-53.770310	-38.194430
0103	94012184800	-53.766937	-38.128587	94012191100	-53.770743	-38.129938
0104	94012193500	-53.807570	-38.126960	94012195200	-53.807572	-38.125093
0105	94012202200	-53.806440	-38.207662	94012203200	-53.805993	-38.204717
0106	94012210200	-53.807382	-38.275663	94012211400	-53.807760	-38.272777
0107	94012214300	-53.808017	-38.349053	94012215800	-53.807862	-38.345265
0108	94012223000	-53.804012	-38.423503	94012224300	-53.801488	-38.421685
0109	94012231500	-53.806720	-38.500342	94012232900	-53.805230	-38.500652
0110	94012234100	-53.803593	-38.498210	94012235500	-53.801915	-38.499642
0111	94013000100	-53.802060	-38.500883	94013001500	-53.801557	-38.502927
0112	94013002000	-53.801422	-38.503258	94013003900	-53.800545	-38.505680
0113	94013015200	-53.931565	-38.574602	94013020400	-53.930445	-38.574108
0114	94013022900	-53.888712	-38.573338	94013024400	-53.886943	-38.575350
0115	94013031700	-53.849445	-38.568085	94013033000	-53.850808	-38.569398
0116	94013035800	-53.807830	-38.572295	94013041200	-53.809205	-38.574118
0117	94013044000	-53.764308	-38.571940	94013045500	-53.764080	-38.570828
0118	94013052100	-53.722817	-38.572950	94013053800	-53.721772	-38.569452
0119	94013060800	-53.682247	-38.570652	94013070500	-53.681402	-38.564845
0120	94013073600	-53.641145	-38.576057	94013083900	-53.640552	-38.573320
0121	94013090800	-53.597558	-38.573377	94013102900	-53.597313	-38.571693
0122	94013110300	-53.555550	-38.572603	94013114700	-53.554323	-38.570800
0123	94013130000	-53.517135	-38.577078	94013143000	-53.509585	-38.572417
0124	94013162100	-53.515755	-38.055847	94013174000	-53.525890	-38.055892
0125	94013180500	-53.559043	-38.055848	94013185900	-53.563402	-38.047052
0126	94013193400	-53.601913	-38.057055	94013200300	-53.602618	-38.053523
0127	94013203200	-53.642993	-38.055060	94013204300	-53.642522	-38.054367
0128	94013210800	-53.683823	-38.056290	94013211800	-53.683225	-38.053627
0129	94013214200	-53.724893	-38.057405	94013215400	-53.723352	-38.055525
0130	94013221800	-53.766948	-38.056947	94013223400	-53.765727	-38.053762
0131	94013225700	-53.806872	-38.056607	94013231300	-53.805422	-38.050923
0132	94013234400	-53.850330	-38.057695	94013235800	-53.849242	-38.051150
0133	94014002500	-53.891138	-38.059772	94014003900	-53.888505	-38.056595
0134	94014010500	-53.931577	-38.059095	94014012200	-53.929983	-38.056542
0135	94014025000	-53.724722	-38.250188	94014025600	-53.725252	-38.250690
0136	94014025900	-53.725198	-38.249315	94014031400	-53.725288	-38.249482
0137	94014040600	-53.714665	-38.132798	94014043100	-53.719367	-38.173810

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0138	94014063500	-53.686295	-38.130988	94014080000	-53.729527	-38.256530
0139	94014092800	-53.699918	-38.168132	94014105000	-53.734095	-38.266348
0140	94014130600	-53.724490	-38.251027	94014132400	-53.725102	-38.251997
0141	94014132900	-53.724952	-38.250588	94014134400	-53.725678	-38.252372
0142	94014134600	-53.725682	-38.252397	94014140300	-53.726128	-38.253590
0143	94014141300	-53.726265	-38.254762	94014143500	-53.726417	-38.257840
0144	94014143500	-53.726417	-38.257840	94014143500	-53.726417	-38.257840
0145	94014143500	-53.726417	-38.257840	94014143500	-53.726417	-38.257840
0146	94014143500	-53.726417	-38.257840	94014143500	-53.726417	-38.257840
0147	94014143500	-53.726417	-38.257840	94014143500	-53.726417	-38.257840
0148	94014143500	-53.726417	-38.257840	94014143500	-53.726417	-38.257840
0149	94014151300	-53.722727	-38.239593	94014153800	-53.723485	-38.238747
0150	94014155000	-53.724897	-38.238978	94014155900	-53.726073	-38.240430
0151	94014160100	-53.726365	-38.240348	94014161800	-53.729168	-38.243640
0152	94014162700	-53.730142	-38.243602	94014164500	-53.732598	-38.247653
0153	94014165000	-53.732872	-38.245590	94014165600	-53.733750	-38.248285
0154	94014175700	-53.698642	-38.164027	94014194000	-53.755915	-38.320938
0155	94014200000	-53.767123	-38.356195	94014200800	-53.763242	-38.352117
0156	94015003200	-53.757613	-38.265218	94015005400	-53.765107	-38.242617
0157	94015010300	-53.762757	-38.238145	94015012400	-53.748658	-38.248193
0158	94015012800	-53.746045	-38.254025	94015015200	-53.729987	-38.292788
0159	94015031000	-53.727898	-38.220267	94015050000	-53.723653	-38.083255
0160	94015070000	-53.713797	-38.389055	94015084000	-53.725347	-38.259767
0161	94016122100	-53.676747	-38.232045	94016140900	-53.743585	-38.295543
0162	94016153100	-53.717707	-38.252745	94016160200	-53.719612	-38.255903
0163	94016160800	-53.720302	-38.256563	94016161600	-53.720840	-38.257602
0164	94016161900	-53.721365	-38.257697	94016163500	-53.723522	-38.259520
0165	94016163800	-53.723262	-38.258623	94016165500	-53.725508	-38.259017
0166	94016175600	-53.677002	-38.200048	94016200000	-53.773005	-38.314470
0167	94017002100	-53.729667	-38.188898	94017020100	-53.709395	-38.309168
0168	94017025900	-53.731920	-38.165198	94017051500	-53.666843	-38.352128
0169	94017073300	-53.731392	-38.197928	94017080800	-53.724018	-38.262492
0170	94017091100	-53.725455	-38.246988	94017091700	-53.724723	-38.246523
0171	94017091900	-53.724748	-38.247145	94017093500	-53.725815	-38.248983
0172	94017093800	-53.726022	-38.249807	94017095300	-53.725973	-38.249485
0173	94017095700	-53.725683	-38.251433	94017101300	-53.725553	-38.250765
0174	94017111600	-53.729778	-38.199482	94017114700	-53.725040	-38.254048
0175	94017121900	-53.725017	-38.248225	94017122600	-53.725465	-38.248357
0176	94017123900	-53.726420	-38.247387	94017124700	-53.726938	-38.246437
0177	94017125000	-53.727117	-38.244742	94017125900	-53.727683	-38.244292
0178	94017130100	-53.727702	-38.243572	94017131700	-53.729615	-38.242507
0179	94017142500	-53.725657	-38.248335	94017145000	-53.726163	-38.236642
0180	94017152000	-53.735360	-38.150665	94017163600	-53.727325	-38.220322
0181	94017173500	-53.723298	-38.236280	94017174300	-53.722707	-38.236607
0182	94017174600	-53.722487	-38.235555	94017180100	-53.723758	-38.235040
0183	94017180300	-53.723808	-38.234807	94017181100	-53.724298	-38.235752

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0184	94017181400	-53.725027	-38.236447	94017182000	-53.725153	-38.237347
0185	94017182300	-53.725515	-38.237338	94017182700	-53.725718	-38.237633
0186	94017193000	-53.716307	-38.178695	94017195800	-53.722218	-38.225438
0187	94017205000	-53.726022	-38.249892	94017205700	-53.725593	-38.249178
0188	94017205800	-53.725880	-38.249553	94017211400	-53.727383	-38.250885
0189	94017215100	-53.724608	-38.247970	94017215700	-53.724830	-38.249348
0190	94017220000	-53.724895	-38.250013	94017221400	-53.726355	-38.252160
0191	94017221700	-53.726205	-38.251795	94017223200	-53.725575	-38.250598
0192	94017223400	-53.725533	-38.250718	94017224800	-53.724800	-38.248805
0193	94017224400	-53.725355	-38.249323	94017225100	-53.724935	-38.248987
0194	94017232700	-53.701933	-38.206323	94018000300	-53.725103	-38.250607
0195	94018005500	-53.724720	-38.250383	94018010000	-53.724573	-38.250490
0196	94018010600	-53.723673	-38.249298	94018012000	-53.723442	-38.247265
0197	94018015500	-53.722958	-38.244988	94018020100	-53.722447	-38.244093
0198	94018020300	-53.721805	-38.243298	94018021900	-53.722077	-38.242162
0199	94018024600	-53.711572	-38.226462	94018032000	-53.737685	-38.268892
0200	94018034400	-53.725215	-38.245180	94018035100	-53.726223	-38.245192
0201	94018035400	-53.725937	-38.244292	94018040900	-53.727922	-38.243778
0202	94018051500	-53.707037	-38.214675	94018054800	-53.733448	-38.264533
0203	94018061700	-53.725037	-38.248043	94018062500	-53.724013	-38.246312
0204	94018062900	-53.724267	-38.247022	94018064500	-53.724235	-38.247748
0205	94018072800	-53.724790	-38.241993	94018073400	-53.724563	-38.241732
0206	94018073700	-53.725378	-38.241095	94018075200	-53.726728	-38.241417
0207	94018084500	-53.711655	-38.222670	94018091500	-53.729158	-38.256517
0208	94018100000	-53.725030	-38.252035	94018100700	-53.725588	-38.251750
0209	94018100900	-53.725422	-38.251347	94018102600	-53.726278	-38.248920
0210	94018110300	-53.726105	-38.249722	94018111000	-53.726107	-38.249323
0211	94018111200	-53.725577	-38.248528	94018113000	-53.726798	-38.246277
0212	94018113400	-53.726953	-38.246245	94018114900	-53.728080	-38.245882
0213	94018140200	-53.724842	-38.248797	94018140800	-53.725523	-38.249210
0214	94018141100	-53.724790	-38.248695	94018142800	-53.726185	-38.247980
0215	94018143400	-53.724182	-38.246213	94018145100	-53.725455	-38.244763
0216	94018165400	-53.708093	-38.216467	94018180700	-53.727895	-38.299215
0217	94018192800	-53.755593	-38.377192	94018203000	-53.762335	-38.425532
0218	94018234600	-53.736432	-38.196355	94019012000	-53.704982	-38.321758
0219	94031191000	-53.541417	-41.835902	94031193000	-53.543552	-41.836773
0220	94031193700	-53.544497	-41.838983	94031194700	-53.545492	-41.840593
0221	94031195100	-53.545955	-41.840720	94031200100	-53.547538	-41.842212
0222	94031200500	-53.548162	-41.841508	94031201700	-53.549820	-41.841945
0223	94032193000	-54.016410	-36.812430	94032202500	-53.984155	-36.897823
0224	94033034500	-53.598303	-38.901557	94033044900	-53.595545	-38.905248
0225	94033045500	-53.595887	-38.906967	94033051000	-53.596150	-38.912918
0226	94033073500	-53.317123	-39.149662	94033083700	-53.326938	-39.154022
0227	94033084700	-53.330133	-39.156335	94033090500	-53.330932	-39.157535
0228	94033112300	-53.036295	-39.399333	94033122500	-53.037340	-39.398622
0229	94033123000	-53.037293	-39.397475	94033124500	-53.036960	-39.397822

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0230	94033152900	-52.751605	-39.637317	94033163100	-52.750413	-39.625437
0231	94033163900	-52.749543	-39.626763	94033165800	-52.750357	-39.623528
0232	94033192100	-52.465892	-39.895158	94033202000	-52.456060	-39.892570
0233	94033202500	-52.455838	-39.891890	94033204500	-52.454503	-39.893242
0234	94033231200	-52.182407	-40.152155	94034011900	-52.182607	-40.158308
0235	94034012800	-52.181132	-40.160212	94034014500	-52.182358	-40.160587
0236	94034043500	-51.900545	-40.379892	94034053400	-51.895077	-40.377377
0237	94034055700	-51.899365	-40.378652	94034061200	-51.898088	-40.374700
0238	94034083000	-51.614680	-40.601945	94034103500	-51.604308	-40.603268
0239	94034111100	-51.604880	-40.587920	94034112900	-51.604945	-40.589597
0240	94034140600	-51.332118	-40.834908	94034161600	-51.328655	-40.832273
0241	94034162800	-51.329735	-40.827945	94034164500	-51.328307	-40.828910
0242	94034190000	-51.048597	-41.061498	94034203200	-51.029872	-41.032117
0243	94034204000	-51.027917	-41.030602	94034205900	-51.021945	-41.028518
0244	94034231800	-50.763787	-41.297253	94035005600	-50.749068	-41.276263
0245	94035010000	-50.749312	-41.275203	94035011800	-50.748283	-41.272598
0246	94035035900	-50.482095	-41.532432	94035050200	-50.487022	-41.534435
0247	94035050600	-50.488360	-41.534590	94035052100	-50.488030	-41.534137
0248	94035073200	-50.200810	-41.768127	94035083500	-50.204597	-41.755497
0249	94035084200	-50.203892	-41.754517	94035090200	-50.202507	-41.752850
0250	94035113600	-50.000875	-41.996067	94035123600	-50.003435	-41.999935
0251	94035125000	-50.003167	-42.000437	94035131200	-50.002485	-42.004042
0252	94035190400	-50.601822	-40.828585	94035212000	-50.450767	-40.852138
0253	94037153100	-49.766580	-37.428053	94037174500	-49.835833	-37.627293
0254	94037205900	-49.799947	-37.458012	94037211400	-49.800553	-37.464723
0255	94037211600	-49.800885	-37.465435	94037212300	-49.801348	-37.468050
0256	94037212500	-49.801327	-37.468930	94037213300	-49.801650	-37.472330
0257	94037233200	-49.767448	-37.416795	94038013000	-49.768393	-37.639512
0258	94038032800	-49.800303	-37.449775	94038033700	-49.800033	-37.450325
0259	94038064400	-49.795347	-37.446038	94038071400	-49.791992	-37.451813
0260	94038104600	-49.773315	-37.407497	94038132300	-49.814960	-37.623710
0261	94038120000	-49.792818	-37.509212	94038123000	-49.800372	-37.547818
0262	94038150400	-49.763283	-37.385465	94038184700	-49.922108	-37.611368
0263	94038154900	-49.795745	-37.445978	94038162000	-49.814067	-37.480335
0264	94038203600	-49.757813	-37.422272	94039001700	-49.937540	-37.587227
0265	94038211400	-49.792035	-37.460288	94038214500	-49.819327	-37.488690
0266	94039014200	-49.801417	-37.455858	94039014600	-49.802058	-37.457432
0267	94039014900	-49.802175	-37.458547	94039020500	-49.803845	-37.464210
0268	94039020700	-49.803713	-37.465400	94039021400	-49.804123	-37.468312
0269	94039043500	-49.808273	-37.358728	94039072100	-49.766712	-37.601650
0270	94039085500	-49.849612	-37.411090	94039113600	-49.731760	-37.570583
0271	94039130600	-49.851580	-37.421432	94039160500	-49.730888	-37.494073
0272	94039131200	-49.846790	-37.424727	94039134000	-49.825557	-37.440092
0273	94039165700	-49.801027	-37.450362	94039174300	-49.809263	-37.464360
0274	94039174500	-49.810293	-37.463843	94039180200	-49.810985	-37.471465
0275	94039180500	-49.811188	-37.473130	94039181200	-49.811645	-37.476377

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0276	94039181900	-49.813715	-37.477388	94039185000	-49.818925	-37.482432
0277	94039195000	-49.857473	-37.369342	94039235900	-49.716947	-37.672770
0278	94039200300	-49.847865	-37.385573	94039202900	-49.832737	-37.411710
0279	94040013200	-49.845320	-37.404240	94040052700	-49.716042	-37.783555
0280	94040054700	-49.718702	-37.790310	94040061700	-49.732725	-37.778390
0281	94040075800	-49.800338	-37.452865	94040082000	-49.803470	-37.463275
0282	94040082200	-49.803760	-37.464637	94040083000	-49.804775	-37.469535
0283	94040092200	-49.780352	-37.364233	94040123000	-49.857182	-37.634217
0284	94040135600	-49.835493	-37.491705	94040151100	-49.832863	-37.611378
0285	94040162000	-49.802035	-37.423058	94040164700	-49.781170	-37.424673
0286	94040165000	-49.778333	-37.424085	94040165700	-49.770850	-37.425445
0287	94040165800	-49.769638	-37.425423	94040171400	-49.752220	-37.428735
0288	94040171700	-49.749143	-37.429472	94040173400	-49.759077	-37.448338
0289	94040191000	-49.768360	-37.327950	94040211500	-49.790158	-37.521583
0290	94040221300	-49.799043	-37.549658	94040231500	-49.795845	-37.654127
0291	94041010300	-49.796042	-37.302882	94041042800	-49.766845	-37.674930
0292	94041044200	-49.767902	-37.671168	94041051700	-49.780402	-37.629548
0293	94041061100	-49.800023	-37.447467	94041061600	-49.798388	-37.448523
0294	94041061900	-49.798352	-37.448938	94041064400	-49.795323	-37.460892
0295	94041064800	-49.794823	-37.463483	94041065500	-49.794502	-37.466993
0296	94041065800	-49.794092	-37.468335	94041071800	-49.793025	-37.479345
0297	94041081100	-49.859488	-37.450752	94041114000	-49.714172	-37.605255
0298	94041120800	-49.730203	-37.594895	94041124500	-49.733253	-37.660382
0299	94041150400	-49.794360	-37.314492	94041190300	-49.795698	-37.759855
0300	94041160000	-49.787908	-37.416425	94041164000	-49.784113	-37.490583
0301	94041210000	-49.800258	-37.448933	94041212000	-49.799678	-37.454135
0302	94041212700	-49.799413	-37.455860	94041214700	-49.799535	-37.464970
0303	94041215000	-49.799332	-37.465170	94041221000	-49.799022	-37.471137
0304	94041221200	-49.799148	-37.471645	94041221800	-49.799668	-37.473893
0305	94042190200	-49.800058	-37.451048	94042192500	-49.798703	-37.453315
0306	94042200000	-49.795828	-37.404733	94042203200	-49.801040	-37.463467
0307	94042213000	-49.796123	-37.448012	94042215000	-49.795002	-37.456978
0308	94042215600	-49.795507	-37.457633	94042220200	-49.795163	-37.459705
0309	94042220900	-49.795130	-37.461368	94042223700	-49.796110	-37.473662
0310	94042224000	-49.796168	-37.473762	94042224700	-49.796825	-37.476852
0311	94043001300	-49.799420	-37.404005	94043004600	-49.799000	-37.461933
0312	94043010500	-49.799925	-37.451357	94043012800	-49.797602	-37.453292
0313	94043013500	-49.797083	-37.453582	94043014100	-49.797103	-37.453650
0314	94043020900	-49.825883	-37.441073	94043024200	-49.787262	-37.450872
0315	94043032900	-49.799073	-37.450895	94043034800	-49.797328	-37.453343
0316	94043035100	-49.796903	-37.453607	94043035900	-49.795525	-37.456122
0317	94043040400	-49.795582	-37.456345	94043042200	-49.792722	-37.461208
0318	94043042800	-49.792185	-37.462297	94043043400	-49.791275	-37.463607
0319	94043051200	-49.828503	-37.448102	94043054100	-49.800340	-37.448912
0320	94043061700	-49.798313	-37.450828	94043063400	-49.796443	-37.457567
0321	94043063700	-49.795382	-37.459015	94043064200	-49.795340	-37.460313

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0322	94043071400	-49.824747	-37.451142	94043074200	-49.796073	-37.461463
0323	94043083300	-49.804128	-37.456848	94043084000	-49.804437	-37.457080
0324	94043084200	-49.803690	-37.457385	94043085900	-49.804555	-37.464948
0325	94044091700	-49.698588	-37.672418	94044121500	-49.708112	-37.694990
0326	94044125100	-49.714733	-37.632415	94044125400	-49.719288	-37.622302
0327	94044130600	-49.737347	-37.582815	94044130900	-49.742095	-37.572987
0328	94044132500	-49.746007	-37.563695	94044142000	-49.743152	-37.582040
0329	94044145400	-49.771313	-37.514198	94044145700	-49.776195	-37.503918
0330	94044151000	-49.796272	-37.458198	94044151300	-49.798580	-37.449935
0331	94044152400	-49.799255	-37.449125	94044153200	-49.798210	-37.451180
0332	94044153400	-49.797980	-37.451367	94044155200	-49.797152	-37.458252
0333	94044155400	-49.797073	-37.458550	94044160100	-49.795535	-37.461498
0334	94044163000	-49.797858	-37.452462	94044192800	-49.783023	-37.456797
0335	94044195700	-49.825925	-37.396738	94044200000	-49.830538	-37.386923
0336	94044202500	-49.856008	-37.335798	94044212100	-49.856395	-37.324840
0337	94044215500	-49.877235	-37.282817	94044215800	-49.882455	-37.271057
0338	94044222500	-49.905188	-37.216160	94044232600	-49.905122	-37.188468
0339	94045001600	-49.935122	-37.160858	94045001900	-49.940892	-37.148347
0340	94045004600	-49.958945	-37.099472	94045014600	-49.953063	-37.073702
0341	94045023000	-49.991130	-37.042420	94045023300	-49.996827	-37.030570
0342	94045025000	-50.012022	-36.998217	94045054800	-49.973865	-36.957395
0343	94045063500	-50.034420	-36.936855	94045063800	-50.040138	-36.925733
0344	94045065900	-50.062995	-36.881280	94045085200	-50.039160	-36.812967
0345	94045093000	-50.072458	-36.864578	94045093300	-50.077665	-36.851117
0346	94045094000	-50.089223	-36.822965	94045094300	-50.094728	-36.811837
0347	94045100700	-50.116200	-36.766658	94045111000	-50.107732	-36.750113
0348	94045114500	-50.147135	-36.704337	94045114800	-50.153050	-36.690992
0349	94045120600	-50.172312	-36.657368	94045121800	-50.171667	-36.658967
0350	94045122400	-50.171163	-36.658478	94045124000	-50.171883	-36.660617
0351	94045124300	-50.172000	-36.659447	94045125900	-50.172298	-36.659297
0352	94045130800	-50.172938	-36.659777	94045154800	-50.178380	-36.655380
0353	94045162400	-50.086748	-36.626905	94045162700	-50.077375	-36.624687
0354	94045163000	-50.067678	-36.622370	94045163300	-50.058068	-36.619903
0355	94045164500	-50.019872	-36.609305	94045164800	-50.009722	-36.606607
0356	94045170000	-49.971555	-36.594878	94045170300	-49.961673	-36.592462
0357	94045171500	-49.922343	-36.581213	94045171800	-49.912925	-36.577837
0358	94045173000	-49.873457	-36.566102	94045173300	-49.863117	-36.563105
0359	94045174500	-49.823198	-36.550968	94045174800	-49.813145	-36.547485
0360	94045180000	-49.773332	-36.533027	94045180300	-49.763135	-36.530027
0361	94045181500	-49.722218	-36.515433	94045181800	-49.712538	-36.511897
0362	94045183000	-49.670647	-36.498555	94045183300	-49.660492	-36.494927
0363	94045184500	-49.619020	-36.481292	94045184800	-49.609025	-36.477910
0364	94045190000	-49.566975	-36.466893	94045190300	-49.556293	-36.464300
0365	94045191500	-49.514445	-36.452952	94045191800	-49.504138	-36.450357
0366	94045194500	-49.452612	-36.432127	94045223800	-49.425972	-36.420485
0367	94045233800	-49.394005	-36.465278	94046014000	-49.362957	-36.658580
0368	94046031800	-49.460193	-36.422980	94046032100	-49.466802	-36.416212

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0369	94046033000	-49.486612	-36.398223	94046033300	-49.493402	-36.392148
0370	94046040700	-49.531030	-36.351842	94046050600	-49.524228	-36.331640
0371	94046053700	-49.565795	-36.315375	94046054000	-49.572853	-36.307603
0372	94046061400	-49.608617	-36.274728	94046082100	-49.599552	-36.246940
0373	94046085100	-49.648413	-36.233862	94046085400	-49.656223	-36.224737
0374	94046092000	-49.681045	-36.200962	94046093000	-49.680655	-36.197735
0375	94046094700	-49.676858	-36.197375	94046115000	-49.663647	-36.185712
0376	94046122500	-49.718527	-36.172813	94046122800	-49.726715	-36.165807
0377	94046124900	-49.758652	-36.136720	94046144900	-49.756230	-36.146800
0378	94046151400	-49.799582	-36.091260	94046151700	-49.807850	-36.082977
0379	94046154300	-49.831715	-36.050283	94046163600	-49.834575	-36.042688
0380	94046170600	-49.868203	-36.024630	94046170900	-49.874838	-36.018287
0381	94046173900	-49.910913	-35.973395	94046183700	-49.914478	-35.968853
0382	94046191000	-49.946465	-35.941993	94046191300	-49.953505	-35.934875
0383	94046193900	-49.986253	-35.902318	94046203000	-49.991668	-35.914282
0384	94046205700	-50.025380	-35.863798	94046210000	-50.034140	-35.855552
0385	94046212000	-50.062820	-35.827427	94046221000	-50.073032	-35.836855
0386	94046223700	-50.101482	-35.781797	94046224000	-50.110410	-35.772393
0387	94046230100	-50.137782	-35.750687	94046235500	-50.147870	-35.752888
0388	94047003200	-50.182065	-35.702847	94047003500	-50.190303	-35.694743
0389	94047011500	-50.215422	-35.677383	94047035000	-50.239207	-35.705937
0390	94047073200	-50.212253	-35.678500	94047073500	-50.221600	-35.680173
0391	94047073700	-50.228153	-35.681192	94047074000	-50.238388	-35.681763
0392	94047080000	-50.304928	-35.690565	94047080300	-50.314822	-35.692837
0393	94047081700	-50.360478	-35.702272	94047082000	-50.370223	-35.704178
0394	94047083200	-50.409018	-35.713227	94047083500	-50.418765	-35.715523
0395	94047085000	-50.466525	-35.728080	94047085300	-50.476108	-35.731715
0396	94047090800	-50.523972	-35.748395	94047091100	-50.532935	-35.752313
0397	94047092500	-50.577765	-35.766852	94047092800	-50.587985	-35.769760
0398	94047093900	-50.623703	-35.780110	94047094200	-50.633463	-35.781985
0399	94047095500	-50.676940	-35.791250	94047095800	-50.686675	-35.792435
0400	94047101000	-50.727112	-35.798233	94047101300	-50.737053	-35.799123
0401	94047102500	-50.777088	-35.802718	94047102800	-50.787118	-35.803232
0402	94047104000	-50.827840	-35.805510	94047104300	-50.837948	-35.806043
0403	94047105500	-50.877448	-35.808493	94047105800	-50.887768	-35.809867
0404	94047111000	-50.930920	-35.813532	94047111300	-50.941295	-35.814755
0405	94047112500	-50.984708	-35.820307	94047112800	-50.995282	-35.821565
0406	94047114000	-51.036872	-35.824463	94047114300	-51.047077	-35.826008
0407	94047115500	-51.088268	-35.839280	94047115800	-51.098095	-35.842423
0408	94047121000	-51.138690	-35.855735	94047121300	-51.148597	-35.859323
0409	94047122500	-51.189325	-35.872503	94047122800	-51.199878	-35.875607
0410	94047124000	-51.240617	-35.890863	94047124300	-51.250787	-35.894810
0411	94047125500	-51.292393	-35.910038	94047125800	-51.303302	-35.913930
0412	94047131000	-51.345423	-35.929007	94047131300	-51.355700	-35.932525
0413	94048051300	-53.856757	-36.541580	94048053000	-53.856508	-36.545285
0414	94048053200	-53.856678	-36.545077	94048055000	-53.856078	-36.546382

Event	Start time	Start Lat	Start Lon	End time	End Lat	End Lon
0415	94048061200	-53.842387	-36.554035	94048071000	-53.813952	-36.566702
0416	94050032500	-54.220512	-35.383408	94050035700	-54.199248	-35.362652
0417	94050043400	-54.221752	-35.462878	94050050600	-54.195952	-35.447367
0418	94051010700	-54.404142	-35.471247	94051012500	-54.402565	-35.473373
0419	94051012800	-54.402313	-35.473912	94051014500	-54.402795	-35.475587
0420	94051014700	-54.402437	-35.476015	94051015500	-54.401802	-35.477455
0421	94051044200	-54.201235	-35.415682	94051050800	-54.221780	-35.404413
0422	94051051800	-54.231363	-35.398722	94051054900	-54.257567	-35.384963
0423	94051060300	-54.260170	-35.396710	94051062900	-54.257927	-35.429137
0424	94051165300	-54.379735	-35.847803	94051170100	-54.378142	-35.843503
0425	94051234500	-54.264738	-35.282177	94052002800	-54.259667	-35.283917
0426	94052003700	-54.256620	-35.285742	94052005600	-54.255993	-35.289628
0427	94052010000	-54.255762	-35.290375	94052011800	-54.256197	-35.294253
0428	94052033400	-54.517357	-35.361378	94052040600	-54.538522	-35.396383
0429	94059114000	-63.075592	-41.075918	94059141200	-63.011542	-41.510017

JR06:

RRS James Clark Ross
Predator/Prey Cruise, South Georgia
Marine Biology
January - March 1994

Annexes V - VII

ANNEX V Oceanographic transects during JR06: start-time, end-time and position

Trans	Start time	Start lat	Start long	End time	End lat	End long
0001	94001000100	-51.822445	-57.356303	94003054500	-50.004788	-42.043948
0002	94003105600	-50.205237	-41.760440	94005192700	-53.607125	-38.893492
0003	94005192700	-53.607125	-38.893492	94005230100	-54.027228	-38.098962
0004	94007002000	-53.970747	-38.073913	94007030600	-53.514697	-37.941240
0005	94007030600	-53.514697	-37.941240	94007084700	-53.472038	-36.946800
0006	94007084700	-53.472038	-36.946800	94007121800	-54.071968	-36.595438
0007	94008002000	-54.114437	-36.489832	94008052200	-54.293258	-35.558072
0008	94008052200	-54.293258	-35.558072	94008091900	-53.917785	-35.386708
0009	94008092400	-53.922653	-35.374330	94008100700	-54.032962	-35.268708
0010	94008101000	-54.037808	-35.273862	94008104600	-54.099078	-35.424787
0011	94008105000	-54.104938	-35.418373	94008112900	-54.160547	-35.232090
0012	94008113400	-54.172865	-35.229492	94008121200	-54.231610	-35.388202
0013	94008121200	-54.231610	-35.388202	94008125200	-54.314188	-35.255037
0014	94008125200	-54.314188	-35.255037	94008160000	-54.485568	-35.599270
0015	94008170000	-54.481400	-35.611845	94008191500	-54.377672	-35.004858
0016	94008191500	-54.377672	-35.004858	94008200400	-54.234907	-35.051492
0017	94008201400	-54.237577	-35.090968	94008211700	-54.284107	-35.398402
0018	94008212900	-54.252252	-35.419740	94008221700	-54.115332	-35.503135
0019	94008233700	-54.109250	-35.443353	94009002700	-54.082763	-35.189358
0020	94009020000	-54.069332	-35.201640	94009111700	-53.380360	-37.880572
0021	94009113700	-53.413362	-37.941193	94009144100	-53.416285	-38.814317
0022	94009144100	-53.416285	-38.814317	94009153300	-53.573962	-38.800192
0023	94009153500	-53.573798	-38.791677	94009183000	-53.574253	-37.938457
0024	94009184000	-53.596805	-37.932865	94009192200	-53.723417	-37.931810
0025	94009192700	-53.724107	-37.948868	94009222700	-53.737982	-38.809025
0026	94009222800	-53.741432	-38.809203	94009225500	-53.816985	-38.811063
0027	94009231700	-53.819812	-38.809338	94010021500	-53.821022	-37.934593
0028	94010021800	-53.827097	-37.931028	94010024900	-53.914590	-37.930750
0029	94010025500	-53.917438	-37.952175	94010054400	-53.917875	-38.803552
0030	94010060000	-53.887137	-38.733072	94010081200	-53.679418	-38.167627
0031	94010082300	-53.677813	-38.207865	94010090800	-53.679377	-38.433960
0032	94010091800	-53.695863	-38.424930	94010100300	-53.695990	-38.194402
0033	94010101300	-53.711982	-38.198123	94010105900	-53.712453	-38.427723
0034	94010111000	-53.728597	-38.421632	94010120000	-53.735645	-38.171735
0035	94010120900	-53.745958	-38.199263	94010125500	-53.745927	-38.426693
0036	94010130400	-53.767070	-38.424883	94010135500	-53.760372	-38.176613
0037	94011014400	-53.718437	-38.235382	94011034600	-53.717242	-38.405717
0038	94011040200	-53.734198	-38.395037	94011053600	-53.737423	-38.220982
0039	94011093700	-53.684503	-38.424748	94011100400	-53.766147	-38.424005
0040	94011101500	-53.765565	-38.398107	94011104300	-53.682213	-38.396605
0041	94011105300	-53.682858	-38.371828	94011112100	-53.766388	-38.372995
0042	94011114000	-53.736827	-38.343943	94011120500	-53.674915	-38.327613
0043	94011120800	-53.681253	-38.319632	94011123500	-53.762592	-38.318745
0044	94011124400	-53.771890	-38.293892	94011131600	-53.681045	-38.290060
0045	94011132500	-53.684677	-38.264083	94011135100	-53.765618	-38.262702

Trans	Start time	Start lat	Start long	End time	End lat	End long
0046	94011140100	-53.765573	-38.231843	94011143000	-53.683855	-38.232528
0047	94011144100	-53.687452	-38.199670	94011150700	-53.766092	-38.198453
0048	94011220000	-53.641852	-38.124812	94012040000	-53.648602	-38.504693
0049	94012050000	-53.683737	-38.498002	94012093000	-53.682423	-38.124975
0050	94012100000	-53.724785	-38.133992	94012134800	-53.724600	-38.499578
0051	94012150000	-53.767317	-38.505303	94012190000	-53.768803	-38.129830
0052	94012200000	-53.809160	-38.143557	94013000100	-53.802060	-38.500883
0053	94013014300	-53.931977	-38.569357	94013143100	-53.509352	-38.571887
0054	94013161500	-53.514803	-38.055405	94014012200	-53.929983	-38.056542
0055	94014204500	-53.793127	-38.497238	94014215800	-53.795878	-38.061403
0056	94014215800	-53.795878	-38.061403	94014221800	-53.870627	-38.058365
0057	94014221800	-53.870627	-38.058365	94014233500	-53.856688	-38.473117
0058	94014233500	-53.856688	-38.473117	94015002000	-53.752042	-38.286785
0059	94015112500	-53.780807	-38.089247	94015114800	-53.836963	-38.059795
0060	94015115100	-53.846533	-38.060483	94015132300	-53.848563	-38.550757
0061	94015132500	-53.844435	-38.552907	94015135300	-53.800538	-38.479460
0062	94015210900	-53.782762	-38.517047	94015225100	-53.780638	-38.513573
0063	94019121900	-54.193250	-36.282783	94019170000	-54.953487	-35.947332
0064	94019170000	-54.953487	-35.947332	94021060000	-60.983008	-42.425323
0065	94021060000	-60.983008	-42.425323	94021120700	-60.891573	-44.504263
0066	94022204500	-60.683745	-45.715955	94023012300	-60.992935	-47.134803
0067	94023013200	-60.987170	-47.160652	94023034300	-60.669810	-46.830888
0068	94023034700	-60.664140	-46.843233	94023064900	-60.314137	-47.663603
0069	94023065200	-60.306477	-47.671328	94023091100	-60.381992	-46.834660
0070	94023091400	-60.376620	-46.824833	94023110600	-60.088370	-46.506857
0071	94023111000	-60.091273	-46.491953	94023131100	-60.419640	-46.339000
0072	94023131500	-60.421257	-46.326012	94023161600	-60.002612	-45.754950
0073	94023162300	-59.989513	-45.769540	94025235900	-51.691582	-57.823545
0074	94033034500	-53.598303	-38.901557	94035130000	-50.002750	-42.001353
0075	94035141700	-50.025515	-42.019288	94035190000	-50.608803	-40.828087
0076	94035220200	-50.415545	-40.895905	94036065500	-50.677542	-39.169228
0077	94036070000	-50.675305	-39.159852	94036092500	-50.310380	-38.833718
0078	94036092500	-50.310380	-38.833718	94036154000	-49.801290	-37.458717
0079	94036155000	-49.797175	-37.413382	94036212000	-49.757633	-36.014282
0080	94036214000	-49.750373	-36.040128	94036225500	-49.764580	-36.385227
0081	94036230000	-49.774783	-36.391613	94037060000	-50.946322	-36.692407
0082	94037060300	-50.949015	-36.688062	94037141500	-49.814952	-37.448082
0083	94044091700	-49.698588	-37.672418	94045154800	-50.178380	-36.655380
0084	94045155200	-50.177510	-36.655245	94045194000	-49.454497	-36.431805
0085	94046030000	-49.422742	-36.472022	94047035000	-50.239207	-35.705937
0086	94047080000	-50.304928	-35.690565	94048090000	-54.119072	-36.595760
0087	94048230000	-54.153892	-36.635323	94049080000	-54.791857	-35.593825
0088	94049080000	-54.791857	-35.593825	94049090000	-54.959475	-35.591540
0089	94049130900	-54.635157	-35.636108	94049180000	-53.825557	-35.156255
0090	94049180400	-53.820467	-35.160962	94049231400	-54.084368	-36.487868
0091	94049232000	-54.089310	-36.481643	94050030900	-54.233188	-35.390178
0092	94050060000	-54.277892	-35.445377	94050085000	-54.786002	-35.594538

Trans	Start time	Start lat	Start long	End time	End lat	End long
0093	94050085400	-54.797663	-35.598107	94050140000	-55.623877	-35.568733
0094	94050140400	-55.626505	-35.555885	94050180500	-55.269628	-34.406327
0095	94050181500	-55.246028	-34.428868	94050224600	-54.801683	-35.597627
0096	94050225000	-54.790183	-35.597370	94051033000	-54.171110	-35.372308
0097	94051072800	-54.264887	-35.133908	94051095500	-54.512877	-35.684227
0098	94051095500	-54.512877	-35.684227	94051102400	-54.453890	-35.764493
0099	94051102400	-54.453890	-35.764493	94051130100	-54.182590	-35.186727
0100	94051130500	-54.174810	-35.183537	94051133300	-54.118618	-35.263173
0101	94051133300	-54.118618	-35.263173	94051164000	-54.379043	-35.833707
0102	94051170000	-54.378255	-35.844065	94051181000	-54.356973	-35.472382
0103	94051181500	-54.350365	-35.449107	94051191500	-54.234658	-35.266098
0104	94051191500	-54.234658	-35.266098	94051194000	-54.194665	-35.339187
0105	94051194000	-54.194665	-35.339187	94051204000	-54.305942	-35.537857
0106	94051204000	-54.305942	-35.537857	94051210500	-54.261227	-35.618337
0107	94051210500	-54.261227	-35.618337	94051220000	-54.140592	-35.423368
0108	94052040000	-54.534218	-35.389968	94052094200	-54.080440	-36.480360
0109	94052094200	-54.080440	-36.480360	94052101000	-54.023163	-36.502070
0110	94052110000	-54.044113	-36.445488	94055080000	-70.202633	-22.702900
0111	94056005500	-71.171122	-20.666382	94056093000	-69.647747	-20.184993
0112	94056100000	-69.574645	-20.317655	94060070800	-60.699323	-45.577858
0113	94060160000	-60.797813	-45.492835	94062070000	-54.088550	-54.865275

Annex VI CTD Reversing Thermometer data

Transect 2

Event	CTD Bottle	Press' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
2	11	809.0	16	4.622	2.227	5.3328	Not sure
			17	4.714			at which depth
			18	4.663			bottles fired
							for events
4	11	808.6	16	5.670	2.218	2.2205	2 & 4.
			17	5.743			Fired on
			18	5.792			descent.
6	11	21.6	16	0.836	5.922	-	Thermometers
			17	-			knocked .
			18	-			Not possible
							to read.
8	11	20.3	16	4.166	4.397	4.3982	
			17	4.104			
			18	4.215			
9	11	20.5	16	2.951	3.050	3.0521	
			17	2.975			
			18	2.997			
10	1	3048.4	16	0.282	0.276	0.2798	
			17	0.274			
			18	0.286			

CTD Reversing Thermometers - Transect 2

Event	CTD Bottle	Press ' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
14	1	3046.9	16	0.302	Data	0.2998	
			17	0.293	missing.		
			18	0.306			
18	5	404.9	16	1.760	1.746	1.7461	
			17	1.752			
			18	1.765			
22	5	505.1	16	1.994	1.987	1.9896	Possibly
			17	1.985			not waited
			18	1.998			20 secs.
26	5	303.3	16	1.705	1.785	1.7570	Bottle 4
			17	1.697			(404.2) =
			18	1.709			1.7107 C
30	5	404.9	16	1.914	1.920	1.9100	
			17	1.906			
			18	1.918			
31	5	404.9	16	1.797	1.781	1.7923	
			17	1.788			
			18	1.801			

CTD Reversing Thermometers - Transect 2

Event	Bottle No.	Press' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
32	5	403.6	16	1.718	1.729	1.7198	
			17	1.710			
			18	1.723			
33	5	303.2	16	1.376	1.561	1.3852	
			17	1.368			
			18	1.380			

CTD Reversing Thermometers - Transect 74

Event	CTD Bottle	Pres' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
224	5	405.2	16	1.775	1.750	1.7677	
			17	1.767			
226	5	607.5	16	1.957	1.948	1.9551	Bottles 3, 4, 5
			17	1.949			at 607.5 db
228	5	403.3	16	1.793	1.815	1.7926	
			17	1.786			
230	5	403.5	16	1.680	1.685	1.6810	
			17	1.672			
232	5	403.1	16	1.886	1.893	1.8851	
			17	1.879			
234	5	505.0	16	1.908	1.899	1.9064	
			17	1.900			
236	5	403.3	16	2.074	2.079	2.0745	
			17	2.065			
238	1	3048.8	16	0.380	0.371	0.3778	
			17	0.371			

CTD Reversing Thermometers - Transect 74

Event	CTD Bottle	Press' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
240	1	2687.5	16	0.634	0.626	0.6309	
			17	0.624			
242	11	19.9	16	-	-	-	Thermometer
			17	-	-	-	cage failed to
							flip round.
244	9	60.1	16	5.983	4.724	5.3022	May not have
			17	5.910			waited for 20
							secs.
246	9	60.6	16	6.630	5.994	6.5870	
			17	6.620			
248	9	60.8	16	5.247	4.835	5.1720	
			17	5.241			
250	9	61.2	16	4.277	4.059	4.2228	
			17	4.268			

CTD Reversing Thermometers - Transect 83

Event	CTD Bottle	Press' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
325	3	1500	16	-	-	-	Cage failed to
			17	-	-	-	flip.
328	3	607.9	16	2.306	2.3053	2.3041	
			17	2.295			
334	3	1517.4	16	2.008	1.9947	2.0034	
			17	1.998			
336	3	605.5	16	2.389	2.3813	2.3879	
			17	2.380			
338	3	606.4	16	2.371	2.3714	2.3694	
			17	2.361			
340	3	606.2	16	2.361	2.3646	2.3608	
			17	2.352			
342	3	1518.5	16	1.601	1.5954	1.6019	
			17	1.592			
344	4	606.1	16	2.003	1.9532	2.0126	
			17	1.995			

CTD Reversing Thermometers - Transect 83

Event	CTD Bottle	Press' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
347	3	604.4	16	1.991	1.9765	1.9892	
			17	1.981			
352	3	1519.0	16	1.566	1.5661	1.5642	
			17	1.556			

CTD Reversing Thermometers - Transect 85

Event	Bottle No.	Press' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)
366	3	1518.0	16	1.758	1.7470	1.7663
			17	1.749		
370	3	605.4	16	2.168	2.1571	2.1625
			17	2.158		
372	3	1011.6	16	1.858	1.8475	1.8555
			17	1.849		
375	3	1011.3	16	1.820	1.8128	1.8178
			17	1.811		
377	3	1011.7	16	1.719	1.7116	1.7160
			17	1.709		
379	3	606.0	16	2.147	2.0841	2.1301
			17	2.138		
381	4	607.3	16	1.925	1.9291	1.9233
			17	1.916		
383	4	606.3	16	1.832	1.8366	1.8250
			17	1.822		

CTD Reversing Thermometers - Transect 85

Event	CTD Bottle	Press' (db)	Thermometer No.	Thermometer Temp (°C)	Level C Temp (°C)	EG & G Temp (°C)	Comments
385	3	606.7	16	2.064	2.0555	2.0612	
			17	2.054			
387	3	606.1	16	2.054	2.0815	2.0571	
			17	2.043			
389	3	1518.4	16	2.081	2.0597	2.0749	
			17	2.070			

ANNEX VII **CTD Bottle data JR06 Leg 1. Transect 2.**

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
2	12	5.350	33.918	Bottles fired on
	20	5.333	33.919	descent.
	40	5.340	33.918	
	59	4.861	33.887	
	101	1.910	33.962	
	202	2.054	34.048	
	302	2.172	34.149	
	404	2.045	34.243	
	506	2.326	34.368	
	606	2.316	34.440	
	809	2.224	34.546	
	1011	2.185	34.620	
4	9	5.845	33.961	Bottles fired on
	20	5.830	33.961	descent.
	41	5.837	33.961	
	60	5.828	33.961	
	102	3.012	33.990	
	203	2.037	34.038	
	302	2.301	34.182	
	408	2.368	34.302	
	507	2.544	34.429	
	605	2.480	34.469	
	809	2.221	34.568	
	1012	2.172	34.639	
6	1010	2.184	34.620	
	816	2.293	34.556	
	607	2.262	34.432	
	506	2.424	34.360	
	405	2.541	34.283	
	304	2.424	34.172	
	204	1.993	34.034	
	99	2.740	33.987	
	60	5.841	33.954	
	40	5.895	33.958	
	22	5.920	33.954	
	11	5.935	33.952	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
8	2026	1.338	34.714	
	1518	1.758	34.707	
	1012	2.085	34.647	
	758	2.205	34.563	
	508	2.314	34.421	
	353	2.338	34.267	
	202	1.684	34.030	
	99	2.033	33.961	
	61	4.268	33.928	
	44	4.398	33.908	
	20	4.398	33.910	
	12	4.412	33.911	
9	2531	0.914	34.701	One of the bottles
	2030	1.289	34.713	didn't fire. I think
	1011	2.016	34.671	it was the one at
	759	2.159	34.610	2531; this means that
	507	2.277	34.481	that Mick + Julian
	354	2.312	34.350	need to be aware that
	205	2.125	34.155	their samples may
	102	1.288	33.962	actually come from a
	62	1.371	33.885	depth displaced by one
	42	2.812	33.816	bottle.
	21	3.052	33.808	
	10	3.051	33.808	
10	3048	0.280	34.670	
	2028	0.785	34.688	
	1012	1.727	34.688	
	760	1.910	34.650	
	504	1.973	34.557	
	355	1.791	34.445	
	200	0.846	34.201	
	100	0.929	33.960	
	60	3.078	33.877	
	41	3.091	33.872	
	22	3.090	33.870	
	11	3.088	33.872	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
14	3047	0.300	34.669	
	2028	0.666	34.683	
	1011	1.519	34.698	
	758	1.720	34.502	
	505	1.785	34.610	
	354	1.702	34.526	
	205	0.496	34.256	
	101	0.996	34.022	
	62	3.170	33.947	
	41	3.160	33.948	
	19	3.173	33.947	
	10	3.177	33.945	
18	1014	1.546	34.696	
	808	1.701	34.683	
	607	1.806	34.644	
	506	1.809	34.605	
	405	1.746	34.543	
	303	1.419	34.436	
	203	0.431	34.237	
	100	1.116	34.020	
	60	2.866	33.895	
	40	2.964	33.891	
	20	3.070	33.889	
	11	3.091	33.890	
22	3048	0.306	34.669	Possible problem with bottle.
	2027	0.744	34.684	
	1012	1.679	34.697	
	759	1.854	34.672	
	505	1.990	34.602	
	354	1.958	34.516	
	201	1.127	34.244	
	101	0.808	34.004	
	62	1.911	33.869	
	40	2.860	33.856	
	21	2.905	33.856	
	10	2.982	33.847	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
26	1011	1.675	34.697	Only 11 bottles fired
	607	2.014	34.642	on this cast as bottle
	506	1.896	34.583	1 broken.
	404	1.711	34.505	
	303	1.757	34.418	
	201	1.146	34.255	
	102	0.659	34.037	
	61	2.321	33.867	
	41	2.896	33.858	
	21	2.933	33.858	
	11	2.933	33.859	
30	1012	1.705	34.699	
	809	1.856	34.682	
	607	1.981	34.636	
	506	1.970	34.587	
	405	1.910	34.527	
	303	1.792	34.414	
	201	0.927	34.205	
	102	0.902	33.981	
	60	2.687	33.876	
	40	2.712	33.873	
	21	2.712	33.873	
	11	2.720	33.874	
31	1013	1.645	34.701	
	809	1.851	34.684	
	607	1.894	34.643	
	506	1.925	34.604	
	405	1.792	34.543	
	303	1.656	34.450	
	202	0.854	34.223	
	101	1.137	33.941	
	61	2.395	33.874	
	40	3.194	33.871	
	20	3.216	33.870	
	11	3.229	33.869	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
32	1012	1.543	34.703	
	809	1.729	34.689	
	606	1.874	34.649	
	504	1.816	34.612	
	404	1.720	34.555	
	303	1.300	34.433	
	202	0.723	34.278	
	101	2.021	33.975	
	62	2.822	33.927	
	40	2.968	33.924	
	21	2.959	33.910	
	10	3.076	33.909	
33	811	1.775	34.684	Data suggests only 11
	606	1.907	34.642	bottles were fired on
	506	1.904	34.600	this cast.
	404	1.851	34.534	
	303	1.385	34.392	
	202	0.595	34.197	
	102	1.658	33.951	
	60	2.749	33.900	
	40	2.749	33.901	
	21	2.855	33.901	
	11	2.887	33.901	

CTD Bottle Data JR06 Leg 1. Opportunistic CTD casts.

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
37	41	2.026	33.882	
71	283	1.046	34.257	
	253	1.042	34.246	
	227	0.925	34.207	
	202	0.799	34.167	
	176	0.765	34.140	
	153	0.645	34.080	
	136	0.708	34.065	
	122	0.718	34.022	
	113	0.729	34.014	
	102	1.032	33.981	
	91	1.226	33.955	
	81	1.450	33.941	
74	72	1.957	33.918	
	62	2.469	33.908	
	51	2.595	33.864	
	40	2.556	33.858	
	31	2.550	33.856	
	20	2.537	33.852	
	11	2.567	33.840	
101	16	2.774	33.837	
124	16	3.505	33.886	
126	250	0.904	34.175	
	198	0.574	34.091	
	152	0.615	34.029	
134	15	2.237	33.880	
162	151	0.718	34.018	
	101	1.204	33.932	
	81	1.359	33.912	
	71	2.384	33.859	
	60	3.106	33.847	
	52	3.200	33.845	
	31	3.262	33.846	
	11	3.272	33.843	
179	201	0.697	34.097	
	15	3.040	33.851	

CTD Bottle Data JR06 Leg 2 - Transect 74.

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
224	1011.2	1.6902	34.674	
	808.7	1.8396	34.652	
	606.1	1.8891	34.599	
	504.6	1.8208	34.562	
	405.2	1.7677	34.480	
	302.4	1.5727	34.408	
	202.2	0.6987	34.171	
	101.8	0.9958	33.951	
	60.7	4.1659	33.841	
	40.3	4.1987	33.837	
	19.8	4.2712	33.835	
	10.8	4.2690	33.832	
226	1012.7	1.6484	34.688	
	809.7	1.8138	34.671	
	607.5	1.9551	34.625	
	505.8	1.9847	34.590	
	403.7	1.8233	34.522	
	302.2	1.4709	34.416	
	201.0	0.7293	34.207	
	100.3	0.9513	33.940	
	61.3	3.7372	33.849	
	40.5	3.8934	33.847	
	19.7	4.0777	33.852	
	10.4	4.0888	33.852	
228	1011.6	1.5925	34.689	
	808.9	1.7584	34.672	
	607.0	1.8551	34.621	
	505.7	1.8817	34.584	
	403.3	1.7926	34.521	
	303.2	1.6359	34.446	
	201.8	0.5424	34.157	
	101.4	0.8646	33.971	
	60.5	4.0076	33.873	
	40.2	4.0822	33.869	
	19.3	4.1601	33.860	
	10.9	4.1740	33.861	
230	1011.1	1.5880	34.691	
	808.6	1.7706	34.681	
	605.9	1.8495	34.639	
	505.8	1.7197	34.572	
	403.5	1.6810	34.508	
	303.0	1.3212	34.404	
	201.0	0.5357	34.228	
	101.8	1.1097	33.967	
	61.3	3.8832	33.848	
	40.2	4.1556	33.839	
	21.3	4.2205	33.841	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
232	1011.2	1.5341	34.693	
	809.2	1.7108	34.676	
	606.3	1.8149	34.631	
	504.2	1.8960	34.601	
	403.1	1.8851	34.544	
	302.8	1.3390	34.402	
	200.8	0.9386	34.248	
	100.7	1.9209	33.941	
	60.5	4.0878	33.881	
	39.8	4.1898	33.873	
	20.2	4.2972	33.874	
	10.4	4.4311	33.877	
234	3048.8	0.3214	34.663	
	2028.1	0.7866	34.680	
	1011.8	1.6304	34.688	
	757.4	1.8462	34.651	
	505.0	1.9064	34.566	
	354.7	1.5269	34.413	
	201.9	0.7469	34.150	
	100.6	0.9159	33.964	
	61.4	4.0126	33.864	
	40.3	4.1575	33.861	
	20.3	4.2500	33.856	
	10.9	4.2511	33.856	
236	1011.4	1.7602	34.685	
	808.7	1.9219	34.658	
	505.6	2.0631	34.552	
	403.3	2.0745	34.488	
	302.8	1.7184	34.339	
	201.1	1.1270	34.172	
	100.5	0.6173	33.919	
	60.0	3.6861	33.792	
	41.0	3.9699	33.791	
	21.1	3.9686	33.791	
	10.8	3.9642	33.791	
238	3048.8	0.3778	34.668	
	2028.2	0.9480	34.687	
	1011.0	1.8733	34.682	
	757.1	1.9577	34.639	
	504.5	2.0460	34.554	
	354.6	1.8502	34.415	
	201.8	0.7795	34.147	
	101.1	0.6318	33.908	
	60.8	3.6224	33.704	
	39.7	3.8620	33.798	
	20.8	3.9940	33.802	
	9.5	4.0130	33.804	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
240	2687.5	0.6309	34.679	
	2027.6	1.1063	34.695	
	1011.6	1.9546	34.679	
	758.1	2.1244	34.624	
	505.7	2.1446	34.512	
	353.4	1.8683	34.363	
	202.1	1.3395	34.123	
	100.6	1.5355	33.929	
	61.2	3.8609	33.845	
	40.9	4.3214	33.821	
	20.8	4.4117	33.827	
	10.4	4.4591	33.818	
242	2028.3	1.2185	34.700	
	1514.9	1.7145	34.698	
	1012.1	2.0372	34.650	
	758.7	2.1341	34.577	
	504.6	2.2590	34.440	
	353.6	2.3423	34.312	
	201.0	2.0901	34.122	
	101.2	1.2681	33.935	
	59.6	4.0896	33.802	
	40.3	5.1202	33.812	
	19.9	5.3414	33.807	
	11.2	5.4050	33.821	
244	2027.9	1.4703	34.714	
	1519.7	1.8743	34.696	
	1011.9	2.1802	34.623	
	758.9	2.2720	34.529	
	505.1	2.5293	34.387	
	353.7	2.3093	34.220	
	201.2	2.0525	34.058	
	101.8	2.2687	33.989	
	60.1	5.3022	33.909	
	40.5	5.7666	33.888	
	20.8	5.8720	33.874	
	10.7	5.9175	33.877	
246	1011.8	2.1520	34.620	
	809.1	2.2497	34.554	
	607.0	2.2954	34.437	
	504.8	2.2411	34.362	
	403.2	2.3045	34.256	
	303.0	2.3042	34.176	
	200.8	2.0466	34.057	
	101.1	2.6968	33.962	
	60.6	6.5870	33.914	
	40.9	7.0522	33.916	
	21.0	7.2365	33.913	
	10.3	7.5073	33.911	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
248	1011.8	2.1827	34.615	
	808.1	2.2556	34.532	
	606.4	2.3644	34.383	
	505.6	2.4388	34.319	
	404.4	2.6900	34.239	
	303.0	2.5483	34.110	
	201.7	2.7453	34.063	
	100.5	3.9786	34.083	
	60.8	5.1720	33.965	
	40.4	6.2743	33.948	
	20.1	6.6642	33.945	
	10.1	6.9295	33.937	
250	1011.1	2.2317	34.586	
	808.8	2.3532	34.493	
	606.1	2.5199	34.376	
	504.7	2.6220	34.307	
	403.5	2.6591	34.231	
	302.7	2.6459	34.147	
	201.9	2.3679	34.048	
	100.6	3.6381	34.128	
	61.2	4.2228	34.024	
	39.6	5.2906	33.894	
	19.8	5.7964	33.859	
	11.0	5.8859	33.857	

CTD Bottle Data - JR06 Leg 2. Opportunistic CTD casts.

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
259	15.6	6.4952	33.951	
273	505.3	2.3825	34.417	
	404.5	2.4095	34.313	
	303.7	2.5051	34.236	
	252.3	2.5264	34.169	
	228.1	2.7269	34.163	
	203.1	2.6755	34.123	
	176.8	3.1796	34.133	
	151.4	3.2430	34.061	
	142.2	3.3787	34.060	
	130.4	3.7265	34.076	
	121.9	3.7975	34.077	
	111.5	3.8669	34.065	
276	121.8	3.6307	34.080	
	111.3	3.7278	34.076	
	101.3	3.7708	34.070	
	91.3	3.8461	34.058	
	80.6	4.2880	34.019	
	69.7	5.2039	34.052	
	61.2	5.7096	33.999	
	51.5	6.1636	33.983	
	41.8	6.4265	33.930	
	30.8	6.4420	33.927	
	19.7	6.4405	33.927	
	10.1	6.4436	33.925	
285	15.6	6.4869	33.979	
301	70.0	6.2687	33.990	
	40.7	6.4764	33.986	
	20.7	6.4748	33.986	
	10.8	6.4743	33.986	
305	15.6	6.5113	33.955	

CTD Bottle Data - JR06 Leg 2. Transects 83 and 85.

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
325	4589.2	0.1704	34.675	
	3048.7	0.3484	34.682	
	1518.2	1.9738	34.762	
	1010.9	2.3730	34.714	
	505.4	2.3291	34.452	
	353.6	2.1379	34.273	
	200.4	2.4705	34.128	
	102.4	3.3281	34.017	
	65.2	6.0273	33.956	
	39.1	6.0398	33.957	
	20.7	6.0397	33.958	
328	1013.6	2.3083	34.692	
	808.5	2.3564	34.621	
	607.9	2.3041	34.493	
	508.3	2.2279	34.405	
	403.5	2.4089	34.321	
	303.9	2.3605	34.190	
	200.6	2.9202	34.135	
	101.3	3.6604	34.059	
	60.7	6.0827	33.978	
	39.9	6.0929	33.983	
	20.9	6.0965	33.980	
334	4588.6	0.1144	34.674	
	3048.0	0.4710	34.689	
	1517.4	2.0034	34.764	
	1011.1	2.3062	34.683	
	505.6	2.3750	34.402	
	354.9	2.5540	34.269	
	202.5	3.1447	34.145	
	99.2	4.8391	34.053	
	61.0	6.0528	34.004	
	40.7	6.0685	34.004	
	20.3	6.0766	34.004	
336	1011.4	2.3040	34.667	
	809.4	2.3392	34.586	
	605.5	2.3879	34.469	
	505.5	2.4250	34.405	
	404.3	2.5012	34.322	
	301.6	2.6508	34.222	
	202.5	3.2498	34.146	
	101.4	4.0725	34.061	
	60.1	6.0834	33.999	
	39.7	6.1028	33.999	
	21.1	6.1032	34.000	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
338	1010.3	2.3132	34.653	
	809.8	2.3387	34.551	
	606.4	2.3694	34.429	
	505.5	2.4123	34.381	
	405.4	2.4778	34.321	
	302.1	2.5195	34.203	
	200.9	3.1356	34.123	
	101.4	3.8392	34.064	
	60.5	5.8651	33.982	
	41.0	6.0687	33.969	
	20.4	6.0712	33.969	
340	1010.9	2.3001	34.684	
	808.7	2.3447	34.612	
	606.2	2.3608	34.497	
	506.4	2.3925	34.412	
	403.6	2.4173	34.332	
	303.0	2.5364	34.222	
	203.5	2.6822	34.118	
	100.4	3.5991	34.053	
	62.5	5.6705	33.993	
	40.5	5.9391	33.953	
	21.3	5.9493	33.953	
342	4587.0	0.1119	34.673	
	3047.9	0.4972	34.690	
	1518.5	1.6019	34.710	
	1011.2	2.1634	34.680	
	504.8	2.2600	34.461	
	352.5	2.2438	34.299	
	201.0	2.2476	34.129	
	100.8	2.8320	34.020	
	60.3	4.7019	33.825	
	40.9	4.6964	33.823	
	20.7	4.6844	33.821	
344	1006.1	1.8546	34.688	
	808.9	1.9755	34.655	
	606.1	2.0126	34.585	
	504.9	1.7431	34.510	
	404.0	1.2803	34.380	
	303.0	1.8030	34.326	
	201.0	1.1853	34.151	
	101.1	0.9650	33.906	
	60.7	4.8145	33.854	
	40.5	4.8247	33.853	
	19.7	4.8262	33.853	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
347	1011.9	1.8416	34.701	
	809.5	1.9431	34.663	
	604.4	1.9892	34.599	
	505.6	2.0665	34.568	
	403.4	1.9985	34.491	
	302.7	1.4321	34.328	
	201.6	0.7469	34.154	
	101.1	2.3694	33.892	
	59.9	5.0011	33.841	
	40.2	5.0976	33.835	
	20.0	5.1154	33.835	
352	3872.3	0.1570	34.677	
	2537.9	0.6311	34.697	
	1519.0	1.5642	34.739	
	1012.0	1.9446	34.711	
	504.7	1.8320	34.534	
	355.2	1.5906	34.417	
	202.1	0.7381	34.155	
	99.8	1.4948	33.913	
	60.6	5.3259	33.838	
	41.1	5.3709	33.839	
	20.7	5.3795	33.839	
366	4588.3	0.0075	34.670	
	3046.7	0.3839	34.686	
	1518.0	1.7663	34.756	
	1010.9	1.8812	34.679	
	505.0	2.0704	34.503	
	353.6	2.2099	34.411	
	201.8	1.5182	34.143	
	100.1	1.1165	33.900	
	60.1	2.7129	33.891	
	40.7	4.9541	33.817	
	20.2	5.1409	33.798	
370	1011.2	1.8115	34.693	
	808.6	2.0050	34.648	
	605.4	2.1625	34.592	
	506.3	2.1358	34.544	
	403.0	1.5093	34.414	
	303.4	1.6673	34.326	
	202.3	0.8203	34.117	
	101.6	1.2289	33.875	
	60.0	5.0139	33.824	
	40.9	5.0384	33.827	
	20.3	5.1791	33.833	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
372	3048.2	0.3362	34.686	
	2027.6	1.1481	34.732	
	1011.6	1.8555	34.703	
	757.9	1.9119	34.651	
	506.6	1.9397	34.561	
	353.4	1.8284	34.428	
	201.4	0.9559	34.157	
	102.9	1.1956	33.925	
	40.0	5.2902	33.830	
	20.4	5.4882	33.831	
375	3049.1	0.3167	34.686	
	2028.1	1.0583	34.727	
	1011.3	1.8178	34.706	
	756.7	1.8762	34.664	
	504.0	1.8386	34.530	
	352.9	1.7928	34.431	
	202.4	0.5606	34.116	
	100.7	1.3052	33.894	
	60.2	5.3241	33.834	
	40.1	5.3367	33.833	
	19.0	5.5105	33.836	
377	2971.5	0.2695	34.683	
	2028.2	1.0206	34.725	
	1011.7	1.7160	34.692	
	758.3	1.8957	34.647	
	504.2	2.1964	34.569	
	354.1	1.7334	34.411	
	202.0	0.7198	34.128	
	100.6	1.6670	33.880	
	60.7	5.4784	33.838	
	41.1	5.6918	33.844	
	20.0	5.7568	33.839	
379	1010.7	1.7406	34.706	
	808.6	2.0290	34.687	
	606.0	2.1301	34.630	
	504.4	2.0333	34.561	
	403.9	1.8402	34.461	
	302.0	1.7713	34.365	
	201.8	0.8465	34.147	
	99.0	1.3405	33.881	
	60.6	5.1849	33.837	
	40.4	5.4739	33.834	
	19.5	5.7566	33.829	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
381	1012.0	1.7950	34.700	
	807.3	1.9583	34.676	
	607.3	1.9233	34.586	
	504.8	1.8303	34.523	
	404.4	1.8497	34.448	
	302.4	1.8062	34.336	
	201.5	0.8498	34.125	
	100.8	1.2232	33.900	
	61.2	4.9460	33.803	
	41.1	5.2140	33.824	
	20.4	5.6359	33.822	
383	1011.1	1.7730	34.697	
	808.1	1.9585	34.660	
	606.3	1.8250	34.554	
	504.2	1.6795	34.479	
	404.6	1.9693	34.445	
	302.9	1.3963	34.271	
	202.7	0.9543	34.120	
	101.2	1.0224	33.923	
	60.3	4.6849	33.840	
	40.5	4.9936	33.811	
	20.6	5.2955	33.815	
385	1010.6	1.8282	34.689	
	809.7	1.9297	34.635	
	606.7	2.0612	34.553	
	504.8	2.0543	34.506	
	403.9	2.0812	34.443	
	302.7	2.0593	34.352	
	201.5	1.5594	34.202	
	100.9	1.1200	33.906	
	60.2	5.0277	33.828	
	40.5	5.2032	33.815	
	20.6	5.5122	33.815	
387	1012.7	1.9337	34.693	
	808.4	1.9494	34.621	
	606.1	2.0571	34.532	
	504.8	1.9711	34.459	
	404.3	1.9773	34.380	
	303.6	1.1168	34.184	
	201.6	0.9687	34.047	
	101.5	2.4234	33.886	
	61.4	6.0444	33.956	
	39.9	5.9300	33.906	
	21.0	5.9189	33.876	

Event	Press (db)	Temp (°C)	Sal (psu)	Comments
389	4073.5	0.1391	34.675	
	3049.7	0.4404	34.689	
	1518.4	2.0749	34.782	
	1011.1	2.3932	34.739	
	506.3	1.9510	34.453	
	354.7	1.4123	34.243	
	201.5	1.7784	34.101	
	101.5	1.9204	33.962	
	61.2	5.5968	33.892	
	40.1	6.0806	33.947	
	20.1	6.0895	33.949	

Annex VIII

Gyro compass errors from astronomical sights for no. 2 gyro for cruise JR06.

Date	Time (GMT)	Latitude	Longitude	Gyro error
30/12/93	22:07	51° 42' S	57° 49' W	+0.5
01/01/94	04:40	51° 39' S	55°53' W	+0.5
03/01/94	02:16	50° 17' S	48° 03' W	+1.0
12/01/94	22:56	53° 48' S	38° 28' W	+1.0
19/01/94	06:37	53° 55' S	36° 58' W	+2.0
19/01/94	22:58	55° 55' S	37° 15' W	+1.0
19/01/94	22:58	55° 55' S	37° 15' W	+2.0
19/01/94	22:58	55° 55' S	37° 15' W	+2.0
24/01/94	00:27	58° 51' S	47° 46' W	+2.0
29/01/94	21:17	51° 45' S	56' 39' W	+1.0
30/01/94	04:47	52° 02' S	54° 09' W	+1.5
30/01/94	21:51	52° 36' S	48° 38' W	+1.5
31/01/94	02:16	52° 44' S	47° 09' W	+1.0
31/01/94	03:55	52° 48' S	46° 37' W	+1.5
31/01/94	03:55	52° 48' S	46° 37' W	+1.0
02/02/94	02:06	53° 39' S	38° 38' W	+1.5
03/02/94	03:35	51° 59' S	40° 18' W	+1.5
03/02/94	09:24	51° 37' S	40° 36' W	+2.0
04/02/94	02:25	50° 41' S	41° 22' W	+1.5
05/02/94	03:07	50° 33' S	39° 54' W	+1.5
05/02/94	07:26	50° 37' S	39° 06' W	+2.0
09/02/94	21:57	49° 48' S	37° 32' W	+1.5
09/02/94	23:46	49° 48' S	37° 35' W	+0.5
14/02/94	21:19	49° 26' S	36° 25' W	+1.5
15/02/94	03:15	49° 27' S	36° 25' W	+0.5
02/03/94	17:46	56° 33' S	51° 47' W	+1.5
02/03/94	21:29	55° 53' S	52° 42' W	+3.0
03/03/94	09:11	53° 39' S	55° 24' W	+3.0
03/03/94	10:59	53° 19' S	55° 49' W	+2.0

Annex IX CHERNIKEEFF LOG CALIBRATION 22/9/93

The following calibration details were taken over several runs of a measured mile. Weather conditions were ideal although there was a tidal element present.

Each run is marked with respect to the ships heading, being either East or West.

WEST	R060	S0588	A0588
EAST	R060	S0466	A0642
WEST	R090	S0787	A0934
EAST	R090	S0907	A0966
WEST	R120	S0990	A1274
EAST	R120	S1292	A1288
WEST	R150	S1149	A1503
EAST	R150	S1575	A1521
WEST	R180	S1272	A1693
EAST	R180	S1755	A1692

Prior to the runs being started all data held in memory was erased and once the runs were completed and the new curve was calculated the following settings are now being used.

R060	S0527	A0615
R090	S0847	A0950
R120	S1141	A1281
R150	S1362	A1512
R180	S1513	A1692

Since heading for Montevideo the Chernikeeff Log has been very accurate, at most 1% in error but frequently much less than that (based on distance covered in a 24 hour period).

Interesting that the above figures are different from all previously taken. Will monitor the speed whilst in the Southern Ocean.

Settings prior to the above test were:

R060	S0483	A0500
R090	S0755	A0850
R120	S0995	A1000
R150	S1193	A1250
R180	S1386	A1550