RRS Discovery Cruise 264

Biophysical studies of zooplankton dynamics in the northern North Atlantic: summer, 25 July - 28 August 2002

MARINE PRODUCTIVITY CRUISE REPORT NO. 3

Photo: A S Brierley

Principal Scientist: Andrew Brierley
School of Biology, University of St Andrews
asb4@st-and.ac.uk

Document Data Sheet

AUTHORS	*PUBLICATION DATE*
ANDREW BRIERLEY and Marine Productivity researchers, with editorial assistance by P Williamson and G Moncoiffe	Oct 2003

TITLE

RRS Discovery cruise 264. Biophysical studies of zooplankton dynamics in the northern North Atlantic: summer, 25 July - 28 August 2002.

REFERENCE

Marine Productivity Cruise Report No. 3 (108 pp)

ABSTRACT

Discovery 264 was the third of four multi-institute and multidisciplinary research cruises supported by the NERC Marine Productivity thematic programme within the wider context of the international Global Ocean Ecosystem Dynamics project (GLOBEC). It provided information on biological and physical conditions during summer in the northern Irminger Basin, along the Reykjanes Ridge and east Greenland shelf-edge, and parts of the Iceland Basin. Scientific effort was directed at: mapping physico-chemical features in terms of water mass distribution, velocity field and mixed layer properties; 14C primary production measurements; collection of water samples for plant pigment, phytoplankton and microzooplankton analyses; determination of 3D abundances of the copepod *Calanus finmarchicus*, other mesozooplankton, and their main invertebrate predators; experimental studies of egg production, nauplii development and feeding behaviour for *Calanus* and *Oithona* spp; molecular analysis of *Calanus* spp identity and embryonic gene expression, and zooplankton collection for further taxonomic, genetic, physiological and biochemical studies. SeaWiFS and AVHRR imagery provided regional and local information on chlorophyll abundance and sea surface temperature.

Weather conditions were generally favourable, and good coverage was obtained for the ocean areas of interest (including a southern E-W transect of the Irminger Basin). The main sampling and data-gathering activities comprised 23 CTD profiles, 26 ARIES tows, 22 Dual Methot net tows, 22 Ocean Sampler tows, 7 Continuous Plankton Recorder (CPR) tows, 37 sets of vertical net hauls, 23 Fast Repetition Rate Fluorometer (FRRF) vertical casts and 28 FRRF underway datasets, 2 MetO float deployments, 6 lowered EK500 deployments and 53 EK500 tows. Provisional data from ARIES and other sources indicated that *Calanus* abundances were greatest in the central areas of the Irminger Basin, and that a significant proportion were below 200m, already in a pre-diapause or diapause state. Additional laboratory studies will be carried out on these aspects of *Calanus* biology.

KEYWORDS

ADCP SYSTEMS, ARGOS FLOAT, ARIES SYSTEM, CALANUS FINMARCHICUS, COPEPOD, CPR SYSTEM, CTD OBSERVATIONS, DISSOLVED OXYGEN, DUAL METHOT NET, EGG PRODUCTION, EUPHAUSIID, FRRF SYSTEM, GLOBEC, ICELAND BASIN, IRMINGER BASIN, MARINE PRODUCTIVITY THEMATIC, MICROPLANKTON, MOLECULAR BIOLOGY, NORTHERN NORTH ATLANTIC, NAUPLII, NUTRIENTS, OCEAN SAMPLER, OITHONA, OPTICAL PLANKTON COUNTER, PHAEOCYSTIS, PHYTOPLANKTON, PRIMARY PRODUCTION, REYKJANES RIDGE, RRS DISCOVERY, SALINITY, SCIENTIFIC ECHOSOUNDER, SEA SURFACE TEMPERATURE, ZOOPLANKTON.

ISSUING ORGANISATION

Natural Environment Research Council, Swindon SN2 1EU, UK

COPIES OF THIS REPORT ARE AVAILABLE (HARD COPY AND ONLINE) FROM

British Oceanographic Data Centre, website www.bodc.ac.uk, email enquiries@bodc.ac.uk
Bidston Observatory, Prenton, Merseyside CH43 7RA, UK; Tel +44 (0)151 653 1510
From early 2004: Joseph Proudman Building, 6 Brownlow Street, Liverpool L3 5DA, UK;
Tel (0)151 795 4884, fax (0)151 795 4912

CONTENTS

LIST OF TABLES

FIGURES

Scientific personnel

Allen, John	SOC	Physical oceanography
Anderson, Kirsty	St. Andrews	Bioacoustics
Brierley, Andrew	St. Andrews	Principal Scientist; bioacoustics
Brown, Louise	SOC	Chemical oceanography
Bunker, Adrian	Heriot Watt	*Calanus* experimental biology
Castellani, Claudia	SOC	*Oithona* experimental biology
Cook, Kathryn	FRS Aberdeen	*Calanus* experimental biology
Edwards, Terry	SOC/UKORS	TLO; electronic engineering
Hay, Steve	FRS Aberdeen	Net sampling; filter fractionation
Hirst, Andrew	BAS	*Calanus* experimental biology
Hunter, Jim	FRS Aberdeen	Net sampling; electronic engineering
Johnson, Clare	East Anglia	Physical oceanography
Lindeque, Penny	PML	*Calanus* genetics
Lucas, Mike	SOC	Primary productivity
Mayor, Daniel	SOC	*Calanus* experimental biology
Phipps, Richard	SOC/UKORS	Mechanical engineering
Pollard, Raymond	SOC	Physical oceanography
Rourke, Liz*	SOC/UKORS	Computing
Saunders, Ryan	St. Andrews	Net sampling; bioacoustics
Seville, Gary	SOC/UKORS	Mechanical engineering
Shannon, Katy	SOC	Physical oceanography
Sherring, Alan	SOC/UKORS	Mechanical engineering
Short, Jonathan	SOC/UKORS	Electronic engineering
Sidey, Johanna	SAHFOS	Continuous Plankton Recorder
Smerdon, Gary	PML	*Calanus* genetics
Titelman, Josefin*	PML	*Oithona* experimental biology
Wilson, Dave	Liverpool	Phytoplankton and ciliate sampling
Yebra Mora, Lidia	PML	*Oithona* experimental biology

**disembarked at Iceland*

BAS, British Antarctic Survey; FRS, Fisheries Research Services; PML, Plymouth Marine Laboratory; SAHFOS, Sir Alister Hardy Foundation for Ocean Science; SOC, Southampton Oceanographic Centre; TLO, Technical Liaison Officer; UKORS, UK Ocean Research Services.

Ship's Personnel

Long, Geoff	Captain
Noden, Derek	Chief Officer
Mitchell, John	Second Officer
Hood, Mike	Third Officer
Jethwa, Jet	Chief Engineer
Slater, Ian	Second Engineer
Bell, Stephen	Third Engineer
Slater, Gary	Third Engineer
Corbett, Shaun	Electrical Engineer, ETO
Searle, Peter	Motorman 1A
Pook, Glen	CPO Deck
Lewis, Greg	PO Deck
Robinson, William	Seaman 1A
Crabb, Gary	Seaman 1A
Ridley, John	Seaman 1A
Barrett, Stewart	Seaman 1A
Staite, Edward	Shipboard Catering Manager
Nagle, Stephen	Chef
Link, Wally*	Steward
Mingay, Graham	Steward

**disembarked at Iceland*

Acknowledgements

We are grateful for the excellent services provided by Captain Geoff Long and his team aboard *RRS Discovery*. We also acknowledge the support provided by the NERC Research Ships Unit (RSU), UK Ocean Research Services (UKORS) and the SOC Ocean Engineering Division (OED) in the planning and execution of this cruise.

Research funding was provided primarily through grants awarded under the NERC Marine Productivity thematic programme. The assistance of the programme's Steering Committee and Science Coordinator in the strategic planning and implementation of the cruise is much appreciated.

Satellite data (including sea surface temperature and chlorophyll) were transmitted to the ship from Plymouth Marine Laboratory, and we thank Peter Miller, Steve Groom and Gareth Mottram for processing and sending the images.

1. The cruise

1.1 Introduction

RRS Discovery cruise 264 was the third of four cruises supported by the NERC Marine Productivity (MarProd) thematic programme. The vessel sailed from Fairlie Quay, Firth of Clyde at 13:00 on 25 July and returned to Fairlie on 28 August 2002. There was a boat transfer off Reykjavik on 12 August to allow three cruise participants to disembark for medical and compassionate reasons.

1.2 Scientific objectives

The overall goal of the Marine Productivity programme is "to develop coupled modelling and observation systems for the pelagic ecosystem, with emphasis on physical factors affecting zooplankton dynamics". The target zooplankton species for programme fieldwork is the copepod *Calanus finmarchicus*. This species was chosen because it is the dominant zooplankton species in the northern North Atlantic, it is a major food supply for fish larvae, and its abundance is known to vary with changing climatic conditions. Understanding the controls on *Calanus finmarchicus* is key to understanding the impact of changes of climate on temperate and sub-polar ecosystems of the North Atlantic.

The specific objectives of the third MarProd cruise were similar to those of the second (*Discovery* 262, spring), and can be categorized as either "broad scale survey" or "process" oriented. The objectives of the broad scale survey component were:

- To map the physical features of the survey region (Irminger Basin and parts of the Iceland Basin) in terms of water mass distribution, velocity field and mixed layer properties
- To measure high resolution profiles of inorganic nutrient concentrations
- To carry out primary production studies and collect water samples for plant pigment and microscopic analyses, to estimate the productivity and biomass of different taxonomic and functional groups of microplankton
- To determine the 3D abundance of the mesoplankton of interest (primarily *Calanus finmarchicus*), and their planktivorous predators (primarily euphausiid spp.) using a variety of net and acoustic sampling techniques, and to obtain material for further physiological, biochemical and taxonomic studies. Molecular genetic analyses were also carried out during *Discovery* 264, to assess the taxonomic composition of *Calanus* spp samples.

The process studies covered:

- Estimation of rates of primary productivity
- *Calanus* egg production and nauplii development
- Influence of food quality on *Calanus* egg production
- *Oithona* and *Calanus* nauplii feeding experiments
- *Oithona* egg production
- Collection of samples for analysis of lipids, hormones and gene expression
- Collection of samples for C/N and stable isotope ratios.

This was an ambitious list for a cruise that was several days shorter than the spring equivalent, requiring close collaboration between the various scientific groups, technical support and ship's

personnel. Although the sampling requirements of the broad scale and process objectives were not totally compatible, it is credit to everyone on board that so much was achieved.

The broad scope of the dataset compiled by the MarProd series of cruises to the Irminger Basin will facilitate comparison with historic datasets (e.g. NORWESTLANT, 1963 and the Continuous Plankton Recorder surveys), the EU-supported zooplankton programmes TASC and ICOS, and other national and international studies. The MarProd programme provides the main UK contribution to the Global Ocean Ecosystem Dynamics project (GLOBEC), co-sponsored by IGBP, SCOR and IOC.

1.3 Cruise overview

The cruise track and site positions are shown in Fig 1. The cruise track was chosen as a compromise that enabled: i) sampling of an E-W section across the central Irminger Basin (approx latitude 61°N) previously worked in MarProd cruises in winter (*Discovery* 258; section D) and spring (*Discovery* 262; section G, renamed DD); ii) multiple 5-day occupations of contrasting provinces (Reykjanes Ridge, open ocean and on-shelf); iii) over 75% reoccupation of the spring process study sites (13 out of 17 such sites occupied on *Discovery* 262); and iv) a southerly section also to be included, running south east from near Cape Farewell on the southern tip of Greenland. In reality the requirements of the process and broad scale components of the cruise were somewhat at odds, but the track enabled the ship to remain within a given province for sufficient time for the process study experiments, whilst mapping a significant part of the Irminger Basin. In addition, we were able to maintain some flexibility to respond to potentially significant features that became apparent from satellite imagery that was provided in near real-time (1 day lag) to the ship.

A detailed cruise diary is given in Appendix A1.1. The details of the work done at each site (the individual stations and gear used) are given in Appendix A1.2. A total of 23 CTD full profiles, 26 ARIES tows, 22 Dual Methot net (DMT) tows, 22 Ocean Sampler (OS) tows, 6 lowered EK500 (LEK) deployments, 37 sets of vertical net hauls, 2 met float deployments, 23 Fast Repetition Rate Flourimeter (FRRF) casts, 7 tows of the Continuous Plankton Recorder (CPR) and 52 tows (462 hr) of the towed EK500 (TEK) were completed. We benefited from exceptionally calm weather for much of the cruise and, apart from the time lost in the unplanned visit to Iceland (approx 3 days), were able to proceed pretty much to plan. The only major exception to this was that a combination of icebergs and thick fog near the Greenland shelf edge (south of around 63°N) hampered our attempts to sample properly on the shelf .

In general, our method of working was to conduct a full suite of activities at 'full sites', with 'intermediate sites' comprising a much-reduced suite of measurements (see cruise event log, Appendix A1.2). We aimed to time the work at full sites so that the vertical net and primary productivity sampling were each accomplished at the same time of day. The order of deployments at a full site that minimised turn-round time was: TEK inboard; water collection at the depth of the chlorophyll maximum using CTD rosette; vertical nets; FRRF; full depth physics CTD; LEK; TEK outboard; OS, DMT and ARIES. On line DD, as with the spring cruise, we found that in a given 24 hr period we were able to: complete a full site; steam for ~30 nautical miles; complete an intermediate site, consisting of a full depth CTD profile and vertical net haul; and conclude by a ~30nm steam to the next full site. However, after the unscheduled visit to Iceland and attempted work on the Greenland shelf, it was not always possible to complete either the full or intermediate suite of activities. Along line G, speeds were reduced because of fog and time became short; as a result, sites were alternately ARIES-centred and CTD-centred, in order to expedite our return across the basin.

Andrew Brierley

2. CTD and lowered ADCP systems

2.1 Lowered CTD: rosette, frame and package equipment

The main CTD system comprised the following instruments:

- Sea-Bird 911+ with dual temperature and conductivity sensors
- Sea-Bird dissolved oxygen sensor
- Chelsea Instruments transmissometer (alphatracka)
- Chelsea Instruments fluorometer (aquatracka)
- Seatech light backscatter sensor
- Datasonics altimeter
- Sea-Bird 24 way system rosette
- 24 x 10 litre Niskin bottles
- RDI 300kHz self contained ADCP
- RDI 600kHz self contained ADCP

A total of 70 lowered CTD casts were performed during the cruise, including 23 full depth profiles and 3 test deployments. Bottles misfired on four occasions; this problem was rectified by cleaning the rosette with freshwater. Two bottles leaked from the lower cap, these bottles were replaced in entirety. One bottle suffered a broken bottom cap, and this was replaced.

System performance was very good overall. T and C sensor location tests continued with the secondary pair being permanently mounted on the stabilising vane, apart from one deep test when they were mounted on a 1.2m extension pole (see 2.2.5). The results look initially promising but a detailed report will follow after further data analysis.

.

The LSS was replaced, a cracked body was found on the original (27 July). Unlikely this can be repaired. A water leak on the sea-cable bulkhead fitting caused some damage to the fitting on the Sea-Bird. It was cleaned and functions satisfactorily but needs replacing. LADCP star cable communications on P1-P4 failed and the cable was replaced. The 300kHz LADCP unit 1903 was initially tested and proved satisfactory. Both the 300kHz and 600kHz LADCP appeared to perform well. The LADCP battery pack was replaced, suspect battery life over.

Fluorometer and transmissometer worked without problems. The altimeter worked well, usually obtaining a good bottom fix at around 70m from seabed.

Calibration certificates are supplied separately.

Jonathon Short, Terry Edwards

2.2 Lowered CTD: sampling, processing and calibrations

2.2.1 Introduction

Two main kinds of CTD stations were sampled on *Discovery* 264. "Full profile" CTDs were full depth, with bottles generally fired at standard depths from the bottom to the surface and from which the usual suite of samples was collected. When these coincided with a requirement to collect water for primary production incubation experiments, the shallowest 7 bottles were fired at 0.1%, 1%, 4.5%, 10%, 21%, 50% and 95% light levels. In addition, "live sampling" CTDs were shallow dips (< 100m) with the sole intention of collecting 240 litres of water from the base of the euphotic zone for process studies. At each fully-worked site, a full profile CTD and a live sampling CTD were taken. Data from both kinds of CTD stations were processed in the standard manner described below.

2.2.2 Sampling and processing

The live sampling CTDs did not have calibration samples and nutrients collected from them (the collection of water from the live sampling CTDs is covered elsewhere in this report). From full profile CTDs, samples were taken in the order: oxygen, nutrients, salinities, chlorophyll and stable isotope samples. The standard bottle firing depths for full profile CTDs were as follows (wire-out in metres):

> 5 (x 2), 10, 25, 50, 75, 100, 125, 150, 200, 300, 400, 600, 800, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, bottom.

The processing of the Sea-Bird CTD data followed the paths established during *Discovery* 258. For full details, see that cruise report (Pollard & Hay, 2002); a summary is given here as Appendix A2.

2.2.3 Calibrations

Salinity

The bottle salinity samples were taken with the express purpose of performing final calibration of the two conductivity sensors. The sensors were calibrated by Sea-Bird prior to the cruise and manufacturers specifications indicate that they should not drift within 0.001 in salinity over 6 months. The calibration is based on the assumption that the bottle samples measure the absolute salinity (to within 0.0001); see Section 5 on Salinometry. The procedure is to recalculate the bottle conductivity (using CTD temperature and pressure) and to compare that to the measured CTD conductivity. The bottle conductivity (botcond) and the differences (botc-ctd, botc-ct2) are calculated in makeresid. The secondary sensors were used as the source of master data during *Discovery* 264, these were mounted on the CTD frame fin to try to avoid the problems of water carried within the dead space of the frame. The relative success of this will be discussed later. The secondary sensor needed just a small offset in conductivity (-0.0032), showing no significant trend with pressure, conductivity or time (Fig 2).

$$cond2_{cal} = -0.0032 + cond2_{raw}$$

Salinity was recalculated using pressure and temperature (sensor 2). After calibration the salinity residuals for sensor 2 had a mean difference of 0.0000 (σ = 0.0010, n = 189). The primary sensor exhibited a conductivity offset of just –0.0010; examination of the salinity residuals showed a much greater scatter with a mean difference of –0.0002 (SD = 0.0028, n = 183). Here there was some indication of a trend with depth, however this was not considered to be above the 0.001 level and was exaggerated by near surface and a few bottom boundary layer values where conductivity gradients were highest.

Oxygen

In each deployment of the CTD rosette, oxygen was first measured with an oxygen sensor on the Sea-Bird CTD and second by analysis of samples taken from the bottles. The results from the oxygen titration of the samples were used to calibrate the Sea-Bird sensor. Before calibration the results from the oxygen titration, which measure oxygen in μmol/l, had to be converted into μmol/kg, the WOCE standard. The equation to convert units is the following:

$$O_2(\mu mol/Kg) = \frac{O_2(\mu mol/l)}{1 + 0.001\sigma_0}$$

where σ_0 is the density of the oxygen samples at the time at which the samples is fixed. It can be computed using Tfix, the temperature of the samples at the time of fixation, and the salinity of the sample (the pressure is set to 0 as the samples are fixed on deck, i.e. at sea level).

Calibrations were carried out on the up-cast sensor readings v. titration value. The oxygen sensor offset appeared to become greater with depth (Fig 3). The preferred calibration was

$$oxycal = 20.5 + Oxygen_{sensor} + 0.0038\ (Pressure).$$

After calibration the mean residual is 2.38 with a standard deviation of 3.79.

Chlorophyll

Samples were drawn from every full depth CTD profile from the top 6 rosette bottles for chlorophyll *a*, other pigment studies, and size fractionation. The Sea-Bird calibration was used to convert the fluorometer reading in volts to nominal 'fluor' in mgm^{-3}. The chlorophyll *a* samples were used to further calibrate the Sea-Bird fluorometer (Fig 4). The differing physiology, environment, health and abundances within the region investigated throughout the cruise result in a very subjective and 'first cut' calibration as follows:

$$Chla = 1.4\ fluor$$

Caution is needed if the data are used quantitatively. The calibration uses only comparisons from below 50 m water depth to avoid the problem of quenching as far as possible. Due to an insufficient level of understanding of the effects of phytoplankton physiology on the fluorescence/Chl*a* relationship, the data were not further manipulated on board.

Applying the calibrations

Calibrations were applied to the ctd145nnn.1hz and sam14nnn files using the script ctdcal which requires 9 command line arguments, the 3 digit station number and 2 calibration coefficients each for cond sensor 1, cond sensor 2, fluor and oxygen. After ctdcal had been run, ctd2 was re-run to create calibrated ctd14nnn.ctu and ctd14nnn.2db files.

2.2.4 CTD sensor performance: relative sensor drift and pressure

Examination of the differences between the two conductivity-temperature sensors showed no discernible drift over the course of the cruise. Pressure hysteresis is expected to be small for the Sea-Bird sensor, and no evidence of it was found.

2.2.5 Frame design problems

As reported from *Discovery* 258, the CTD data quality was affected by the frame design. The quantity of instruments on the frame and the abundance of wide horizontal brackets appeared to have led to the frame dragging a body of water with it through the water column. Thus the data recorded did not truly represent the original structure of the water column. In bad weather when the ship was rolling this was most obvious as peaks (over more than 1 sec) in temperature and salinity which occurred when the ascent or descent rate was momentarily reduced (of order 0.1°C, 0.01 psu). The peaks were to higher salinity if the gradient was high to low (in the direction the CTD was moving, up or down), and *vice versa*. Details of this problem were given in the *Discovery* 258 cruise report.

For most of the cruise, the secondary sensors were mounted on the stabilising fin on the CTD frame. This followed the investigations on *Discovery* 262 which indicated that it may be possible to avoid sampling water disturbed by the CTD package by getting the sensors as far from the bulk of the frame as possible. For most stations, the secondary sensors provided a less disturbed temperature and conductivity profile when mounted this way (Fig 5, upper). However, there were a number of stations where the problem appeared to be exaggerated on the secondary sensors (Fig 5, lower). This indicated that there may be a 'radius of influence' for the disturbance of the CTD package.

John Allen, Clare Johnson

2.3 ARIES CTD sampling, processing and calibrations

2.3.1 Introduction

The ARIES platform includes a Sea-Bird 911 CTD and a rosette of 59 bottles of 300ml volume. After each cast the CTD data and ARIES firing files were ftp'd to Unix directories and processed in Pstar format. The processing path followed the procedure used on the preceding *Discovery* 262 MarProd cruise (Richards, 2003).

2.3.2 Sampling protocol

The water bottles were fired at the same time as the nets, with some proportion (generally more than half) fired on the downcast, and the rest on the upcast. The water was sampled by means of a tube that opened the bottle valve when clicked onto each tap. Care was taken to rinse the tube, but the small volume water bottles meant that this allowed only for very small samples of water to be taken. Generally the surface 2 bottles were sampled for chlorophyll, every other downcast bottle for nutrients (100m intervals) and 4 - 6 upcast bottles for salinity. See *Discovery* 258 cruise report for more discussion of the limitations of sampling in this way.

2.3.3 Processing

Broadly speaking the Pstar processing path followed that of the lowered CTDs (where 14nnn is the *Discovery* station number; see note in Appendix A2):

asam0	Creates the ari14nnn file and fir14nnn file. List ari14nnn to find latitude and longitude at maximum pressure
ctd0	Creates the ctd14nnn.1hz file
actd1	Edits the original file and calculates some derived variable. Output ctd14nnn.1hz
actd2	Creates ctd14nnn.ctu and ctd14nnn.2db
actdplots	Creates standard profile and temperature-salinity plots
asam1	Creates the sample file sam14nnn including the CTD data from firing time. Excludes bottles fired on deck for shallow casts
apassam	Pastes sample data into the sam14nnn file
amakeresid	Creates residual file (res14nnn).

2.3.4 Calibrations

Salinity

The same procedure for calibrating the conductivity and salinity from the ARIES CTD was tried as for the lowered CTD. The calibration was expected to be less good than the lowered CTD for two reasons: i) error in the sampling, due to the small bottles and problems with rinsing the bottle and tube; and ii) because data were recorded as 1 second data without any removal of spikes from the raw 24Hz data. Inspection of the uncalibrated conductivity showed a small offset was required, with no significant relationship with pressure, conductivity or time. However this offset did not agree with that suggested by comparing deep σ/s profiles between ARIES and the lowered CTD. Indeed the bottle salinity samples drawn from ARIES appeared to be systematically biased high. This could be consistent with insufficient water to flush both the sampling tube and sample bottle, however further investigation would have to be carried out after the cruise. From matching σ/s profiles (Fig 6) the following calibration was determined for ARIES:

$$salcal_{aries} = 0.002 + salin_{aries}$$

Fluorescence

Likewise, the small numbers of chlorophyll samples from the surface layer were not used to calibrate the ARIES fluorescence. Bearing in mind our lack of confidence in the lowered CTD chlorophyll calibration, no attempt to cross calibrate between fluorometers was made during the cruise.

Applying the calibration

As for the lowered CTD, the script actdcal was used to calibrate the ctd14nnn.1hz files and the sam14nnn files. Uncalibrated back-up files were saved as ctd14nnn.ucal and sam14nnn.ucal. Following actdcal the script actd2 was re-run to create calibrated ctd14nnn.ctu, ctd14nnn.2db.

John Allen, Clare Johnson

2.4 Lowered Acoustic Doppler Current Profilers (LADCPs)

2.4.1 Overview

Two LACDPs were fitted to the CTD rosette frame on *Discovery* 264, RDI 300 kHz and RDI 600 kHz workhorse ADCPs. The 600 kHz had been used on the two previous MarProd cruises, *Discovery* 258 and 262, and was principally intended for mean volume backscatter (MVBS) studies, to establish whether MVBS at a suitable frequency can be calibrated and used as a proxy for *Calanus* and similar sized zooplankton. The 300 kHz was in use for the first time on a MarProd cruise, but had been trialed previously by Brian King on a JCR cruise.

The LADCPs were used on all full depth CTD casts. They were not switched on for the shallow "chlorophyll max" casts, whose primary purpose was to collect water for on-board experiments. The raw data files were ftp-transferred from the dedicated LADCP PC in the deck lab to the shipboard system and processed using the Visbeck 2002 software. Most attention was paid to establishing good bottom tracking, as all casts went to within 10m or less of the bottom. It was found that both instruments gave similar readings for near-bottom velocities, where the velocity (current) profiles are well constrained by the absolute reference of the velocity of the package relative to ground. Thus the 600 kHz can be used to give reasonable velocity profiles near bottom (within 60-80 m).

Once constrained by the bottom-tracking, the Visbeck inverse velocity profiles were clearly better than those derived from the shear method, or downcast only. When compared with the two vessel-mounted (VM) ADCPs (which intercompared within 1-2 cm/s), the Visbeck solutions were usually a reasonably match to the VM profiles, with 49 out of 66 differences being less than 3 cm/s, and the worst offset being 9 cm/s. We favour the Visbeck technique for future use, but conclude that the inverse calculation should be constrained by matching to the VM profiles near surface.

Backscatter was logged from both LADCPs for all profiles using the software developed by Nick Crisp and Sophie Fielding on *Discovery* 262. Profiles plotted for 4 bins differed sufficiently that it was clear that range corrections were needed. It is suspected that the RDI software has already made some allowance for the attenuation coefficient α, because application of the correct α for the frequency did not collapse the profiles on top of each other. Because information from RDI is awaited, the profiles were not analysed further at sea. It was also noted that there were spikes to high MVBS at quasi-regular intervals. The cause of these has not been sought.

2.4.2 Directory structure

A complex directory structure had evolved, starting with the structure used for the Firing processing, but complicated by trial use of the new Visbeck processing method, the use of more than one LADCP simultaneously, and by retaining data and processing on board from previous MarProd

cruises (*Discovery* 258 and 262). On *Discovery* 264, we used only the Visbeck route, because it: i) incorporates the Firing technique as the "shear method"; ii) allows easy access to echo amplitude information, needed to calculate backscatter; and iii) has the ability to use enhanced echo amplitudes to determine bottom echos, and hence determine absolute bottom velocities. The Firing structure consists of the following directories:

Top level:	ladcp
Second level:	150khz 300khz 600khz
Third level, for each frequency:	logs pro raw

Below this level, each previous cruise apparently developed a different structure, with unnecessary subdirectories. Although the Firing directory structure was not deleted, it was rationalized as follows:

- CTD and navigation data required to span a deployment (CTD cast) are common to any LADCPs used. Therefore they are stored at the second level, in directories ctd and nav.
- Using Matlab, it is convenient to have all the m scripts in a single directory. Therefore the m directory was also placed at the second level, and results were initially written into the m directory. Other execs (e.g. to create ctd and nav files) were also placed in the m directory.
- Each cast generates figures, text and Matlab data files from each of the two LADCPs. These were printed or plotted at the end of processing, after being transferred into a third level cast directory ladcp/pro/res. The exception was the master output .mat files which were moved to the second level directory ladcp/pro. Thus the processed outputs are no longer split by frequency (ladcp/300khz/pro), but are identified by a different letter for each frequency, namely 'd' for 150 kHz, 'w' for 300 kHz and 'b' for 600 kHz.
- One further directory ladcp/ppro has been added at the second level. This Pstar PROcessed directory contains any Pstar files created from the pro data for comparison with other data, such as VM ADCP. Execs to create these files are also in ladcp/ppro.

Thus the new directory structure is

Top level:	ladcp							
Second level:	m	ctd	nav	pro	ppro	150khz	300khz	600khz
Third level:				res		raw	raw	raw

2.4.3 Software modifications and processing path

Some modifications were made to adapt the Visbeck software for optimal SOC use and to correct errors. Standard formats were created for CTD and navigation files to handle all dates. Magnetic deviation constants were updated from IGRF95 to IGRF00 (2000). Figures created in the Visbeck software were tidied and saved so that they can be re-examined later. Bottom tracking was made more robust and the option provided to specify the depth using the altimeter reading at the CTD maximum depth. These software modifications are described in more detail in Appendix A3, together with information on the processing path.

2.4.4 Bottom determination

A particular improvement introduced by Visbeck is to use the enhanced amplitude of acoustic returns from the bottom to identify those bottom returns and hence calculate the distance of the package from the bottom and the velocity of the package relative to the bottom. This allows water velocities near bottom to be calculated absolutely. RDI software has been modified to do this without setting the ADCP into bottom track mode. At the start of the cruise, the option (set in ladmaster.m) was to use the RDI calculation of bottom data. This was found to be unreliable, not finding the bottom or

getting the depth wrong. Better results were obtained by using only the post-processing Visbeck option.

The post-processing option calculates the bottom depth from every ping which has enhanced amplitude. Obviously, this only occurs for one bin at a time, and within that bin the depth cannot be resolved to better than the bin width (8 or 10 m). Therefore a curve is fitted through all the bottom depths calculated, and the depth extracted from that curve at the time the package reaches its maximum depth. However, the bottom can be calculated even more accurately using the altimeter that is mounted as standard on the frame at SOC to ensure that the package can be lowered close to the bottom without risk of grounding it. This option was not in the Visbeck software, so has been added, simply by adding the minimum altimeter reading in the ladmaster.m file for the station, then over-riding the bottom determined Visbeck with (CTD maximum depth + altimeter), immediately after the bottom depth is calculated in getdpth.m.

While the post-processing route often found bottom within a few metres of the altimeter-calculated value, it was not always reliable, and on occasion the fitted curve was found to slope strongly with time. This was eventually traced to zero values in the d.hbot array, the distance from the package to the bottom determined by the post-processing route. Determining the cause of the errors defeated me, as determination of d.hbot is buried deep in the loadrdi routine. However, a simple fix was to test for d.hbot ~= 0 in the code that extracts good bottom returns. Thereafter, the post-processed bottom depth usually agreed with the altimeter determined bottom depth within a couple of metres.

2.4.5 Results

Bottom velocities

Table 1 Bottom velocities extracted from both the 300 (w) and 600 (b) kHz profiles.

Station no.	Depth m	uw cm/s	ub cm/sec	uw - ub cm/sec	vw cm/s	vb cm/sec	vw - vb cm/s
14697	2780	7.2	-999.0	-999.0	-1.9	-999.0	-999.0
14703	1860	-2.8	-999.0	-999.0	2.7	-999.0	-999.0
14712	1600	-2.3	-3.5	1.2	-5.5	-8.6	3.1
14717	620	-2.0	0.2	-2.2	-3.6	-1.6	-2.0
14726	1320	-9.4	-8.1	-1.3	0.4	1.3	-0.9
14729	1680	10.4	2.2	8.1	13.2	8.4	4.9
14735	1840	-5.1	-4.1	-1.0	-10.0	-8.2	-1.7
14744	2040	-1.7	0.4	-2.1	6.3	4.9	1.4
14763	720	-3.3	-2.9	-0.4	14.1	9.6	4.4
14772	1580	11.3	9.6	1.7	9.7	11.4	-1.7
14777	1860	4.2	3.3	0.9	2.9	4.4	-1.5
14788	2280	-4.9	-3.9	-1.0	0.4	2.1	-1.7
14794	2700	-1.0	1.5	-2.5	-8.7	-7.1	-1.6
14804	2960	2.4	-1.7	4.1	-2.5	-4.1	1.6
14810	2980	-18.3	-16.0	-2.3	-9.8	-5.8	-3.9
14819	2900	-3.5	-999.0	-999.0	2.4	-999.0	-999.0
14825	2860	0.3	-999.0	-999.0	-2.5	-999.0	-999.0
14834	2800	-7.3	-5.6	-1.7	-2.9	-1.8	-1.1
14849	2480	-13.7	-14.3	0.6	1.9	0.2	1.7
14856	2300	6.8	-999.0	-999.0	-21.2	-999.0	-999.0
14861	1980	-35.9	-30.4	-5.5	-21.5	-24.0	2.4
14879	2640	-4.3	-2.5	-1.8	-8.0	-3.0	-4.9
14881	2200	-31.4	-27.2	-4.2	-8.4	-3.2	-5.2
14894	1440	-23.5	-22.1	-1.4	-12.7	-5.9	-6.8
14896	1340	-6.0	-1.0	-5.0	36.8	30.8	6.0
14899	1280	-10.7	-7.8	-2.9	-14.4	-10.0	-4.4
14902	900	1.4	3.9	-2.5	-4.0	-2.5	-1.5

14912	340	-3.6	-1.7	-1.9	-8.7	-7.8	-0.9
14917	440	1.0	2.5	-1.6	2.0	3.7	-1.8
14927	320	-4.9	-3.8	-1.1	3.4	11.0	-7.6
14933	240	0.7	2.0	-1.3	4.5	7.0	-2.5
14944	1420	-42.2	-36.5	-5.6	-30.9	-22.3	-8.6
14964	2020	-3.1	-2.6	-0.5	-15.3	-10.8	-4.5
14976	1980	-12.8	-12.6	-0.3	-17.6	-11.6	-6.o
14983	1820	0.1	1.6	-1.5	-12.2	-6.8	-5.4
14988	360	-16.5	-15.6	-0.9	-28.9	-22.3	-6.6
14997	440	-15.7	-15.7	0.0	-24.5	-24.5	0.0
15012	2920	-13.1	-10.9	-2.2	10.5	7.3	3.2
15037	2540	10.3	4.8	5.5	3.1	6.7	-3.6

mean uw - ub = -1.0± 2.8 cm/s mean vw - vb = -1.7 ± 3.7

These values are encouragingly close, showing that the 600 kHz LADCP can obtain reasonable velocities (within a few cm/s) when constrained by bottom tracking. One exception has slipped into the table. On station 14997, the 600kHz was replaced by the backup 300 kHz LADCP, which was the one that had not worked on *Discovery* 262 and had since been repaired. Note that i) the two 300 kHz LADCPs give identical answers for bottom track velocities; and ii) there are large near-bottom velocities on some stations. The latter are plotted in Fig. 7. Most of the large bottom velocities are associated with either the east Greenland current (shelf and shelf edge) or the Denmark Strait Overflow Water (deep values just east of Greenland shelf).

Full depth profiles

Visbeck software outputs three different east and north velocity profiles, for (a) the full inverse, (b) down cast only, (c) shear method. From Visbeck's recent paper (Deep velocity profiling using lowered acoustic Doppler current profiler: bottom track and inverse solutions, submitted to *J Atmos & Oceanic Technol*), we infer that the shear method profile is equivalent to the Firing profile.

From plots of all three sets of profiles for both east and north, and for both 300 and 600 kHz LADCPs, we conclude:

- Bottom tracking provides a major constraint on the inverse profile. With it, both 300 kHz and 600 kHz profiles are probably within a few cm/s of correct values within 60-100 m of the bottom.
- The 600 kHz inverse solutions have large error bounds above the bottom boundary layer, and display implausibly large shears with large (hundreds of m) vertical wavelength. This results from their short range and limited number of shear profiles. Do not use the 600 kHz to obtain velocities except where constrained by bottom tracking.
- For the 300 kHz LADCP, the shear profiles display implausibly large shears, and neither the profiles derived from the down cast only nor from the shear method are at all close to the near-bottom velocities.

Profiles from both LADCPs (300 and 600 kHz) and from both ship-mounted ADCPs (150 kHz and 75 kHz) were merged (see compvels under processing path in Appendix A3). The 20 m binned data were further averaged between 60 m (to avoid errors in top few bins) and 380 m (maximum range of 150 kHz VM ADCP), then differenced. As on the previous cruise, the two vessel-mounted ADCPs were very close, within 2 cm/s and with similar structure in their profiles. Statistics are:

u (75-150kHz): -0.10 ± 0.57 (SD) range -1.87 to 0.81 cm/s
v (75-150kHz): -0.14 ± 0.68 (SD) range -1.62 to 1.08 cm/s

Accepting the surveyor data therefore as accurate within 1-2 cm/s, Table 2 (below) compares the Visbeck east and north velocities, averaged over the same depth range (60-380 m) with the Surveyor velocities. Statistics of the differences are:

u(sur-vis):	- 0.36 ± 2.74 (SD)	range -8.0 to 5.2 cm/s
v(sur-vis):	- 0.93 ± 3.04 (SD)	range -8.6 to 6.4 cm/s

While we have not shown how the difference varies with depth over the 60-380 m range, we noted by eye that it was usually reasonably constant. More careful comparisons to depths > 380 m are still to be done. Nevertheless, we may conclude that the Visbeck inverse profiles are beginning to come reasonably close to the true velocity profiles, the offsets being < 4 cm/s in 55 out of 66 comparisons, and < 3 cm/s in 49 out of 66 comparisons. Probably what ought to be done is to include the VM ADCP profiles as constraints in the inverse calculation.

Table 2. Comparison of Visbeck and Surveyor water column velocities for depth range 60-380m.

Station no.	uvisw cm/s	absvesur cm/s	usur - vis cm/s	vvisw cm/s	absvnsur cm/s	vsur - vis cm/s
14697	2.43	4.34	1.91	15.55	14.84	-0.71
14703	-7.02	-5.83	1.18	3.38	3.46	0.08
14712	-10.03	-9.26	0.76	-7.35	-7.64	-0.29
14717	0.99	0.93	-0.07	2.80	1.44	-1.36
14726	-20.30	-20.69	-0.39	-5.33	-8.30	-2.97
14729	12.90	18.09	5.19	6.62	8.16	1.55
14735	7.20	6.59	-0.61	6.47	4.30	-2.18
14744	5.50	1.38	-4.12	-2.46	-2.57	-0.10
14763	-6.92	-5.86	1.05	-1.92	-0.26	1.66
14772	11.50	14.29	2.79	3.12	3.55	0.43
14777	17.49	19.53	2.04	13.03	11.32	-1.71
14788	-12.26	-8.96	3.30	-8.34	-11.47	-3.13
14794	-27.57	-26.49	1.08	7.33	12.18	4.85
14804	8.15	11.14	2.99	14.04	16.41	2.37
14810	-9.89	-10.69	-0.79	-9.40	-18.01	-8.61
14819	-7.28	-5.62	1.66	26.34	27.65	1.30
14825	-10.78	-12.14	-1.36	-0.58	-1.32	-0.75
14834	-0.98	-3.66	-2.68	0.49	1.50	1.01
14861	-7.58	-9.26	-1.68	4.43	2.95	-1.48
14879	0.45	-3.59	-4.04	-5.18	-8.60	-3.42
14881	-21.76	-25.50	-3.73	9.87	5.13	-4.74
14894	-9.92	-12.09	-2.17	3.61	-2.45	-6.07
14896	6.34	-1.61	-7.96	6.64	13.06	6.42
14899	-6,92	-6.85	0.07	-12.91	-11.56	1.35
14902	-4.05	-3.84	0.21	-22.08	-20.80	1.28
14912	-2.70	-4.01	-1.31	-10.48	-9.92	0.55
14917	6.23	3.60	-2.62	2.05	-0.24	-2.29
14927	-3.47	-5.84	-2.37	2.95	-2.90	-5.85
14933	0.37	-0.40	-0.77	1.19	-0.98	-2.17
14944	-70.45	-66.20	4.24	-22.62	-21.69	0.94
14976	-10.56	-12.36	-1.81	-7.21	-9.04	-1.84
14983	-9.12	-7.90	1.21	-23.60	-27.59	-4.00
14988	-17.36	-20.55	-3.18	-18.38	-19.20	-0.82

Raymond Pollard

3. Lowered EK500 scientific echosounder (LEK)

The lowered EK500 scientific echosounder package (LEK) comprises a drop frame housing the 'behemoth' (an EK500 echosounder with a logging/control notebook PC), a battery pack, three transducers operating at 38kHz, 120 kHz and 200 kHz, and a Scanmar transmitter. It is deployed on station to collect good resolution higher frequency echosounder data from depths > 500m. At the start of the cruise, before any data were collected, an attempt was made to calibrate the equipment to enable the

correct integrator and target strength gain values to be applied during post-processing. Unfortunately, the behemoth's pressure housing was inadequately sealed and water leaked in. The calibration was then abandoned and efforts were made to repair the echosounder throughout the cruise (see below).

3.1 Deployment diary and data collected

Initial examination of the behemoth by Jim Hunter suggested that the major effects of the water in the housing had been to the power supply system. The power monitoring card was repaired, two power smoothing boards were removed and the main transformer was replaced with a series of diodes. Once this work had been completed, the system was tested at site DD11. After a successful near surface deployment (14778), a full deployment (14779) was attempted to collect data from 300 m and 400 m below the surface. The opportunity was also taken to mark the lifting wire at 100 m intervals between deployment depths of 100 m and 500 m, as assessed using the Scanmar system. On recovery, it was found that the EK500 had stopped transmitting data after 50 minutes. A third scheduled deployment, to collect data with the calibration sphere suspended beneath the transducers, was abandoned when Ethernet communication could not be re-established between the notebook PC and the EK500.

A series of further tests were then carried out using the SOC EK500 echosounder to provide spare boards and the TEK EK500 echosounder as a 'known good' control system. The major problems appeared to be related to the inability of the behemoth's EK500 to retain its internal settings when it was switched off. The loss of the correct Ethernet settings would then prevent communication being re-established when it was re-started. After replacing the behemoth central processor (CP) and Display/Ethernet boards with those from the SOC EK500, a further deployment was attempted at site C9 (14918). The calibration sphere was suspended below the transducers and data were successfully collected from all three frequencies for the 15 min deployment. However, when the LEK was recovered the sphere lines were found to have tangled and the returns from the 38 kHz transducer appeared unusually weak. The behemoth's EK500 38 kHz transceiver and digitiser cards were replaced with those from the SOC EK500, and its high voltage circuit output was increased from 150v to 165v to try and resolve this problem. A similar deployment to 100 m for 120 min took place at site C6 (14934), with the calibration sphere again used.

On examination of the data collected, it was noticed that there had been no definite improvement in the quality of the 38 kHz data and that both the 200 kHz and 120 kHz echograms were exhibiting unusual noise patterns. Comparison with the data from the previous MarProd cruises (*Discovery* 258 and 262) suggested this was not a new phenomenon, and both the 120 kHz and 200 kHz transceiver and digitiser cards in the behemoth EK500 were replaced with those from the SOC EK500. During the transfer of the boards, the behemoth's 200 kHz signal processing (SP) board failed. This was replaced with the 120 kHz SP board, which was in turn replaced with the SOC EK500's 200 kHz SP board. During the reassembly of the LEK system, the transducer cables were rung through. It was then discovered that the 38 kHz transducer only had one quadrant out of four functioning correctly (Quadrant 2). Prior to the cruise, it had already been discovered that the 120 kHz transducer had one failed quadrant (Quadrant 3). As this meant neither of the split-beam transducers was functioning correctly, no further attempts were made to collect scientific data from the 38 kHz or 120 kHz transducers. However, attempts were made to ascertain the cause of the unusual noise patterns seen in the 120 kHz and 200 kHz data, and the LEK was deployed at DD1 for this purpose (14977).

No noticeable improvement was detected in the data from either frequency, and a final deployment was conducted at D4 to collect data from the 200 kHz transducer for analysis (15021). These data were collected under the presumption they could be adequately calibrated using the data collected at DD1, where the calibration sphere was used with the same set of boards (Appendix A4).

Table 3. Sites where LEK data were collected, with station numbers and deployment depths

Site	Station no.	Deployment depth(s)	Notes
Calibration	---	Surface	Abandoned due to leak
DD11	14778	Surface	Test deployment for 10 min
DD11	14779	300 m, 400 m (plus wire marking 100 m to 500 m)	Data only logged for 50 min
C9	14918	100 m	Calibration sphere used
C6	14934	100 m	Calibration sphere used
DD1	14977	100 m	Calibration sphere used
D4	15021	400 m	Data collection

3.2 Deployment technique

The deployment technique developed on the previous MarProd cruise (*Discovery* 262) was followed for all deployments and again worked well. The extended CTD track way, with the second flat bed trolley located at the far end, was used to store the LEK between deployments. The trolley had been modified with the addition of corner brackets, which held the bottom of the LEK frame securely and prevented it sliding in rough weather. The LEK was deployed from the centre of the track way using a wire run from a 5 tonne Lebus winch, sited further aft on the starboard deck, through the main block on the CTD gantry. The angle of the wire was controlled using a scrolling device situated 1m forward of the winch and immediately aft of the metal deck plate covering the pipe work crossing the deck. The mains supply for the Behemoth and the chargers for the battery pack were sited in the water bottle annexe, behind the roller door, with the cables run under the door through a foam strip located on top of the sill. The aerial for the remote control PC was located above the main entrance off the starboard deck, and the Behemoth's operation was controlled remotely from the PC located in the main laboratory.

To simplify the deployments, the winch wire was marked at 100 m intervals from deployment depths of 100 m to 500 m, with an extra mark at 450 m, so that the Scanmar system was not needed for standard deployments. When the Scanmar system was used, the signal was received via the Scanmar towfish and the 'bird cage' hydrophone was not used. Again, it should be noted that at least four people are required to complete launch and recovery operations safely, as two people are required to assist the frame in and out, whilst another two people are required to drive the winch and gantry respectively. Beyond this, no problems were experienced and no further modifications to either the LEK or the deployment strategy appear necessary.

Cairistiona Anderson, Andrew Brierley, Ryan Saunders

4. Towed EK500 scientific echosounder (TEK)

The towed EK500 echosounder package (TEK) comprises a towed body containing three transducers, operating at 38 kHz, 120 kHz and 200 kHz, connected directly to an EK500 echosounder, which in turn is connected to a desktop logging PC. The system is deployed whenever the ship is underway, to collect broad-scale survey data in the top 1000 m of the water column, both in conjunction with the various towed nets and on transects between sites. The towed body is deployed on the starboard side of the ship, aft of the winch cabin, using a lifting wire, and is towed from a boom deployed forward of the CTD gantry. The boom must be stowed inboard during each CTD deployment, so the towed body is recovered before each CTD station and re-deployed afterwards. As with the LEK, before any data were collected, the equipment was calibrated to enable the correct integrator and target strength gain values to be applied during post-processing (see Appendix 4).

4.1 Deployment diary and data collected

Few problems were found in using the TEK towed body, and the deployment strategy developed during *Discovery* 262 generally worked well (see 4.2 below). The TEK was deployed when the ship was steaming between all sites, except around site W4 where the presence of ice prevented its use. In total, data were collected during 54 deployments (52 tows) as shown in Table 4.

Table 4. Station number of each TEK deployment, with sites between which data were collected.

Discovery **station no.**	**Start site**	**End site**	**Notes**
(Calibration)	(Brodick Bay)	---	CTDs occurred next day at same site
14681	Test	---	No data logged
14685	(I)	(I)	Retrieved for checks as first full deployment
14689	(I)	I	Follows 14689 almost immediately
14698	I	I3	
14704	I3	I1a	
14713	I1a	B1	
14718	B1	B2	
14728	B2	B3	
14731	B3	B4	
14736	B4	B5	
14746	B5	DAN	
14748	DAN	DD13	Break in data as Ethernet cables used for LEK tests
14764	DD13	DD12	
14773	DD12	DD11	
14780	DD11	DD10	
14790	DD10	DD9	
14795	DD9	DD8	Includes Dual Methot comparison
14806	DD8	DD7	
14811	DD7	DD6	
14821	DD6	DD5	
14826	DD5	DD4	
14835	DD4	DD3	
14841	DD3	DD2a	
14850	DD2a	DD2	'Rug' on front of TEK at end of tow
14851	DD2	DD2	
14857	DD2	C8	
14862	C8	W2	
14872	W2	---	Tow towards Reykjavik, Iceland
14875	N1	B8	
14880	B8	C10b	
14883	C10b	C10	
14895	C10	C9c	
14898	C9c	C9b	
14901	C9B	C9a	
14904	C9a	C9d	
14913	C9d	C9	
14919	C9	X	
14929	X	C6	
14935	C6	C6a	File names = Correct time – 20 mins. (Data times are correct)
14943	C6a	C9	
14951	C9	H10a	
14954	H10a	H10	
14965	H10	W3	
14967	W3	DD1	
14980	DD1	---	Tow aborted due to presence of ice
14982	---	D1a	Tow started once out of ice
14984	D1a	D1	
14989	D1	D2	
14998	D2	D2	
15007	D2	D3	
15013	D3	D4	
15022	D4	D5	
15035	D5	D6	
15038	D6	---	Break in data due to LEK board tests. End at eastern edge of Iceland Basin

No problems were found with the towing cable package or other gear and no major adjustments had to be made during the cruise. However, it was noticed that much of the interference seen in the data from the 120 kHz transducer could be removed by not placing the EK500's VGA monitor on top of the echosounder box, and by turning the monitor off when not in use.

4.2 Deployment technique

The basic deployment technique used on *Discovery* 262 was repeated for this cruise, with the extended Schatt davit used to lift and swing the towed body over the side, and the 2 tonne Lebus winch used to wind the lifting wire. As before, the winch was located 2 m inboard of the mooring bollards on the starboard side of the after deck. However, the davit was located 4m further aft, rather than 3 m as on *Discovery* 262, although it was still 1 m closer to the bulwark than the winch. The lifting wire (approximately 75 m long) was run from the winch, via two snatch blocks (one on deck 3 m aft of the inboard side of the winch and one attached by a chain to the foot of the davit), then through a trawl block at the end of the davit arm and down to the towed body.

This arrangement proved very robust, with both deployment and retrieval safely accomplished in all the weather conditions experienced. However, questions were raised about the arrangement of the blocks, and its affect on the weight experienced when turning the davit, particularly as the re-positioning of the FRS container limited the number of people who could turn the handle. It was recommended that for the next cruise, a third block was provided at the base of the arm, and that both that and the block at the foot of the davit were secured to pad eyes rather than via chains. It would also probably help if the davit was returned to its original position 3 m aft of the winch. The only other cause for concern was that the towed body might damage the hydraulics on the outboard side of the winch, but this was again overcome by lashing a board in place to protect them.

Between deployments, the towed body was still secured to the mooring bollards, which would have presented the same problems as on *Discovery* 258 if similar weather conditions had been experienced. However, no simple solution appears possible, and due to the light weather conditions experienced during the cruise, no damage was sustained to the towed body.

Cairistiona Anderson, Andrew Brierley, Ryan Saunders

5. Salinometry

A Guildline Autosal salinometer (model 8400A, serial no. 56.747) was installed in the chemlab (chemistry laboratory). The chemlab, rather than the constant temperature laboratory, was used because the latter was required for biological incubation experiments at temperatures below the operating range of the salinometer. Not having access to controlled environmental conditions is a problem for salinometry. According to the manual, the 8400A can operate successfully at temperatures between 4°C above and 2°C below the bath temperature (set at 24°C or 21°C for most of this cruise), the preferred temperature being in the middle of this range.

A thermometer was used to measure the temperature of the chemlab, which varied between 18- 24°C throughout the cruise. Efforts to maintain the chemlab at an appropriate temperature were hampered by temperature fluctuations associated with variations in the state of air conditioning or the number of doors to the outside which were open. Please refer to the *Discovery* 258 cruise report for possible temperature-associated problems.

Good quality salinity measurements were obtained. The average double conductivity ratio of the standard seawater jumped when the water bath temperature was changed from 24°C to 21°C (Fig. 8), but no jump appeared in the calibration residuals to the CTD. The measurements of standard

seawater (SSW) before and after each crate of samples showed drifts of less than 0.00006 in conductivity (0.0001 in salinity) over the two hours or so taken to process each crate.

Salinity values were obtained from the double conductivity ration measurements in the usual way, using an Excel spreadsheet, then transferred to the Unix system in the form of a tab-delimited ASCII file containing the four columns statnum, sampnum, botsal and botsalf – following the simplified method of the first MarProd cruise, *Discovery* 258. Data from the ASCII files were incorporated into the sam files using the Pstar script passam.

John Allen, Clare Johnson

6. Phytoplankton studies: primary production, pigments and biomass

Phytoplankton studies on *Discovery* 264 were directed at determining the plant food resources available to *Calanus* and other zooplankton herbivores. In addition to the pigment analyses (with associated biomass estimates, as previously carried on *Discovery* 258 and 262) and the FRRF measurements (underway and profiles; see Section 9.2), ^{14}C incubations were carried out for the first time on a MarProd cruise, to determine production rates for total phytoplankton and the <10µm fraction. These studies, together with other data, should provide insights into the biogeochemical and physical controls on primary production and phytoplankton size-structure in the Irminger Basin and on the Greenland shelf, with implications for the structure and functioning of the ecosystem as a whole.

6.1 Size-fractionated productivity measurements

Rate measurements were based on simulated *in situ* (on-deck) ^{14}C radioisotope tracer incubation experiments for each of 7 light depths sampled by the CTD (97%, 50%, 21%, 10%, 4.5%, 1 % and 0.1% of surface PAR, as determined from prior deployment of the Chelsea Instruments FRRF). The on-deck incubation tubes, which were cooled with running surface seawater, were screened with neutral density filters to mimic the underwater light field (as measured and calculated from the 2π light sensor deployed with the FRRF, and the ship-based 2π PAR sensor).

The protocol used was as follows. For each depth, 2 sets of 3 x 80ml polycarbonate "light bottles" and 1 x "dark bottle" were filled with seawater and inoculated with 10µCi/100µl buffered $NaH^{14}CO_3$ working stock. The "spiked" bottles were placed in the on-deck incubators for 24 hours. For total community production, one set of bottles were filtered onto 25mm (0.2µm) polycarbonate Nuclepore filters to retain the phytoplankton. For the <10µm fraction, the second set of bottles were post-fractionated through a 10µm plankton screen prior to filtering onto 0.2µm Nuclepore filters as before. All filters were then fumed over 10% HCl for 20mins to remove unfixed inorganic ^{14}C prior to being placed in 7ml plastic pony vials to which 5mls Packard "Hisafe 3" scintillation cocktail had been added.

The precise activity of the ^{14}C spikes was determined from standards. Exactly 100µl of the working stock was added to 10ml Carbasorb and from this, 5 replicates of 100µl were placed in 7 ml pony vials to which 5mls Packard "Supermix" scintillation cocktail was added.

It was hoped to count (DPM) the samples on-board ship, using a Wallac 1414 WinSpectral DSA-based liquid scintillation counter, loaned from QUB. Unfortunately this instrument malfunctioned during the first run of counts and remained out of action for the duration of the cruise. Counts and subsequent calculation of productivity rates will therefore be carried out post-cruise at SOC.

Table 5. Sites and CTD stations (n = 20) where size-fractionated production studies were carried out

Site	CTD station	Date	Site	CTD station	Date
I3	14703	30/07/02	B8	14879	13/08/02
B1	14717	31/07/02	C10	14894	14/08/02
B4	14735	1/08/02	C9	14917	15/08/02
DD13	14763	3/08/02	C6	14933	16/08/02
DD11	14777	4/08/02	H10	14964	18/08/02
DD9	14794	5/08/02	DD1	14976	19/08/02
DD7	14810	6/08/02	D1	14988	20/08/02
DD5	14825	7/08/02	D2	15006	21/08/02
DD3	14840	8/02/02	D4	15019	22/08/02
C8	14861	10/08/02	D6	15037	23/08/02

Mike Lucas

6.2 Pigment studies

Chlorophyll, HPLC and phytoplankton sampling focused on the top 150 m of the water column. When the CTD was fired on percentage light depths, nine samples were taken for analysis (100%, 50%, 21%, 10%, 4.5%, 1% and 0.1% light depths, and also 100 m and 150 m). If extra bottles were fired at 5 m or the chlorophyll maximum, these samples were also taken. When the CTD was fired at standard depths, seven samples were taken (usually fired at 5, 10, 25, 50, 75, 100 and 150 m). The CTD was sampled at 38 stations. Samples were collected in 5 litre carboys, which were rinsed in the sample prior to being filled.

For HPLC analysis, water samples (1 litre from the bottom three depths sampled, 500 ml from every other depth) and duplicates were filtered through 25 mm Whatman GF/F filters using a specially developed positive pressure filtration unit. The filter papers were then immediately stored in cryovials and stored in a –70ºC freezer for subsequent HPLC analysis at SOC.

For total chlorophyll analysis, a 200 ml aliquot was filtered through 25 mm Whatmann GF/F filters at low pressure. The filter was then placed in an amber glass vial containing 10 mls of 90% acetone and immediately stored in the dark at 5ºC for 24 hrs in order to extract the chlorophyll. In total 38 full-depth CTD, 26 chlorophyll maximum CTD, 17 ARIES and 19 Ocean Sampler stations were analysed during the cruise.

Chlorophyll size fractionation of the CTD samples was also carried out with three depths (usually 5 m or 50% light, chlorophyll maximum, and 0.1% light) being analysed. This was performed at 27 CTD stations. Water was filtered through 20, 5 and 0.2 μm polycarbonate filters at low pressure and the same procedure as for total chlorophyll followed. Between passing through the 20 and 5 μm filters, the filtrate was passed through a 10 μm mesh. A 10 μm chlorophyll size fraction was calculated by difference, subtracting the 20, 5 and 0.2 μm size fractions from the total chlorophyll value. This led to a negative value for the 10 μm size fraction on a few occasions. The reason for this was suspected to be the size difference between the 0.2 μm filter and the GF/F filter used for the total chlorophyll measurement (GF/F filters have 0.7 μm pores). To provide a correction value to compensate for this difference, a number of total chlorophylls were measured on both GF/F filters and 0.2 μm (Table 6). Most of the chlorophyll values for the 0.2 μm were lower than those for GF/F filters, despite the fact that 0.2 μm filters were measuring a larger chlorophyll fraction. This was possibly due to cells being ripped through the thinner 0.2 μm filter despite only a low vacuum pressure being applied. On the next cruise, it may be advisable to use GF/F filters for the smallest size fraction instead of 0.2 μm filters, thus alleviating this problem.

Table 6. Differences in chlorophyll *a* measured on GF/F and 0.2 μm polycarbonate filters.

Station No.	Depth (m)	Chlorophyll a (μg/l) GF/F	0.2 μm
14879	6	1.23	1.19
	19	1.10	0.98
	56	0.23	0.21
14927	5	2.01	1.86
	17	3.43	2.84
	50	0.17	0.14
14976	6	1.40	1.36
	25	1.37	1.23
	56	0.19	0.19
14988	7	1.01	1.03
	30	0.91	0.80
	66	0.15	0.15

Underway samples were usually taken and analysed every 4 hours to calibrate both the FRRF and underway fluorometer. In total 146 underway samples were analysed for total chlorophyll.

Early on in the cruise, the bottle annex seceded from the evil Discovery Republic. Currency remained the same, but visitors were asked to perform a display of air guitar as a substitute for passport control. All filtering was carried out to a soundtrack of the Smiths, Stone Roses and Happy Mondays on 'Madchester' days. On non-Madchester days the sound of reggae, dub, ska and various other beats could be heard, usually provided by DJ Dan 'Top Cheesy House' Mayor. When the mood got too ebullient, we were invariably brought back down to earth by Smog. The bottle annex rocked. Chairman Dan and myself (the proletariat) would like to thank all those who came to support the fledgling independent nation in its struggle to break the shackles of imperialistic control.

Filtering is a hard job carried out by upright, dedicated citizens. By contrast counting copepod eggs is the haunt of degenerates and wimps. The winner of the bottle annex dancing competition was Jo Sidey with her Uma Thurman (or was it John Travolta?) dance. Dan Mayor and Andy Hirst both received commendations. Some of the moves performed by John Allen are considered illegal in some countries

Dave Wilson

6.3 Chlorophyll analysis and biomass

Samples were warmed to room temperature before the fluorescence was measured using a Turner Designs Fluorometer (TD700). Chlorophyll standard solutions (Sigma) covering the expected chlorophyll range were used for calibration of the fluorometer prior to each set of samples being analysed. Their chlorophyll concentrations were calculated from the absorbance measured at 750, 664, 647 and 630 nm in a Cecil Spectrophotometer, using the equations of Jeffrey and Humphrey 1975 (*Biochem. Physiol. Pflanzen*, 167:191-4).

Preliminary results for chlorophyll biomass indicated that, almost without exception, this was confined to the upper 40-60m, constrained by the 1% light depth. Biomass was typically of the order 0.25-0.5mg m^{-3} within the deep basins and dominated (>80%) by cells <10 μm in size at a chlorophyll maximum depth corresponding to the 10% or 5% light depths. However, over the eastern Greenland Shelf, biomass rose typically to approx. 1.2-1.5 mg m^{-3} and at one station (14917), to nearly 5 mg m^{-3}. Here cells were dominated (>50%) by the size-fraction >10 μm. Almost everywhere, it would appear that phytoplankton were Si rather than NO_3 limited which would account for the dominance of small sized phytoflagellate cells.

Mike Lucas, Louise Brown, Dave Wilson

6.4 Other phytoplankton studies

Phytoplankton samples for microscope speciation studies at SOC were taken at three depths (50% light, chlorophyll maximum and 0.1% light). Two amber glass bottles were filled for each depth and preserving agents (Lugol's iodine and buffered formalin) added to each. In addition phytoplankton samples down to 150 m were also taken from the Ocean Sampler.

Picoplankton samples were taken from the same bottles as those sampled for HPLC and preserved with filtered formaldehyde. These were then placed in the fridge to fix for 24 hr before being transferred to the –70 ºC freezer for subsequent analysis by Flow Cytometry.

Samples from the CTD and also all bottles from the Ocean Sampler were collected and preserved in 10% Lugol's iodine for micro-zooplankton analysis by Dave Wilson at the University of Liverpool.

The help of Claire Johnson, Katy Shannon, Kathryn Cook and Mike Lucas for various filtering activities was greatly appreciated. Also thanks to Louise Brown and Dan Mayor for reading chlorophylls whilst under the influence of acetone.

Dave Wilson

7. Nutrients and oxygen

7.1 Nutrients

7.1.1 Methods

Concentrations of the dissolved inorganic nutrients nitrate and nitrite (henceforth referred to as nitrate), orthophosphate, and silicate were measured on unfiltered water samples on a Skalar SanPlus segmented flow autoanalyser. The analytical methods were based on those of Kirkwood (1983), but incorporated some modifications to the phosphate flow rates introduced on the first MarProd cruise, *Discovery* 258, to improve peak shape. Phosphate reagent flow rates were 0.16 ml/min and sample flow rate was 1.4 ml/min. In the first set of reagents made up, the concentration of ammonium chloride buffer in the nitrate line was doubled from 3 g/l to 6 g/l to try to improve performance; however, this appeared to have no effect and the standard method was retained thereafter. Sample and wash times were maintained at 90 and 60 seconds respectively from the beginning of the cruise until 5 August, when wash time was increased to 75 seconds to counteract possible sample carryover effect on the nitrate line. Throughout each sample run, wash and drift standards were run every 10-15 standards to enable baseline and drift corrections to be made to the data.

Samples for shipboard inorganic nutrient analysis were collected from Niskin bottles on all full-depth casts from CTD and ARIES sample collection systems. Samples from CTD casts were collected from every depth sampled. On ARIES casts, samples were typically taken from every second depth on the downcast and either every second or every fourth bottle on the upcast, to determine if bottle leakage affected nutrient concentrations. Additional underway samples were taken every 4 hr from the ship's non-toxic seawater supply. A total of 1220 CTD/ARIES samples and 146 underway samples were analysed. All samples were collected in brand new 40 ml diluvials and immediately refrigerated at 4ºC until analysis. Analysis of CTD and ARIES samples took place usually within 12 hr and always within 24 hr from the time of sampling. Samples for total nitrate analysis were also collected at sites which repeated those sampled on *Discovery* 262 (i.e transect DD, C6-C9, B1-B4). Water was drawn directly from all CTD bottles above 1000 m depth into 60 ml sterile screw top containers and immediately frozen, for analysis on return to shore.

Nutrient concentrations were calculated using calibrations curves obtained from dilutions of the same working standards used on both previous MarProd cruises *Discovery* 258 and 262. The performance of the analyser was monitored throughout the cruise by the gradient of the calibration curves

obtained from the in-house standards, and measurement of the deep ocean bulk seawater sample collected on *Discovery* 262. Duplicates of 2-3 samples per site, and all underway samples, were also measured to check for consistency throughout the run. After completion of each run, data was processed using Skalar Flow Access v. 1.4 software and saved in both Flow Access runfile and Excel format. The analyser was cleaned daily, and between runs, by rinsing with 10% Decon solution, followed by a deionised water rinse. The polythene tubing connecting the reagents to the analyser was cleaned weekly by removing from the reagent bottles and rinsing with Decon/deionised water.

The autoanalyser was located in the forward port side corner of the deck lab following safety problems encountered with containerisation of the autoanalyser on *Discovery* 262. This location was generally preferable to the container, and no apparent effects on analyser performance due to fluctuating temperatures were observed.

7.1.2 Operations

New pump tubes and reagents were installed for all methods at the start of the cruise and during the break in sampling at the mid-cruise port call to Keflavik. Due to air bubbles entering the nitrate line during initial testing, the flow through the waste tube from the nitrate line de-bubbler was increased from 0.42 to 0.6 ml/min before sampling commenced. After the mid-cruise tube change, the tube diameter on the phosphate de-bubbler at the start of the line was decreased from 0.23 to 0.16 ml/min. The new tubes supplied by Skalar specified a diameter of 0.25 ml/min, this appeared to lead to an insufficient sample flow through the photocell, allowing air to enter the cell.

A new cadmium column was fitted to the nitrate line at the start of the cruise, and replaced in response to deteriorating nitrate peak on 15 August. However, on 20 August, a problem with the autosampler allowed air to enter the new column, reducing the Cd, and the old column was refitted.

Towards the end of the cruise, significant deterioration was also observed in the phosphate and silicate lines, with peak shape changing from the preferred square shape to a less sharp pointed peak. This was initially noted on 20 August and continued to end of sampling on 23 August, potentially affecting samples from station 14976 onwards. Repeated cleaning of the lines with Decon and distilled water, and replacement of tubes and reagents did not improve peak shapes on either line to any great extent and the cause of the problem has not yet been identified. One possibility may be a bad batch of H_2SO_4, which is used in preparation of phosphate and silicate reagents, but not nitrate, which was seemingly unaffected.

7.1.3 Performance of the analyser

Baselines and calibration

Calibration constants were determined for each run using nutrient standard solutions (time series shown in Fig 9). The nitrate calibration shows three distinct stages: an initial run of high calibration constants (runs 1-7), a middle period (8-30) where calibration jumps to a low value then gradually increases, and a final period (31-40) of generally high calibration. The second change corresponds with a renewal of pump tubes on the phosphate line and tightening of the compressor pump nut which had worked itself loose, but there is no obvious explanation for the first jump in calibration. The phosphate calibration was variable throughout the cruise, whilst silicate was relatively stable.

Changes in the analyser baseline and the goodness of fit of the calibration curve are shown in Figs. 10 and 11 as indicators of instrument stability. The nitrate baseline was initially quite variable, but after the mid-cruise port call, became more constant. Phosphate increased gradually throughout the cruise whereas silicate tended to change with each change in reagents. Goodness of fit for phosphate and silicate was > 0.999 throughout the cruise, but nitrate was more variable and also slightly lower.

This may be due to some carryover in the nitrate line; tests will be carried out on return to SOC to see if a longer wash time is required to improve nitrate calibration.

The efficiency of the nitrate reduction step in the cadmium column was monitored daily by running a 10 μM nitrite standard and comparing the value obtained with that from the 10 μM nitrate standard 2. Both the initial and replacement columns had efficiencies exceeding 100%, indicating the column was over reactive, reducing some of the nitrite present as well as the nitrate. Efficiencies were 107.95% ± 1.65% for column 1, and 108.87 ± 1.99% for the replacement column.

Standards and duplicates

A 10 litre subsample of deep water (>1500 m) was collected prior to commencement of sampling in order to determine day to day variations in autoanalyser precision. Each sample run included three of these bulk seawater samples and the mean value and standard deviation of the samples was calculated. The mean values for the whole cruise were 10.25 ± 0.23 μmol/l for nitrate, 0.79 ± 0.04 μmol/l for phosphate, and 10.94 ± 0.27 μmol/l for silicate.

A sample of Low Nutrient Seawater (Ocean Scientific International) was also analysed on each run to determine to precision of the instrument at low nutrient concentrations. Mean values were nitrate = 0.02 ± 0.06 μmol/l, phosphate = -0.01 ± 0.01 μmol/l and silicate = 0.61 ± 0.06 μmol/l. Negative values observed for the phosphate indicate possible contamination of the artificial seawater and/or reagents; however, this effect was less severe than was observed on *Discovery* 262.

At least five replicate samples were analysed on each run - two or three duplicate samples were analysed per CTD or ARIES cast, and as many of the underway samples as was practicable. Both the absolute difference (mean of value 1 – value 2, expressed as a positive number) and true difference (actual mean of value 1 – value 2) were calculated for each run of samples, and are shown in Fig. 12. Absolute differences are noticeably greater in the final three days, when problems with the phosphate and silicate peaks were observed. The mean absolute differences for the entire cruise (expressed as a percentage of the mean value of the two samples) were significantly higher than on *Discovery* 262, primarily because of the low values measured in the surface underway samples which made up a large proportion of the replicates. However, the actual absolute differences, expressed in μmol/l, were improved slightly relative to the previous MarProd cruise: nitrate = 0.15 μmol/l (0.18 μmol/l on *Discovery* 262), phosphate = 0.16 μmol/l (0.17 μmol/l), silicate = 0.07 μmol/l (0.09 μmol/l). True differences for phosphate and silicate were close to zero with no consistent direction of offset, with the exception of the last three days where silicate true difference was large and positive; i.e. the first measurement was consistently higher. True difference for nitrate was generally larger, but still with no consistent direction of offset throughout the cruise.

A comparison between values obtained from samples collected at the same depth on the up- and down-casts of the ARIES system was undertaken to determine if bottle leakage on samples collected on the down-cast had any significant effect on the nutrient concentrations. These data have not yet been fully examined but it appears that up/down-cast differences are indistinguishable from the differences observed on repeat measurements of the same sample.

7.1.4 Preliminary results

Regression analysis of nitrate and phosphate data from all CTD/ARIES samples indicated the relationship N = 14.81 x P, with a correlation coefficient of 0.96 (Fig. 13).

Fig. 14 shows a plot of silicate concentration against depth for all samples. Surface concentrations were typically <1 μmol/l, whilst nitrate at most stations remained at concentrations of 3-5 μmol/l, suggesting that silicate depletion is the primary limitation on productivity. Stations with a depth

greater than about 400 m on transect DD and lines B and C on the Greenland shelf side of the basin displayed a signal of low silicate (8-9 μmol/l) which persisted from the seafloor to a maximum of about 50 m from the bottom. The preliminary interpretation is that this is recently overturned nutrient-depleted water, either from the Greenland shelf or Denmark Strait overflow.

7.2 Dissolved oxygen

Dissolved oxygen (DO) samples were taken from 6-8 Niskin bottles fired at all main CTD stations using the semi-automated Winkler titration method outlined in Holley & Hydes, 1995 (*Procedures for the determination of dissolved oxygen in seawater*; JRC Internal Document 20). The oxygen samples were the first to be taken from the CTD rosette, immediately after the CTD had been secured to the deck. Samples were collected using Tygon tubing into pre-calibrated glass DO bottles with ground glass tops, which were rinsed three times before being filled with the sample. Dissolved oxygen was then fixed immediately by addition of 1 ml manganous chloride and 1 ml alkaline iodide from Anachem dispensers, then the bottles sealed and shaken. A second DO bottle was rinsed and filled with sample from the same Niskin and the temperature of the water measured using a hand held electronic thermometer.

After storage for 1 hr, samples were acidified using 2.5 ml 5M H_2SO_4 and immediately titrated with sodium thiosulphate from a Metrohm DMS 716 titrino unit with amperometric endpoint detection. This system was located at the forward end of the wet chemistry laboratory. The normality of the thiosulphate solution was checked daily by determining the quantity of thiosulphate required to titrate triplicate samples of 10 ml of an in-house known concentration (approx 0.01 N) potassium iodate standard (Fig. 15). The oxygen concentration, in μmol/l was then determined using the equations of Dickson (1994). Analyses were completed within 6 hr of sampling, and a single batch of chemicals was used throughout the entire cruise. One replicate sample, usually from the deepest station, was measured for each cast. Over the whole cruise, the difference between the two replicates was 1.20 μmol/l (0.5 %).

Louise Brown

8. MetO buoy deployments

Shortly before the cruise the Meteorological Office asked if we were able to deploy two surface drifting atmospheric pressure / temperature sensors (Metocean WOCE SVP Drifters) to gather data for weather forecasting. Deployment was simply a matter of activating the buoys by removal of a magnet, and streaming the buoys and drogues over the stern at slow speed: there was no requirement for the ship to deviate from the planned track. The buoys were deployed on 9 August at 40°W (Argos No 21570) and on 23 August at 35°W (Argos No 21512). Further information on the buoys and details of their drift tracks can be obtained from Sarah North, UK Meteorological Office (e-mail sarah.north@metoffice.com), or from www.cmr.no/conmar/egos/.

Andrew Brierley

9. Underway data

9.1 Surfmet and thermosalinograph

9.1.1 Instruments

Underway surface meteorology and thermosalinograph (TSG) measurements were made by the RVS/UKORS Surfmet system throughout *Discovery* 264. The instruments used, together with their serial numbers and manufacturer, are listed below.

Table 6. Sensors for Surfmet and thermosalinograph.

Instrument	Manufacturer	Serial number
OTM (temperature) Housing	FSI	1374 *
OTM (temperature) Remote	FSI	1360 *
Fluorometer	Wetlabs	117, later 248
Transmissometer	SeaTech	T1005
Barometric pressure	Vaisala	S361008
Temperature/ humidity	Vaisala	1850014
PAR (DRP-5) (port)	Didcot/ELE	32057 *
PAR (DRP-5) (starboard)	Didcot/ELE	32058
TIR (Pyranometer) (port)	Kipp & Zonen	994132
TIR (Pyranometer) (starboard)	Kipp & Zonen	994135 *
OCM (Conductivity)	FSI	1376
Sensor collector (QL150)	Vaisala	R381005
Anemometer	Vaisala	P50421
Wind vane	Vaisala	R07101

* Different to Discovery 258

The instruments were the same as used for *Discovery* 262, although there had previously been some changes relative to *Discovery* 258. The temperature sensors now deal with calibrations internally and submit a true value to the RVS datastream. However there will be an offset in this. The original fluorometer produced rubbish data and, after failing altogether on 6 August, was replaced on the 10 August. The values from the replacement fluorometer were rather high and a calibration was not possible in the time available on board. A Fast Repetition Rate Fluorometer (see 9.2) was also attached to the TSG water supply, so surface fluorescence measurements are available.

9.1.2 Processing

Processing of underway data was undertaken at least once daily, more often during times of special interest (eg ice excursions). The Pstar scripts are given below (also see *Discovery* 262 cruise report):

smtexec0 used to read the data stream Surfmet on the RVS level C in to Pstar format using datapup. The resultant file was smt264**.raw.

smtexec1a ensured absent Surfmet data values were set to –999. The script also calculated TSG salinity using housing temperature, conductivity and a zero pressure value. This script also averaged the data to create a 2 minute interval smt264**.av file.

9.1.3 Salinity calibration

Samples for salinity analysis were collected approximately every 4 hr from the non-toxic supply as it left the FRRF. Spot values from the smt264**.av files were compared with underway bottle salinities (Fig 16) and the following calibration offset was derived:

$$salin(cal) = -0.084 + salin(raw)$$

The calibration was applied to the appended 2 min averaged files and renamed smt264ap.av. The mean residual between the bottle salinity and the calibrated TSG salinity was 0.0024 ± 0.0297.

9.1.4 Chlorophyll and nutrients

Chlorophyll samples were collected at c 4 hr intervals and analysed (see 6.3). The different biogeo-chemical provinces throughout the cruise track have a large impact on the fluorescence/Chl*a* relationship. However it was not possible in the time available to fully investigate the variation and calibrate the dataset appropriately. Concurrent nutrient samples (nitrate, phosphate, silicate) were also collected and analysed onboard. The data are available but were not investigated with respect to chlorophyll variations.

Clare Johnson, John Allen

9.1.5 Operation of Surfmet system

The Surfmet system generally performed well. However, there were a couple of minor equipment failures. The windvane failed and was replaced on the met system (25 July) and the fluorometer on the surface sampling was also replaced (10 August). The port TIR sensor became progressively noisier during the cruise, and no spare was available.

Jon Short

9.2 Fast Repetition Rate Fluorometer (FRRF)

The FRRF is an active fluorescence instrument, which can be used to make rapid, non-destructive, and *in situ* measurements of phytoplankton physiology (Kolber ZS, Prasil O & Falkowski PG, 1998; *Biochem. Biophys. Acta* 1367, 88-106). Such data can then be used in biophysical models to estimate the rate of phytoplankton photosynthesis at scales comparable to those of physical variability within the environment (Kolber ZS & Falkowski PG, 1993; *Limnol. Oceanogr.* 38, 1646-65).

One instrument was kept permanently attached to the ship's non-toxic supply to provide a continuous record of changes in near-surface phytoplankton physiology, and hence a comparison (and means of data quality verification) with the other instruments deployed *in-situ*. Power was provided to the instrument using a standard Chelsea Instrument deck box. Data were recorded internally and downloaded at 24 hr intervals to a PC laptop. A total of 28 files were collected (Table 8, below). The optical chamber was cleaned every 2 days using a soft white tissue and a small finger. An embryonic Pstar exec was written to read in the ASCII d264**.csv files created by the Chelsea software on the PC laptop; however, this was completed too late in the cruise to be other than briefly tested.

Table 8. Data files with start times for underway FRRF

File	Start: J day	hh:mm:ss	Inst time – ship time sec
d26401.bin	208	11:56:25	0
d26402.bin	209	14:38:11	1
d26403.bin	210	18:54:42	0
d26404.bin	211	13:13:30	0
d26405.bin	212	14:07:08	0
d26406.bin	213	13:30:50	0
d26407.bin	214	12:56:56	-2
d26408.bin	215	12:58:46	-2
d26409.bin	216	13:19:25	-4
d26410.bin	217	14:06:29	-3
d26411.bin	218	12:45:52	-3
d26412.bin	219	13:41:14	-3
d26413.bin	220	14:32:40	-3
d26414.bin	221	15:56:05	-4
d26415.bin	222	13:02:54	-4
d26416.bin	223	21:58:07	-5
d26417.bin	224	16:45:29	-5
d26418.bin	225	13:25:13	-5
d26419.bin	226	13:41:18	-5
d26420.bin	227	14:01:31	-6
d26421.bin	228	13:59:11	-6
d26422.bin	229	13:42:24	-7
d26423.bin	230	13:32:48	-7
d26424.bin	231	12:47:42	-8
d26425.bin	232	16:06:41	-8
d26426.bin	233	13:17:17	-9
d26427.bin	234	13:14:56	-10
d26428.bin	235	13:53:19	-10

The instrument settings were:

*** Boot Protocol = 1 ***
6. 65535 Acquisitions
7. 16 Flash sequences per acquisition
8. 100 Saturation flashes per sequence
9. 4 Saturation flash duration (in instrument units)
A. 0 Saturation interflash delay (in instrument units)
B. ENABLED Relaxation flashes
C. 20 Relaxation flashes per sequence
D. 4 Relaxation flash duration (in instrument units)
E. 61 Relaxation interflash delay (in instrument units)
F. 10000 ms sleeptime between acquisition pairs
G. 16 PMT Gain in autoranging mode
H. ENABLED Analog output
I. ENABLED Desktop (verbose) mode
J. INACTIVE Light chamber (A)
K. ACTIVE Dark chamber (B)
L. ENABLED Logging mode to internal flashcard
M: 77 Upper limit autoranging threshold value
N: 23 Lower limit autoranging threshold value

A second instrument was used for short vertical casts (Table 9) before each primary productivity CTD cast. Whilst this was principally used to provide a light profile to target the euphotic zone bottle stops, these FRRF profiles will also be directly comparable with the primary production incubation results.

Table 9. Data files for FRRF vertical casts

File	Station	Start J Day	Inst time – ship time (seconds)
d14696.bin	14696	210	0
d14702.bin	14702	211	-2
d14716.bin	14716	212	-1
d14734.bin	14734	213	-2
d14762.bin	14762	215	-3
d14776.bin	14776	216	-3
d14793.bin	14793	217	-5
d14809.bin	14809	218	-5
d14824.bin	14824	219	-6
d14839.bin	14839	220	-7
d14854.bin	14854	221	-8
d14860.bin	14860	222	-8
d14878.bin	14878	225	-10
d14893.bin	14893	226	-10
d14916.bin	14916	227	0
d14932.bin	14932	228	-2
d14953.bin	14953	229	-3
d14963.bin	14963	230	-3
d14975.bin	14975	231	-4
d14987.bin	14987	232	-5
d15003.bin	15003	233	-7
d15018.bin	15018	234	-7
d15036.bin	15036	235	-8

The settings for the profiling FRRF were:

```
*** Boot Protocol = 1 ***
6.      65535    Acquisitions
7.      16    Flash sequences per acquisition
8.      100    Saturation flashes per sequence
9.      4    Saturation flash duration (in instrument units)
A.      0    Saturation interflash delay (in instrument units)
B.      ENABLED   Relaxation flashes
C.      20    Relaxation flashes per sequence
D.      4    Relaxation flash duration (in instrument units)
E.      0    Relaxation interflash delay (in instrument units)
F.      0    ms sleeptime between acquisition pairs
G.      1    PMT gain in normal mode
H.      DISABLED   Analog output
I.      DISABLED   Desktop (verbose) mode
J.      ACTIVE  Light chamber (A)
K.      ACTIVE    Dark chamber (B)
L.      ENABLED   Logging mode to internal flashcard
M:      77    Upper limit autoranging threshold value
N:      23    Lower limit autoranging threshold value
```

John Allen, Clare Johnson

9.3 Navigation and vessel-mounted ADCPs

9.3.1 Introduction

Two RDI Vessel-Mounted Acoustic Doppler Current Profilers (VM-ADCPs) were operated on *Discovery* 264; the 150kHz VM-ADCP and the 75 kHz Phased Array instrument (Ocean Surveyor) that had been fitted immediately prior to FISHES (*Discovery* 253, May-June 2001). This report follows the same format as that by Allen *et al* from the first MarProd cruise *Discovery* 258, but does not cover in detail aspects which are unchanged from that cruise. This section summarises the operation and data processing paths for navigation data and for both ADCPs.

9.3.2 Navigation

Ship's position can be obtained from one of several GPS receivers, namely gps_g12, gps_4000, gps_glos and gps_ash, using the names of the RVS data streams. For most of the cruise the main data source for *Discovery* 264 was the Ashtech G12 positioning system, as it had been on *Discovery* 258. This means that the G12 was the primary source input to bestnav, the data stream with 10 second values of position throughout the cruise. However, the G12 had an intermittent problem (possibly a temperature cut-out) so that it ceased logging from time to time. An examination of positional accuracy, whilst tied up alongside at Fairlie pier, confirmed what had been found on *Discovery* 258, namely that the corrected GPS 4000 system provided higher positional accuracy than the new Ashtech G12 system. When the G12 problem persisted, the GPS 4000 was made the master, but this was not done until 22 August, close to the end of science activities on *Discovery* 264..

Data were transferred daily from the RVS Level C bestnav stream to the Pstar absolute navigation file, abnv2641. The G12, gps-4000, gps_glos, gps_ash and gyro (gyronmea) data streams were also transferred daily. Processing paths were exactly as for *Discovery* 258, so are not reproduced here.

On 18 August (day 227) the gps_ash stream clock seized up and logged constant times from 0718 to 1236. However, positions continued to be logged at one-second intervals, albeit with the constant timestamp. This stream is vital to obtain accurate headings for the VM ADCPs, so a method of interpolating time was sought. It was found that the variable 'sec' output by the satellite, was in fact

HHMMSS, i.e. time within day. Comparison with the RVS timestamp showed that the RVS timestamp was in general 1 second ahead of the satellite value. Therefore, the satellite value was used to recover the time base.

This led us to ask: do all GPS streams carry their own timestamp? if so, which is to be preferred for accuracy and reliability? It was found that all but GPS 4000 have their own timestamp, but there are bad values in the timestamps, which appear to relate to time gaps, whether due to failures in RVS logging or gaps in the data from the satellites. It is for this reason that the stream bestnav is used for navigation, as gaps and errors have been screened and a reliable monotonic output stream results. Changes in the comparability of timestamps were also investigated. The master gps_g12 1-second file was screened to remove bad data cycles, then the difference (UTC time - RVS time) calculated and plotted. Fig. 17 shows that RVS times are always earlier than UTC times, and the two times drift apart over the period of the cruise. The cause is unknown.

The reliability of the GPS streams was compared by looking for data gaps. Findings are summarized in Table 10 below. On this cruise, gps_4000 was more reliable than gps_g12, with only two time gaps greater than a minute. Interestingly, the gps_glos stream is even more reliable. However, its absolute accuracy has not been looked at. The gps_ash stream is known to be less reliable, its primary purpose being to determine ship's heading. There were frequent gaps of 10-40 seconds. Only those over 2 minutes are shown in the table under gps_ash.

Table 10. Time gaps in GPS streams

gps system	Time gap (yr, J day, hr, min, sec)	Duration
Gps_g12 gaps over 29 sec	02 210 00:48:03 to 02 210 01:59:26	71.4 min
	02 213 03:52:36 to 02 213 03:57:04	4.5 min
	02 216 16:36:55 to 02 216 16:37:26	31 s
	02 222 13:11:48 to 02 222 13:32:27	20.6 min
	02 223 00:08:33 to 02 223 01:28:23	79.8 min
	02 223 03:23:54 to 02 223 04:20:29	56.6 min
	02 224 00:08:58 to 02 224 00:20:41	11.7 min
	02 227 00:19:54 to 02 227 00:32:38	12.7 min
	02 227 03:10:43 to 02 227 03:27:40	16.9 min
	02 228 00:23:22 to 02 228 00:57:15	33.9 min
	02 230 00:07:30 to 02 230 01:57:04	109.6 min
	02 234 14:59:24 to 02 234 18:33:23	3.6 hr
gps_4000 gaps over 29 sec	02 206 10:32:45 to 02 206 10:33:15	30 s
	02 210 23:49:57 to 02 210 23:50:30	33 s
	02 213 03:52:26 to 02 213 03:57:01	4.6 min
	02 214 06:00:20 to 02 214 06:00:53	33 s
	02 222 12:41:42 to 02 222 12:43:30	108 s
	02 222 12:44:16 to 02 222 12:44:47	31 s
	02 225 08:00:19 to 02 225 08:00:55	36 s
	02 232 07:23:23 to 02 232 07:23:57	34 s
	02 232 20:15:35 to 02 232 20:16:05	30 s
	02 233 07:18:33 to 02 233 07:19:08	35 s
	02 235 03:58:07 to 02 235 03:59:04	57 s
gps_glos gaps over 29 sec	02 206 10:32:45 to 02 206 10:33:15	30 s
	02 212 08:32:37 to 02 212 08:33:14	37 s
	02 213 03:52:27 to 02 213 03:57:00	4.5 min
gps_ash gaps over 2 min	02 213 03:52:28 to 02 213 03:57:00	4.5 min
	02 214 04:35:17 to 02 214 05:13:17	38.0 min
	02 214 05:14:12 to 02 214 05:41:22	27.2 min
	02 220 16:14:32 to 02 220 17:10:19	55.8 min
	02 222 12:00:16 to 02 222 12:13:24	13.1 min
	02 227 07:18:30 to 02 227 12:36:08	5.3 hr

9.3.3 150 kHz ADCP

The 150kHz RDI ADCP was logged using IBM Data Acquisition Software (DAS) version 2.48 with profiler software 17.20. The instrument was configured as for *Discovery* 258, sampling over 120 s intervals using 100 bins of 4 m thickness, pulse length 4 m and a blank beyond transmit of 4 m (settings to optimise the remote detection of zooplankton patchiness). Bottom track mode was used when working over shallow water (at the start; on passage to and from Keflavik; and on the Greenland shelf), but water track was the normal mode for the majority of the cruise. The two vessel-mounted ADCPs were configured to synchronise their pings over the ensemble period, with the 150 as the Master and the 75 as the Slave as recommended by RDI. This resulted in 51 pings per ensemble in water track mode (but only 24 pings per ensemble for the Surveyor).

The PC logging the ADCP data had been changed from *Discovery* 258, and this caused several problems. First, every ping pushed the screen display up a line, consequently the plot of the previous 2 min ensemble was only visible for a few pings. No fix was found for this. Second, the PC clock was no longer synchronised with ship's master clock. To avoid having to reinstate adpexec1 (written to correct for this), a daily check on the PC clock was kept, and it was found to drift between 1 and 3 sec/day. When the offset reached about 6 sec, logging was stopped briefly, and the clock reset. Third, partway through the cruise it was found that the PC was failing to write to the backup floppy disk. Thus logging would fail at the end of each ensemble, when the write failed. This was cured simply by turning off the 'log to disk' DAS command. Thus we relied on the direct link to level C.

At the start of the cruise, the level of percent good returns seemed rather low, indicative of bubbles in the tranducer well. However, these soon cleared, and for the remainder of the cruise the returns were excellent, often giving good data to the full range of over 400 m. Of course, there were long periods of slow towing (2.5 knots) with the underway nets (ARIES, Ocean Sampler and Dual Methot), but even on passage legs at 10 knots or over, the percent good returns remained high. We ascribe this to the excellent weather, lack of pitch and lack of bubbles under the hull. Indeed, during the passage run at the end of the cruise, a short spell of bad weather caused much more normal(!) pitching and rolling and the percent good returns dropped considerably, but recovered when the weather eased. This confirms that the bleed pipe that allows bubbles to clear has remained free since cleared on *Discovery* 258.

The calibration of the 150 kHz ADCP was checked on the initial passage run across the Hebridean shelf. From 0523Z to 0751Z on day 208, a speed of 8 knots was maintained. Comparing the bottom track mean velocity with gps navigation data yielded a calibration of

$A = 1.0018 \pm 0.003$ (cf: *Discovery* 253, A = 0.9966; *Discovery* 258, A = 1.0005 ± 0.0050)
$\phi = 3.88° \pm 0.08°$ (cf: *Discovery* 253, $\phi = 3.814$; *Discovery* 258, $\phi = 3.82$)

These calibrations are not significantly different from those on previous cruises, so it was decided to retain the *Discovery* 258 values of A = 1.0000 and $\phi = 3.82$. On previous cruises the new 45° orientation of the transducers relative to the hull had been included in ϕ. Thus $\phi = 48.82$ for *Discovery* 258. For *Discovery* 264, the 45° was included in the VM DAS setup, so the ϕ to be applied should have been 3.82°. Unfortunately, it was only discovered when preparing this report at the end of the cruise that a typo had resulted in a setting of $\phi = 3.48°$, a 0.34° error, in adpexec3. The data should be reprocessed from this point, as a 0.34° error could result in an absolute velocity error of 500 sin ϕ = 3.0 cm/s error at 10 knots. However, for the on station comparisons with the LADCP, the error in ϕ is irrelevant, and for the slow net tows at 2.5 knots, the error is less than 1 cm/s.

9.3.4 75 kHz ADCP

On *Discovery* 264 the RDI Ocean Surveyor 75 kHz Phased Array ADCP was configured to sample over 120 sec intervals with 60 bins of 16m depth, pulse length 16m and a blank beyond transmit of

8m. Bin 1 distance is output as 23.96 m from the instrument, thus adding the transducer depth of 5.3 m gives depth of bin 1 as 29.26 m. The instrument is a narrow band phased array ADCP with 76.8 kHz frequency and a 30° beam angle. Pings were at 2 sec intervals, but were slaved to the 150 kHz ADCP so in fact there was a synchonised ping only every 4 seconds, resulting in only 24 pings per 2-min LTA ensemble. The PC was running RDI software VmDAS v1.2.012 and WinADCP v1.1.0. Gyro heading, and GPS Ashtech heading, location and time were fed as NMEA messages into the software which was configured to use the Gyro heading for co-ordinate transformation. The software logs the PC clock time, stamps the data (start of each ensemble) with that time, and records the offset of the PC clock from GPS time. This offset was applied to the data in the processing path before merging with navigation. The ADCP was fitted in the forward well previously occupied by the unsuccessful ACCP and before that the ADCP prior to the 1992 re-fit. During fitting a nominal offset of 45° was intended, but the April 2001 trials cruise ascertained that the offset was in fact 60°, and this offset was accounted for in the RDI software. Bottom tracking was switched on during passage over shallow water as for the 150 khz ADCP, but including passage over Rockall.

The 2 min averaged data were written to the PC hard disk in files with a .LTA extension, eg D264005_000000.LTA, D264006_00000.LTA. Sequentially numbered files were created whenever data logging was stopped and re-started. For some reason the logging PC was not networked, or the network interface was not properly set up. Data transfer was therefore by zip disk every few days. The .LTA and .ENX files were transferred to a networked Mac for ftp'ing to the Unix directory /data62/surveyor; .ENX files contain the raw ping by ping profiles ready for averaging and were recorded in case they could be useful for looking at deep acoustic backscatter signals. Broadly speaking the new processing path followed the steps outlined for the 150 kHz ADCP.

Table 11. Surveyor 75kHz ADCP: raw and processed file name correspondence

File	Start time Jday	hhmmss	Stop time Jday	hhmmss	ADCP file name	
sur26402	208	181331	209	110538	D264005_000000.LTA	
sur26403	209	110923	209	200101	D264006_000000.LTA	
sur26404	209	200345	209	201348	D264007_000000.LTA	
sur26405	210	052427			D264009_000000.LTA	
					D264010_000000.LTA	
					D264011_000000.LTA	
					D264012_000000.LTA	
					D264013_000000.LTA	
			213	210844	D264014_000000.LTA	
sur26406	213	215122	215	085928	D264015_000001.LTA	
sur26407	215	090131	216	085933	D264015_000001.LTA	
sur26408	216	090137	217	085739	D264015_000001.LTA	
sur26409	217	090001	218	085803	D264015_000001.LTA	
sur26410	218	090002	219	085950	D264015_000001.LTA	
sur26411	219	090150	220	085950	D264015_000001.LTA	
sur26412	220	090151	221	085956	D264015_000001.LTA	
sur26413	221	090158	222	085759	D264016_000000.LTA	
sur26414	222	090003	223	085911	D264016_000000.LTA	
sur26415	223	090109	224	062712	D264016_000000.LTA	
sur26417	224	062922	225	025929	D264017_000000.LTA	*BT
sur26418	225	030807	227	035618	D264018_000000.LTA	*BT
sur26419	227	035900	229	123511	D264019_000000.LTA	*BT
sur26420	229	124002	233	232626	D264020_000000.LTA	
sur26421	233	232727	236	085941	D264021_000000.LTA	
sur26422	236	090139	238	090000	D264022_000000.LTA	

*BT indicates bottom track files too

No decent calibration was obtained at the beginning of the cruise, and therefore the values derived during *Discovery* 253 were used instead. That calibration was established from bottom tracking data collected on long straight SeaSoar runs of Fine Scale Survey 2. The values were:

$$\phi = 1.3578 \text{ (sd = 0.078)} \quad A = 1.0050 \text{ (sd = 0.0031)}$$

However, after several bottom track runs on the Iceland and Greenland shelves, a reliable calibration was obtained:

Where	course	start time	stop time	duration	A	ϕ
Iceland shelf	270°	08/12 180129	232927	5h 28m	1.00513	0.905
Greenland shelf	283°	08/15 161105	201504	4h 04m	1.00586	0.873
Greenland shelf	173°	08/16 063706	090909	2h 32m	1.00597	0.905
Averaged values to be used:					1.00565	0.894

These values differ from the D253 values by .00065 for A (error of 0.3 cm.s at 5 m/s) and 0.4638 for phi (error of 4.0 cm/s at 5 m/s). Thus the surveyor data should be recalibrated post-cruise.

The ADCP files and their Pstar equivalents are listed in Table 11 above for the convenience of future users of the .ENX files.

9.3.5 Processed data handling

Data were extracted from the Pstar files of the two vessel mounted ADCPs corresponding to the deployment times of the CTD. This was done to compare the 150kHz and 75kHz vessel mounted ADCP profiles with those of the lowered ADCP.

Using CTD beginning and end of deployment times from the station log, mlist was used to find the datacycles occurring within this time, from adp264nn.abs and sur264nn.abs; pcopya then created a file containing this data cycle range, and allav produced a single averaged profile from this time period. The names of the resultant files are shown in Table 12. The single profiles for both vessel mounted ADCPs were plotted using oneprof.pdf. Comparisons between the 150 kHz and 75 kHz VM ADCPs were excellent, and are described under the LADCP report.

Table 12. Extraction of on-station profiles from underway data

Site	Station No.	Date	Jday	CTD begin	CTD end	150kHz adp*.abs	150kHz data cycles	Surveyor sur*.abs	Surveyor data cycles
I	14697	29-Jul	210	13:27	16:09	26404	13401-21500	26405	14461-19320
I3	14703	30-Jul	211	11:44	13:51	26405	8301-14600	26405	54541-58320
I1a	14712	31-Jul	212	3:45	5:40	26405	56301-62000	26405	82561-86760
B1	14717	31-Jul	212	13:03	14:08	26406	12201-15400	26405	100021-102000
B2	14726	31-Jul	212	22:59	0:40	26406	42001-47000	26405	117901-120960
B3	14729	1-Aug	213	4:14	6:04	26406	57701-63100	26405	127381-130680
B4	14735	1-Aug	213	12:36	14:57	26407	10901-17900	26405	142441-146640
B5	14744	2-Aug	214	5:13	7:08	26407	60801-66500	26406	13261-16680
DD13°	14763	3-Aug	215	17:42	18:52	26409	26201-29300	26407	15601-17520
DD12	14772	4-Aug	216	3:40	5:14	26409	53601-58300	26407	32101-34920
DD11	14777	4-Aug	216	11:36	13:45	26410	7801-14300	26408	4621-8520
DD10	14788	5-Aug	217	4:19	6:27	26410	58001-64400	26408	34741-38520
DD9	14794	5-Aug	217	12:45	15:18	26411	11301-18900	26409	6781-11340
DD8	14804	6-Aug	218	5:00	7:46	26411	60001-68300	26409	36001-40980
DD7	14810	6-Aug	218	13:45	16:45	26412	14301-23300	26410	8581-13980
DD6	14819	7-Aug	219	4:29	7:08	26412	58301-66300	26410	35101-39840
DD5	14825	7-Aug	219	12:36	15:30	16413	10901-19600	26411	6421-11700
DD4	14834	8-Aug	220	3:07	5:35	16413	54401-61800	26411	32581-37020

Site	Station No.	Date	Jdav	CTD begin	CTD end	150kHz adp*.abs	150kHz data cycles	Survevor sur*.abs	Survevor data cycles
DD3+	14840	8-Aug	220	13:30	16:00	16414	13601-21100	26412	8041-12540
DD2a	14849	9-Aug	221	2:00	4:23	16414	51101-58200	26412	30541-34860
DD2	14856	9-Aug	221	14:50	17:06	26415	17601-24400	26413	10441-14520
C8	14861	10-Aug	222	11:21	13:25	26416	7101-13300	26414	4201-7980
B8	14879	13-Aug	225	11:29	14:10	26419	7501-15600	26418	15001-19860
C10b	14881	13-Aug	225	18:15	20:41	26419	27801-35100	26418	27181-31560
C10	14894	14-Aug	226	12:00	13:15	26420	9101-12800	26418	59161-61380
C9c	14896	14-Aug	226	15:05	16:58	26420	18301-24000	26418	64681-68100
C9b	14899	14-Aug	226	18:35	20:17	26420	28801-33900	26418	70981-74040
C9a	14902	14-Aug	226	21:55	23:15	26420	38801-42800	26418	76981-79380
C9d	14912	15-Aug	227	7:59	8:39	26420	69001-71000	26419	7201-8400
C9	14917	15-Aug	227	13:12	14:18	26421	12701-16000	26419	16561-18540
X	14927	16-Aug	228	1:26	2:13	26421	49401-51700	26419	38641-40020
C6	14933	16-Aug	228	13:15	14:06	26422	12801-15400	26419	59881-61380
C6a	14944	16-Aug	228	22:25	00:00	26422	40301-45100	26419	76381-79200
H10	14964	18-Aug	230	8:18	10:16	26423	69901-71900	26419	94201-97680
						26424	1-3800		
DD1	14976	19-Aug	231	7:48	9:46	26424	68501-72000	26420	77641-81180
						26425	1-2300		
D1a	14983	20-Aug	232	5:37	7:24	26425	61901-67200	26420	116941-120120
D1	14988	20-Aug	232	14:36	15:23	26426	16901-19200	26420	132961-134460
D1	14997	20-Aug	232	20:30	21:00	26426	34601-36000	26420	143701-144600
D3	15012	21-Aug	233	17:10	19:50	26427	26401-32600	26420	180901-185700
D6	15037	23-Aug	235	12:35	15:00	26429	10801-18000	26421	66841-71160

+ no ladcp °data loss output files: sdp#.ave for 150kHz and sur#.ave for surveyor

Raymond Pollard, Katy Shannon

9.4 Precision echosounder (PES) data

A combination of two precision echosounders were used to record bottom depth throughout *Discovery* 264. The main instrument was the 10/12 kHz Simrad EA500 hydrographic echosounder mounted on a fish on the port side, and the secondary instrument was the hull mounted 12 kHz transducer. Data from both instruments were recorded as separate Level A/B data streams (ea500d1 for the hull and ea500d2 for the fish) but were merged, edited and corrected for the speed of sound in the Level C "prodep" data stream. Preference was given to the PES fish data in prodep, except during ARIES tows when the fish mounted transducer was switched to 10 kHz for tracking the movement of ARIES. For most of the cruise data were of reasonable quality.

The Simrad EA500 10KHz performed well, the PES fish needing slight attention to fairing and adjustment of towing arm. The 12KHz transceiver board failed (16 August). This meant that during deep ARIES tows, the 10KHz had to be used on a 20sec sampling interval to prevent interference with the UW modem. This worked satisfactorily. The Pstar processing steps were given in the *Discovery* 262 Cruise Report.

Jon Short

10. Towed zooplankton net systems

10.1 FRS net systems: deployment

We collected zooplankton and associated specimen samples with the FRS Autosampling Recording Instrumented Environmental Sampler (ARIES), Dual Methot net system (DM) and Ocean Sampler (OS), as outlined in Table 13 below. The ARIES and Ocean samplers also collected water samples, that were fully or partly analysed for nutrients, chlorophyll and salinities, or preserved for

phytoplankton and ciliate analyses. ARIES and OS samplers each catch two Pup net depth-integrated samples. These were preserved from all deployments, one in ethanol and one frozen. Selected salinity and chlorophyll sampling will allow CTD and fluorometer calibration. The ARIES Optical Plankton Counter (OPC), Seabird 911 CTD, fluorometer and transmissometer data, and OS OPC data, describe plankton size and environmental conditions, for integration with standard CTD casts.

The sampling programme with the FRS net systems was successfully undertaken, and a high rate of data and samples was returned. The assistance and efforts of the UKORS technical staff on the gear deployment and recovery was much appreciated, notably Terry Edwards and Jon Short working with Jim Hunter, aided by the winch operators, deck crew and ship's officers. The deployment methods were as previously reported for cruises *Discovery* 258 and 262, as were the procedures for sample handling, specimen sorting and selection and sample preservation.

Samples of plankton specimens for biochemical analyses were taken from the ARIES and Dual Methot nets, see Section 10.2 below. Some video footage was taken of the operations on board and of specimens, the latter using a microscope-mounted camera. This video material will add to that obtained on the winter and spring cruises, continuing the documentation of the research programme.

A number of vertical net samples were collected near sites proposed by Graham Savidge (QUB) for his genetic work on microsatellites. All or a portion of these samples containing sufficient *Calanus*, preserved in absolute ethanol. The zooplankton sampling also included comparative tows of the ARIES sampler with the CPR. This is documented further in Section 10.3.

Complete results for the plankton sampling await onshore work on the samples. However, some data are available from the Optical Plankton Counters deployed on ARIES and Ocean samplers, and from observations during sample collection. The OPC results are, however, compromised by the presence of other particles in the water which register in the same size categories as *Calanus*. Therefore this preliminary information needs to be viewed cautiously, pending further detailed analyses and comparisons with the net catches. Fig 18 shows the mapped distribution for estimated standing stocks of *Calanus* sized particles in the total water column for adults (C6) and for stages C4-C5. Fig 19 displays preliminary OPC results for *Calanus* stages C4-C5 and for adults as vertical distributions of numbers per cubic meter for appropriately-sized particles.

Throughout the cruise, the sampled *Calanus* populations were most abundant in near-surface waters. Nevertheless, in contrast to the spring cruise, significant numbers of *Calanus* were also found at depths to around 1200m (where such depths occurred). The physiological status of the populations and determination of whether any *Calanus* were in a diapause state will await the biochemical analyses of the specimens collected.

Table 13. Deployments of FRS net systems

Key: O , Optical Plankton Counts; C, Seabird CTD; F, Fluorometer; T, Transmissometer. Specimens extracted for L, Lipids/hormones; G, Genetics; I, C:N & Isotope ratios; and E, Enzymes

Site	Gear type	No of zoo-samples	No of water samples	Max-depth sampler	Average depth seabed (m)	Plankton pup nets	Associated sampling (see key above)
Test	OS	4	4	97	104	2	O
I (4)	OS	7	7	407	1933	2	O
I (4)	AR	88	60	2053	2600	2	O,C,F,T L,G,I
I (4)	DM	2	0	806	2795		L,G,I
I3	OS	7	7	413	1908	2	O
I3	DM	2	0	800	1942		L,G,I
I3	AR	74	60	1805	1909	2	O,C,F,T L,G,I
B1	OS	7	7	415	650	2	O
B1	DM	2	0	618	750		L,G,I
B1	AR	32	32	765	905	2	O,C,F,T L,G,I

Site	Gear type	No of zoo-samples	No of water samples	Max-depth sampler	Average depth seabed (m)	Plankton pup nets	Associated sampling
B4	OS	7	7	409	1885	2	O
B4	DM	2	0	816	1892		L,G,I
B4	AR	76	60	1819	1852	2	O,C,F,T L,G,I,E
B5	AR	18	0	12	1963	2	O,C,F,T
E13	AR	61	0	1322	1683	2	O,C,F,T L,G,I,E
DD13	AR	17	0	12	1581	2	O,C,F,T
DD13	OS	7	7	411	946	2	O
DD13	DM	2	0	806	1083		L,G,I
DD13	AR	49	49	1176	1280	2	O,F,T L,G,I,E
DD11	OS	7	7	412	1841	2	O
DD11	DM	2	0	799	1844		L,G,I
DD11	AR	70	60	1720	1975	2	O,C,F,T L,G,I,E
DD9	OS	7	7	423	2342	2	O
DD9	DM	1	0	800	2460		L,G,I
DD9	AR	67	60	2425	2644	2	O,C,F,T L,G,I,E
DD9	DM	1	0	806	2617		L,G,I
DD7	OS	7	7	411	3022	2	O
DD7	DM	1	0	805	3012		L,G,I
DD7	AR	75	60	2714	2980	2	O,C,F,T L,G,I,E
DD5	OS	7	7	414	2897	2	O
DD5	DM	1	0	806	2905		L,G,I
DD5	AR	75	60	2717	2923	2	O,C,F,T L,G,I,E
DD3	OS	7	7	411	2618	2	O
DD3	DM	2	0	797	2588		L,G,I
DD3	AR	97	60	2405	2499	2	O,C,F,T L,G,I,E
C8	OS	7	7	410	2044	2	O
C8	DM	2	0	799	2117		L,G,I
C8	AR	84	60	2069	2334	2	O,C,F,T L,G,I,E
C10	DM	2	0	804	1838		L,G,I
C10	AR	43	60	1463	1659	2	O,C,F,T L,G,I,E
C10	OS	7	7	413	1498	2	O
C9	DM	2	0	444	457		L,G,I
C9	AR	36	36	431	465	2	O,C,F,T L,G,I,E
C9	OS	7	7	413	473	2	O
CX	DM	1	0	223	280		L,G,I
CX	AR	22	22	251	260	2	O,C,F,T L,G,I,E
CX	OS	4	4	252	293	2	O
C6	OS	5	5	243	261	2	O
C6	DM	1	0	240	257		L,G,I
C6	AR	22	22	251	269	2	O,C,F,T L,G,I,E
C6	DM	2	0	352	364		L,G,I
C6	AR	31	0	11	230	2	O,F,T
H10	AR	73	60	1703	2063	2	O,C,F,T L,G,I,E
H10	DM	2	0	837	2020		L,G,I
H10	OS	7	7	415	2140	2	O
DD1	DM	2	0	797	1960		L,G,I
DD1	AR	75	60	1813	1927	2	O,C,F,T L,G,I,E
DD1	OS	7	7	421	1977	2	O
D1	OS	7	7	394	400	2	O
D1	DM	2	0	340	356		L,G,I
D1	AR	32	32	378	403	2	O,C,F,T L,G,I,E
D2	DM	2	0	805	2450		L,G,I
D2	AR	100	60	2410	2685	2	O,F,T L,G,I,E
D2	OS	7	7	408	2687	2	O
D4	DM	2	0	809	3135		L,G,I
D4	AR	46	48	1950	3120	2	O,F,T L,G,I,E
D4	OS	7	7	411	3105	2	O
D5	AR	43	43	1969	2817	2	O,C,F,T L,G,I,E
D5	OS	7	7	411	3068	2	O
D6	AR	60	60	1475	1506	2	O,C,F,T L,G,I,E

Preliminary observations on the collected samples indicated that: i) a significant proportion of the animals were full of storage lipid (for both deep and surface populations); ii) the majority of animals were fairly active, even when retrieved from depth; and iii) deep-caught *Calanus* seemed to have little or no food in their guts, in contrast to surface animals. We also noted wide size ranges in the C5 and adult females, probably representing generation differences (but which may have other causes).

At Ocean Weather Station India and the initial sites in the Iceland basin, not very high numbers of adult *Calanus* were present but significant numbers of juvenile *Calanus* were in the samples, suggesting ongoing growth and production. Also there were large numbers of invertebrate predators present and at OWS India quite high numbers of *Salpa fusiformis*.

On the eastern side of line B and over the Reykjanes Ridge we found *Calanus* numbers were higher generally than in the Iceland Basin with increasing amounts to the west of the ridge. Across the central DD section in the Irminger Basin, *Calanus* abundances were high, increasing to the west over the deeper water and with significant numbers of *Calanus* in the deep samples. Visual inspection of the sample nets suggests a consistent pattern of most *Calanus* in the surface and in decreasing numbers over the first 200-300 m, then often a sparse distribution down to between 700- 1200 m where there were often distinct peaks in *Calanus* numbers. Very few of these animals were in early copepodite stages, nearly all being C5 with relatively few adults and C4 stages.

The unscheduled run to Reykjavik allowed a CPR tow and vertical net deployment on the shelf SE of Reykjavik, expected to yield useful comparison data. The population of *Calanus* in the vertical net on the Iceland shelf was high and very active with numerous juvenile stages.

At the offshore sites east of Greenland there were many *Calanus* and again a majority in the surface mixed layer, with decreasing amounts over the first 200-300 m and a significant increase in density around 1000m. At the sites on the shelf there were many more juvenile stages found, and quite high population numbers generally (although significantly less than in the offshore sites). There appear to be marked differences in abundance and productivity between the populations in the cold inshore waters and the warmer offshore areas. The limiting factors to the transportation of *Calanus* populations and production across the shelf seems, as in the spring cruise, to depend on the advection caused by eddies and filaments associated with the east Greenland current and strong thermal fronts. These dynamics are obviously important factors in the process of productivity for *Calanus* and other species in the region.

On the southern line D, back across the Irminger Basin from near Cape Farewell, there were large populations of *Calanus* in the surface waters. Again there were the same deeper layers with significant numbers of late stage *Calanus* C5 and adults with some C4s, although this pattern is not so evident from the OPC data as it was further north on transect lines DD or B.

Analyses of the Dual Methot hauls confirm the abundance of chaetognaths, predatory copepods such as *Euchaeta norvegica* and a diversity of jellyfish alongside euphausiids and many other plankton species. As well as all of the MarProd target species (*Calanus* spp. and the euphausiids, *Thysanoessa longicaudata* and *Meganyctiphanes novegica)*, there were a number of other dominants. These included the euphausiid *Thysanoessa inermis* on the Greenland shelf, the predatory copepod *Euchaeta,* and many other predatory species including the chaetognaths *Sagitta maxima* and *Eukrohnia hamata.* Several medusae species were found repeatedly, small scyphomedusae and the trachymedusan *Aglantha* were particularly abundant and siphonophores were often abundant, the amphipod *Parathemisto* sp. and a range of others including deep-water shrimps and fishes. Examination of the net catches indicated that on some occasions the furcilia and juvenile stages of euphausiids *M. norvegica* and *T. longicudata* were relatively abundant in the upper layers of the water column, whilst few nauplii and early stages were observed. We have collected specimens of

some of the abundant non-target species for later biochemical analyses, particularly for lipid, CHN and isotope ratio studies. It is hoped that analyses of these will lead to interesting observations of the food chain dynamics in our study area.

Steve Hay

10.2 FRS net systems: biological sorting

10.2.1 Sampling summary

As noted above, zooplankton and associated specimen samples were collected with ARIES, the Dual Methot (DM) and Ocean Sampler (OS) systems to provide data on zooplankton populations and distribution, on food chain interactions and on environmental conditions.

There were 22 DM (38 samples), 21 OS (142 zoo & 135 water samples) and 26 ARIES (1466 zoo & 1124 water samples) deployments. Sub-sampling onboard of plankton specimens for biochemical analysis from the ARIES and DM nets was carried out. This material will be used for studies of lipids, hormones, tRNA synthetase activity, genetics and CN/isotope ratios. Biochemical sampling and sample handling was done by Ryan Saunders, Steve Hay and Joh Sidey, with help from Penny Lindeque and Gary Smerdon, and the sampling is documented in a spreadsheet. All depth samples from the OS nets were preserved for subsequent microscope analysis and species enumeration.

10.2.2 Deck work and sorting procedures

These procedures were essentially as described in the *Discovery* 258 cruise report. In the light of experience of *Phaeocystis* effects on *Discovery* 262 (spring cruise), a small power-washer was used to wash down plankton nets more quickly and effectively during *Discovery* 264.

Specimens picked out for future laboratory analyses were preserved as follows:

- Lipids/ hormones/enzymes – into plain cryovials and stored in liquid nitrogen
- Genetics – into sealed cryovials and specimens preserved in pure 100% ethanol
- CN/isotope ratios – into glass screw top vials placed in –20°C freezer

Information is given below on the main species picked out for further analysis (where * denotes MarProd target species). A typical number of sets of individuals, dependent on abundance, is given in parenthesis. Where possible, sets of specimens were picked from both surface and deeper nets for comparisons. From ARIES samples 6308 *Calanus* were picked out, and from the Dual Methot hauls 1836 specimens were picked out.

Picked from ARIES nets for lipids, hormones, enzymes, genetics and CN/Isotope ratios:

Copepoda	**Calanus* (3 – 6 sets x 10)

Plus occasionally specimen sets of other species for the CN/isotope ratios studies.

Picked from Dual Methot net for lipids, genetics and CN/isotope ratios:

Euphausiidae	**Meganctiphanes norvegica* (3 sets x 5) **Thysanoessa longicaudata* (3 sets x 5) *Thysanoessa inermis* (3 sets x 5)

Plus CHN/isotope ratio specimens, a standard species set where found, with some others.

Copepoda	*Calanus hyperboreus* adults or late copepodites (6) *Euchaeta spp.* females (6)
Decapoda & Mysidaceae	Common species, including Sergestiid shrimps and deep water spp.

Chaetognatha	*Sagitta maxima* (6) *Eukronia hamata* (6)
Amphipoda	*Parathemisto spp.* (3)
Fish	Specimens of representative deep water species
Jellyfish	representative species/specimens including *Periphylla, Atolla, Aglantha* and some siphonophores

Plus a number of other species as encountered.

A very preliminary species list for Dual Methot samples is given in Appendix A5.

Ryan Saunders

10.3 Continuous Plankton Recorder deployments

On seven occasions a Continuous Plankton Recorder (CPR) was deployed on passage legs between sites. In the MarProd programme as a whole, historical CPR data are being used to describe a broad background distribution of key zooplankton taxa in the MarProd study region. One of the main reasons for using the CPR on *Discovery* 264 was to enable a comparison of the ARIES and CPR sampling systems. The CPR also provided an opportunity to collect surface samples of *Calanus* and other zooplankton integrated over a greater distance (10 nm per sample) at key locations between sites along the survey track.

The ARIES and CPR systems sample very differently. The CPR samples continuously at 7-10 m depth, at 10 knots, onto a moving roll of 270 μm "fuzzy" silk mesh. The ARIES system collects up to 110 individual 200 μm mesh samples at 2.5 knots with either time (here 4-6 min) or depth-resolved sampling intervals and to depths of 3000 m. Additional aids to data interpretation will be provided by the surface seawater sampling onboard the ship along with the additional ARIES instruments (onboard 60 water sample rosette, Seabird 911 CTD, fluorometer, transmissometer and an Optical Plankton Counter). The CPR also carries its own CTD system.

To enable broadscale description of the zooplankton composition in the area and to allow effective comparisons between gears, the CPR was towed between three pairs of sites where ARIES was deployed, along CPR transects 3, 4 and 7. ARIES tows were located to cover the ends of the CPR tow tracks. To allow suitable catch comparisons with the surface layer sampling, ARIES was towed normally but either only the surface layer was sampled or ARIES was towed for an extended period in the surface layer at the start or end of a deep deployment. The data will allow some comparison of relative catch rates and composition. Also we will be able to consider the extent to which the surface sample description the CPR provides, reflects and records the species abundance and diversity of the whole water column.

During the cruise, the CPR was also towed between sites A1 (just off Iceland) and B8, a distance of 200 nautical miles. This will provide zooplankton data where no other plankton sampling was being undertaken from an on-shelf to off-shelf position (CPR transect 5, Fig 20). In total, the CPR was deployed for 73 hr, and sampled over a distance of approximately 730 nautical miles. In effect we have CPR tows across the top and bottom of the Irminger Basin and down both sides.

The CPR was also towed across the Iceland Basin, from site I (Ocean Weather Station India) to site I3 just east of the Reykjanes Ridge. This is also a very useful dataset that allows comparisons of species assemblages, population abundance and spatial variability between the two areas. We also have the normal ARIES tows at these positions for comparisons. The wide range of sites and species assemblages should allow the gear efficiency comparisons to cover a broad range.

Johanna Sidey

11. Process studies

11.1 Recruitment and mortality of *Calanus* eggs and nauplii

11.1.1 Background

The aims of this project are to explore the demography, mortality and factors controlling the survival of *Calanus finmarchicus* and *Calanus helgolandicu*s. We will use data collected from *Discovery* 264 and other MarProd cruises. In addition high-resolution seasonal studies will be undertaken at the L4 (English Channel off Plymouth) and Stonehaven (western North Sea) sites over the coming year.
Mortality is a much understudied phenomenon, yet it can be more important than the positive terms of growth and fecundity in controlling the distribution, biomass and success of zooplankton. Historically we have many measurements on the positive demographic terms and little on loss rates. During the cruise we examined several key parameters that will aid in determining rates of natural mortality. Our efforts are primarily focussed upon eggs and early nauplii, as these are the most vulnerable stages. Eventually we will use parameters described herein together with stage-abundance data from ARIES and Ocean Sampler to examine field survival and mortality using vertical life table approaches and a modified version of the Peterson and Kimmerer egg mortality equation (A G Hirst & T Kiørboe. 2002. *Mar. Ecol. Prog. Ser*. 230: 195-209).

Below is a brief description of the work undertaken on *Discovery* 264, with some early results analysed on board. Given the early nature of these data, some modifications may take place on completion of analyses.

11.1.2 Parameters examined

Individual female egg production rates

Table 13. Mean egg production rates per female. Standard deviation (SD) calculated from the 15 individuals in each experiment. Chlorophyll *a* values are from the fluorescence maximum (missing values are those not derived on board), as supplied by Dave Wilson.

Site	Date	Incubation temperature (°C)	Mean egg production rate (eggs. fem^{-1}. d^{-1})	SD	Total Chl a ($\mu g. l^{-1}$)
OSI	29/07/02	9.7	15.67	17.88	1.18
I3	30/07/02	9.6	2.31	5.21	1.13
B1	31/07/02	9.2	26.86	31.48	0.99
B4	01/08/02	9.8	15.82	16.38	0.72
DD13	03/08/02	9.7	8.17	11.75	0.71
DD11	04/08/02	9.6	8.45	12.39	0.7
DD9	05/08/02	9.5	26.78	25.70	1.34
DD7	06/08/02	9.4	11.01	15.92	0.62
DD5	07/08/02	9.5	4.86	9.27	0.58
DD3	08/08/02	9.1	1.22	5.94	0.53
DD1	19/08/02	9.2	10.23	13.24	-
D4	22/08/02	9.4	8.80	16.58	-
D2	21/08/02	9.1	10.02	18.59	-
D1	20/08/02	4.5	20.53	19.45	-
C8	10/08/02	9.1	1.63	3.22	1.94
C10	14/08/02	9.1	10.12	11.45	1.44
C9	15/08/02	5.2	10.79	11.25	4.13
C6	16/08/02	5.1	10.72	9.48	-
Stn X	16/08/02	6.1	8.70	14.06	-
C6 day 2	17/08/02	4.5	4.78	6.92	-
H10A	18/08/02	9.3	6.70	7.81	-

At all full sites (as listed in Table 14 above) we collected live female *Calanus finmarchicus* using 1m ring nets from 120 to 0 metres. Animals were rapidly sorted in the constant temperature laboratory at 9.1°C. We incubated 15 adults over 24 hr in individual containers in the dark. These containers have meshed bottoms that allow eggs to settle through but exclude the females, this design reduces egg cannibalism. Water collected from the fluorescence maximum and screened through a 95 μm mesh to remove eggs and nauplii was used as the incubation medium. The 'cold' (4.5°C) or 'warm' (9.1°C) constant temperature rooms were used for incubation – depending upon the CTD temperature profile at the collection site. After 24 hr, eggs were drained off and counted.

Egg development rates and hatch success

At several sites we picked 600-1000 live adult female *Calanus finmarchicus,* subsequently housed in incubation tubes under dim light at ~9.1°C. These 'bulk' females were used to produce eggs for a variety of experiments.

To determine egg hatch rates we collected eggs produced by the bulk females over 1 hour. Groups of 10-20 eggs were incubated in screened seawater in individual cell wells. At regular intervals the number of unhatched eggs were counted. Fig. 21 gives egg hatching profiles under the two temperature regimes examined, 9.1°C and 4.5°C. To explore how eggs integrate temperature, we also moved eggs between these temperatures on a 6 hourly basis, so that they experienced 4.5°C for 6 hr then 9.1°C for 6 hr, and then 4.5°C once again etc (results presented in Fig 21c). Our results suggest that the commonly used "time to 50% hatch" is biased towards the faster developing individuals. Mean time to hatch is superior, as it allows for the clear left skew in hatch-time distribution.

To derive egg hatch success we collected the eggs produced by the bulk females over a single hour. Only bulk caught within 48 hr were used, as longer periods of storage may alter female fertility or egg quality. Eggs were counted and incubated in screened seawater in groups of 10-20 per cell well, and hatch progress was recorded at regular intervals. Hatch success is derived as the percentage of incubated eggs which successfully hatch into NI. On all occasions this value was >80%.

Nauplii development rates

Eggs produced over 12 hr by the bulk females were used to produce an artificial cohort of animals with a very similar age. Of these eggs, 2000-5000 were incubated in 15 litres of fluorescence-maximum sea water. An air-lift system was used to gently move the water and aerate it, whilst avoiding contact between bubbles and the animals. Every 24 hr, 5 litres of this water were removed and replaced with fluorescence-maximum water collected that day. Samples for chlorophyll and microplankton analysis were taken from the incubation vessels at this point. Artificial cohorts were sub-sampled every 8 hr (at 0800, 1600 and 0000) and neutral red added to them. This vital stain allowed us to identify live animals. These were counted, isolated from any dead, and preserved in formaldehyde for later laboratory stage determination. These results should allow us to determine nauplii development rates, an essential term in examining mortality using vertical life table approaches. In one of these cohorts we were very pleased that after 15 days of incubation some individuals reached copepodite stage I. A total of 13 separate cohorts were established and cultured during *Discovery* 264.

Adrian Bunker, Kathryn Cook, Andrew Hirst

11.2 *Oithona* and *Calanus* nauplii studies

11.2.1 Net sampling: *Oithona* spp. and *Calanus* standing stock

The standing stock of *Oithona* and *Calanus* early stages was determined at the main sites and some intermediary sites using material collected by a 63 μm mesh size Bongo net (35 samples) and a single WP-2 200 μm mesh sized net (20 samples) towed vertically from a 120 m depth. The samples

were immediately concentrated by sieving through an appropriate filter and fixed in 4% buffered formaldehyde. The *Oithona* in the samples will be enumerated, sized and staged in the laboratory. Abundance data for *Oithona* will be converted to biomass by means of the length-weight regression reported by M Sabatini & T Kiorboe, 1994 (*J. Plank Res*. 16: 1329-51).

The population structure of *Oithona* and *Calanus* within the Irminger Basin differed with a larger proportion of early copepodite stages and nauplii present in both the Iceland and Greenland shelf sites whereas older stages were found in the oceanic and offshore sites. Unlike in spring, *Calanus* eggs were never found in large numbers. In contrast, *Oithona* spp were generally reproducing well, with most females observed to carry egg sacs. The differences observed in the copepod stage structure seemed strongly associated with different feeding environments. The Icelandic and Greenland shelves were dominated by a very varied and dense growth of diatoms and micro-zooplankton which were absent in the (dinoflagellate-dominated) oceanic areas. We found that *Calanus* females and nauplii had dramatically decreased since the spring cruise and the larger part of the *Calanus* were now represented by the copepodite V stage, particularly offshore. On the other hand, *Oithona spp.* numbers seemed to have increased since the spring and all the stages were well represented at all sites. With regard to the distribution of the different *Oithona* species in the Irminger Basin we found that *O. spinirostris* and *O. nana* were more commonly found in the shelf area, whereas *O. similis* dominated in the oceanic regions.

Other species regularly found were, *Euchaeta sp.* (copepodites), *Calanus hyperboreus, Pseudo-Calanus/Para-Calanus, Microsetella sp*. and *Metridia sp*.

11.2.2 *Oithona* spp. egg production rate (EPR)

Egg production experiments were conducted at a number of sites depending on the availability of copepods. A total of 16 experiments were conducted. Females were gently sampled using a 63 μm net with a small mouth diameter and a large cod end and the catch diluted in a large bucket with water from the non-toxic supply. After collection 3 replicates of 10 females were incubated into tissue culture flasks of 700 ml volume on plankton wheel at the average *in situ* temperatures of 5 ± 0.5°C (Greenland shelf) to 9 ± 0.5°C (Irminger Basin). The water used for the incubation was collected with a CTD at the chlorophyll maximum. The egg production was monitored daily over a 2-4 day period. At the end of incubations the eggs produced were counted, sized and the female cephalothorax length measured for conversion to biomass by means of the length-weight regression (Sabatini & Kiorboe, 1994; reference above).

The egg production obtained from the incubation experiment will be also compared with egg production estimates obtained with the egg-ratio method counting the egg sacs and the number of females extracted from the preserved samples. The *Oithona*'s population specific egg production (SEP day^{-1}) will be calculated from the egg to female ratio (E/F), temperature dependent hatching rate (HR d^{-1}) and carbon content of the eggs and female from:

$$SEP = (E/F)*HR*(\text{egg carbon}/\text{female carbon})$$

Two long-term egg production experiments were also conducted to estimate the inter-clutch duration (i.e. the time elapsing between the production of two successive egg sacs) in oceanic and coastal conditions. Twenty *Oithona sp.* were incubated as described above and their egg production monitored under low power microscope every day or every 12 hr during one spawning cycle. The water in the culture flask was changed every two days.

11.2.3 Grazing and predation experiments

We carried out 17 experiments (see Table 15 below) on the feeding behaviour of *Oithona spp.* and nauplii of *Calanus* with about 150 samples to be counted back in the laboratory. In general we found

four different main food conditions: i) high concentration of mixed diatoms (*Rhizosolenia sp.*) and dinoflagellates (*Ceratium sp.*) on and around the Reykjanes Ridge; ii) high concentration of chain diatoms and ciliates in the Icelandic and Greenland shelf; iii) varying concentrations of dinoflagellates in the oceanic conditions south of Iceland and across the Irminger Basin (transects D and B), and iv) large amount of faecal pellets just offshore from the Greenland shelf.

Table 15. Summary of *Oithona* and *Calanus* sampling and experiments carried out at different sites during *Discovery* 264. A, ARIES; DM, Dual Methot.

Site	Net 63µm	Net 200µm	*Oithona* feeding	Nauplii feeding	*Oithona* EPR	Size fractionated SGR and proteins	*Calanus* growth rate	*Calanus* moulting rate
I	√	√						
I3	√	√	√	√	√	√		
B1	√	√	√	√	√	√	√	
B2	√							
B3	√							
B4	√	√	√		√	√	√, A	
B5	√			√	√	√	A	
DD13	√	√			√	√	√	
DD11	√	√	√	√	√	√	√	
DD10	√							
DD9	√	√				√	√, A, DM	
DD8	√							
DD7	√	√			√	√	√, A	√
DD6	√		√					
DD5	√	√			√	√	√	
DD3	√	√				√	√, A	
DD2	√					√	√, A	
C8	√	√	√	√		√	√, A	√
W2	√							
N1	√	√				√	√	
B8	√					√	√	
C10b	√					√		
c10	√	√	√		√	√	√, A	
C9c	√					√		
C9b	√					√		
C9a	√					√		
C9	√	√	√		√	√	√, A	
X	√					√	A	
C6	√	√			√	√	√, A	√
H10	√					√	√	
DD1	√	√	√		√	√	√, A	√
D1	√	√	√		√	√	√, A	
D2	√	√	√		√	√	√, A	
D4	√	√			√	√		
D5	√	√	√		√	√		
Total	**35**	**20**	**12**	**5**	**16**	**28**	**21**	**4**

We also carried out three experiments investigating the predator-prey relationship between different stages of *Calanus* and *Oithona*. These were 1) *Calanus* females feeding on early *Oithona* nauplii, 2) *Oithona* females feeding on *Calanus* eggs and 3) *Oithona* females feeding on early *Calanus* nauplii. The specimens were collected from 63 µm and 200 µm vertical towed nets (see net sampling) whereas the eggs were collected from *Calanus* females spawned in the laboratory. Three (*Calanus*) to 10 (*Oithona similis*) were incubated into 1 litre glass bottles or 100 ml tissue culture flasks filled

with 0.2 μm filtered sea-water with different preys concentration on a plankton wheel for 24 hours. Preliminary results indicate that *Calanus* can feed on *Oithona* nauplii whereas *Oithona* feeds on *Calanus* nauplii but not on *Calanus* eggs.

11.2.4 *C. finmarchicus* experiments and other studies

Calanus *specific growth rates and gut fluorescence*

Groups of 20 CV, 20 females and 25 CIV were collected from vertical hauls (WP2 and Bongo nets) at every site, when available, and preserved in liquid nitrogen. The activity of the enzymes aminoacyl-tRNA synthetases (ARS) and the protein content of the samples will be assayed in the laboratory to determine the specific growth rate of different stages of *C. finmarchicus* in the areas under study. ARS activity will be determined using the method of L Yebra, 2002 (PhD thesis, Univ de Las Palmas de Gran Canarias) and protein content will be determined following the modification by WR Rutter, 1967 [In: *Methods in developmental biology*, Wilt, FH & Wessel, NK (eds), Crowell Co., New York, pp. 671-84] of the method by PH Lowry et al, 1951 (*J.Biol.Chem*., 193: 265-75). The same samples will be used to determine gut fluorescence of the individuals by extracting Chl *a* and phaeopigments in 90% acetone.

In the same way groups of 20 CV and 25 CIV where collected from the ARIES and Dual Methot (DM) nets (see Table 15) to asses specific growth rates and gut fluorescence of *C. finmarchicus* at different depths.

Moulting rate

Groups of 20 CV collected at different sites were incubated to determine moulting rate and dormancy in oceanic and in shelf areas. Copepodites were stored in 1 litre Duran bottles at the collection temperature and provided with (food-containing) water from the deep chlorophyll maximum (DCM). The developmental stage of the individuals was checked every 24-48 hr.

Growth and development rates

Two experiments were conducted, in the Iceland shelf and in the Greenland shelf, where there was greatest the availability of young stages. 300 CIV where incubated in 30 litres carboys and fed with water from the DCM. Every 48 hours 50 copepodites were sampled and stored in liquid nitrogen for further enzyme and protein analyses in the laboratory. The developmental stage of each copepod was determined before freezing the samples.

Epizooplankton specific growth rates, biomass and feeding

Other upper-ocean zooplankton collected with vertical hauls (see 11.2.1) were size-fractionated (63-200 μm, 200-450 μm and 450-1000 μm) and stored in liquid nitrogen. Specific growth rates, biomass (as protein content) and gut fluorescence will be determined, as explained above, to asses possible interzonal and size structure variations of the epizooplankton in the Irminger Basin.

Claudia Castellani, Lidia Yebra Mora, Josefin Titelman

11.3 Nutritional regulation of egg production of *Calanus*

11.3.1 Introduction

In the North Atlantic, the abundance of *Calanus finmarchicus* is closely linked to the survivorship of many juvenile fish of commercial importance. Food type is known to strongly affect the fecundity of *Calanus*, and recent research has illustrated the importance of nutritional quality over quantity, replacing the classical diatom-*Calanus* link with an emphasis on the role of dietary diversity. Food quality is often described by elemental stoichiometric ratios, but fecundity is not always limited by

the bulk elemental composition (C or N) of the diet. Dietary micronutrients, particularly poly-unsaturated fatty acids (PUFAs) are also important, since they can influence both fecundity and the viability of the eggs and nauplii. By comparing ratios of substrates in consumer tissues and ingested food, and assuming that the component in least supply relative to the demand is limiting, elemental stoichiometry can be extended to micronutrients (eg. fatty acids), providing a more detailed understanding of the animals nutritional requirements. When considering micronutrients, additional attention has to be paid to the possibility that *Calanus* may possess the (limited) ability to synthesise certain micronutrients, rather than obtaining them directly from their food.

A key concern of contemporary research is the consequences of global warming. If this causes a change in the timing and speciation of phytoplankton blooms, will the flux of different PUFAs up the food chain be altered, thus influencing the reproductive success of zooplankton and the survival of larval fish? Understanding both the trophic transfer efficiency and the degree to which *Calanus* can synthesise PUFAs will help understand the flow of key nutrients in the marine food web, and ultimately modelling the relationship between phytoplankton, zooplankton and larval fish.

The objectives of this study were:

- To determine the quantity and quality of food consumed when presented a natural diet, and the efficiencies with which C,N and essential fatty acids are used for egg production.
- To understand the relationship between the biochemistry of copepod eggs and that of ingested food. Does the fatty acid composition of the eggs change in response to the availability in food?
- To examine the ability of copepods to elongate fatty acids and thus biosynthesise 'essential' fatty acids (PUFAs).

Sites sampled for main experiments (animals collected on day one):

Day	Experiment 1	Experiment 2	Experiment 3
1	I3	DD9	C9
2	B1	DD7	C6
3	B4	DD5	C6
4	'DAN'	DD3	W3
5	Non-toxic 60° 48'22.10N 29° 19'00.94W	Non-toxic 61° 25'24.26N 39° 39'48.41W	W4

11.3.2 Methods

Animals were collected with a 1 m ring-net (250 μm) from 120 m to the surface (vertical hauls) at various sites on and off the continental shelf. The contents of the cod-end was poured into a 20 litre bucket of sea water (from non-toxic supply), and female *Calanus finmarchicus* were subsequently sorted into groups of ten under the dissection microscope, using a pipette. In addition to experimental animals, replicate samples of females were frozen for later carbon/nitrogen (C/N) and lipid analyses (initial animals).

Water was collected daily from the chlorophyll maximum and placed into a 110 litre polyethylene bin (in bad weather, seawater from the non-toxic supply was used). This was gently 'inverse filtered' (90μm mesh) and siphoned into 14 Duran bottles (2200 ml each) via silicone tubing. Care was taken when moving the water to minimize disturbance (splashing and swilling damages ciliates and other microorganisms). Each bottle was filled a little at a time to ensure maximum homogeneity between bottles. Ten females were placed into six of the experimental bottles (bottles #1-6), with four bottles (#6-10) serving as control bottles to assess the impact of microzooplankton grazing

during the experimental period. All bottles were placed on a water-cooled plankton wheel (1 rev per min) and maintained at ambient temperature and light regime.

At the start of each day, a single (200 ml) sample of the 90 μm 'inverse filtered' water (taken from bottle #14) was preserved in Lugols iodine (10% v/v) for later microzoo- and phytoplankton identification and enumeration (initial plankton). A single 500 ml water sample was filtered onto GF/F filter for chlorophyll extraction in acetone. In addition, six 1000 ml samples were taken (from bottles #11-13) for C/N and lipid analysis (initial C/N and lipid). Each sample was vacuum filtered through a GF/F filter. Filters for lipid analysis were stored in 2 ml vials with solvent (chloroform:methanol 2:1 v/v). All samples were stored at –70ºC.

After 24 hr, females were removed via a dip-tube and placed into bottles with fresh seawater (as above) and returned to the plankton wheel for a further 24 hr. Initial plankton, chlorophyll, lipid and C/N samples were taken every day from the fresh water. The water in each bottle from the previous day was initially 'immersion filtered' (53 μm) to remove eggs and faecal pellets, and then sampled (100 ml) for microzoo- and phyto-plankton (final plankton). Two 1000 ml samples were filtered (GF/F) for C/N and lipid analysis (final C/N and lipid). Control replicates (bottles 6-10) were sampled in exactly the same format. Chlorophyll samples (200 ml) were taken from two control bottles at the end of each 24 hr period.

Each day, the eggs were pooled and then split for C/N and lipid analyses (stored on GF/F filters and in 1 ml vials respectively). After removing the eggs from the filtrate, the remainder (faecal pellets etc.) was pipetted onto 25mm GF/F filters and frozen for later lipid and C/N analysis. This procedure continued for 5 days. At the end of the experimental period, half the animals were stored in 1 ml vials with solvent for lipid analysis and frozen at -70ºC, with the remainder frozen in tin capsules for later C/N analysis (final animals). Three complete experimental trials were completed during the cruise. To date, the only conclusion to be drawn from these experiments is that egg production is highly variable, ranging from 11 to 227 eggs per bottle (containing 10 females). It does appear that egg production was higher on the shelf area, but the significance of this is difficult to fully assess without fully processing the samples collected.

To assess the variability of egg production, at the start of the experimental period individual females were placed into 200 ml pots and left for 24 hr. The water was subsequently filtered (53 μm) to remove eggs for counting.

To examine how the food environment changes over 24 hr in response to grazing, a time-series experiment was completed (site D2). In total, 12 bottles were used. Two replicates for individual treatments (6, 12 and 24 hr, 10 females per bottle) and two controls for each time period were used. Experimental conditions were exactly the same as above. Initial and final plankton samples (200 ml) were taken from each bottle and preserved in Lugol's iodine (10% v/v). Initial and final chlorophyll measurements were also made.

A further 24 hr experiment to examine the effect of grazer-density on the food environment was run at sites W2 and B8, using densities of 5, 10 and 20 female *C. finmarchicus*. Three replicates for the controls (no grazers) and for each density were used. Again, all experimental conditions remained the same as above. A 200 ml plankton sample was taken at the beginning and end from each bottle and preserved using Lugol's iodine (10% v/v). This experiment was subsequently repeated at site D5 using four replicates of C5 copepodites at densities of 10 and 20 animals per bottle.

In addition, three replicate plankton samples (100 ml each) were taken at Ocean Weather Station India, and preserved with Lugols iodine at 1, 2 and 10% (total of 9 samples). These will serve to illustrate and compare the differences in preservation quality of the microzooplankton.

Daniel Mayor

11.4 Molecular analysis of *Calanus* populations

11.4.1 *Calanus* community structure

Background

The critical issue to be resolved by the molecular analysis of community structure is the co-occurrence of *Calanus finmarchicus, C. helgolandicus* and *C. glacialis*. These species cannot be reliably separated in mixed samples by optical microscopy except in the adult stages, and then only with difficulty. The presence of *C. hyperboreus* is an added complication for the identification of naupliar and early copepodite stages. Data from NORWESTLANT and more recently in the Labrador Sea and from TASC show that we can expect to find *C. glacialis* and *C. hyperboreus* mainly in the cold East Greenland shelf current, and *C. finmarchicus* and *C. helgolandicus* in the warmer Atlantic waters. We are therefore applying a molecular method for the unambiguous identification of these four species of *Calanus* at any developmental stage, using a robotic molecular biology platform for the majority of the manipulations. This cruise afforded the opportunity to take the robotic instrument to sea, optimising its performance for molecular identification and assessing its suitability for use on future sea-going programmes.

Methods

Animals were collected using the ARIES system, and subsamples of *Calanus* spp. individuals sorted by moult stage and depth. Animals were preserved in ethanol in cryovials with a maximum of 10 per ml. For selected samples each individual was identified to species level according to the RFLP signature of its mitochondrial 16S rDNA, following PCR amplification, restriction digestion and agarose gel electrophoresis, using the method of P Lindeque *et al*, 1999 (*Mar Biol* 133, 91-96).

Additional subsamples of individuals from onboard *Calanus finmarchicus* incubation/culturing experiments were preserved and analysed to confirm the identity of the animals using RFLP signatures. This was particularly important when experiments had been set up using animals from regions containing more than one species of *Calanus*.

Results

Details (station, net/depth, number and stage of individuals) of the subsamples of *Calanus spp*. collected from ARIES, and those analysed on board, are listed in Table 16. Molecular identification of various staged *Calanus* from diverse depths was achieved for 17 stations. Whilst the majority of animals identified to date were *C. finmarchicus*, RFLP signatures have also shown the presence of *C. glacialis* at stations 14921 (site X) and 14940 (site C6). Further identifications to be performed back at the laboratory will give a better indication of the extent of *C. glacialis* distribution.

Samples taken from net hauls used for the onboard *C. finmarchicus* incubation/culturing experiments were shown to contain *C. hyperboreus*, but importantly all animals taken from the incubation experiments for which *C. finmarchicus* adult females had been selected by microscopy were shown to be *C. finmarchicus* by RFLP analysis.

A considerable amount of time was spent optimising the RFLP methodology such that the reactions could be performed on the robotic workstation. Whilst this has not been totally achieved, a significant proportion of the method can now be performed in 96 well plates in an automated manner. Completion of the automation process will be performed at PML. We have also shown that the MWG Roboamp 4202 is a suitable platform for shipboard analyses.

Table 16. Samples of *Calanus* spp collected for molecular analysis

Date	Station	C III	C IV	C V	Female adults	Male adults	Analysed on board
29.08.02	14690 - 077		1 x 10	2 x 10			1*10 CV 1*10 CIV
	14690 - 088		1 x 10	1 x 10			1*10 CV 1*10 CIV
30.07.02	14709 - 061		1 x 5	3 x 10			1*10 CV 1*5 CIV
	14709 - 074		1 x 10	2 x 10			1*10 CV 1*10 CIV
31.07.02	14723 - 028			3 x 10	1 x 3	1 x 10	1*10 CV 1*6 CV 3*females
	14723 - 032		1 x 10	1 x 10			1*10 CV 1*10 CIV
01.08.02	14741 - 057			2 x 10			1*10 CV
	14741 - 063		1 x 9				1*9 CIV
	14741 - 064			1 x 10			1*10 CV
	14741 - 076		1 x 10	2 x 10			1*10 CIV
02.08.02	14753 - 045		1 x 10	2 x 10			
	14753 - 048	1 x 5	2 x 10	2 x 10			1*5 CIII
	14753 - 035			2 x 10			
	14753 - 039			1 x 10			1*10 CV
03.08.02	14769 - 049	2 x 10	1 x 10	1 x 10	1 x 10		1*10 CIII
	14769 - 035			1 x 10			
04.08.02	14785 - 069				2 x 10	1 x 5	1*10 females 1* 5 males
	14785 - 066			1 x 10			
	14785 - 055			3 x 10 *			1*10 CV
	14785 - 054			1 x 10			
05.08.02	14800 - 053			2 x 10			1*10 CV
	14800 - 058			1 x 10			
	14800 - 066			2 x 10			
06.08.02	14816 - 075		1 x 10	2 x 10			1*10 CIV 1*10 CV
	14816 - 065			1 x 10	1 x 4		4 females
	14816 - 068			1 x 10			
07.08.02	14831 - 064			1 x 10	1 x 10		
	14831 - 065			1 x 10	1 x 10		
	14831 - 074			2 x 10			1*10 CV
	14831 - 070			2 x 10			No ethanol
08.08.02	14846 - 087			2 x 10	1 x 10		1*10 CV
	14846 - 078			1 x 5	1 x 8		
	14846 - 097			2 x 10			
10.08.02	14867 - 071			1 x 10			
	14867 - 070		1 x 10	3 x 10			1*10 CV
	14867 - 082			1 x 10			
	14867 - 084			1 x 10			
14.08.02	14885 - 021		1 x 10	1 x 10			
	14885 - 001			2 x 10	1 x 10		1*10 CV
15.08.02	14906 - 028		1 x 10	2 x 10			
	14906 - 036	1 x 10	1 x 10	2 x 10			1*10 CIII 1*10 CIV 1*10 CV
	14906 - 021			2 x 10			
15.08.02	14921 - 011			2 x 10			2*10 CV
	14921 - 022			2 x 10			2*10 CV
16.08.02	14940 - 014	1 x 10	1 x 10	1 x 10			1*10 CII 1*10 CIII 1*10 CIV 1*10 CV
	14940 - 021			1 x 10			1*10 CV
17.08.02	14955 - 060			1 x 10			1*10 CV
	14955 - 072			2 x 10	1 x 10		2*10 CV
	14955 - 053		1 x 10	1 x 10			1*10 CV
19.08.02	14969 - 075			2 x 10	1 x 10		
	14969 - 063		1 x 10	2 x 10	1 x 6		8 CV
20.08.02	14994 - 032			3 x 10			
	14994 - 028		1 x 10	3 x 10			

Date	Station	C III	C IV	C V	Female adults	Male adults	Analysed on board
21.08.02	15000 - 100			1 x 10	2 x 10		
	15000 - 086			3 x 10			
	15000 - 002			2 x 10			
	15000 - 016			2 x 10			
21.08.02	15015 - 040			2 x 10			
	15015 - 027			1 x 10	1 x 10		
	15015 - 036			2 x 10			
23.08.02	15027 - 020			2 x 20			
	15027 - 035		1 x 10	1 x 10			
	15027 - 034		1 x 10	1 x 10	1 x 10		

11.4.2 Embryonic gene expression in *Calanus finmarchicus*

Background

The study of developmental genes is critical for understanding how an organism makes itself and the control mechanisms which operate during the development process. Study of such genes in terrestrial organisms (vertebrate and invertebrate) has been both intense and fruitful, but to date little work has been done on marine species. We have been studying embryonic gene expression in the marine copepod *Calanus* to investigate the effect of environmental factors on embryo development, particularly the first 24 hours. In spring 2002 we participated in a PML cruise (*Discovery* 261) to the Celtic Sea, focussing on the physical and biological changes associated with the spring bloom, and used that platform to study changes in embryonic gene expression in *C. helgolandicus* during the development of the diatom bloom. On *Discovery* 264 we investigated whether the systems developed for the investigation of early development in *C. helgolandicus* can be transposed to *C. finmarchicus*. Given the high degree of conservation of developmental gene structure throughout the animal kingdom the likelihood of such a transposition is high.

Methods

To study gene expression in early embryos, eggs must be collected for 24 hr in 4 hr cohorts (from 0000-0400, 0400-0800, 0800-1200 … 2000-2400). *Calanus* adults were collected with a vertically hauled (120 m to surface) 1 m ring net (250 μm) and the animals washed from the cod end into a bucket. Animals were transferred immediately to the constant temperature room (9^{o}C) for sorting.

Adult female *C. finmarchicus* were identified by microscopy (the identity of a representative sample was later confirmed by RFLP analysis) and incubated for 12 or 24 hr in filtered sea water (95μm) for egg production and mortality studies (see 11.1 above). Females (between 380 and 800 in number) were then placed in 200 μm mesh bottomed plexiglass tubes in 5 litre beakers of filtered (53μm) seawater. Females were transferred in their plexiglass tubes every four hours into clean beakers of filtered seawater and the eggs remaining in the beakers were further incubated at 9^{o}C. After 24 hr all age classes of developing eggs were homogenised in RNA lysis buffer and stored at -70^{o}C.

This was repeated twice, at sites I3 and DD13. At DD13 preparation for both total RNA extractions and solid phase cDNA library constructions were performed. RNA extractions will be processed further for the quantitative analysis of embryonic gene expression with real-time PCR. The expression of developmental genes by real-time PCR will be compared to gene analysis ascertained by solid-phase cDNA libraries. In addition, using animals collected from DD11 and pre-incubated as above for egg production and mortality studies, eggs laid over 24 hr were collected as a single cohort and processed in RNA lysis buffer. This sample will provide the basis of the construction of a 0-24 hour *C. finmarchicus* cDNA library for the future cloning of embryonic genes in this species.

11.4.3 Changes in gene expression associated with 'diapause' in *Calanus finmarchicus*

Background

Diapause is a developmentally-programmed form of dormancy, prevalent (and relatively well-studied) in insects, which involves specific physiological and behavioural preparations that take place before the arrival of hostile conditions. There has been little work on marine organisms, and the controls governing overwintering for *C. finmarchicus* remain unclear. Nevertheless, the over-wintering phenotype has some similarities with interrupted life stages of other organisms, such as diapause in insects, hibernation of mammals, overwintering in vertebrates, the dauer larval stage of *Caenorhabditis elegans*, sporulation of bacteria and yeast, seed dormancy of plants and perhaps even the G_o stage of the cell cycle. Whether these are examples of a widespread ability of all organisms to wait out adverse environmental conditions or separate, independently evolved life stage strategies is still unknown. Research into the molecular controls of these stages is beginning to indicate that the former is true. Our aim is to determine whether the patterns of gene expression surrounding the overwintering phase of the *Calanus* lifecycle are analogous to the diapause state in insects, and whether genetic similarities exist with interrupted life stages of other organisms. Once the genetic basis of the overwintering phenotype are understood we will be better able to ascertain the mechanisms controlling the onset and break from this critical stage of *C. finmarchicus* life history.

Methods

Regulation of overwintering (diapause) in *C. finmarchicus* was investigated through differential gene expression in animals at varying depths compared to those at the surface. Where the distribution of *Calanus* appeared to be discretely banded, animals were picked out on ice as soon as possible after ARIES was brought onboard. At station 14785 (site DD11) 2 x 15 CV *C. finmarchicus* were picked from net 055 (average depth of collection, 820 m), at station 14846 (DD3) 10 CV were picked from net 78 (1019 m) and at station 15000 20 CV were picked out from nets 93 (370 m) and 86 (720 m). For comparison, surface animals were obtained both from ARIES station 15000 (D2) (net 100, 9.67 m; 20 CV) and from vertically hauled (120m to surface) 1m ring nets at site D2 (20 CV). Immediately after the animals had been picked they were placed in an RNase-free microcentrifuge tube, homogenized in 175 µl SV RNA lysis buffer and stored at -70^{o}C. Samples were transported back to the laboratory on dry ice and used for the preparation of subtractive cDNA libraries for the analysis of changes in gene expression associated with the overwintering phenotype.

11.4.4 Nutritional and endocrine regulation of diapause in *Calanus finmarchicus*

Background

As noted above, an important, yet poorly understood phase in the life cycle of *C. finmarchicus* is during the winter when they enter a resting (diapause) stage and metabolic processes are considerably reduced, or entirely suppressed. However, possibly as a consequence of the difficulties of recreating an open ocean environment in the laboratory, the specific cue(s) that regulate the initiation and termination of diapause in *C. finmarchicus* are unknown. A simple model of the allocation of energy reserves into various metabolic processes has suggested that *C. finmarchicus* must accumulate a critical threshold of lipid storage reserves before entering diapause. These lipid reserves are necessary to fuel vertical migration, moulting and gonad formation, and an analogous situation is well documented for insects, which must accumulate sufficient glycogen energy reserves before diapause can be initiated. In higher organisms, the endocrine system regulates a broad spectrum of biochemical and physiological processes, including diapause. Although practically nothing is known about the endocrinology of marine calanoid copepods, it seems probable that development in *Calanus*, in line with other crustaceans, is regulated by ecdysteroids. It is necessary to obtain fundamental information about edysteroid levels and action during development because this information does not exist for any copepod species. This may then be used as a basis to assess the role of ecdysteroids in diapause.

Methods

Animals were collected from vertical net hauls (0-120m, 1m ring net) and microscopically sorted according to stage. Batches of animals were stored in 4 ml methanol in screw top glass vials. In general, animals were preserved in batches of 50 for hormone (ecdysteroid) analysis, or batches of 10 for lipid analysis. Further bulk samples were collected by filtering through a 500μm mesh and transferring the bulk plankton plug to a GF/F filter in a small petri dish. The sample was then frozen at -70^{o}C for transport back to the laboratory.

Pennie Lindeque, Gary Smerdon

11.5 Microplankton CN and stable isotope studies

11.5.1 Total CN samples

Following the protocol employed on cruise *Discovery* 262, water samples (1-2 litre) were collected from Niskin bottles on the CTD and used to determine total CN. Most full sites were sampled, as follows:

C N	Sites sampled
Total	I, B1, B4, DD13, DD11, DD9, DD7, DD5, DD3, DD2, C8, B8, C10, C9, CX, C6, C6a, H10a, DD1, D0a, D1, D2, D3, D4, D6
Filter Fractionated	I, B1, B4, DD13, DD11, DD7, DD3, DD2, C8, B8, C10, C9, C6, H10a, DD1, D0a, D1, D2, D4, D6

Each sample was filtered through a 25 mm pre-ashed GF/C filter. Filters were placed in 1.5 ml microcentrifuge tubes and frozen (-20^{o}C). Samples will be dried and analysed for total particulate CN and stable isotope ratio (^{13}C:^{12}C and ^{15}N:^{14}N) at Swansea using a Europa 20:20. On *Discovery* 262, standard depths of 5, 25, 50, 75, 100, 150, 300 and 600 m were sampled. On this cruise light levels established by the lowered FRRF determined sampling in the surface 100m layer. These 1 litre samples will allow the CN data to relate directly with measurements for chlorophyll, filter fractionated chlorophyll, HPLC pigments and primary production. Generally we sampled the 50, 10, 1 and 0.1% light levels with occasionally other depths to allow for good comparisons with other and previous data. Samples of 2 litre at 100, 150, 300 and 600 m were collected as per the spring cruise.

11.5.2 Filter fractionated CN samples

At a subset of stations (see above), 10 litre water samples for filter fractionation were collected from 5 m, or the 50% light level, and from the lower part of the chlorophyll maximum layer. The 5 m water samples were always collected from the 'physics' CTD whereas the chlorophyll maximum samples were at times collected from the 'experimental water collection' CTD. Water samples were separated into 200-95, 95-45, 45-20, 20-10 and <10 μm size fractions using appropriate sized sieves/mesh (200, 95, 45, 20, 10 μm). Water was gently siphoned through the sieves and great care was taken to avoid damage to organisms and to prevent dust contamination. Particles collected on the sieves were rinsed using GF/F filtered sea water and filtered through a 25mm pre-ashed GF/C filter. Filters were then placed in a microcentrifuge tube and frozen (-20^{o}C). Samples will be dried and analysed for total particulate CN and stable isotope ratio (^{13}C:^{12}C and ^{15}N:^{14}N) back in the Swansea laboratory using a Europa 20:20.

Ryan Saunders, Steve Hay

12. Mechanical systems

12.1 ARIES, Ocean Sampler and Dual Methot net deployments

The 20 t winch system was used with the trawl wire for deployments of ARIES, the Ocean Sampler and Dual Methot nets. This winch system operated without problems for the duration of the cruise.

The cable haulers wheels were found to be slipping during the early part of the cruise causing a problem when paying out or hauling in wire on deck and when the deployed package was close to the surface with little outboard tension on the wire. It was found the groove in the wheels had worn deeper allowing the upper and lower wheels to contact each other and hence not grip the wire fully. The problem was rectified by skimming the outside diameter of the wheels.

The trawl wire was re-terminated twice during the cruise. The first time, 160 m of cable were cut from the trawl wire to remove a damaged section near the outboard end and cable worn by the cable haulers. The second time to remove a section which had "cats pawed" on recovery of ARIES when the load was taken off the wire. It is believed the cable twisted during the deployment due to the swivel fitted not rotating freely when under load. Gunebo type swivels were fitted for subsequent deployments.

A 2 t deck-mounted winch fitted inside the hanger allowed ARIES and the Ocean Sampler to be winched along the deck and stored in the hanger space. The units were pulled out onto the aft deck using the main warp. Two plastic tubes were bolted to the deck to form guides to prevent sideways movement of the equipment on the aft deck. This system worked satisfactorily throughout the cruise.

The aft gantry operated without problems for the duration of the cruise.

12.2 CTD deployment

The 10 t winch CTD storage drum system failed during the mobilisation of the cruise. This was traced to the electronic back tension control unit (TCS unit). The spare TCS unit on board was found to have a software problem and was unusable. The TCS unit was removed completely and the system PLC was re-programmed so that the back tension could be controlled purely mechanically by adjusting hydraulic relief valves. After a couple of trial CTD deployments to carry out running adjustments the winch operated satisfactorily. The winch system operated without further problems for the remainder of the cruise.

Problems were experienced with the CTD wire caused by the package spinning during some deployments. This caused the wire to become twisted / kinked and have its strands opened up after recovery of the CTD. The wire had to be cut back to remove damaged sections, re-terminated, and the new termination load tested several times during the cruise.

The starboard gantry operated without problems for all deployments.

12.3 TEK and LEK deployments

The TEK was towed from the starboard side using a bulwark-mounted davit just forward of the starboard gantry. A 5 t deck winch with a modified Schatt davit (height increased) mounted on the aft deck was used to lift the package into the water. A wire ran from the winch through two snatch blocks and through the davit sheave. The operation of the davit required a considerable amount of effort to swing it over the side of the ship. It was discovered towards the end of the cruise the davit was actually installed 1 m further aft than the previous cruise creating more of a pull on the wire against the movement of the davit.

The LEK was deployed over the starboard gantry hanging block using a 5 t deck-mounted winch and 10 t GPC level wind system (operated manually). The LEK was mounted on a railway system to allow it to be moved under the gantry as required. Brackets were welded to the trolley during the cruise mobilisation to locate the LEK frame and prevent it from moving in heavy seas. The winch was initially positioned to far aft causing the wire to foul the top of the level wind carriage. The winch was repositioned and further deployments carried out without problems.

12.4 Other gear deployments (plankton nets, FRRF and CPR)

Several types of plankton net were deployed using the starboard gantry mounted winch fitted with Kevlar rope. The winch and gantry operated satisfactorily for the duration of the cruise.

The FRRF was deployed using the same method as the plankton nets. No problems were encountered during deployments.

The CPR was deployed using a 0.5 t deck winch mounted on the port aft deck with the towing wire passing through a sheave on the aft gantry extension arm. No problems were encountered during deployments.

12.5 Non-toxic water system and Millipore water purifier

The non-toxic system was run on one pump throughout the cruise without problems. An RO12 Plus MilliQ 185 system was set up in the constant temperature lab. Apart from a pre-filter change the system required no maintenance during the cruise.

Terry Edwards, Jonathan Short, Richard Phipps, Gary Seville, Alan Sherring

13. Shipboard computing and communication systems

13.1 Data logging

Data were logged using the ISG ABC System. The Level A system collects data from individual pieces of scientific equipment and time stamps them before passing them along RS232 lines to the Level B. The Level B collects each of the Level A SMP (Ship Message Protocol) messages and writes them to both a hard disk drive and a quarter inch cartridge tape. It also monitors the frequency of the messages and warns the operator when messages fail to appear. The Level B outputs a single data stream across the 100baseT network which is grabbed by the Level C. The Level C system takes these messages and parses them into data streams, allowing further processing to be performed on the data using the Level C's own or the Pstar suite of processing software

The following list shows the data collected on *Discovery* 264:

Chernikeef Log	LOG_CHF	MkII Level A
Ships Gyro	GYRONMEA	MkII Level A
Trimble GPS	GPS_4000	MkII Level A
Ashtec ADU	GPS_ASH	MkII Level A
Ashtec Glonass GPS	GPS_GLOS	MkII Level A
Echo-sounder (10Khz)	EA500D1	MkII Level A
(12Khz)	EA500D2	MkII Level A
G12	GPS_G12	MkII Level A
Winch	WINCH	SEG PC
ADCP	Level C direct log	ADCP PC
Surface Logger	SURFMET	SIG PC

Problems during the cruise:

- The GPS_ASH Level A (logging data from the Ashtec ADU GPS system) failed resulting in the data being time stamped with the same time for several hours. The Level A was replaced and the data was adjusted using the GPS's own time stamp.

- There were several crashes of the Level B in the early part of the cruise which lost approximately five minutes of data each time. The problem was traced to the quarter inch cartridge tapes, these were replaced and there were no more problems.
- The Fugro SeaStar G12 GPS system continued to suffer problems relating to its power supply, which was replaced at the beginning of 243. The problems appear to be thermal in nature and a workable solution was not found on board. For this reason the Trimble 4000DS GPS system was used as the primary source of navigation for much of the cruise.
- The HP2000C failed early in the cruise due to faulty printer cartridges, colour printing was switch to the HP1200 which operated well for the duration of the cruise.

13.2 Email system and radios

The e-mail system is a Linux/Samba based system newly installed at the beginning of *Discovery* 263, due to this fact there were a number of teething problems during the cruise. These problems were satisfactorily solved and the system appeared to work adequately.

The new radios gave no problems during the cruise.

13.3 Data processing and data problems

The GDD Pstar team did the majority of physics data processing. The Level C plotting suite was used extensively to produce annotated plotting sheets showing the GEBCO depth contours. True wind data was produced using 'windcalc'.

Depths corrected for Carter's area were produced from an edited file of EA500D1 and D2 data.

Raw depth data existing on ea500d2 data stream interrupted by the use of the pinger on the CTD. After the failure of the 12kHz PES system the data stream was switched to EA500D1. These data have been integrated into a single stream and corrected for Carters Area into the 'prodep' stream.

13.4 Dartcom satellite system

The Dartcom system was used daily with the ship's met data to predict coming weather.

Jonathan Short

14. Satellite imagery: SeaWiFS and AVHRR

Although fully cloud-free days were uncommon during *Discovery* 264, sufficient SeaWiFS coverage was obtained to show the basin-wide patterns of primary production and their changes. Chlorophyll *a* monthly composites for July and August 2002 depict the main spatial and temporal features relating to phytoplankton abundance over the period of the cruise (Fig. 22). Before the cruise the highest production was focussed in the Iceland Basin, but during the cruise became more widely distributed near to Greenland and in the south of the region. A rare break in the clouds on 5 August revealed both the dynamic physical processes and the biological variability they control (Fig 23; showing SST, chlorophyll and true colour).

Chlorophyll *a* concentrations were calculated using the OC4 algorithm (Reilly 2000); for additional background see www.npm.ac.uk/rsdas/ and www.npm.ac.uk/rsdas/projects/marprod/. Both composite and single-day images were processed at Plymouth, geo-referenced and provided in near real-time to *Discovery*. In addition, AVHRR (Advanced Very High Resolution Radiometer) imagery was used to

estimate: i) sea surface temperature, SST and ii) sea-ice cover, with emphasis on the eastern Greenland shelf.

Table 17. Chlorophyll-a and SST imagery for Irminger Basin and Iceland Basin, mid-July to end of August 2002

Chlorophyll-a	SST
single days:	single days:
10 July (Jday 191)	28 July (209)
15 July (196)	05 Aug (217)
05 August (217)	09 Aug (221)
08 August (220)	15 Aug (227)
13 August (225)	20 Aug (232)
15 August (227)	
20 August (232)	
composites:	composites:
8-14 July (189-195)	7-13 July (188-194)
13-19 July (194-200)	24-30 July (205-211)
24-30 July (205-211)	26 July-1 August (207-213)
28 July-3 August (209-215)	8-14 August (220-226)
8-14 August (220-226)	

Table 17 above identifies the SeaWiFS and AVHRR images providing reasonably good coverage for chlorophyll *a* and SST (in addition to monthly composites, for July and August). Future users of the SST images should note that their colour scales may have been adjusted between images, to enhance the visual representation of the structures present.

Peter Miller, Gareth Mottram, Kate Evans-Jones, Steve Groom
(Plymouth Marine Laboratory)

APPENDICES

A1. Diary and station information

A1.1 *Discovery* 264 cruise narrative

Thursday 25 July 2002 (Julian day 206)
Bunkering continued at 07:00 (BST). We sailed at 13:00 and were at anchor off Arran in Brodick Bay by 15:00. Echosounder calibration commenced after a seawater temperature measurement had been obtained from the non-toxic supply: the usual pre-calibration CTD cast was not possible due to a winch problem. TEK calibration proceeded well.

Friday 26 July (207)
Echosounder calibration ended at 01:30 with the detection of a leak in the LEK housing. Tests on the CTD winch commenced at 06:00. There was a meeting to confirm the CTD water volume requirements of the various science parties at 10:00, followed by a muster and boat drill at 11:00. We departed Brodick 11:30 for net test deployments, TEK tow trials and further CTD winch tests. By 13:00 the winch tensioning problem had been fixed but a problem with the balance between motors that had been apparent on the previous MarProd cruise (*Discovery* 262) recurred. A 200 m cast was required to allow work on this problem and so, after receiving LEK spares and a balance from the Ayr pilot boat at 17:15, we set sail towards the closest water of this depth (56° 13' N, 9° 10' W) on the transect to OS India.

Saturday 27 July (208)
Speed was reduced to 8 knots from 06:15 until 09:00 to enable ADCP calibration. We arrived at 200 m depth contour at 09:45 for CTD winch work. Work was completed with the winch operating satisfactorily by 10:30. After a PES fish test, we continued towards OS India. A cruise-track planning meeting was held at 14:00. The outcome of this was that we would attempt to occupy sites in the following order: India, I3; B1; B4; DD13; DD11; DD9; DD7; DD5; DD3; C8; C10; C9 proceeding on shelf (ice permitting); C6 remaining on shelf to Original 11, DD1 remaining on shelf to Cape Farewell and then out along line G [Note that DD sites were originally called D on *Discovery* 262, but subsequently relabelled]. The merits of this approach were: line DD would be surveyed early in the cruise (low risk); multiple 5-day occupations of "ridge", "ocean" and "shelf" environments could be achieved; sampling in the south of the Irminger Basin would be possible; and there would be 65% reoccupation of *Discovery* 262 process sites.

Sunday 28 July (209)
Ship time was altered to GMT at 02:00. A talk explaining the objectives of the cruise and of MarProd generally was given to some of the ship's crew at 10:30. The CPR was deployed at 11:30. The TEK was deployed at 20:00 for further tow tests. We arrived at OS India at 22:00 and commenced shake-down station activities with the Ocean Sampler.

Monday 29 July (210)
OS India activities were completed at 16:00. The on-site time became extended because, due to the steeply sloping bathymetry and the ship's movement, water depth increased from 1700 to 2700 m by the time of the ARIES deployment. We then proceeded towards site I3. The CTD wire had to be re-terminated overnight after twisting on recovery at the end of the full depth cast.

Tuesday 30 July (211)
We arrived at site I3 at 09:00 with the sea continuing to be calm. Station sampling commenced early, but within the bounds of 24 hr repeatability acceptable to the process experiments. The CTD wire had again to be re-terminated after twisting on recovery. Station sampling was completed by 22:45.

Wednesday 31 July (212)
An intermediate CTD station half way between I3 and B1 was occupied at 03:45. We then continued on towards site B1 at 05:40, with passage-time becoming extended because of the need of the ship's engineers to reduce speed to 4 knots for about 30 minutes. We arrived at B1 at 10:00. B1 was completed by 20:00 and we

proceeded towards B2 to undertake intermediate station activities. B2 was reached by 23:00 and work continued with a bongo net for *Oithona*.

Thursday 1 August (213)
The CTD at B2 was completed by 00:40. We then proceeded to B3 for a further intermediate site and began the CTD there at 04:15. An *Oithona* sample was also taken. The PES fish was recovered at 07:00 to replace slipped faring. We arrived at B4 at 09:15 but could not begin sampling immediately because of a problem with the CTD winch. B4 was completed by 00:30

Friday 2 August (214)
After B4 we proceeded westwards to B5 for the last CTD cast on line B, which was completed by 07:00. The distance between line B and line DD (approx. 150 miles) meant that it was not possible to reach the first DD site in time for full coverage today. The opportunity was therefore taken to carry out ARIES / CPR comparisons. After a CTD at 10:00 (site W1; 21 miles from B5; timed to provide water for experimentalists on the usual 24 hr cycle) ARIES was deployed at 11:30 (half an hour on from W1) for a near-surface tow. After this tow (13:30) we returned up the track of the ARIES tow and deployed the CPR to fish back over the ARIES track. The CPR tow continued towards E13 until 20:30 when the required 60+ miles had been sampled. At this point we returned 5 miles back up track to deploy ARIES for the second part of the comparison. ARIES was deployed at 21:30 and towed for 4 hr.

Saturday 3 August (215)
Following recovery of ARIES we relocated to the ARIES deployment point and deployed the CPR. The CPR was recovered at 08:30 and, after relocating back 5 miles, ARIES was deployed for the final part of the ARIES/CPR comparison. The ARIES tow ended at 10:45 but, because our speed during the previous CPR tow had been less than the planned 10 knots (due to fog and the Irminger current), we were approximately 40 miles from site DD13. Passage to DD13 took several hours, and we did not start station work until 15:00.

Sunday 4 August (216)
DD13 was completed by 01:30. We relocated the remaining 15 miles to D12 (15 miles of the 30 mile passage had been made during the net tows) for an intermediate CTD. Following this CTD we relocated a further 30 miles to site D11. The usual suite of activities began at 08:30 and vertical deployments included the LEK for the first time since its repair. By 16:30 when the ocean sampler was deployed the wind had increased to approx. 30 knots from the north. Tows were therefore conducted in a northerly direction.

Monday 5 August (217)
Site DD11 was completed by 00:30. A CTD was then carried out at DD10 (completed by 06:30) and, following an *Oithona* net, we continued to DD9 where sampling began at 09:45. Station activities were easier today as the wind had calmed considerably. Problems with the LEK prevented its deployment and the time thus save was allocated to an additional night-time DMK; previous DMK tows had not been in complete darkness and there was a belief that nets fished in darkness may result in a different catch composition.

Tuesday 6 August (218)
The dark DMK sample was fished from 01:15 until 03:00, after which we steamed to DD8. Depth there was 3000 m and the CTD did not finish until 08:00. Relocation to DD7 took a further 3 hr and station activities began at 11:15; the usual suite of activities were conducted at DD7.

Wednesday 7 August (219)
The ARIES tow at DD7 was finished by 03:30, after which we steamed to the intermediate CTD site DD6. The CTD and bongo netting at DD6 were completed by 07:30, at which point we moved on to DD5. Station activities at DD5 began at 09:45 in very calm seas.

Thursday 8 August (220)
The ARIES tow at DD5 was completed at 01:30, following which we relocated to DD4. The CTD at DD4 was completed at 05:15 and we arrived at DD3 at 08:00, again in very calm seas. Bongo nets were fished for *Oithona* since it was too early for the chlorophyll max CTD. A fault in the sea cable subsequently delayed the deployment of the CTD but, nevertheless, the water sample was obtained by 11:45.

Friday 9 August (221)
The ARIES tow at DD3 was completed by 00:45. We then steamed to DD2a, completing the CTD there by 04:30. After passage on to DD2 we were in position to deploy the CTD at DD2 by 07:00 but a cable twist required re-termination. In the time needed to re-terminate the wire, we relocated to 40°W (10 miles) to deploy the first met buoy. This was deployed at 10:30 and we then returned to DD2. At DD2 the CTD wire was veered 1000 m with a large weight and swivel attached in an attempt to unwind twists. This completed, a shallow CTD cast was made, followed by bongo netting followed by a full depth CTD. There was a fire muster / boat drill at 16:15. Station sampling was completed by 05:30, at which point we began the steam north to C8.

Saturday 10 August (222)
During the passage north to C8 we passed over a filament of cold water. We arrived at C8 at about 08:30 and proceeded smoothly through the usual sequence of station activities. The ARIES tow was completed by 22:00 and, after recovering the two PES fish, we turned for Keflavik for personnel to disembark.

Sunday 11 August (223)
We stopped at 10:00 in order to collect water from the chlorophyll max layer required for ongoing copepod incubations. The station (W2; w = water) lay approximately on sampling line B. On station we also took the opportunity to fish vertical nets briefly for *Calanus* and *Oithona*. We left the station at 11:00, proceeding onward to Keflavik.

Monday 12 August (224)
We arrived off Keflavik at 08:00, recovered the TEK and proceeded closer inshore to meet the pilot boat. The boat transfer (for Link, Rourke and Titelman) was completed by 10:30 and we headed back out to sea, stopping at the 100 m line (at about 12:15) to take vertical net samples. We completed these by 13:15 and departed for B8, deploying the CPR as we left.

Tuesday 13 August (225)
We arrived at B8 at 09:30. Station work was completed by 14:00 and we departed for the mid-point between B8 and C10 (C10b). We arrived at C10b in worsening weather (force 8 from NW) at 18:00. Work at C10b was completed by 21:00 but we were required to remain hove to while the CTD was sampled. At 21:15 we set off for a point 15 nautical miles downwind of site C10, with the intention that the horizontal nets would be towed in to the site, arriving more or less on station by the time the vertical activities were to begin.

Wednesday 14 August (226)
The first net tow (DMT) began to the south east of C10 at around 01:00. Netting activities were completed at a point just 1 mile to the north of C10 by 09:00. After relocating to the site, vertical work began at around 09:30. It was apparent from the full-depth CTD that the Denmark Strait deep water was still present at this longitude and so a series of three intermediate sites (C9c, C9b, C9a), each progressively a further 8 miles to the west, was set for the passage between C10 and C9 in an attempt to try to find the boundary of this water. C9c was occupied by 15:00 and completed by 17:30; C9b was occupied by 18:30 and completed by 21:00. The position of C9a was modified on the basis of observations at the previous two sites; its position became as close as was possible for the ship to maintain the 850 m contour. The site was occupied by 21:45 and completed by 23:45.

Thursday 15 August (227)
From C9a we relocated to a point 8 miles south of C9 (the first full on-shelf site), such that the horizontal net tows would be completed near the site itself, minimizing relocation time. The DMT to the south of C9 began at 02:00. Horizontal tows were completed by 06:30, allowing sufficient time for an additional CTD on the C10 – C9 section, this time at 350 m. That CTD cast was begun at 07:45 and we left the site at 08:45 to return to C9 (10 miles west) for the vertical component of the full site. Station work, including a LEK deployment, was completed by 15:15 and, following this, we set off for site X. The weather was clear, sunny and calm, and our passage took us close to a number of icebergs. The mountainous coast of Greenland was visible on the horizon. Work at X began with the DMT at 20:50, which was followed by an ARIES deployment at 22:50 into the sunset.

Friday 16 August (228)
Work at X was completed by 03:00 and we steamed south towards C6. Speed was reduced to 5 knots during night darkness as a precaution against collision with ice. We arrived at C6 and began work at 09:45. The station activities were completed by 21:30 Because the site tomorrow is distant and off-shelf, and because there is a requirement to collect water on shelf every morning for five days (today is day 2) we planned to a CTD cast at C6 again early tomorrow morning before heading off. This provided about 10 hr for work in the vicinity overnight. A CTD cast was made at 1500 m depth east of C6 and completed by midnight.

Saturday 17 August (229)
After the CTD we relocated back on to the shelf and, at 02:30, made a DMT tow in darkness for comparison with the earlier daylight haul. This was followed by a shallow, five-mile ARIES tow running from a point 5 miles south of C6 en route to H10a. This collected samples for comparison with those to be taken over the same track by the CPR at the start of the passage from C6 to H10a. A CTD cast to sample water from the chlorophyll maximum layer was undertaken at 09:00, followed by vertical zooplankton nets. We then headed off shelf towards H10a, towing the CPR. This site was positioned to be as near as possible to the centre of a zone of high primary productivity as identified from satellite imagery. We arrived at H10a at approximately 17:00, recovered the CPR and deployed the FRRF before relocating 10 miles back up track for the final shallow ARIES deployment of the CPR / ARIES comparison. ARIES was deployed at 18:45, and was followed by the DMT, the OS and a full depth CTD.

Sunday 18 August (230)
The CTD at H10a was delayed after it became necessary to re-terminate the cable. Vertical netting and an FRRF deployment were carried out during the re-termination time, and the CTD was eventually completed by. We then steamed towards W3, the nearest on-shelf location, to collect the morning's water and net samples. Passage to W3 was hindered by dense fog and icebergs and, at 16:30 with the need for a water sample becoming ever more pressing, we opted to stop short of the site to sample. The station was in approximately 500 m. After this we headed for DD0 but at 18:30 came upon a band of ice and had to turn east. Efforts to progress westwards at slightly lower latitude were unsuccessful. The Arctic Pilot describes Kap Daniel Rantzau, the cape just east of DD0, as "a precipitous headland … under which at times the ice becomes closely packed". At 23:00 we deployed the DMT on the line between DD0 and DD1 (which was just 15 miles east) and towed towards DD1 with the expectation that netting should finish at this off-shelf site. Given the lateness at which on-shelf water was collected today, we should be able to complete the offshore site and return to the shelf to collect water tomorrow inside the 24 hour limit – ice permitting.

Monday 19 August (231)
We were at DD1 for the FRRF at 07:20 and the full depth CTD was begun at 07:45. Station activities were completed by 13:00 and we steamed south west for the shelf. The coast was visible in the distance but, as we approached, the fog and ice, which had prevented access to the shelf yesterday, again became apparent. The TEK was recovered at 16:00 because of very poor visibility and the presence of ice. It became obvious that we would be unable to reach the shelf and, at 16:45 we stopped to collect the day's water sample (site W4). After this we back-tracked out of the fog and ice and attempted to relocate south for the final on shelf site before the southern-most transect and home.

Tuesday 20 August (232)
Passage south overnight was again hampered by fog. At 05:00 we stopped in about 1800 m of water for a CTD intermediate between D1 and D2 (site D1a). After this, at about 07:30, we turned west to try and get on shelf. Progress was slow with a combination of fog and icebergs, which appeared to be grounded on the shelf break, impeding our passage. However, we reached the 400 m contour by 12:00 and began work at this point, which became D1. The fog thickened during the vertical wire work and by 15:30, when the CTD was inboard, visibility was too poor for towing. We thus moved off to the east to attempt to find better visibility, which we did by 17:00. Net tows were completed by 20:00 and, after a further CTD to collect water from the chlorophyll max and to tests an ADCP, we began the steam to D2 40 miles off. The strategy for the crossing the Irminger Basin was to be alternation between ARIES / netting stations and full depth CTD deployments at 40 mile intervals, with a CPR tow over the middle of the basin that would span two sites without recovery.

Wednesday 21 August (233)
We arrived at D2 at about 02:00. The DMT was deployed first and a CTD problem on ARIES was repaired during that tow. The ARIES deployment was completed by 09:00, although the CTD had flooded and no data were recovered. Furthermore the tow cable was kinked on recovery. In the time needed to strip the kinked wire and reattach the OS, vertical work was undertaken. OS was eventually completed by about 14:30 and we set off for D3 in mounting seas. We reached D3 by 17:00 in deteriorating visibility and completed the CTD by 20:00, following which we left for D4. We arrived at D4 just before midnight and recovered the CPR before commencing station activities.

Thursday 22 August (234)
Work at D4 was completed by about 14:15, but again ARIES CTD data were not obtained. The CPR was deployed for the 90-mile passage to D5, which was completed by 23:00. Because of time constraints neither the DMT nor the LEK were deployed here.

Friday 23 August (235)
We left D5 at 08:00 with all planned activities except the FRRF completed. The FRRF was deferred until the following site (D6) in order to bring the sample more closely in line with a 24 hr cycle from previous casts. We had to slow to recover the PES fish, which had shed cable faring, at 09:00 and arrived at D6 at 12:00. The CTD was completed at 15:00. There was a muster / boat drill at 16:15 on passage to E4 and, shortly afterwards we deployed the second of our two met buoys as we crossed 35°W. We arrived at E4 at 19:00 for the final ARIES deployment, which was completed by 22:30. The Scanmar fish was recovered and the vessel began the long steam home at 23:00

Saturday 24 August (236)
Passage home through building seas and strengthening winds. The TEK was left outboard as conditions were too rough for safe recovery.

Sunday 25 August (237)
Homeward passage continued. The TEK was recovered at 13:30.

Monday 26 August - Tuesday 27 August (238-239)
Homeward passage continued, with packing underway.

Wednesday 28 August (249)
We docked at Fairlie at 08:00.

Andrew Brierley

A1.2 Cruise event log

Table 18. Reference information on sites (sampling locations) and stations (gear casts/hauls) for *Discovery* 264. BE, begin; BO, bottom, EN, end.

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time (GMT) HH:MM	latitude	longitude	Comments
	14676	CTD	BE	26/07/02	06:28	55 35.42N	05 06.10W	Anchored - test
			EN	26/07/02	06:44	55 35.42N	05 06.10W	Anchored - test
	14677	CTD	BE	26/07/02	08:59	55 35.42N	05 06.10W	Anchored - test
			EN	26/07/02	09:14	55 35.42N	05 06.10W	Anchored - test
	14678	OS	BE	26/07/02	13:37	55 34.20N	04 58.50W	test
			EN	26/07/02	14:12	55 32.70N	04 59.20W	test
	14681	TEK	BE	26/07/02	15:00	55 30.50N	04 51.70W	
			EN	26/07/02	15:05	55 30.44N	04 51.55W	LEK failed
	14683	CTD	BE	27/07/02	09:15	56 14.34N	09 11.41W	CTD winch tests
			EN	27/07/02	09:35	56 14.74N	09 11.15W	CTD winch tests
	14684	CPR	BE	28/07/02	11:30	58 07.38N	16 04.43W	
			EN	28/07/02	19:54	58 50.23N	18 24.60W	
I	14685	TEK	BE	28/07/02	20:00	58 50.26N	18 24.83W	
			EN	29/07/02	00:04	59 00.90N	19 02.80W	
I	14686	OS	BE	28/07/02	22.40	58 59.43N	18 58.17W	
			BO	28/07/02	23:06	58 59.97N	19 00.03W	
			EN	28/07/02	23:43	59 00.78N	19 02.45W	
I	14689	TEK	BE	29/07/02	00:28	59 01.18N	19 03.44W	
			EN	29/07/02	09:40	59 12.90N	19 37.53W	
I	14690	ARIES	BE	29/07/02	01:20	59 01.91N	19 05.59W	
			BO	29/07/02	04:18	59 05.92N	19 17.15W	
			EN	29/07/02	06:30	59 09.66N	19 28.08W	
I	14693	DMK	BE	29/07/02	07:32	59 10.39N	19 29.97W	
			BO	29/07/02	08:26	59 11.44N	19 33.83W	
			EN	29/07/02	09:25	59 12.85N	19 37.45W	
I	14694	CTD	BE	29/07/02	10:38	59 13.01N	19 37.76W	all bottles
			BO	29/07/02	10:44	59 13.00N	19 37.73W	20m = chl max
			EN	29/07/02	11:00	59 12.98N	19 37.65W	
I	14695	NETS	BE	29/07/02	11.13	59 12.95N	19 37.64W	1 x 63µm dual bongos
			EN	29/07/02	12.19	59 13.10N	19 37.50W	1 x 200µm, 2 x 250µm
I	14696	FRRF	BE	29/07/02	12:36	59 13.12N	19 37.49W	
			BO	29/07/02	12:39	59 13.12N	19 37.48W	
			EN	29/07/02	12:43	59 13.11N	19 37.46W	
I	14697	CTD	BE	29/07/02	13:27	59 13.19N	19 37.43W	full profile
			BO	29/07/02	14:34	59 13.42N	19 37.09W	
			EN	29/07/02	16:09	59 14.00N	19 36.45W	
I	14698	TEK	BE	29/07/02	16:21	59 14.06N	19 36.59W	
			EN	29/07/02	08:57	59 12.14N	19 35.83W	
I	14699	CPR	BE	29/07/02	16:25	59 14.20N	19 36.93W	
			EN	30/07/02	08:37	60 51.69N	24 35.45W	
I3	14700	CTD	BE	30/07/02	09:16	60 52.41N	24 37.84W	all bottles at 18m Chl max
			BO	30/07/02	09:18	60 52.43N	24 37.87W	
			EN	30/07/02	09:33	60 52.45N	24 38.09W	
I3	14701	V. NETS	BE	30/07/02	9:40	60 52.44N	24 38.10W	2 x bongo 63µm, 2 x 200µm
			EN	30/07/02	11:15	60 52.74N	24 38.14W	3 x live nets 250µm
I3	14702	FRRF	BE	30/07/02	11:17	60 52.51N	24 38.41W	
			BO	30/07/02	11:20	60 52.50N	24 38.41W	
			EN	30/07/02	11:24	60 52.49N	24 38.39W	
I3	14703	CTD	BE	30/07/02	11:44	60 52.42N	24 38.34W	full profile
			BO	30/07/02	12:34	60 52.58N	24 38.15W	
			EN	30/07/02	13:51	60 52.77N	24 37.98W	
I3	14704	TEK	BE	30/07/02	14:04	60 52.58N	24 37.99W	
			EN	31/07/02	02:16	61 16.13N	25 49.84W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
I3	14705	OS	BE	30/07/02	14:47	60	51.56N	24	38.28W	
			BO	30/07/02	15:09	60	50.71N	24	38.96W	
			EN	30/07/02	15:47	60	49.30N	24	40.47W	
I3	14708	DMK	BE	30/07/02	16:40	60	48.22N	24	41.38W	
			BO	30/07/02	17:39	60	45.96N	24	43.32W	
			EN	30/07/02	18:36	60	43.85N	24	44.98W	
I3	14709	ARIES	BE	30/07/02	19:20	60	47.60N	24	42.27W	
			BO	30/07/02	21:05	60	51.04N	24	48.91W	
			EN	30/07/02	22:43	60	54.16N	24	55.71W	
I1a	14712	CTD	BE	31/07/02	03:45	61	15.88N	25	50.44W	full profile
			BO	31/07/02	04:34	61	15.66N	25	50.12W	
			EN	31/07/02	05:40	61	15.63N	25	50.57W	
I1a	14713	TEK	BE	31/07/02	05:47	61	15.63N	25	50.65W	
			EN	31/07/02	09:55	61	40.37N	27	00.36W	
B1	14714	CTD	BE	31/07/02	10:10	61	40.50N	27	00.86W	all bottles at 17m
			BO	31/07/02	10:18	61	40.55N	27	00.95W	yo-yo at bottom
			EN	31/07/02	10:29	61	40.60N	27	01.10W	
B1	14715	NETS	BE	31/07/02	10:45	61	40.75N	27	00.87W	2 x 63µm bongo, 3 x 200µm
			EN	31/07/02	11:25	61	40.81N	27	00.68W	3 x 250µm (live)
B1	14716	FRRF	BE	31/07/02	12:34	61	40.71N	27	00.57W	
			BO	31/07/02	12:38	61	40.71N	27	00.54W	
			EN	31/07/02	12:43	61	40.71N	27	00.49W	
B1	14717	CTD	BE	31/07/02	13:03	61	40.71N	27	00.27W	full profile
			BO	31/07/02	13:22	61	40.66N	27	00.05W	
			EN	31/07/02	14:08	61	40.70N	26	59.54W	
	14718	TEK	BE	31/07/02	14:15	61	40.58N	26	59.45W	
			EN	31/07/02	22:07	61	59.49N	27	45.40W	
B1	14719	OS	BE	31/07/02	14:44	61	39.90N	26	59.15W	
			BO	31/07/02	15:04	61	39.03N	26	58.91W	
			EN	31/07/02	15:44	61	37.18N	26	58.45W	
B1	14722	DMK	BE	31/07/02	16:37	61	40.74N	27	01.28W	
			BO	31/07/02	17:17	61	41.75N	27	03.70W	
			EN	31/07/02	18:00	61	42.88N	27	06.46W	
B1	14723	ARIES	BE	31/07/02	18:33	61	43.79N	27	08.47W	
			BO	31/07/02	19:15	61	45.12N	27	11.24W	
			EN	31/07/02	19:54	61	46.23N	27	13.66W	
B2	14726	CTD	BE	31/07/02	22:59	61	59.20N	27	46.53W	full profile
			BO	31/07/02	23:39	61	58.90N	27	47.09W	
			EN	01/08/02	00:40	61	58.87N	27	47.77W	
B2	14727	NETS	BE	31/07/02	22:15	61	59.57N	27	45.86W	1 bongo 63µm
			EN	31/07/02	22:25	61	59.60N	27	46.08W	
B2	14728	TEK	BE	01/08/02	00:50	61	58.65N	27	47.77W	recover Scanmar fish
			EN	01/08/02	04:00	62	20.97N	28	33.14W	
B3	14729	CTD	BE	01/08/02	04:14	62	20.86N	28	33.01W	full profile
			BO	01/08/02	04:55	62	21.23N	28	32.27W	
			EN	01/08/02	06:04	62	21.64N	28	30.92W	
B3	14730	NETS	BE	01/08/02	06:03	62	21.63N	28	30.95W	1 x bongo 63µm
			EN	01/08/02	06:16	62	21.72N	28	30.62W	1 x 3nets 200µm
B3	14731	TEK	BE	01/08/02	06:24	62	21.76N	28	30.66W	
			EN	01/08/02	09:00	62	38.33N	29	13.71W	
B4	14732	CTD	BE	01/08/02	09:50	62	38.62N	29	15.02W	all bottles 25m
			BO	01/08/02	09:56	62	38.62N	29	14.96W	
			EN	01/08/02	10:10	62	38.56N	29	14.81W	
B4	14733	NETS	BE	01/08/02	10:15	62	38.55N	29	14.81W	2 x 63µm, 3 x 200µm
			EN	01/08/02	12:10	62	38.70N	29	13.28W	3 x live nets
B4	14734	FRRF	BE	01/08/02	12:12	62	38.70N	29	13.22W	
			BO	01/08/02	12:18	62	38.69N	29	13.06W	
			EN	01/08/02	12:22	62	38.69N	29	12.97W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
B4	14735	CTD	BE	01/08/02	12:36	62	38.78N	29	12.76W	full profile
			BO	01/08/02	13:43	62	39.03N	29	12.43W	
			EN	01/08/02	14:57	62	39.23N	29	11.37W	
B4	14736	TEK	BE	01/08/02	15:08	62	39.09N	29	11.03W	
			EN	02/08/02	04:55	62	00.75N	29	59.86W	
B4	14737	OS	BE	01/08/02	15:56	62	38.27N	29	09.31W	
			BO	01/08/02	16:28	62	36.94N	29	08.07W	
			EN	01/08/02	17:04	62	35.13N	29	07.09W	
B4	14740	DMK	BE	01/08/02	17:44	62	34.71N	29	07.62W	
			BO	01/08/02	18:44	62	32.24N	29	07.56W	
			EN	01/08/02	19:37	62	30.01N	29	07.61W	
B4	14741	ARIES	BE	01/08/02	20:30	62	29.21N	29	08.46W	
			BO	01/08/02	22:13	62	25.27N	29	11.79W	
			EN	02/08/02	00:15	62	21.08N	29	16.89W	
B5	14744	CTD	BE	02/08/02	05:13	63	00.97N	29	59.88W	full profile
			BO	02/08/02	06:00	63	01.03N	30	00.38W	
			EN	02/08/02	07:08	63	00.93N	29	59.67W	
B5	14745	NETS	BE	02/08/02	07:13	63	00.90N	29	59.53W	
			EN	02/08/02	07:22	63	00.87N	29	59.30W	
B5	14746	TEK	BE	02/08/02	07:30	63	00.78N	29	59.07W	
			EN	02/08/02	10:02	62	40.17N	29	51.92W	
Dan	14747	CTD	BE	02/08/02	10:18	62	40.17N	29	51.86W	all bottles at 25m
			BO	02/08/02	10:21	62	40.14N	29	51.84W	
			EN	02/08/02	10:42	62	39.99N	29	51.71W	
Dan	14748	TEK	BE	02/08/02	10:47	62	39.86N	29	51.60W	no data 12:48 - 16:30
			EN	03/08/02	14:53	60	10.85N	29	12.24W	
	14749	ARIES	BE	02/08/02	11:27	62	36.37N	29	50.03W	surface tow
			EN	02/08/02	12:37	62	33.69N	29	48.98W	
	14752	CPR	BE	02/08/02	13:35	62	37.73N	29	50.59W	
			EN	02/08/02	20:40	61	33.39N	29	26.13W	
not E13	14753	ARIES	BE	02/08/02	21:28	61	38.61N	29	27.80W	no bottles fired
			BO	02/08/02	23:29	61	34.13N	29	26.63W	
			EN	03/08/02	01:37	61	29.58N	29	24.74W	
	14756	CPR	BE	03/08/02	02:52	61	38.12N	29	27.47W	
			EN	03/08/02	08:34	60	47.12N	29	18.50W	
	14757	ARIES	BE	03/08/02	09:40	60	51.98N	29	19.53W	surface tow
			EN	03/08/02	10:53	60	49.41N	29	19.20W	
DD13	14760	CTD	BE	03/08/02	15:11	60	10.68N	29	21.20W	all bottles at 24m
			EN	03/08/02	15:35	60	10.59N	29	12.20W	
DD13	14761	NETS	BE	03/08/02	15:30	60	10.60N	29	12.20W	2 x bongo 63µm
			EN	03/08/02	17:15	60	10.06N	29	11.73W	3 x 200µm, 3 x live nets
DD13	14762	FRRF	BE	03/08/02	17:20	60	10.02N	29	11.71W	
			BO	03/08/02	17:23	60	09.99N	29	11.70W	
			EN	03/08/02	17:28	60	09.95N	29	11.65W	
DD13	14763	CTD	BE	03/08/02	17:42	60	09.98N	29	11.68W	full profile
			BO	03/08/02	18:01	60	09.92N	29	11.73W	
			EN	03/08/02	18:52	60	09.77N	29	11.93W	
DD13	14764	TEK	BE	03/08/02	19:01	60	09.68N	29	11.93W	
			EN	04/08/02	03:23	60	16.75N	30	09.04W	
DD13	14765	OS	BE	03/08/02	19:22	60	09.68N	29	13.06W	
			BO	03/08/02	19:32	60	09.80N	29	13.77W	
			EN	03/08/02	20:26	60	10.38N	29	18.64W	
DD13	14768	DMK	BE	03/08/02	21:15	60	10.70N	29	20.82W	
			BO	03/08/02	22:00	60	11.08N	29	24.05W	
			EN	03/08/02	22:53	60	11.62N	29	28.19W	
DD13	14769	ARIES	BE	03/08/02	23:34	60	11.89N	29	30.11W	
			BO	04/08/02	00:30	60	12.50N	29	34.51W	
			EN	04/08/02	01:37	60	13.26N	29	39.91W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
DD12	14772	CTD	BE	04/08/02	03:40	60	16.81N	30	09.00W	full profile
			BO	04/08/02	04:18	60	16.95N	30	08.47W	
			EN	04/08/02	05:14	60	17.04N	30	07.99W	
DD12	14773	TEK	BE	04/08/02	05:28	60	16.99N	30	08.38W	
			EN	04/08/02	08:20	60	20.93N	31	01.74W	
DD11	14774	CTD	BE	04/08/02	08:37	60	21.00N	31	01.42W	all bottles at 22m
			BO	04/08/02	08:42	60	21.05N	31	01.28W	
			EN	04/08/02	08:55	60	21.09N	31	00.86W	
DD11	14775	NETS	BE	04/08/02	09:09	60	21.16N	31	00.43W	2 x bongos 63µm, 2x200µm
			EN	04/08/02	10:55	60	21.58N	30	58.08W	3 x live nets
D11	14776	FRRF	BE	04/08/02	10:59	60	21.62N	30	58.05W	
			BO	04/08/02	11:03	60	21.67N	30	58.02W	
			EN	04/08/02	11:08	60	21.70N	30	57.97W	
DD11	14777	CTD	BE	04/08/02	11:36	60	21.99N	30	57.73W	full profile
			BO	04/08/02	12:28	60	22.11N	30	56.89W	
			EN	04/08/02	13:45	60	22.60N	30	56.57W	
DD11	14778	LEK	BE	04/08/02	14:06	60	22.73N	30	56.47W	test
			EN	04/08/02	14:09	60	22.73N	30	56.46W	
DD11	14779	LEK	BE	04/08/02	14:50	60	23.00N	30	56.37W	sampling
			EN	04/08/02	16:15	60	23.34N	30	55.55W	
DD11	14780	TEK	BE	04/08/02	16:40	60	23.79N	30	55.30W	
			EN	05/08/02	03:55	60	32.04N	32	03.73W	
DD11	14781	OS	BE	04/08/02	16:54	60	24.23N	30	55.34W	
			EN	04/08/02	17:57	60	27.13N	30	56.01W	
DD11	14784	DMK	BE	04/08/02	18:41	60	27.79N	30	55.53W	
			BO	04/08/02	19:39	60	30.34N	30	56.39W	
			EN	04/08/02	20:38	60	32.98N	30	57.75W	
DD11	14785	ARIES	BE	04/08/02	21:13	60	33.80N	30	57.88W	
			BO	04/08/02	22:52	60	38.07N	31	00.31W	
			EN	05/08/02	00:33	60	42.16N	31	03.00W	
DD10	14788	CTD	BE	05/08/02	04:19	60	31.90N	32	04.31W	full profile
			BO	05/08/02	05:12	60	31.69N	32	05.07W	
			EN	05/08/02	06:27	60	31.38N	32	05.89W	
DD10	14789	NETS	BE	05/08/02	06:32	60	31.36N	32	05.91W	1x bongo 63µm
			EN	05/08/02	06:42	60	31.32N	32	05.99W	
DD10	14790	TEK	BE	05/08/02	06:35	60	31.35N	32	05.94W	
			EN	05/08/02	09:42	60	38.99N	32	59.92W	
DD9	14791	CTD	BE	05/08/02	09:56	60	39.00N	33	00.05W	all bottles 26m
			BO	05/08/02	09:59	60	39.00N	33	00.10W	
			EN	05/08/02	10:15	60	39.03N	33	00.27W	
DD9	14792	NETS	BE	05/08/02	10:30	60	39.07N	33	00.31W	2 x bongos 63µm
			EN	05/08/02	11:51	60	38.87N	33	01.59W	2 x 200µm, 3 x live
DD9	14793	FRRF	BE	05/08/02	12:17	60	38.84N	33	01.84W	
			BO	05/08/02	12:21	60	38.83N	33	01.83W	
			EN	05/08/02	12:26	60	38.85N	33	01.85W	
DD9	14794	CTD	BE	05/08/02	12:45	60	38.87N	33	02.12W	full profile
			BO	05/08/02	13:47	60	39.03N	33	02.70W	
			EN	05/08/02	15:18	60	38.35N	33	04.20W	
DD9	14795	TEK	BE	05/08/02	15:29	60	38.24N	33	04.70W	
			EN	06/08/02	04:34	60	46.03N	33	57.89W	
DD9	14796	OS	BE	05/08/02	15:51	60	37.95N	33	06.05W	
			BO	05/08/02	16:15	60	37.38N	33	08.37W	
			EN	05/08/02	16:54	60	36.40N	33	12.21W	
DD9	14799	DMK	BE	05/08/02	17:32	60	36.14N	33	13.68W	
			BO	05/08/02	18:20	60	35.23N	33	17.59W	
			EN	05/08/02	19:09	60	34.39N	33	21.10W	
DD9	14800	ARIES	BE	05/08/02	19:56	60	39.20N	33	23.32W	
			BO	05/08/02	21:55	60	38.92N	33	32.21W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
			EN	05/08/03	23:55	60	36.02N	33	40.60W	
	14803	DMK	BE	06/08/02	01:24	60	41.83N	33	32.20W	
			BO	06/08/02	02:11	60	40.15N	33	33.38W	
			EN	06/08/02	02:57	60	38.55N	33	34.36W	
DD8	14804	CTD	BE	06/08/02	05:00	60	46.19N	33	58.21W	full profile
			BO	06/08/02	06:07	60	46.24N	33	58.12W	
			EN	06/08/02	07:46	60	46.78N	33	58.11W	
DD8	14805	NETS	BE	06/08/02	07:50	60	46.82N	33	58.09W	1 x bongo 63µm
			EN	06/08/02	08:00	60	46.92N	33	58.06W	
DD8	14806	TEK	BE	06/08/02	08:14	60	46.86N	33	58.35W	
			EN	06/08/02	11:18	60	50.93N	34	58.98W	
DD7	14807	CTD	BE	06/08/02	11:28	60	50.89N	34	59.11W	all bottles 47m
			BO	06/08/02	11:33	60	50.90N	34	59.14W	
			EN	06/08/02	11:45	60	50.89N	34	59.36W	
DD7	14808	NETS	BE	06/08/02	11:50	60	50.86N	34	59.46W	2 x bongo 63µm
			EN	06/08/02	13:19	60	49.99N	35	00.77W	2 x 200µm, 3 x large 200µm
DD7	14809	FRRF	BE	06/08/02	13:20	60	49.97N	35	00.79W	
			BO	06/08/02	13:25	60	49.90N	35	00.90W	
			EN	06/08/02	13:30	60	49.84N	35	01.00W	
DD7	14810	CTD	BE	06/08/02	13:45	60	49.65N	35	01.24W	full profile
			BO	06/08/02	14:56	60	48.75N	35	02.05W	
			EN	06/08/02	16:45	60	47.46N	35	03.31W	
DD7	14811	TEK	BE	06/08/02	17:00	60	47.34N	35	03.40W	
			EN	07/08/02	04:09	61	00.44N	35	52.20W	
DD7	14812	OS	BE	06/08/02	17:25	60	48.83N	35	01.71W	
			BO	06/08/02	17:46	60	48.85N	35	03.54W	
			EN	06/08/02	18:22	60	48.87N	35	06.75W	
DD7	14815	DMK	BE	06/08/02	18:58	60	48.84N	35	08.13W	
			EB	06/08/02	19:53	60	48.98N	35	13.64W	
			EN	06/08/02	20:47	60	49.37N	35	18.90W	
DD7	14816	ARIES	BE	06/08/02	21:16	60	49.75N	35	20.02W	
			BO	07?08/02	00:28	60	52.89N	35	38.30W	
			EN	07/08/02	03:29	60	56.62N	35	54.63W	
DD6	14819	CTD	BE	07/08/02	04:29	61	00.73N	35	52.37W	full profile
			BO	07/08/02	05:40	61	01.03N	35	52.65W	
			EN	07/08/02	07:08	61	01.57N	35	53.20W	
DD6	14820	NETS	BE	07/08/02	07:15	61	01.62N	35	53.21W	1xbongo 63µm
			EN	07/08/02	07:29	61	01.69N	35	53.28W	
DD6	14821	TEK	BE	07/08/02	07:35	61	01.78N	35	53.64W	
			EN	07/08/02	09:50	61	07.28N	36	40.14W	
DD5	14822	CTD	BE	07/08/02	10:01	61	07.27N	36	40.51W	all bottles at 35m
			BO	07/08/02	10:06	61	07.25N	36	40.60W	
			EN	07/08/02	10:19	61	07.15N	36	40.77W	
DD5	14823	NETS	BE	07/08/02	10:28	61	07.07N	36	40.91W	3 x 63µm bongo, 2 x 200µm
			EN	07/08/02	12:13	61	07.21N	36	41.49W	3 x 200µm large live nets
DD5	14824	FRRF	BE	07/08/02	12:15	61	07.21N	36	41.50W	
			BO	07/08/02	12:20	61	07.21N	36	41.52W	
			EN	07/08/02	12:25	61	07.21N	36	41.55W	
DD5	14825	CTD	BE	07/08/02	12:36	61	07.22N	36	41.60W	full profile
			BO	07/08/02	13:42	61	07.20N	36	41.88W	
			EN	07/08/02	15:30	61	07.13N	36	42.26W	
DD5	14826	TEK	BE	07/08/02	15:37	61	07.00N	36	42.29W	
			EN	08/08/02	02:49	61	09.09N	37	32.00W	
DD5	14827	OS	BE	07/08/02	15:58	61	06.55N	36	42.47W	
			BO	07/08/02	16:19	61	05.68N	36	42.76W	
			EN	07/08/02	16:49	61	04.49N	36	43.25W	
DD5	14830	DMK	BE	07/08/02	17:34	61	03.35N	36	44.39W	
			BO	07/08/02	18:16	61	01.74N	36	45.82W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
			EN	07/08/02	19:06	60	59.89N	36	47.79W	
DD5	14831	ARIES	BE	07/08/02	19:43	60	59.32N	36	49.43W	
			BO	07/08/02	22:25	60	56.47N	37	04.77W	
			EN	08/08/02	01:20	60	55.40N	37	23.25W	
DD4	14834	CTD	BE	08/08/02	03:07	61	09.24N	37	32.39W	full profile
			BO	08/08/02	04:09	61	09.23N	37	32.69W	
			EN	08/08/02	05:35	61	09.13N	37	32.57W	
DD4	14835	TEK	BE	08/08/02	05:46	61	09.15N	37	32.68W	
			EN	08/08/02	08:07	61	20.36N	38	14.28W	
DD3	14836	NETS	BE	08/08/02	08:15	61	20.40N	38	14.45W	1 x bongo 63µm
			EN	08/08/02	08:45	61	20.39N	38	14.55W	1 x 200µm
DD3	14837	CTD	BE	08/08/02	11:15	61	21.10N	38	15.36W	all bottles at 37m
			BO	08/08/02	11:25	61	21.15N	38	15.38W	
			EN	08/08/02	11:48	61	21.27N	38	15.27W	
DD3	14838	NETS	BE	08/08/02	12:10	61	21.41N	38	15.24W	1 x bongo 63µm
			EN	08/08/02	12:50	61	21.16N	38	15.23W	2 x 200µm, 3 x live
DD3	14839	FRRF	BE	08/08/02	12:56	61	21.65N	38	15.22W	
			BO	08/08/02	12:59	61	21.67N	38	15.21W	
			EN	08/08/02	13:06	61	21.70N	38	15.16W	
DD3	14840	CTD	BE	08/08/02	13:30	61	21.80N	38	14.99W	full profile
			BO	08/08/02	14:20	61	21.99N	38	14.56W	
			EN	08/08/02	16:00	61	22.38N	38	13.56W	
DD3	14841	TEK	BE	08/08/02	16:25	61	22.42N	38	13.63W	
			EN	09/08/02	01:42	61	22.93N	38	57.31W	
DD3	14842	OS	BE	08/08/02	16:41	61	22.51N	38	14.31W	
			BO	08/08/02	17:03	61	22.93N	38	16.14W	
			EN	08/08/02	17:36	61	23.46N	38	18.73W	
DD3	14845	DMK	BE	08/08/02	18:19	61	23.39N	38	20.55W	
			BO	08/08/02	19:05	61	23.77N	38	24.65W	
			EN	08/08/02	19:54	61	24.10N	38	29.19W	
DD3	14846	ARIES	BE	08/08/02	20:34	61	24.03N	38	30.99W	
			BO	08/08/02	22:40	61	26.50N	38	40.78W	
			EN	09/08/02	00:50	61	29.88N	38	50.81W	
DD2a	14849	CTD	BE	09/08/02	02:00	61	22.77N	38	57.64W	all top taps on bottles open
			BO	09/08/02	02:55	61	22.76N	38	57.49W	
			EN	09/08/02	04:23	61	22.61N	38	57.18W	
DD2a	14850	TEK	BE	09/08/02	04:33	61	22.59N	38	57.57W	
			EN	09/08/02	06:38	61	25.17N	39	39.77W	
DD2	14851	TEK	BE	09/08/02	09:29	61	25.22N	39	40.42W	CTD wire problem
			EN	09/08/02	11:32	61	25.42N	39	43.85W	
DD2	14852	MET BUOY	BE	09/08/02	10:30	61	26.31N	40	00.03W	
	14853	CTD	BE	09/08/02	13:42	61	24.70N	39	39.88W	all bottles at 45m
			EN	09/08/02	13:55	61	24.64N	39	39.89W	
DD2	14854	FRRF	BE	09/08/02	14:02	61	24.60N	39	39.91W	
			BO	09/08/02	14:06	61	24.58N	39	39.93W	
			EN	09/08/02	14:11	61	24.55N	39	39.96W	
DD2	14855	NETS	BE	09/08/02	14:15	61	24.53N	39	40.00W	1 x bongo 63µm
			EN	09/08/02	14:50	61	24.47N	39	40.34W	1 x 200µm
DD2	14856	CTD	BE	09/08/02	14:50	61	24.47N	39	40.34W	full profile
			BO	09/08/02	15:40	61	24.42N	39	40.93W	
			EN	09/08/02	17:06	61	24.47N	39	41.84W	
DD2	14857	TEK	BE	09/08/02	17:30	61	24.72N	39	41.75W	
			EN	10/08/02	08:45	63	29.98N	36	01.47W	
C8	14858	CTD	BE	10/08/02	08:56	63	29.95N	36	01.64W	all bottles at 15m
			EN	10/08/02	09:07	63	29.86N	36	01.79W	
C8	14859	NETS	BE	10/08/02	09:15	63	29.85N	36	02.04W	2 x bongo 63µm
			EN	10/08/02	10:50	63	29.74N	36	03.69W	2 x 200µm, 3 x live
C8	14860	FRRF	BE	10/08/02	10:52	63	29.74N	36	03.71W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
			BO	10/08/02	10:56	63	29.74N	36	03.75W	
			EN	10/08/02	11:01	63	29.75N	36	03.81W	
C8	14861	CTD	BE	10/08/02	11:21	63	29.74N	36	03.97W	full profile
			BO	10/08/02	12:05	63	29.88N	36	04.58W	
			EN	10/08/02	13:25	63	30.21N	36	05.49W	
C8	14862	TEK	BE	10/08/02	13:33	63	30.22N	36	05.15W	
			EN	11/08/02	10:04	62	38.60N	29	14.85W	
C8	14863	OS	BE	10/08/02	13:54	63	30.25N	36	03.90W	
			BO	10/08/02	14:22	63	30.23N	36	00.82W	
			EN	10/08/02	15:03	63	30.26N	35	36.34W	
C8	14866	DMK	BE	10/08/02	15:40	63	30.28N	35	54.61W	
			BO	10/08/02	16:35	63	30.48N	35	49.93W	
			EN	10/08/02	17:29	63	30.70N	35	35.74W	
C8	14867	ARIES	BE	10/08/02	18:08	63	30.87N	35	43.85W	
			BO	10/08/02	19:59	63	31.36N	35	35.89W	
			EN	10/08/02	21:47	63	31.79N	35	27.89W	
W2	14870	CTD	BE	11/08/02	10:18	63	45.07N	30	44.15W	all bottles at 20m
			BE	11/08/02	10:20	63	45.06N	30	44.16W	
			EN	11/08/02	10:32	63	44.97N	30	44.16W	
W2	14871	NETS	BE	11/08/02	10:35	63	44.93N	30	44.16W	1 x bongo 63µm
			EN	11/08/02	10:59	63	44.81N	30	44.23W	1 x 250µm net (live)
W2	14872	TEK	BE	11/08/02	11:06	63	44.87N	30	44.09W	
			EN	12/08/02	08:05	64	07.18N	23	10.33W	
N1	14873	NETS	BE	12/08/02	12:30	64	08.86N	23	14.01W	1 x bongo 63µm
			EN	12/08/02	13:00	64	09.00N	23	14.03W	2 x 200µm, 1 x 250µm
N1	14874	CPR	BE	12/08/02	13:15	64	09.08N	23	14.89W	
			EN	13/08/02	09:15	64	10.97N	31	26.81W	
N1	14875	TEK	BE	12/08/02	17:31	64	09.34N	25	00.54W	
			EN	13/08/02	09:22	64	10.99N	31	27.50W	
B8	14876	CTD	BE	13/08/02	09:34	64	11.11N	31	28.07W	all bottles at 11m
			BO	13/08/02	09:40	64	11.09N	31	28.17W	
			EN	13/08/02	09:55	64	11.05N	31	28.31W	
B8	14877	NETS	BE	13/08/02	10:03	64	11.04N	31	28.33W	1 x bongo 63µm
			EN	13/08/02	10:44	64	11.00N	31	28.58W	1 x 200µm, 1 x 250µm
B8	14878	FRRF	BE	13/08/02	10:58	64	11.07N	31	28.52W	
			BO	13/08/02	11:03	64	11.07N	31	28.52W	
			EN	13/08/02	11:08	64	11.03N	31	28.56W	
B8	14879	CTD	BE	13/08/02	11:29	64	10.97N	31	28.64W	full profile
			BOI	13/08/02	12:30	64	10.65N	31	28.41W	
			EN	13/08/02	14:10	64	10.71N	31	29.04W	
B8	14880	TEK	BE	13/08/02	14:16	64	10.71N	31	28.94W	
			EN	13/08/02	18:02	64	21.68N	32	50.50W	
C10b	14881	CTD	BE	13/08/02	18:15	64	21.77N	32	50.87W	full profile
			BO	13/08/02	19:08	64	21.74N	32	52.16W	
			EN	13/08/02	20:41	64	21.87N	32	55.00W	
C10b	14882	NETS	BE	13/08/02	20:30	64	21.78N	32	54.59W	1 x bongo 63µm
			EN	13/08/02	20:45	64	21.86N	32	55.17W	
C10b	14883	TEK	BE	13/08/02	21:18	64	22.11N	32	56.24W	
			EN	14/08/02	08:53	64	34.03N	34	10.64W	
C10b	14884	DMK	BE	14/08/02	00:50	64	17.98N	34	13.03W	
			BO	14/08/02	01:47	64	20.11N	34	13.20W	
			EN	14/08/02	02:44	64	22.02N	34	13.39W	
	14885	ARIES	BE	14/08/02	03:27	64	22.74N	34	13.59W	
			BO	14/08/02	05:03	64	26.63N	34	12.23W	
			EN	14/08/02	06:44	64	31.02N	34	11.24W	
C10	14888	OS	BE	14/08/02	07:35	64	31.59N	34	11.62W	
			BO	14/08/02	08:04	64	32.73N	34	11.48W	
			EN	14/08/02	08:39	64	34.03N	34	10.78W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
C10	14891	CTD	BE	14/08/02	09:35	64	32.57N	34	12.99W	all bottles at 17m
			BO	14/08/02	09:37	64	32.57N	34	12.99W	
			EN	14/08/02	09:51	64	32.55N	34	13.09W	
C10	14892	NETS	BE	14/08/02	10:00	64	32.55N	34	13.23W	2 x bongo 63µm
			EN	14/08/02	11:35	64	32.58N	34	14.91W	3 x 200µm, 3 x live250µm
C10	14893	FRRF	BE	14/08/02	11:38	64	32.56N	34	14.94W	
			BO	14/08/02	11:41	64	32.53N	34	15.01W	
			EN	14/08/02	11:47	64	32.49N	34	15.11W	
C10	14894	CTD	BE	14/08/02	12:00	64	32.41N	34	15.36W	full profile
			BO	14/08/02	12:35	64	32.37N	34	15.96W	
			EN	14/08/02	13:15	64	32.34N	34	16.84W	
C10	14895	TEK	BE	14/08/02	13:55	64	32.50N	34	17.64W	
			EN	14/08/02	14:43	64	34.01N	34	30.27W	
C9c	14896	CTD	BE	14/08/02	15:05	64	34.31N	34	31.02W	full profile
			BO	14/08/02	15:40	64	34.80N	34	31.47W	
			EN	14/08/02	16:58	64	35.88N	34	31.49W	
C9c	14897	NETS	BE	14/08/02	17:03	64	35.95N	34	31.51W	1 x bongo 63µm
			EN	14/08/02	17:24	64	36.19N	34	31.45W	1 x 200µm
C9c	14898	TEK	BE	14/08/02	17:32	64	36.26N	34	31.76W	
			EN	14/08/02	18:26	64	36.14N	34	49.38W	
C9b	14899	CTD	BE	14/08/02	18:35	64	36.20N	34	49.23W	full profile
			BO	14/08/02	19:05	64	36.37N	34	49.12W	
			EN	14/08/02	20:17	64	36.61N	34	49.06W	
C9b	14900	NETS	BE	14/08/02	20:30	64	36.66N	34	49.04W	1 x bongo 63µm
			EN	14/08/02	20:50	64	36.66N	34	49.04W	1 x 200µm
C9b	14901	TEK	BE	14/08/02	20:57	64	36.76N	34	48.84W	
			EN	14/08/02	21:44	64	37.53N	35	00.61W	
C9a	14902	CTD	BE	14/08/02	21:55	64	37.11N	34	59.26W	full profile
			BO	14/08/02	22:30	64	37.20N	34	58.98W	
			EN	14/08/02	23:15	64	37.25N	34	59.21W	
C9a	14903	NETS	BE	14/08/02	23:15	64	37.25N	34	59.21W	1 x bongo 63µm
			EN	14/08/02	23:47	64	37.28N	34	59.35W	1 x 200µm
C9a	14904	TEK	BE	14/08/02	23:55	64	37.35N	34	59.29W	
			EN	15/08/02	07:45	64	37.94N	35	07.57W	
C9	14905	DMK	BE	15/08/02	02:07	64	32.27N	35	39.60W	
			BO	15/08/02	02:32	64	33.24N	35	39.26W	
			EN	15/08/02	03:02	64	34.35N	35	38.78W	
C9	14906	ARIES	BE	15/08/02	03:45	64	35.17N	35	37.72W	
			BO	15/08/02	04:15	64	36.30N	35	36.19W	
			EN	15/08/02	04:44	64	37.32N	35	34.81W	
C9	14909	OS	BE	15/08/02	05:28	64	37.68N	35	34.02W	
			BO	15/08/02	05:56	64	38.85N	35	32.58W	
			EN	15/08/02	06:24	64	40.07N	35	31.19W	
C9d	14912	CTD	BE	15/08/02	07:59	64	37.95N	35	07.59W	full profile
			BO	15/08/02	08:12	64	38.03N	35	07.67W	
			EN	15/08/02	08:39	64	38.03N	35	07.82W	
C9d	14913	TEK	BE	15/08/02	08:46	64	38.17N	35	07.87W	
			EN	15/08/02	09:30	64	39.72N	35	24.67W	
C9	14914	CTD	BE	15/08/02	09:58	64	40.22N	35	30.19W	all bottles at 12m
			BO	15/08/02	10:04	64	40.27N	35	30.32W	
			EN	15/08/02	10:18	64	40.32N	35	30.62W	
C9	14915	NETS	BE	15/08/02	10:31	64	40.36N	35	30.94W	2 x bongo 63µm
			EN	15/08/02	12:46	64	41.39N	35	32.50W	1x200µm 6x200µm
C9	14916	FRRF	BE	15/08/02	12:49	64	41.40N	35	32.54W	
			BO	15/08/02	12:53	64	41.41N	35	32.60W	
			EN	15/08/02	12:58	64	41.43N	35	32.66W	
C9	14917	CTD	BE	15/08/02	13:12	64	41.46N	35	32.81W	full profile
			BO	15/08/02	13:24	64	41.49N	35	32.97W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
			EN	15/08/02	14:18	64	41.70N	35	33.49W	
C9	14918	LEK	BE	15/08/02	14:45	64	41.88N	35	33.98W	
			EN	15/08/02	15:07	64	41.96N	35	34.44W	
C9	14919	TEK	BE	15/08/02	15:15	64	42.02N	35	35.14W	
			EN	16/08/02	01:01	64	42.78N	37	44.12W	
X	14920	DMK	BE	15/08/02	20:54	64	53.23N	37	48.33W	
			BO	15/08/02	21:20	64	51.96N	37	48.11W	
			EN	15/08/02	21:46	64	50.61N	37	47.64W	
X	14921	ARIES	BE	15/08/02	22:48	64	48.69N	37	47.00W	
			BO	15/08/02	23:02	64	48.13N	37	46.67W	
			EN	15/08/02	23:18	64	47.33N	37	46.21W	
X	14924	OS	BE	15/08/02	00:00	64	45.96N	37	45.91W	
			BO	16/08/02	00:21	64	44.74N	37	45.26W	
			EN	16/08/02	00:43	64	43.46N	37	44.44W	
X	14927	CTD	BE	16/08/02	01:26	64	42.37N	37	44.43W	full profile
			BO	16/08/02	01:43	64	42.23N	37	44.76W	
			EN	16/08/02	02:13	64	41.94N	37	45.41W	
X	14928	NETS	BE	16/08/02	02:15	64	41.93N	37	45.46W	1 x bongo 63µm
			EN	16/08/02	02:55	64	41.77N	37	46.46W	1 x 200µm, 1 x 250µm
X	14929	TEK	BE	16/08/02	03:16	64	41.21N	37	46.67W	
			EN	16/08/02	09:56	63	44.37N	37	29.25W	
C6	14930	CTD	BE	16/08/02	10:08	63	44.37N	37	29.23W	all bottles at 18m
			BO	16/08/02	10:10	63	44.38N	37	29.26W	
			EN	16/08/02	10:26	63	44.43N	37	29.42W	
C6	14931	NETS	BE	16/08/02	10:34	63	44.43N	37	29.45W	2 x bongo 63µm
			EN	16/08/02	12:16	63	44.46N	37	30.04W	3 x 200µm
C6	14932	FRRF	BE	16/08/02	12:19	63	44.45N	37	30.06W	
			BO	16/08/02	12:22	63	44.45N	37	30.08W	
			EN	16/08/02	12:28	63	44.45N	37	30.07W	
C6	14933	CTD	BE	16/08/02	13:15	63	44.32N	37	30.45W	full profile
			BO	16/08/02	13:23	63	44.31N	37	30.52W	
			EN	16/08/02	14:06	63	44.31N	37	31.03W	
C6	14934	LEK	BE	16/08/02	14:28	63	44.33N	37	31.34W	
			EN	16/08/02	16:28	63	44.73N	37	32.79W	
C6	14935	TEK	BE	16/08/02	16:41	63	44.64N	37	32.81W	
			EN	16/08/02	22:11	63	40.10N	36	57.90W	
C6	14936	OS	BE	16/08/02	17:05	63	44.09N	37	32.44W	
			BO	16/08/02	17:19	63	43.56N	37	32.10W	
			EN	16/08/02	17:41	63	42.70N	37	31.56W	
C6	14939	DMK	BE	16/08/02	18:20	63	42.68N	37	31.75W	
			BO	16/08/02	18:39	63	43.20N	37	30.93W	
			EN	16/08/02	18:56	63	43.70N	37	30.29W	
C6	14940	ARIES	BE	16/08/02	19:35	63	43.99N	37	29.31W	
			BO	16/08/02	19:48	63	43.91N	37	28.53W	
			EN	16/08/02	20:07	63	43.81N	37	27.09W	
C6a	14944	CTD	BE	16/08/02	22:25	63	40.03N	36	58.52W	full profile
			BO	16/08/02	22:57	63	39.79N	36	59.76W	
			EN	17/08/02	00:00	63	39.82N	37	01.62W	
C6a	19443	TEK	BE	17/08/02	00:20	63	40.03N	37	02.07W	
			EN	17/08/02	09:06	63	43.04N	37	31.22W	
	14945	DMK	BE	17/08/02	02:50	63	49.68N	37	07.90W	
			BO	17/08/02	03:12	63	49.10N	37	10.03W	
			EN	17/08/02	03:43	63	48.38N	37	12.32W	
	14946	ARIES	BE	17/08/02	05:45	63	40.84N	37	34.65W	CPR comparison
			EN	17/08/02	07:55	63	35.86N	37	42.61W	
C9	14949	CTD	BE	17/08/02	09:20	63	43.16N	37	31.10W	all bottles at 11m
			BO	17/08/02	09:22	63	43.17N	37	31.10W	
			EN	17/08/02	09:31	63	43.20N	37	31.02W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
C9	14950	NETS	BE	17/08/02	09:40	63	43.26N	37	30.97W	2xlive
			EN	17/08/02	10:15	63	43.25N	37	30.66W	
C9	14951	TEK	BE	17/08/02	10:18	63	43.18N	37	30.79W	
			EN	17/08/02	17:17	62	45.05N	38	59.99W	
C9	14952	CPR	BE	17/08/02	10:25	62	42.89N	37	31.39W	
			EN	17/08/02	17:12	62	45.13N	38	59.86W	
H10a	14953	FRRF	BE	17/08/02	17:21	62	45.01N	39	00.03W	
			BO	17/08/02	17:24	62	45.00N	39	00.06W	
			EN	17/08/02	17:30	62	44.96N	39	00.08W	
H10a	14954	TEK	BE	17/08/02	17:35	62	45.04N	39	00.07W	
			EN	18/08/02	03:09	62	38.81N	39	09.67W	
H10	14955	ARIES	BE	17/08/02	18:50	62	53.36N	38	47.64W	
			BO	17/08/02	21:04	62	48.80N	38	53.88W	
			EN	17/08/02	22:23	62	46.17N	38	57.63W	
H10	14958	DMK	BE	17/08/02	23:30	62	44.97N	38	59.80W	
			BO	18/08/02	00:18	62	43.61N	39	02.09W	
			EN	18/08/02	01:05	62	42.43N	39	04.19W	
H10	14959	OS	BE	18/08/02	01:48	62	41.72N	39	05.32W	
			EN	18/08/02	02:54	62	39.08N	39	09.17W	
H10	14962	NETS	BE	18/08/02	06:15	62	38.43N	39	10.72W	1 x bongo 63µm
			EN	18/08/02	06:59	62	37.78N	39	10.87W	1 x 200µm, 2 x 250µm
H10	14963	FRRF	BE	18/08/02	07:03	62	37.72N	39	10.84W	
			BO	18/08/02	07:06	62	37.67N	39	10.82W	
			EN	18/08/02	07:12	62	37.60N	39	10.81W	
H10	14964	CTD	BE	18/08/02	08:18	62	36.90N	39	10.81W	full profile
			BO	18/08/02	09:08	62	36.42N	39	10.90W	
			EN	18/08/02	10:16	62	36.01N	39	10.77W	
H10	14965	TEK	BE	18/08/02	10:25	62	35.84N	39	10.88W	
			EN	18/08/02	16:31	62	08.47N	40	35.70W	
W3	14966	CTD	BE	18/08/02	16:42	62	08.22N	40	36.04W	all bottles at 15m
			EN	18/08/02	16:54	62	08.00N	40	36.36W	
W3	14967	TEK	BE	18/08/02	17:01	62	07.98N	40	36.57W	
			EN	19/08/02	06:46	61	29.63N	40	26.92W	
W3	14968	DMK	BE	18/08/02	23:01	61	34.31N	40	47.81W	
			BO	18/08/02	23:50	61	32.99N	40	45.15W	
			EN	19/08/02	00:39	61	32.15N	40	42.13W	
DD1	14969	ARIES	BE	19/08/02	01:27	61	31.43N	40	40.03W	
			BO	19/08/02	02:58	61	29.45N	40	34.16W	
			EN	19/08/02	04:25	61	27.61N	40	27.96W	
DD1	14972	OS	BE	19/08/02	05:25	61	27.05N	40	26.49W	
			EN	19/08/02	06:30	61	29.36N	40	26.72W	
DD1	14975	FRRF	BE	19/08/02	07:20	61	27.57N	40	22.18W	
			BO	19/08/02	07:24	61	27.59N	40	22.21W	
			EN	19/08/02	07:30	61	27.62N	40	22.27W	
DD1	14976	CTD	BE	19/08/02	07:48	61	27.68N	40	22.45W	full profile
			BO	19/08/02	08:38	61	27.49N	40	23.05W	
			EN	19/08/02	09:46	61	27.06N	40	23.74W	
DD1	14977	LEK	BE	19/08/02	10:17	61	26.92N	40	24.08W	
			EN	19/08/02	11:06	61	26.63N	40	24.65W	
DD1	14978	CTD	BE	19/08/02	11:20	61	26.55N	40	24.83W	all bottles at 24m
			BO	19/08/02	11:23	61	26.54N	40	24.87W	
			EN	19/08/02	11:34	61	26.52N	40	25.04W	
DD1	14979	NETS	BE	19/08/02	11:43	61	26.47N	40	25.22W	2 x bongo 63µm
			EN	19/08/02	12:57	61	26.25N	40	26.88W	2 x 200µm, 2 x live
DD1	14980	TEK	BE	19/08/02	13:08	61	26.37N	40	27.28W	
			EN	19/08/02	15:41	61	15.31N	41	11.76W	
W4	14981	CTD	BE	19/08/02	16:42	61	13.06N	41	14.51W	all bottles at 25m
			EN	19/08/02	16:52	61	13.05N	41	14.66W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
	14982	TEK	BE	19/08/02	18:44	61	06.03N	41	05.37W	
			EN	20/08/02	05:13	59	59.98N	41	42.55W	
D1a	14983	CTD	BE	20/08/02	05:37	59	59.69N	41	42.45W	full profile
			BO	20/08/02	06:23	59	59.11N	41	42.20W	
			EN	20/08/02	07:24	59	58.22N	41	42.07W	
D1a	14984	TEK	BE	20/08/02	07:31	59	58.13N	41	42.04W	
			EN	20/08/02	11:56	59	53.90N	42	14.41W	
D1	14985	CTD	BE	20/08/02	12:08	59	53.67N	42	14.71W	all bottles at 19m
			EN	20/08/02	12:30	59	53.16N	42	14.94W	
D1	14986	NETS	BE	20/08/02	12:35	59	53.03N	42	15.04W	2 x bongo 63µm
			EN	20/08/02	14:06	59	51.02N	42	17.78W	2 x 200µm, 3 x live
D1	14987	FRRF	BE	20/08/02	14:10	59	50.95N	42	17.92W	
			BO	20/08/02	14:13	59	50.88N	42	18.01W	
			EN	20/08/02	14:19	59	50.76N	42	18.21W	
D1	14988	CTD	BE	20/08/02	14:36	59	50.48N	42	18.78W	full profile
			BO	20/08/02	14:43	59	50.38N	42	19.01W	
			EN	20/08/02	15:23	59	49.80N	42	20.32W	
D1	14989	TEK	BE	20/08/02	15:33	59	49.96N	42	20.93W	
			EN	20/08/02	20:09	59	50.42N	42	16.52W	
D1	14990	OS	BE	20/08/02	17:03	59	50.70N	42	17.55W	
			BO	20/08/02	17:19	59	50.94N	42	17.20W	
			EN	20/08/02	17:42	59	51.26N	42	17.10W	
D1	14993	DMK	BE	20/08/02	18:23	59	51.03N	42	18.53W	
			BO	20/08/02	18:38	59	51.40N	42	18.82W	
			EN	20/08/02	18:56	59	51.75N	42	19.10W	
	14994	ARIES	BE	20/08/02	19:24	59	50.79N	42	17.96W	
			BO	20/08/02	19:40	59	50.67N	42	17.44W	
			EN	20/08/02	19:54	59	50.55N	42	16.81W	
D2	14997	CTD	BE	20/08/02	20:30	59	50.18N	42	17.03W	all bottles at 15m
			BO	20/08/02	20:44	59	49.94N	42	17.50W	
			EN	20/08/02	21:00	59	49.73N	42	17.83W	
D2	14998	TEK	BE	20/08/02	21:08	59	49.27N	42	17.88W	
			EN	21/08/02	09:24	59	19.11N	40	47.72W	
D2	14999	DMK	BE	21/08/02	01:55	59	35.98N	40	56.48W	
			BO	21/08/02	02:45	59	34.35N	40	54.00W	
			EN	21/08/02	03:32	59	32.84N	40	51.80W	
D2	15000	ARIES	BE	21/08/02	04:04	59	31.97N	40	52.37W	CTD logger failed
			BO	21/08/02	06:37	59	25.37N	40	50.37W	
			EN	21/08/02	09:10	59	19.38N	40	47.76W	
D2	15003	FRRF	BE	21/08/02	09:36	59	19.11N	40	47.62W	
			BO	21/08/02	09:39	59	19.11N	40	37.67W	
			EN	21/08/02	09:44	59	19.12N	40	47.65W	
D2	15004	CTD	BE	21/08/02	09:59	59	19.25N	40	47.69W	all bottles at 25m
			BO	21/08/02	10:01	59	19.28N	40	47.68W	
			EN	21/08/02	10:18	59	19.40N	40	47.59W	
D2	15005	NETS	BE	21/08/02	10:26	59	19.46N	40	47.56W	2 x 63µm bongo
			EN	21/08/02	11:50	59	19.84N	40	46.54W	2 x 200µm, 3 x live
D2	15006	CTD	BE	21/08/02	11:56	59	19.87N	40	46.47W	light profile
			EN	21/08/02	12:25	59	20.02N	40	45.84W	
D2	15007	TEK	BE	21/08/02	13:00	59	20.65N	40	45.73W	
			EN	21/08/02	17:00	59	13.59N	39	54.32W	
D2	15008	OS	BE	21/08/02	13:12	59	20.99N	40	45.47W	
			BO	21/08/02	13:33	59	21.77N	40	44.53W	
			EN	21/08/02	14:04	59	22.64N	40	43.09W	
D3	15012	CTD	BE	21/08/02	17:10	59	13.58N	39	54.19W	full profile
			BO	21/08/02	18:17	59	14.08N	39	54.45W	
			EN	21/08/02	19:50	59	14.64N	39	55.28W	
D3	15013	TEK	BE	21/08/02	20:00	59	14.60N	39	55.29W	

MarProd site code	*Discovery* station no.	Instrument	Code	Date DD/MM/YY	Time HH:MM	Lat		Long		Comments
			EN	22/08/02	08:32	59	06.61N	38	26.67W	
D4	15014	DMK	BE	22/08/02	00:30	58	50.93N	38	50.62W	
			BO	22/08/02	01:21	58	52.96N	38	48.82W	
			EN	22/08/02	02:11	58	54.80N	38	46.72W	
D4	15015	ARIES	BE	22/08/02	03:00	58	55.56N	38	44.94W	CTD logger failed
			BO	22/08/02	05:11	59	00.23N	38	38.15W	
			EN	22/08/02	08:22	59	06.57N	38	27.17W	
D4	15018	FRRF	BE	22/08/02	08:34	59	06.62N	38	26.58W	
			BO	22/08/02	08:43	59	06.49N	38	26.20W	
			EN	22/08/02	08:57	59	06.46N	38	25.68W	
D4	15019	CTD	BE	22/08/02	09:15	59	06.50N	38	25.78W	light profile to 150m
			BO	22/08/02	09:19	59	06.48N	38	25.80W	
			EN	22/08/02	09:30	59	06.43N	38	25.82W	
D4	15020	NETS	BE	22/08/02	10:00	59	06.38N	38	26.06W	2 x bongo 63µm
			EN	22/08/02	11:25	59	06.39N	38	26.21W	2 x 200µm, 3 x 200µm
D4	15021	LEK	BE	22/08/02	11:32	59	06.41N	38	26.29W	
			EN	22/08/02	12:33	59	06.34N	38	26.81W	
D4	15022	TEK	BE	22/08/02	12:43	59	06.49N	38	26.99W	
			EN	23/08/02	06:02	57	54.99N	36	24.37W	
D4	15023	OS	BE	22/08/02	12:59	59	06.75N	38	27.30W	
			BO	22/08/02	13:25	59	07.74N	38	28.46W	
			EN	22/08/02	14:05	59	09.21N	38	29.88W	
D4	15026	CPR	BE	22/08/02	14:45	59	06.04N	38	23.94W	
			EN	22/08/02	23:18	57	58.51N	36	29.08W	
D5	15027	ARIES	BE	22/08/02	23:30	59	34.73N	35	23.79W	
			BO	23/08/02	01:57	57	53.16N	36	25.59W	
			EN	23/08/02	03:42	57	49.95N	36	24.80W	
D5	15030	OS	BE	23/08/02	04:38	57	50.58N	36	24.67W	
			BO	23/08/02	05:10	57	52.26N	36	24.55W	
			EN	23/08/02	05:50	57	54.63N	36	24.43W	
D5	15033	NETS	BE	23/08/02	06:15	57	55.20N	36	24.37W	2 x 63µm bongo
			EN	23/08/02	07:35	57	55.34N	36	24.14W	2 x 200µm, 2 x 200µm
D5	15034	CTD	BE	23/08/02	07:39	57	55.33N	36	24.17W	all bottles at 20m
			BO	23/08/02	07:42	57	55.35N	36	24.18W	
			EN	23/08/02	07:51	57	55.36N	36	24.22W	
D5	15035	TEK	BE	23/08/02	07:57	57	55.35N	36	24.29W	
			EN	23/08/02	11:57	57	35.14N	35	26.13W	
D6	15036	FRRF	BE	23/08/02	12:12	57	35.01N	35	25.78W	
			BO	23/08/02	12:17	57	34.96N	35	25.72W	
			EN	23/08/02	12:21	57	34.95N	35	25.65W	
D6	15037	CTD	BE	23/08/02	12:35	57	34.94N	35	25.37W	full profile
			BO	23/08/02	13:29	57	34.88N	35	24.54W	
			EN	23/08/02	15:00	57	34.69N	35	23.05W	
D6	15038	TEK	BE	23/08/02	15:11	57	34.52N	35	23.10W	
			EN	25/08/02	13:36	56	22.36N	22	39.86W	
	15039	MET BUOY	BE	23/08/02	16:43	57	25.69N	35	01.51W	
E4	15040	ARIES	BE	23/08/02	19:18	57	11.56N	34	22.95W	
			BO	23/08/02	21:01	57	07.12N	34	19.01W	
			EN	23/08/02	22:38	57	03.15N	34	17.62W	

A2. Sea-Bird CTD processing

Five-digit *Discovery* station numbers were used throughout the cruise. In the text below, the station numbers are referred to as 14nnn since most scripts request just the last 3 digits. After the change to 15nnn during *Discovery* 264, a null value for $THOUSAND was set and all 5 digits of the station numbers were then used in the Pstar processing.

A2.1 Sea-Bird CTD software (SeaSoft) processing

The following steps were run on the binary 24 Hz data. Input file was ctd14nnn.dat in directory "C:\D262ctd", output file was ctd14nnn.dat in subdirectory "C:\D262ctd\Processed" on the PC used for SeaSoft processing.

datcnv Converts raw data, copies selected variables (set only to copy measured, not derived, variables)

wildedit Run twice, edits spikes in the 24 Hz data in preparation for averaging (using *Discovery* 258 values)

alignCTD Advances the oxygen variable to match timing of other variable (*Discovery* 258 values)

translate Converts the data to ASCII

rossum Averages the Sea-Bird .ros file into one value per bottle (not run on 'live sampling' CTDs).

Output ASCII files were ctd14nnn.cnv and ctd14nnn.btl. These were then ftp'd to the Unix directory where further processing in Pstar was done.

A2.2 Pstar processing for Sea-Bird CTD

ctd0 Translates the 24 Hz Sea-Bird ctd14nnn.cnv file into Pstar format. Requires the latitude and longitude of the bottom of the cast. These are manually entered from details on the cast logsheet, but can be automatically checked and corrected later. Output ctd14nnn.24hz

ctd1 Performs further editing of 24 Hz file, averages into 1 Hz data, calculates derived variables salinity, potential temperature and density. Output ctd14nnn.1hz

ctd2 Requires datacycle numbers of the first good in-water data (i.e. after soaking), the bottom of the downcast (maximum pressure) and the last in-water data (all obtained manually by listing ctd14nnn.1hz using mlist). Extracts data from the 1 Hz file to produce the entire in-water 1 Hz cast (ctd14nnn.ctu) and the downcast profile averaged to 2dbar intervals (ctd14nnn.2db).

ctdplots Produces standard profile and temperature-salinity plots for deep and shallow stations.

sam0 Converts the ASCII .btl file into a Pstar file that contains the CTD variables from the bottle firing times. Output fir14nnn.

sam1 Converts the firing file into a master sample file, into which bottle oxygen, nutrient, salinity and chlorophyll data will be pasted. Output sam14nnn.

passam Pastes ASCII sample (oxygen, nutrient, salinity or chlorophyll) data into the master sample file. Requires tab-delimited text file with sample numbers that match those already in the sam14nnn file (convention for sample number is nnn01 to nnn024).

oxycalib After pasting in the bottle oxygen data, this script re-calculates the bottle oxygen in units µmol/kg for direct comparison with CTD oxygens (new variable botoxyk in sam14nnn).

makeresid Calculates the bottle conductivity (using bottle salinity and CTD pressure and temperature). Calculates the difference between bottle and CTD oxygens, bottle chlorophyll and CTD fluorescence, bottle salinity and CTD salinity, and bottle conductivity and CTD conductivity. Can be run with some bottle data absent, re-run as necessary. Output file res14nnn.

ctd4 Checks the true position and water depth from the master navigation and master bathymetry files. Allows user to correct the information in all CTD and sample files.

A3. LADCP software, formats and processing

A3.1 Date formats for CTD and Nav files

The Visbeck software stores times in full Julian day format, in which Julian day 2440000 begins at 0000 hours on May 23, 1968. This is the Pstar standard (compare gregoria.m with julymd.F) which avoids all Y2K and leap year problems. This is greatly to be preferred over the old RVS approach (still in use on the ships) in which date is given as day of year. Therefore the execs to create CTD and Nav files for input to the Matlab LADCP processing were revised to provide time in full YYYYMMDD HHMMSS format, by simply changing the mlist time output with "fmt time HMS". Routines loadctdsoc.m and loadnavsoc.m were modified to unpack these times and convert them to full Julian day.

To create the ASCII CTD and Nav files, the following execs are provided:

doctdasc Mlists the .1hz initial CTD file, writing time, pressure, temperature and salinity to the file ladcp/ctd/ctdAAAAA.asc in the format 20020729 132902 65.5597 10.1555 35.2933 with no header or trailer. AAAAA is the *Discovery* station number.

donavraw & **donavpro** Both create navigation (time, latitude, longitude) spanning the period of the ctd + ladcp cast in file ladcp/nav/navAAAAA.asc in the format 20020729 131719 -19.623387 59.219467 with no header or trailer. Note that longitude is stored before latitude. Both execs obtain their navigation data from the gps4000 stream. If the navigation spanning the ctd period has already been processed into Pstar, then use **donavpro**, which merges the ctd.1hz file onto the pstar gps4000 master file then mlists the result. This avoids having to specify start and stop times. If the navigation has not been processed, use **donavraw**, which obtains the gps4000 data from the rvs raw data stream using datapup, edits it and mlists it. In this case start and stop times must be specified in rvs format.

A3.2 IGRF2000

Some weeks into the cruise, new 2000 constants (IGRF00.m) for the IGRF magnetic deviation calculation were emailed to the ship, to replace the 1995 values (IGRF95.m). These resulted in magnetic deviations (used to rotate the velocity vectors) about 1-2° different from the 1995 values.

A3.3 Figures

The Matlab processing generates a number of figures, some of which flash on the screen for seconds. These were tidied, by providing standard headers (streamers) and saving the output as .ps files in the ladcp/pro/res directory, so that they can be examined or printed at leisure. Figures so retained [*but not shown in this report*] are:

Fig. 1 (from laproc.m, plotinv.m) East and north velocity profiles for the full inverse, down cast only and shear method; post processed bottom track velocities; and useful statistics. Hardcopy of this figure is always useful.

Fig. 2 (from laproc.m, plotraw.m) Raw LADCP data, showing vertical velocity, depth, tilt and heading versus ensemble number, also echo amplitudes and correlation for each beam. This figure is useful to identify problems such as a weak beam and excessive package rotation.

Fig. 3 (from prepinv.m) Scatter plots of raw data and initial velocity profiles.

Fig. 5 (from loadctdsoc.m) CTD pressure v. time in hours from start of cast. Can be useful to check that CTD cast is correctly truncated at start and end.

Fig. 4a (from getdpth.m) CTD depth v ensemble together with bottom depth data. Discussed further below.

Fig. 7 (from getinv.m) Temporary plots of CTD track through the water, probably not necessary, as summarized in a subplot of Fig. 1.

Fig. 10 (from svcalc4.m) MVBS plots from 4 bins.

A3.4 Format of results from Visbeck software

Five structured arrays are produced: d, dr, f, p and ps. Since these are not described anywhere that I am aware of, here is a brief summary:

f the input file names and information for the output files

d the ping by ping profiles and related data, e.g. d.ru: [16x8382 double], raw(?) u velocities for 16 bins and 8382 profiles

dr inversion results and time averaged data, e.g. dr.z: [128x1 double], depths at 20 m intervals; dr.shiplon: [1x247 double], ship longitudes at about 30 second intervals

p numerous constants specific to the cast. (the MVBS data are also in this array, which is not logical, but I realised this too late to change it for the cruise)

ps a few more constants related to the inversion process.

A3.5 Main modifications made to Visbeck software

- ladmaster.m changed to (a) cope with more than one frequency on one cast; (b) add minimum distance of altimeter off bottom p.altr_ht; (c) use only post-processed bottom calculation p.btrk_mode = 2; ignore random pauses in the processing with 'pause off'.
- Calls to several major routines (mostly from laproc.m) changed to include array f, thus allowing figures to be saved.
- loadctdsoc.m and loadnavsoc.m changed to read ASCII files with full two word times.
- getdpth.m has override that sets the bottom depth using CTD maximum depth plus altimeter, if available.
- The test for near-bottom data in getdpth.m has been changed (iok=find((max(zz)-zz)<200 & isfinite(d.hbot) & abs(d.wm)>0 & d.hbot~=0) to test for zeros in d.hbot. This is because zeros in the distance of the package from the bottom (for reasons unknown) signify bad data.

A3.6 Processing path

1. Given two downward looking ADCPs on the CTD rosette frame, one will be defined as the Master and the other the Slave. On *Discovery* 264, the master was the 300 kHz, the slave the 600 kHz. From the LADCP logging PC, ftp the two files:

AAAAAm.000 (the master) to /data62/ladcp/300khz/raw
AAAAAs.000 (the slave) to /data62/ladcp/600khz/raw

where AAAAA is the station number (e.g. 14697 on *Discovery*). Rename these files to the conventions I have adopted: d for 150 kHz, w for 300 kHz and b (backscatter) for 600 kHz. Thus, on *Discovery* 264:

mv AAAAAm .000 wAAAAA.000
Top level: ladcp
Second level: 150khz 300khz 600khz
Third level: For each frequency: logs pro raw

2. Note CTD start and stop times and positions, max wire out and altimeter minimum distance in m off the bottom, taking the information from the CTD log completed during the cast. Only the altimeter needs to be accurate. Positions should be reasonably accurate, as they are averaged and used to calculate the magnetic deviation, the angle by which the velocities are rotated. Start and stop times should span the cast. Wire out is for comparison only. All these values except the altimeter are recalculated in the Visbeck software.

3. cd ladcp/m

4. vi ladmaster.m in the ladcp/m directory, to paste in the station number wherever it occurs (the edit instruction :1,$g/AAAAA/s/AAAAA/14697/g is given as a comment in the script), and the start and stop times and positions, max wire out and altimeter. Save the edited file as ladAAAAA.m - the master file is read only. This script is the same for both the master and the slave, i.e. for both frequencies.

5. doctdasc - enter the cast number when asked.

6. donavraw - if nav data for the cast period has not yet been transferred to Pstar, or donavpro if nav data exist, especially for back processing. Up to here, all processing has been the same for both LADCPs mounted on the same CTD frame. From here on, both the station number and a single letter for the LADCP frequency are required, where d = 150 kHz, w = 300 kHz and b = 600 kHz.

7. Run 'matlab', still in the ladcp/m directory, type in the cast, e.g. 'lad14697' then the frequency, e.g. 'w'. This calls the Visbeck software, which processes the cast, displaying several plots on screen, and saves the final arrays, log and plots. This may take 5 minutes or so (for a 3000 m cast, on *Discovery* 6). Scan the log file on screen for potential problems, e.g. bottom not found.

8. ladexec0 - this exec copies the cast specific files and plots from the ladcp/m directory into ladcp/pro for the master data file (e.g. w14772result.mat) and into ladcp/pro/res for all other output (e.g., all names of the form w14772result…….). Edit ladexec0 before running it to control which plots and listings are to be sent to hardcopy. Ladexec0 can also be rerun any time to hardcopy further plots and listings. At the end of step 7, all the arrays created by Visbeck remain in matlab, and can be inspected (or reloaded from the *.mat file). Remaining processing is specific to Ptar, and we here detail the execs that proved useful on *Discovery* 264.

9. ladexec1 - enter the cast number and frequency code. Ladexec1 uses pmatlb to extract the depth (dr.z), pressure (dr.p) and major velocity (dr.u, etc) arrays, usually calculated at 20 m intervals and copy them to Pstar. Also copied are the bottom velocity arrays dr.zbot, dr.ubot and dr.vbot. I have found that dr.zbot may not be aligned with dr.z, so take care. Probably these ought to be in a different file, or be shifted so that the depths align. The output files are called lv{$freq}{$station}, e.g. lvw14697. Thus 'l' is for ladcp, 'v' is for visbeck, 'd' 'w' or 'b' identifies the frequency. These files are stored in ladcp/ppro.

10. cd ladcp/ppro

11. I used 'compvels' to merge into file 'velAAAAA' the data from 4 different instruments, namely the two ladcp files lvwAAAAA and lvbAAAAA, and the two VM ADCPs: the 150 kHz, in /data62/adcp/sdpAAAAA.ave and the 75 kHz surveyor, in /data62/surveyor/surAAAAA.ave. The VM profiles were created (see underway processing) by 'pcopya' the on-station columns from the .abs 2-minute files then running 'allav' on them. The resultant file has east and north velocities for these four instruments, at 20m intervals, and several differences, such as (surveyor - Visbeck) and (surveyor-adcp).

12. Finally, pgridp was used to used to append the velAAAAA files (using 20,1000,20 to extract the top 1000 m without further interpolation), starting with 14697 and appending all files in 'velprofiles'. Pcopyg and pavrgc were used to extract a range of depths and average across them to create statistics of the differences between the velocities for the different instruments.

Raymond Pollard

A4. Calibration of scientific echosounders (LEK and TEK)

Attempts were made to calibrate the lowered EK500 (LEK) and the towed EK500 (TEK) scientific echosounders at the beginning of the cruise using a standard method for a towed body calibration (after MacLennan & Simmonds, 1992; *Fisheries Acoustics*, Chapman & Hall, London). The calibration procedures were carried out between 15:00 25 July and 02:00 26 July, whilst the ship was at anchor in Brodick Bay, Isle of Arran (approx 55º 35’ N, 5º 6’ W). Once the equipment was assembled, calibration data were first collected from the TEK (between 15:52 and 19:50), then the LEK was deployed (at approx 20:30). However, as soon as data collection commenced it was apparent that the LEK echosounder had failed and it was recovered. On

opening the water tight housing it was found that it had not sealed properly and that the equipment had suffered from immersion in the water. Further attempts to collect calibration data from the LEK, both at the surface and at depth, were made during the cruise [see Section 3: Lowered EK500 scientific echosounder (LEK) for details] but none produced data of a high enough quality to accurately calibrate any of the transducers.

For the calibration of the TEK, a 38.1 mm tungsten carbide standard target sphere was suspended approx 10 m below each transducer in turn, and data were collected using the usual logging systems. As the CTD could not be deployed prior to the calibration a sound speed of 1500 ms^{-1} was derived from water taken from the non-toxic seawater supply, and this value was used for all calculations that took place during the calibration. A successful CTD cast was made at the same location the following day, which gave a sound speed of 1498.5 ms^{-1} in the top 25 m of the water column. This gave the following expected target strengths for the standard target [taken from standard curves (Foote, 1990, *J. acoust. Soc. Am*., 88: 1543-6)] which were used in all subsequent calculations:

38 kHz transducers	-42.350 dB
120 kHz transducers	-39.540 dB
200 kHz transducers	-39.085 dB

Data were collected to calibrate both the integrator (SV) gain and the Target Strength (TS) gain for each transducer. After the initial data collection at the standard gain setting (26.5 dB in all cases), several further iterations of adjusting the gain to a new calculated value and collecting data were performed for each parameter for each transducer. The final calculations of the calibrated gain values were made at a later date using the adjusted sound speed and target strength values.

The final gain values were calculated solely from on-axis 'pings' where possible, or those as close to on-axis as possible. The divergence from the on-axis positions was calculated from the sum of the absolute along and athwart offsets (measured in degrees) from the expected on-axis position. Pings were rejected if this summed offset exceeded 0.5º. In the case of the single beam transducers (120 kHz and 200 kHz), the position of the sphere relative to the transducer was taken from the 38 kHz split-beam transducer single target detection data, adjusted for the relative positions of the transducers. The TS gain (TS_G) values were calculated using single target detection values exported directly from Echoview® (v. 2.25.82, SonarData, 1995) and the equation (all values in dB):

$$TS\_G_{New} = TS\_G_{Old} - ((TS_{Measured} - TS_{Expected}) / 2)$$

The SV gain (SV_G) values were calculated using the SA (= NASC or Nautical Area Scattering Coefficient in Echoview®) values derived from the integration, in Echoview®, of the target sphere's echo for single pings and the equation (gain values in dB, SA values in m^2nmile^{-2}):

$$SV\_G_{New} = SV\_G_{Old} + ((10 * \text{Log}\,(SA_{Measured} / SA_{Theoretical}) / 2)$$

Theoretical SA values were calculated from the expected TS of the sphere (TSexpt), the transducer's 2-way beam angle (TransA) and the distance to the sphere from the transducer face (Range) using the equation:

$$SA_{Theoretical} = (4\pi * 10^{(TSexp/10)} * 1852^2) / (10^{(TransA/10)} * Range^2)$$

The final calibrated gain values are given below.

Table 19. TEK calibrations for *Discovery* 264

Transducer Frequency	SV Gain	TS Gain
38	26.65	26.66
120	20.57	20.56
200	23.24	23.36

NOTE: During the cruise all data were collected using the standard SV and TS gain settings of 26.5 dB (the calibrated gain values were only applied during post processing).

Cairistiona Anderson, Andrew Brierley, Ryan Saunders

A5. Preliminary species list for Dual Methot net samples

Euphausiacea
- *Meganyctiphanes norvegica*
- *Thysanoessa inermis*
- *Thysanoessa longicaudata*
- *Thysanopoda acutifrons*
- *Nematobrachion boopis*
- *Stylochieron maximum*

Decapoda
- red deep sea decapod spp
- red decapod-slim sp
- decapod larvae

Pasiphaea
- *Sergestes* sp

Mysidacea

Amphipoda
- *Parathemisto sp.*
- *Parathemisto gracilipes*
- *Parathemisto gaudichaudi*
- *Hyperia galba*

Copepoda
- *Euchaeta norvegica*
- *Calanus hyperboreus*
- *caligid copepod (on sandeels)*

Ctenophora
- *ctenophore bits*
- *Beroe cucumis*
- *Beroe ovata*
- *Pleurobrachia*
- *?Mnemiopsis?*

Ceriantheria
- *Arachnactes* sp

Hydromedusa
- *Laodicea undulata*

Trachymedusa
- *Aglantha digitalis*

Siphonophora
- agalmid siphonophore
- *Agalma elegans*
- agalmid cormidium
- dyphid siphonophore
- *Lensia* sp

Scyphozoa
- red *scyphomedusa* sp
- *Periphylla*
- *Atolla*

Pteropoda
- *Limacina helicoides*
- *Spiratella limacina*
- *Euclio* spp
- *Clione limacina*

Chaetognatha
- *Eukrohnia hamata*
- *Sagitta maxima*

Thalliacea
- *Salpa fusiformis*

Acantharia

Cephalopoda

Polychaeta
- *Aphrodites* sp?
- *Tomopteris septentrionalis*
- orange polychaete

Pisces
- Myctophid type fish
- hatchet fish
- long-thin deepwater fish
- sandeel larvae

Ryan Saunders

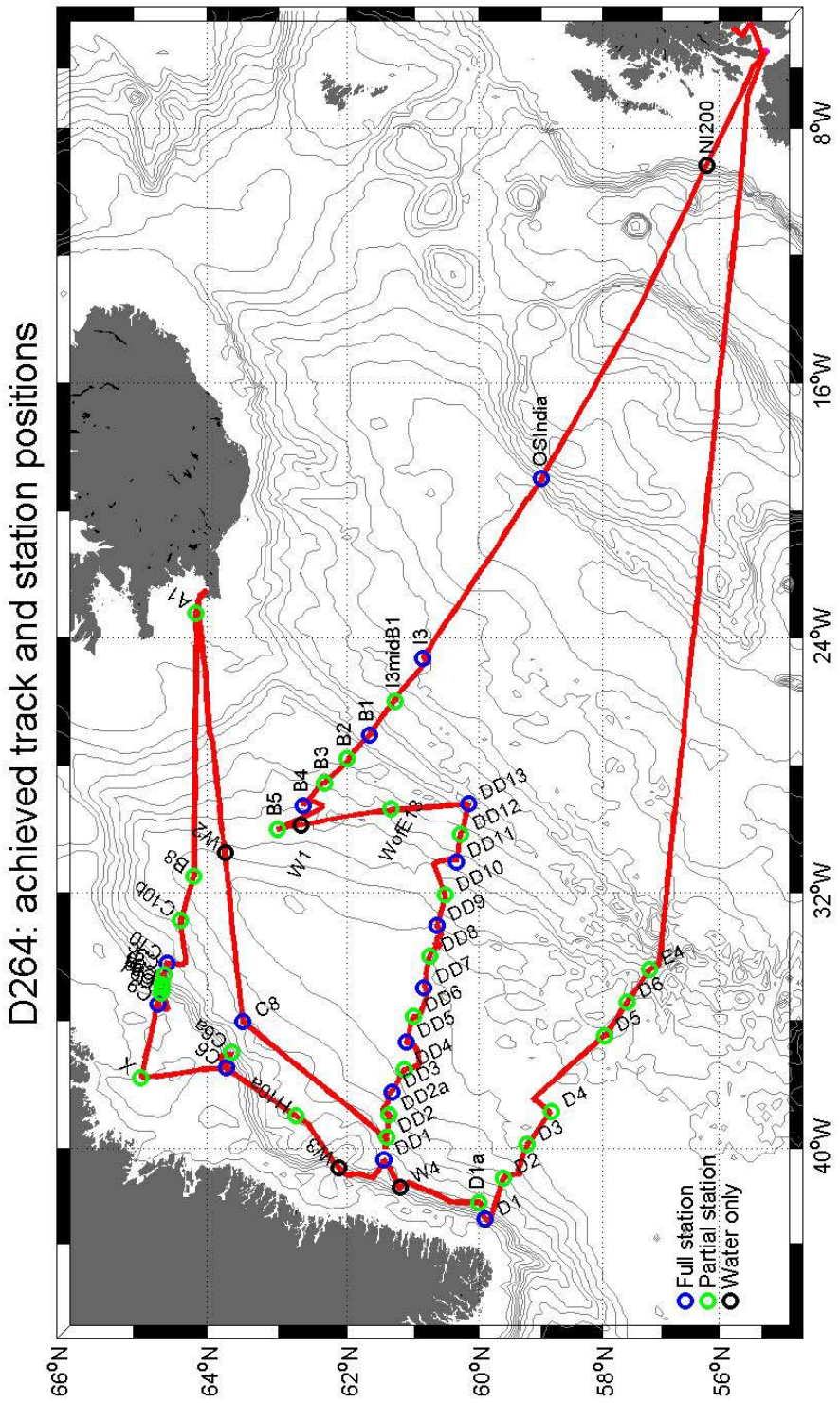


Fig. 1 Cruise track and sampling sites for *Discovery* 264. [Text section 1.3]

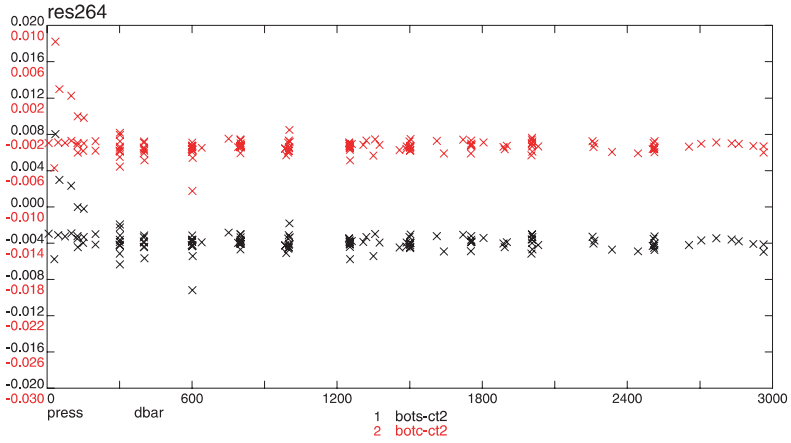


Fig. 2 Residuals for secondary sensor on lowered CTD. Bottle sample minus CTD conductivity (red) and bottle sample minus CTD salinity (black). [Text section 2.2.3]

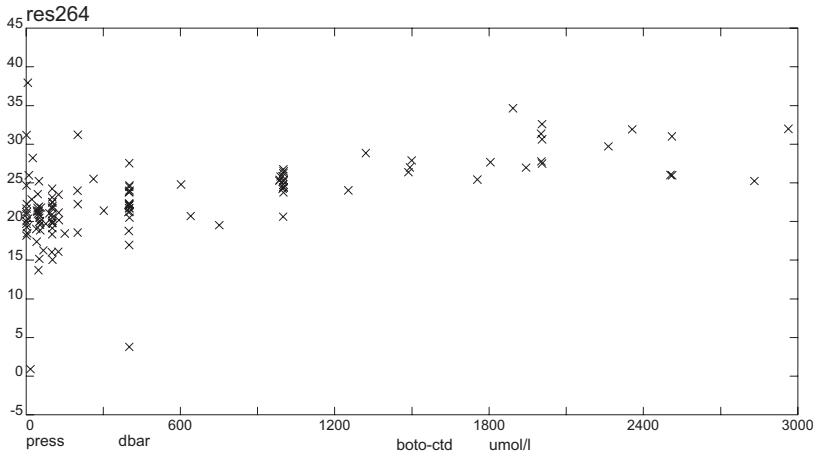


Fig. 3 Residuals for lowered CTD oxygen sensor, bottle sample minus CTD oxygen. [Text section 2.2.3]

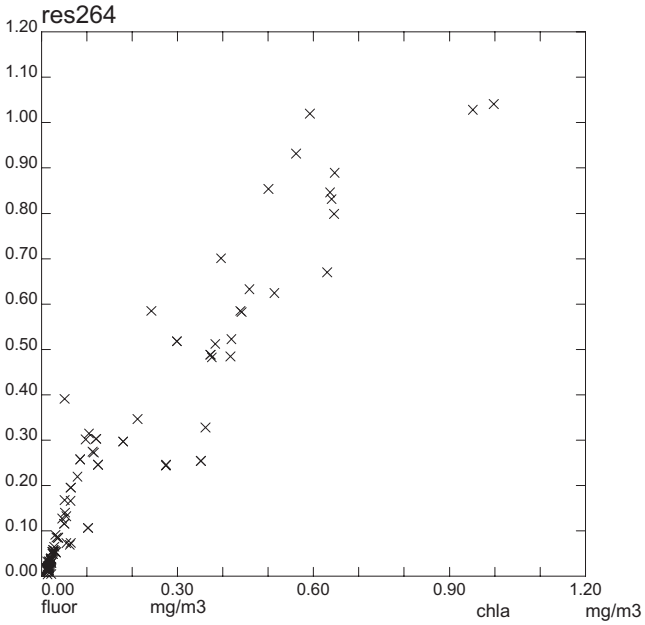
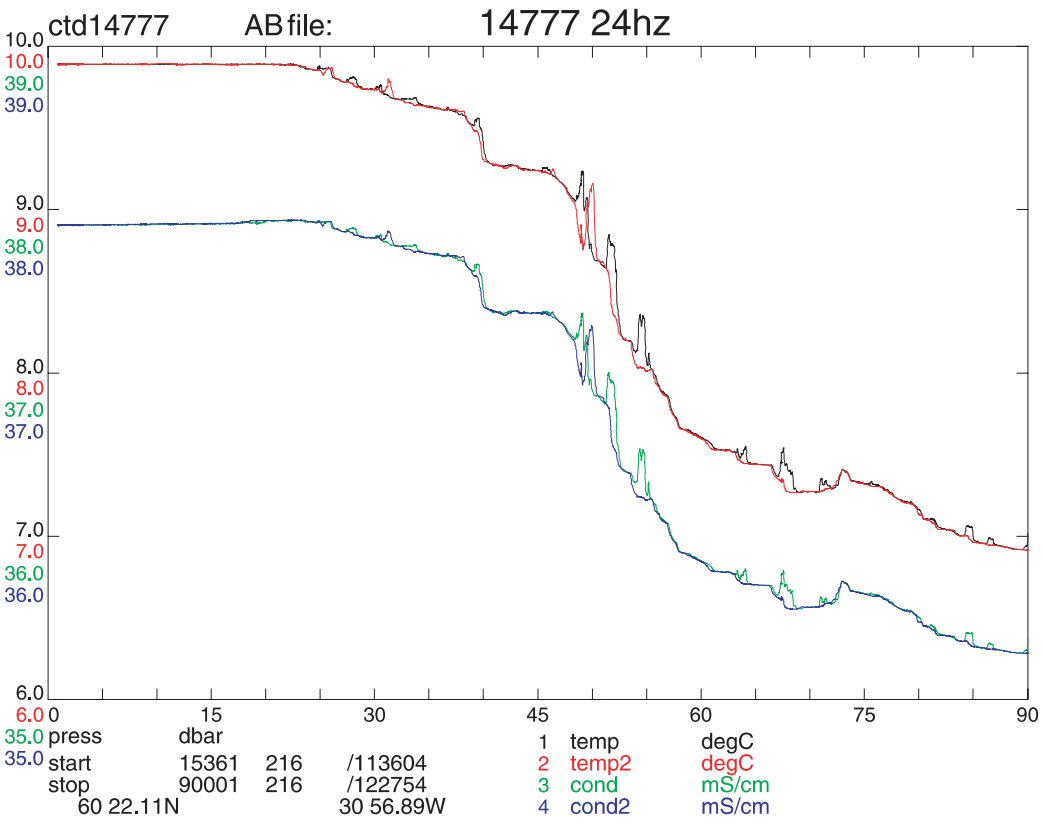


Fig. 4 Bottle sample total chlorophyll concentration against lowered CTD nominally calibrated fluorescence. Data plotted for night time or depths greater than 50 m. [Text section 2.2.3]



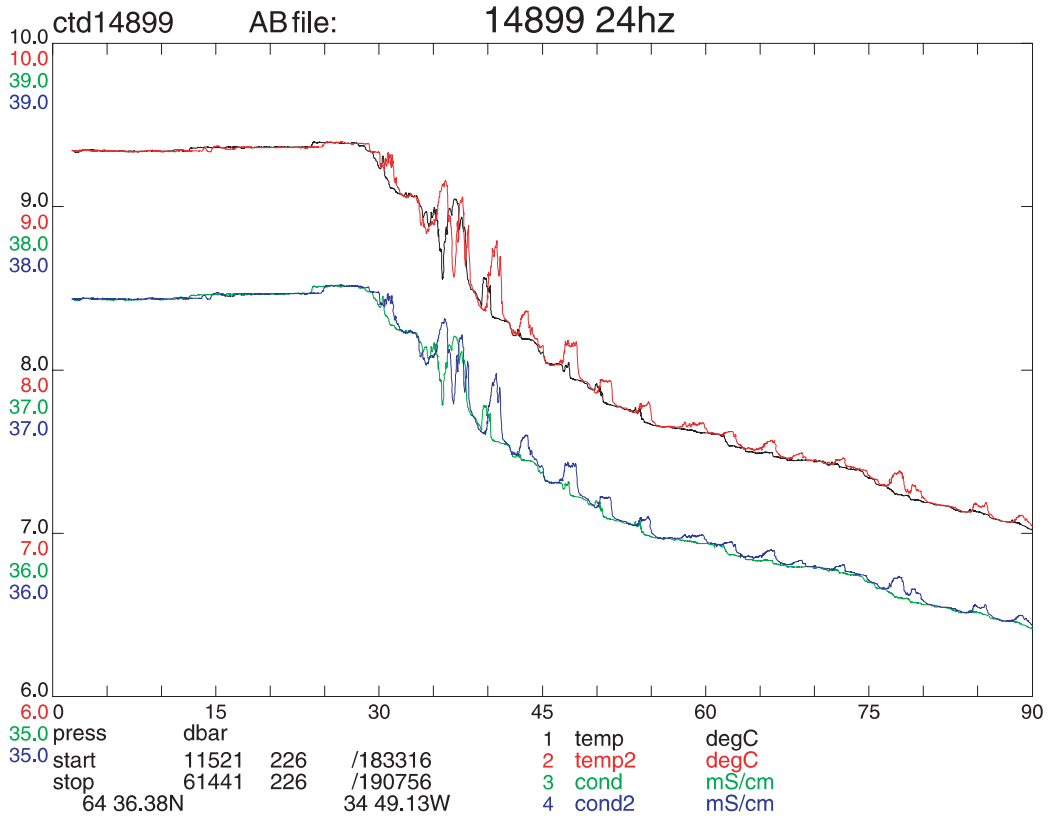
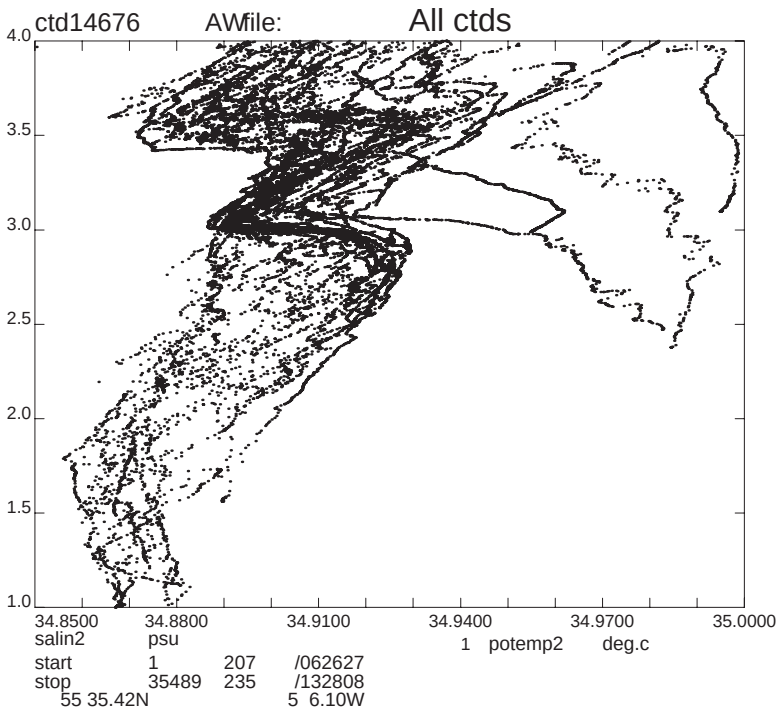


Fig. 5 Temperature and conductivity sensor comparisons. Upper graph, data typical for most CTD stations; lower graph, an example where sensors were badly affected by the water disturbance of the CTD frame. [Text section 2.2.5]



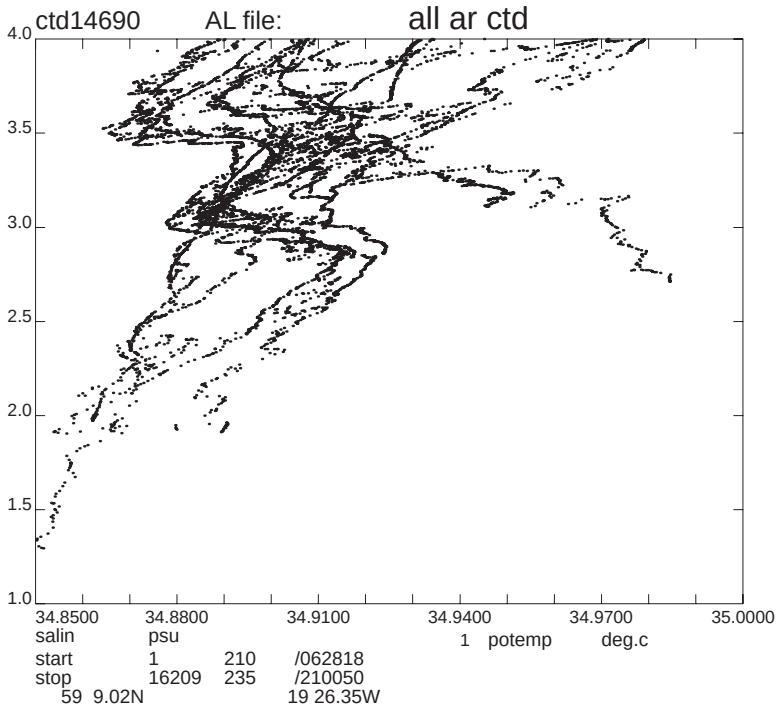


Fig. 6 Expanded plots of potential temperature (θ) against salinity for deep water from the lowered CTD stations (top) and ARIES stations (bottom). [Text section 2.3.4]

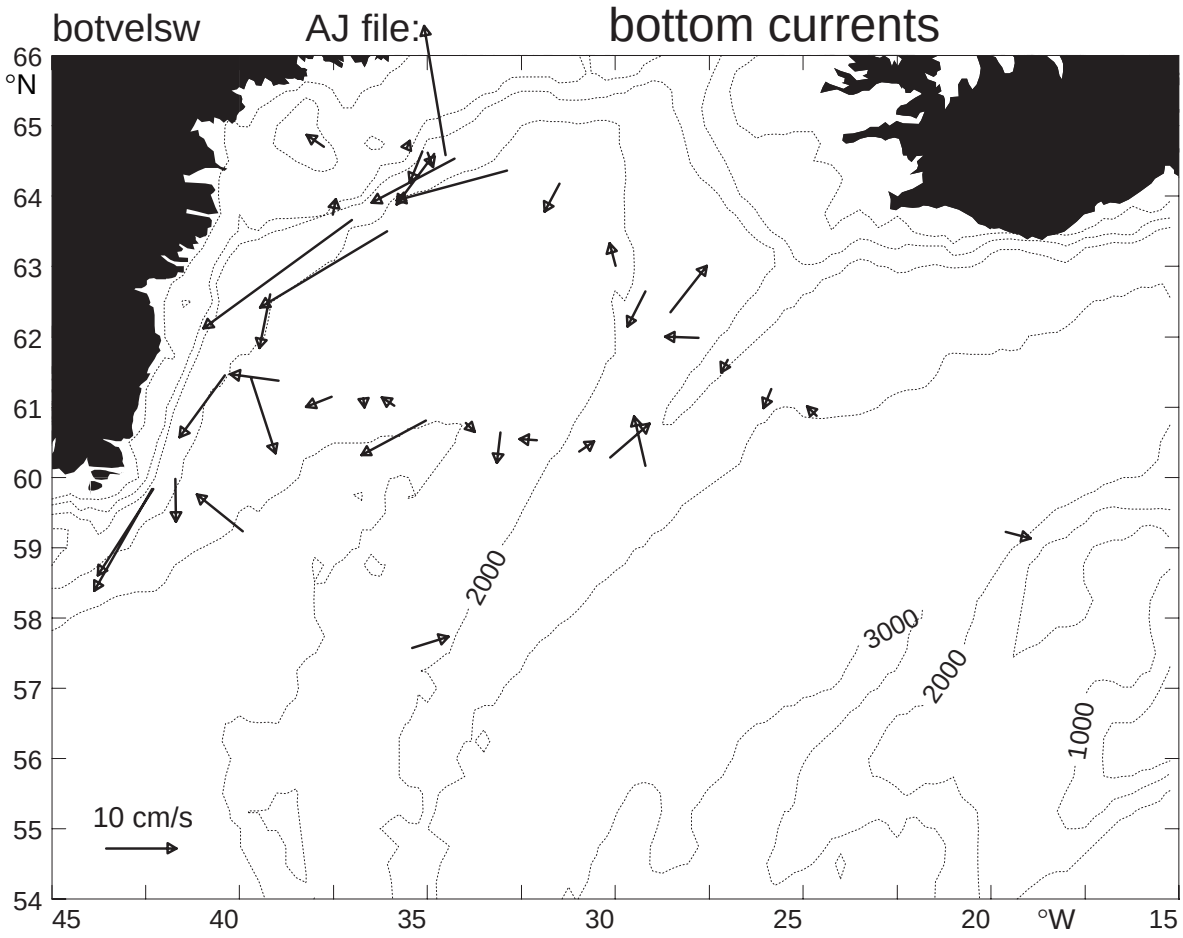


Fig. 7 Map of near-bottom current estimates for *Discovery* 264, determined from LADCP data. [Text section 2.4.5]

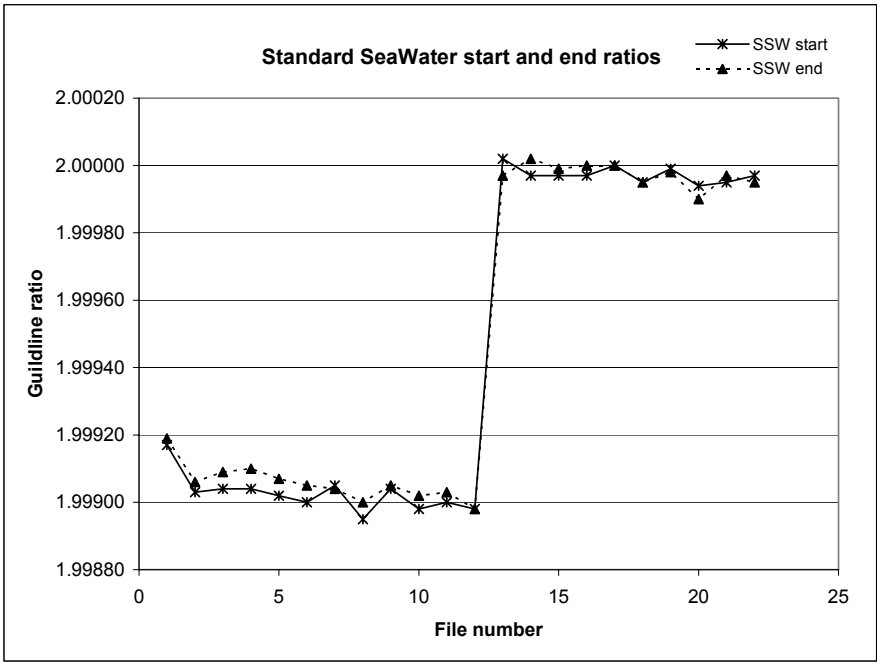


Fig. 8 Standard seawater double conductivity ratio. Note the jump which coincided with the need to change bath temperature from 24°C to 21°C. [Text section 5]

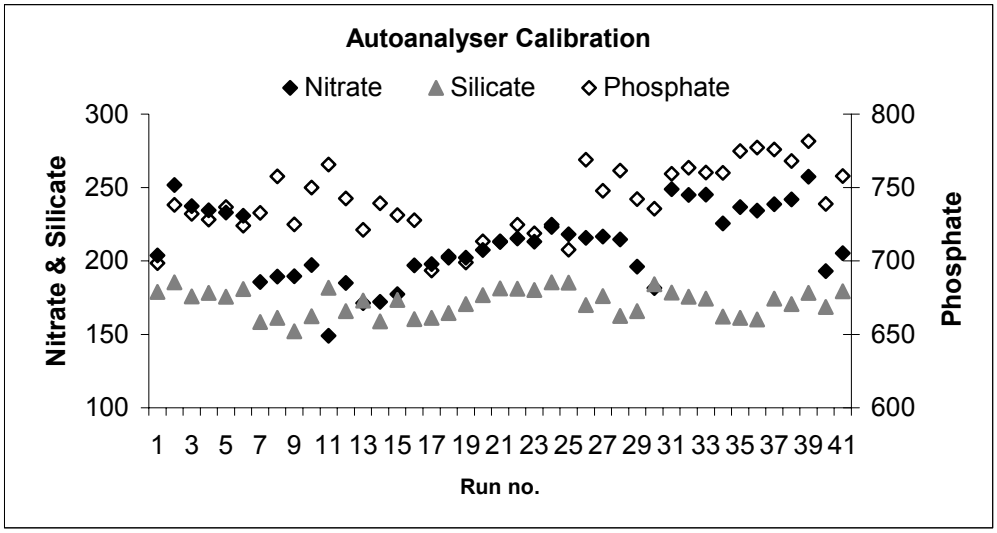


Fig. 9 Nitrate, phosphate and silicate calibration constants obtained on the Skalar San-plus continuous flow autoanalyser for *Discovery* 264. [Text section 7.1.3]

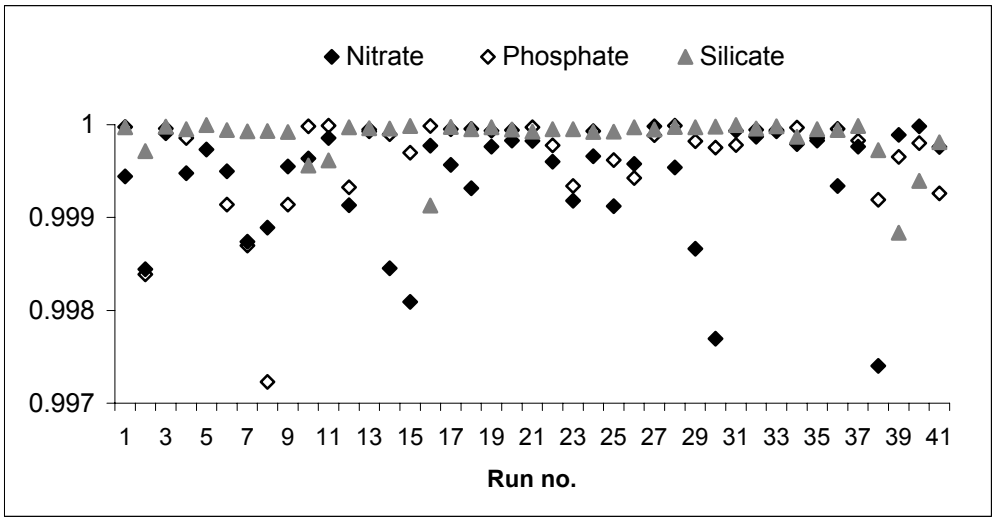


Fig. 10 Goodness of fit (least squares regression) of the nutrient calibration curves. [Text section 7.1.3]

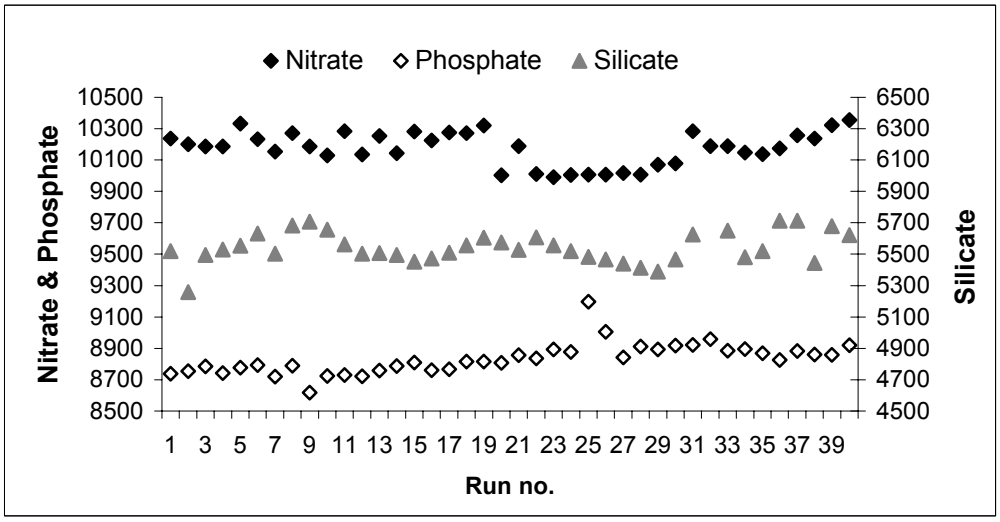


Fig. 11 Variation in nutrient autoanalyser baselines. [Text section 7.1.3]

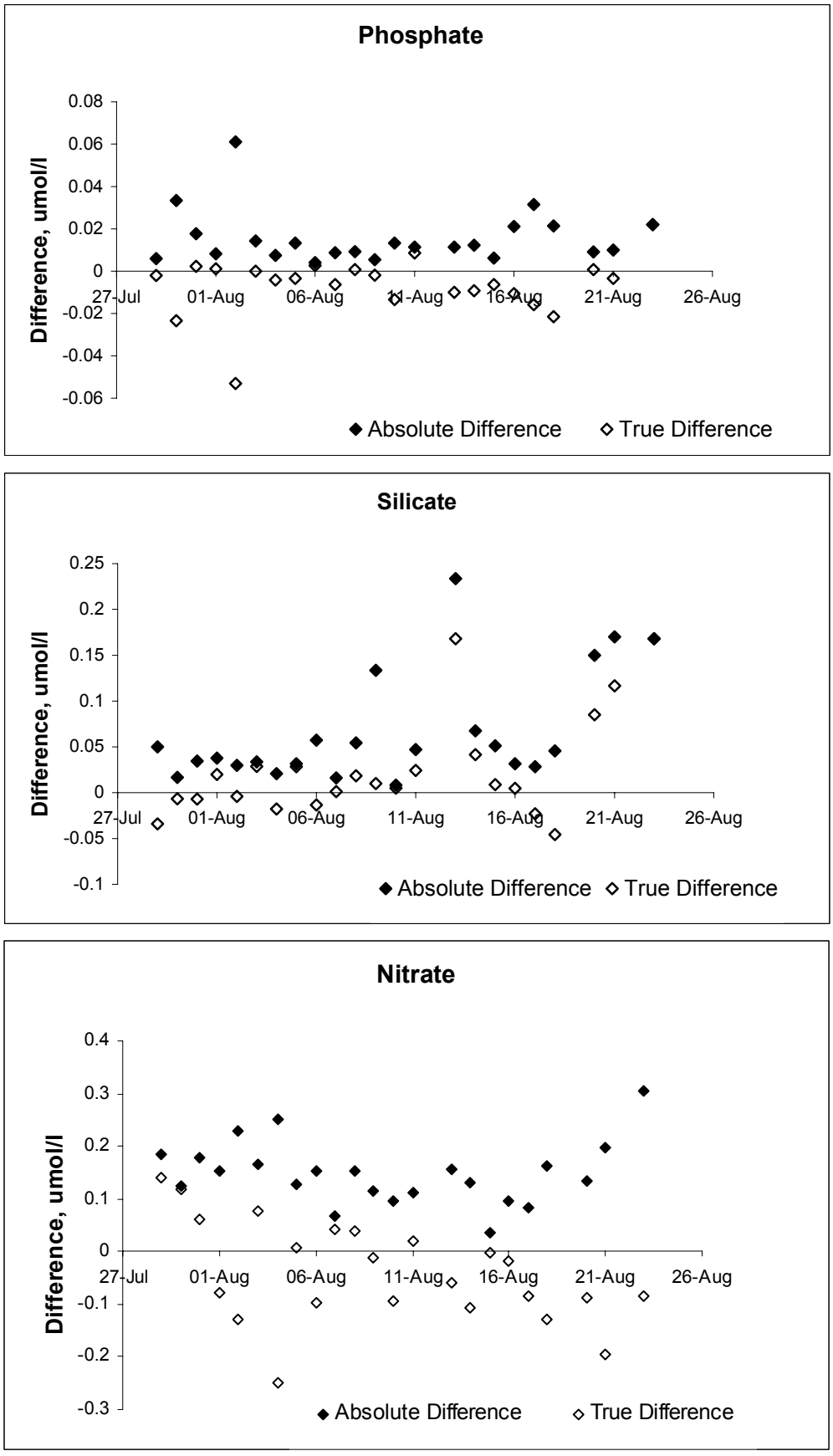


Fig. 12 Mean daily value of the absolute and true differences between replicate sample measurements for phosphate, silicate and nitrate [Text section 7.1.3]

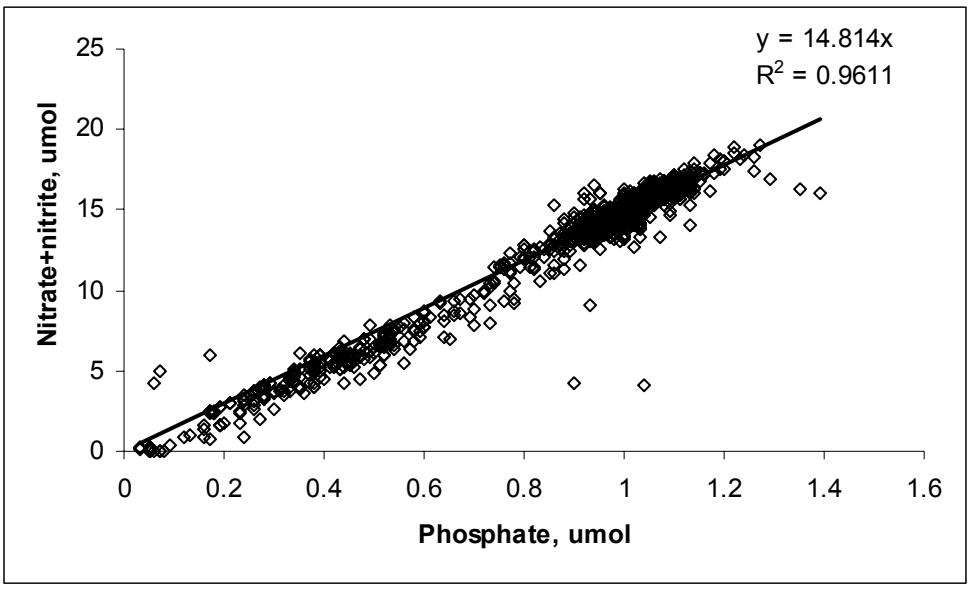


Fig. 13 Regression of nitrate and phosphate data for all CTD and ARIES nutrient measurements. [Text section 7.1.4]

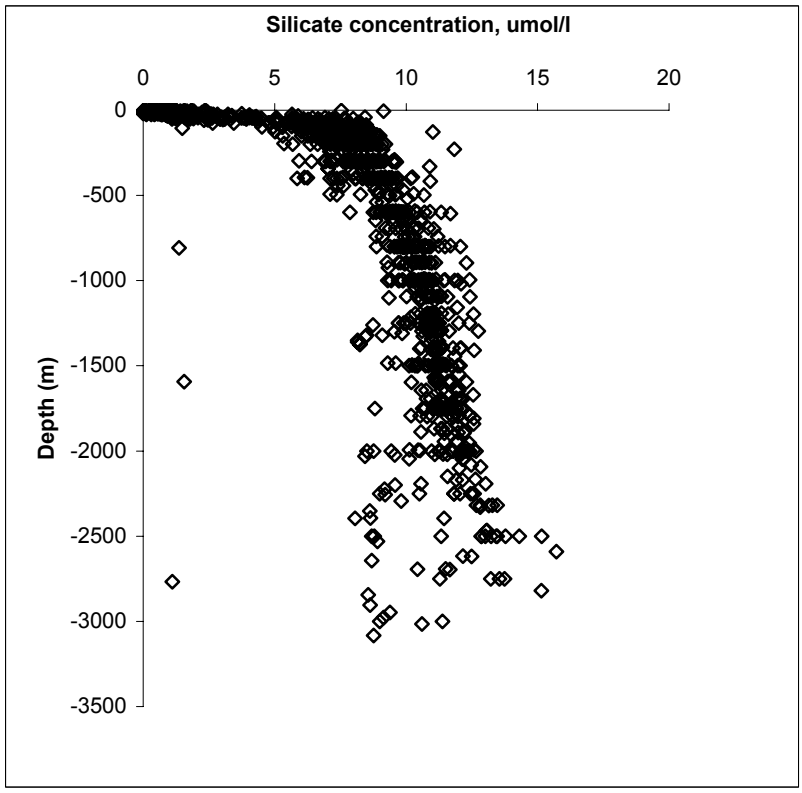


Fig 14. Plot of silicate concentration against depth for all CTD and ARIES casts. [Text section 7.1.4]

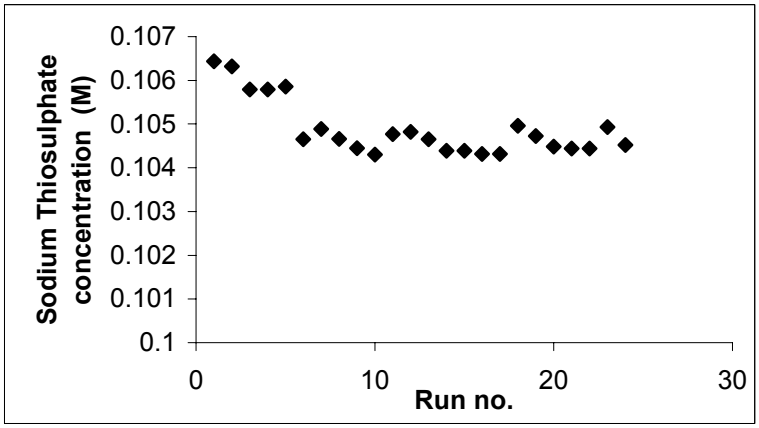


Fig. 15 Concentration of sodium thiosulphate solution used to determine dissolved oxygen concentrations, as determined by titration of potassium iodate standard before each set of oxygen analyses. [Text section 7.2]

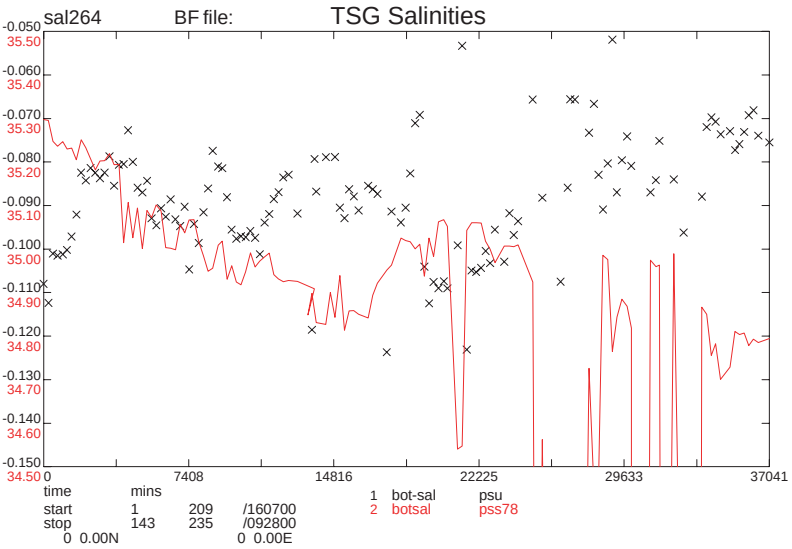


Fig. 16 Thermosalinograph (TSG) salinity offsets, bottle sample minus TSG salinity (black crosses) and TSG salinity (red). [Text section 9.1.3]

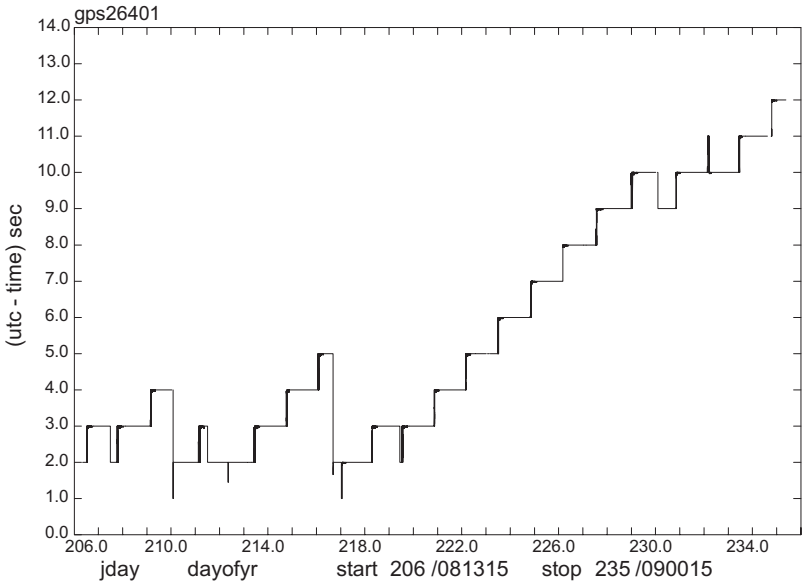


Fig. 17 Difference between Universal Time Clock (UTC, from satellite) and RVS timestamp shows that RVS timestamp leads with a drift rising from 2 to 12 seconds. Data shown are averaged over half-minute intervals. The master file has 2.5 million data cycles. [Text section 9.3.2]

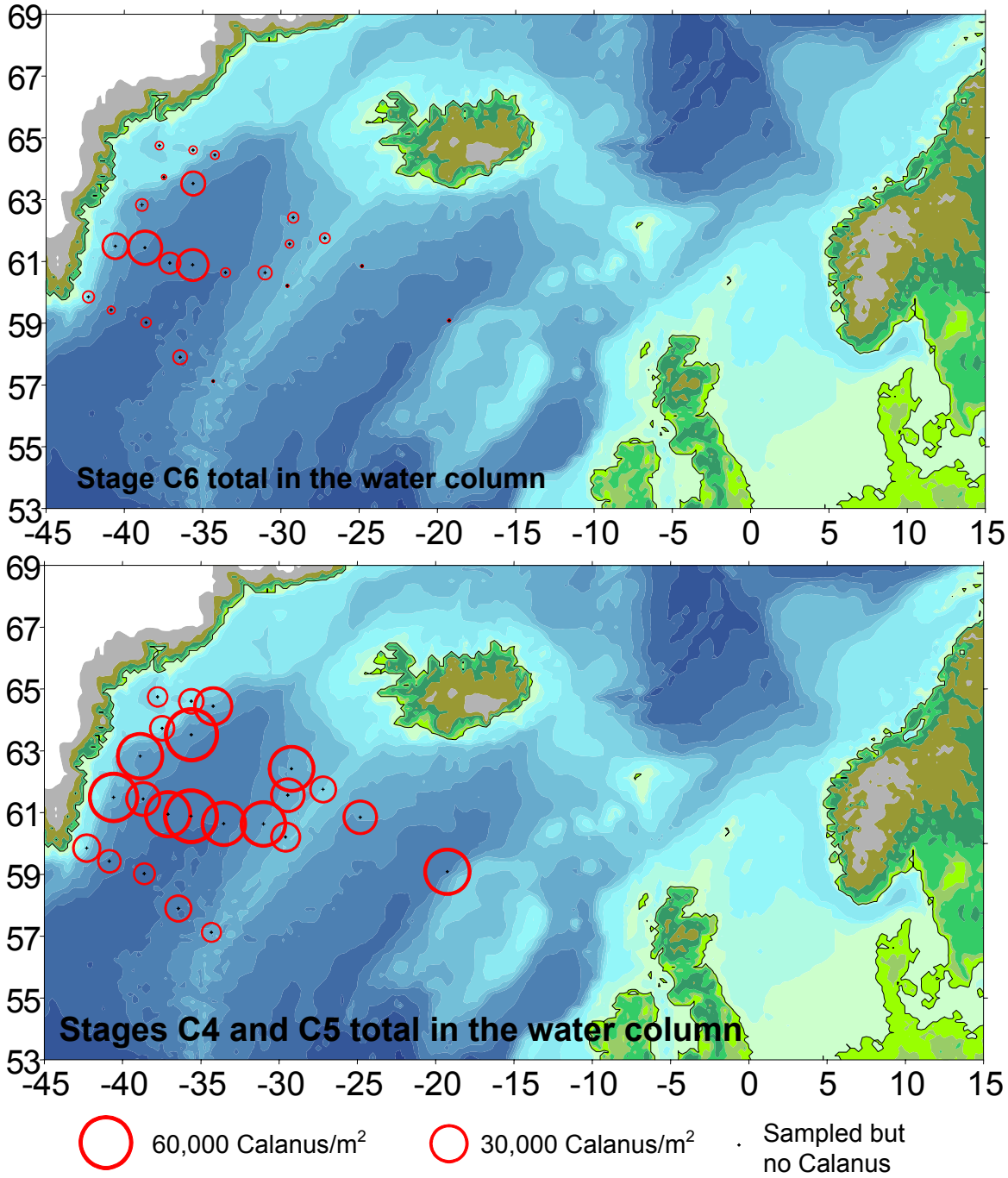


Fig. 18 Estimated standing stocks of *Calanus*-sized particles from preliminary ARIES Optical Particle Counter (OPC) data. Upper map, adults, C6; lower map, copepodites C4-C5. [Text section 10.1]

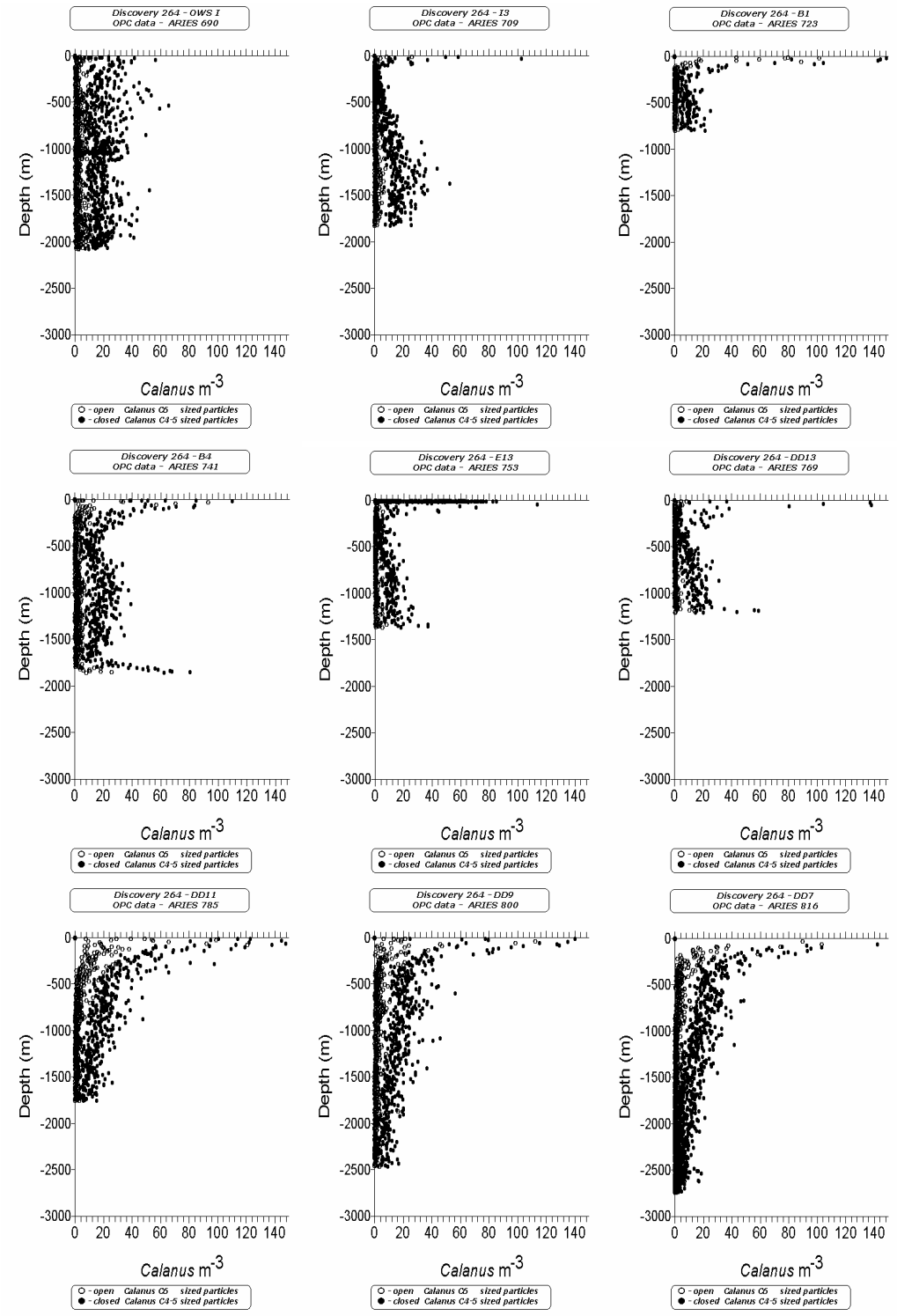


Fig. 19 Optical Particle Counter (OPC) estimates of *Calanus*-sized particles as a function of depth, distinguishing adults (C6) and larger copepodites (C4-C5). Data for stations 14690 - 14816; calibration subject to confirmation. [Text section 10.1]

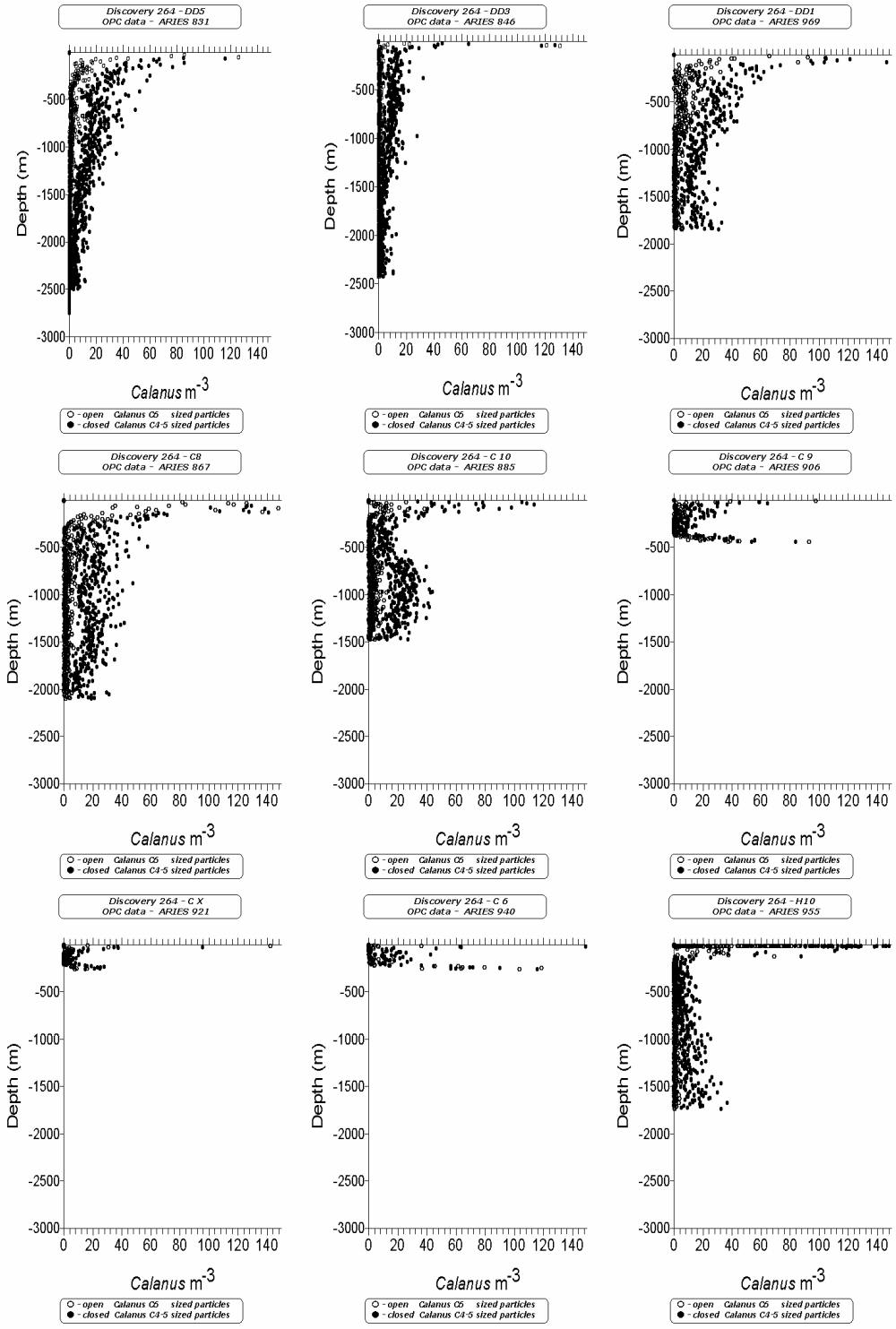


Fig. 19 - continued. Data for stations 14831- 14955. [Text section 10.1]

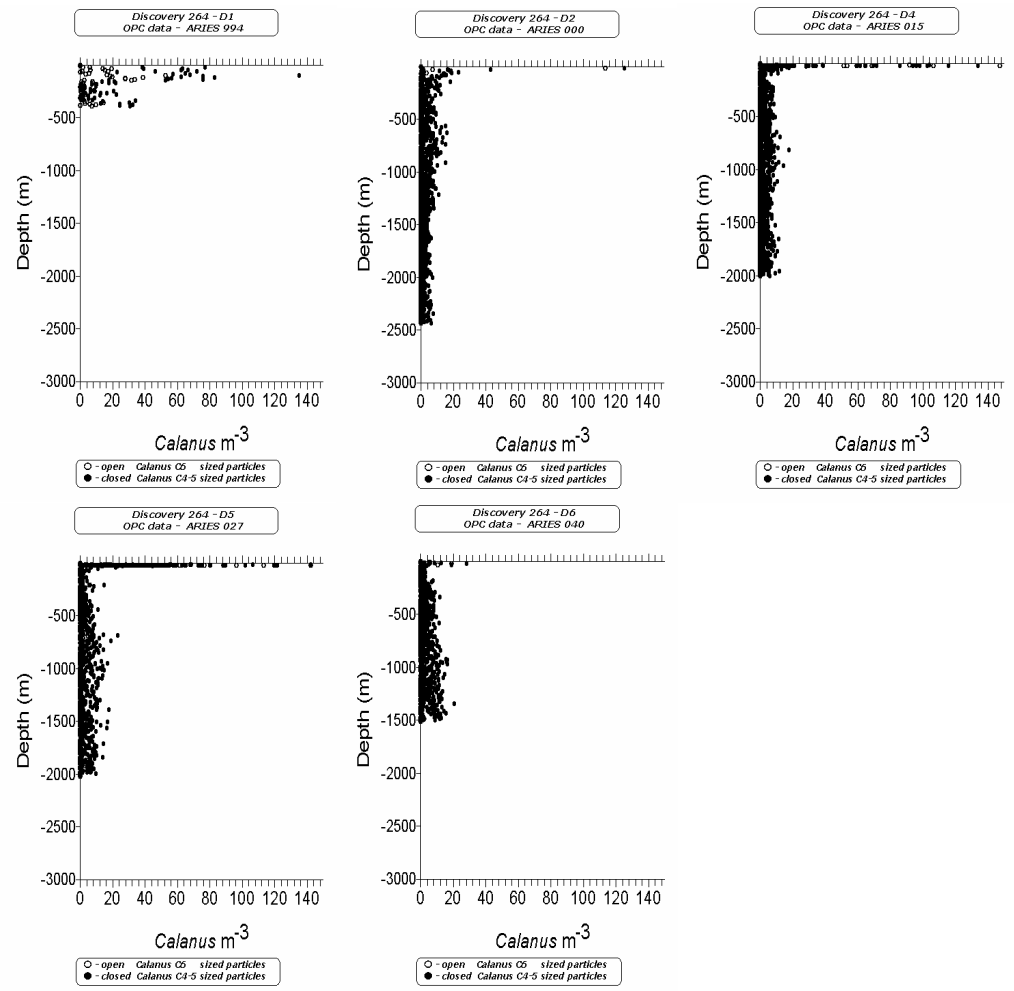


Fig. 19 - continued. Data for stations 14994 - 15040. [Text section 10.1]

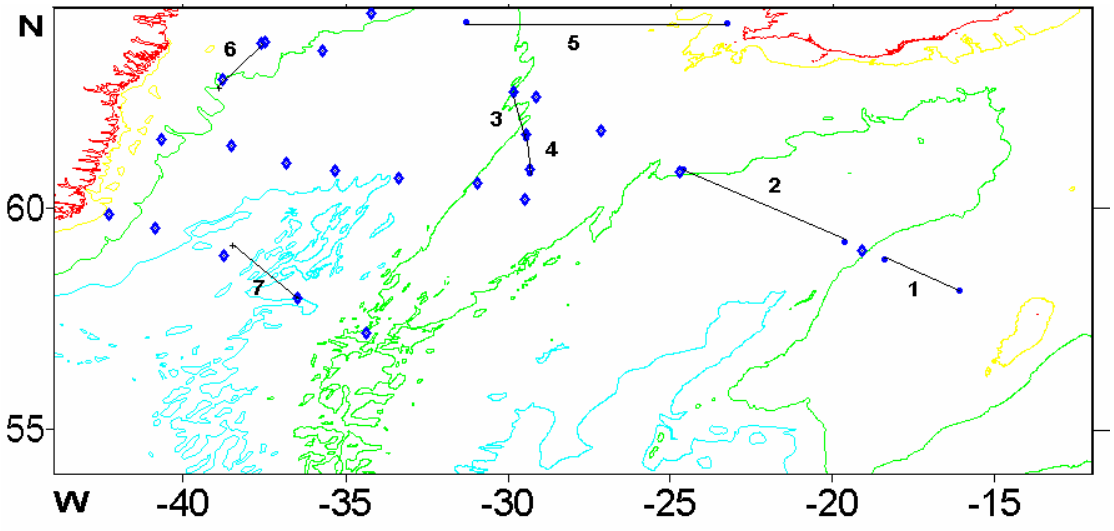


Fig. 20 Deployments 1-7 of the Continuous Plankton Recorder (CPR) on *Discovery* 264. Location of ARIES stations also shown (blue diamonds). [Text section 10.3]

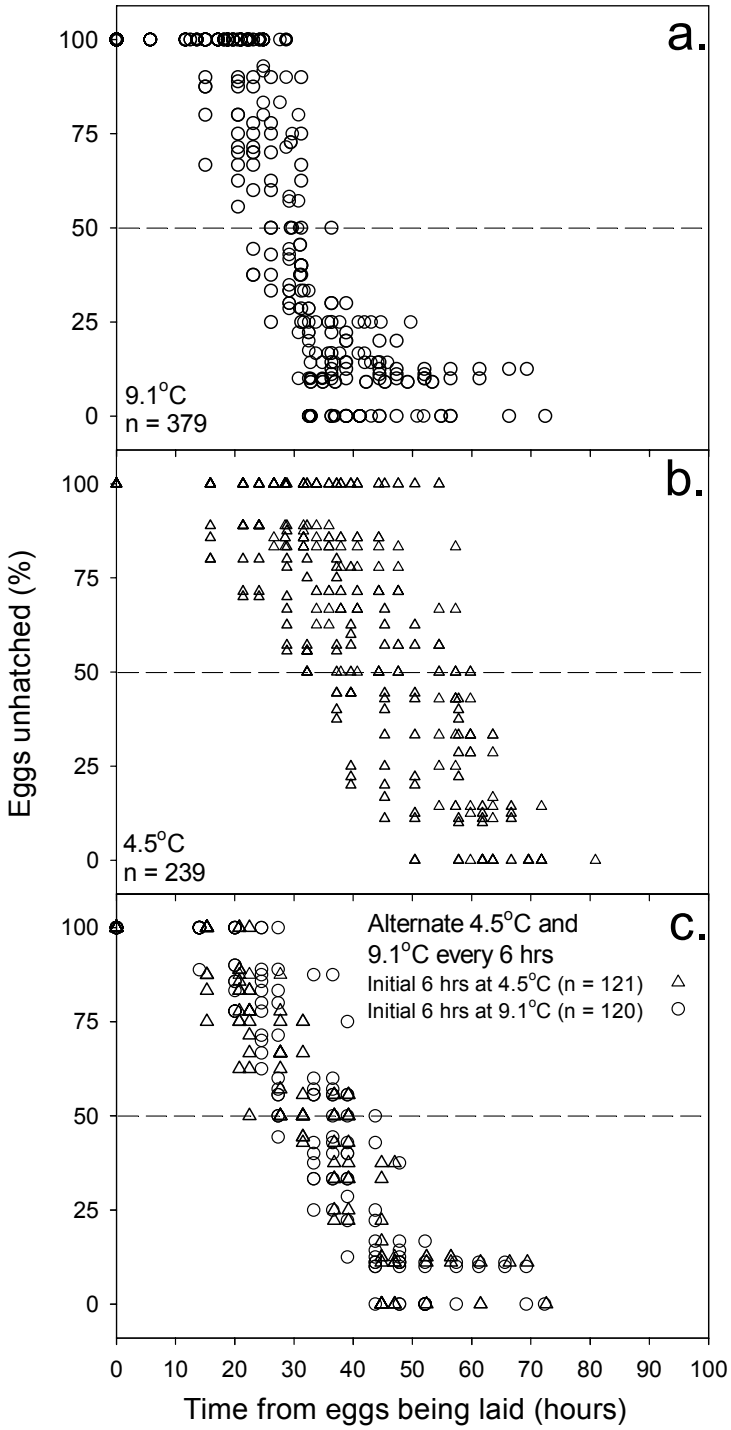


Fig. 21 Egg hatching in *Calanus finmarchicus* incubated in various temperature regimes: a) 9.1°C; b) 4.5°C; and c) alternated between 4.5 and 9.1°C every 6 hours. Percentage hatching is calculated for each well replicate. The females supplying the eggs were collected from a variety of sites during *Discovery* 264. 50% hatch is indicated by the dashed line, this equates to 30 hours at 9.1°C, and 50 hours at 4.4 °C. n = total number of eggs examined at each temperature regime, this number includes those that are unsuccessful at hatching.

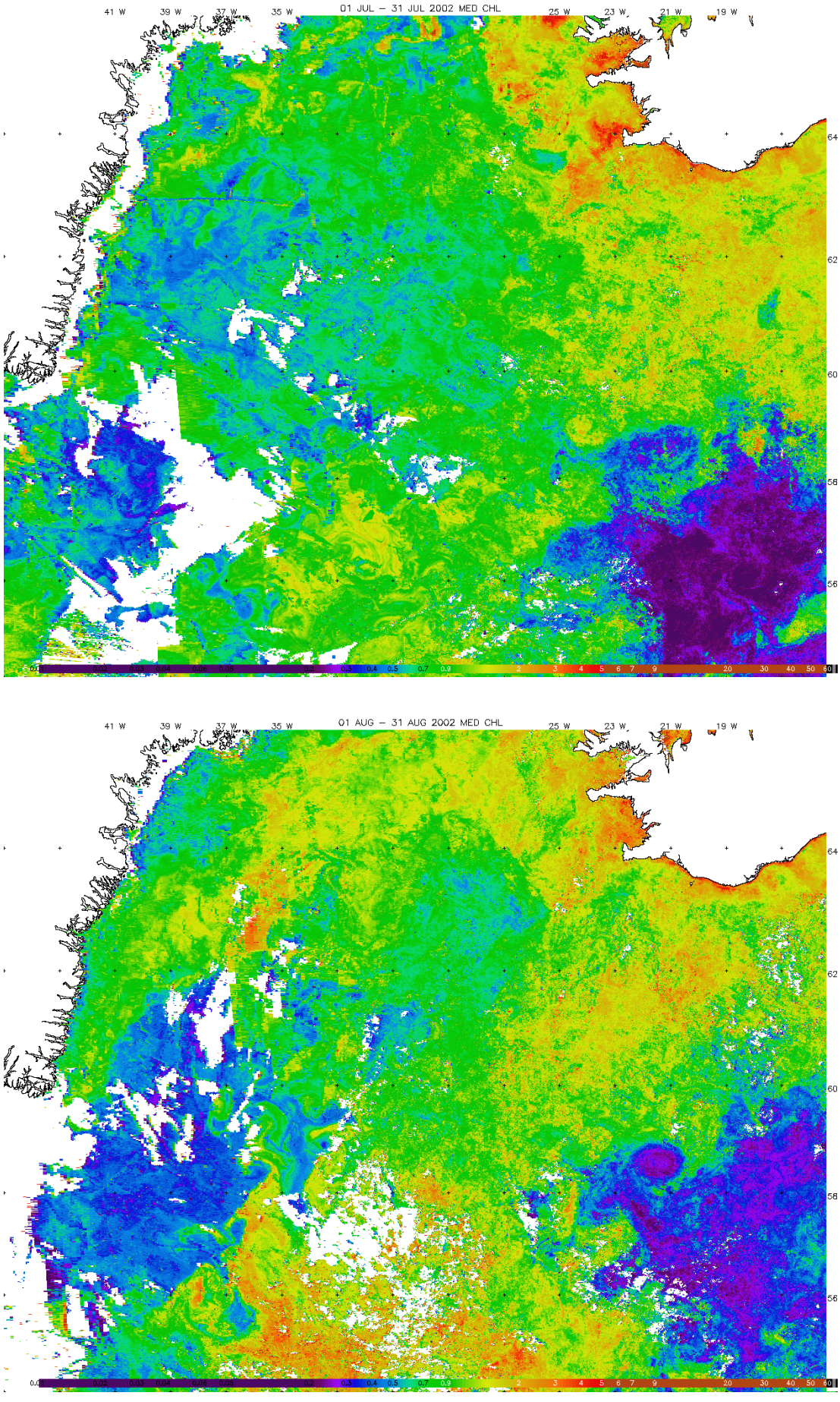


Fig. 22 SeaWiFs monthly composites for chlorophyll-a for July (upper) and August 2002 (lower). [Text section 14]

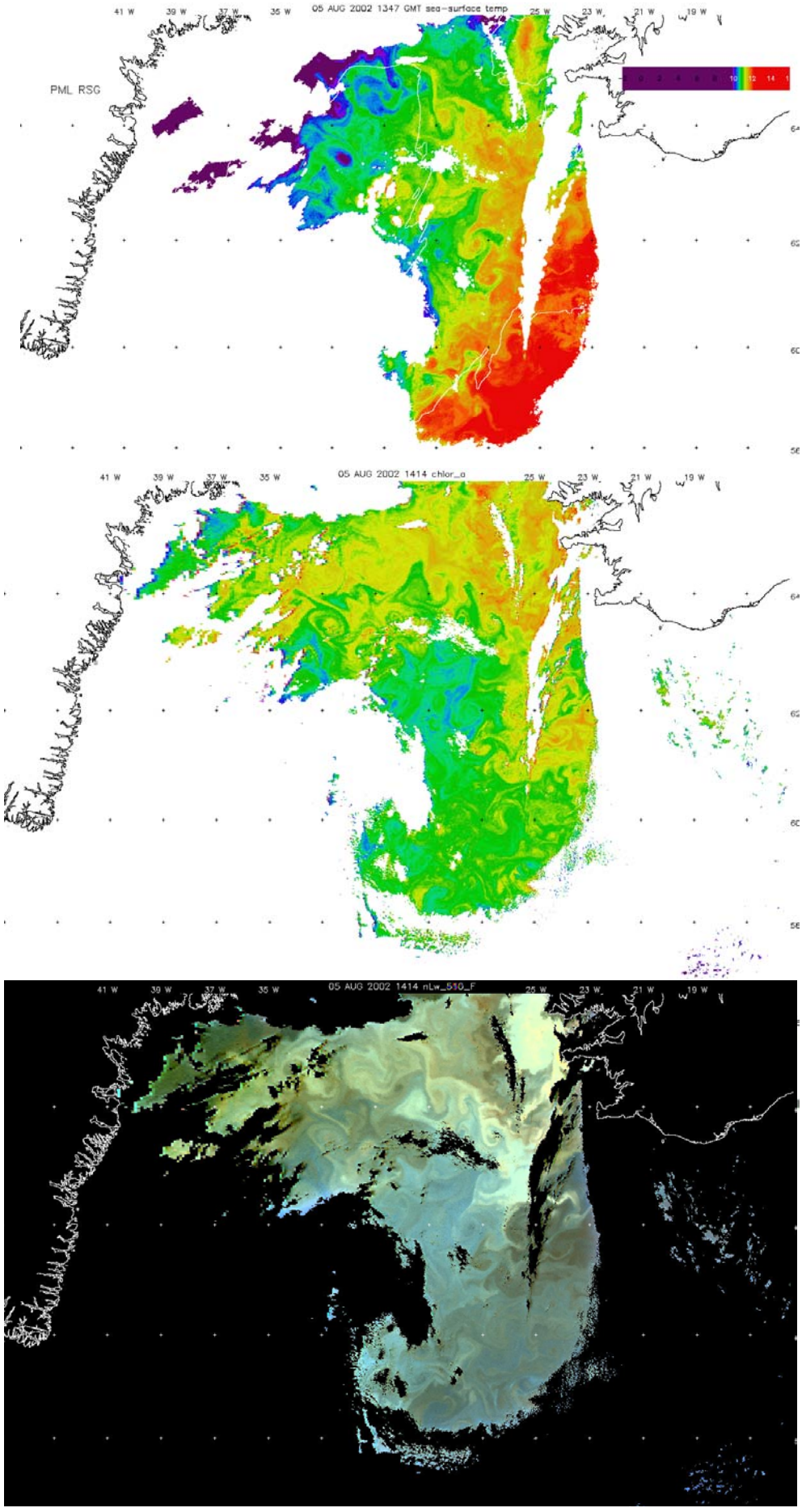


Fig. 23 Satellite data for 5 August 2002, showing sea surface temperature (upper), chlorophyll-a (middle) and true colour (lower). [Text section 14]