~PRIME~

RRS *DISCOVERY* CRUISE 221

11 JUNE - 23 JULY 1996

CRUISE REPORT

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CONTENTS

1. OVERVIEW

1.1 INTRODUCTION

RRS *Discovery* Cruise 221 was dedicated to the requirements of the PRIME Special Topic Programme. The cruise formed the second component of the fieldwork associated with the Programme, the other component being the Mesocosm Experiments carried out in Bergen earlier in 1996. A wide range of disciplines were represented on the cruise ranging from physics through to molecular biology; however, one of the main hallmarks of the cruise programme was the close integration of the various science components represented. To a considerable extent the integrated nature of the cruise reflected the emphasis placed on the modelling input to the development of the overall cruise strategy. Although the underlying requirements of the modellers was important in shaping the programme, the needs of the individual science components were also carefully considered throughout within the overall context of the cruise objectives.

The cruise was divided into two legs with a mid-cruise port call being made at Reykjavik to allow a changeover of part of the scientific company and replenishment of the ship's freshwater supply. The first leg focused on obtaining an eight day time series of observations in Lagrangian mode within a mesoscale eddy in the vicinity of 59°N 20°W. The second leg was designed to carry out a similar range of observations at set stations on a transect between 59°N and 37°N along the 20°W meridian and also to obtain a time series of observations in the vicinity of 37°N 19°W comparable to those obtained at 59°N 20°W on the first leg.

There was considerable pressure on time over the duration of the cruise. One of the basic requirements of the PRIME Programme was to obtain the two sets of time series observations from markedly contrasting biological oceanographic sites. However, in order to ensure fulfilment of the requirement for contrasting, but locally consistent, conditions, it was necessary to separate the two main sampling locations by a considerable latitudinal spacing. This condition, which resulted in a considerable amount of steaming time, together with the required duration of the time series and necessary back-up observations, gave rise to a tight cruise schedule.

Despite the tight schedule of the cruise programme, the objectives were essentially all met. This was due to a range of particularly favourable circumstances. Weather conditions throughout the cruise were generally good, although uncomfortable at times during the first leg. The favourable conditions were of particular significance to the work adjacent to 59°N 20°W where significant cruise time loss due to weather may have been expected, even in summer, but where the actual time lost during the cruise was of the order of 6h. Even the local daily weather patterns at this northern location complemented well the planned day-to-day work schedules. Furthermore, no significant time losses were sustained during the cruise as a result of either ship or equipment problems. Full credit must also be given at this point to the very hard work put in by the scientific party and the excellent co-operation received from the ship's company and RVS technical staff.

1.2 SPECIFIC OBJECTIVES

Three specific objectives were encompassed within the overall objectives of the cruise:
(i) To obtain an eight day time series of integrated physical, biological and chemical data in Lagrangian mode at a location associated with a distinct mesoscale eddy feature in the vicinity of 60°N 20°W. There was a requirement that the time series observations at this location be preceded and succeeded by a large scale physical box survey centred around the time series site.
(ii) To obtain a time series of data in Lagrangian mode comparable to that derived for Objective (i) over a minimum of seven days at a station adjacent to 35°N 20°W.
(iii) To derive a suite of data comparable to that in Objective (i) at a series of stations along a transect between approximately 60°N 20°W and 35°N 20°W.
For all three objectives, it was a requirement that the data sets to be obtained should, as far as possible, be compatible with the needs and objectives of the PRIME modelling community and the

individual PRIME cruise participants, as outlined in the original ship-time proposal and subsequently developed at cruise planning meetings and at the individual project level.

The objectives relating to the PRIME modelling community were endorsed at a meeting of the community on 3 June 1996, with a copy of the endorsement being sent to the PSO on RRS *Discovery* on 6 June 1996.

1.3 CRUISE SUMMARY

Cruise 221 of RRS *Discovery* commenced with the departure of the ship from Southampton at 05.30h on Tuesday 11 July 1996, following three days of loading scientific equipment and completion of the preparation of shipboard facilities. Passage was made to the target area of the Lagrangian Experiment in the vicinity of 60°N 20°W via the south and west of Ireland. During the passage, opportunity was taken to set up and commission the extensive suite of scientific equipment required for the first leg of the cruise, including calibration of the ADCP system. Once clear of Irish territorial waters, sampling from the ship's surface seawater supply was commenced with the U-TOW zooplankton sampler also being deployed. A plan of the cruise track for the first leg of the cruise is shown in Fig.1.

The immediate objective of the first leg was to attempt to locate a mesoscale eddy in the vicinity of the target area which would act as a suitable feature for locating the Lagrangian Experiment. Fortunately a composite thermal image of the target area had been obtained for the six day period prior to the commencement of the cruise, and from this the presence of two apparent cold core eddies within the general area was inferred (Fig.2). The centre of the best defined feature, which was characterised by a diameter of the order of 50 km, was located adjacent to 59°N 20.2°W and the decision was made to focus initially on this apparent eddy feature as a possible site for the northern Lagrangian Experiment. As a consequence, course was altered during the later stages of the transit passage to allow commencement of an initial large scale physical survey around the feature somewhat to the south of its centre at 57.5°N 20.25°W.

The location for the start of the initial large scale physical survey around the target feature was arrived at by 16.30h on 14 June. Following arrival, a shakedown CTD and sampling station was carried out which revealed certain problems with the CTD winch system. These, fortunately, were able to be rectified the following day. The first component of the main physical survey, which was devoted to ADCP measurements, commenced at 22.00h with a transect leg aligned slightly to the west of north starting from ~57.5°N 20.25°W. The decision to focus on the feature identified from the satellite image was soon vindicated both from the thermosalinograph (TSG) data which confirmed the presence of a distinct patch of cool water bounded by defined margins and also from the ADCP data which showed an apparent circulatory flow associated with the area of cool water. In addition, although there was no marked change in the surface chlorophyll fluorescence (chl) status of the water associated with the patch, there were however significantly elevated nutrient concentrations present in the surface cooler water compared to the surrounding warmer waters. The diameter of the patch of cool water was confirmed to be of the order of 50-60 km, that is, characteristic of the diameter of mesoscale eddies in this sector of the North Atlantic. The initial TSG/ADCP survey was completed by 15.32h on 15 June, by which time it was confirmed that the feature which was provisionally identified from the surface data as a cold core eddy, was discrete and approximately circular in shape. It was also clear that, contrary to expectation, the position of the eddy had not moved much since its original location was established from the earlier composite image of 3-9 June.

Given the strength of the surface signals associated with the eddy together with both the circulatory current pattern inferred from the ADCP measurements and the stability of the feature indicated from the satellite images, a decision was readily taken to focus the initial Lagrangian Experiment on this feature. Consequently Seasoar was deployed by 17.04h on 15 June to initiate an approximate 100 x 100 km box survey around the expected centre of the eddy. The survey consisted of five legs aligned E-W with lengths varying between 20 - 100km depending on their location within the survey frame together with a final N-S leg running through the approximate centre of the eddy (Fig.3). The Seasoar survey was highly successful and from data obtained from the surface 300m confirmed the presence of a strongly defined cold core eddy. ADCP data obtained during the Seasoar survey also confirmed an unexpected feature observed on the initial ADCP survey; that was, the presence of a strong anti-

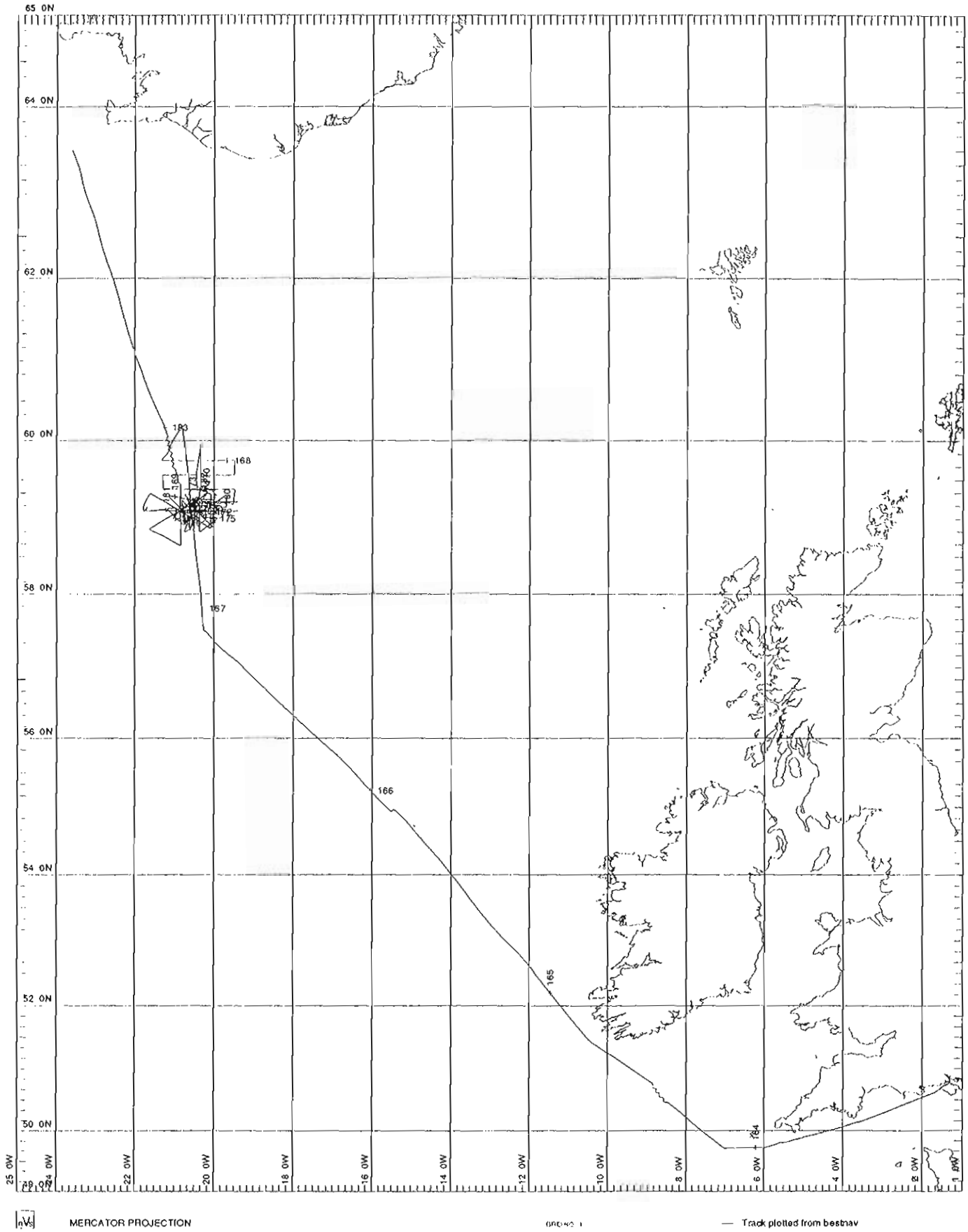


Fig. 1. Plan of cruise track, RRS Discovery Cruise 221, Leg 1, 11 June-2 July 1996.

cyclonic flow around the centre of the eddy. From classical considerations, it had been expected that the circulation associated with a cold core eddy would flow in a cyclonic sense.

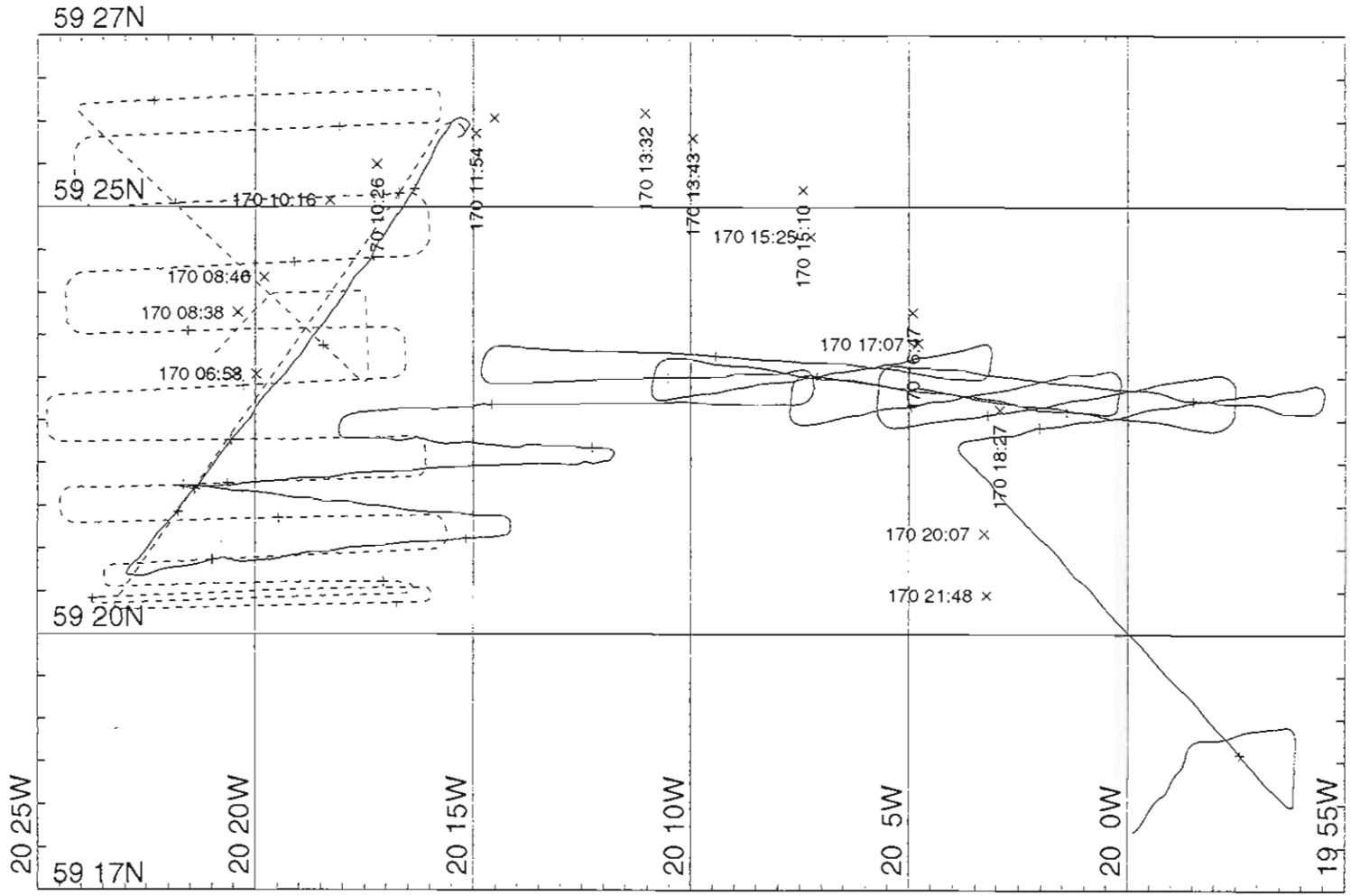
Following the Seasoar survey, which was completed by 17.25h on 17 June and which allowed the approximate location of the centre of the eddy to be defined, an Argos buoy was deployed some 10km west of the defined centre at 59.367°N 20.433°W. Passage was then rapidly made to the surmised position of eddy centre where a full suite of CTD casts, zooplankton net hauls and water bottle sampling for biological and chemical samples was carried out. While this station was occupied, a considerable ship drift of the order of 50 cm s^{-1} was observed suggesting that the location of this site was distant from the the actual centre of the eddy. On completion of the station work, the notional centre of the eddy was hence shifted 3.5 km to the west of the originally inferred centre and on arrival at this location two Argos buoys and a GPS buoy were deployed in an equi-spaced triangular array centred on the redefined notional focus of the eddy with 1 km spacing between the buoys. This operation was completed by 04.35h on 18 June.

A major component of the first leg of the cruise was to attempt to follow a patch of water in Lagrangian mode within the targeted eddy using SF_6 gas as the tracer of water movement. Ideal weather conditions with only light winds together with a shallow surface mixed layer prevailed on 18 June and deployment of the SF_6 patch commenced at 06.30h at 59.430°N 20.254°W and continued throughout the day to 22.45h. The SF_6, which had been equilibriated over the previous three days in a closed tank containing approximately 2500l of seawater, was deployed over the stern of the ship through a length of reinforced plastic hosing fitted with a depressor. Problems were encountered early on in the operation with kinking of the hose where it was attached to the depressor, and after a short trial it was found that it was not necessary to use the depressor and subsequently the hose was trailed at the surface well astern of the ship in the wake.

Navigation was of critical importance during the deployment operation. In order to seed an approximately square area of sea surface of dimension 7 x 7 km with SF_6 relative to GPS positions, it was essential to correct the ship's track for the influence of current drift. This was of particular importance within the eddy owing to the strong currents (up to 50 cm s^{-1}) that were encountered. Corrections for the influence of current drift were continuously applied during the deployment period using data from the ship's EM Log and the ship was navigated in real time using the corrected positioning. The importance of the corrected navigational data is highlighted in Fig.4 where the potential distortion of the SF_6 deployment, if it had been based solely on GPS positioning, is seen to be very marked. From the corrected navigational data presented in Fig.4, the SF_6 is shown to have been seeded within a box area with spacing between the individual legs of the box being of the order of 1 km. The ship's on-line seawater supply was switched off for the duration of the SF_6 deployment in order to reduce the risk of SF_6 contamination within the body of the ship during the subsequent Lagrangian experiment.

Immediately following the deployment of the SF_6 patch, routine time series sampling was commenced adjacent to the centre of the SF_6 patch. A basic daily pattern was established for the Lagrangian experiment observations in which the main hydrographic and water sampling was carried out between approximately midnight and 04.00h in order to optimise sampling for production work and zooplankton hauls. A comparable but reduced sampling schedule was carried out between local noon and 14.00h. The early morning sampling typically comprised 80l water bottle casts for marine snow samples followed by a series of zooplankton net hauls and two CTD casts, with one cast to 300m for general water bottle sampling and confirmation of the physical structure of the water column and the second cast to between 30-60 m for water samples to be used for the determination of production and nutrient uptake rates. The sampling routine concluded with a series of Go-Flo water bottle casts for samples for a variety of purposes as required for individual projects. The mid-day sampling routine was generally confined to 80l water bottle casts as previously, together with a 300m CTD cast for general purpose sampling and zooplankton net hauls. these latter allowing comparison of changes in zooplankton vertical distributions between mid-day and midnight.

In between the regular station work, the ship was deployed in survey mode with the core object of tracking the movement of the SF_6 patch and locating its approximate centre, thus allowing definition of the position for the succeeding CTD and sampling stations. The morning slot between the midnight



MERCATOR PROJECTION

SCALE 1 TO 150000 (NATURAL SCALE AT LAT. 59)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 0

GRID NO. 1

— Track plotted from bestnav

- - Track plotted from livenav

\+ Fixes plotted from gpsbuoy

RRS Discovery 221 GPS navigation - SF6 deployment

Fig. 4. Plans of ship's track, uncorrected and corrected for current flow using ship's navigational data, during deployment of SF_6 patch, 18 June 1996.

and mid-day stations was devoted entirely to surveying the distribution of the SF_6 using semi-continuous sampling from the ship's on-line seawater supply and with the ship's course being determined from the real time output of the spatial distribution of the SF_6. During the mid-day to midnight slot, it was intended that a small spatial scale Seasoar survey of the area immediately adjacent to the SF_6 patch would be carried out on a daily basis. However it became clear that although the distribution of SF_6 could be monitored during the Seasoar survey, the restriction on the manoeuvrability of the ship when towing Seasoar together with the reduced spatial resolution of the SF_6 data at the higher ship speed required to tow Seasoar effectively, resulted in only a limited amount of extra information being obtained on the distribution of SF_6 during this period. On a number of days during the Lagrangian experiment, it was not possible to achieve a clear picture of the SF_6 distribution within the patch during the morning survey period alone and consequently only a limited number of small spatial scale Seasoar surveys (four in total) were carried out during the afternoons. The problem of obtaining a satisfactory resolution of the patch position and structure became more marked when stronger winds were encountered, resulting in restricted ship capability, or when the current vectors changed rapidly and also towards the end of the survey period when concentrations of SF_6 within the patch were decreasing and the patch was becoming more diffuse. Some flexibility was allowed in the timing of the mid-day and early morning station sampling schedules in order to ensure that as satisfactory a fix as possible on the SF_6 patch centre had been obtained for locating the appropiate time series sampling site.

The routine daily sampling at the centre of the SF_6 patch commenced in full on 18 June and continued through until 28 June with only two short breaks in the pattern as a result of weather conditions. In the early morning of 24 June the ship was forced to heave to as a result of strong winds associated with the passage of the decaying tropical storm 'Arthur' and the corresponding station sampling had to be abandoned. SF_6 surveying was resumed at 08.00h. Weather conditions also forced the abandonment of the mid-day sampling routine on 26 June, with work being resumed by 18.00h on that day.

Over the period of the Lagrangian experiment, it was clear from the surface records, from satellite images transmitted to the ship and from the small scale Seasoar surveys that the eddy retained its identity as a discrete feature. Over the same period the Argos and GPS buoys separated little and tracked in well defined anticyclonic loops of period 2-3 days, suggesting that they were rotating around the notional centre of the eddy (Fig. 5). Two of the Argos buoys and the GPS buoy were recovered on 26 June with the remaining Argos buoy being left deployed to be recovered at the beginning of the second leg. Data from this buoy and also from the other buoys indicated that the eddy itself was also moving in an anticyclonic sense and it was considered possible that the eddy was topographically trapped on the western margin of the Hatton Bank. The net movement of the eddy over the period of the survey was minimal.

The track of the SF_6 patch over the experimental period corresponded well with the net movement of the buoys, again displaying an anti-cyclonic circulation pattern. Although confirmation of the net separation of the centre of the SF_6 patch and the three buoys originally deployed at the patch centre awaits more detailed analysis, it appears initially that their separation after the ten days of the experiment was of the order of 3 miles. This difference is not large and may reflect the generally low mean wind speeds over the period and the strength of the circulation associated with the eddy. As was to be expected, the SF_6 patch became more diffuse with time with a concurrent decrease in SF_6 concentrations. The initial maximum detected concentration of SF_6 on a relative scale following deployment of the patch was of the order of 2×10^6, with a corresponding value at the end of the experiment of 8×10^4. Vertical sampling indicated that there was little loss of SF_6 across the thermocline and it is hence assumed that the majority of loss was across the sea surface. Until the observed distribution of SF_6 within the patch is corrected on a daily basis for the effects of current movement, it is difficult to assess the change in shape of the SF_6 patch with time, although there were suggestions that towards the end of the experiment the patch was becoming elongated, possibly due to its being spun out from the centre of the eddy.

As a result of the anomalous circulation pattern associated with what had appeared to be, from the hydrographic data from the upper 300m, a cold core eddy, a transect of seven deep CTD casts was worked across the diameter of the eddy on 27-28 June immediately prior to the final large scale

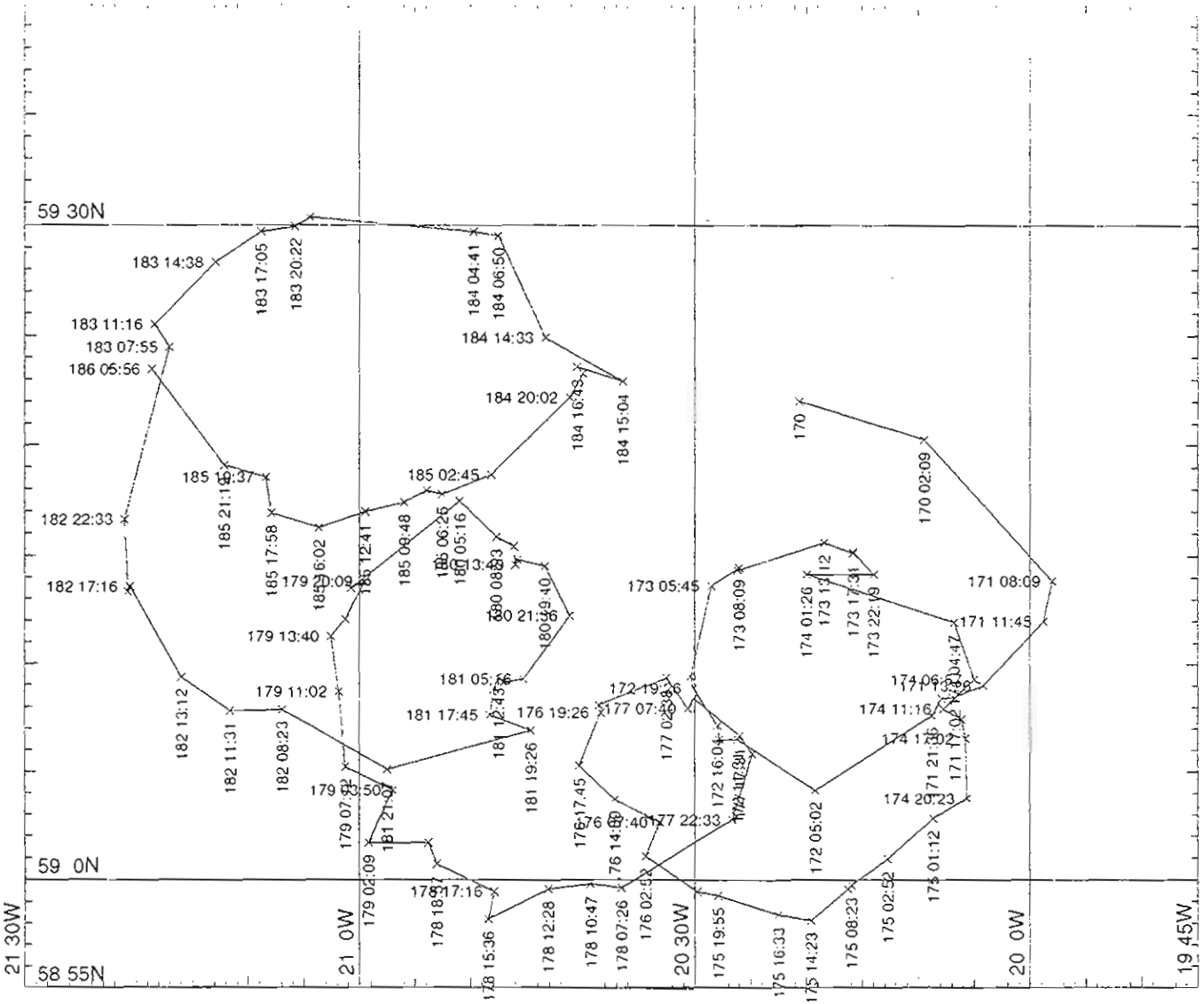


Fig. 5. Track of central Argos buoy deployed on 18 June (Day 170) adjacent to centre of surface defined cold core eddy through to 4 July 1996.

Seasoar survey of the feature. The data obtained was extremely valuable and showed the surface cold core feature which defined the eddy, to be continuous with and capping a major intrusion of warmer water in the deep layers below 600m. The influence of the intrusion, which formed a marked thermostad between 200-800m, appeared to be felt to the bottom at a depth of the order of 2800m. The deeper section of the eddy, that is below 600m, thus exhibited the classic features of a warm core eddy and although it was not possible to estimate currents in the deeper layers, it was assumed that the circulation in the deeper layers around the warm core was strongly anticyclonic. The possibility was suggested that this anticyclonic circulation in the deeper layers was of sufficient strength to superimpose its signal on the circulation of the surface layers, thus resulting in the apparently anomalous surface circulation pattern consistently observed from the buoy and ADCP data during the survey. It was considered possible that the eddy had originally been shed from the main flow of the North Atlantic Current as a warm core eddy and had been present in the survey area for a considerable length of time while showing little net movement.

The transect of deep CTD stations, in which samples were also taken outside the ambit of the main body of the eddy, was also of value in highlighting some of the features of the biology of the eddy. Surface concentrations of new nutrients were consistently elevated within the eddy thus giving strong evidence of upwelling in the cool surface waters. Although phytoplankton chlorophyll fluorescence values were not markedly different inside and outside of the eddy, nevertheless there were clear differences between the two constituent phytoplankton communities. The community within the eddy was mixed with representatives of diatoms, dinoflagellates, coccolithophorids (the dominany species provisionally identified as *Coccolithus pelagicus*) and a range of taxa of smaller sized organisms. However, in the waters outside of the eddy, the smaller taxa were clearly predominant, while coccolithophorids appeared to be essentially absent. Possibly the most obvious biological contrast was in the mesozooplankton. Within the ambit of the eddy a mixed community predominated with representatives of copepods, euphausids and *Sogitta*, whereas in the waters without the eddy the population was dominated by jelly-like forms, particularly salps and doliolids, with these latter groups occurring at high densities.

The final phase of the first leg of the cruise consisted of a large scale Seasoar survey. Time was insufficient to allow a repeat of the track pattern carried out at the start of the experiment, and in place a 'cloverleaf' pattern survey of three essentially equi-spaced triangles with overall spatial dimensions of 100 km was carried out (Fig. 6). The survey confirmed that the structure of the eddy had changed very little over the course of the experiment and that the feature appeared to be well established. Seasoar was recovered by 17.15h on 30 June and course was set for Reykjavik following deployment of U-TOW. A further calibration of the ADCP system was carried out during passage. *Discovery* docked at Reykjavik at 07.30h on 2 July.

During the port call at Reykjavik, twelve scientists and one RVS technician disembarked and were replaced by thirteen scientists who had flown out from the UK the previous Saturday. Three scientists form the Icelandic Marine Research Institute were welcomed on board RRS *Discovery* by kind permission of the Master and entertained to lunch before being given a tour of the ship. Having replenished the ship's freshwater tanks, *Discovery* departed from Reykjavik for Leg 2 of the PRIME cruise at 19.10h on 2 July.

Passage was continued on 3 July to the last reported position of the remaining Argos buoy deployed at the centre of the eddy on the previous leg. The PES fish to be used for on-line sampling for iron analyses, U-TOW and the UOR were also deployed during the morning when the ship was well clear of coastal influences. Although the general locational area of the Argos buoy was reached in the early hours of 4 July, visual contact with the buoy was not able to be made; a DF signal was detected shipboard but this proved difficult to interpret and the search was terminated by 03.30h as dawn arose, causing the buoy marker light to be switched off automatically and thus greatly reducing the chance of visual location. The surface TSG record at this point indicated the ship to be located on the SE margin of the eddy. Further evidence for this location to be within the ambit of influence of the

eddy was provided from data from phytoplankton taxonomic samples which demonstrated the presence of coccolithophorids; in the previous leg this taxon had been shown to be closely associated with eddy waters. A plan of the ship's track during occupation of the time series station adjacent to 37°N 20°W during the second leg of the cruise is shown in Fig. 7.

Station work was commenced at 59.310°N 21.119°W at 03.35h in order to allow meaningful sampling for productivity, zooplankton and other required samples in relation to the diel cycle. This sampling, which also included a standard 300m CTD cast, was completed by 07.45h and was followed by the successful deployment of a 10l Go-Flo bottle to 2400m for a sample of deep water for the analysis of dissolved and complexed iron species. A final shallow CTD cast commencing at 11.25h was carried out at the station for samples for stable isotope analysis before the search was resumed for the Argos buoy. An update on the buoy position had been received by mid-morning and the buoy, whose position had turned northwards since the last position update the previous evening, was rapidly located and brought inboard by 12.50h. The towing wire for the UOR, which had been damaged in the previous deployment, was then retensioned following splicing thus allowing the UOR to be deployed. U-TOW was also deployed and course was set at full speed for 47°N 20°W.

For the next three days during passage to 47°N 20°W, that is between 5 - 7 July, a standard work pattern was established with the ship heaving to shortly after midnight for approximately three hours to allow the main daily biological sampling programme to be carried out. The programme consisted essentially of a suite of zooplankton net samples followed by a routine 300m CTD cast for general sampling purposes and concluded with a range of 30l Go-Flo water bottle samples as required for individual project work. UOR and U-TOW were subsequently deployed and towed until approximately local mid-day when there was a further stop to allow a limited number of zooplankton net hauls to be made together with an optical cast; this latter was made over the starboard wing of the ship using the aft crane to ensure that the optical sensor was well clear of the ship. As it was possible to carry out the net and optics sensor casts concurrently, the mid-day stop was limited to the order of an hour or less. U-TOW and the UOR were again deployed during the resumed passage in the latter part of the day. However, owing to time constraints, it was found necessary to suspend deployment of the UOR on the southwards transect leg along 20°W from 6 July onwards. The average distance travelled each day between stations along the transect was of the order of 210 miles.

A well-defined front was encountered during the transect immediately before the mid-day station on 6 July at approximately 51.5°N. Between the northernmost station and the front, conditions had remained relatively constant with only a slow latitudinal increase in surface temperature southwards (Fig. 8) and surface nitrate concentrations generally being in the range 3-5 μM. The composition of the mesozooplankton as determined from initial inspection of net hauls had also remained similar with clear domination of the population by gelatinous forms. Biological changes across the were marked. A clear increase in chlorophyll *a* fluorescence was noted to the south of the front with a concomitant decrease in surface NO_3 concentrations to values <0.1μM, while the salp and doliolid dominated mesozooplankton community was replaced by a more balanced community characterised by copepods and amphipods and a range of other species more typical of warmer waters. Although the immediate frontal boundary was clearly defined, considerable variability in the temperature and biological conditions was apparent in the continuous surface records up to 100km to the south of the front; this variability was assumed to reflect mesoscale activity in the southern boundary region of the front. As the frontal boundary region was exited to the south, surface conditions became more uniform with NO_3 concentrations consistently ~10nM or less and chlorophyll concentrations <0.05 mg m^{-3}.

An extended sampling programme was carried out on arrival at 47°N 20°W at 00.30h on 8 July. Extra Go-Flo samples were taken following the routine early morning zooplankton and CTD casts in order to accommodate a wider range of biological experimentation. Upon completion of the early morning sampling at 04.39h, a LHPR tow was undertaken after which the ship was repositioned on 47°N 20°W before further zooplankton net sampling was intiated at 10.26h. Work at the station was completed by a shallow CTD cast and optics cast before passage to the second time series station at 37°N 19°W was resumed. A daily sampling programme similar to that carried out between 59°N - 47°N was undertaken on 9 and 10 July prior to arrival at 37°N 19°W on 11 July.

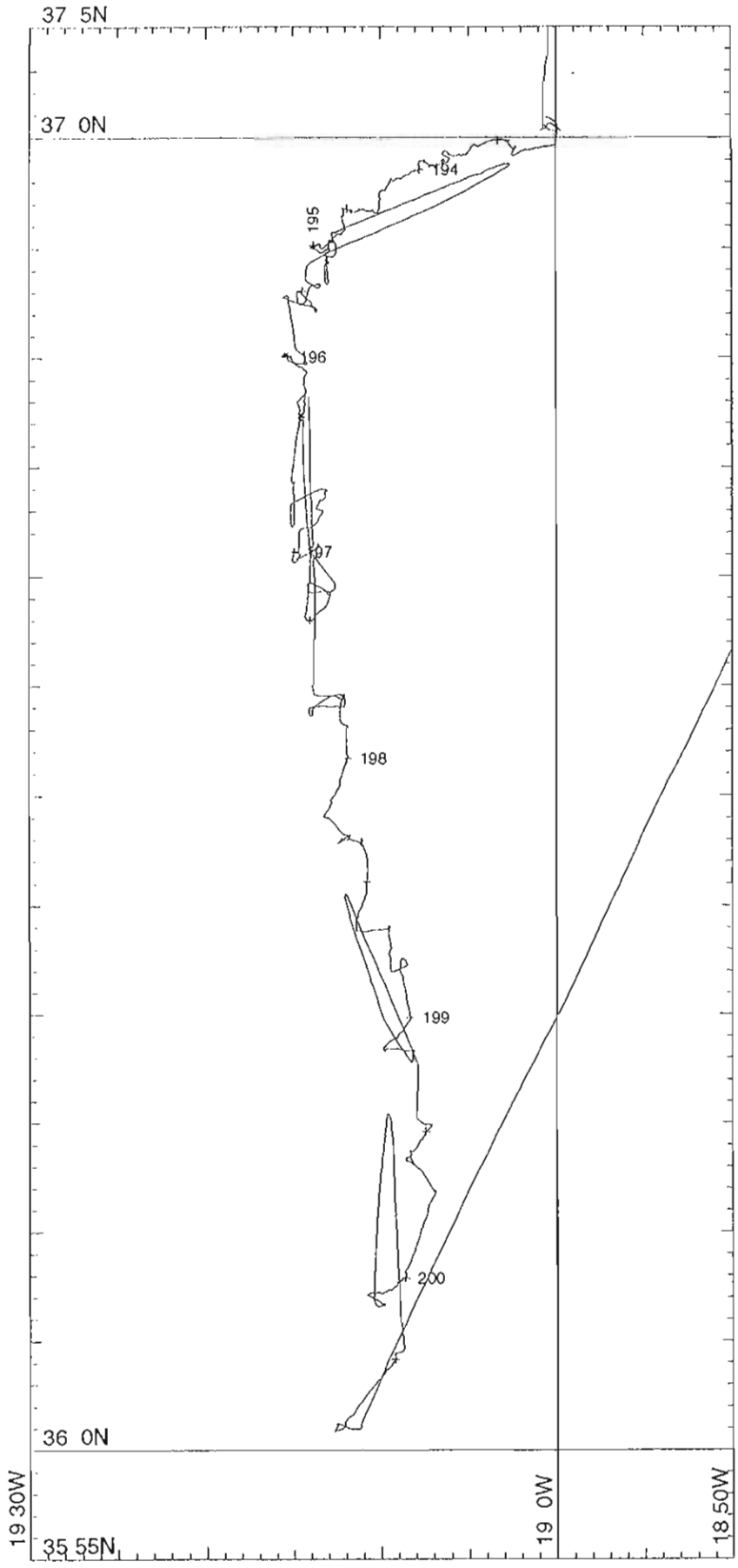


Fig. 7. Plan of cruise track, RRS Discovery Cruise 221, in vicinity of Argos buoy, Leg 2 12 July-18 July 1996.

MERCATOR PROJECTION

GRID NO. 1

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INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 0

RRS Discovery 221 37N Station

Scaled to fit

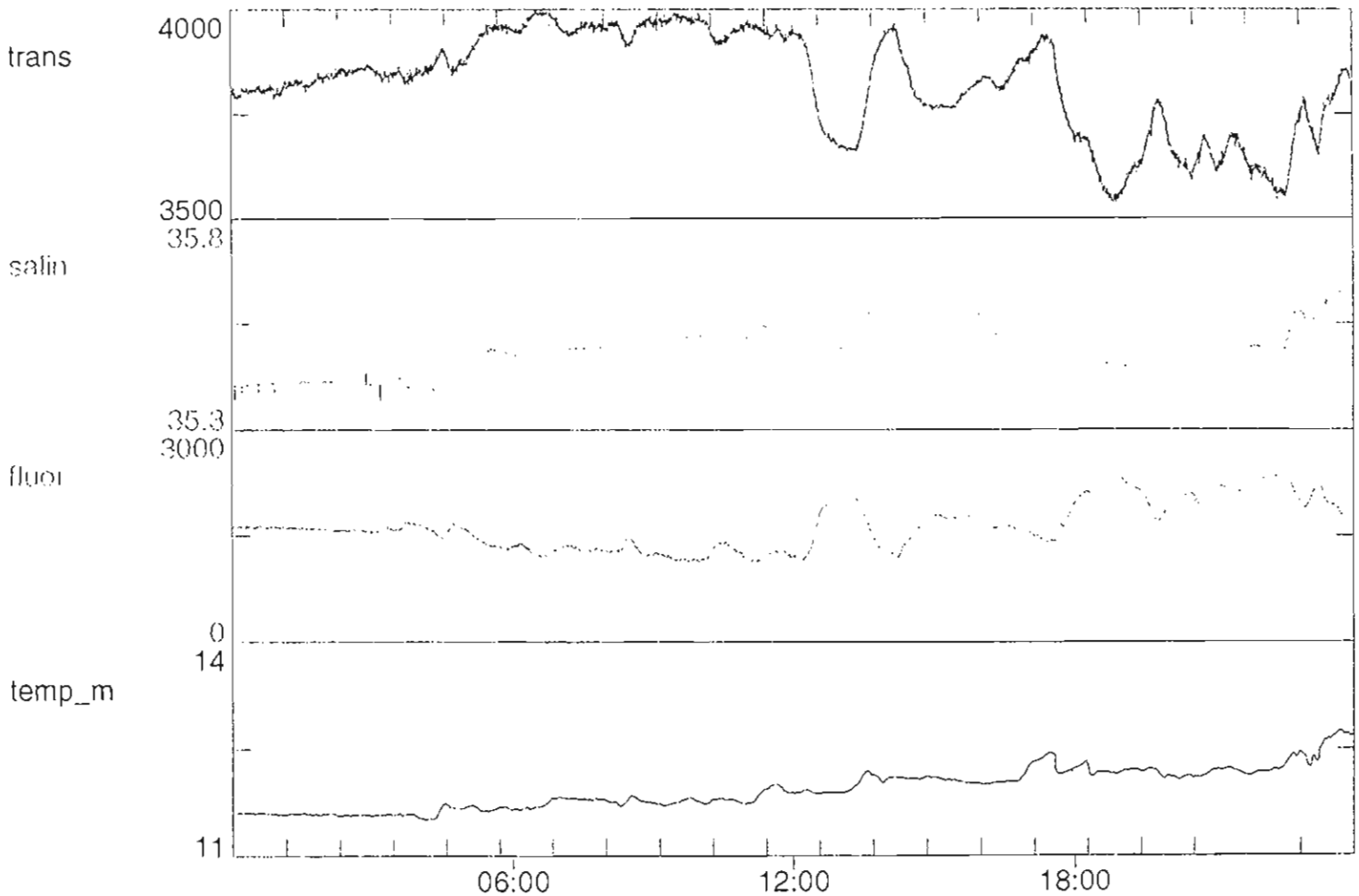
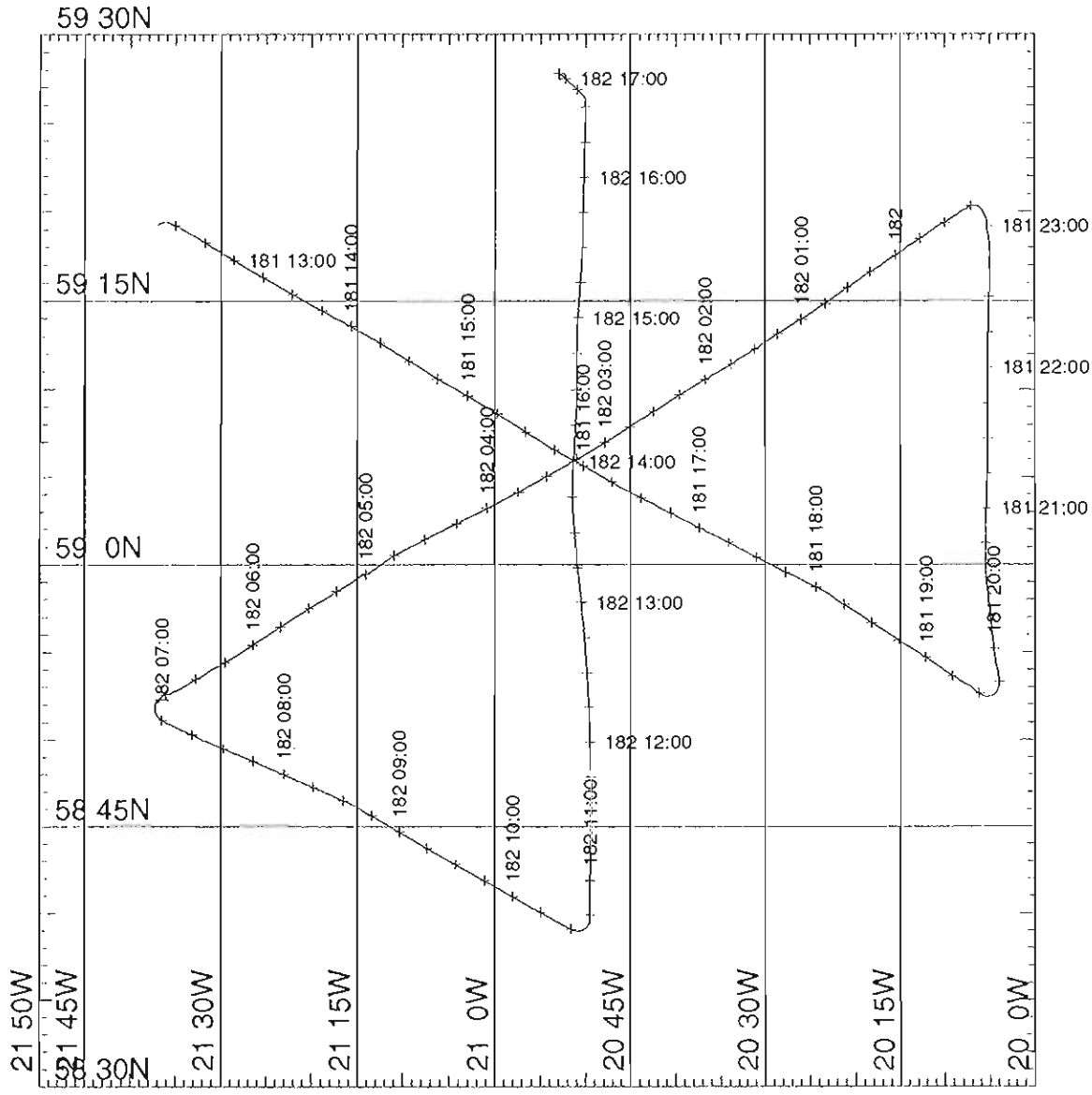


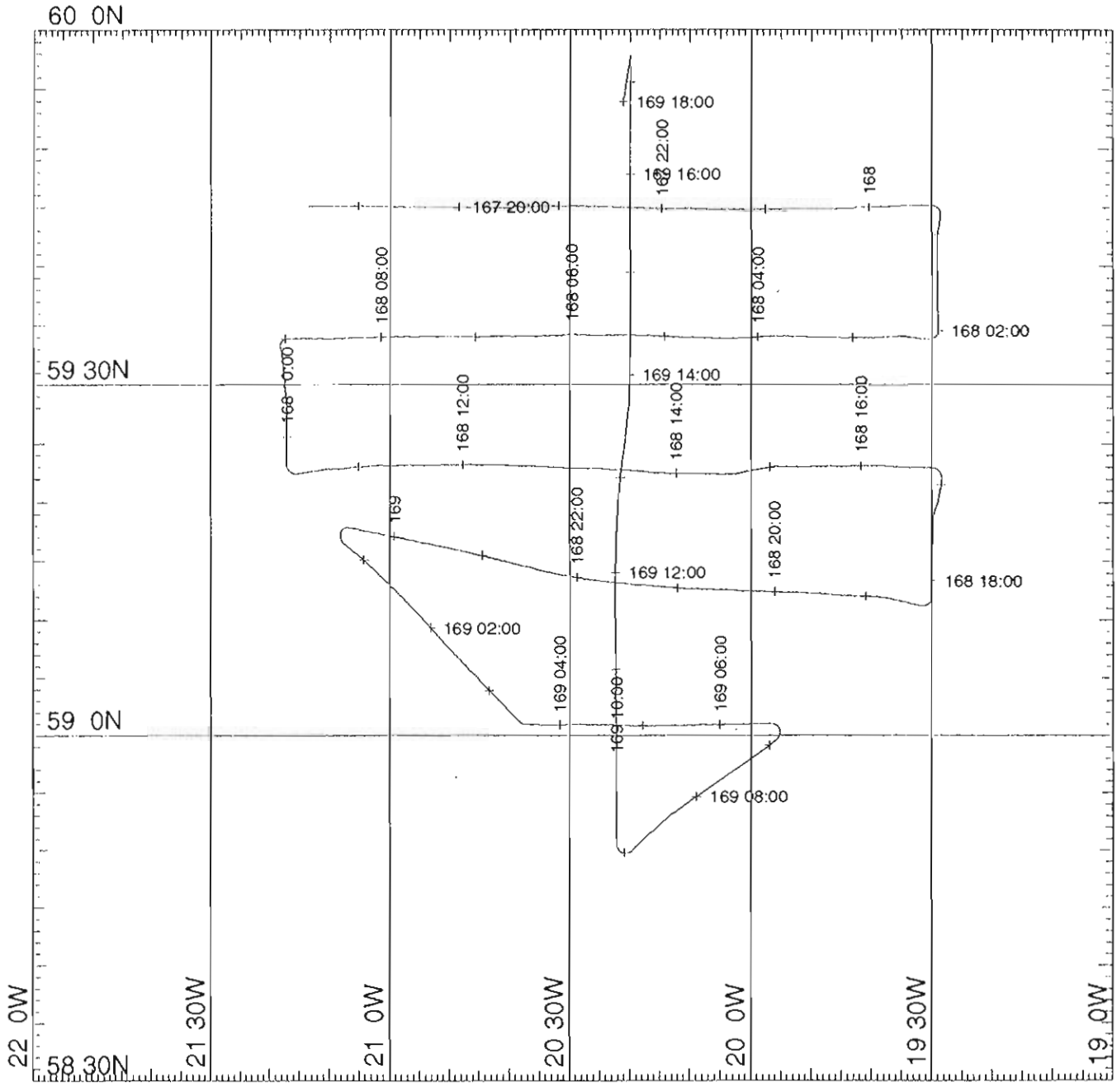
Fig. 8. Surface temperature (^{o}C), salinity, chlorophyll a fluorescence and transmittance 00.00h 5 July-00.00h 6 July. Time scale corresponds approximately to 57.55^{o}N 21.12^{o}W at 00.00h 5 July to 54.06^{o}N 20.71^{o}W at 00.00h 6 July. Note steady increase in temperature southwards.

Fig. 6. Plan of track of final large-scale Seasoar survey of eddy centred on approximately 59°N 20°W 29-30 June 1996.



RRS Discovery 221 Seasoar deployment No. 6

Fig. 3. Plan of track of first large-scale Seasoar survey of eddy centred on approximately 59°N 20°W, 15-17 June 1996.



The location of the southern time series station was moved from the originally designated position of 35°N 20°W to the new position in order to ensure that *Discovery* would remain outside of Portugese territorial waters for the duration of the time series observations. Arrival at the site by 01.28h on 11 July allowed a full day's suite of samples to be collected during the early morning, this initiating the time series of observations. In addition to the usual range of samples being taken between 01.41 - 05.15h, a further zooplankton net haul and CTD cast were subsequently made, the latter dedicated to sampling at selected depths for DNA analysis of the cyanophyte and *Prochlorococcus* populations. CTD fluorometric and analytical flow cytometer data obtained from the stations occupied on the two days prior to arrival at 37°N 19°W indicated the progressive development of a deep chlorophyll maximum (DCM) and increasing dominance of the picoplankton within this layer with cyanophytes and *Prochlorococcus* becoming the major representatives.

On completion of the early sampling schedule, an Argos buoy was deployed at 37.007°N 19.012°W in order to act as a Lagrangian marker for the remainder of the time series sampling to be carried out at the southernmost station. A deep CTD cast to 2500m was then made to obtain samples for the processing of bacterial production estimates, this being followed by a series of zooplankton, optics, CTD and water bottle sampling runs. Problems had been experienced with the spooling gear on the CTD winch during the morning deep cast with the cable crossing on the winch drum before reaching one of the end plates. A dummy deep run on the CTD winch was made during the afternoon to allow adjustment of the spooling mechanism and this ensured satisfactory operation of the winch system for the remainder of the cruise.

Following the sampling carried out on the first day, a core daily sampling schedule was established which was repeated on the succeeding days and which was complemented by other sampling activities as required on a daily basis. The core programme consisted of the standard early morning zooplankton net hauls, CTD casts for both general experimental and sampling usage and productivity determinations and Go-Flo water bottle casts for a range of large volume sample requirements. Mid-day sampling for the core programme routinely included both a shallow CTD cast for samples for stable isotope analysis and a standard 300m cast together with zooplankton net hauls, optics casts and further Go-Flo samples as required. It became apparent during sampling on the first day that there was considerable short-term variability in the structure of the DCM at the time series station and consequently two further CTD casts were made on a daily basis at approximately 06.00 and 18.00h. All sampling at the southern station was done adjacent to the Argos buoy which drifted consistently southwards at an average speed of 20 cm s^{-1} during the time on the station (Fig. 9). The daily sampling schedule was augmented by deep casts for iron samples, four LHPR samples taken during both the early morning and afternoon on the 13, 15, 17 and 18 July and extra CTD casts made for a range of sampling requirements together with further zooplankton net hauls. On two further days samples were taken on a six-hourly basis from the 300m CTD casts for the estimation of nutrient, dissolved oxygen and plant pigment concentrations and for other routine purposes in order to establish the pattern of diel changes in the main biological parameters. In addition, on 13 and 15 July *in situ* rigs were deployed between dawn and dusk for the estimation of primary production, nutrient uptake and microzooplankton grazing rates to allow comparison with parallel estimates made shipboard using 'on deck' incubation procedures.

A full daily sampling schedule was performed over the eight days of occupation of the southern time series station between 11-18 July. During this time the overall hydrographic conditions changed little with a sharply defined surface mixed layer of average depth 30m and a DCM, characterised by the dominance of *Prochlorococcus*, being consistently observed. Cell densities of *Prochlorococcus* were typically of the order of $1x10^{-8}$ cells l^{-1}. Nutrient concentrations in the surface layer remained low: NO_3 concentrations were at or less than the level of detection (10nM) while NH_3 concentrations also were particularly low. However in the case of Si concentrations, although the values were again generally low (<0.2μM), local increases in the surface layer to values of the order of 0.6μM were apparent over the observational period. Chlorophyll *a* fluorometric concentrations in the surface layer were also uniformly low with values typically <0.03 mg m^{-3}. The 1% PAR light depth was usually located at around 100m.

Sampling at the southern time series station was completed by 17.58h on 18 July and following recovery of the Argos buoy used as the Lagrangian marker for the study, course was set for

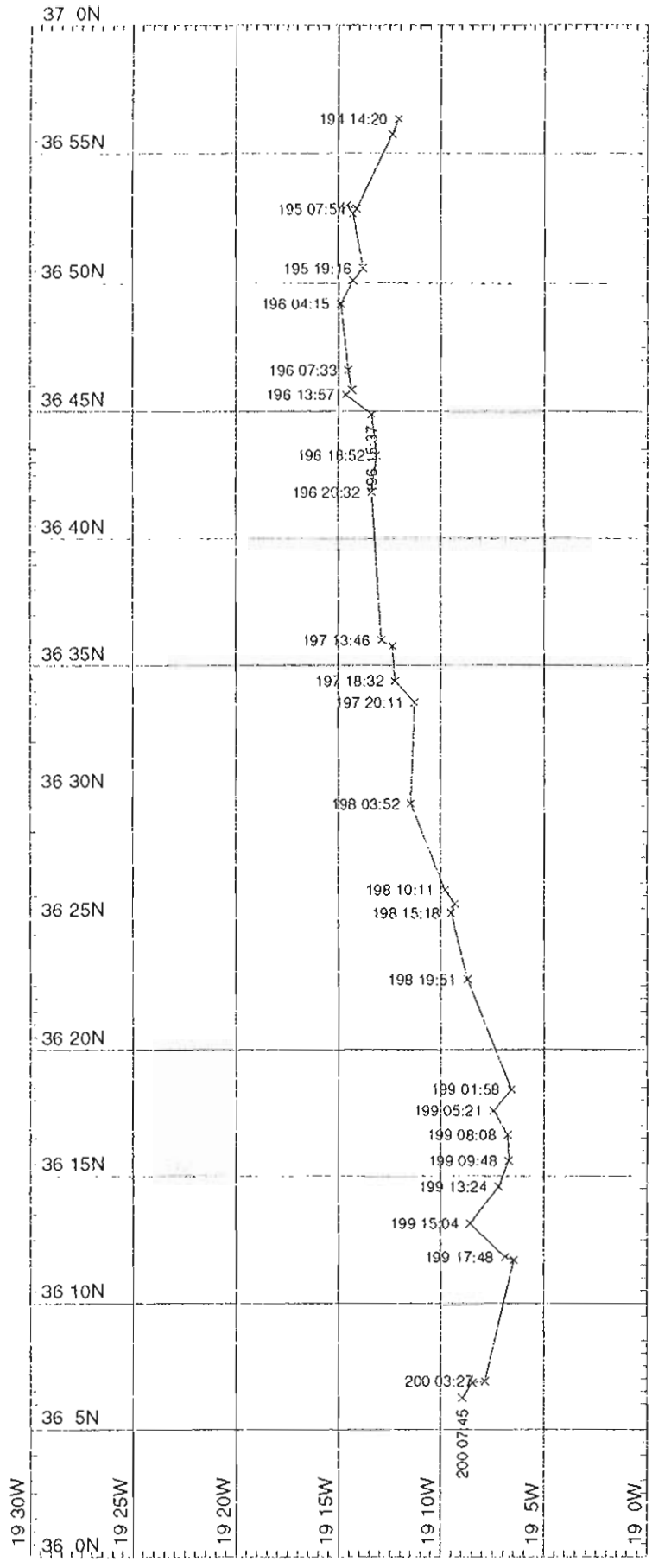


Fig. 9. Drift of Argos buoy at southern time series station in the vicinity of 37°N 20°W, 12-18 July 1996.

MERCATOR PROJECTION

SCALE 1 TO 400000 (NATURAL SCALE AT LAT 37)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 0

GRID NO. 1

Track plc

Fixes plc

RRS Discovery - 37N buoy

Scaled to fit

Southampton. U-TOW was deployed for a further 36h before being recovered owing to a system malfunction. On-line sampling continued for a selection of parameters until 22 July when the ship crossed the shelf-break in the Western Approaches. RRS *Discovery* docked at Southampton at approximately 08.30h on 23 July on completion of the cruise.

1.4 SCIENTIFIC ACHIEVEMENTS

1. Successful execution of a SF_6 Lagrangian tracer experiment in a high energy marine environment.

2. Location and demonstration of the presence of a strongly defined, slowly advecting eddy in the north-west Atlantic Ocean characterised by a deep warm core structure on which was superimposed a surface cold core structure exhibiting a strong anti-cyclonic circulation.

3. Completion of a detailed hydrographic survey of the defined eddy.

4. Demonstration of strongly contrasting planktonic community composition and structure in the surface layers within and without the surface defined cold core eddy. The surface waters of the eddy appeared to be influenced by upwelling conditions.

5. Acquisition of approximate eight day suites of continuous time series data describing all major aspects of the planktonic ecosystem at two sites in northern temperate and sub-tropical Atlantic waters. The data sets were designed to be compatible with the requirements of novel generic plankton ecosystem models being developed by the PRIME community.

6. The testing of novel techniques and approaches for investigation of selected aspects of the plankton ecosystem as encompassed by the PRIME Scientific Programme.

7. Demonstration of strong physical-biological interactions controlling the vertical structure and extent of the sub-surface chlorophyll maximum inthe area of formation of the sub-tropical component of Eastern North Atlantic Central Water.
8. Characterisation of physical and biological changes in transiting from north temperate to sub-tropical waters along 20°W and confirmation of the importance of associated frontal regions as biological boundary zones.

1.5 EQUIPMENT PERFORMANCE

In overall terms, both ship and scientific equipment performed wellduring the cruise and this resulted in only minimal loss of working time out of the scheduled programme. Where problems did occur, these were able for the most part to be rectified or ameliorated by expert on-board assistance. The help received from several personnel, particularly those from the RVS Technical Support staff, is readily acknowledged.

Concerning ship equipment, the major on-going problem related to the communications facilities. Given the highly integrated nature and complexity of the cruise, a high communications usage had been predicted. However it became clear that there were certain inefficiencies in the system which were a function of the age of the equipment installed. Following completion of the cruise, it is understood that updating of the communications equipment on RRS *Discovery* has been confirmed. Minor problems were experienced with the spooling mechanism on the CTD winch; these fortunately were able to be rectified by RVS Technical staff with no significant loss of working time.

In terms of scientific equipment, one 200μm WP-2 zooplankton net was lost under difficult wind and current conditions during Leg 1 when the net caught on the bilge keel of the ship when being hauled. Seasoar performed well, although some problems which could have been more serious were encountered with the towing cable out of the sheave on the main 'A'-Frame block and becoming trapped between the sheave and the wing of the mounting frame. The problem again appeared to relate to the relatively strong current conditions encountered. Some minor damage occurred to the

Seasoar fish and the body of the UOR during recovery operations under difficult conditions. The CTD and Rosette systems performed reliably with termination problems on the CTD cable only causing any problems. Appropiate calibration data were not immediately available for the CTD and Seasoar recording units and although these data became available during the latter part of the cruise, some delays in the on-board data processing were encountered. One CTD transmissometer unit and one TSG fluorometer failed during the cruise: both units were replaced with spare units carried as part of normal RVS instrument stock.

Three Argos buoys together with one GPS Argos buoy were deployed during Leg 1 of the cruise. All four buoys performed satisfactorily and were recovered before departing from the northern Lagrangian experiment area.

1.6 CREW LIST AND AFFILIATIONS: RRS *DISCOVERY* CRUISE 221: LEG 1

K O Avery	Master	RVS
J D Noden	Chief Officer	RVS
S Sykes	Second Officer	RVS
J W Mitchell	Third Officer	RVS
B Donaldson	Radio Officer	RVS
S A Moss	Chief Engineer	RVS
J R Crosbie	Second Engineer	RVS
S J Bell	Third Engineer	RVS
G Slater	Third Engineer	RVS
G A Pook	Chief Petty Officer (Deck)	RVS
P R Bennett	Petty Officer (Deck)	RVS
S C Cook	Seaman	RVS
G Cooper	Seaman	RVS
H R Hebson	Seaman	RVS
A MacLean	Seaman	RVS
P Allison	Seaman	RVS
J P Allam	Senior Catering Manager	RVS
C K Perry	Chef	RVS
A S Duncan	Steward	RVS
W J T Link	Steward	RVS
J A Orsborn	Steward	RVS
D J Hanlon	Petty Officer (Motors)	RVS
G Savidge	Principal Scientist	Queen's University of Belfast
A R Baker	Scientist	University of Liverpool
T L Bentley	Scientist	University of Wales Bangor
K E Davey	Scientist	Plymouth Marine Laboratory
K Donald	Scientist	Queen's University of Belfast
E S Edwards	Scientist	Plymouth Marine Laboratory
R P Harris	Scientist	Plymouth Marine Laboratory
M Hartman	Scientist	Southampton Oceanography Centre
G C Hays	Scientist	University of Wales Bangor
R Kirby	Scientist	Plymouth Marine Laboratory
C S Law	Scientist	Plymouth Marine Laboratory
M I Liddicoat	Scientist	Plymouth Marine Laboratory
A D Martin	Scientist	Southampton Oceanography Centre
G P Middleton	Scientist	University of Wales Bangor
D W Pond	Scientist	Plymouth Marine Laboratory
A P Rees	Scientist	Plymouth Marine Laboratory
J E Robertson	Scientist	Southampton Oceanography Centre
G A Tarran	Scientist	Plymouth Marine Laboratory
S M Turner	Scientist	University of East Anglia
I P Wade	Scientist	University of East Anglia
E M S Woodward	Scientist	Plymouth Marine Laboratory
M Wyman	Scientist	University of Stirling
A W Poole	Technician/Scientist	RVS
P A Duncan	Technician/Scientist	RVS
R B Lloyd	Technician/Scientist	RVS
C J Rymer	Technician/Scientist	RVS
P G Taylor	Technician/Scientist	RVS
D Teare	Technician/Scientist	RVS

1.7 CREW LIST AND AFFILIATIONS: RRS *DISCOVERY* CRUISE 221: LEG 2

K O Avery	Master	RVS
P D Gauld	Chief Officer	RVS
S Sykes	Second Officer	RVS
J W Mitchell	Third Officer	RVS
P J Kilbane	Radio Officer	RVS
S A Moss	Chief Engineer	RVS
J R Crosbie	Second Engineer	RVS
S J Bell	Third Engineer	RVS
G Slater	Third Engineer	RVS
G A Pook	Chief Petty Officer (Deck)	RVS
P R Bennett	Petty Officer (Deck)	RVS
S C Cook	Seaman	RVS
G Cooper	Seaman	RVS
H R Hebson	Seaman	RVS
A MacLean	Seaman	RVS
P Allison	Seaman	RVS
J P Allam	Senior Catering Manager	RVS
C K Perry	Chef	RVS
A S Duncan	Steward	RVS
W J T Link	Steward	RVS
J A Orsborn	Steward	RVS
D J Hanlon	Petty Officer (Motors)	RVS
G Savidge	Principal Scientist	Queen's University of Belfast
L M Al-Haddad	Scientist	University of Glamorgan
A R Baker	Scientist	University of Liverpool
A P Bedford	Scientist	Southampton Oceanography Centre
T L Bentley	Scientist	University of Wales Bangor
C Castellani	Scientist	University of Wales Bangor
K Donald	Scientist	Queen's University of Belfast
C P Gallienne	Scientist	University of Plymouth
S W Gibb	Scientis	Plymouth Marine Laboratory
G C Hays	Scientist	University of Wales Bangor
R N Head	Scientist	Plymouth Marine Laboratory
A J Machin	Scientist	British Oceanographic Data Centre
K L MacKenzie	Scientist	University of Liverpool
G P Middleton	Scientist	University of Wales Bangor
A P Rees	Scientist	Plymouth Marine Laboratory
D J Scanlan	Scientist	University of Warwick
C E Stelfox	Scientist	Plymouth Marine Laboratory
G A Tarran	Scientist	Plymouth Marine Laboratory
A G Westbrook	Scientist	University of Plymouth
W H Wilson	Scientist	University of Warwick
E M S Woodward	Scientist	Plymouth Marine Laboratory
M Zubkov	Scientist	University of Southampton
A W Poole	Technician/Scientist	RVS
R B Lloyd	Technician/Scientist	RVS
C J Rymer	Technician/Scientist	RVS
P G Taylor	Technician/Scientist	RVS
D Teare	Technician/Scientist	RVS

2. CRUISE NARRATIVE

Saturday 8 June 1996
The scientific party commenced loading equipment during the morning and this continued throughout the day.

Sunday 9 June 1996
A start was made on the setting up of the scientific equipment, with this activity continuing over the course of the day. Modifications to the starboard gantry and the aft 'A'-Frame were completed by RVS staff and contractors, although testing of the gear had to be left to the following day. RVS staff were also engaged in the fitting out of the new radiotracer and clean chemistry Container Laboratories.

Monday 10 June 1996
The setting up of the scientific equipment continued. With the exception of the air conditioning units, the fitting out of the new Container Laboratories was completed by the early afternoon. In order to allow completion of the fitting and testing of the air conditioning units and also to facilitate crewing arrangements, a decision was made in mid afternoon to postpone the sailing time until 05.00h the following morning. This fortuitously allowed repairs to be made to a hydraulic pipe on one of the main cranes which had broken during loading operations in the early evening. The scientific party received a pre-cruise safety briefing during the afternoon.

Tuesday 11.6.96
Departed Southampton at 05.30h on a grey, cool morning. Course set for the study area to the south of Iceland passing to the south and west of Ireland. Work continued throughout the day on the setting up and commissioning of the scientific equipment and ancillary systems. A meeting of the scientific party was held in the afternoon to allow an update of cruise plans, to review progress in commissioning equipment and to confirm sampling requirements in order to allow sampling schedules to be drawn up. Weather conditions deteriorated in the late afternoon, slowing progress in the preparation of facilities.

Wednesday 12.6.96
Ship-time was reset to GMT in the early morning. Weather conditions were excellent all day and a successful calibration run for the ADCP, consisting of eight 'zigzag' legs set at 90° and of 30 mins duration each, was carried out at eight knots commencing at 09.05h and ending at 13.00h. The background, objectives and strategy for the cruise were described to the officers and crew at a meeting convened by the Principal Scientist. Excellent progress was made in the preparation of the scientific and ancillary equipment over the course of the day.

Thursday 13.6.96
A meeting was held in the morning between the scientists involved in the SF_6 patch dynamics and the Master and the navigating officer to confirm the basis and arrangements for the deployment and tracking of the SF_6 patch. In the absence of real-time position data from a GPS reference buoy, the ship's course during both the deployment and subsequent survey of the SF_6 patch was to be corrected for current drift using data from the ship's gyro compass and EM log. At the meeting, Ian Wade presented a composite thermal image of the North Atlantic for the period 3-9 June which had been received that morning from Steve Groom at PML. The image showed two well defined discrete areas of cool water of approximate diameter 50-70 km centred on 59.2°N 20.6°W and 58.2°N 22.0°W together with a less clearly defined patch of warmer water located around 57.5°N 20.2°W. Images taken prior to the composite had indicated the cool water feature centred at 59.2°N 20.6°W to have held approximately the same position for the week previous to 3 June. Following the meeting, various options were considered for a track for the initial ADCP survey and it was decided to commence the survey at 57.5°N 20.25°W and then follow a course slightly west of north to 59.7°N 20.7°W in order to have the possibility of crossing both the warm water and northernmost cool water feature.

Seasoar was deployed in mid-afternoon for test purposes and also to repair the cable fairing. The operation was successfully completed by 20.30h, following which the two 80l water bottles to be used on this Leg were thoroughly flushed by lowering from the aft gantry to remove the hydraulic oil with which they had been accidentally coated as a result of the hydraulic burst on the main crane in Southampton prior to sailing. U-TOW and the PES fish to be used for on-line sampling for dissolved iron were also successfully deployed before resuming course for 57.50°N 20.25°W at 21.40h.

Friday 14.6.96
A brief meeting of the scientific party was held in the morning to update members with the revised plans together with the rationale for the initial ADCP survey and also to confirm arrangements for the "shakedown" CTD station scheduled for immediately prior to the start of the ADCP survey. Data on the nutrient concentrations and pCO_2 values obtained from the first on-line samplings were also presented. These data (~7μM NO_3, ~0.4μM PO4, ~0.8μM Si, ~0.1μM NH_3 and average pCO_2 values of 330 ppm) indicated that substantial uptake of Si by diatoms had occurred previously, although this uptake had not been matched by an equivalent uptake of NO_3. The small change in the pCO_2 value from equilibrium suggested that substantial growth of the phytoplankton, such as may have been associated with a spring bloom had not occurred.

On arrival at the start point for the 24h initial ADCP survey (57.5^{0}N 20.25^{0}W) at approximately 16.30h, the U-TOW was brought inboard prior to commencement of a 'shakedown' CTD, water sampling and zooplankton net station routine to be used later during the survey. The two 80 l "Snow-Catcher" water bottles were successfully deployed while only minor problems were encountered with the zooplankton net hauls. However, during the initial CTD dip, although the CTD and associated Rosette water bottle sampling systems performed satisfactorily, major problems were encountered with the CTD winch and the dip was aborted at 90m. The problem was traced to the clutch mechanism for the spooling drive. Following recovery of the CTD at 21.15h, it was decided to terminate the "shakedown" station and to commence the initial ADCP survey, the results from the earlier ADCP calibration having apparently proved successful. U-TOW was deployed and the 24h initial ADCP survey was commenced at 22.10h with a course being steered towards 60.0^{0}N 20.75^{0}W at a speed of 11 kts.

Saturday 15.6.96
Passage along the northerly transect was continued during the early part of the day. However, although the previous calibration run for the ADCP had appeared successful, considerable problems were encountered in applying the necessary corrections and it was not found possible to output current vector data of sufficient accuracy to allow definition of specific dynamic features. As a consequence, the hydrographical structure of the area was assessed primarily from on-line surface data.

Data from the transect indicated surface temperatures to be generally in the range 10-11^{0}C. At approximately 04.30h a marked temperature increase of the order of 0.4^{0}C was observed with a concurrent increase in chlorophyll fluorescence and this feature was interpreted to represent the Sub-Antarctic front separating the branch of the north Atlantic Current flowing to the north-west of the Hatton Bank from cooler water to the north. Northwards of the front, surface temperatures were approximately constant for about 10 miles, following which they decreased steadily by about 1^{0}C over 30km before increasing again by a similar magnitude over the next 30km. The temperature decrease was mirrored by an increase in silicate concentrations to a maximum of the order of 2.5μM. The centre of the cool water patch was located at approximately the same position as the cool water patch observed on the 3-9 June composite thermal image centred at 59.2^{0}N 20.6^{0}W and it was hence assumed that the cold core feature observed was coincident with the eddy recorded in the image. It thus appeared that the cold core eddy had been present at an essentially constant position for approximately three weeks before the survey commenced. In subsequent discussions after exiting the domain of the eddy, the decision was taken to focus the PRIME 60^{0}N Lagrangian Experiment on the observed cold core eddy.

The initial 48h large scale Seasoar survey was scheduled to be centred on the location of the temperature minimum recorded on the northwards transect, and at 13.00h course was set to 59.75^{0}N 19.92^{0}W to commence the Seasoar survey. A stop was made one hour before arrival at the start location of the survey in order to recover U-TOW and to deploy Seasoar. A trial run of the CTD

winch was also carried out to confirm that the system had been repaired satisfactorily. At 18.18h the Seasoar survey was commenced with the initial transect of 100km being aligned West-East. The final survey pattern was designed to consist of four further W-E legs of 100km length with 20km spacing between each leg, as shown previously in Fig.2.

Sunday 16.6.96
The large scale survey of the cold core eddy continued throughout the day according to schedule. Seasoar performed well and we had the first period of clear skies and sun since arriving in the working area, with the hope of a possible satellite image for the following day. The decision was taken later in the day to truncate Legs 7 and 9 of the survey grid at their western ends as it was clear that the ship was out of the ambit of the eddy well before the location of the ends of the Legs as designed in the original survey plan.

In the early evening the first corrected plot of ADCP current vector data for the northwards transect to 60^0N and Legs and Legs 1-3 of the Seasoar survey became available. These indicated on anti-cyclonic circulation around the cold core eddy, contrary to perceived dynamical understanding, while the location of the centre of the eddy as defined by the current data coincided well with the position of the centre as inferred from the hydrographic data. In order to provide initial confirmation of the sense of the ADCP current sectors, the ship held a constant heading of 278^0 when travelling E-W on Leg 7. The resultant plot of the actual ship's track indicated a heading of $273\text{-}274^0$ to the east of the suggested eddy centre and a reduced southwards drift westwards of the centre, thus supporting the conclusions of an anti-cyclonic flow pattern derived from the ADCP.

Monday 17.6.96
A grey day, but winds generally moderating all the while. The main Seasoar survey continued through the early morning and included an extra track to a point 20km south of Leg 9 on longitude 20.33^0W in order to attempt to define more closely the southern limit of the eddy. At 08.53h, course was altered to the north at the southernmost point of the survey in order to do a north-south transect to define the centre of the eddy in the meridional sense. Seasoar again performed well over the day and was recovered at the northernmost point of the survey at 17.25h. Course was set at full speed at 17.38h for a site approximately 12km to the west of the approximately inferred location of the centre of the eddy to allow deployment of an Argos buoy to confirm the circulation pattern around the eddy. During passage a close assessment of the complete data set obtained during the Seasoar survey was made, including the ADCP data, and a decision was taken to locate the SF_6 experiment at 59.37^0N 20.25^0W, the projected centre of the eddy. The Argos buoy which was drogued at 14m, was subsequently deployed at 59.37^0N 20.43^0W. Course was then resumed due eastwards and the SF_6 deployment location was arrived at at 21.58h.

An initial CTD dip to 1000m was carried out on arrivial at the station to check the CTD winch spooling mechanism and to establish the deep structure of the eddy. This was followed by a scheduled CTD, water sampling and zooplankton station with a maximum CTD depth of 300m.

Tuesday 18.6.96
Following completion of the CTD station started late the previous day, position was taken up at the estimated location of the centre of the eddy. Additional ADCP and hydrographic data had indicated this position to be some two miles to the west of the previously estimated location. Deployment of the SF_6 deployment commenced at the central location at approximately 06.30h at the position 59.430^0N 20.254^0W and, following some initial problems with a leaky seal on the SF_6 tank and kinking of the SF_6 deployment hose which was overcome by using the ship's reinforced deck hose, continued without problems over the day. Although the day was overcast, conditions for the deployment were ideal with very light winds and a thin surface mixed layer of 25-30m thickness. During the deployment, the ship described a grid survey within a 7.5x7.5 km box with legs aligned E-W and spaced at 0.5km intervals. The box was centred on the speculated location of the core of the eddy with the grid being defined from the ship's position corrected from the forward component of the ship's EM log in order to conpensate for the movement of the water relative to the ship. Comparison of the GPS and EM-corrected plots of the ship's track was particularly instructive and again indicated the strong anti-cyclonic nature of the surface circulation associated with the eddy (Fig.4). In the final stages of the SF_6 deployment, the area immediately adjacent to the centre of the grid was reseeded and the

operation was completed at approximately 22.45h with the ship being on station at the centre of the patch at 59.306°N 19.981°W. The day ended with the commencement of a routine CTD, water bottle and zooplankton sampling station at the estimated location of the centre of the SF_6 patch.

Wednesday 19.6.96

The CTD sampling commenced late the previous day was completed by 03.30h and this was followed by the start of a detailed on-line survey of the distribution of SF_6 within the patch area. Comparison of the ADCP data with that from the Argos buoys suggested at this stage that the position of the SF_6 patch was located somewhat to the SE of the centre of the eddy. The initial leg of the SF_6 survey, which was carried out in a westwards direction from 59.193°N 20.020°W showed the outer edge of the patch to be sharply defined. Unfortunately, serious problems developed with the on-line SF_6 analytical system soon after completion of the first leg which prevented further use for the remainder of the day. As a result, a course was steered later in the morning towards the projected centre of the SF_6 patch (59.133°N 20.083°W) which was used as the location for the routine noon CTD and biological sampling station. After completion of the station work, Seasoar was deployed and although some initial problems were encountered in setting the poise of the fish, possibly as a result of the strong cross-currents associated with the eddy, the system eventually settled down and flew well for the remainder of the day. A series of transects aligned generally in an E-W direction were covered over the day, ending up with a short southerly leg to the estimated position of the central GPS buoy which had been updated at 16.54h by DML and telexed to the ship. Seasoar was recovered at 22.55h and the GPS buoy observed from the ship at 23.15h. The weather throughout the day remained overcast with occasional showers but light winds.

Thursday 20.6.96

A good day - with the winds staying light and the clouds clearing away around mid-day to give a really bright afternoon, allowing the sighting of some sun-seekers on the foredeck, but only, it seemed where there was shelter from the moving, cool air! Earlier the day had commenced in what was by now the standard way with a routine CTD cast to 300m together with the required water sampling and a range of vertical zooplankton net tows at a station adjacent to the estimated position of the centre of the eddy. Both the morning and afternoon survey periods were given over solely to surface SF_6 monitoring with no deployment of Seasoar; this strategy was taken to allow improved chances of defining the centre of the SF_6 patch following the SF_6 analytical problems of the previous day. During the morning survey, it was initially assumed from the previous ADCP and ship drift observtions that the eddy was still tracking westwards. However, some fruitless time was spent steaming to the west of the national patch centre, as inferred previously, before it became apparent that the SF_6 patch was, in fact, tracking northwards. This problem resulted in a slight delay to the noon CTD station, which commenced at 13.00h. Valuable information on the possible locus of the patch was provided by an update of the position of the GPS buoy at 11.10h which indicated that the true centre of the patch was to the east of the noon sampling location. As a consequence, the location of the afternoon/evening survey period was concentrated well to the east of the earlier area and a clear SF_6 patch centre was defined by late evening in time for the first CTD station of the following day. It thus appeared that the SF_6 patch encountered earlier in the day to the west may have represented a secondary feature spun off from the original patch. The day's operations provided a much clearer picture of the overall patch dynamics. The day ended with a superb sunset.

Friday 21.6.96

Surveying of the SF_6 patch was commenced following successful completion of the standard early morning CTD and water and biological sampling station. Data from the Argos drogues and ADCP had indicated that the main patch was moving towards the NW and during the early part of the morning the general area to the west of the early morning CTD station was surveyed to confirm whether separation of the patch was occurring. Although moderately high concentrations were again recorded from the secondary SF_6 patch to the west suggesting spin-off of this feature from the main patch, confirmation of this will await more detailed analysis of the data on return to the laboratory. Following an update on the position of the GPS buoy by DML in the late morning, initial thinking indicated that the centre of the SF_6 patch, as represented by the zone of maximum concentration, had split away from the GPS buoy which had originally been deployed in the patch centre. Fortunately this initial concern proved unfounded when a minor computer error was noticed. Resolution of the problem indicated that, in fact, the position of the GPS buoy had remained faithful to the SF_6 patch

centre, this presumably reflecting the light wind conditions which had been experienced. Further confirmation of the concordance of the buoy position and the patch was given by a sighting of the buoy adjacent to the ship when heaving to for the, slightly delayed, noon station.

A Seasoar leg was run in the afternoon and evening from outside the ambit of the eddy (approximately 50km from the inferred centre) back to the centre following a westwards course. The survey gave no obvious indications that the eddy was breaking up or relaxing and showed clearly the intensification of the thermocline resulting from the heating effect associated with the good weather conditions of the previous two days. During recovery of Seasoar at 22.47h, the faired cable slipped off the block and jammed between the sheave and the frame. Prompt action by the winchman fortunately prevented any serious damage to the cable and Seasoar was successfully recovered by 23.42h after a delay of about one hour. An easterly course was then set to re-locate the expected centre of the SF_6 patch.

Saturday 22.6.96
Sampling at the early morning station commenced at 01.19h and was successfully completed by 04.39h. Extra Go-Flo samples were taken at this station between 50-200m for the estimation of dissolved Fe concentrations. With the exception of the noon sample station, the remainder of the day was devoted to surveying the SF_6 patch. The survey was highly successful and resulted in excellent definition of the patch; this, in part, appeared to be due to the increased winds experienced during the day having homogenised the lateral distribution of the SF_6 within the patch. SF_6 concentrations were believed to have remained high owing to the generally light winds experienced since the deployment of the patch while SF_6 losses downwards through the water column were reduced as a result of the intensification of the thermocline. The survey clearly indicated that the patch had retained its integrity while increasing in size to a diameter of approximately 15km over the four days of its existence. Updated data from the Argos and GPS buoys again indicated that these had remained near the centre of the patch and showed well that the patch had circulated around the centre of the eddy describing an open loop, with the suggestion that the eddy centre had tracked in a southerly direction over the previous four days.

Sunday 23.6.96
A strong southwesterly residual current was evident from ship drift during the early stages of the midnight sampling station and the position of the ship had to be relocated to the east following completion of the zooplankton net sampling in order to remain near the centre of the SF_6 patch. The station was successfully completed by 03.28h with SF_6 concentrations remaining high following relocation of the ship and the strong southwesterly drift being maintained. The surface SF_6 distribution was surveyed over the remainder of the morning with a good definition of the patch again being achieved. However, the wind strength had increased consistently since the previous evening and this had been accompanied by a marked decrease in SF_6 concentrations from the day before as a result of the increasing loss of SF_6 across the sea surface.

A Seasoar survey was successfully carried out in the afternoon through to the evening covering the main area of the SF_6 patch and outer boundary. The 8.0°C isotherm, which was assumed to define the boundary of the cold core water of the eddy, remained, on the basis of comparison with earlier surveys, at a depth of approximately 100m, thus providing further evidence that the eddy structrue was continuing to maintain its integrity.

At a brief meeting held in the afternoon, preliminary accounts were given of the biological and chemical characteristics to date. Overall the impression obtained to this point indicated that a relatively stable situation prevailed within the ambit of the SF_6 patch in the eddy. Nutrient and pCO_2 values remained quite high while chl *a* concentrations had changed very little over the period of observation, although there was evidence of changes in the structure of the phytoplankton and flagellate population structure. Marine snow concentrations appeared to be quite variable while, interestingly, the low DMS concentrations associated with the centre of the eddy showed a steady increase in the mean, with values increasing centrewards from the edge of the eddy. No major shifts in the biology had been noted as yet as a result of the better weather conditions experienced over the previous two days or so.

Monday 24.6.96
Strong southerly winds (30-35 knots) associated with the decaying tropical storm 'Arthur' prevented sampling at the usual midnight station and the ship was hove to until 08.00h. By that time, the sea had moderated somewhat, although a strong swell remained and the decision was taken to resume the SF_6 survey. Despite the strong currents experienced late the previous day, the SF_6 patch was soon relocated with its centre still keeping near to the marker buoys. Overall, the concentrations of SF_6 had dropped significantly from the previous day as a result of the winds. The usual noon sampling schedule was undertaken at the approximate location of the centre of the SF_6 patch. Some difficulty was experienced in getting a firm picture of the total patch shape during the resumed SF_6 survey in he afternoon/evening period as a result of the effect of the earlier winds. The overall distribution appeared more irregular whilst there was some evidence that the patch had elongated in an E-W direction. It was not clear whether an area of higher SF_6 elongated in an E-W direction was a streamer breaking off from the main patch or represented an overall change in the shape of the patch. Insufficient time was available to establish the continuity of the elongated segment with a broader, but apparently lower concentration area encountered on a section to the NE of the elongated patch. Resulting from the survey, the decision was taken to establish the forthcoming midnight station within the elongated patch at approximately 59.132^{0}N 20.758^{0}W.

Tuesday 25.6.96
The day was generally bright with a fresh wind and commenced with the usual CTD and biological sampling at the estimated location of the patch centre. Although the magnitude of the SF_6 signal remained more than adequate for establishing the location of the patch, nevertheless the distributional pattern was becoming more difficult to interpret as a result of the patch circulation dynamics and wind effects. In addition, the relationship between the patch and marker buoy positions was becoming less clear. However, a reasonable fix on an area of high SF_6 was made in time for the noon. CTD and biological sampling and this work was completed satisfactorily. Despite the increased irradiance, no obvious changes in the biology were yet apparent.

Seasoar was deployed following completion of the noon station and a survey was initiated covering an area in an eastwards direction in order to assess the physical structure in the main direction of movement of the SF_6. The Seasoar data again gave no indication of that the eddy structure was beginning to break down. Some delays and problems were encountered in receiving buoy position updates during the day which made assessment of the tracking of the patch within the eddy difficult; however the results from the SF_6 survey overall were excellent and showed the SF_6 patch to have followed an easterly course in the morning and turning towards a more southerly direction in the evening.

The wind increased over the course of the day maintaining a westerly quarter while a pattern of frequent squally showers had developed by the late evening. Some minor damage was done to Seasoar during recovery in the late evening resulting from the faired cable again jumping out of the block and becoming jammed. Although Seasoar was recovered successfully, the cable had to be parted to free it from the block with a subsequent re-termination in the vehicle.

Wednesday 26.6.96
Uncomfortable working conditions were experienced during the midnight sampling sequence, although a full suite of samples was able to be collected, including 'clean' samples for iron analysis. SF_6 patch surveying was resumed at 05.25h and although a zone of high SF_6 concentration was located by 12.00h, the routine sampling at this station was not possible owing to the confused sea and swell conditions. However frequent updating of the locations of the Argos and GPS buoys had been requested and a course was set towards their location at 14.00h at reduced speed in order to effect recovery when sea conditions allowed. Fortunately all four buoys had remained very close together and at 15.50h Argos buoy No. 8 was spotted and, as sea conditions had improved, was able to be recovered by 16.10h. Argos buoy No. 2 and the GPS buoy were also located visually shortly afterwards and were recovered by 16.40h and 17.17h respectively. The track of the buoys in their final hours before recovery indicated that the SF_6 patch was advecting rapidly westwards with a velocity of the order of 30-40 cm s^{-1}. This conclusion was fully supported by the observations from the SF_6 survey

which was continued successfully for the remainder of the day, and which demonstrated the patch to be distributed, with reference to GPS, as a thin filament aligned approximately E-W. An area of high SF_6 concentration was relocated in the late evening and the ship hove to at 22.38h ready to commence the routine 00.00h station sampling the following day.

Thursday 27.6.96
Both the 00.00h and 12.00h routine CTD and biological sampling programmes were successfully carried out at the approximate positions of the SF_6 patch centre. The final detailed SF_6 survey of the patch was completed in the morning and showed the patch to have remained elongated in an E-W direction on a geographical basis, consistent with the continuing strong westward drift of the remaining Argos buoy over the preceding period. Following completion of the station at 14.10h, course was set for the first of seven deep cast CTD stations to be occupied on the E-W transect across the eddy. Stations were located at 20km intervals across the transect, giving a total transect length of 120km compared to an approximate eddy diameter of 60km. Routine CTD and biological samplings were scheduled for the two stations at the ends of the transect (CS1and CS7) and also at the station at the eddy centre (CS4). The exercise was designed to provide comparative information on biological conditions outside of the eddy and also to obtain physical data which could allow insight into the dynamics controlling the eddy structure. Deep CTD casts to 2500 and 2800m respectively were carried out at both stations CS3 and CS2, located some 20km to the east of station CS3, in addition to a WP2 net cast at each site.

Friday 28.6.96
In terms of weather conditions, the best day yet. Although there was a fresh breeze all day, skies were virtually clear with a delightful "midnight sun" sky at the time of the midnight sampling. Station CS1 to the outside of the eastern side of the eddy was occupied at 00.38h at a position 59.097^0N 19.449^0W and a full CTD and biological sampling programme was carried out in the top 300m. Some delay was experienced in commencing the subsequent deep CTD cast to 2800m owing to a break in the CTD conducting cable which required retermination. As a consequence, the water samples required for productivity experiments were collected using Go-Flo bottles rather than from the CTD rosette. On completion of station CS1, course was made for station CS4 at the centre of the eddy with estimated position 59.43^0N 20.5^0W with, as previously at station CS1, a full complement of CTD and biological sampling being undertaken prior to a deep CTD cast being done. Station CS4 was occupied between 12.45-17.12h. Deep CTD casts to 2800m were also carried out later in the day at stations CS5 and CS6 located approximately 20 and 40km to the west of the eddy centre respectively.

Saturday 29.6.96
Station CS7 on the western end of the transect line was shifted westwards of the originally intended position to 59.11^0N 21.71^0W in order to allow for the westward drift of the eddy associated with the anti-cyclonic movement of the eddy centre indicated by the positions of the Argos buoy. The station was arrived at at 02.47h and a full suite of CTD and biological sampling was carried out prior to the deep CTD cast. Following breakfast, the UOR wire was tensioned on the winch drum and this operation was succeeded by the deployment of Seasoar. This operation took slightly longer than usual as a new rigging system on the aft 'A' frame was used to allow greater control of the towing cable and sheave. The system involved lowering the block during deployment using the crane and then transferring the block to the UOR winch for towing so as to bring it closer to deck level. Seasoar was fully deployed by 10.23h with a ship heading of 025^0 to start the final large scale survey of the eddy area based on a 'three-leaf' pattern. Conditions were excellent for towing Seasoar and the remainder of the day was spent Seasoaring along the survey track.

Initial results from the deep CTD transect showed that the influence of the cold core eddy extended well to 2500m with a thermostad defined by the 8^0C isotherm extending some 600m between 300-900m. The deeper warm core section of the eddy was presumed to be associated with a strong anti-cyclonic influence and it was considered possible that this circulation imprint was sufficiently strong to nullify a cyclonic circulation signal associated with the cold core upper section of the eddy. Data from the first Seasoar transect across the eddy showed SF_6 still to be present in a definable patch at the eddy centre and the eddy still to be clearly demonstrated in the upper layers.

Sunday 30.6.96

The final Seasoar survey was continued along the planned survey track for most of the day. Strong winds gusting to >35 knots and a heavy swell made conditions difficult, particularly during the early part of the morning, when speed had to be reduced for about 2 hours, making the control of Seasoar difficult. Although the sea state fell away over the day, the swell remained and with the general course of the ship abeam to the swell for much of the survey track, an uncomfortable day was had. Despite the conditions, Seasoar was recovered successfully by 17.15h and U-TOW deployed for the final run to Iceland. During the early part of the evening a second ADCP calibration was run with the ship steaming a 'saw-tooth' track consisting of twelve legs of 20 mins duration each with alternate headings of 030^0 and 300^0. A fixed speed of 8 knots was maintained for the run.

Monday 1.7.96
The passage to Reykjavik was continued with sea conditions much improved from the previous day. The transition to the richer shelf waters of Iceland was clearly marked by the greener colour of the sea and the increased number of seabirds and presence of whales. U-TOW continued to be deployed until recovery at 19.38h.

Tuesday 2.7.96
Docked in Reykjavik at 08.00h. The incoming scientific party for Leg 2 arrived at the ship at approximately 09.15h while the outgoing party organised a short tour of some of the more spectacular local sightseeing places prior to departing for the airport at 14.00h. Three members of the Iceland Marine Institute were invited to lunch by courtesy of the Master and given a tour of the ship. During the afternoon, the incoming scientific party set up their equipment or effected the transfer of equipment from personnel on Leg 1 as appropriate.

Discovery departed from Reykjavik at approximately 19.10h and having cleared the harbour at 19.25h set course for the approximate location of Argos buoy No 5 at 59.33^0N 20.25^0W which had remained deployed at the Leg 1 Lagrangian survey site.

Wednesday 3.7.96
Passage was continued during the morning to the estimated position of the Argos buoy, with the course being altered later to allow for updated buoy positions as received from RVS on an hourly basis. These positions indicated that the buoy was still describing a series of anticyclonic loops, presumably within the eddy system, and that the centre of the eddy itself was continuing to track anticyclonically. Although only light winds prevailed, an uncomfortable beam-on swell was felt over the day as a result of the passage of a relatively deep depression the previous day. Despite this, both U-TOW and the PES-fish for iron sampling were deployed during the morning together with the UOR. The UOR was recovered at 16.52h for checking and data assessment and subsequently redeployed at 19.07h. A later check indicated that the stopper used to hold the UOR towing cable when underway was beginning to chafe the towing wire and an alternative stopper was fitted and used for the remainder of the tows. The chafe on the wire was repaired the following morning with a splice.

Thursday 4.7.96
U-TOW and UOR were both recoverd by 01.00h and passage was continued to the Argos buoy position as estimated from the last previous fix of 12.45h the previous day. Despite good weather conditions, a preliminary search for the buoy starting at 02.30h failed to locate it, possibly because dawn was breaking causing the marker light to switch off. The DF system received a weak but inconsistent signal from the buoy possibly indicating it to be to the north and west of the ship's position, and from this information and previous buoy track data, the ship was headed north and west. Although the buoy was not located, the ship stopped on station 201 at 59.310^0N 21.119^0W at 03.32h to commence sampling. A full suite of zooplankton net, CTD and biological sampling was successfully carried out over the course of the morning including samples for productivity, iron and stable isotope estimates and a deep (2400m) cast for a sample for the estimation of dissolved iron. For the latter sample, the 10l Go-Flo bottle was attached to the bottom of a 30m length of Kevlar line which in turn was attached to the end of the CTD cable from which the CTD had been disconnected. The Go-Flo bottle was fired by a messenger located on the Kevlar line attached to a dummy 10l Go-Flo bottle mounted on the CTD cable immediately above the termaination point with a long length of monofilament spanning the join between the CTD cable and the Kevlar line. This arrangement was

used in preference to the hydrographic cable in order to save changeover time on the winches. Great enjoyment was given at this station by a school of playful and highly inquisitive pilot whales which at times came remarkably close to the ship. Station work was completed by 11.51h and course was set for the latest updated position of Argos buoy No 5 received that morning, which was rapidly located and recovered by 12.50h. The UOR and U-TOW were subsequently deployed by 13.45h and were towed for the remainder of the day.

From a preliminary examination of the data, it was clear that station 201 was not located within the main body of the eddy studied in the pevious leg, but was situated on the margin. This was demonstrated from the surface temperature record and also from the considerable difference observed in the near surface temperature structure recorded between the down and up CTD casts, suggestive of active mixing on the margins of the eddy. However, coccolithophorids similar to those observed previously within the eddy, were present although not in as high numbers as in the main body of the eddy. Very shortly after leaving the CTD station to pick up the Argos buoy, the surface temperature decreased and the water gained a milky appearance characteristic of increased coccolithophorid biomass, indicating that the buoy had remained closely associated with the eddy.

Friday 5.7.96
A generally cloudy day with a fresh wind and following sea. The day commenced with the routine zooplankton net hauls, CTD casts and biological sampling at station 202 (57.545^{0}N 21.117^{0}W) as scheduled for the intermediate transect stations. Both U-TOW and UOR were deployed following completion of the station until a stop was made at mid-day to allow an optical cast and zooplankton net haul to be carried out. To allow the optical cast, the ship was manoeuvered as so the aft was facing approximately south. However this caused problems associated with the formation of bubbles from the heaving of the ship's counter and it was decided to undertake future casts using the starboard aft crane to deploy the sensor well clear of the ship's influence. Following the mid-day station work, the PES fish was brought inboard to reconnect the hose to the inlet cone. On completion of repairs, the PES fish together with the UOR were redeployed and course resumed at full speed for 47^{0}N 20^{0}W.

Saturday 6.7.96
For the first time there was a hint of warmer climes in the air during both the midnight sampling station and also later in the day! But then, of course, the night sampling was marked by the absence of any daylight! The regular sampling programme of CTD and zooplankton net casts and biological water sampling was carried out at station 203 at 53.993^{0}N 20.699^{0}W, followed by redeployment of U-TOW. Given various constraints in the ship programme, a decision was taken at this time to suspend deployment of the UOR. However, it was confirmed that the optical casts would be continued at the mid-day stations and this was implemented at the noon station, which also comprised a zooplankton net tow. The optical cast was found to be highly successful based on deployment of the optical sensor well clear of the ship using the aft starboard crane and UOR winch. U-TOW was redeployed following completion of the station.

Immediately before stopping at the mid-day station, a sharp rise in the surface temperature, salinity and chlorophyll fluorescence values was recorded together with a concurrent decrease in nutrient concentrations, indicative of crossing a frontal boundary. Further, initial inspection of mesozooplankton samples revealed a marked change in the population collected in the mid-day net haul from that from the frontal region. Whereas previously on the transect the communities had been dominated by salps and doliolids and other jelly-like forms, in the warmer waters of the frontal region a much more mixed community was recorded with substantial contributions from copepods, euphausiids and chaetognaths. The initial impression given was that this community was quite similar to that observed within the eddy on the previous leg. Following departure from the mid-day station considerable variability and patchiness was observed in the surface physical, nutrient and biological fields before more stable, oligotrophic conditions were encountered later in the day.

Sunday 7.7.96
A relatively straightforward day's schedule whilst on the transect run, commencing at 00.52h with the usual transit station routine of CTD and zooplankton net casts and water sampling at station 204 at 50.336^{0}N 20.326^{0}W, and continuing with the later mid-day station involving a zooplankton net haul and optical cast. The hose from the PES fish used for on-line Fe samples again became kinked during

the morning preventing flow, and this was repaired and redeployed following completion of the mid-day station work. U-TOW was successfully deployed during the morning and afternoon passages.

Monday 8.7.96
The mid-transect sampling site at 47°N 20°W (station 205) was arrived at at 00.30h and a major sampling programme commenced at 01.00h, following recovery of U-TOW, with a series of both WP-2 and Apstein zooplankton net hauls. Although some problems concerning tensions on the CTD cable were encountered during the main CTD casts (Casts 49 and 50), these were readily rectified. A very full suite of Go-Flo samples was subsequently taken in order to allow a full range of biological experimentation to be carried out and to patch in for misfires on the CTD rosette sampler. The first cruise deployment of the LHPR was carried out following completion of the water bottle sampling. Calm conditions were experienced throughout the day and the LHPR was deployed on 1000m of cable at a lowering rate of 30m min^{-1} and hauled in at 15m min^{-1} some ten minutes after full deployment. The LHPR was brought onboard by 07.10h and initial inspection indicated that it had performed successfully. Course was then set to recover the sampling location at 47°N 20°W. Work at the station concluded with a further set of zooplankton net tows, a CTD cast (Cast 50) for water samples for stable isotope analysis and an optical cast. U-TOW was deployed by 12.26h and course resumed for 37°N 19°W.

Tuesday 9.7.96
A routine transit station sampling programme was commenced at station 206 located at 44.464°N 19.730°W at 01.30h. However, the CTD failed due to conducting core breakage in the cable on the up-run of the main (300m) CTD cast and those standard water sampling depths (50, 40 and 30m) were subsequently covered by Go-Flo samples, as were the productivity samples normally taken on the shallow second routine CTD cast. The CTD cable was repaired following resumption of passage at 04.12h. The standard mid-day transit station programme of a zooplankton net tow and optics cast was carried out at 42.968°N 19.568°W following which passage to 37°N 19°W was resumed. A meeting of the scientific party was held at 10.00h to assess the data obtained to date on the Leg and also to establish sampling requirements at the time series station at 37°N.

Wednesday 10.7.96
A successful transect station sampling programme of CTD casts and zooplankton net hauls was carried out in the early morning at station 207 (40.606°N 19.340°W), together with the usual mid-day optics cast and net haul which were done at 39.188°N 19.218°W. Although some sunny intervals occurred over the day, there were frequent showers and a fresh NE wind. Good time was made on the passage legs.

Thursday 11.7.96
The arrival at the time series station at 37.008°N 19.002°W at 01.28h was greeted with a fresh NE wind and no sight of moon or stars and the generally overcast and humid conditions were the pattern for the remainder of the day. A very full sampling schedule commencing at 01.41h initiated the time series of observations at the station including, in sequential order, three 200µm zooplankton Bongo net hauls, a CTD cast (54) to 300m for general sampling, a series of Go-Flo water bottle samples for various biological measurements, a CTD cast (55) to 110m for productivity samples, further Go-Flo bottle samples, zooplankton net haul (500µm) to 200m and a further CTD cast to 90m (56) for phytoplankton DNA samples. Following the initial sampling run, an Argos buoy drogued at 14m was deployed at 06.38h at 37.007°N 19.012°W, with a CTD cast to 2500m being carried out subsequently to obtain deep water for bacterial work. A marked feature of the CTD profile was the presence of the warm, high salinity Mediterranean outflow water centred at a depth of 1100m. During the up-run of the cast, minor spooling problems were encountered with the CTD winch which were remedied later in the afternoon during a dummy CTD drop to 1200m. Routine station work continued around noon with three zooplankton net hauls, two optics casts, CTD casts 58 (for stable isotope samples) and 59 (for general sampling) and a final suite of Go-Flo bottle samples. Sampling for the day was completed with a final set of zooplankton net hauls commencing at 21.00h.

Friday 12.7.96
The main sampling activity for the day was centred around core 300m CTD casts taken at approximately 6h intervals at 02.00, 06.00, 13.00 and 18.00h designed to establish diel changes in the

upper water column (CTD casts 60, 62, 64 and 65). This core programme was complemented by the standard routine of zooplankton net hauls at approximately 00.00, 05.00, 12.00 and 21.00h, Go-Flo bottle sampling following the main CTD casts and an optics cast at mid-day, together with shallower CTD casts in the early morning and pre-noon for productivity and stable isotope samples respectively. Generally overcast conditions prevailed over the day, although the fresh NE wind showed signs of moderating during the evening. The Argos buoy continued to drift southwards at a steady speed.

Saturday 13.7.96
At the commencement of the day's sampling a fresh NE wind was still blowing with the current continuing to flow in a southwards direction. While maintaining station for the second zooplankton "Bongo" net haul, the net caught under the bilge keel of the ship and was lost from the Kevlar line. Further net tows at this time were suspended. The programme resumed at 02.08h with a standard CTD cast to 300m (Cast 66) followed by Go-Flo water bottle sampling, a further CTD cast to 100m (Cast 67) for productivity samples, further Go-Flo sampling and a 500μm zooplankton Bongo net haul from 200m. In all, a total of twenty 30l Go-Flo water bottle samples were collected between 02.43-05.09h - a record for the cruise to date. The ship was positioned about 2km distant from the Argos buoy by 06.02h, immediately prior to the deployment of an *in situ* productivity rig comprising two joined floats from which were suspended samples to determine microzooplankton grazing rates and samples for the estimation of primary production and phytoplankton nutrient uptake rates. The ship then proceeded to return to the Argos buoy position to allow a LHPR tow to be carried out with the deployment of 1200m of cable. The tow was successful and the LHPR was brought inboard by 08.33h following which *Discovery* was again re-positioned adjacent to the Argos buoy. The usual CTD casts (Casts 68 and 69) were carried out around noon for stable isotope and general samples respectively, together with an optics cast and zooplankton net hauls.

During the afternoon a deep bottle cast to 4000m was made to collect samples for Fe analysis. Unfortunately the Go-Flo bottle failed to fire and a further attempt to collect the sample was scheduled for 15 July. The up-run for the cast took longer than expected owing to spooling difficulties with the CTD winch. As indicated previously, the CTD data from 12 July indicated substantive changes in the upper layers of the water column which appeared to have consequences for the vertical distribution of the DCM. Resulting from this, a programme of approximately 6h CTD casts to 300m was implemented for the remainder of the time at the station, which involved daily casts at around 06.00 and 18.00h in addition to the standard 02.00 and 12.00h casts. It was only possible, however, to take Ll chl measurements and salinity calibration samples from the extra casts on a regular basis. The first extra cast (CTD Cast 70) commenced at 19.09h. Following the cast, *Discovery* was relocated on the *in situ* productivity rig which was recovered successfully by 20.03h. The wind had fallen away considerably over the course of the day and the first consistent spell of sunshine encountered at $37^{0}19^{0}$W was recorded over the day. Operations concluded with a zooplankton net haul at approximately 21.00h carried out adjacent to the Argos buoy.

Sunday 14.7.96
Scientific activity for the day commenced with a series of four successful zooplankton net tows, followed routinely by a 300m CTD cast (71) for general sampling purposes and eighteen Go-Flo bottle samples for a range of biological sampling requirements. In order to allow comparison of the whole column water mass structure with that recorded at the northern end of the transect line, a deep CTD cast (72) was commenced at 06.03h with the CTD being stopped at 5026m at 08.30h. A delay of approximately 1h was experienced during the up-run to allow adjustments to be made to the CTD winch scrolling gear. By the time the CTD was inboard, visual contact with the Argos buoy had been lost and the ship steamed 2.5 miles in a southerly direction, as inferred from the DF. However, although a DF signal was picked up, the buoy was not located visually and as a considerable delay on the start of the mid-day sampling had been incurred, the decision was taken to commence the mid-day sampling schedule at 13.38h. The schedule started with CTD cast 73 to 150m for stable isotope samples and continued with the usual series of zooplankton net hauls, optics cast, 300m CTD cast (74) for general samples and Go-Flo bottle samples.

After completion of the delayed sampling schedule, DF contact with the Argos buoy was again made and the ship steamed an approximately NE course and closed the buoy within a distance of 1.5 miles. A part of the reason why the buoy had been lost sight of originally was the loss of the marker flags

very soon after the original deployment. As a consequence, the buoy was brought inboard at 17.41h and a new marker flag attached before returning the buoy outboard by 17.45h. Updates on positions of the Argos buoy confirmed that although the net movement over the day was still in a southerly direction, an eastward component of drift had developed. The day was completed with a 300m CTD cast (75) and a final 500µm mesh zooplankton net haul.

Monday 15.7.96
A very full day's schedule commenced at 00.13h with the standard early morning round of zooplankton net hauls, CTD casts (Nos. 76 for general sampling and 77 for productivity samples) and Go-Flo bottle sampling for both biological samples and Fe analyses. A productivity rig was deployed at 05.51h at 36.660^{0}N 19.237^{0}W, that is approximately 1 mile NW of the Argos buoy, for the *in situ* estimation of microzooplankton grazing rates at 10m and column production and nutrient uptake rates. The rig was successfully recovered by 19.47h. Following a standard 300m CTD cast at 06.15h, a deep bottle cast to 4000m was made for samples for Fe analysis, with the bottle operating successfully in this instance. The, by now, routine lunch-time sampling schedule of standard 300m and shallow stable isotope CTD casts (79 and 80 respectively) together with zooplankton net hauls, optics cast and Go-Flo sampling was carried out on time and this sequence was followed by a successful LHPR deployment on 1200m of cable. *Discovery* was subsequently repositioned on the Argos buoy prior to a further 300m CTD cast (81) at 18.40h and, after recovery of the productivity rig, the day's sampling was completed with a further Go-Flo bottle sample and zooplankton net haul.

Tuesday 16.7.96
The main focus for the day's science was to obtain a further series of observations on diel changes in a range of biological and chemical properties at the time series station. The programme centred on the four main CTD sampling periods over the day of 02.00, 06.00, 13.00 and 18.00h, with the standard 300m CTD casts at three times being supplemented by the, by now, standard routine of zooplankton net hauls, Go-Flo bottle sampling and optics cast. All operations were carried out successfully and although the morning was overcast, the sun eventually came out in the afternoon to help things along in the final stages of the scientific work. As was usual, the sampling for the day concluded with a zooplankton net haul around 20.00h. As on the previous day, substantial variability was observed in the detailed structure of the water column over the course of the day, with this again being related to the fine scale physics of the upper layers.

Wednesday 17.7.96
The first really fine and sunny day encountered at the southern time series station. The previously established sampling programme was continued commencing with a series of zooplankton net hauls shortly after midnight followed in sequence by a 300m CTD cast (89) and Go-Flo bottles for general sampling, two further shallow CTD casts for productivity and DNA analysis samples (90 and 91) separated by more Go-Flo sampling, and with a zooplankton net haul, leading into the next 300m CTD cast (92) at 06.16h. The LHPR was subsequently successfully deployed on a 1200m cable haul during the late morning. The ship was then repositioned on the Argos buoy to allow the start of the mid-day sampling schedule. This took the usual format but with the addition of extra Go-Flo samples to allow a close time sequence of DNA changes to be followed, and an extra optics cast. A further sample for DNA analysis was taken at 20.02h and the day finished with the regular 500µm zooplankton Bongo net haul to 200m at 20.23h.

Thursday 18.7.96
The final day's sampling was carried out under ideal conditions with warm, sunny weather and only a light breeze occurring over the whole day. A full sampling schedule was undertaken to allow completion of an eight day time series of observations at the station. Following the series of zooplankton net tows starting just after midnight, sampling continued at 02.02h with a 300m CTD cast (96) for general scientific purposes with a further similar cast (98) being undertaken at 06.04h. A shallow CTD cast (97) for productivity samples was interpersed between the two 300m casts, together with 13 standard 30l Go-Flo bottle casts and a zooplankton net haul. Subsequent to the early morning sampling, the LHPR was successfully deployed on 1200m cable. Sampling recommenced at 11.09h with a shallow CTD cast (99) for stable isotope samples, followed by the usual CTD net hauls, optics cast, 300m CTD cast (100) and Go-Flo sampling. The final standard 300m CTD cast (101) of

the cruise was commenced at 17.31h. Following completion of the cast, *Discovery* recovered the Argos buoy No. 8 located adjacent to the site of the CTD station which had been used as the marker for the Lagrangian Experiment and then proceeded to deploy U-TOW. Course was then set at 18.36h at full speed for Southampton. On-line sampling of selected variables continued during the passage. Later during the evening an intermittent fault developed on the on-line fluorometer, which was tracked to a faulty connector. The problem was subsequently rectified.

Friday 19.7.96
Passage continued to Southampton under excellent conditions with U-TOW deployed and on-line sampling continuing. Decommissioning of equipment commenced.

Saturday 20.7.96
On passage to Southampton. U-TOW recovered at 09.07h following data transmission problems, together with PES fish. On-line sampling for selected variables continued over the day, together with decommissioning and packing of equipment.

Sunday 21.7.96
On passage to Southampton. Decommissioning and packing of equipment continued.

Monday 22.7.86
On passage to Southampton. On-line sampling discontinued a.m. Decommissioning and packing of equipment continued.

Tuesday 23.7.86
Arrival at Southampton 08.30h.

3. SCIENTIFIC ACTIVITIES: LEG 1

3.1. Physical Oceanography (Adrian Martin, Ian Wade)

Satellite images of AVHRR Sea Surface Temperatures (SST's) were made available for the few weeks before the cruise by Steve Groom (PML). Although cloud cover was typically greater than 60% several features were observed that were marked as being suitable for this study. Generally the cold core rings were much more clearly defined than their warm core counterparts on satellite images in the study area. A well defined cold core ring was identified at approximately 59.5°N 20.5°W that had been present at this location for several weeks and it was decided initially to head for this feature. A composite SST image was sent to *Discovery* soon after leaving Southampton covering the period 3 to 9 June. From this image a second feature, a poorly defined warm core ring, was located at approximately 58.0°N 20.0°W. The initial heading north to 60°N 20°W was altered slightly to cut across both eddies.

Thermo-salinograph (TSG) results showed the more northerly cold core eddy to be a better choice for an initial Seasoar survey as the apparent warm core feature did not show up clearly on the TSG section. The estimated length scale of a temperature drop (up to 1.2°C) was approximately 60 km across suggesting that we had transected the cold core eddy close to centre. The centre was estimated as being at approximately 57.30°N 20.25°W. A 100 × 100 km Seasoar survey was initiated using this position as a centre point. The cold core eddy was clearly identified in the centre of the survey area. An extra south-north section was done through the centre to help define the meridional limits.

The anticipated cyclonic circulation around the centre of the eddy was contradicted by ADCP results. After careful checking of the ADCP we could come up with no obvious reason why this cold core feature should rotate anti-cyclonically against what basic geostrophic theory dictates. Any anti-cyclonic circulation should force mass into the eddy centre producing downwelling. Instead, both the domed isopycnals and silicate, nitrate and DMS distributions suggested that there was upwelling at the core. It was decided to perform a series of deep (at least 2500 m) CTD stations across the eddy at the end of the Lagrangian experiment to try and answer some of the dynamical questions raised.

An Argos buoy (drogued at 14 m) was released just west of the predicted eddy centre to track the rotation of the eddy. We then steamed to the predicted eddy centre for an initial CTD station to 1000 m. A drift of 4 nm in 4 hours to the southeast and then south during the CTD station suggested that perhaps we were not at the centre and the site was moved 2 nm west for the beginning of the SF_6 release. Three buoys were released close to the new predicted centre (2 Argos and 1 GPS). During the cruise we were kept informed of the positions of the GPS buoy on a daily basis by David Meldrum of DML and of the Argos buoys by RVS. The trajectories of all four buoys remained remarkably close throughout the entire study period, rarely deviating more than the initial distance apart from one another. All buoys followed a general anti-cyclonic circulation with a secondary 'looping'. Towards the end of the Lagrangian experiment two of the Argos buoys and the GPS buoy were retrieved leaving one Argos buoy to be collected on Leg 2. Indications of a slight south to southwesterly drift of the entire eddy was suggested by the estimated centres of rotation from each loop in the trajectory.

An analysis of the ship's path when navigating by dead-reckoning to lay the SF_6 also revealed a strong anti-cyclonic circulation. Modified versions of a program used to analyse the drift were later used to estimate the position and shape of the patch at a given time and the expected position of the buoys. This technique was only partially successful with the best estimations being predicted when we had been close to the buoy positions for most of the day. On leaving the area (e.g. to perform Seasoar sections) we experienced different current regimes to the buoys and therefore the predictions became less reliable.

Subsequent Seasoar surveys (although limited spatially) showed no relaxation of the density gradients, implying that the eddy was remaining coherent. A final calibration for the Seasoar sensors was not available until comparatively late in the cruise. The biggest problem was the calibration for the pressure sensor. We had been given a calibration for a 6500 dbar sensor instead of the more shallow sensor that we were using. Eventually tests performed on board by Phil Taylor (RVS) and the use of polynomial fitting software found aboard cleared this problem up and processing could be completed. Seasoar data for the initial and final surveys were cleaned and calibrated up to the final TSG

calibrations on board using pre-tested PSTAR execs. One observation that was clearly noticed in the 'despiking' phase of the data cleaning was the presence of quite intense interleaving (making despiking rather difficult) at the edges of the eddy at intermediate pressures of between 400 and 700 dbars.

The deep CTD line across the eddy consisted of 7 stations extending to pressures in excess of 2500 dbars, often to within 50 dbars of the bottom. Initial results showed a strong pycnostad between σ_0 = 27.40 and 27.45 centred at 600 dbar. This density range extended approximately 600 dbars in the vertical at the centre. The strong reversal from doming isopycnals in the surface 600 dbars (as seen from the Seasoar survey in the top 350 dbars) to depressed isopycnals below this depth is likely to be a major cause of the observed anti-cyclonic surface circulation around a northern hemisphere cold-core feature. Depression of the isopycnals was clearly seen as deep as at least 2500 dbars on the σ_0 = 27.80 surface. A salinity minimum centred at 1800 dbars associated with Labrador Sea Water was clearly observed overlying a slightly more saline bottom water that has probably formed in the northern seas and flowing over the ridges between Scotland and Iceland.

Surface driven anti-cyclonic rotation of the eddy - a theory?

The eddy exhibited clear anti-cyclonic flow below 600 dbars characterised by marked depressions in the isopycnals. It is possible that this feature originated as a warm core eddy shed from the Subarctic Front prior to the last winter mixing in this region and subsequently moving northwards. Typical winter mixed layer depths in this region are 600 dbars and occur around March/April. If this eddy experienced a homogenisation of the upper 600 dbars through winter mixing the convergence at the deeper levels can now create up and down-welling from this 600 dbar layer through conservation of mass. When the warm core ring extends to the surface, mass can only be forced downwards. This could give the observed pycnostad structure, but why should a strong anti-cyclonic flow at depth also lead to anti-cyclonic flow at the surface ? An answer to this may come from the thermal wind equations :-

$$-f\frac{\partial v}{\partial z} = \frac{g}{\rho}\frac{\partial \rho}{\partial x} \quad , \quad f\frac{\partial u}{\partial z} = \frac{g}{\rho}\frac{\partial \rho}{\partial y}$$

where f is the Coriolis parameter, ρ is the density and g the acceleration due to gravity.

If below 600 dbars we have an anti-cyclonically rotating structure with density increasing out from the centre then these equations imply that the magnitude of the currents increase as we move up the water column. On encountering the pycnostad however the bulging of isopycnals due to convergence causes the density gradient to be reversed with denser water now on the inside of the eddy. The thermal wind equations now predict that the magnitude of the current will decrease as we move further upwards, but the flow is still anti-cyclonic. The displaced isopycnals are allowing the eddy to influence the waters above it. Hence we have the curious situation of what looks like a cold-core eddy rotating anti-clockwise at the surface. This matches both ADCP current data and observations of nutrients, silicate and DMS which all point to upwelling at the surface inside the eddy. Using continuity and the Thermal Wind equations it can be shown that the upwelling velocity at the eddy centre is 0.005 cm s^{-1} (5 m day^{-1}).

3.2 ADCP Measurements (Mark Hartman)

The RDI 150kHz Acoustic Doppler Current Profiler (ADCP) mounted aboard RRS *Discovery* is primarily a current measuring device that produces water velocities relative to the ship. When used in conjunction with satellite navigation (GPS) water velocities relative to the Earth are achievable. A secondary feature: measurement of acoustic backscatter from the instrument, provides estimates of the abundance of scatterers such as euphasiids when it is combined with hydrographic data. The ADCP was run continuously throughout cruise 221, sampling 128 4m bins and averaging to a 2 minute

interval. This enabled measurements of water currents and acoustic backscatter to be made between depths of 11 and typically 300m. The raw beam data was logged as well as averaged.

Calibration of the instrument was made on the passage leg at the start of the cruise in shelf waters of approximately 100m depth and was performed in water tracking mode. GPS coverage was good with PDOP only rising above 4 for some scattered points during two of the legs. Unfortunately coverage by the 3 dimensional Ashtec GPS system was only good for the last 3 legs of the calibration run and this was not deemed sufficient for ADCP calibration purposes. The run itself consisted of a zig-zag track of 8 x 30 minute legs each leg perpendicular to the previous, the first being to the North, the next West, then North again, etc. The ship was required to steam at 8 kts throughout. The pointing angle, phi, was calculated to be 6.065 degrees and the amplitude scaling factor 1.029

It was found necessary to edit out data during a 15 minute interval following the commencement of each turn in order to obtain data where the gyrocompass oscillation had died away to acceptable limits. The GPS scatter was estimated from data while the ship was alongside at Southampton. Over an interval of 45 minutes the positional error was as large as 25m. The calibration provided currents that were indicative of the trend of the flow but that were not satisfactory for detailed analysis, as results from an antiparallel leg of the cruise track revealed discrepancies between it and the previous leg that were too large to be accounted for in terms of a change in current.

A second calibration run was performed towards the end of the cruise in an attempt to improve the accuracy of the current measurements; this consisted of 12 legs, 20 minutes per leg, on headings of 030 and 330 degrees. These data have not as yet been analysed but with post processing of the data set and the incorporation of Ashtec data matters should improve.

The ADCP was successful in identifying that the eddy singled out for investigation was rotating contrary to how it was expected to rotate. This was confirmed by subsequent measurements such as ship drift and the paths of satellite tracked buoys. Some preliminary processing of backscatter measurements revealed that the eddy possesses an interesting bioacoustic structure worthy of further investigation of the data set at a later stage.

Data processing

The data from the ADCP's data acquisition software (DAS) were passed via a printer buffer to the RVS level C; it appears that somewhere during this path the data stream was periodically corrupted and preventedthe ADCP data from being logged. This loss of data was minimised by restarting the data logging automatically each time this occurred. Unfortunately when this happened a single record was written where there should have been 128 and this consequently involved manual editing of the files until an automated method of removing these single records was devised. This was not an ideal remedy but sufficed until the problem in the logging can be identified and resolved.

The data processing routine is already fairly well documented but a brief summary follows:-

After the data is read from the RVS system, they are processed using the PEXEC suite of Fortran programs. Because of the quantity of data, running these manually would have been very time consuming so they were run from UNIX scripts called ADPEXEC-0 through ADPEXEC-4. These read the data from RVS format, average the data to (in this case) a 10 minute sampling interval, add a pointing angle and amplitude scaling factor correction and then merge the data with navigational information to produce absolute current measurements.

Salinity measurements

Samples were taken on a 2 hourly basis throughout the first leg of D221 from the non-toxic supply to the thermosalinograph (TSG) with the exception of the period when the supply was interrupted for the SF_6 deployment. As well as the time of the sample, the temperature and salinity as recorded by the TSG were noted. Samples were also taken from the deepest and shallowest bottles from each CTD station with additional samples being obtained from the seven deep CTD stations.

The samples were analysed after allowing at least 24 h to achieve ambient laboratory temperature. A Guildline Autosal model 8600A was used to measure the salinity of the samples using standard

seawater Batch P128 with $K_{15} = 0.99986$ and corresponding salinity of 34.994 as a standard. The salinometer was attached to a PC. SiS Softsal V1.2 software was used to generate the salinities from the conductivity ratios: these values were also checked against those generated by using the equations for salinity. From comparison of these results and the TSG values, it was apparent that there was a positive linear offset to the TSG data of 0.1693, with the standard deviation of the differences between the TSG and bottle samples amounting to 0.0147 for the period starting on 14 June at 19.53h and ending 27 June at 12.01h.

3.3 SF_6 Tracer Studies (Cliff Law, Malcolm Liddicoat and Jane Robertson)

The man-made gas sulphur hexafluoride (SF_6) has been used as an oceanographic tracer in a number of applications in recent years, including measurements of air-sea exchange, mixing within the thermocline and in-situ manipulation experiments studying phytoplankton micronutrient limitation. Its increasing use is due to the potential it provides for studying mesoscale features with relatively small quantities of tracer, partly resulting from the sensitivity of the analytical systems and partly the extremely low oceanic background levels. The PRIME cruise provided the first opportunity to use SF_6 as an observational tool of temporal biological and biogeochemical change, and also mixing and circulation of the mixed layer within an eddy. As such, the SF_6 functioned as a label for the surface waters of the eddy centre, and so provided a framework and strategy for Leg 1.

Saturation and Release

Initially 2300 litres of surface seawater were saturated with pure SF_6 in a steel tank during the passage leg. The saturation took longer than the anticipated 30 hours as a result of restricted circulation in the pumping system. Monitoring by TCD-GC (Thermal Conductivity Detector- Gas Chromatography) determined that saturation was complete by 72 hours, and the tank was sealed 10 hours prior to release. The SF_6-saturated water was released into the surface waters at a rate of approximately 2.2 l/min by gravity feed. Freshwater input from an overlying header tank filled a large bladder within the tank ejecting the saturated water and preventing loss of SF_6 by volatilisation and also dilution of the tracer signal. The saturated water was mixed immediately with a make-up flow of surface seawater (150 l/min) to assist mixing and dispersion, and then released at a depth of 7.5-10m through a tube attached to a 45kg depressor. The release began at 06.00h at a ship speed of 4.5 kts on the 18 June and, after initial problems with the release line, continued uninterrupted until 22.45h. The release was centred around three ARGOS buoys and one GPS-ARGOS buoy which would function as locators of the patch centre during the following survey.

A dead-reckoning method was used to produce a coherently-labelled patch of surface water with a concentrated centre. This was achieved by superimposing the release track, of a square with dimensions of approximately 7.5 x 7.5 km, upon the actual surface water advection by incorporating data from the ships gyro and electromagnetic log. Whereas the patch would be ideally centred around a particular point, this would be moving within space and time during the release; the dead reckoning method provided the best correction procedure using the assumption that the ship and centre point were similarly influenced by surface advection with the track being corrected accordingly. This method was ideally suited to the exceptionally calm meteorological conditions during the release day, and the dead-reckoned cruise track (livenav) and actual ships GPS position (bestnav) are shown in Fig. 4. The ships GPS track shows that the labelled water body was advected relatively rapidly in a narrow band around the northern edge of a loop which was to become a regular feature of the following patch survey. Post-cruise correction for surface water advection using the buoy data will confirm whether the dead-reckoning method was completely successful.

Surveying

Continuous analysis of surface water SF_6 concentrations began at 06.00h on the 19 June approximately 24h after the release start. Measurements were obtained every three minutes using a fully automated stripping and cryogenic trap system with detection by ECD- GC (Electron Capture Detector-Gas Chromatography). The patch was initially surveyed at a ship speed of 5 kts but this was

increased to 7.5 kts (one measurement every 0.75 km) as this provided greater coverage with no significant decrease in resolution. The patch was located to the south-east of the release position and appeared to be relatively coherent with some suggestion of fringing to the east on the outer edge of the eddy. Concentrations in the centre exceeded 150 fmol/l (1 fmol = 1 x 10^{-15} mol) which was approximately 160 times greaterthan the background levels.

The buoys were regularly sighted during surveying with all four remaining in close contact with the patch centre throughout the survey period. This was an unexpected bonus, resulting from the good meteorological conditions and the low windage of the buoys, and considerably aided location of the patch centre throughout the survey period, particularly during the large scale Seasoar surveys. Both patch and buoys circumnavigated the eddy centre, completing the first revolution within two-three days. Fig. 10 shows a contour plot of the patch five days after release (D5) with the ships track superimposed. At this stage the patch was approximately 14km^2, with a broad centre of 60 fmol/l and relatively sharp boundaries. This estimate was corrected for drift based upon comparison of the ships GPS position and EM log data, and will be further refined using the buoy data during post-cruise analysis.

Surveying was suspended overnight on D5 whilst the ship was hove to in the tail of tropical storm Arthur (winds Force 8-9, 35 kts gusting to 40). The patch was relocated relatively quickly on D6, still with the buoys closely associated. SF_6 concentrations had dropped to about half the previous day through loss to the atmosphere and dilution and mixing, with the patch appearing to be less homogenous and with some evidence of filamenting. Surveying over the following few days showed that the patch was still revolving anti-cyclonically around the eddy but had become strained out along its circular path. Despite further periods of high winds the patch remained stable in both shape and concentration during D6-D9. During the final large scale Seasoar survey over D11-D12 the SF_6 patch with a data point every 30 seconds during the surface was still detectable at the eddy centre, as a long filament stretching in an east-west direction, with maximum concentrations exceeding 10 fmol/l (11 x background levels).

Vertical structure

The daily surveying routine included location of the patch centre, or at least a localised "hot-spot", at midday and midnight in order to undertake the required routine biological and biogeochemical sampling. Vertical profiling within the SF_6 patch to a depth of 100m was achieved by collection of 350ml samples from Go-Flo bottles on the CTD and analysis by a similar discrete system which incorporated a vacuum-sparge step. Twenty-four vertical profiles were obtained, which predominantly exhibited a trend of uniformly high SF_6 concentrations in the mixed layer decreasing sharply at the pycnocline to background levels (as shown in Fig. 11). Occasionally the SF_6 profile deepened in association with a weaker pycnocline gradient. This was most pronounced in Cast 20 located on the edge of a filament where SF_6 penetrated to 75m coincident with a decrease in the thermal structure of the upper water column, possibly as a result of shear.

In addition to the standard 100m profiles we also took advantage of the deep physical oceanography casts during the 27 and 28 June to examine the penetration of atmospheric SF_6 into the deep water. Rather disappointingly an increased SF_6 signal was not apparent in the deep saline water originating from waters recently ventilated in the Northern Seas.

The PRIME SF_6 Langrangian study was judged to have been particularly successful, and bodes well for future applications as a tool for studying temporal change in the ocean. In addition to a general thanks to all the "water-watchers", we would particularly like to thank Ian Wade, Graham Savidge and Adrian Martin for their help during the survey, Malcolm Woodward, Andy Rees, and Rob Lloyd for assistance with the release and Dave Teare for the buoy deployments. We would also like to thank Dave Meldrum and Neil McDougall of DML for the loan of the GPS-ARGOS Buoy and their daily position updates.

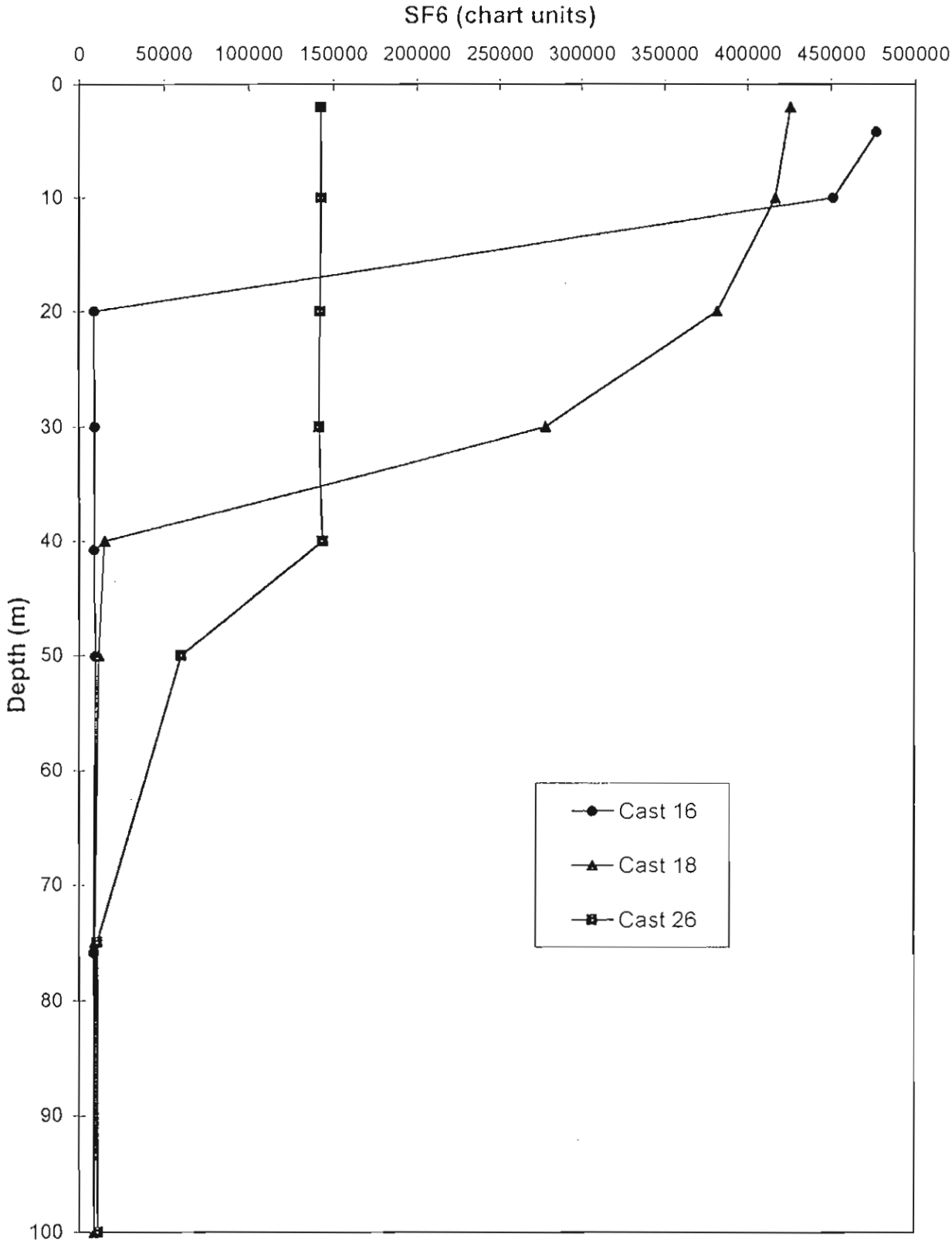


Fig. 11. Vertical distributions of SF_6, CTD casts 16, 18 and 26.

3.4 pCO_2, TCO_2 and Underway Oxygen Electrode (Jane Robertson)

pCO_2

An underway 'on-line' system for measuring pCO_2 using FID gas chromatography was used during the cruise. The system was connected to the ship's de-bubbled non-toxic supply and carbon dioxide stripped from the system using a 'spray-head' type equilibriator. A sampling tube for pumping marine air into the instrument system was placed above the bridge and connected via the ship's superstructure down into the laboratory. A sampling programme of 13.5 mins was used with two measurements of CO_2, one of standard and another of marine air per cycle. initial runs of the equipment showed a poor reproducibility of standard and marine air measurements which was traced to the draught that came into the deck laboratory when the door to the hangar was kept open. A large sheet of wood was fitted onto the bench in front of the machine by the RVS Engineering Group, shielding the GC and this successfully reduced the problem to an acceptable level. The temperature in the equilibriator was recorded and showed an average increase of 0.75 degrees above the temperature recorded at the intake of the non-toxic supply. The CO_2 measurements will have to be corrected for this slight warming before the data are placed on the BODC database. The system was run during all SF_6 and Seasoar surveys and performed well with no major faults or breakdowns. In general, the levels observed within the patch (335-340 ppm) were slightly higher than those outside (320-330 ppm) although no large deficits with respect to the atmospheric levels were observed during the cruise (generally 20-30 ppm below atmospheric CO_2 levels). The higher levels associated with the patch and centre of the eddy are presumed to have resulted from the upwelling of deep, high-CO_2 water. No significant change in the surface CO_2levels over time was observed from the initial dataset. Temperature correction and additional calibration may provide evidence of change due to productivity once the dataset has been checked through.

TCO_2

Discrete analyses of total dissolved inorganic carbon (TCO_2) were made coulometrically from the surface non-toxic supply and from various depths taking samples from both the CTD Rosette and 30l Go-Flo bottles. The system performed well with no major faults or breakdowns. The discrete numbers will need to be calibrated against seawater standards used during the cruise and corrected for salinity once a final calibration for the TSG and CTD conductivity cells exist.

Online Oxygen Electrodes

A system for recording underway oxygen values was placed on the cruise by Dr D Purdie from Southampton University. Data from two electrodes were recorded throughout the cruise during all SF_6 and Seasoar surveys. Discrete oxygen samples were taken three times a day (three replicates each time) to provide a calibration set for the electrodes.

3.5 Micro and Nano Nutrient Analyses (Malcolm Woodward, Andy Rees)

Objectives

To study the spatial and temporal variations of the micro nutrients nitrate, nitrite, phosphate, silicate and ammonia in the water column, and to deploy for the first time in the Atlantic Ocean a nanomolar ammonia analysis system, and also where required to use a nanomolar chemiluminescence analysis system for detection of nitrate and nitrite. A specific objective during Leg 1 was to study the nutrient distributions relating to the anti-cyclonic eddy structure studied during the SF_6 tracer experiment.

Methodology

The methodologies to be described were employed during both Legs 1 and 2. The nutrient analyser used was a 5 channel Technicon AAII segmented flow autoanalyser. The specific chemical methodologies used were as follows:

Nitrate: (Brewer and Riley, 1965); nitrite: (Grasshoff, 1976); phosphate: (Kirkwood, 1989); silicate: (Kirkwood, 1989) and ammonia: (Mantoura and Woodward, 1983). Nanomolar nitrate and nitrite detection was according to Garside (1982), with the nanomolar ammonia system adapted from the method of Jones (1991).

Samples from the CTD Rosette bottles were sub sampled into clean Nalgene bottles and analysis of the samples was in every case completed within 2 h of sampling. No samples were stored. Underway continuous surface samples were derived from the non-toxic water system, for which the water flow was in-line filtered (Morris *et al*, 1978) before analysis. Data output from the analytical system was stored on the ships mainframe computer for all 5 channels with a data point recording frequency ofevery 30 seconds during surface sampling mode.

Equipment Performance

All CTD samples were analysed successfully with a very low sample loss rate. The loss of silicate data from two CTD casts may be highlighted: this was due to a peristaltic pump failure which was subsequently rectified. Overall, the Technicon Autoanalyser system showed its reliability and reproducibility in the extreme environment of marine research.

A new valve system on the nanomolar ammonia system caused many problems during Leg 1, but repairs were finally effected allowing good analyses to be carried out during the whole of Leg 2. The new system was shown to work well both for underway surface sample analysis from the filter block, and for discrete sample analyses of aliquots derived from the large volume autosampler deployed during Leg 2. This sample system enabled both the 5 channel nutrient analyser and the nanomolar ammonia system to sample from the same sealed sample vessels, thereby reducing atmospheric contamination to an absolute minimum. The nanomolar nitrate/nitrite chemiluminescent system worked as expected, although the technique was at the limits of its detection for many samples at the oligotrophic station at 37°N. A summary of the CTD nutrient samples analysed during Leg 1 and the on-line sampling schedule appears in Tables 1 and 2 following.

Table 1. CTD nutrient samples analysed: Leg 1.

CTD	DATE/JD	DEPTHS	CTD	DATE/JD	DEPTHS
CTD 02	17.6/169	1 depth	CTD 19	24.6/176	12 depths
CTD 03	18.6/170	12 depths	CTD 20	25.6/177	12 depths
CTD 04	19.6/171	11 depths	CTD 21 P	25.6/177	8 depths
CTD 05. P	19.6/171	6 depths	CTD 23	25.6/177	12 depths
CTD 06	19.6/171	12 depths	CTD 24	26.6/178	12 depths
CTD 07	20.6/172	12 depths	CTD 25 P	26.6/178	7 depths
CTD 08. P	20.6/172	6 depths	CTD 26	27.6/179	12 depths
CTD 09	20.6/172	12 depths	CTD 27 P	27.6/179	7 depths
CTD 10	21.6/173	12 depths	CTD 28	27.6/179	12 depths
CTD 11. P	21.6/173	8 depths	CTD 31	28.6/180	12 depths
CTD 12	21.6/173	10 depths	GoFlos CS1 P	28.6/180	6 depths
CTD 13	22.6/174	12 depths	CTD 33	28.6/180	12 depths
CTD 14 P	22.6/174	8 depths	CTD 34	28.6/180	3 depths
CTD 15	22.6/174	11 depths	CTD 37	29.6/180	12 depths
CTD 16	23.6/175	12 depths	CTD 38	29.6/180	3 depths
CTD 17 P	23.6/175	8 depths			
CTD 18	23.6/175	12 depths			

Table 2.On line sampling schedule: Leg 1.

14.6.96 0930 - 14.6.96 1635
14.6.96 2110 - 16.6.96 2230
17.6.96 0330 - 17.6.96 1725
25.6.96 1604 - 25.6.96 2300
29.6.96 0840 - 30.6.96 1500

Preliminary Results

The nutrients concentrations recorded during Leg 1 were on average 4-6 μmoles l^{-1} for the surface nitrate concentrations, the phosphate was up to 0.5 μmoles l^{-1} in the surface and the silicate about 2 μmoles l^{-1} . However, during the surface mapping carried out during the detailed Seasoar surveys of the eddy structure, the surface silicate and nitrate concentrations were enhanced in the area under the influence of the upwelled waters of ther eddy. The preliminary results derived from the surface mapping exercise during the first major Seasoar survey of the eddy are shown in Figs. 12 and 13 for nitrate and silicate. From these distributions it is clear that the area of enhanced nutrient concentrations coincided with the zone of increased chlorophyll and decreased temperature.

3.6 Flow Cytometry and Microbial Ecology (Glen Tarran)

Introduction and Objectives

During Leg 1 of the PRIME cruise, flow cytometry was used to study a number of aspects of the microbial ecology of the cold core eddy, as centred on the approximate position 59° N 20° W. Studies included the quantification of the nano and picophytoplankton community in terms of their distribution, population and size structure, phytoplankton activity in the mixed layer and mortality of phytoplankton due to microzooplankton grazing.

Phytoplankton Community Structure and Abundance

A dual sampling protocol was used to analyse the picophytoplankton (<2μm) and nanophytoplankton (approx. 2-20μm) separately from the CTD casts to provide vertical profiles of phytoplankton abundance per litre (Table 3). Two picophytoplankton groups were present; cyanobacteria and picoeucaryotes. The nanophytoplankton could generally be separated into 6 clusters (see Section 4.6), one of which was subsequently identified as the coccolithophorid *Coccolithus pelagicus*.

Table 3: Leg 1 CTD casts sampled for phytoplankton community structure with peak abundance and depth

				Peak cell numbers per litre			
Date	CTD cast		Position	Nanopplk	Depth	Pico pplk	Depth
June	Pre-dawn	Post midday					
18	3		59.346°N 20.175°W	$9.80x10^6$	2	$4.35x10^7$	20
19	4		59.294°N 19.998°W	$1.20x10^7$	20	$3.41x10^7$	20
19		6	59.146°N 20.084°W	$1.04x10^7$	2 & 20	$4.30x10^7$	20
20	7		59.087°N 20.152°W	$1.20x10^7$	2	$3.60x10^7$	2
20		9	59.089°N 20.505°W	$9.65x10^6$	2	$3.00x10^7$	10
21	10		59.243°N 20.538°W	$1.36x10^7$	20	$2.75x10^7$	20
21		12	59.233°N 20.337°W	$1.21x10^7$	2 & 20	$2.75x10^7$	20
22	13		59.223°N 20.154°W	$1.52x10^7$	10	$2.80x10^7$	30
22		15	59.089°N 20.029°W	$1.83x10^7$	20	$3.00x10^7$	30
23	16		58.984°N 20.007°W	$1.73x10^7$	20	$2.40x10^7$	20
23		18	58.976°N 20.362°W				
24		19	59.063°N 20.619°W	$1.42x10^7$	20	$2.70x10^7$	10
25	20		59.132°N 20.758°W	$1.52x10^7$	2-20	$2.40x10^7$	20
25		23	59.194°N 20.628°W				
26	24		59.189°N 20.495°W				
27	26		58.997°N 20.644°W				
27		28	59.050°N 20.978°W	$1.32x10^7$	2	$1.70x10^7$	2
28	31		50.099°N 19.438°W				
28		33	59.094°N 20.506°W	6.8x106	2	1.4x107	2-20
29	37		59.105°N 21.710°W				

Grazing Experiments

Three types of grazing experiment were conducted during the cruise as follows:

a) *Diel experiments (DIEL1)* - Successive samples taken over a 24 h period using a combination of the dilution technique and flow cytometry to quantify the daily turnover of phytoplankton standing stock by microzooplankton and also to study times of day when grazing was most intense (Table 4).
b) *Bottle effect experiments (BE)* - Study of the effects of using different sized incubation bottles on microzooplankton grazing and sampling at T0 and T24 hours (in collaboration with Elaine Edwards)
c) *Start point experiments (DIEL2)* - Study of the effects of the start point of incubations on microzooplankton grazing.

Table 4. Grazing experiments carried out with daily turnover rates of nanophytoplankton standing stock

Date	Experiment type	Sample depth m	Position	Bottles used	Phytoplankton turnover d^{-1} %
18 June	BE	10	59.346°N 20.175°W	2 l 0.25 l	24.96 9.58
19 June	DIEL1 DIEL2	10 10	59.286°N 20.084°W 59.132°N 20.127°W	0.25 l 0.25 l	38.4 16.7
20 June	BE	10	59.085°N 20.505°W	2 l 0.25 l	14.08 31.29
21 June	DIEL1 DIEL2	10 10	59.243°N 20.538°W 59.240°N 20.330°W	0.25 l 0.25 l	22.89 38.54
22 June	BE	15	59.220°N 20.132°W	2 l 0.25 l	28.78 31.71
23 June	DIEL1 DIEL2	15 15	58.973°N 20.018°W 58.976°N 20.362°W	0.25 l 0.25 l	0 9.1
25 June	BE	15	59.139°N 20.751°W	2 l 0.25 l	13.14 16.3
26 June	DIEL1	10	59.189°N 20.495°W	0.25 l	31.37
27 June	BE	10	58.997°N 20.644°W	2 l 0.25 l	26.0 37.63
28 June	BE	15	59.099°N 19.438°W	0.25 l	10.38

Size Distribution of Phytoplankton by Size Fractionation
Water samples from the mixed layer were gravity filtered through 10, 5, 3, 2, 1, 0.6, 0.4 and 0.2µm Nuclepore filters and the filtrate analysed by flow cytometry to enumerate the phytoplankton. The cell counts were then compared to unfiltered seawater cell numbers by plotting % cells remaining compared to unfiltered seawater against filter pore size . The median cell diameters were read off the X-axis where they intersected with the 50% line on the Y-axis (Table 5)

Table 5: Median cell diameters (µm) recorded from flow cytometric analysis during Leg 1

Date	Nanophytoplankton (~2-20µm)	Picoeucaryotes (~< 2µm)	Cyanobacteria
18 June	2.92	1.5	0.83
20 June	2.84	1.56	0.80
24 June	To be determined	To be determined	To be determined

Summary
On arrival at the study site the total nanophytoplankton population density was just below $1x10^7$ cells l^{-1}. Abundance reached a maximum of $1.83x10^7$ cells l^{-1} after 8 days and had decreased to $6.8x10^6$ l^{-1} by the end of the study. Picophytoplankton abundance was at $4.35x10^7$ l^{-1} at the beginning of the study, with the population consisting mainly of cyanobacteria. Their abundance decreased steadily during the study and was approximately one third of the initial abundance by the end of the study. The most striking component of the phytoplankton community was the presence of the coccolithophorid *Coccolithus pelagicus*. It persisted throughout the study and was found to be confined to the eddy with

none being found at the two CTD stations CS1 and CS7 located outside the eddy. Although cell numbers never exceeded $4x10^5$ cells l^{-1} they still contributed significantly to the phytoplankton biomass and were clearly visible in the deck incubators as a mustard coloured silt.

Preliminary results of microzooplankton grazing showed that it was significant throughout the study, 9 to 38% of the nanophytoplankton community being turned over daily (Table 4). Further analysis will be carried out back in the laboratory to assess the contribution of the different nanophytoplankton clusters identified to total grazing.

3.7 Phytoplankton DNA/RNA Characterisation (Mike Wyman)

An intensive sampling programme was completed to obtain high quality phytoplankton DNA, RNA and protein samples from surface waters within and outside of the eddy. Routine samples were also taken daily from a depth of 2m for determination of photosynthetic parameters by ^{14}C-incorporation and analysis of phytoplankton pigments by HPLC.

The spatial variability in pigments and phytoplankton DNA was examined at the beginning and at the completion of the drifting station and an inter-comparison between the two datasets will be made on shore. Taxonomic information from HPLC will be compared with the distribution of phytoplankton DNA utilising group specific labelled oligonucleotides targeted to the gene (rbcL) encoding the large subunit of RubisCO.

Temporal variability in the abundance of transcripts originating from chloroplast encoded genes including rbcL will be examined utilising RNA samples obtained twice daily from 2m (03.00h and 14.30h) during the course of the drifting station. In addition four diel experiments were completed on alternate days during the nine day occupancy of the drifting station. RNA samples were obtained from the ships non-toxic supply every 2-3 hours during the diel experiments from within the SF_6 patch. These samples will be analysed to examine the diel variability in the relative abundance of rbcL and psbA transcripts utilising general and group specific probes for rbcL and a universal probe for psbA.

P_{max} was determined for the entire phytoplankton community on each day of the drifting station by ^{14}C incorporation during short term incubations in a light box. Uncorrected data for the experiment reveal that P_{max} varied by a factor of 2 during the course of the study being higher at the start (19-20 June) and end (25-27 June) of the experiment than for the period between the 21 and 25 June.

A number of other samples of a more opportunistic nature were obtained during the cruise. These included samples of aggregates obtained from 500m during CTD cast #CS5 for the investigation of bacterial composition by amplification of 16S rRNA genes by PCR, a coccolithophorid enriched sample obtained from settled material in a deck incubator for amplification of rbcL, and 15 salp stomachs contributed by Dr. D. Pond for investigation of the bacterial nature of this animals diet.

3.8 Nutrient Uptake and Primary Production (Kirsten Donald, Andy Rees)

Samples were collected during both legs of the cruise for the estimation of phytoplankton nutrient uptake rates and primary production at the two major time series stations (60^0N 20^0W & 37^0N20^0W) and also during the southerly transect along the 20^0W meridian. At each sampling point, a series of incubations of seawater sampled from throughout the euphotic zone (defined as the limit of the 1% light depth) was made following the addition of radioisotopes ^{14}C and ^{33}P and the stable isotope ^{15}N. The additions were made in order to provide rate estimates of carbon fixation and phosphate assimilation together with relative uptake rates of nitrate and ammonium to allow derivation of new production. Water samples were collected from eight depths pre-dawn using the CTD-rosette system.. To avoid light shock to the phytoplankton, the water was kept in the dark and following addition of the relevant tracers, samples were incubated either on-deck in a series of plastic boxes covered with neutral density filters to give a simulated ambient light profile, or *in situ* using a free floating buoyed rig. Samples incubated on-deck were maintained at surface temperature by pumping seawater from 2.5m through the system.

^{14}C and ^{33}P

Aliquots of water collected from each depth were transferred into two triplicate 60ml clear polycarbonate bottles and 2 x 60ml black polycarbonate bottle prior to inoculation with 10 µCi $NaH^{14}CO_3$ and 1 µCi ^{33}P-orthophosphate. Incubations were terminated after 24h by filtration onto polycarbonate filters through a cascade system of filters which allowed phytoplankton to be size fractioned into >5 µm, <5->2 and <2µm size classes. Filters were then placed in scintillation vials prior to counting of incorporated material using the onboard liquid scintillation counter.

^{15}N

Assimilation rates of nitrate and ammonium were determined following the incorporation of the stable isotope ^{15}N. Triplicate samples of water from each depth were distributed into 500ml clear polycarbonate bottles to which were added ^{15}N-NO_3 and ^{15}N-NH_4 to give a final concentration of 10% ambient nitrate or ammonium concentration. Incubations were made for both 24h and for shorter time periods of approximately 4h over midday as described previously. Incubations were then terminated by filtration (<40 cm Hg vacuum) onto ashed Whatman GF/F filters, which were then stored frozen until return to the laboratory, where they will be analysed by continuous flow nitrogen analysis-mass spectrometry.

Chlorophyll-a concentration

Total and size-fractionated chlorophyll concentrations were measured by fluorometric analysis of extracted pigments (90% acetone). Two x 100ml of water collected from each depth were filtered (a) through the cascade system of filters to measure size fractionated chlorophyll concentrations and (b) through 0.2 µm polycarbonate filters to measure total chlorophyll present.

Dissolved Organic Carbon

Seawater samples for the analysis of DOC by Axel Miller (PML) were collected from the CTD rosette Go-Flo water bottles at a number of stations throughout the cruise. Samples were decanted into 250ml glass bottles and filtered under positive pressure through a GF/F filter. Duplicate aliquots were sealed in glass ampoules and stored in the dark at 4°C prior to transfer to PML for processing. Samples were taken on the following dates over the number of depths indicated:

Date	Station	No. of Depths
18/6	CTD 03	7
20/6	CTD 09	8
22/6	CTD 15	8
25/6	CTD 23	7
27/6	CTD 28	8

3.9 Level I Chlorophylls and POC/PON (Graeme Hays)

Estimates of chlorophyll a concentrations to be used for the calibration of the on-line chlorophyll *a* fluorometer were made using an acetone extraction and fluorometric assay procedure from samples collected underway every 2 hours during the initial and final Seasoar surveys of the eddy. Concurrent samples were also taken for POC/PON analysis. Chlorophyll concentrations were also assayed for calibration purposes in samples taken from 8 depths during the midnight and midday CTD stations; complementary POC/PON samples were only taken from the midnight CTD casts. All chlorophyll samples were analysed onboard while the POC/PON samples were frozen and will be analysed post-cruise at PML by Bob Head/Roger Harris with Level 1 funding.

3.10 Mesozooplankton (Roger Harris, David Pond)

Sampling concentrated on the main Lagrangian patch study, although additional underway sampling of surface particulate material was undertaken on the two Seasoar surveys as required.

The sampling programme during the SF_6 tracer release focused on the midday and midnight periods of the diel cycle, using vertically hauled 200μm WP-2 nets to sample the upper 100m following the JGOFS "Level 1" protocol. Samples were size fractionated in to JGOFS size categories, >2000μm, 2000-1000μm, 1000-500μm, and 500-200μm, using wet sieving. Triplicate samples were then taken for CHN analysis and gut pigment analysis, onto glass-fibre and "sharkskin" filters and immediately deep frozen. The remainder of each sample was preserved in formalin for identification and counting.

Samples were also taken using a vertically hauled 50μm WP-2 net (0-100m) to sample the early developmental stages of copepods in order to allow a more comprehensive analysis of the population dynamics.

In addition, live zooplankton were collected with vertically hauled 500μm WP-2 nets (0-100m) for experimental work. These collections were used to provide adult female *Calanus finmarchicus*, the primary focus of the lipid and stable isotope work. Daily egg production experiments were conducted, both on individual females, and replicates of 20 animals. Eggs produced were counted and stored for lipid analysis. The live samples were also used to isolate *Calanus* for CHN and body lipid estimation. Other dominant representatives of the mesozooplankton (medusae, CV *Calanus*, adult *Euchaeta*, *Metridia*, *Pleuromamma*, *Clione*, *Sagitta*, Ctenophores, Euphausiids, Doliolids, Salps, Ostracods, *Thecosomata* and *Tomopteris*) were also sorted for CHN, carbon stable isotope and lipid biochemistry

A listing of all zooplankton samples taken is given in Table 6.

In addition to each day:night zooplankton net sampling, 30l Go-Flo samples from 10 and 30m were also taken. Analyses of Lugol and formalin samples, chlorophyll, CHN and particulate fatty acids will be used to characterise the nutritional environment in relation to the *Calanus* egg production experiments.

During the two underway Seasoar surveys, surface samples were collected every 2h for Lugol and formalin, chlorophyll, CHN and lipid biochemistry. These will be used to "map" the temporal and spatial evolution of the surface particulate environment during the eddy study.

Compared with previous BOFS cruises in the area, the most striking feature of the zooplankton community was the abundance of large predatory organisms (*Sagitta*, Medusae and *Euchaeta*) together with other gelatinous zooplankton (Ctenophores, Salps and Doliolids). *Calanus* were relatively abundant enabling a full experimental programme to be achieved successfully (unlike some previous BOFS cruises). *Calanus* egg production was generally in the range of 5-16 eggs/female/day. This value is low relative to the physiological reproductive maximum, indicating possible food limitation, consistent with the relatively low chlorophyll levels 0.4 - 1.1 μg/l observed.

The objectives of the mesozooplankton project were generally successfully met, the main limitation being the number of days allocated to process work on the cruise. RRS *Discovery* was at sea for twenty-two days, of which twelve were devoted to the patch study time-series itself.

3.11 U-TOW (Graeme Hays)

The U-TOW was towed for about 700 miles on passage to the eddy and then on passage to Iceland. The U-TOW samples mesozooplankton in discrete 10 mile sections of tow at a depth of 10m as well as recording the temperature and salinity and depth of the tow vehicle. Samples will be analysed post-cruise and will allow (a) the mesozooplankton abundance to be compared with results obtained over the last 45 years using CPRs and (b) will allow the large scale distribution of mesozooplankton to be analysed in relation to mesoscale hydrographical features.

Table 6 Mesozooplankton Sampling

Date	Time	Lat	Long	Station	Formalin									
					> 2000	(split)	2000-1000	(split)	1000-500	(split)	500-200	(split)	> 50	(split)
14-Jun	1803	57.5	20.25	Shakedown	D221/1	850/1000	D221/2	850/1000	D221/3	850/1000	D221/4	850/1000		
18-Jun	0014	59.21	20.11	eddy study	D221/5	total	D221/6	850/1000	D221/7	850/1000	D221/8	850/1000	D221/9	total
18-Jun	2339	59.17	20	eddy study	D221/10	total (2 nets)	D221/11	850/1000	D221/12	850/1000	D221/13	850/1000	D221/14	total
19-Jun	1215	59.15	20.09	eddy study	D221/15	total (2 nets)	D221/16	850/1000	D221/17	850/1000	D221/18	850/1000	D2211/9	total
20-Jun	0028	59.052	20.091	eddy study	D221/20	total (2 nets)	D221/21	850/1000	D221/22	850/1000	D221/23	850/1000	D221/24	total
20-Jun	1310	59.08	20.49	eddy study	D221/25	total (2 nets)	D221/26	850/1000	D221/27	850/1000	D221/28	850/1000	D221/29	total
21-Jun	0036	59.145	20.324	eddy study	D221/30	total (2 nets)	D221/31	850/1000	D221/32	850/1000	D221/33	850/1000	D221/34	total
21-Jun	1329	59.24	20.33	eddy study	D221/35	total (2 nets)	D221/36	850/1000	D221/37	850/1000	D221/38	850/1000	D221/39	total
22-Jun	0046	59.135	20.098	eddy study	D221/40	total (2 nets)	D221/41	850/1000	D221/42	850/1000	D221/43	850/1000	D221/44	total
22-Jun	1230	59.108	19.942	eddy study	D221/43	total (2 nets)	D221/44	850/1000	D221/45	850/1000	D221/46	850/1000	D221/47	total
23-Jun	0005	59	20.025	eddy study	D221/48	total (2 nets)	D221/49	850/1000	D221/50	850/1000	D221/51	850/1000	D221/52	total
23-Jun	1247	58.978	20.358	eddy study	D221/52	total (2 nets)	D221/53	850/1000	D221/54	850/1000	D221/55	850/1000	D221/56	total
24-Jun	1234	59.062	20.614	eddy study	D221/57	total (2 nets)	D221/58	850/1000	D221/59	850/1000	D221/60	850/1000	D221/61	total
25-Jun	0030	59.0798	20.436	eddy study	D221/62	total (2 nets)	D221/53	850/1000	D221/64	850/1000	D221/65	850/1000	D221/66	total
25-Jun	1211	59.194	20.632	eddy study	D221/67	total (2 nets)	D221/68	850/1000	D221/69	850/1000	D221/70	850/1000	D221/71	total
26-Jun	0043	59.18	20.48	eddy study	D221/72	total (2 nets)	D221/73	850/1000	D221/74	850/1000	D221/75	850/1000	D221/76	total
27-Jun	0018	58.998	20.64	eddy study	D221/77	total (2 nets)	D221/78	850/1000	D221/79	850/1000	D221/80	850/1000	D221/81	total
27-Jun	1214	59.048	20.972	eddy study	D221/82	total (2 nets)	D221/83	850/1000	D221/84	850/1000	D221/85	850/1000	D221/86	total
28-Jun	0052	59.099	19.44	Stn.1 Transect	D221/87	total (2 nets)	D221/88	850/1000	D221/89	850/1000	D221/90	850/1000	D221/91	total
28-Jun	1251	59.095	20.505	Stn.4 Transect	D221/92	total (2 nets)	D221/93	850/1000	D221/94	850/1000	D221/95	850/1000	D221/96	total
29-Jun	0253	59.1	21.711	Stn.7 Transect	D221/97	total (2 nets)	D221/98	850/1000	D221/99	850/1000	D221/100	850/1000	D221/101	total

Table 6 Mesozooplankton Sampling

Date	Time	Lat	Long	Station	Biomass						Pigment		
					2000-1000	(split)	1000-500	(split)	500-200	(split)	2000-1000	1000-500	500-200
14-Jun	1803	57.5	20.25	Shakedown	1001	50/1000	1002	50/1000	1003	50/1000			
18-Jun	0014	59.21	20.11	eddy study	1007	50/1000	1008	50/1000	1009	50/1000	1004	1005	1006
18-Jun	2339	59.17	20	eddy study	1013	50/1000	1014	50/1000	1015	50/1000	1010	1011	1012
19-Jun	1215	59.15	20.09	eddy study	2037	50/1000	2038	50/1000	2039	50/1000	2034	2035	2036
20-Jun	0028	59.052	20.091	eddy study	2049	50/1000	2050	50/1000	2051	50/1000	2046	2047	2048
20-Jun	1310	59.08	20.49	eddy study	2062	50/1000	2063	50/1000	2064	50/1000	2059	2060	2061
21-Jun	0036	59.145	20.324	eddy study	2070	50/1000	2071	50/1000	2072	50/1000	2067	2068	2069
21-Jun	1329	59.24	20.33	eddy study	2090	50/1000	2091	50/1000	2092	50/1000	2087	2088	2089
22-Jun	0046	59.135	20.098	eddy study	2098	50/1000	2099	50/1000	2100	50/1000	2095	2096	2097
22-Jun	1230	59.108	19.942	eddy study	2110	50/1000	2111	50/1000	2112	50/1000	2107	2108	2109
23-Jun	0005	59	20.025	eddy study	2117	50/1000	2118	50/1000	2119	50/1000	2120	2121	2122
23-Jun	1247	58.978	20.358	eddy study	2130	50/1000	2131	50/1000	2132	50/1000	2133	2134	2135
24-Jun	1234	59.062	20.614	eddy study	2143	50/1000	2144	50/1000	2145	50/1000	2140	2141	2142
25-Jun	0030	59.0798	20.436	eddy study	2153	50/1000	2154	50/1000	2155	50/1000	2150	2151	2152
25-Jun	1211	59.194	20.632	eddy study	2165	50/1000	2166	50/1000	2167	50/1000	2165	2166	2167
26-Jun	0043	59.18	20.48	eddy study	2175	50/1000	2176	50/1000	2177	50/1000	2172	2173	2174
27-Jun	0018	58.998	20.64	eddy study	2192	50/1000	2193	50/1000	2194	50/1000	2189	2190	2191
27-Jun	1214	59.048	20.972	eddy study	2207	50/1000	2208	50/1000	2209	50/1000	2204	2205	2206
28-Jun	0052	59.099	19.44	Stn.1 Transect	2215	50/1000	2216	50/1000	2217	50/1000	2212	2213	2214
28-Jun	1251	59.095	20.505	Stn.4 Transect	2229	50/1000	2230	50/1000	2231	50/1000	2226	2227	2228
29-Jun	0253	59.1	21.711	Stn.7 Transect	2240	50/1000	2241	50/1000	2242	50/1000	2237	2238	2239

3.12 Microzooplankton Herbivory and Community Structure (Elaine Edwards)

The specific aims on this cruise were to a) quantify herbivorous interactions between microzooplankton and phytoplankton in the surface waters during the SF_6 Lagrangian experiment b) collect and fix water samples in order to generate a time series of microzooplankton (20-200 mm) and heterotrophic nanoplankton (2-20 mm) community structure within the surface waters and c) collect phytoplankton and bacteria samples for other PRIME colleagues during the same time-series experiment.

Grazing experiments

Microzooplankton grazing experiments were carried out using the dilution technique described by Landry & Hassett in 1982 (*Mar Biol* 67: 283-288). This method has been developed and used successfully during previous projects (eg. BOFS, ARABESQUE, OMEX).

Experimental water was collected pre-dawn from the surface mixed layer using 30 litre Go-Flo bottles. Half of this water was filtered through a 0.2 µm Gelman Supor-capsule filter which had been pre-rinsed in deionised water. The remaining water was pre-screened using a 200 µm mesh bag. A series of dilutions were made up by gently combining the screened water with the filtered water in 2 l polycarbonate bottles. Sub-samples were taken at T0 from each dilution bottle for the measurement of chlorophyll, flow cytometric analysis by Glen Tarran and for the determination of community structure. Each bottle was then gently topped up to remove any air and placed into the deck incubator. All incubations lasted for 24 h (with the exception of one on 23 Junewhich due to weather conditions lasted 28h) and were incubated on deck using a 33% or 55% light screen. At the end of the incubation period, further sub-samples were taken for chlorophyll and flow cytometric analysis and fixed in Lugols for community structure determination. All chlorophyll samples were extracted with 90% acetone and analysed on board by fluorometry. All community structure samples will be analysed on return to the laboratory.

Details of each grazing experiments carried out are shown in Table7. The grazing work went very well and preliminary results suggest that microzooplankton grazing increased throughout the time-series to a maximum daily turnover rate of 73% of the chlorophyll stocks per day.

Table7. Microzooplankton grazing experiments

Date	Station	Depth
18/06/96	1	10m
19/06/96	2	10m
20/06/96	4	10m
22/06/96	8	15m
23/06/96	10	15m
25/06/96	14	15m
27/06/96	16	5m
28/06/96	CS1	15m

Water Sample Collection

Water samples were collected at 8-10 depths from 10 l water bottles on the CTD Rosette and were fixed as follows:

Microzooplankton

500ml in 1% acid Lugols for the subsequent determination of total microzooplankton biomass and species composition.

500ml in 2% hexamine buffered formaldehyde, for the enumeration and identification of autotrophic components of the community.

The above samples will be analysed at PML using inverted microscopy and image analysis.

Heterotrophic Nanoplankton

25-50ml in 0.3% glutaraldehyde, dual-stained with DAPI and proflavin (final concentration 5 mg ml^{-1}) and filtered onto 0.8mm black polycarbonate filters. The filters were mounted onto slides and frozen until subsequent analysis at PML by inverted fluorescence microscopy.

Bacteria

Triplicate 1.8 ml and duplicate 0.5ml samples were fixed in glutaraldehyde and stored frozen until required for bacterial analysis by Mike Zubkov at the University of Southampton.

Phytoplankton

150ml of water sample was fixed in (i) Lugol's and (ii) formalin. These samples will be analysed by Marion Yallop at the University of Bristol for information on phytoplankton species composition and biomass.

Pigments

In addition to all the above samples , 2.1 l of water were collected from 8 depths and filtered onto 25mm GF/F glass fibre filters . The filters were frozen in liquid nitrogen until further analysis of pigment content using HPLC. Sample details are shown below.This work will be carried out by Stuart Gibb at PML. Details of all samples collected are given in the following Table 8.

Table 8.

Date	Station	CTD	Samples collected	Depths
18/06/96	1	#3	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
19/06/96	2	#4	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
19/06/96	3	#6	Phytoplankton	2-150m
			Microzooplankton (formalin)	10-50m
20/06/96	4	#7	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
20/06/96	5	#9	Phytoplankton	2-150m
			Microzooplankton (formalin)	10-50m
21/06/96	6	#10	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
21/06/96	7	#12	Phytoplankton	2-150m
22/06/96	8	#13	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
22/06/96	9	#15	Phytoplankton	2-150m
			Microzooplankton (formalin)	10-30m
23/06/96	10	#16	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
23/06/96	11	#18	Phytoplankton	2-150m
24/06/96	12	#19	Phytoplankton	2-150m
25/06/96	13	#20	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
25/06/96	14	#23	Phytoplankton	2-150m
26/06/96	15	#24	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
27/06/96	16	#26	Phytoplankton; bacteria; HPLC	2-150m

			Microzooplankton; Nanoflagellates	2-100m
27/06/96	17	#28	Phytoplankton	2-150m
28/06/96	CS1	#31	Phytoplankton; bacteria; HPLC	2-150m
			Microzooplankton; Nanoflagellates	2-100m
28/06/96	CS4	#33	Phytoplankton	2-150m
29/06/96	CS7	#37	Phytoplankton; Microzooplankton	2-150m

Apstein Net Sampling

A series of Apstein net hauls from 50m to the surface were carried out between 19 June and 22 July. The Apstein net was fitted with a 20 µm mesh net and allows the qualitative assessment of the larger rarer and less delicate of the microzooplankton such as the tintinnids, large heterotrophic dinoflagellates, sarcodines and metazoa, together with the larger phytoplankton cells. Samples were observed using an inverted microscope fitted with fluorescence. This system was linked via a colour camera to an SVHS video system and was used to capture live plankton images. The phytoplankton community composition remained similar throughout the duration of the cruise. The dominant genera was *Ceratium* with *C.fusus*, *C.furca*, *C.minutum* being the most common species, but with other species also being represented. Of the diatoms, species such as *Rhizosolenia* spp., *Chaetoceros* spp., *Coscinidiscus* sp. and *Nitzschia spp.* were the most common, while *Dactyliosolen* was abundant in all net hauls. Of the microzooplankton, heterotrophic dinoflagellates seemed to be very abundant in the net samples including *Protoperidinium* spp, *Pronoctiluca*, *Cochlodinium* and other members of the Gymnodiniales, particularly *Gyrodinium* spp. Of the tintinnids found, the most common was *Favella sp.*; also present were *Dictyocysta* sp., *Acanthostomella*, *Codonellopsis* spp., *Salpingella* spp and *Ptychocylis* sp.. Ciliates were generally not common in net samples; however, some taxa such as *Tiarina fusus*, *Leegardiella* and some Oligotrichs were observed. Radiolarians, acantharians, foraminiferans and metazoan nauplii were also present.

3.13 Aggregate Formation and Bacterial Activity (Richard Kirby, Katherine Davey)

The aim of the project was to compare community diversity and metabolic activity of bacteria associated with marine aggregates with that of free living bacteria in the water column. Samples were collected using two marine snow catchers (80l and 90l water bottles) deployed at midday and midnight at varying depths in the water column (Table 9). Sample depths were chosen to provide a composite profile of aggregates in the surface layers of the eddy as it was tracked during the Lagrangian experiment, while samples from 5m were taken routinely to monitor the diversity of free living bacteria within the surface layer. For the analysis of bacterial diversity, seawater was filtered to 0.22um and the filters frozen at -70C for subsequent analysis of 16SrRNA sequence diversity. Bacterial associated proteolytic activity within both free living and aggregate associated communities was determined during the cruise by fluorometric enzymatic assay.

Table 9 details the sampling times, locations and depths and the analyses performed. Throughout the Lagrangian experiment free living bacteria were sampled at midday at a depth of 5m. At midnight, free living and aggregate associated bacteria were sampled for diversity and metabolic activity at depths above the thermocline Unfortunately, despite careful monitoring of CTD profiles and choice of depths, aggregate material was only obtained on two occasions during the cruise perhaps reflecting tight coupling between autotrophs and heterotrophs with little production of detrital material. Despite the lack of aggregate material, informative depth profiles of free living bacteria together with estimates of metabolic activity were obtained. Bacterial counts were taken for later analysis.

Although the lack of aggregate material was disappointing, this did not prevent useful samples of the free living bacterial community being collected. As discussed above, tight coupling between autotrophs and heterotrophs may explain the absence of marine snow with the presence of a coccolithophore bloom and the relative absence of diatoms also being associated factors. Diatoms are considered among the most significant contributors of TEPs (Transparent Exopolymeric Particles) which are important in the formation of marine snow.

TABLE 9.

Date	Time	Position (Lat, Lon)	Depth (m)	Volume Filtered for Bacterial diversity(l)	Proteolytic Activity in Filtered Seawater Vmax(uM/min), Km(uM)	Proteolytic Activity in Seawater Vmax(uM/min), Km(uM)	Proteolytic Activity on Aggregates Vmax(uM/min, Km(uM)
18/6/96	00.00	59.33, 20.16	1000	40			
18/6/96	00.00	59.33, 20.16	35	40	0.0015,104	0.0014, 104	
19/6/96	00.00	59.26, 20.01	25	60			
19/6/96	12.00	59.14, 21.10	5	40			
20/6/96	00.00	59.08, 20.33	25	40	0.0015, 105	0.0009, 416	
20/6/96	12.00	59.10, 20.52	5	40			
21/6/96	00.00	59.25, 20.51	15	40			
21/6/96	00.00	59.25, 20.51	100		0.0005, 217	0.0003, 220	
21/6/96	00.00	59.25, 20.51	200		0.0002, 145	0.0006,221	
21/6/96	12.00	59.23, 20.33	5	40			
22/6/96	00.00	59.18, 20.10	50	40	0.0003, 447	0.0009, 226	0.0005, 273
22/6/96	12.00	59.08, 20.02	5	40	0.0004, 227	0.0013, 106	
23/6/96	00.00	59.96, 20.03	30	40			
23/6/96	12.00	58.98, 20.36	5	40			
24/6/96	00.00	-	-	-			
24/6/96	12.00	59.06, 20.62	5	40			
25/6/96	12.00	59.19, 20.60	5	40			
26/6/96	00.00	58.59, 20.50	100	40			
27/6/96	00.00	59.00, 20.64	5	40			
27/6/96	12.00	59.05, 20.98	5	40			
28/6/96	00.00	59.09, 19.45	5	40	0.0006, 750	0.0015, 189	
28/6/96	00.00	59.09, 19.45	25	40	0.0005, 413	0.0016,169	
29/6/96	00.00	59.01, 21.20	1000	40			

3.14 Size-Fractionated Respiration (Tracey Bentley)

The core objectives of the project are listed as follows: (i) the collection from the mixed layer of size fractionated samples for POC/PON and chlorophyll *a* analysis for incorporation into a size generic model of the plankton system, (ii) to collect information on size fractionated respiration at the two time series stations, (iii) to establish changes in whole community and <0.8µm size fraction respiration rates along the N-S transect between 60°N - 37°N and (iv) to process discrete oxygen samples for the calibration of both the CTD and on line dissolved oxygen sensors.

Samples were taken for the estimation of respiration rates and other parameters from within the ambit of the eddy on 18 June (Day 1), 19 June (Day 2), 20 June (Day 3), 21 June (Day 4), 22 June (Day 5), 23 June (Day 6), 24 June (Day 7), 25 June (Day 8) and 26 June (Day 10). On all occasions water was sampled from the mixed layer (around 10m), size fractionated as required and sub-samples used for the estimation of POC/PON and chlorophyll concentrations and for the determination of size particle distribution using a Coulter Counter. The range of size fractions used included: whole community, <53um,<20um, <5um, <2um and <0.8um. Filters for POC/PON analysis were oven dried at 60°C and stored in a dessicator for later analysis back at the laboratory using a CHN Analyser.

Size fractionated respiration was measured using the automated "Winkler" oxygen titration technique with respiration rates being determined from the difference in oxygen concentration between the time

zero sample and the equivalent sample incubated for 24 h in the dark. the full suite of size-fractionated rates was determined on three occasions, Day 1, Day 6 and Day 10.

Size-fractionated Cholorophyll Data (mg m^{-3})

FRACTION	DAY							
	1	2	4	5	6	8	9	10
0.8um	0.04	0.01	0.03	0.02	0.07	0.01	0.02	0.02
2.0um	0.12	0.11	0.15	0.15	0.23	0.21	0.22	0.2
5.0um	0.23	0.3	0.25	0.27	0.4	0.33	0.33	0.07
20um	0.47	0.86	0.63	0.47	0.72	0.67	0.67	0.6
53um	0.51	0.77	0.52	0.49	0.8	0.67	0.61	0.61
WC	0.64	0.91	0.74	0.65	0.83	0.78	0.74	0.78

In general there was little change in the chlorophyll concentrations in the surface waters of the eddy associated with the various fractions over the period of the Lagrangian experiment. Highest concentrations were consistently found in the two largest fractions.

Preliminary data on size-fractionated respiration rates are presented in the following table:

Size-fractionated Respiration Data (μmol l^{-1})

	Day 1	sd	Day 6	sd	Day 10	sd
0.8um	4.48	1.1	0.3	1.2	2.01	0.11
2.0um	6.41	1.1	0.56	0.5	2.25	1.24
5.0um	6.98	1.6	1.85	0.3	2.34	0.2
20um	7.81	0.4	3.82	0.1	5.15	1.18
53um	6.04	0.8	3.54	0.4	4.25	0.62
WC	12.68	0.8	5.17	0.4	4.22	0.21

Calibrations for the on-line oxygen sensor were carried out at approximately eight hour intervals with the CTD sensor being calibrated from depth profiles on seven occasions. Although the absolute oxygen concentrations from depth profiles differed between casts, a similar pattern of distribution was recorded for each profile with minimal concentrations observed between 75 - 125m and maximal values generally found between 10-20m.The difference between the maximum and minimum values was usually of the order of 16μmol l^{-1}.

Coulter Counter data were used to confirm that the fractionating meshes and filters were working effectively. The data also showed that the size distribution did not change significantly during the period of observation with the chief feature being a bimodal population with size peaks at 5μm and 11μm. Larger organisms or fractions were not represented in the samples.

3.15. Isotopic Composition of Suspended Particulate Organic Matter and the Disssolved Inorganic Carbon System and Primary Productivity (Hilary Kennedy and Gideon Middleton)

Introduction

The ratio of $^{13}C/^{12}C$ in particulate organic carbon ($\delta^{13}C_{POC}$) within the marine environment negatively co-varied with the concentration of dissolved molecular CO_2 ($CO_{2(aq)}$). However, the physiological factors which ultimately gave rise to this change are still being investigated. The explanations which have been suggested to account for changes in the isotopic signal, can be broadly divided into three categories concerning the acquisition of inorganic carbon by photosynthetic cells:

i. That the phytoplankton are wholly dependent on the $CO_{2(aq)}$ pool for the supply of inorganic carbon and shifts in the $\delta^{13}C_{POC}$ simply reflect a kinetic signal which may possibly indicate the degree of carbon limitation.

ii. Phytoplankton, under conditions of low concentrations of $CO_{2(aq)}$, increase the supply of inorganic carbon by the active uptake of bicarbonate (HCO_3^-) and therefore the isotopic signal reflects the relative proportions of $CO_{2(aq)}$ and HCO_3^- transported into the cell.

iii. In order to overcome the effects of $CO_{2(aq)}$ limitation, phytoplankton produce or increase the production of internal and/or external carbonic anhydrase (CA) to catalyse the reaction between $CO_{2(aq)}$ and HCO_3^- in order to ensure that the rate supply of $CO_{2(aq)}$ via diffusion into the cell is maximal.

Objective

To investigate the mechanism(s) which contribute to the observed changes in $\delta^{13}C_{POC}$ in relation to $[CO_{2(aq)}]$ by modelling the chemical and isotope kinetics of the dissolved inorganic carbon system (ΣCO_2) in and around actively photosynthesising phytoplankton cells.

Methodology

Samples were collected during the cruise for estimation of the following parameters required to parameterise the model: $\delta^{13}C_{POC}$, $\delta^{13}C_{\Sigma CO2}$, $[\Sigma CO_2]$, pH and ^{14}C primary productivity. In addition, experiments were carried out on both Legs of the cruise to attempt to directly assess the roles of CA, active HCO_3^- transport and the possible degree of carbon limitation. These experiments involved the addition of an anion exchange inhibitor (4, 4-diisothiocyanostilbene-2, 2-disulphonic acid (DIDS)), CA and a CA inhibitor (acetazolamide (AZ)). Samples for the estimation of $\delta^{13}C_{POC}$, $\delta^{13}C_{\Sigma CO2}$, pH and $[\Sigma CO_2]$ were collected twice daily at 60°N at approximately 00.00h and 12.00h from a depth of 2m using Go-Flo bottles. Approximately~concurrent 24h ^{14}C primary productivity incubations were also carried out over the appropiate daily period.

Results

Preliminary results from the pH and $[\Sigma CO_2]$ measurements are shown in Fig. 14 The increase in pH tand decrease in $[\Sigma CO_2]$ that occurred during the first half of the experimental period indicated that $CO_{2(aq)}$ was being actively removed from the surface waters by phytoplankton through photosynthesis. By day 174 the rate of change of both these parameters had decreased and towards the end of the sampling period a concurrent increase $[\Sigma CO_2]$ and pH was observed.

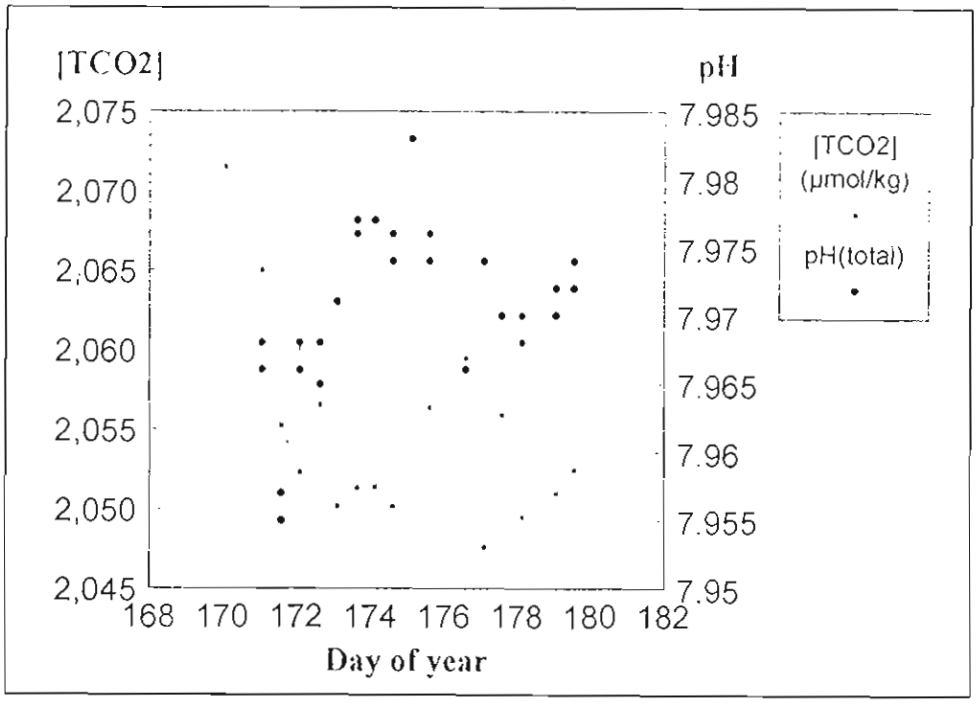


Figure 14. Changes in the $[\Sigma CO_2]$ and pH during Leg 1 The pH results are not adjusted to *in situ* temperatures and have all been measured at 20°C.

Initial results from the ^{14}C incubations conducted to assess the different methods by which the phytoplankton may be acquiring their inorganic carbon showed that the additions of CA and AZ did not significantly alter the rate of net primary productivity and thus it appeared that the catalytic effect of CA was not important in maintaining the daily rate of photosynthesis observed.

3.16 Dimethyl Sulphide (DMS), Dimethylsulphoniopropionate (DMSP) and Dimethyl sulphoxide (DMSO) (Sue Turner)

Two instruments were installed on board for the first cruise leg: a prototype continuous DMSP analyser designed to sample from the ship's pumped water supply and a discrete system for manual analyses. The DMSP analyser was used for a short period but demanded full time attention, since it had not been possible to complete one aspect of the electronic control in time for the cruise. Despite the brevity of the test period, a favourable comparison was made between the results obtained from the on-line instrument and a limited number of shipboard discrete DMSP analyses indicating that the instrument could be used satisfactorily at sea. The discrete system employed a new GC, which was an order of magnitude more sensitive than the instruments generally used. This, together with the relatively high concentrations found during the experiment, made it possible to double the normal rate of sample analysis.

DMS concentrations were measured in samples (n=480) from the ship's pumped water supply during the majority of the large-scale Seasoar surveys, most of the SF_6 patch surveys and in bottle samples on CTD casts 4, 6, 9, 12, 15, 18, 19, 23, and 28. Samples for DMSP particulate determination (n=300) were stored for analysis back in the laboratory. Seventy samples for DMSO analysis were also taken from the CTD casts and from the central part of the eddy as indicated by high SF_6 concentrations during the surveys. These samples will also be analysed later.

Preliminary Results:

1) The range of concentrations of DMS found (3.5 - 15nM) is consistent with data we have collected on previous cruises in the NE Atlantic in June and July, where the highest levels were associated with blooms of *E. huxleyi* and other coccolithophorids.

2) Data from the initial Seasoar survey of the study area showed that DMS was consistently lower within the eddy than in the surrounding water. Preliminary contour plots of surface DMS and temperature show similar patterns in the distribution of major features.

3) DMS concentrations generally increased in the SF_6 patch with time. There were also marked concentration gradients in DMS across the patch.

4) Results from the final Seasoar survey showed that DMS concentrations had increased over the entire eddy and for the most part were higher than those in the surrounding water.

Full interpretation of the data will require deconvolution of the coordinates of time and space by using positional data from the buoys and SF_6 measurements. Information from the SF_6 measurements will also enable description of lateral and vertical mixing which is vital if for the derivation of production rates for DMSP and DMS. Information from cell counts/speciation and accessory pigment distributions will also be valuable for interpretation.

In conclusion, this proved to be an extremely successful cruise and will, I believe, provide valuable information following full assessment of the data set. It is likely also that the strong winds associated with the tracking of tropical storm Arthur may have been a blessing in disguise since these would resulted in an increase in the the degassing rate of DMS from the mixed layer and hence provide a further aspect for the analysis of the data set.

Many thanks go to Graham (PSO), the crew, officers and RVS chaps who enabled the study.
Also to Cliff, Malcolm and Jane (the SF_6-ers) and Ian and Adrian (the "buoys"), without whom none of the DMS work would have been possible.

3.17 Biogeochemistry of Iron (Alex Baker)

The primary objectives of the programme were as follows: (i) the continuous measurement of total iron concentrations in surface water and (ii) the measurement of Fe II / III redox speciation in discrete surface and deep samples. In addition discrete samples were to be collected for the further study in the laboratory of iron biogeochemistry and for analysis for other metals (e.g. Co, Zn, Ni).

Measurement with the discrete, and particularly, the continuous analysers was severely hampered by the strong vibrations experienced in the clean chemistry container. The source of the vibrations was principally from the ship's engines and winches and occasionally from the container itself rocking on its mountings. A number of attempts were made to dampen the vibrations experienced by the continuous analyser which was also relocated to the Chemistry Lab and later to the Stable Laboratory which appeared to have lower levels of vibration. The assistance provided in this by Tony Poole and Chris Rymer of RVS Mechanical Engineering Group is greatly appreciated.

The instrument manufacturers in the Netherlands were also contacted during the cruise and the instrument's software was altered to provide an alternative measurement technique. Unfortunately none of these measures proved to be successful and the continuous analyser did not provide any useful data. Measurement with the discrete system also proved to be very difficult, but some data on total iron concentrations were obtained. Relocation of the discrete system to another laboratory was not viable, as none was equipped with facilities for clean trace metal work.

Problems were also experienced with the clean water supply connection to the PES fish. At high speeds the drag on the pipe caused it to buckle and break off the fish (as on 14 and 27 June). On the latter occasion, which occurred during the final transect of the eddy, there was not sufficient time to make a repair immediately and shallow (5m) Go-Flo samples were substituted at most of the transect stations. The fish was not reconnected before the final Seasoar survey of the study area and thus it was not possible to take samples for a more detailed spatial study at this time.

4. SCIENTIFIC ACTIVITIES: LEG 2

4.1 Physics and Chlorophyll *a* Fluorescence (Graham Savidge)

The more restricted physical and chlorophyll *a* fluorescence observations that were made during Leg 2 of the cruise compared to Leg 1, and in particular the absence of Seasoar data, meant that although a satisfactory background for the biological and chemical data was able to be described, a full three-dimensional physical interpretation of the hydrographic background was not possible.

On the N-S transect made during the first part of Leg 2, surface temperature as recorded from the TSG increased relatively steadily southwards from approximately 10.7°C to 13.2°C between 59°N and the vicinity of 51.5°N. At this location, a marked front was evident characterised by temperature and salinity increases of the order of 1.1°C and 0.18 respectively (Fig. 15). The front was assumed to mark the boundary of the main body of the North Atlantic Current and may likewise have delimited the boundary between the temperate Eastern North Atlantic Central Water (ENACW) and the sub-tropical ENACW. Considerable mesoscale activity was suggested in the region immediately to the south of the front by the presence of marked local variations in the surface temperature and slainity distributions, these being reflected also in the corresponding chlorophyll distributions. The presence of the front is shown clearly in the temperature, salinity and density sections along the transect as derived from the daily CTD casts (Figs. 16-18). To the south of the frontal region, surface temperatures again increased steadily southwards.

At the time series station at 37°N 20°W, the gross characteristics of the water column varied little over the eight days of observation. However, considerable changes were recorded in the fine scale structure of both the water column and the deep chlorophyll maximum (DCM) as may be noted from Figs. 19-21. Over the first four days a complex water mass structure was evident in the surface 150m. Beneath the main thermocline at 30m, a shallow water body with vertical extent ranging between 30 and 90m and characterised by a pronounced salinity minimum with values generally between 35.9 -36.0 (uncalibrated) was apparent. Beneath this low salinity water was a band of higher salinity water (uncalibrated values 36.0-36.3) extending at times down to 250m. The presence of a rich microstructure in the boundary region between the two water bodies indicated active mixing. The expression of the band of higher salinity water was rather variable and there appeared to be a relationship between the distribution of chlorophyll in the DCM and the definition of the two water bodies. A sharper definition of the deeper higher salinity water was associated with a more sharply constrained DCM with maximum chlorophyll *a* concentrations of the order of 0.3-0.4 mg m^{-3}, whereas when the salinity gradient of the deeper water was less well defined the DCM was observed to occur over a vertical extent of approximately 80m but with a maximum chlorophyll concentration of <0.1 mg m^{-3}.

By 15 July a change in the basic distribution of surface water bodies was apparent consistent with the southwards drift of the ship while on station. The low salinity water immediately below the surface mixed layer disappeared and relatively high salinity water (36.2 -36.3), presumably of similar origin to that observed in the previous four days at the station, was present from the base of the surface mixed layer down to ~250m. The salinity of the surface mixed layer remained fairly constant at approximately 36.18 over the entire period on station. This structure prevailed through to 17 July and was characterised by a well-defined DCM of limited vertical extent and low maximum chlorophyll concentrations, typically of the order of <0.1 mg m^{-3}. Over the last two days, despite the continued southward drift of the ship at the station, there was evidence of a return of the lower salinity water in the layer immediately below the surface mixed layer accompanied by an enhancement in the maximum chlorophyll concentrations associated with the DCM. An overall pattern was thus established in which a DCM was present over the entire observational period at the southernmost time series station, but which showed maximal development of chlorophyll biomass when a marked interface was present between the contrasting lower and higher salinity water masses.

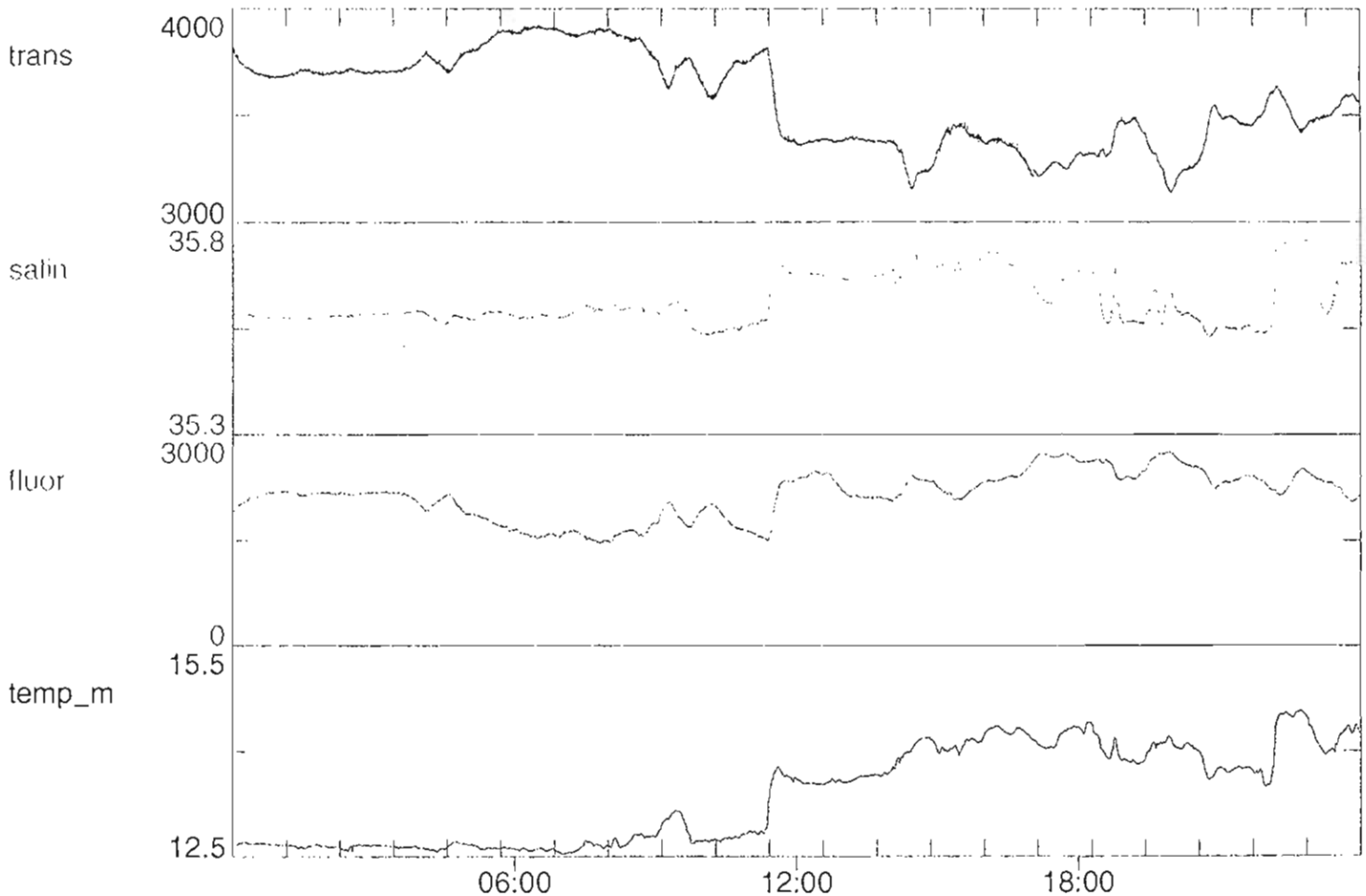


Fig. 15. Surface temperature (^{o}C), salinity, chlorophyll a fluorescence and transmittance 00.00h 6 July-00.00h 7 July. Time scale corresponds approximately to 54.07^{o}N 20.71^{o}W at 00.00h on 6 July to 5o.34^{o}N 20.33^{o}W at 00.00h ib 7 July 1996. Position of front located at approximately 51.5^{o}N shown by sharp temperature increase just before 12.00h.

4.2 Optics (Guy Westbrook)

The objective of the programme was to supply, configure, and operate an undulating oceanographic recorder (UOR) and a light metering system for use as required during Leg 2 of the PRIME cruise. It was decided this could best be achieved by using separate systems, taking advantage for the light measurements of the availability of the University of Plymouth high specification SeaWiFS irradiance meter mounted on a platform suitable for vertical profiling. It became apparent during the N-S transect that the irradiance data was likely to be of greater overall value than the physical structure data derived from the UOR, and thus greater effort was put into obtaining irradiance profiles.

The files listed in the following table were successfully downloaded and processed; in the case of the UOR the data were presented as time plots (for CTD-F) while for the irradiance (PRR-600) data values for Lw/Ed/R were recorded for wavelengths of 412,443,488,510,560 and 665 nm over the approximate depth range Z=0-90m. Values for the water leaving radiance (lw), temperature (^{0}C), chlorophyll concentration (mg m^{-3}) and the 1%, 3%, 7%, 14%, 20%, 33% and 55% PAR depths were also determined.

UOR data files:

Tow 1 - 03/07/96	p96071.dat	from	09:35 (62.159435N/22.800403W)
		to	17:00 (60.845225N/21.952523W)
Tow 2 - 3-4/07/96	p96072.dat	from	19:15 (60.452832N/21.683615W)
		to	01:00 (59.622455N/21.00634W)
Tow 3 - 4/07/96	p96073.dat	from	13:45 (59.444855N/21.31958W)
		to	23:20 (57.545688N/21.114312W)
Tow 4 - 5/07/96	p96074.dat	from	03:15 (57.510223N/21.107687W)
		to	12:30 (Location from BODC)
Tow 5 - 5-6/07/96	p96075.dat	from	16:15 (55.54715N/20.847562W)
		to	00:15 (54.008578N/20.704647W)

PRR data files:

Profile 1 - 5/07/96	p960707a.bin/crd	start 12:39:42 end 13:00:16 location - noon transect station
Profile 2 - 6/07/96	p960706a.bin/crd	start 12:16:44 end 12:28:32 location - noon transect station
Profile 3 - 7/07/96	p960707a.bin/crd	start 12:13:30 end 12:38:20 location - noon transect station
Profile 4 - 8/07/96	p960708a.bin/crd	start 11:55:53 end 12:20:55 location - noon transect station
Profile 5 - 9/07/96	p960709a.bin/crd	start 12:10:19 end 12:32:27 location - noon transect station
Profile 6 - 10/07/96	p960710a.bin/crd	start 12:14:34 end 12:37:32 location - noon transect station
Profile 7 - 11/07/96	p960711a.bin/crd	start 10:52:04 end 11:17:37 location - ARGOS buoy site
Profile 8 - 11/07/96	p960711b.bin/crd	start 13:40:06 end 14:11:17 location - ARGOS buoy site
Profile 9 - 12/07/96	p960712a.bin/crd	start 12:36:27 end 12:55:41 location - ARGOS buoy site
Profile 10-13/07/96	p960713a.bin/crd	start 12:18:31 end 12:31:04 location - ARGOS buoy site
Profile 11-14/07/96	p960714a.bin/crd	start 15:03:53 end 15:20:46 location - ARGOS buoy site
Profile 12-15/07/96	p960715a.bin/crd	start 12:42:35 end 12:58:20 location - ARGOS buoy site
Profile 13-16/07/96	p960716a.bin/crd	start 13:03:53 end 13:17:01 location - ARGOS buoy site
Profile 14-17/07/96	p960717a.bin/crd	start 12:47:52 end 13:00:23 location - ARGOS buoy site

PRR Data Files Listing Continued

Profile 15-17/07/96	p960717b.bin/crd	start 13:00:42 end 13:08:46 location - ARGOS buoy site
Profile 16-17/07/96	p960717c.bin/crd	start 15:11:14 end 15:28:43 location - ARGOS buoy site
Profile 17-18/07/96	p960718a.bin/crd	start 12:53:14 end 13:23:20 location - ARGOS buoy site
Profile 18-18/07/96	p960718b.bin/crd	start 13:23:36 end 13:33:18 location - ARGOS buoy site

Preliminary Results:

The attached table of values (Table 10) presents the Ed(488nm) and Ed(PAR) attenuation coefficients calculated for the profile sites, as well as the 1% PAR depths. The profiles were quality controlled during processing by comparison with the chl-*a* filtrations and CTD casts. The close relationship between the in-water biology and the light field in Case 1 waters will enable relationships between the two controlling variables to be established.

4.3 Micro and Nano Nutrient Analyses (Malcolm Woodward, Andy Rees)

The overall objectives for Leg 2 were similar to those outlined for Leg 1 with the methodology described previously for Leg 1 being applied to the southwards transect from approximately 59°N to 37°N and also at the southern time series station. Surface concentrations were monitored continuously during the transect and were supplemented by samples from daily CTD casts. Discrete samples taken from CTD casts as required were assayed at the time series station. Equipment performance during this Leg is also covered by the comments appended to the Leg 1 report above. A listing of the CTD and Go-Flo casts sampled in Leg 2 is given in Table 11, while the corresponding data for the on-line samplingruns appears in Table 12.

Table 11. CTD samples analysed during Leg 2

CTD	DATE/JD	DEPTHS	CTD	DATE/JD	DEPTHS
CTD 39	4.7/186	12 depths	CTD 67 P	13.7/195	6 depths
CTD 40 P	4.7/186	7 depths	CTD 69	13.7/195	12 depths
CTD 42	5.7/187	12 depths	CTD 71	14.7/196	12 depths
CTD 43. P	5.7/187	7 depths	CTD 72	14.7/196	9 depths
CTD 44	6.7/188	12 depths	CTD 74	14.7/196	12 depths
CTD 45 P	6.7/188	7 depths	CTD 76	15.7/197	12 depths
CTD 46	7.7/189	12 depths	CTD 77 P	15.7/197	8 depths
CTD 47 P	7.7/189	7 depths	CTD 80	15.7/197	12 depths
CTD 48	8.7/190	12 depths	CTD 82	16.7/198	12 depths
CTD 49 P	8.7/190	7 depths	CTD 83 P	16.7/198	8 depths
CTD 51	9.7/191	12 depths	CTD 85	16.7/198	12 depths
Go Flos P	9.7/191	4 depths	CTD 87	16.7/198	12 depths
CTD 52	10.7/192	12 depths	CTD 88	16.7/198	12 depths
CTD 53 P	10.7/192	7 depths	CTD 89	17.7/199	12 depths
CTD 54	11.7/193	12 depths	CTD 90 P	17.7/199	8 depths
CTD 55 P	11.7/193	8 depths	CTD 94	17.7/199	12 depths
CTD 59	11.7/193	12 depths	CTD 96	18.7/200	12 depths
CTD 60	12.7/194	12 depths	CTD 97 P	18.7/200	8 depths
CTD 61 P	12.7/194	7 depths	CTD 100	18.7/200	12 depths
CTD 62	12.7/194	12 depths			
CTD 64	12.7/194	12 depths			
CTD 65	12.7/194	12 depths			
CTD 66	13.7/195	12 depths			

Table 12. On-line sampling schedule: Leg 2

4.7.96 1300 - 4.7.96 2359
5.7.96 0400 - 6.7.96 0052
6.7.96 0450 - 7.7.96 0030
7.7.96 0427 - 8.7.96 0025

Preliminary Results

The data on nitrate, phosphate and nitrite distributions obtained from the CTD rosette samples collected during the north-south transect are presented in Figs. 22-24 as a series of sections over the upper 300m. The distributions of nitrate and phosphate showed similar features with relatively nutrient rich conditions in the surface waters at 59°N with values decreasing gradually southwards to 44°N where a sharp frontal feature was identified, to the south of which the surface waters were depleted in nitrate and phosphate. Depletion of new nutrients was consistently observed in the surface layer down to the thermocline (50-60 m) during the time series station at 37°N. The distribution of nitrite concentrations generally demonstrated the presence of a primary maximum centred around the region of the thermocline and deep chlorophyll maximum. The depth of the nitrite maximum was observed to increase markedly from 50 to 65 m following the crossing of the front at 44°N.

Ammonia concentrations obtained from the new nanomolar analyser system showed surface ammonia concentrations at 59°N in the range 100 - 150 nanomoles l^{-1}. A very marked ammonia maximum was normally located at a slightly shallower depth than the nitrite maximum and exhibited concentrations on average between 0.8 - 1.0 µmoles l^{-1} of ammonia, but with a maximum observed value around 2.0 µmoles l^{-1}. The surface ammonia concentrations similarly decreased in the southerly transect and south of the front at 44°N were generally between 50 - 80 nanomoles l^{-1}. With very few exceptions, the maxima in ammonia concentrations observed in the more northerly latitudes were absent from most of the CTD samples taken at 37°N.

Acknowledgements

Our thanks to the officers, crew and fellow scientists for making this marathon cruise somewhat more bearable. Special thanks to Polly Machin on this Leg for invaluable help in the data work up of the CTD nutrient samples enabling the raw processing of the complete data set to be finished before the end of the cruise with the exception of that obtained from the surface transects which will be worked up at BODC.

4.4 Underway Oxygen Monitoring (Andrew Bedford)

The operation of the ENDECO oxygen meter connected in to the ship's on-line seawater supply was monitored. The equipment was reset and run following departure of the ship from Iceland, with the retrieved data being automatically recorded in both soft and hard formats. Initial inspection of the data appeared to indicate that both probes remained in good condition and that there was a general decline in the concentration of dissolved oxygen in the surface waters as the ship progressed south along the transect. However, confirmation of this conclusion depends on calibration of the data against discrete samples taken from the on-line supply analysed by Winkler titration as carried out by Tracey Bentley and Claudia Castellani. The full suite of calibrated data will not be available until after the return to the UK.

4.5 Flow Cytometry and Microbial Ecology (Glen Tarran)

Introduction and Objectives

During Leg 2 of the PRIME Cruise, flow cytometry was used to measure the abundance of nano and picophytoplankton and to carry out further grazing experiments as in Leg 1 in collaboration with

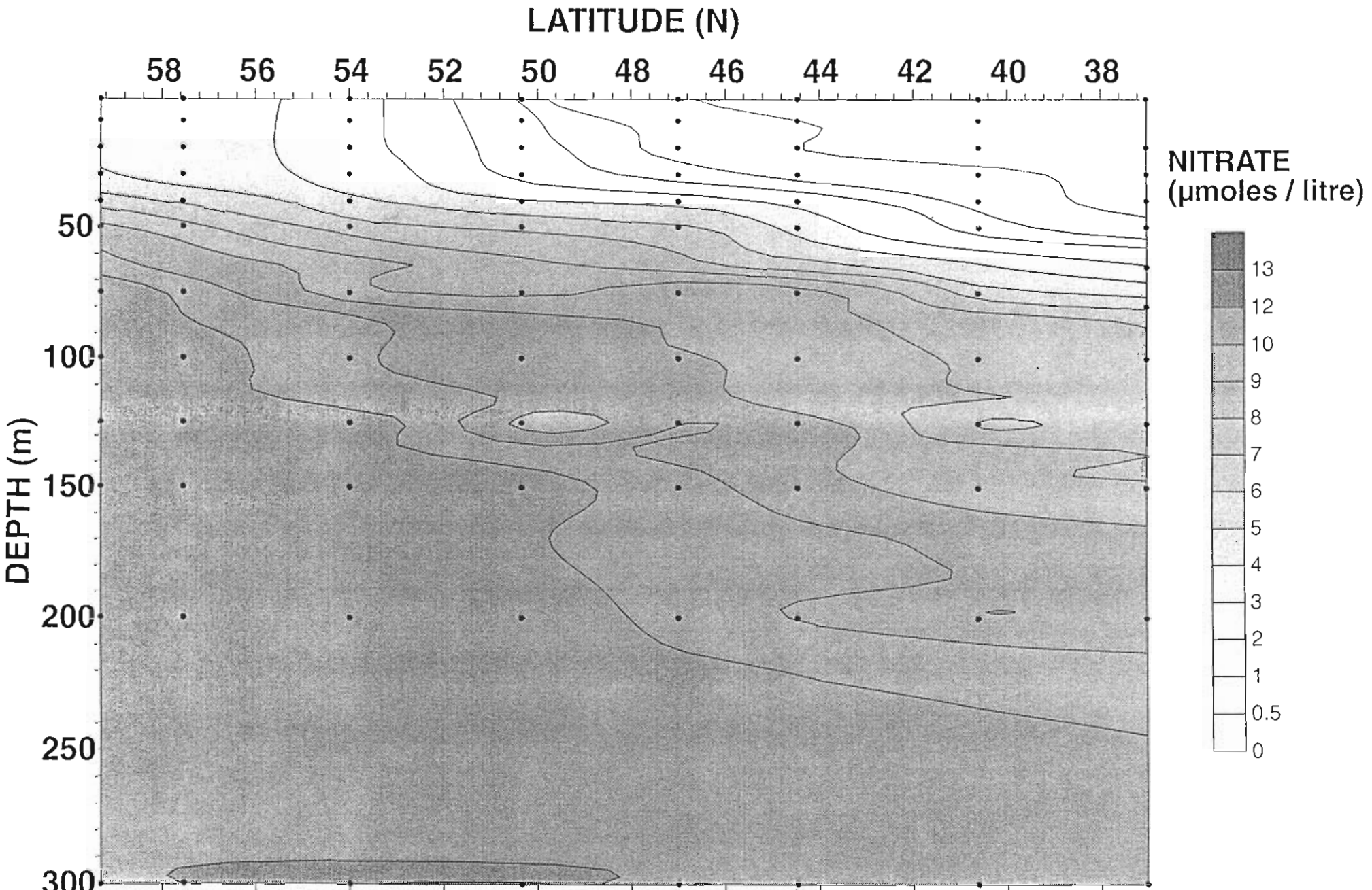


Fig. 22. Distribution of nitrate concentration (μmol l^{-1}) along N-S transect between approximately 59°N 21°W 37°N 20°W, July 1996.

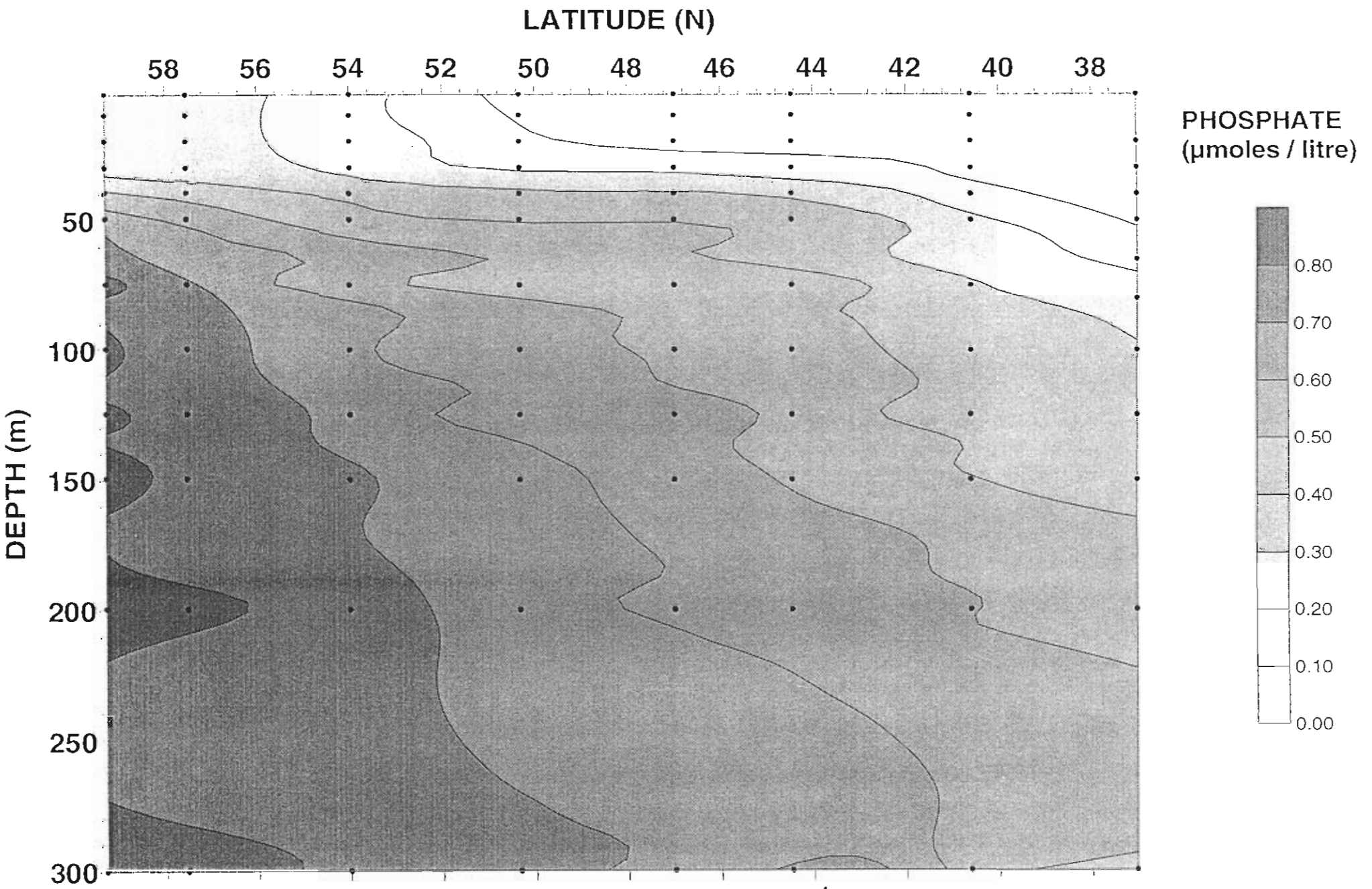


Fig. 23. Distribution phosphate concentration (μ mol l^{-1}) along N-S transect between approximately 59°N 21°W 37°N 20°W, July 1996.

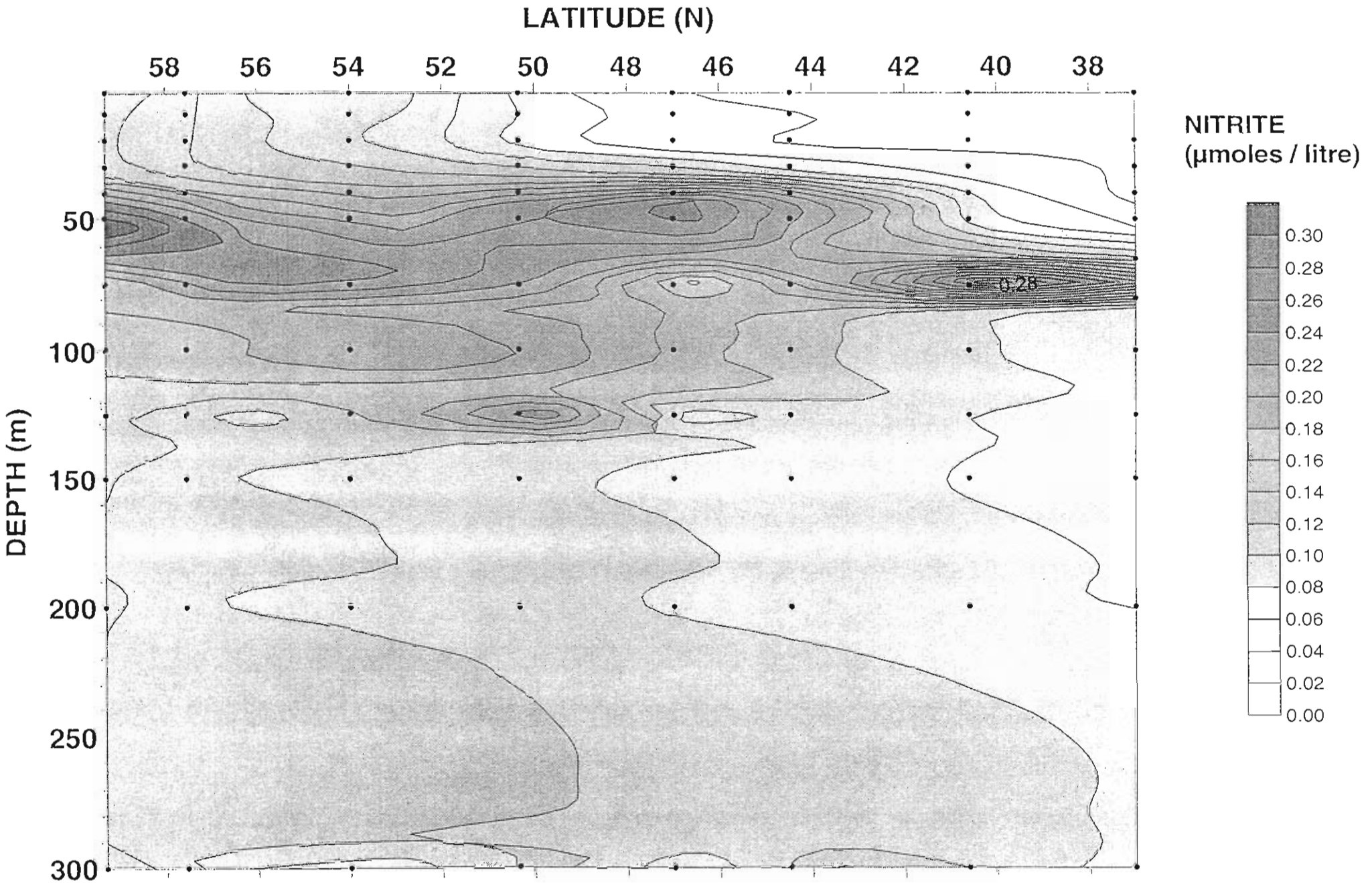


Fig. 24. Distribution of nitrite concentration (μ mol l^{-1}) along N-S transect between approximately 59°N 21°W 37°N 20°W, July 1996.

Claire Stelfox. In addition to these studies there was collaboration with Luan Al-Haddad from the University of Glamorgan who has been developing artificial neural networks for the identification of phytoplankton species from their flow cytometric signatures. Collaborative studies were also carried out to investigate bacterial grazing and growth with Mike Zubkov from University of Southampton and also with Willie Wilson and Dave Scanlan from the University of Warwick to characterise the abundance of *Prochlorococcus* spp. and *Synechococcus* spp. As a final component, a series of experiments was planned to study the primary productivity of specific phytoplankton groups using a combination of ^{14}C labelled populations and flow cytometric cell sorting.

Phytoplankton community structure and abundance

Both pico and nanophytoplankton abundances were initially measured at the northern end of the north-south transect; however, nanophytoplankton community diversity was observed to decrease over the first few days of the transect to the extent that only small flagellates remained and these were observed to be present at very low abundance ($<1x10^7$ l^{-1}). Thus after 9 July (Julian Day 191) measurements were made only of picophytoplankton abundance, some results for which appear in Table 13.

Table 13: Leg 2: CTD casts sampled for phytoplankton community structure. Table also shows peak abundances and associated depth.

				Peak cell numbers per litre					
Date	CTD cast	Time GMT	Position	Cyanobacteria	Depth	Prochloro-phytes	Depth	Pico-eucaryotes	Depth
July									
4	39	0427	59.310°N 21.125°W	$1.10x10^7$	2 & 20	0	-	$8.63x10^6$	2
5	42	0038	57.545°N 21.115°W	$5.30x10^7$	2-30	0	-	$1.70x10^7$	20
6	44	0120	53.993°N 20.700°W	$3.40x10^7$	2	0	-	$4.68x10^6$	3
7	46	0118	50.336°N 20.323°W	$1.80x10^8$	10-20	0	-	$3.34x10^6$	10
8	48	0140	46.998°N 20.001°W	$1.30x10^8$	30	$3.00x10^6$	10	$1.05x10^7$	20
9	51	0158	44.462°N 19.731°W	$1.33x10^8$	20	$1.90x10^7$	2-30	$1.47x10^7$	3-10
10	52	0205	40.606°N 19.341°W	$8.20x10^7$	30	$1.51x10^8$	30	$6.76x10^6$	40
11	54	0234	37.008°N 19.001°W	$2.80x10^7$	50	$1.39x10^8$	60	$4.35x10^6$	50
12	60	0207	36.969°N 19.146°W	$3.75x10^7$	40	$1.50x10^8$	30	$3.48x10^6$	40
12	62	0605	36.956°N 19.167°W	$2.10x10^7$	40-60	$1.20x10^8$	30-40	$3.00x10^6$	30
12	64	1309	36.947°N 19.202°W	$2.10x10^7$	50	$1.11x10^8$	40	$2.88x10^6$	40
12	65	1805	36.922°N 19.212°W	$1.65x10^7$	40	$1.20x10^8$	30	$2.93x10^6$	30
13	66	0208	36.918°N 19.219°W	$1.85x10^7$	40	$1.41x10^8$	30	$2.35x10^6$	20
13	69	1243	36.883°N 19.242°W	$1.45x10^7$	40	$1.40x10^8$	30	$2.1x10^6$	2
14	71	0207	36.824°N 19.237°W	$1.25x10^7$	40	$1.60x10^8$	30	$2.64x10^6$	30
14	74	1532	36.737°N 19.249°W	$7.00x10^6$	50-60	$1.52x10^8$	30	2.50x106	20
15	76	0204	36.691°N 19.225°W	$1.00x10^7$	50	$1.70x10^8$	30-40	$2.51x10^6$	40
15	78	1615	36.653°N 19.214°W	$1.20x10^7$	60	$1.80x10^8$	40	$2.70x10^6$	20
15	80	1309	36.633°N 19.235°W	$5.87x10^6$	60	$1.70x10^8$	40	$2.41x10^6$	20
15	81	1840	36.574°N 19.202°W	$3.46x10^6$	40	$1.50x10^8$	50	$2.51x10^6$	20
16	82	0207	36.918°N 19.219°W	$1.50x10^7$	60	$1.90x10^8$	50	$2.46x10^6$	2
16	84	0535	36.470°N 19.197°W	$8.57x10^6$	40	$2.20x10^8$	50	$1.43x10^6$	10
16	87	1333	36.420°N 19.183°W						
16	88	1807	36.384°N 19.157°W						
17	89	0210	36.319°N 19.150°W						
17	91	0536	36.319°N 19.150°W						
18	96	0202	36.124°N 19.156°W						
18	101	1731	36.019°N 19.208°W	$1.40x10^7$	60	$2.10x10^8$	60	$2.38x10^6$	3

Cyanobacteria abundance was greatest between 50 - 44° N, exceeding $1x10^8$ cells l^{-1} between 10 and 30m (Fig. 25). Numbers then dropped by almost an order of magnitude through to 37° N. During the

time series at 37° N numbers fell a further order of magnitude from $3x10^7$ cells l^{-1} to $3x10^6$ cells l^{-1} (Table 13). Picoeucaryote abundance also decreased at the study site by a factor of three. Prochlorophytes were absent at the north end of the transect but were detected at 47° N. From 40.6° N to 37°N numbers remained above $1x10^8$ cells l^{-1}. During the time series at 37° N, prochlorophyte numbers increased, in contrast to the decline in cyanobacterial abundance.

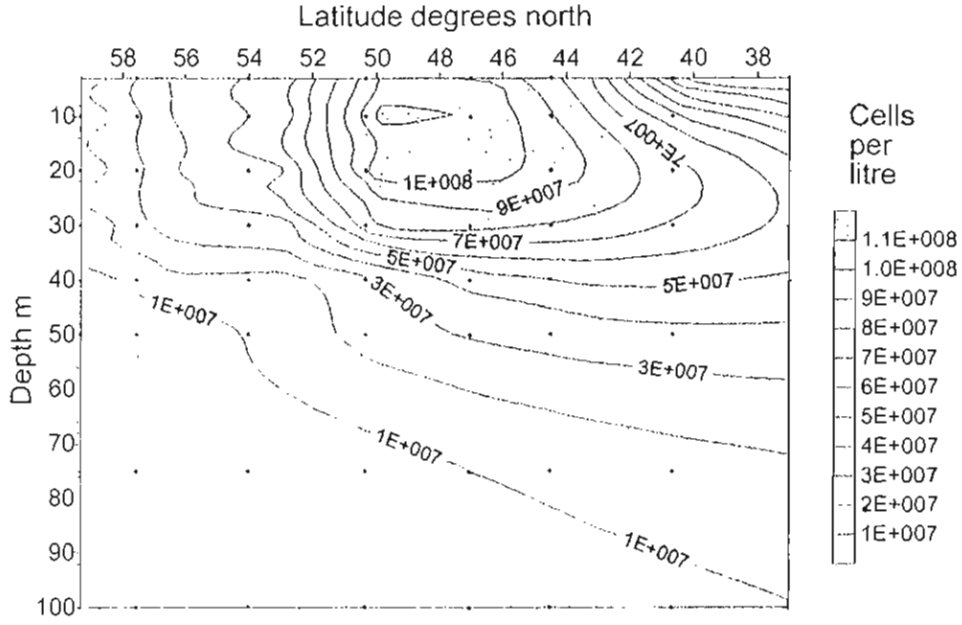


Figure 25: Abundance of Cyanobacteria along the transect from 59 to 37° N 20°W in cells l^{-1}

Grazing Experiments

Two types of dilution grazing experiment were carried out. In the first samples were analysed from Claire Stelfox's experiments to compare the effects of adding nutrients to dilution bottles (NUTRIENTS). The second set of experiments was carried out with Mike Zubkov to quantify microzooplankton grazing on both picophytoplankton and bacteria and to test the effect of using 0.22μm filtered seawater and unfiltered seawater from ≥300m on bacterial growth (BACTERIA). Analysis of these experiments will be carried out back in the laboratory.

Table 14: Summary of grazing experiments carried out during Leg 2.

Date	Experiment type	Sample depth m	Position	Bottles used
4 July	NUTRIENTS	10	59.313°N 21.175°W	2 l
5 July	NUTRIENTS	10	57.545°N 21.115°W	2 l
6 July	NUTRIENTS	10	53.993°N 20.700°W	2 l
7 July	NUTRIENTS	10	50.336°N 20.323°W	2 l
8 July	NUTRIENTS	10	46.998°N 20.001°W	2 l
10 July	NUTRIENTS	10	40.627°N 19.357°W	2 l
13 July	BACTERIA	30	36.918°N 19.219°W	0.25 l
15 July	NUTRIENTS	25	36.691°N 19.225°W	0.25 l
17 July	BACTERIA	25	36.312°N 19.158°W	0.25 l
17 July	NUTRIENTS	25	36.312°N 19.158°W	2 l
18 July	BACTERIA	25	36.124°N 19.156°W	0.25 l
18 July	NUTRIENTS	25	36.124°N 19.156°W	2 l

Other Experiments

A single ^{14}C incubation was carried to assess group specific primary production at 37° N 20°W. However, after the 8 h incubation period flow cytometric analysis of the samples revealed that the populations had changed dramatically, with both prochlorophytes and picoeucaryotes having disappeared, with only cyanobacteria remaining in the samples. It was therefore decided to discontinue these experiments. The work carried out with Dave Scanlan and Willie Wilson is ongoing and will be completed in the laboratory.

Acknowledgements

I would like to say a thank you to the RVS technicians and to the officers and crew of RRS *Discovery*, and particularly to the catering boys for providing such an endless supply of tempting goodies.

4.6 Phytoplankton Recognition by Artificial Neural Network Analysis (Luan Al-Haddad)

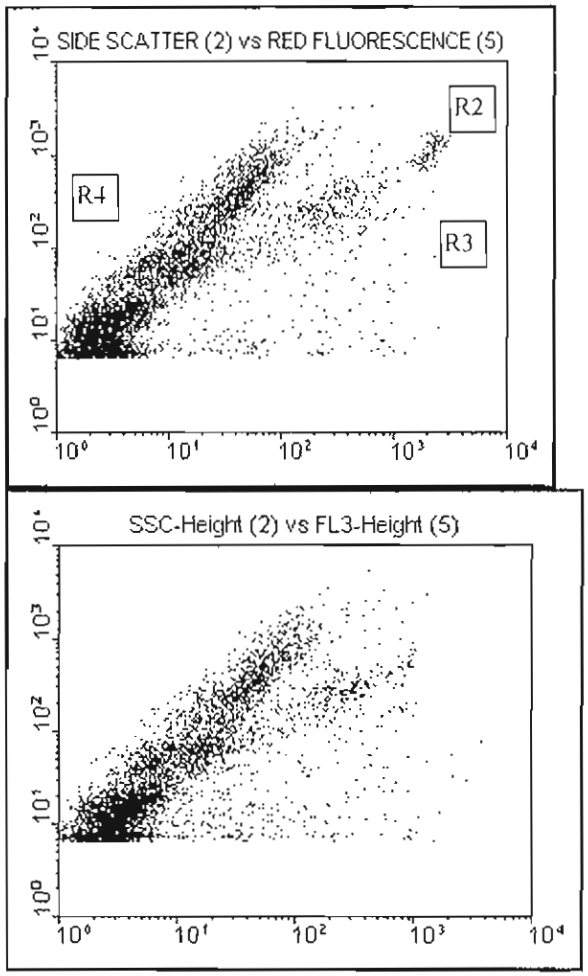
Prior to the PRIME cruise various neural networks, both supervised and unsupervised, were trained for recognition of a total of sixty-two species/strains from five taxonomic groups of marine phytoplankton, based on their flow cytometric signatures. The unsupervised networks have been trained for clustering taxonomic groups. The supervised neural networks were trained as five separate networks for each of the five groups to recognise individual species within their respective group.

Objectives

1. To test Artificial Neural Networks (ANN's) developed in the laboratory.
2. To judge the performance of the ANN's by sorting natural seawater samples and analysing the sorted material by microscopy to confirm community composition.
3. To characterise different phytoplankton communities along the transect.
4. To add any new species to the database of species.

Results

The development of the artificial neural networks concentrated on samples from the northern end of the transect since towards the southern end, samples did not contain sufficient material to allow sorting of the three main groups that were present to take place, i.e. *Synechococcus spp.*, *Prochlorococcus spp.* and picocucaryotes were not present in the 'lab grown' data, so were therefore not available for training the networks. The supervised networks performed exceptionally well. It was considered that at this stage of the project that it was premature to use the Cortex-Pro networks so previous models were adopted. However, these earlier models were based on no more than forty-two species. After selection of criteria with Glen Tarran, based on the microscopic analysis of gravity filtered seawater samples, it was decided to focus attention on forty-six of the sixty-two species. A number of networks were trained and optimised to a maximum, given the allowance for lack of memory within the program limiting the number of hidden nodes available. This lack of memory was due to the algorithm being originally designed for forty-two species only.



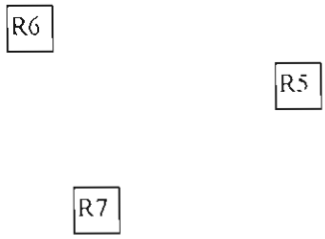


Fig. 26 Fig. 27

Figs. 26 and 27 show six clusters from a two dimensional plot of Side Scatter (SSC-Height) against red fluorescence (FL3-Height). The cluster R2 was identified as *Coccolithus pelagicus* a large (15-20 μ m) coccolithophore and was therefore gated out, added to the species database and used as a set of training data for a new forty-seven species network. When tested, *Coccolithus pelagicus* gave a 98% correct classification factor as expected, due to its distinctive SSC-H v FL3-H plot. The cluster R3 was suspected to be made up of small coccolithophores such as *Emiliania huxleyi* and this was proved by the supervised trained networks, which also classified some of the patterns as large coccolithophores and a very small percentage of other species, this latter owing to the gating process being a rectangle around a cluster rather than a free shape, and hence including other events. R7 was suspected to be flagellates in the size range 1- 4 μ m and this was confirmed by the Radial Basis Function networks identifying the cluster as *Micromonas pusilla*, a flagellate, 1-3 μ m in size with a 98% classification success. Classes R5 and R6 were suspected to be large flagellates and this was again validated by the networks classifying them as various larger flagellates.

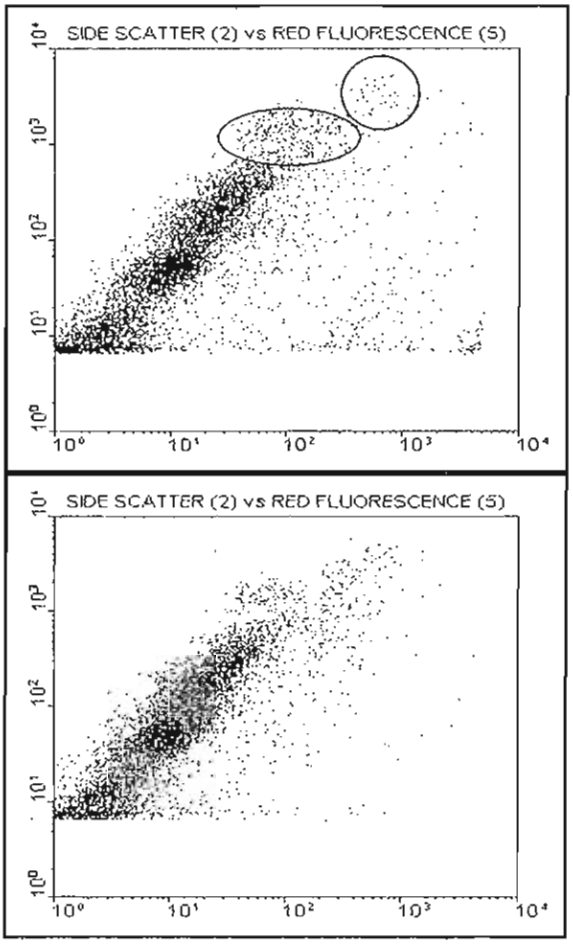


Fig. 28 Fig. 29

A second group of files (Figs. 28 and 29) shows two clusters in the upper regions of the plots suspected to be dinoflagellates. The RBFs gave confirmation of this, identifying mainly areas of larger dinoflagellates and some flagellates. Again the areas of discrepancies lie in the gating process and the memory problem of using a network for forty-seven species that was designed for forty-two. Using Cortex-Pro to display SSC-H v FL3-H for the individual taxa gave further confirmation of the species in Figs. 26 - 29 even though the Cortex-Pro plots were drawn from laboratory grown cultures.

It was considered that the cruise, if a little early in respect of some of the Artificial Neural Networks, was highly valuable. Opportunity was provided to analyse the neural networks performance in the actual environment that they are required for and also to ascertain what is needed of them with regards to their on board use in conjunction with the flow cytometer. It was of particular value being able to work directly with both Glen Tarran and Claire Stelfox and to appreciate from first-hand experience of observing other areas of biological oceanographic research, the importance of having a sound knowledge of the structure of phytoplankton populations which, in turn, is based on rapid and objective identification of the individual population components.

4.7 Phytoplankton Chemotaxonomy and Chemotaxonomic Primary Production (Stuart Gibb)

Introduction

In biological oceanography the photosynthetic pigments, in particular chlorophyll *a*, have long been recognised as unique and convenient markers of phytoplankton biomass. Although spectrophotometric and fluorimetric techniques have been widely used to determine biomass, the utilisation of high performance liquid chromatography (HPLC) not only permits a more accurate measurement of chlorophyll *a*, but also allows simultaneous separation and quantification of a range of other

chloropigments and carotenoids in marine phytoplankton. Many of these secondary pigments have strong chemotaxonomic associations through which is it is possible to obtain an understanding of the taxonomic composition of the overall phytoplankton biomass *e.g.* measurement of the carotenoid fucoxanthin is used to infer the presence of diatoms, whilst the presence of 19'-hexanoyloxyfucoxanthin is used as a biomarker of prymnesiophytes including coccolithophores. There is growing evidence that the various classes of phytoplankton exhibit a unique impact on ocean chemistry and this has important implications for biogeochemical cycling.

An important advance in the utilisation of pigments in oceanography has been the ability to determine specific growth rates and carbon biomass of growing phytoplankton using ^{14}C labelled pigments in extracts of ^{14}C primary production filters. This technique has been developed to derive taxon-specific growth rates for diatoms, cyanobacteria, and prymnesiophytes and used to map specific production rates of these algal groups in different water masses. Such techniques can thus be used in tandem with pigment chemotaxonomy to both map spatial bloom development and to monitor taxon-specific primary productivity.

Objectives

- To map the taxonomic composition of the overall phytoplankton biomass spatially along the transect 60°N to 37°N and temporally at 37°N using the distribution of chemotaxonomic marker chlorophyll and carotenoid pigments.
- To elucidate the spatial relationship between the respective concentrations of particulate silicate and calcite with the carotenoid biomarker pigments fucoxanthin (diatoms) and 19'-hexanoyloxyfucoxanthin (prymnesiophytes).
- To determine the specific growth rates of chemotaxonomic groups of phytoplankton using ^{14}C incubations and HPLC separation for the analysis of ^{14}C labelled pigments

Sample Collection

J. Day	Station (CTD)	CHEMOTAXONOMIC MARKERS			PRODUCTIVITY
		Pigments (no. samples)	*Calcite* (no. samples)	*Silicate* (no. samples)	*^{14}C labelling experiments*
185-193	Underway 201-208	every 4hrs (80% in triplicate)	every 4hrs	every 4hrs	
186	201 (39)	0-300m (12)	0-300m (12)	0-300m (10)	depth profile
187	202 (42)	0-300m (12)	0-300m (12)	0-300m (11)	24hr time series
188	203 (44)	0-300m (12)	0-300m (12)	0-300m (12)	
189	204 (46)	0-300m (12)	0-300m (12)	0-300m (12)	
190	205 (48)	0-300m (12)	0-300m (12)	0-300m (11)	depth profile
191	206 (51)	0-300m (12)	0-300m (12)	0-300m (12)	
192	207 (52)	0-300m (12)	0-300m (12)	0-300m (12)	24hr time series
193	208 (54)	0-300m (12)	0-300m (12)	0-300m (8)	depth profile
	208 (59)	0-300m (12)			
194	208 (62)	0-300m (12)	0-300m (12)	0-300m (12)	
	208 (64)	0-300m (12)			
195	208 (66)	0-300m (12)	0-300m (12)	0-300m (12)	
	208 (69)	0-300m (12)			

196	208 (71)	0-300m (12)			
	208 (74)	0-300m (12)	0-300m (12)	0-300m (12)	
197	208 (76,78,80, 81)	0-300m (12, 12, 11, 12)			depth profile
198	208 (82, 85, 87, 88)	0-300m (12, 12, 12, 11)			
199	208 (89, 92, 94)	0-300m (12, 12, 12)			
200	208 (96, 100)	0-300m (12, 12)			

Post-Cruise Objectives

- Analysis of chlorophyll and carotenoid pigments and their associated breakdown products in filter extracts by reverse phase HPLC with absorbance and fluorometric detection.
- Determination of particulate calcite and silicate concentrations in coincident filters and examination of relationship between their concentrations and those of the carotenoids fucoxanthin and 19'-hexanoyloxyfucoxanthin.
- Development and optimisation of extraction, preconcentration and clean-up procedures for the HPLC analysis of ^{14}C labelled pigments. Utilisation of this technique to determine taxon specific ^{14}C uptake in PRIME samples.
- Full data set compilation, interpretation and presentation.

4.8 *Prochlorococcus*: Community Structure and Nutrient Status (Dave Scanlan)

The free-living marine prochlorophyte *Prochlorococcus marinus* represents a major component of the picoplankton in several ocean provinces, particularly in oligotrophic regions, including the Atlantic and Pacific Oceans as well as the Mediterranean Sea. *Prochlorococcus* is the first prochlorophyte to be described that possesses three chlorophylls: it contains low amounts of a Chl *c*-like pigment besides unique divinyl derivatives of both Chl *a* and *b*. Sequence analysis of 16S rRNA, RNA polymerase and *psbA* genes indicates that *Prochlorococcus* are most closely related to the marine cyanobacteria, but that they diverge greatly from the other known prochlorophytes *Prochlorothrix hollandica* and *Prochloron didemni*. This projects specifically aims to use molecular techniques to identify the factors responsible for the ability of these organisms to grown in high-light nutrient-deplete surface waters as well as at depths less than 100m (low-light nutrient-replete conditions).

Specific Objectives

i. Collection of a depth series of DNA, RNA and protein samples at 37°N 20°W for subsequent examination of the genetic diversity and phosphorus status of *Prochlorococcus* within the water column.

ii To make opportunistic use of a spatial series of samples along the 20°W transect to examine the phosphorus status of marine *Synechococcus* using a specific molecular marker, Pst.S.

Prochlorococcus community structure

In order to examine the genetic diversity of *Prochlorococcus* within a single water column in the natural environment a series of depth profile samples as collected at 37°N 20°W ranging from surface waters down to 110m for subsequent extraction of DNA and RNA. At the 37°N 20°W station *Prochlorococcus* typically represented between 93-97% of the total picoplankton population (1-2 x 10^5 cells ml^{-1}). Using the PCR (polymerase chain reaction) we shall specifically amplify a region of the 16S rRNA from these organisms and examine the change in genotypes through the water column.

Prochlorococcus P status

To correlate changes in genotype with phenotypic changes we also collected large volume samples (ca 150l) at depths of 5m, 30m, 40m, 50m and 80m for protein extraction and examination of the nutritional status of these organisms, with particular regard to phosphate. Samples were concentrated to ca 250ml by tangential flow filtration using a 0.3 µm cut-off membrane and cell pellets collected by centrifugation. This approach will use a protein marker, specifically a periplasmic phosphate-binding protein (PstS) identified in pure cultures, and induced or de-repressed only when inorganic phosphate (P) levels are less than 50nM, as indicative of P stress. Antibodies raised against this protein specifically cross-react only with the *Prochlorococcus* and *Synechococcus* genera and can be used to identify PstS expression in populations of cells (using Western blotting) and recently in single cells using a fluorescently tagged secondary antibody and fluorescence microscopy. At each depth, 24 h on-deck incubations were set up in order to examine changes in PstS expression following addition of 1µM P or N (the latter as nitrate or ammonium). At 37^{0}N 20°W phosphate concentrations were typically between 20-30nM at the surface, ranging to 0.5µM at 300m.

Synechococcus P status

During the north-south transect between 60^{0}N and 37^{0}N, large volume samples (ca 150l) were obtained daily from the ships non-toxic supply for subsequent protein extraction and examination of PstS expression, as well as for on-deck incubations to assess changes in PstS abundance following nutrient addition, using the techniques as described above.

4.9 Phytoplankton DNA/RNA Characterisation (Andrew Bedford)

The programme was designed to continue the sampling of phytoplankton for DNA/RNA analysis commenced on the first Leg by Mike Wyman. As on the previous Leg, all samples collected on Leg 2 were stored following initial processing for analysis on return to the University of Stirling.

On passage from Iceland to 37°N samples were taken every 4 h from the non-toxic supply and stored for the later analysis of phytoplankton DNA and HPLC assayed pigment concentrations. Additionally, at around 04.00h at each of the underway stations a Go-Flo sample was taken from 2m and processed as above, with an additional sample being taken for the determination of the maximum photosynthetic rate (P_{max}) by ^{14}C incorporation. These data will be made available later.

On station at 37°N 20°W, two separate sampling strategies were undertaken. On each day two Go-Flo samples were taken from 2m at around 04.00 and 13.00h. Both of the samples were filtered and stored for analysis of phytoplankton RNA and HPLC assay. In addition the P_{max} value was determined using the ^{14}C technique for a sub-sample from the 04.00h Go-Flo sample. As well as the daily sampling programme, three diel experiments were carried out on the 11, 13 and 16 July. Samples were retrieved every 2-3 h over the 24 h period from the non-toxic supply and preserved for future RNA and HPLC analysis. Unfortunately owing to illness, it was not possible to collect the final two samples of the first diel experiment.

Following departure from the time series station at 37°N 20°W on 18 July, regular sampling at four hourly intervals from the non-toxic supply for DNA analysis was resumed. This sampling was continued until the edge of the continental shelf was reached.

4.10 Nutrient Uptake and Primary Production (Kirsten Donald, Andy Rees)

The methodologies and sampling rationale employed for this project during Leg 2 are described in Section 3.7 above.

Samples were taken from a series of stations along the N-S transect and also on the majority of days at the southern time series station for the determination of size-fractionated chlorophyll concentrations, primary production and phosphate uptake rates. As on the previous Leg, the parallel inorganic nitrogen uptake rates were based on whole community activity

P vs I incubations

A series of P:I incubations were also undertaken during the Leg on behalf of Dr M Wyman to allow estimation of P_{max} for whole fraction samples. In these experiments, the rate of incorporation of ^{14}C-labelled bicarbonate was determined for water samples incubated in a light box at a range of irradiances in order to estimate a value for P_{max} at each station. 500ml of water was collected from a depth of 5 m using a pre-cleaned 30 l Go-Flo bottle. The water was distributed into 5 x 60 ml polycarbonate bottles and 10 µCi $NaH^{14}CO_3$ added to each bottle. These were then incubated in a light box for approximately 5 h. Incubations were terminated by filtration onto 0.2 µm polycarbonate filters. Filters were dried prior to counting of the ^{14}C incorporated using the onboard liquid scintillation counter. The sampling schedule was as follows:

Date	Position	Date	Position
4/7	59.310N21.125W	13/7	36.910N19.217W
5/7	57.544N20.692W	15/7	36.685N19.227W
6/7	54.005N20.692W	16/7	36.490N19.216W
7/7	50.338N20.343W	17/7	36.308N19.163W
8/7	47.001N20.005W	18/7	36.121N19.171W
10/7	10.627N19.358W		

Dissolved Organic Carbon

The collection of samples for the analysis of DOC by Dr A Miller that was commenced on the previous Leg was continued on Leg 2. the approach used for the sampling was the same as that employed on Leg 1. The sampling schedule was as follows

Date	Station	No. Depths
5/7	CTD 42	1
6/7	CTD 44	1
7/7	CTD 46	1
8/7	CTD 48	3
9/7	CTD 51	1
10/7	CTD 52	1
12/7	CTD 64	8
15/7	CTD 80	8
17/7	CTD 94	8
18/7	CTD 100	8

4.11 Level I Chlorophylls and POC/PON (Graeme Hays)

The methods used for the collection of the chlorophyll and POC/PON samples during Leg 2 and for their subsequent processing for storage or analysis as appropiate were the same as those employed during Leg 1. Estimates of chlorophyll concentrations were made every hour on the southwards transect along 20°W and samples taken for POC/PON analysis every 8 h. At the 37°N time series station extracted chlorophyll concentrations for CTD calibration purposes were typically measured four times a day at eight depths at the dawn, midday, dusk and midnight CTD stations with POC/PON samples being taken from eight depths at each midnight station only

4.12 Mesozooplankton Grazing (Bob Head)

Objectives

The overall objective during the second leg of the PRIME cruise was to obtain data to complement that derived from the AMT-translatitudinal study of zooplankton communities using optical techniques. For the comparison to be effective it was important to ensure that the sampling protocols and stategies used remained consistent between the AMT and PRIME cruises. The specific objectives relating to the PRIME cruise are listed in order of priority:

- To make core measurements as developed for the AMT Programme of integrated mesozooplankton biomass and seawater particulate distributions at midday and midnight for both the transect from 60°N to 37°N and for the time series sampling at 37°N.

- To obtain a series of Level I integrated mesozooplankton WP2 net hauls at 37°N for samples for size fractionated carbon biomass and gut fluorescence estimates in order to establish temporal and diurnal variability during the time series at sampling 37°N.

- To characterize surface water properties along the transect from 60°N to 37°N.

Sampling Protocol: Transect along 20°W from 60°N to 37°N.
(a) Underway Sampling.
Samples were taken from the non toxic supply at regular intervals for the determination of chlorophyll concentrations, particulate C/N ratios and phytoplankton speciation.

(b) Midnight Station Sampling.
(i) Mesozooplankton.
Integrated vertical hauls of mesozooplankton were carried out with a WP2-200μm net from 200-0m, 100-0m and 20-0m at a haul rate of 0.5m sec^{-1}. For stations 201 and 205 only (59° 18'N and 47°N 20°W), vertical hauls were taken at 200-0m, 100-0m and 20-0m. Samples from the 200m and 100m hauls were split, with half being used for the OPC/video and the other half for size fractionated biomass estimates. Biomass size fractions (2000-1000μm, 1000-500 μm and 500-200μm) were subsampled onto 24mm GF/C microfibre filters and frozen at -20° C for estimation of carbon and nitogen on return to the laboratory. The half used for the OPC and the remainder of the biomass samples were preserved in 4% formaldehyde. The shallow 20m sample was preserved after OPC/video work.
(ii) Seawater Particulates.
Samples were taken from Go-Flo bottles from two depths immediately after the main 300m CTD profile at 5m (non toxic depth to give compatability with underway sampling) and with the other depth varied to coincide with the chlorophyll fluorescence maximum. Samples were then filtered for total chlorophyll concentration and in triplicate for size fractionated C/N (total, <200μm, <10μm, <5μm and <2μm) and with a further sub-sample preserved in Lugols/formalin for phytoplankton taxonomic analysis.

(c) Midday Station Sampling.
(i) Mesozooplankton Sampling
Due to time allocation only a single vertical net haul of 200-0m was carried out at midday stations. The sample was processed as in (b)(i) above.
(ii) Seawater Particulates.
Water was sampled from the non-toxic supply for the determination of chlorophyll concentration, size fractionated C/N(total, <200μm, <10μm, <5μm and <2μm) and for phytoplankton taxonomic analysis.

Sampling Protocol: Time Series Sampling at 37°N 20°W.

(a) OPC/Video.
Integrated WP2-200μm net hauls of 200-0m and 20-0m were collected at mid-day and midnight for the duration of the station. The 200m haul was split for OPC/video and size fractionated biomass estimates. Biomass size fractions (2000-1000μm, 1000-500μm and 500-200μm) were subsampled onto 24mm GF/C microfibre filters and frozen at -20° C for estimation of carbon and nitogen. The OPC half and the remainder of the biomass samples were preserved in 4% formaldehyde. The shallow 20m sample was preserved after OPC/video work.

(b) Level I Size Fractionated Biomass and Gut Pigments.
(i) Size Fractionated Biomass.
A single integrated vertical WP2-200um net haul 100-0m was made for estimates of size fractionated biomass. Biomass size fractions (2000-1000μm, 1000-500μm and 500-200μm) were subsampled onto 24mm GF/C microfibre filters and frozen at -20° C for estimation of carbon and nitogen. After subsampling the individual fractions were preserved in 4% formaldehyde.
(ii) Size Fractionated Gut Pigments.
A single integrated vertical WP2-200μm net haul 100-0m was made for analysis of the size fractionated gut pigment content. After anaesthetising the zooplankton with carbonised water and size fractionation (2000-1000μm, 1000-500μm and 500-200μm) samples were filtered onto sharkskin filters (Schleicher and Schuell) and frozen for subsequent pigment analysis.

(c) Seawater Particulates
Samples were taken from Go-Flo bottles immediately after the early afternoon 300m CTD profile from two depths, 5m (non toxic depth to give compatability with underway sampling) and with the other depth varied to sample at the chlorophyll fluorescence maximum, normally 65m. Samples were then filtered in triplicate for size fractionated chlorophyll *a* (total, >10μm, >5μm, >2μm and >1μm) and for size fractionated C/N (total, <200μm, <10μm, <5μm and <2μm) and a further subsample preserved with Lugols/formalin for phytoplankton taxonomic analysis.

3. Provisional Results.
Chlorophyll values at 37°N were extremely low at the surface with values of the order of 0.05μg l^{-1} (mean 0.052 μg l^{-1}, sd 0.005). The water column exhibited a deep chlorophyll maximum at 60-80m with concentration in the range 0.2-0.5 μg l^{-1} (mean 0.228μg l^{-1}, sd 0.127). These values are in close agreement with data collected on RRS *Charles Darwin* cruises CD66/91, CD83/93 and CD97/95 in the same area.

Table 15 summarises the mean size fractionated chlorophyll *a* data during the time series at 37°N. One obvious feature of the results is that the average retention of a 1μm nucleopore was ~15% or less of the total chlorophyll. (as measured on a GF/F filter) Reports in the literature suggest that GF/F filters (nominal pore size 0.7μm) may not retain all the pigment containing particles in oligotrophic waters. An experiment was carried out to compare the retention of GF/F filters versus 0.2μm Nucleopore filters using water collected from both 5m and 65m. Table 16 gives the results of this comparison.

Table 15. Summary of size fractionated chlorophyll values recorded during the time series at 37°N.

(a) Water collected from 5m at 15.00h on 16 July.

Size fraction	Total Chl	>10μm Chl	>5μm Chl	>2μm Chl	>1μm Chl
Mean (mg m^{-3})	0.052	0.004	0.006	0.007	0.008
Std-dev	0.005	0.002	0.002	0.002	0.002
% Total Chl	100	8.2	10.7	13.1	15.8

(b) Water collected from 65m at 15.00h on 16 July.

Size fraction	Total Chl	>10μm Chl	>5μm Chl	>2μm Chl	>1μm Chl
Mean (mg m^{-3})	0.228	0.014	0.022	0.032	0.032
Std-dev	0.127	0.008	0.009	0.014	0.007
% Total Chl	100	6.2	9.8	14.1	13.8

Table 16. Comparison of chlorophyll values derived from samples filtered through GF/F and 0.2μm Nucleopore filters. Water collected on 16 July using 30 litre Go-Flos from 5m and 65m.

Depth (m)	Chl (mg m-3) GF/F	Std-dev GF/F	Chl (mg m-3) 0.2μm Nucleopore	Std-dev 0.2μm Nucleopore
10	0.050	0.002	0.048	0.004
65	0.196	0.005	0.193	0.014

4.13 Optical Plankton Counter (OPC) and Video System (Chris Gallienne)

Objectives

The optical characterisation of mesozooplankton in the surface layer using laboratory OPC in both flow through mode using the ship's surface non-toxic supply and pump through mode using samples collected from 200-0m WP-2 net hauls. The work carried out was designed to extend PRIME supported work carried out on AMT cruises from 47°N southward on the 20°W meridian.

The OPC work was combined with developmental trials of an automated video zooplankton classification system; however data on this system are not presented as the device is still under development.

Sampling Protocol: Transect from 60°N to 37°N

During the transect from 60°N to 37°N, surface seawater from the ship's non-toxic supply was continuously sampled through the OPC and video system with the sampling being interrupted twice a day at approximately midnight and mid-day at 60°N and 47°N for WP-2 net hauls from 200-0 m with the discrete samples being passed through the OPC and video systems. Aliquots of the discrete samples were preserved for later detailed analysis.

Sampling Protocol: Time Series Sampling at 37°N

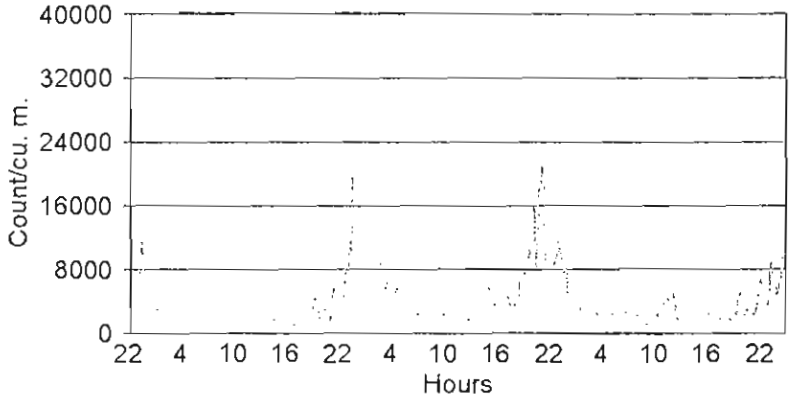
Discrete samples obtained from WP-2 net hauls 200-0m at approximately midnight and mid-day were run through the OPC and video systems with an aliquot preserved as previously. Work was continued on the development of the video zooplankton analyser using net samples collected at various times during the time at the station.

Results:

Data were processed on board and are presented in summary form as diagrams of raw counts per cubic metre (underway: in top two following diagrams) and as continuous records of biovolume in p.p.m. (mg m^{-3}) in four JGOFS size classes for transect stations (following bottom left diagram) and station work at 37°N (following bottom right diagram). The latter two figures show alternating day/night data in both cases, against latitude for the transect data and against sequential cast number for the station at 37°N, beginning with midnight on day 193.

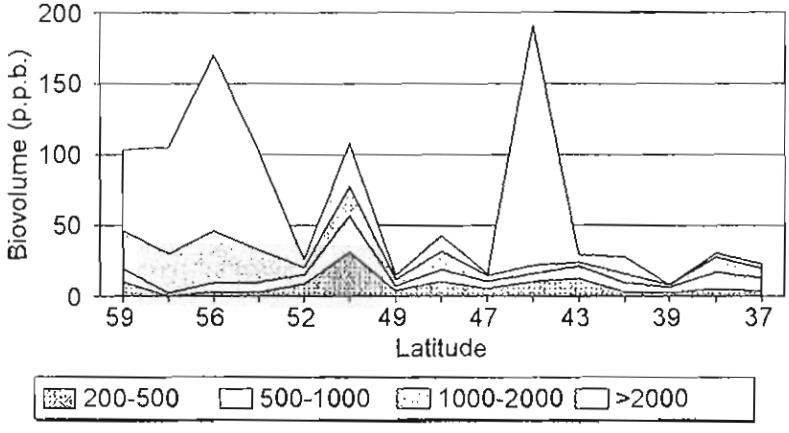
OPC Raw Count - Days 185-188

Underway



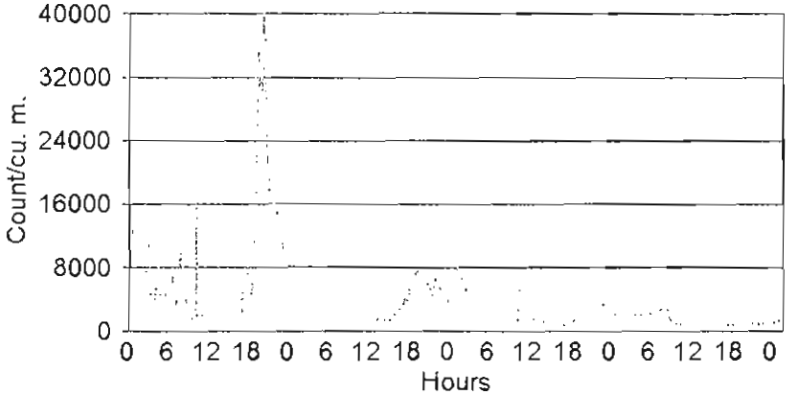
Vertical 200m. Net Hauls Thro' OPC

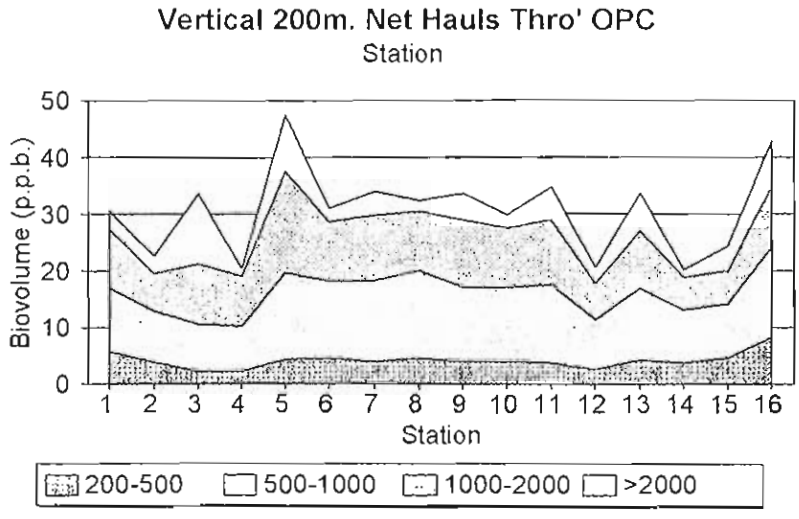
Transect



OPC Raw Count - Days 189-192

Underway





4.14 LHPR Tows (Graeme Hays)

Preliminary work was carried out on the LHPR during the passage south from Iceland in order to establish the operation of the equipment. The system was successfully deployed initially at the transect station at 47°N 20°W and was subsequently deployed a further four times at the time series station at 37°N 20°W. For each tow approximately 1200m of wire was paid out allowing sampling of the mesozooplankton at discrete depths down to around 400m with the temperature/depth and salinity of each sample being recorded. In addition, data from the ship's ADCP was logged on each tow. The zooplankton samples will be analysed post-cruise with the data being used to validate the ADCP readings recording back-scatter from mesozooplankton. Data from the samples will also supplement other zooplankton observations from the cruise and will be of particular assistance in quantifying the day-time vertical distribution of various species. This will allow more rigorous interpretation of both the vertical WP-2 net hauls (typically 0-100m or 0-200m), the U-TOW samples (10m) and the data obtained from the on-line OPC/video imaging system.

4.15 Microzooplankton Herbivory and Community Structure (Claire Stelfox)

Objectives

The specific objectives of the work were similar to those carried out in the same discipline on Leg 1 and included:

- Quantification of the grazing impact of microzooplankton on phytoplankton along the transect from 60°N to 37°N and to perform a time series of grazing experiments at the southerly station.
- Investigation of the effect of nutrient limitation on microzooplankton herbivory.
- Comparison of the dilution and fluorescently labelled algae techniques as estimators of microzooplankton grazing rates using simultaneous experiments.
- Comparison of herbivory rates of microzooplankton populations sampled during Leg 2 with comparable rates obtained during Leg 1.
- The collection from transect and time series stations of preserved microzooplankton and phytoplankton samples for later taxonomic and community structure analyses for other PRIME programmes.

Microzooplankton herbivory

Two techniques were used for quantification of microzooplankton grazing, the dilution experiment approach of Landry and Hassel (*Mar Biol*, 67:283-288, 1982) and the fluorescently labelled algae approach (FLA) described by Sherr *et al* in 1987 (*Appl Environ Microbiol*, **53**:958-965).

Water was collected pre-dawn from a depth corresponding to the 33% PAR level using replicate 30l Go-Flo water bottles as required. Forty litres of sample was filtered through a 0.2µm Gelman Supor-

capsule filter and combined with the remaining unfiltered water by passing through a 200µm mesh bag into 2.3l polycarbonate bottles to make a series of 10, 40, 70 and 100% dilutions. In most of the experiments additional bottles were prepared in the same way and spiked with nutrients made up from a stock solution. Sub-samples were taken at time zero for chlorophyll, flow cytometric and community analyses. Each sample bottle was then gently re-filled to the same dilution and incubated in the deck incubator using a 33% light cover for 24h. Two experiments were also incubated in-situ. At the end of the incubation sub-samples were again taken for chlorophyll and for flow cytometric and community structure analysis. Chlorophyll was extracted using 90% acetone and analysed shipboard by fluorometry. The community structure of the picoplankton was analysed by Glen Tarran using the flow cytometer, whilst microzooplankton samples were fixed in 1% Lugols and 0.3% glutaraldehyde (see below) for later analysis in the laboratory.

Aliquots of unfiltered water from the Go-Flos was also gently passed through a 200µm mesh bag into two polycarbonate bottles and incubated ondeck using a 33% light filter. One bottle was inoculated at tracer concentrations (10-20% of natural prey abundance) with *Chlorella stigmatophora* and the second with *Synechococcus* sp which had been heat stained using the fluorescent dye DTAF. Sub-samples were fixed in 1% Lugols at T0 and at 10 minute intervals thereafter for one hour to obtain short term uptake rates. The experimental bottles were incubated for a further 24 hours when a final sample was taken. Analysis will take place in the laboratory by settlement microscopy to quantify the short-term uptake rates by specific protozoa and by flow cytometry to measure the rate of fluorescence disappearance over 24 h and thus quantify microzooplankton grazing. A listing of the grazing experiments carried out is given in the following table:

Date	Grazing Experiment	Depth
4.7.96	Dilution	10m
5.7.96	Dilution & FLA	10m
6.7.96	Dilution & FLA	10m
7.7.96	Dilution & FLA	10m
8.7.96	Dilution & FLA	10m
10.7.96	Dilution	10m
11.7.96	Dilution & FLA	25m
13.7.96	Dilution* & FLA	25m
15.7.96	Dilution* & FLA	25m
16.7.96	Dilution & FLA	25m
17.7.96	Dilution & FLA	25m

Phytoplankton and microzooplankton community structure

Phytoplankton samples are to be analysed by Marion Yallop at the University of Bristol for community abundance and biomass whilst the microzooplankton and nanozooplankton will be analysed by Elaine Edwards at Plymouth Marine Laboratory. Water samples were collected daily by Luan Al-Haddad from CTD casts and fixed as follows:

- For phytoplankton 100ml of water from 10 depths per profile were fixed in Lugols and a further 100ml fixed in formalin.
- Microzooplankton samples from 8 depths per profile (500ml) were fixed in 1% Lugols for taxonomic identification, cell concentration and biomass determination. 500ml were also fixed in 2% hexamine-buffered formaldehyde for the identification and enumeration of the autotrophic and mixotrophic microzooplankton.
- Nanozooplankton samples were fixed (25-50ml) in 0.3% (final concentration) glutaraldehyde. Samples were then dual stained with 5mg ml^{-1} (final concentration) DAPI and Proflavin, filtered onto 0.8µm black polycarbonate filters and mounted onto slides and immediately frozen.

* *In-situ* rig and deck incubation

A record of samples taken for the determination of phytoplankton and microzooplankton community structure appears in the following table:

Date	CTD	Sample collected	Depth
4.7.96	39	Phyto-, Micro- & Nanozooplankton	2-150m
5.7.96	42	Phyto-, Micro- & Nanozooplankton	3-150m
6.7.96	44	Phyto-, Micro- & Nanozooplankton	2-150m
7.7.96	46	Phyto-, Micro- & Nanozooplankton	2-150m
8.7.96	48	Phyto-, Micro- & Nanozooplankton	2-150m
9.7.96	51	Phyto-, Micro- & Nanozooplankton	2-150m
10.7.96	52	Phyto-, Micro- & Nanozooplankton	2-150m
11.7.96	54	Phyto-, Micro- & Nanozooplankton	20-200m
12.7.96	60	Phyto-, Micro- & Nanozooplankton	2-150m
12.7.96	64	Phytoplankton	2-150m
12.7.96	65	Phytoplankton	2-150m
13.7.96	66	Phyto-, Micro- & Nanozooplankton	2-150m
14.7.96	71	Phyto-, Micro- & Nanozooplankton	2-150m
14.7.96	74	Phytoplankton	2-150m
15.7.96	76	Phyto-, Micro- & Nanozooplankton	2-150m
15.7.96	80	Phytoplankton	2-150m
16.7.96	82	Phyto-, Micro- & Nanozooplankton	2-150m
16.7.96	87	Phytoplankton	2-150m
17.7.96	89	Phyto-, Micro- & Nanozooplankton	2-150m
17.7.96	94	Phytoplankton	2-150m
18.7.96	96	Phyto-, Micro- & Nanozooplankton	2-150m
18.7.96	100	Phytoplankton	2-150m

Qualitative microzooplankton community structure

An Apstein net fitted with a 200µm mesh was hauled vertically through the upper 100m at each of the three transect stations. The collected sample allows the qualitative analysis of the larger, less delicate microzooplankton, namely the dinoflagellates and tintinnids. 250ml of the fresh sample was fixed in 1% Lugols for future analysis. The remaining sample was immediately analysed using an inverted microscope fitted with fluorescence source and linked via a CCD camera to an SVHS video.

Along the transect the microzooplankton community showed small changes in structure. At 60°N the sample contained a mixture of autotrophic and heterotrophic cells showing large diversity. Coccolithophorids, dinoflagellates such as *Ceratium* spp, *Protoperidinium* spp, *Dinophysis* sp and tintinnids such as *Eutintinnus* sp, *Favella* sp and *Amphorides* sp, were common. At 47°N the community appeared to be dominated by autotrophic cells such as the dinoflagellates *Gonyaulax* sp and *Prorocentrum micans*. Tintinnids were not common in the sample although several larger ciliates were found. The community again changed slightly at 37°N with a high diversity of both autotrophic and heterotrophic dinoflagellates, *Ceratium extensum, C.candelabrum, C. furca, C. tripos, Gonyaulax* sp, *Amphidoma caudata, Oxytoxum scolopax, Prorocentrum* sp, *Cochlodinium* sp, *Protoperidinium* spp, and several of the gymnodinoids *Gyrodinium* spp and *Gymnodinium* spp. Tintinnid diversity was high and included several species such as *Salpingella acuminata, Codonella acerca, Dictyocysta lata, Rhabdonella* spp, *Ptychlocylis* sp, *Steenstrupsiella* sp, *Eutintinnus* spp *and Amphorides* sp. Throughout the samples Acantharians, Radiolarians and Foraminiferans were present in low numbers.

4.16 Microbial Loop Studies: Bacterial Dynamics (Mike Zubkov)

Studies of the microbial loop carried out under this programme included quantification of the activity and distributions of two general microbial groups, that is the heterotrophic bacteria and the nanoflagellates, in terms of their vertical distributions, size structure, bacterivory and control of bacterial numbers by protozoa.

Bacterioplankton Size Structure, Abundance and Production
Samples were taken from routine CTD casts to provide data on the vertical distribution of bacterioplankton using both epifluorescence image analysis techniques and flow cytometry, with the latter being carried out in collaboration with Glen Tarran. Size fractionation of bacteria was used to estimate the median cell diameter of bacterial populations inhabiting the surface layer, the thermocline zone and the deeper water below the thermocline. Samples were filtered through Nuclepore filters with pore size 0.4, 0.6, 0.8 and 1 μm and the filtrate fixed for subsequent analysis by flow cytometry and epifluorescence microscopy. Bacterioplankton production was estimated using simultaneous uptake of ^{3}H-thymidine and ^{14}C-leucine by bacteria with samples being collected from six depths and inoculated with radioactive precursors prior to incubation in the dark.

Heterotrophic Nanoflagellate Abundance and Bacterivory
Samples to be used for the estimation of the vertical distribution of heterotrophic flagellate abundance by epifluorescence microscopy were taken from the same routine CTD casts as above. The activity of bacterivorous flagellates was evaluated from assay of enzymes that cut off glucosamine at acid pH (disrupting bacterial cell wall in protozoan food vacuoles). These analyses were conducted in conjunction with the measurements of bacterial production. The experiments designed to determine bacterivory were carried out using dual radioactive labelled bacterial prey; these were either laboratory cultures of *Vibrio natriegens* or natural bacterioplankton. A set of experiments was carried out at the 37°N time series station with Glen Tarran in order to quantify protozoan grazing on both autotrophic and heterotrophic bacteria using flow cytometry.

The analysis of all collected material and samples will be carried out back in the laboratory.

4.17 Characterisation of Marine Viruses (Willie Wilson)

Viruses have recently been recognised as ubiquitous components of the marine environment, with concentrations in excess of 10^{8} ml^{-1} being reported. It is generally regarded, therefore, that viruses play an active role in population dynamics and structure of marine microbial and plankton communities. A significant proportion of viruses in the marine environment are known to infect oceanic primary producers and it is thought that phytoplankton community succession dynamics may be influenced by viruses; however, the full role of viruses remains largely unknown.

The main reason for the shortfall in knowledge is the lack of accurate techniques to identify and enumerate marine virus populations. One of the principal objectives of this study was to develop a tool based on the use of molecular techniques, to measure viral populations. Much of the work performed during the cruise was aimed at collecting samples which will be used to test various PCR (polymerase chain reaction)-based probes, both at a qualitative and a quantitative level, back at the laboratory.

Phylogeny of virus and *Synechococcus* spp. populations
The population structure and phylogeny of viruses and *Synechococcus* spp. will be studied using virus (initially cyanophage, but eventually moving on to *Phaeocystis* virus) and *Synechnococcus* spp. specific PCR primers. The objective of this part of the programme was to consider the phylogeny of the populations from a single depth during the N-S transect and also over a depth series at 37° N. For the required samples, 20l of water was collected and size fractionated using tangential flow filtration to concentrate different virus-containing fractions.

Isolation of Virus Populations
Viral populations were isolated to interrogate different phytoplankton strains back at the laboratory. These will then be characterised and ultimately used to design further probes. For sampling, between 150 and 175l of seawater were concentrated by tangential flow filtration and the viral fraction stored at 4°C. Sampling frequency was restricted to once every other day on the transect from 60°N to 37°N with a further two samples being taken at 37°N.

Nutrient Incubations
Seawater samples were incubated with a range of contrasting nutrients in order to establish differences in viral induction or production patterns. As previously, the objective was to take samples

from a single depth at prescribed intervals along the N-S transect and also over a depth series at 37° N. For the series of enrichment experiments, 6 x 2.4l volumes of seawater were collected and added to clear Nalgene bottles and the following nutrient additions made:

1. Control #1: no additions and no incubation (pre-incubation control)
2. Control #2: no additions and incubated for 24 hours.
3. Nitrate to final concentration of 1μM.
4. Phosphate to final concentration of 1μM.
5. Phosphate and nitrate to final concentrations of 1μM each.
6. Ammonium to final concentration of 1μM.

Each of the bottles was then incubated for 24h on deck at the appropriate irradiance. Following incubation (or prior to incubation for control #1), 2ml was fixed for virus counts in 1% glutaraldehyde, with a further sample being given to Glen Tarran for flow cytometric counts of *Synechococcus* spp: and *Prochlorococcus* spp. prior to (control #1) and following incubation. Half the water was filtered for DNA extraction and half for protein extraction.

Concluding Comments

Owing to the nature of these experiments, it is difficult to draw any specific conclusions until DNA extracted from the above samples has been analysed. However, preliminary data indicate that *Synechococcus* spp. counts from the nutrient incubations enriched with phosphate demonstrated a consistent increase, suggesting that ambient phosphate concentrations may be limiting *Synechococcus* spp. growth.

4.18 Respiration Measurements (Tracey Bentley and Claudia Castellani).

The underlying objectives of the programme were similar to those described for Leg 1.

Samples for the estimation of the rates of respiration (whole community and <0.8μm) along the N-S transect from 60°N were taken from the ship's on line seawater supply. Initial inspection of the dataset suggests that the bacterial fraction contributed up to half of the measured respiration (Table 17). Comparable data for whole community respiration rates estimated at stations along the transect are given in Table 18.

Table 17. Size-fractinated respiration rates at selected stations along N-S transect, Leg 2.

position	59N		46N		36N		36N		36N		36N	
depth	10m		10m		10m		60m		60m		10m	
Date	04/07/96	sd	08/04/96	sd	11/07/96	sd	13/07/96	sd	17/07/96	sd	18/07/96	sd
WC	4.06	0.5	4.5	0.3	0.6	0.7	3.42	0.48	1.8	0.58	1.8	0.34
53um	2.44	0.6	3.9	0.1	1.05	0.1	3.6	0.84				
20um	2.19	0.4	3.91	0.3	1.85	0.25	4.82	0.47				
5.0um	0.44	0.6	2.5	0.2	1.99	0.4	4.15	0.98				
2.0um	2.05	0.6	2.4	0.7	2.92	0.42	3.64	0.19	3.5	0.43	0.98	1.22
0.8um	0.04	0.4	1.63	0.3	2	0.4	3.52	0.6	3.88	0.51	1.26	0.18

Table 18. Whole community respiration rates along N-S transect 20°W

DATE	04/07/96		04/07/96		05/07/96		05/07/96		06/07/96		06/07/96	
TIME	05:00		19:30		08:00		19:30		08:00		13:30	
POSITION	59N 21W											
	At station	sd		sd		sd		sd		sd		sd
WC	4.96	0.48	1.93	0.16	0.94	0.31	2.89	0.27	0.6	0.6	5.59	0.2
0.8um	0.04	0.42	-0.2	0.44	0.51	0.26	1.37	0.18	0.69	0.7	2.32	0.5

DATE	06/07/96		07/07/96		08/07/96		08/07/96		09/07/96		09/07/96	
TIME	19:30		08:00				19:15		08:00		18:50	
POSITION					46N							
		sd		sd		sd		sd		sd		sd
WC			3.67	0.4	4.5	0.33	4.29	0.39	3.27	0.3	1.49	0.4
0.8um	1.31	0.25	1.52	0.28	1.63	0.28	2.14	0.2	4.3	0.4	1.52	0.6

DATE	10/07/96	
TIME	08:00	
POSITION		
		sd
WC	1.4	0.09
0.8um	1.67	0.2

Following occupation of the time series station at 37°N 20°W, the same sampling procedure as that employed on Leg 1 at the time series station at 60°N was adopted. Each day samples were collected for the estimation of size fractionated POC/PON and chlorophyll concentrations and also for Coulter Counter determinations. These data were specifically collected for use in the PRIME ecosystem model.

Chlorophyll concentrations were, as may be expected, higher at the more northerly stations along the N-S transect than at the southerly stations (Table 19). However, as with the observations at the northern time series station on Leg 1, there appeared to be no major change in chlorophyll concentration during the time spent at the time series station at 37°N 20°W (Table19). Maximum chlorophyll concentrations at 37°N were clearly associated with the deep chlorophyll maximum as indicated by the data for the 60m samples. Data obtained from the Coulter Counts showed the dominance of the smaller size particles ie <5µm. Oxygen concentrations were generally considerably lower (approximately 50µmol l^{-1}) at the southern time series station compared to the more productive northern station. Respiration rates were higher in the samples taken from the northern stations and in those samples taken from the deep chlorophyll maximum at the southern station. The bacterial fraction again made a significant contribution to total respiration.

Table 19. Size-fractionated chlorophyll concentrations (mg m

Position	59N	46N	36N	36N	36N	36N	36N	36N	36N
Date	04/07/96	08/07/96	11/07/96	12/11/96	13/07/96	15/07/96	16/07/96	17/07/96	18/07/96
Depth	10m	10m	10m	10m	60m	10m	10m	60m	10m
FRACTION									
0.8um	0.03	0.02	0.02	0.02	0.01	0.02	0.023	0.08	0.023
.2.0um	0.13	0.12	0.03	0.03	0.08	0.04	0.041	0.2	0.04
5.0um	0.24	0.25	0.03	0.05	0.07	0.07	0.05	0.24	0.04
20um	0.53	0.34	0.05	0.1	0.2	0.06	0.05	0.25	0.07
53um	0.57	0.46	0.05	0.12	0.1	0.06	0.05	0.25	0.12
WC	0.65	0.58	0.05	0.12	0.1	0.06	0.06	0.25	0.15

4.19. Isotopic Composition of Suspended Particulate Organic Matter and the Disssolved Inorganic Carbon System and Primary Productivity (Hilary Kennedy and Gideon Middleton)

The objectives and methodologies employed for the programme on Leg 2 were similar to those described for Leg 1 (see Section 3.15).

Sampling for parameterisation of the model $\delta^{13}C_{POC}$, $\delta^{13}C_{\Sigma CO_2}$, pH and $[\Sigma CO_2]$) was continued along with daily productivity incubations from the surface waters during the transect from 60°N to 37°N. In addition, these parameters and daily primary productivity measurements were carried out at three different depths at the major stations in conjunction with CA, AZ and DIDS experiments to assess changes in the mechanism of inorganic carbon acquisition with depth and latitude.

The pH and $[\Sigma CO_2]$ results taken during the transect are plotted in Figure 30. The major feature associated with the transect was the front located in the vicinity of 51.5°N which marked the boundary between an area of high $[\Sigma CO_2]$ and low pH to the north and low $[\Sigma CO_2]$ and high pH to the south.

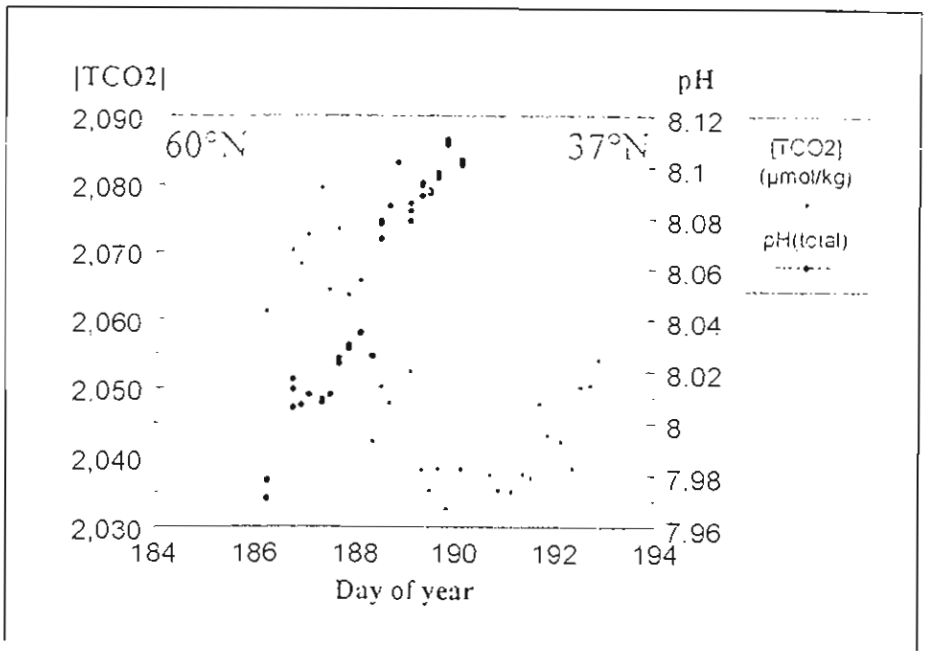


Fig. 30. Changes in $[\Sigma CO_2]$ and pH along 20°W transect from 60°N to 37°N.

During the Lagrangian study at 37°N samples were collected as previously at selected intervals from depths corresponding approximately to the 97, 33 and 7% light levels and used for the estimation of productivity. For model parameterisation, more detailed sampling for chemical and isotopic assays was maintained from daily CTD casts in the upper 150m of the water column. At two day intervals, the routine ^{14}C incubations were supplemented with further experiments containing additions of CA, AZ and DIDS designed, as previously, to assess the importance of the various possible methods of carbon acquisition.

4.20 Biogeochemistry of Iron (Alex Baker, Karen Mackenzie)

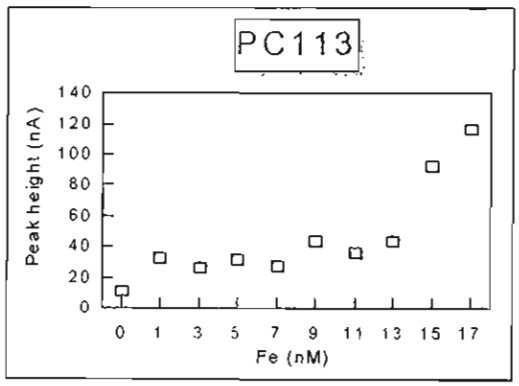
The objectives for this programme for Leg 2included the two objectives detailed for Leg 1 together with the further objective of determining the iron binding ligand concentrations and strengths and a preliminary investigation of these ligand effects on the microorganisms present in the water. This third objective was the responsibility of Karen Mackenzie who joined the team for Leg 2. Also as

previously, discrete samples were collected for further study of iron biogeochemistry, and for analysis for other metals (e.g. Co, Zn, Ni) on return to the laboratory in Liverpool.

With respect to the iron determinations and redox speciation, vibrations and the PES fish continued to give problems. The connection to the fish broke twice during the passage south (5 and 7 July), causing minor interruptions in the collection of surface samples along the transect. The discrete Fe redox system suffered worse problems than on Leg 1 and it was not possible make measurements even when the ship was stationary and no winches were in operation.

Fe binding ligand measurements.
Ligand strength and complexing capacity is determined by competition of a strong iron binding ligand of known concentration with the natural ligands. The natural ligand is then titrated with iron by additions of 0 to 17nM Fe to ten aliquots of the sample. During the programme, separation and concentration of the natural ligands was designed to be carried out by tangential flow ultra filtration. The concentrates from the filtration were to be added to deck based incubations in various dilutions with iron additions to these also being planned. However due to the vibrations from both the ship's engines and winches, it was very difficult to make any reliable measurements while the ship was in transit or when stopped. The component titrations, instead of taking the expected 4h to complete, were found to require approximately 9.5h. As a result of the problems with the measurement of the Fe concentrations outlined above, there was insufficient time available to collect and concentrate the large samples (160 l) required for size fractionation of ligands.

Results
Titrations



The data presented in Fig. 31 (immediately above) from surface sample PC113, indicate a high complexing capacity of around 7-9nM Fe.

Incubations
Deck incubations were carried out for the first three days of the N-S transect in order to assess the possible influence of iron enrichment on the growth rates of selected components of the phytoplankton. Growth of the phytoplankton components was estimated from incubations made over 24h using flow cytometry, which was carried out shipboard by Glen Tarran. Preliminary results showed that the nanoplankton community responded to the iron additions made with a 5% increase in total cell numbers for these individuals being found over the incubation period. No response was evident in the picoplankton fraction. Total chlorophyll *a* concentrations were also constant over the course of the experiments. Following the incubations, samples were filtered and stored frozen for analysis on return to the laboratory in Liverpool.

Discrete Samples
A total of 200 surface and sub-surface samples were collected for analysis on return to Liverpool.

4.21. Data Archiving (Polly Machin)

Objectives

To complete an accurate record of all sampling events on board so that every measurement may be related back to continuously logged parameters (e.g. temperature, salinity, PAR, chlorophyll fluorescence, wind velocity) as required.

To monitor the performance of the basic CTD and underway instruments so that the data obtained can be processed and calibrated to an acceptably high standard.

To assist with sampling the Level I chlorophyll and POC/PONs and general watchkeeping duties as required.

Work Achieved

Thanks to the splendid efforts of Rob Lloyd (RVS Computing) and the watchkeepers and officers on the bridge, a fully comprehensive and accurate record of all cruise events was obtained. This should hopefully be used as the definitive version of the cruise log and I shall be very happy to provide information on this, such as: what samples were taken off the non-toxic supply while the LHPR was being towed; how much did the ship drift during the deep CTD and how many surface measurements of chlorophyll were made at the 47^0N 20^0W station.

An excellent set of chlorophyll and salinity measurements for calibration of the underway and CTD fluorometers and salinity sensors were analysed on board and a comprehensive suite of POC/PON samples were collected, largely due to the unstinting efforts of Graeme Hays, Phil Taylor and Dave "where's my flag gone?" Teare.

The underway and CTD instruments generally worked very well, with the only major gaps in the data set being associated with the humidity sensor and the echo-sounder (water depth) for the first half of the leg. The replacement of the CTD transmissometer and the underway fluorometer due to malfunction should be able to be compensated for by careful screening and calibration of the data to produce a seamless dataset. Preliminary comparisons of the meteorological data (absolute wind velocity, barometric pressure, air temperatures) against independent observations by the officers of the bridge are very encouraging and indicate no systematic bias.

Data You Are All Encouraged to Get Your Sticky Mitts On

All cruise participants are strongly encouraged to make use of the following data, which I shall be happy to send if you contact me at BODC. The underway data were logged at 30 second intervals, but can be easily supplied as 10 minute, hourly or daily averages or subsamples. The CTD data were logged at 1 second (approximately half a metre depth) intervals, but again can be supplied as averages over a specified depth inteval. In return, I would very much appreciate it if the PRIME database could be fattened up by your results, which I would like to see as soon as they are finished.

A summary table of the status of the majority of the Level I data set follows:

Instrument	What it Measures	What Needs to be Done	When Data Ready?
GPS	latitude	check and interpolate	end of July
GPS	longitude	check and interpolate	end of July
GPS	distance run	compute	end of August
TSG	sea surface temp	calibrate against CTD	end of August
TSG	sea surface salinity	calibrate against samples	end of August
Fluorometer	chlor. fluorescence	calibrate against Level Is	end of August
Transmissometer	water transparency	convert to attenuance	end of July
Echo-sounder	water depth	check quality	end of July
Oxygen probe	dissolved oxygen	calibrate against Winklers	to be decided
2xPAR meters	PAR.	pressure check quality	end of July
Psychrometers	dry bulb air temp	calibrate	end of July
2xlight meters	total irradiance	calibrate	end of July
Anemometer	relative wind speed	convert to absolute	end of July

Table continued from previous page

Barometer	barometric	compare port and stbd	end of August
Psychrometers	wet bulb air temp	compare port and stbd	end of August
Auto Analyser	5xnutrients	clean up and calibrate	see Malc. W. (PML)
Pressure sensor	depth	calibrate	end of August
CTD	temperature	check	end of August
CTD	salinity	calibrate against samples	end of August
Fluorometer	chlor. fluorescence	calibrate against Level 1's	end of August
Transmissometer	water transparency	convert to attenuance	end of August
Light meter 1	upwelling PAR	calibrate	end of August
Light meter 2	downwelling PAR	calibrate	end of August

4.22. RVS Computing (Rob Lloyd)

General

Prior to the cruise two major improvements were made to the computing system on RRS *Discovery*. Extra disc space was provided on all four SUN workstations comprising the 'Level C' network. This greatly simplified the data management enabling, for instance, the continuous logging of ship's log and gyro during Leg 1. The other major, and perhaps more significant, development was the separating of the data and processing networks. An Ethernet bridge was installed on the 'Discovery 2' workstation that linked the two networks. The first consisted of the CTD Level A, the Level B, Discovery 1 and Discovery ; the second network consists of Discovery two, three and four and all the peripherals (plotters,etc.). Thanks must go to Martin Beney and Alan Taylor for the faultless way these improvements performed during the seven weeks of the cruise.

Data Logged

LOG-CHF - Chernikeeff electromagnetic log recording fore/aft and port/starboard speed through the water. No time was available for calibrations but at speeds below 10kts this had no significant effect. The P/S values were unreliable and ignored for calculation of DR positions.

GYROSYNC - Ship's gyro heading. The advent of the Ashtec attitude sensor (see below) has revealed that the instrument is unstable for some minutes after turns and currently has a misalignment error of 2.5 degrees.

GPS-ASH - Ship's attitude sensor based on an array of GPS receivers measuring relative phase differences. This provides a very accurate heading for ADCP post processing. Multipath errors and poor GPS coverage sometimes degraded the data, particularly at the 60°N 20°W survey site. The sensor performed better the further south the ship sailed.

GPS-4000 - Standard Trimble Surveyor GPS set. No obvious problems. Recent improvements to the Level A software have solved the 'Serial overrun' error.

MX1107 - Old (very!) Transit based satellite navigator provided as a backup to GPS.

EA500D1 - Simrad echo sounder providing depth data. Some data were lost due to an oversight at the start of Leg 2.

RVS-CTDF - Upgraded VME based RVS Level A logger for the CTD. Run during this cruise using the faster Ethernet link to the Level B rather than the more usual serial line.

SEASOAR - A separate Level A application run of the same hardware as the CTD. Used during Leg 1 only.

BOTTLES - Mk.1 serial Level A recording time and firing code from the tone fire CTD bottle system.

METLOGGR - RVS Labview based PC met logger using Ship Message Protocol (SMP) to link to the Level B.

SURFLOG - A PC similar to the above recording underway TSG, fluorescence and transmission data. This device still occasionally corrupts its time data - a bug that has been solved in the METLOGGR.

WINCH - A PC based winch data logging system.

ADCP - The Acoustic Doppler Current Profiler is separate from the main logging network transmitting its data directly to the Level C (Discovery 1). As in the past logging 128 data 'bins' and raw data caused some problems. Paul Duncan on Leg 1 implemented a simple work around that limited the data loss on such occasions to only one record. However there remained a bug that corrupted completely the serial port on Discovery 1. This occurred twice on Leg 1 but only once at the beginning of Leg 2.

Other sources of data transferred to the Level C were ARGOS buoy positions and satellite image, both via e-mail.

Level B
The Level B performed generally very well. Only three 'black hole' events occurred, one of which was closely observed leading to confirmation that tape problems are the cause. Throughout the cruise data was written to new, erased and initialised tape. A total of nineteen 150Mb. tapes were used. An opportunity to clean the tape drives was taken during a pause in work on the 37°N station. the new 4Gb disc drive on the Level C enabled the reading and archiving of all the Level B tapes.

Level C
Routine data processing included the derivation of 'bestnav', absolute wind data, surface salinity and the calibration of CTD and Seasoar data. Surface contours were produced together with contoured CTD and Seasoar sections. During the SF_6 experiment on Leg 1 an extra navigation data stream was produced. This consisted of uncorrected dead reckoned navigation which was used to produce near realtime estimates of the circulation of the eddy. During the 16h deployment of the tracer patch the ship was navigated using DR data only.

Overall some 16Gb of raw and processed data were recorded and over 2000 plots produced.

Communication Office Computer
The Ship to Shore (STS) computer used to send and receive e-mail over the Inmarsat system is old and in urgent need of at least a new disc drive a:. As a stopgap measure it was necessary to transfer files using five and a quarter inch discs.

4.23. Instrumentation (Phil Taylor)

Seasoar Operations
Six tows were completed, varying in duration from 6h to 48h. The vehicle used was a Chelsea Instruments Mk 2 Seasoar towed from 500m of faired cable. Onboard instrumentation comprised a Neil Brown Mk 3b CTD (s/n 1055) fitted with a Sensor Medies O_2 sensor and a Chelsea Instruments Mk 3 Fluorometer (s/n 88/2960/160) for the estimation of chlorophyll *a* fluorescence.

Following some initial problems the system performed well, undulating between the surface and 350m. This was achieved using a wing down angle of 18 degrees and a towing speed of 6.5-7.5 kts. On certain courses the strength of the sub-surface currents associated with eddy restricted the maximum undulation depth that could be achieved.

Recovery of Seasoar in Force 7/8 conditions at the end of run#5 resulted in a bent tail fin assembly and damaged tow cable. These were repaired on board, allowing operations to resume two days later in better weather. Following this incident tactics for the launching and recovery of Seasoar were

modified. The portside aft ship's crane was used for both deployment and recovery operations. Once Seasoar was outboard the towing sheave was transferred onto a wire from the SAPS winch and suspended from the centre block on the A-frame. This procedure enabled the 500m of faired cable to be deployed and recovered with minimum damage.

No instrument or vehicle failures occurred.

CTD Profiling

The system employed comprised a Neil Brown Mk 3b CTD (s/n 1195) fitted with a Sensor Medics O_2 sensor, a Sea Tech Transmissometer (s/n 104D) and a Chelsea Instruments Mk 2 Fluorometer (s/n 229). The associated water sampler was a General Oceanics (GO) 1015-10 unit fitted with 12x10l lever action Niskin bottles and a GO Tone Fire system. Two SIS RTM 4002 reversing thermometers were used to provide temperature checks on the CTD.

One hundred and one CTD casts were completed during the cruise. These varied in depth from 60m to 3000m, with occasional deployments to 5000m. Two casts had to be aborted because of wire failures: one resulting from a short circuit 20m from the end of the cable and the other a termination failure. On occasions the Rosette firing module indicated a misfire condition, but this usually cleared on the second attempt at firing. A few of the lever action Niskin bottles initially failed to seal properly because of incorrect lanyard tensions. These were subsequently adjusted and gave no further trouble. Transmissometer s/n 104D failed after cast #74 as a result of water ingressing the detector assembly and the unit was replaced by the spare unit s/n 637D.

Surface Systems

Surface temperature and salinity measurements were made using a Falmouth Scientific TSG. The remote temperature sensor (s/n 226) together with a Sea Tech Transmissometer (s/n 103D) and Chelsea Instruments Fluorometer were sited in a deck tank in the hangar. Calibration samples as required were routinely taken from the ship's non-toxic supply. The Fluorometer failed on day 37 and was replaced with the equivalent unit from the CTD (sn 229) for the passage leg back to Southampton.

Shipborne ADCP

The RDI 150khz VM ADCP was run continuously throughout the cruise, sampling 128x4m bins and averaging the data over 2 minutes. Profiles were obtained to depths greater than 300m. Raw and averaged data were logged by the ship's logging system and the system PC. Approximately half way through Leg 2 the hard disc on the PC started producing 'disc seek' errors and it was found necessary to terminate logging to the hard disc in order to keep the system running.

Meteorological System

The system was run continuously throughout the cruise and worked well apart from a faulty humidity sensor, which was later found to have water ingress, and also some initial problems with the hull temperature sensor. Air temperature, sea temperature, wind speed and direction, total irradiance and PAR data were routinely logged.

Ship Systems

The EA500 echo sounder and Chernikeeff speed log gave no problems.

Argos Drifters

Three Argos and one GPS drifting buoys (the latter on loan from DML) were deployed on the first leg of the cruise at the centre of the SF_6 gas tracer deployment grid. Due to the clement weather conditions the buoys performed reasonably well in marking the tracer patch and their track confirmed the anti-cyclonic rotation of the eddy. One Argos buoy remained deployed through to Leg 2 in order to allow approximate relocation of the main Leg 1 sampling site as the initial station on the N-S transect. All buoys were deployed and retrieved successfully.

5. ACKNOWLEDGEMENTS

The success of the cruise depended so much on the efforts, support and goodwill of many people. Particular thanks are due to:

Captain K O Avery, Master of RRS *Discovery* for Cruise 221, the Officers and Crew for their interest and all their practical assistance during the six and a half weeks of the cruise,

the RVS Technical and Support staff for their help both during the lengthy preparatory phase of the cruise and also for keeping all the basic shipboard systems functioning during the cruise itself and for supplying information on Argos buoy positions,

the RVS Operations staff for smoothing the cruise preparations and for acting as liason during the cruise,

David Meldrum (DML) for the loan of a GPS Argos buoy and for providing position updates so readily during the first Leg of the cruise,

Steve Groom and his assistants for provision of satellite images,

the Scientists, both first-timers and the more experienced, who were involved in the planning of the cruise or who participated in the cruise itself: their enthusiasm, support and interest and ability to put up with the vagaries of both circumstance and the PI contributed so much to the success of the Programme. Thank you for making my task so much the easier,

the Scientific Co-Ordinator of the PRIME Programme, Professor P J LeB Williams, for initiating the cruise and the Project Manager, Graeme Hays, for his assistance in enabling the cruise arrangements.

To those who also helped in the success of the cruise but whom I have not mentioned individually, again I pass on my thanks.

Graham Savidge
Portaferry
Northern Ireland

18 November 1996

APPENDICES

In all appendices, the event number is logged, together with the start and end dates and times and the start and end positions. Extra details are also given as appropriate.

APPENDIX 6.1

CTD CASTS

DI221	CTD1	CTD		6/14/96 19:15	6/14/96 21:07	57.50037	-20.24830	57.50226	-20.23710		WINCH PROBLEMS
DI221	CTD2	CTD		6/17/96 22:20	6/17/96 23:30	59.36344	-20.23580	59.35811	-20.20290		
DI221	CTD3	CTD		6/18/96 0:56	6/18/96 1:34	59.34397	-20.17170	59.33575	-20.16430		
DI221	CTD4	CTD		6/19/96 0:33	6/19/96 1:14	59.27229	-20.00810	59.26423	-20.01000		75m bottle FAILED
DI221	CTD5	CTD		6/19/96 2:53	6/19/96 3:08	59.24471	-20.01360	59.24186	-20.01420		prod cast
DI221	CTD6	CTD		6/19/96 13:03	6/19/96 13:39	59.13846	-20.10510	59.13362	-20.11980		30m bottle LEAKED
DI221	CTD7	CTD		6/20/96 1:11	6/20/96 1:54	59.08502	-20.17070	59.08445	-20.19180		200m bottle LEAKED
DI221	CTD8	CTD		6/20/96 2:51	6/20/96 3:11	59.08663	-20.22090	59.08545	-20.23210		prod cast
DI221	CTD9	CTD		6/20/96 14:08	6/20/96 14:53	59.09062	-20.50780	59.09763	-20.51980		
DI221	CTD10	CTD		6/21/96 1:19	6/21/96 2:00	59.24568	-20.52870	59.24612	-20.52010		
DI221	CTD11	CTD		6/21/96 2:55	6/21/96 3:20	59.24568	-20.50900	59.24541	-20.50410		prod cast
DI221	CTD12	CTD		6/21/96 14:36	6/21/96 15:09	59.23166	-20.33630	59.22893	-20.33030		
DI221	CTD13	CTD		6/22/96 1:30	6/22/96 2:03	59.21788	-20.14310	59.21005	-20.12980		
DI221	CTD14	CTD		6/22/96 3:01	6/22/96 3:19	59.19332	-20.11510	59.18904	-20.10980		prod cast
DI221	CTD15	CTD		6/22/96 13:46	6/22/96 14:18	59.08813	-20.02970	59.08214	-20.02940		
DI221	CTD16	CTD		6/23/96 1:15	6/23/96 1:47	58.98128	-20.00850	58.97381	-20.01440		
DI221	CTD17	CTD		6/23/96 2:45	6/23/96 3:00	58.96157	-20.02420	58.95942	-20.02900		
DI221	CTD18	CTD		6/23/96 13:35	6/23/96 14:11	58.97457	-20.36270	58.97315	-20.36930		
DI221	CTD19	CTD		6/24/96 13:08	6/24/96 13:43	59.06581	-20.62340	59.06749	-20.63050		
DI221	CTD20	CTD		6/25/96 0:49	6/25/96 1:22	59.13726	-20.74880	59.14107	-20.74120		
DI221	CTD21	CTD		6/25/96 2:40	6/25/96 2:56	59.14339	-20.73090	59.14282	-20.72610		prod cast
DI221	CTD22	CTD		6/25/96 3:56	6/25/96 4:15	59.14471	-20.72700	59.14691	-20.72880		
DI221	CTD23	CTD		6/25/96 13:02	6/25/96 13:32	59.19319	-20.61510	59.19102	-20.60040		
DI221	CTD24	CTD		6/26/96 1:37	6/26/96 2:19	59.18220	-20.48220	59.17225	-20.46750		
DI221	CTD25	CTD		6/26/96 3:33	6/26/96 3:54	59.16088	-20.45690	59.15671	-20.45080		prod cast
DI221	CTD26	CTD		6/27/96 0:52	6/27/96 1:27	58.99218	-20.65860	58.98932	-20.66390		
DI221	CTD27	CTD		6/27/96 2:18	6/27/96 2:31	58.98355	-20.67490	58.98245	-20.67780		
DI221	CTD28	CTD		6/27/96 12:55	6/27/96 13:26	59.05363	-20.98680	59.05915	-20.99630		
DI221	CTD29	CTD		6/27/96 17:03	6/27/96 19:02	59.09818	-20.14390	59.08601	-20.18300		
DI221	CTD30	CTD		6/27/96 20:41	6/27/96 23:12	59.09577	-19.79530	59.07888	-19.81970		deep cast
DI221	CTD31	CTD	CS1	6/28/96 1:39	6/28/96 2:13	59.09716	-19.44670	59.09678	-19.44810		prod cast
DI221	CTD32	CTD		6/28/96 6:57	6/28/96 9:27	59.10420	-19.42590	59.09713	-19.40990		deep cast
DI221	CTD33	CTD	CS4	6/28/96 13:41	6/28/96 14:14	59.08926	-20.51680	59.08329	-20.52930		
DI221	CTD34	CTD	CS4	6/28/96 14:57	6/28/96 17:12	59.07762	-20.54520	59.06469	-20.59890		deep cast
DI221	CTD35	CTD	CS5	6/28/96 18:57	6/28/96 20:57	59.10452	-20.85640	59.10193	-20.90070		deep cast
DI221	CTD36	CTD	CS6	6/28/96 22:59	6/29/96 1:11	59.10215	-21.20680	59.12326	-21.22100		

DI221	CTD37	CTD	CS7	6/29/96 3:51	6/29/96 4:28	59.11045	-21.71080	59.11719	-21.70850		prod cast	
DI221	CTD38	CTD	CS7	6/29/96 5:08	6/29/96 7:23	59.12522	-21.70820	59.15063	-21.69950		deep cast	
DI221	CTD39	CTD		04/07/96 03:25	04/07/96 04:20	59.30985	-21.14445	59.30980	-21.14085	2,878.00	prod cast	
DI221	CTD40	CTD		04/07/96 06:11	04/07/96 06:24	59.31778	-21.20431	59.31954	-21.21071	2,881.00		
DI221	CTD41	CTD		04/07/96 11:25	04/07/96 11:44	59.36642	-21.33805	59.36954	-21.34462	2,879.00	stable isotopes	
DI221	CTD42	CTD	202	05/07/96 00:38	05/07/96 01:11	57.54363	-21.11630	57.54240	-21.11663	2,337.00	Level1	
DI221	CTD43	CTD	202	05/07/96 02:13	05/07/96 02:27	57.54358	-21.11839	57.54411	-21.11600	2,331.00	prod cast	
DI221	CTD44	CTD		06/07/96 01:20	06/07/96 01:50	53.99454	-20.69887	53.99988	-20.69652	2,586.00	Level1	
DI221	CTD45	CTD		06/07/96 02:59	06/07/96 03:12	54.00581	-20.69180	54.00607	-20.69108	2,607.00	prod cast	
DI221	CTD46	CTD		07/07/96 01:18	07/07/96 01:52	50.33645	-20.32645	50.33728	-20.33350	4,422.00	Level1	
DI221	CTD47	CTD		07/07/96 02:50	07/07/96 03:04	50.33886	-20.34654	50.33961	-20.34952	4,408.00	prod cast	
DI221	CTD48	CTD		08/07/96 01:36	08/07/96 02:32	46.99335	-20.00080	46.98327	-20.00292	4,506.00	Level1	
DI221	CTD49	CTD		08/07/96 04:12	08/07/96 04:27	46.96744	-20.01371	46.96716	-20.01492	4,450.00	prod cast	
DI221	CTD50	CTD		08/07/96 11:17	08/07/96 11:44	46.99850	-20.00292	46.99748	-20.00551	4,503.00	stable isotopes	
DI221	CTD51	CTD		09/07/96 01:57	09/07/96 02:23	44.45987	-19.73205	44.45591	-19.73593	4,134.00	Level1	
DI221	CTD52	CTD		07/10/96 02:05	07/10/96 02:35	40.61170	-19.34536	40.61621	-19.35087	4,809.92	prod cast	
DI221	CTD53	CTD		07/10/96 03:55	07/10/96 04:05	40.62680	-19.35837	40.62855	-19.35932	4,758.92		
DI221	CTD54	CTD		07/11/96 02:34	07/11/96 03:11	37.00974	-19.00484	37.00795	-19.00169	4,589.18	Level1	
DI221	CTD55	CTD		07/11/96 04:35	07/11/96 04:55	37.00977	-19.00251	37.00980	-19.00536	4,630.38	prod cast	
DI221	CTD56	CTD		07/11/96 06:13	07/11/96 06:27	37.00619	-19.01168	37.00545	-19.01357	4,616.48		
DI221	CTD57	CTD		07/11/96 08:05	07/11/96 10:11	36.99136	-19.03967	36.99775	-19.04808	4,672.61	deep cast	
DI221	CTD58	CTD		07/11/96 11:28	07/11/96 11:48	36.99834	-19.05181	36.99860	-19.05378	4,690.64	stable isotopes	
DI221	CTD59	CTD		07/11/96 12:45	07/11/96 13:22	36.99694	-19.06414	36.99448	-19.07114	4,703.00	Level 1	
DI221	CTD60	CTD		07/12/96 02:05	07/12/96 02:38	36.96932	-19.14746	36.96850	-19.15182	4,924.99	Level1	
DI221	CTD61	CTD		07/12/96 03:47	07/12/96 04:06	36.96753	-19.15706	36.96698	-19.15674	4,942.50	prod cast	
DI221	CTD62	CTD		07/12/96 06:03	07/12/96 06:34	36.95385	-19.16648	36.95206	-19.16793	4,968.77		
DI221	CTD63	CTD		07/12/96 11:21	07/12/96 11:46	36.94499	-19.19550	36.94520	-19.19699	4,981.64	stable isotopes	
DI221	CTD64	CTD		07/12/96 13:09	07/12/96 13:41	36.94620	-19.20203	36.94197	-19.20084	4,985.76	Level 1	
DI221	CTD65	CTD		07/12/96 18:03	07/12/96 18:40	36.92189	-19.21141	36.92216	-19.21157	4,858.04		
DI221	CTD66	CTD		13/07/96 02:06	13/07/96 02:33	36.91775	-19.21523	36.91439	-19.21507	0	Level1	
DI221	CTD67	CTD		13/07/96 03:43	13/07/96 03:57	36.91097	-19.21764	36.90858	-19.21690	4,848.77	prod cast	
DI221	CTD68	CTD		13/07/96 11:07	13/07/96 11:32	36.88417	-19.24467	36.88292	-19.24257	5,020.27	stable isotopes	
DI221	CTD69	CTD		13/07/96 12:42	13/07/96 13:17	36.88192	-19.24182	36.87971	-19.23801	5,023.87	Level 1	
DI221	CTD70	CTD		13/07/96 19:08	13/07/96 19:32	36.86998	-19.22615	36.86998	-19.22712	4,943.02		
DI221	CTD71	CTD		14/07/96 02:05	14/07/96 02:39	36.82371	-19.23673	36.82326	-19.23597	4,512.63	Level 1	
DI221	CTD72	CTD		14/07/96 06:03	14/07/96 12:14	36.79462	-19.24328	36.78851	-19.24153	5,019.75	deep cast - spooling p	

DI221	CTD73	CTD		14/07/96 13:38	14/07/96 14:03	36.73809	-19.24953	36.73876	-19.24899	5,208.82	stable isotopes
DI221	CTD74	CTD		14/07/96 15:32	14/07/96 15:59	36.73657	-19.24902	36.73444	-19.24942	5,208.82	Level 1
DI221	CTD75	CTD		14/07/96 20:19	14/07/96 20:48	36.70842	-19.22593	36.70649	-19.22830	5,157.34	
DI221	CTD76	CTD		15/07/96 02:04	15/07/96 02:30	36.69059	-19.22479	36.68937	-19.22549	5,142.84	Level1
DI221	CTD77	CTD		15/07/96 03:34	15/07/96 03:47	36.68559	-19.22686	36.68488	-19.22801	5,220.26	prod cast
DI221	CTD78	CTD		15/07/96 06:15	15/07/96 06:40	36.65339	-19.21380	36.65187	-19.21420	5,412.70	
DI221	CTD79	CTD		15/07/96 11:04	15/07/96 11:33	36.63312	-19.23096	36.63223	-19.23192	5,432.98	stable isotopes
DI221	CTD80	CTD		15/07/96 13:09	15/07/96 13:41	36.63314	-19.23595	36.63385	-19.23719	5,431.94	Level 1
DI221	CTD81	CTD		15/07/96 18:38	15/07/96 19:06	36.57654	-19.20028	36.57560	-19.20301	5,444.94	
DI221	CTD82	CTD		16/07/96 02:07	16/07/96 02:35	36.50756	-19.20515	36.50313	-19.20877	5,471.86	Level1
DI221	CTD83	CTD		16/07/96 03:57	16/07/96 04:12	36.49048	-19.21540	36.48859	-19.21761	5,436.10	prod cast
DI221	CTD84	CTD		16/07/96 05:34	16/07/96 05:49	36.46834	-19.19828	36.46725	-19.20051	5,434.54	
DI221	CTD85	CTD		16/07/96 06:13	16/07/96 06:41	36.46733	-19.20349	36.46414	-19.20617	5,428.30	
DI221	CTD86	CTD		16/07/96 11:17	16/07/96 11:48	36.44487	-19.17904	36.43699	-19.17951	5,201.02	stable isotopes
DI221	CTD87	CTD		16/07/96 13:32	16/07/96 14:03	36.41988	-19.18314	36.41558	-19.18484	4,994.00	Level 1
DI221	CTD88	CTD		16/07/96 18:06	16/07/96 18:37	36.38402	-19.15668	36.38023	-19.15865	5,426.22	
DI221	CTD89	CTD		17/07/96 02:09	17/07/96 02:35	36.31485	-19.15239	36.31322	-19.15728	5,498.64	Level1
DI221	CTD90	CTD		17/07/96 03:41	17/07/96 03:54	36.30786	-19.16372	36.30789	-19.16408	5,499.16	prod cast
DI221	CTD91	CTD		17/07/96 05:35	17/07/96 05:49	36.30396	-19.13626	36.30241	-19.13660	5,501.73	
DI221	CTD92	CTD		17/07/96 06:16	17/07/96 06:40	36.29955	-19.13636	36.29689	-19.13723	5,501.73	
DI221	CTD93	CTD		17/07/96 11:08	17/07/96 11:33	36.24660	-19.12022	36.24485	-19.12219	5,507.40	stable isotopes
DI221	CTD94	CTD		17/07/96 13:26	17/07/96 13:54	36.23491	-19.13070	36.23198	-19.13225	5,306.58	Level 1
DI221	CTD95	CTD		17/07/96 18:11	17/07/96 18:41	36.22162	-19.14404	36.22066	-19.14243	5,499.16	
DI221	CTD96	CTD		18/07/96 02:02	18/07/96 02:30	36.12209	-19.15742	36.12132	-19.16142	5,488.86	Level1
DI221	CTD97	CTD		18/07/96 03:33	18/07/96 03:48	36.12050	-19.17050	36.12010	-19.17307	5,487.83	prod cast
DI221	CTD98	CTD		18/07/96 06:03	18/07/96 06:30	36.10961	-19.16835	36.11035	-19.17150	5,489.89	
DI221	CTD99	CTD		18/07/96 11:09	18/07/96 11:43	36.07373	-19.15331	36.07153	-19.15294	5,495.04	stable isotopes
DI221	CTD100	CTD		18/07/96 13:42	18/07/96 14:13	36.05684	-19.16514	36.05070	-19.17218	5,496.58	Level 1
DI221	CTD101	CTD		18/07/96 17:30	18/07/96 17:57	36.02076	-19.20744	36.01977	-19.20983	5,445.98	

APPENDIX 6.2

GO-FLO BOTTLE CASTS

DI221	GF1	Go-Flos		6/18/96 1:43	6/18/96 2:34	59.33299	-20.16340	59.32185	-20.15620		GM,TB,EE,DP/RH
DI221	GF2	Go-Flos		6/19/96 1:27	6/19/96 4:07	59.26237	-20.01100	59.22919	-20.01620		GM,TB,EE,DP/RH,AB
DI221	GF3	Go-Flos		6/19/96 13:46	6/19/96 14:18	59.13293	-20.12270	59.13018	-20.14120		DP/RH,GM,GT,MW
DI221	GF4	Go-Flos		6/20/96 2:02	6/20/96 3:32	59.08522	-20.19640	59.08497	-20.24480		GM,DP/RH,EE,MW
DI221	GF5	Go-Flos		6/20/96 14:59	6/20/96 15:11	59.09844	-20.52150	59.09993	-20.52480		RH/DP,GM,MW
DI221	GF6	Go-Flos		6/21/96 2:07	6/21/96 4:02	59.24593	-20.51830	59.24534	-20.49550		GM,TB,RH/DP,GT,M
DI221	GF7	Go-Flos		6/21/96 15:15	6/21/96 15:32	59.22798	-20.32890	59.22638	-20.32400		GM,RH/DP,GT,MW
DI221	GF8	Go-Flos		6/22/96 2:35	6/22/96 4:39	59.20076	-20.12190	59.16666	-20.09870		GM,TB,RH/DP,EE,M
DI221	GF9	Go-Flos		6/22/96 14:26	6/22/96 14:46	59.08112	-20.02940	59.07645	-20.02960		GM,RH/DP,MW
DI221	GF10	Go-Flos		6/23/96 2:17	6/23/96 3:29	58.96811	-20.02100	58.95264	-20.03620		GM,TB,RH/DP,EE,M
DI221	GF11	Go-Flos		6/23/96 14:17	6/23/96 14:45	58.97327	-20.36930	58.97338	-20.37300		GM,DP/RH,GT,MW
DI221	GF12	Go-Flos		6/24/96 13:50	6/24/96 14:10	59.06863	-20.63190	59.06859	-20.63320		GM,RH,MW
DI221	GF13	Go-Flos		6/25/96 2:11	6/25/96 3:28	59.14327	-20.73320	59.14441	-20.72680		GM,TB,RH,EE,MW,A
DI221	GF14	Go-Flos		6/25/96 13:40	6/25/96 14:25	59.19017	-20.59670	59.18471	-20.58270		GM,RH,MW
DI221	GF15	Go-Flos		6/26/96 3:00	6/26/96 3:58	59.16673	-20.46040	59.15560	-20.45060		GM,TB,RH,EE,MW,A
DI221	GF16	Go-Flos		6/27/96 1:42	6/27/96 3:04	58.98813	-20.66810	58.98146	-20.68400		GM,RH,TB,EE,MW
DI221	GF17	Go-Flos		6/27/96 13:32	6/27/96 13:47	59.05860	-20.99790	59.06075	-21.00230		GM,RH,MW
DI221	GF18	Go-Flos	CS1	6/28/96 2:57	6/28/96 4:10	59.09349	-19.44830	59.09113	-19.44730		AB,RH/DP,EE,AR
DI221	GF19	Go-Flos	CS4	6/28/96 14:23	6/28/96 14:39	59.08262	-20.53410	59.08032	-20.54160		RH,AR,MW,AB
DI221	GF20	Go-Flos	CS5	6/28/96 18:43	6/28/96 18:45	59.10491	-20.85000	59.10467	-20.85110		1 bottle
DI221	GF21	Go-Flos	CS6	6/28/96 22:23	6/28/96 22:25	59.10015	-21.20460	59.10048	-21.20480		1 bottle
DI221	GF22	Go-Flos	CS7	6/29/95 7:33	6/29/96 7:38	59.15108	-21.69930	59.15289	-21.70000		AB,DP/RH
DI221	GF23	GoFlos		04/07/96 05:25	04/07/96 07:45	59.31290	-21.17616	59.33014	-21.24667		APB,HK,SG,RH,TB,C
DI221	GF24	GoFlos		04/07/96 08:18	04/07/96 11:15	59.33453	-21.26172	59.36447	-21.33288		deep bottle
DI221	GF25	Go-Flos	202	05/07/96 01:20	05/07/96 02:49	57.54269	-21.11797	57.54269	-21.11797		HK,RH,GT,CS,AB,AR
DI221	GF26	Go-Flos		06/07/96 02:00	06/07/96 03:36	54.00054	-20.69463	54.00858	-20.69299		HK,RH,CS,APB
DI221	GF27	Go-Flos		07/07/96 02:00	07/07/96 03:26	50.33756	-20.33508	50.33786	-20.35290		HK,RH,AB,CS,AR,AP
DI221	GF28	Go-Flos		08/07/96 02:40	08/07/96 04:37	46.98164	-20.00365	46.96638	-20.01456		HK,SG,RH,APB,AB,T
DI221	GF29	Go-Flos		09/07/96 02:53	09/07/96 04:03	44.44881	-19.74227	44.43715	-19.75590		HK,RH,AR,APB,AB
DI221	GF30	Go-Flos		07/10/96 02:43	07/10/96 03:38	40.61761	-19.35182	40.62538	-19.35709	4,797.68	HK,RH,AB,CS,APB
DI221	GF31	Go-Flos		07/11/96 03:20	07/11/96 05:15	37.00841	-19.00131	37.01050	-19.00418	4,665.40	HK,TB,AB,CS,APB
DI221	GF32	Go-Flos		07/11/96 13:27	07/11/96 13:34	36.99362	-19.07220	36.99329	-19.07356	4,736.47	APB,RH
DI221	GF33	Go-Flos		07/12/96 02:46	07/12/96 04:20	36.96785	-19.15321	36.96661	-19.15628	4,940.96	HK,TB,APB,AB
DI221	GF34	Go-Flos		07/12/96 13:47	07/12/96 14:22	36.94204	-19.20082	36.94160	-19.20168	4,982.16	AB,RH
DI221	GF35	Go-Flos		13/07/96 02:42	13/07/96 05:12	36.91446	-19.21542	36.90723	-19.21758	4,472.85	HK,TB,AR,AB,CS,AP
DI221	GF36	Go-Flos		13/07/96 13:23	13/07/96 18:12	36.87897	-19.23769	36.86782	-19.22730	5,029.02	2,10,30,65,4000M

DI221	GF37	Go-Flos		14/07/96 02:47	14/07/96 05:03	36.82237	-19.23697	36.81381	-19.23850	4,514.16	HK,AB,APB,DS,AR
DI221	GF38	Go-Flos		14/07/96 16:05	14/07/96 16:40	36.73329	-19.24937	36.73077	-19.25020	5,209.34	AB,RH
DI221	GF39	Go-Flos		15/07/96 02:40	15/07/96 04:40	36.68848	-19.22601	36.68131	-19.22792	5,204.66	HK,TB,AB,CS,APB,D
DI221	GF40	Go-Flos		15/07/96 06:50	15/07/96 10:40	36.65115	-19.21488	36.63611	-19.22904	5,422.06	deep bottle
DI221	GF41	Go-Flos		15/07/96 13:50	15/07/96 14:15	36.63500	-19.23709	36.63529	-19.23799	5,431.42	AB,APB,DS/WW,RH
DI221	GF42	Go-Flos		15/07/96 20:44	15/07/96 20:49	36.55228	-19.19781	36.55169	-19.19833	5,480.10	WW
DI221	GF43	Go-Flos		16/07/96 02:41	16/07/96 04:29	36.50166	-19.20881	36.48577	-19.21930	5,457.94	HK,TB,AB,APB,DS
DI221	GF44	Go-Flos		16/07/96 14:06	16/07/96 15:06	36.41576	-19.18508	36.40772	-19.18845	5,272.07	APB,AB,RH
DI221	GF45	Go-Flos		17/07/96 02:43	17/07/96 04:27	36.31299	-19.15826	36.30582	-19.16347	5,499.16	HK,TB,CS,AB,APB,D
DI221	GF46	Go-Flos		17/07/96 14:00	17/07/96 14:25	36.23137	-19.13277	36.22886	-19.13531	5,503.79	WW/DS,AB,APB,RH
DI221	GF47	Go-Flos		17/07/96 20:23	17/07/96 20:29	36.18805	-19.12110	36.18678	-19.12134	5,496.58	WW
DI221	GF48	Go-Flos		18/07/96 02:37	18/07/96 04:12	36.12100	-19.16208	36.11940	-19.17711	5,488.34	HK,TB,CS,APB,DS
DI221	GF49	Go-Flos		18/07/96 14:19	18/07/96 15:25	36.04924	-19.17340	36.03619	-19.18609	5,494.52	APB,RH,WW

APPENDIX 6.3

LHPR TOWS

DI221	LHPR1	LHPR		08/07/96 05:08	08/07/96 07:10	46.96386	-20.02250	46.93751	-20.21689	
DI221	LHPR2	LHPR		13/07/96 06:28	13/07/96 08:33	36.92849	-19.21103	36.98003	-19.04660	5,009.97
DI221	LHPR3	LHPR		15/07/96 14:40	15/07/96 17:03	36.64477	-19.23634	36.80159	-19.23843	5,431.42
DI221	LHPR4	LHPR		17/07/96 06:55	17/07/96 09:03	36.30024	-19.14126	36.42410	-19.20049	5,501.73
DI221	LHPR5	LHPR		18/07/96 06:48	18/07/96 08:57	36.11658	-19.17388	36.25603	-19.16084	5,487.83

APPENDIX 6.4

MESOZOOPLANKTON NET HAULS

		MESH SIZE							DEPTH
DI221	WP2-1	WP2-500	6/14/96 18:02	6/14/96 18:14	57.49981	-20.24840	57.50110	-20.24570	100m - shakedown
DI221	WP2-2	WP2-200	6/14/96 18:18	6/14/96 18:26	57.50103	-20.24540	57.50175	-20.24420	100m
DI221	WP2-3	WP2-200	6/14/96 18:28	6/14/96 18:35	57.50199	-20.24380	57.50229	-20.24270	100m
DI221	WP2-4	WP2-50	6/14/96 18:37	6/14/96 18:45	57.50223	-20.24230	57.50292	-20.24070	100m - NO SAMPLE
DI221	WP2-5	WP2-200	6/18/96 0:14	6/18/96 0:23	59.35295	-20.18540	59.35093	-20.18260	100M
DI221	WP2-6	WP2-500	6/18/96 0:26	6/18/96 0:33	59.35014	-20.18200	59.34904	-20.17960	100M
DI221	WP2-7	WP2-50	6/18/96 0:35	6/18/96 0:42	59.34875	-20.17920	59.34728	-20.17670	100M
DI221	WP2-8	WP2-50	6/18/96 23:39	6/18/96 23:47	59.28506	-20.00180	59.28329	-20.00320	100M
DI221	WP2-9	WP2-500	6/18/96 23:50	6/19/96 0:00	59.28238	-20.00390	59.28003	-20.00480	100M
DI221	WP2-10	WP2-500	6/19/96 0:02	6/19/96 0:13	59.27940	-20.00490	59.27707	-20.00610	100M
DI221	WP2-11	WP2-200	6/19/96 0:13	6/19/96 0:20	59.27707	-20.00610	59.27558	-20.00700	100M
DI221	WP2-12	WP2-50	6/19/96 12:15	6/19/96 12:22	59.14503	-20.08480	59.14335	-20.08750	100M
DI221	WP2-13	WP2-500	6/19/96 12:24	6/19/96 12:30	59.14308	-20.08830	59.14164	-20.09060	100M
DI221	WP2-14	WP2-500	6/19/96 12:32	6/19/96 12:39	59.14157	-20.09120	59.14083	-20.09420	100M
DI221	WP2-15	WP2-200	6/19/96 12:41	6/19/96 12:47	59.14047	-20.09470	59.13958	-20.09750	100M
DI221	WP2-15B	Apstein net	6/19/96 12:52	6/19/96 12:57	59.13915	-20.09900	59.13870	-20.10160	
DI221	WP2-16	WP2-50	6/20/96 0:28	6/20/96 0:35	59.08697	-20.15240	59.08647	-20.15530	100M
DI221	WP2-17	WP2-500	6/20/96 0:37	6/20/96 0:43	59.08691	-20.15580	59.08622	-20.15890	100M
DI221	WP2-18	WP2-500	6/20/96 0:45	6/20/96 0:51	59.08605	-20.15990	59.08547	-20.16260	100M
DI221	WP2-19	WP2-200	6/20/96 0:53	6/20/96 1:00	59.08544	-20.16360	59.08554	-20.16630	100M
DI221	WP2-20	WP2-50	6/20/96 13:12	6/20/96 13:20	59.08402	-20.49100	59.08517	-20.49390	100M
DI221	WP2-21	WP2-500	6/20/96 13:22	6/20/96 13:29	59.08541	-20.49470	59.08612	-20.49630	100M
DI221	WP2-22	WP2-500	6/20/96 13:31	6/20/96 13:39	59.08657	-20.49700	59.08734	-20.49970	100M
DI221	WP2-23	WP2-200	6/20/96 13:41	6/20/96 13:47	59.08753	-20.50020	59.08827	-20.50200	100M
DI221	WP2-23B	Apstein net	6/20/96 13:51	6/20/96 13:56	59.08837	-20.50280	59.08907	-20.50430	
DI221	WP2-24	WP2-50	6/21/96 0:27	6/21/96 0:35	59.24247	-20.53980	59.24299	-20.53800	
DI221	WP2-25	WP2-500	6/21/96 0:41	6/21/96 0:48	59.24315	-20.53600	59.24266	-20.53430	
DI221	WP2-26	WP2-500	6/21/96 0:51	6/21/96 0:58	59.24356	-20.53310	59.24383	-20.53120	
DI221	WP2-27	WP2-200	6/21/96 1:00	6/21/96 1:07	59.24406	-20.53100	59.24472	-20.53060	
DI221	WP2-28	WP2-50	6/21/96 13:29	6/21/96 13:36	59.24055	-20.33430	59.24011	-20.33350	100M
DI221	WP2-29	WP2-500	6/21/96 13:39	6/21/96 13:45	59.24010	-20.33280	59.23952	-20.33100	100M
DI221	WP2-30	WP2-500	6/21/96 13:47	6/21/96 13:55	59.23933	-20.33010	59.23876	-20.32690	100M
DI221	WP2-31	WP2-200	6/21/96 14:02	6/21/96 14:09	59.23534	-20.32800	59.23448	-20.32760	100M
DI221	WP2-31B	Apstein net	6/21/96 14:20	6/21/96 14:26	59.23312	-20.33720	59.23266	-20.33680	
DI221	WP2-32	WP2-50	6/22/96 0:46	6/22/96 0:53	59.22484	-20.16310	59.22410	-20.15890	100M

DI221	WP2-33	WP2-500		6/22/96 0:53	6/22/96 0:56	59.22410	-20.15890	59.22380	-20.15720		100M	
DI221	WP2-34	WP2-500		6/22/96 1:01	6/22/96 1:04	59.22351	-20.15490	59.22294	-20.15450		100M	
DI221	WP2-35	WP2-200		6/22/96 1:10	6/21/96 1:12	59.22163	-20.15200	59.24542	-20.52950		100M	
DI221	WP2-36	WP2-50		6/22/96 12:20	6/22/96 12:27	59.10826	-19.94130	59.10639	-19.94040			
DI221	WP2-37	WP2-500		6/22/96 12:29	6/22/96 12:37	59.10584	-19.94060	59.10396	-19.93980			
DI221	WP2-38	WP2-500		6/22/96 12:39	6/22/96 12:45	59.10367	-19.93950	59.10249	-19.93890			
DI221	WP2-39	WP2-200		6/22/96 12:48	6/22/96 12:55	59.10132	-19.93890	59.09919	-19.93900			
DI221	WP2-39B	Apstein net		6/22/96 12:58	6/22/96 13:04	59.09809	-19.93890	59.09666	-19.93830			
DI221	WP2-40	WP2-50		6/23/96 0:05	6/23/96 0:12	58.99749	-20.04170	58.99719	-20.04460		100M	
DI221	WP2-41	WP2-500		6/23/96 0:14	6/23/96 0:20	58.99638	-20.04540	58.99438	-20.04610		100M	
DI221	WP2-42	WP2-500		6/23/96 0:22	6/23/96 0:29	58.99437	-20.04560	58.99278	-20.04740		100M	
DI221	WP2-43	WP2-200		6/23/96 0:32	6/23/96 0:38	58.99239	-20.04740	58.99045	-20.04850		100M	
DI221	WP2-44	WP2-50		6/23/96 12:48	6/23/96 12:55	58.97801	-20.35800	58.97766	-20.35780		100M	
DI221	WP2-45	WP2-500		6/23/96 12:57	6/23/96 13:04	58.97783	-20.35790	58.97788	-20.35800		100M	
DI221	WP2-46	WP2-500		6/23/96 13:06	6/23/96 13:12	58.97789	-20.35830	58.97729	-20.35960		100M	
DI221	WP2-47	WP2-200		6/23/96 13:15	6/23/96 13:22	58.97705	-20.35990	58.97615	-20.36140		100M	
DI221	WP2-48	WP2-50		6/24/96 12:23	6/24/96 12:32	59.06152	-20.61400	59.06205	-20.61660		100M	
DI221	WP2-49	WP2-500		6/24/96 12:34	6/24/96 12:41	59.06232	-20.61680	59.06265	-20.61790		100M	
DI221	WP2-50	WP2-500		6/24/96 12:44	6/24/96 12:51	59.06354	-20.61840	59.06360	-20.61940		100M	
DI221	WP2-51	WP2-200		6/24/96 12:54	6/24/96 13:01	59.06405	-20.62030	59.06510	-20.62180		100M	
DI221	WP2-52	WP2-50		6/25/96 0:03	6/25/96 0:10	59.13251	-20.75730	59.13348	-20.75620		100M	
DI221	WP2-53	WP2-500		6/25/96 0:12	6/25/96 0:18	59.13354	-20.75640	59.13463	-20.75580		100M	
DI221	WP2-54	WP2-500		6/25/96 0:20	6/25/96 0:27	59.13499	-20.75540	59.13517	-20.75440		100M	
DI221	WP2-55	WP2-200		6/25/96 0:29	6/25/96 0:36	59.13611	-20.75400	59.13702	-20.75220		100M	
DI221	WP2-56	WP2-50		6/25/96 12:11	6/25/96 12:19	59.19374	-20.63500	59.19378	-20.63210		100M	
DI221	WP2-57	WP2-500		6/25/96 12:20	6/25/96 12:26	59.19372	-20.63180	59.19414	-20.62970		100M	
DI221	WP2-58	WP2-500		6/25/96 12:29	6/25/96 12:38	59.19414	-20.62860	59.19389	-20.62510		100M	
DI221	WP2-59	WP2-200		6/25/96 12:40	6/25/96 12:46	59.19401	-20.62410	59.19382	-20.62080		100M	
DI221	WP2-60	WP2-500		6/26/96 0:42	6/26/96 0:51	59.19092	-20.50080	59.18961	-20.49700			
DI221	WP2-61	WP2-500		6/26/96 0:55	6/26/96 1:03	59.18979	-20.49570	59.18806	-20.49280			
DI221	WP2-62	WP2-200		6/26/96 1:07	6/26/96 1:14	59.18752	-20.49260	59.18628	-20.49080			
DI221	WP2-63	WP2-50		6/26/96 1:18	6/26/96 1:25	59.18544	-20.49000	59.18428	-20.48780			
DI221	WP2-64	WP2-50		6/27/96 0:04	6/27/96 0:07	58.99751	-20.64180	58.99668	-20.64310		100M	
DI221	WP2-65	WP2-500		6/27/96 0:12	6/27/96 0:15	58.99683	-20.64480	58.99608	-20.64640		100M	
DI221	WP2-66	WP2-500		6/27/96 0:25	6/27/96 0:32	58.99550	-20.64970	58.99506	-20.65210		100M	
DI221	WP2-67	WP2-200		6/27/96 0:34	6/27/96 0:41	58.99497	-20.65270	58.99400	-20.65500		100M	

DI221	WP2-69	WP2-50		6/27/96 12:14	6/27/96 12:22	59.04747	-20.97120	59.04891	-20.97320		100M
DI221	WP2-70	WP2-500		6/27/96 12:24	6/27/96 12:30	59.04910	-20.97380	59.04988	-20.97810		100M
DI221	WP2-71	WP2-500		6/27/96 12:33	6/27/96 12:39	59.05010	-20.98000	59.05066	-20.98140		100M
DI221	WP2-72	WP2-200		6/27/96 12:42	6/27/96 12:49	59.05143	-20.98290	59.05232	-20.98500		100M
DI221	WP2-73	WP2-500		6/27/96 23:19	6/27/96 23:25	59.07795	-19.82240	59.07641	-19.82450		50M
DI221	WP2-74	WP2-50	CS1	6/28/96 0:52	6/28/96 0:59	59.09897	-19.43880	59.09921	-19.44030		100M
DI221	WP2-75	WP2-500	CS1	6/28/96 1:01	6/28/96 1:09	59.09885	-19.44010	59.09838	-19.44150		100M
DI221	WP2-76	WP2-500	CS1	6/28/96 1:11	6/28/96 1:17	59.09816	-19.44100	59.09814	-19.44270		100M
DI221	WP2-77	WP2-200	CS1	6/28/96 1:20	6/28/96 1:27	59.09807	-19.44250	59.09742	-19.44370		100M
DI221	WP2-78	WP2-50	CS4	6/28/96 12:51	6/28/96 13:00	59.09719	-20.50080	59.09592	-20.50340		100M
DI221	WP2-79	WP2-500	CS4	6/28/96 13:08	6/28/96 13:17	59.09414	-20.50550	59.09283	-20.50820		100M
DI221	WP2-80	WP2-500	CS4	6/28/96 13:20	6/28/96 13:27	59.09218	-20.50960	59.09154	-20.51160		100M
DI221	WP2-82	WP2-500	CS5	6/28/96 18:22	6/28/96 18:41	59.10534	-20.84170	59.10509	-20.84900		200M
DI221	WP2-83	WP2-500	CS6	6/28/96 22:03	6/28/96 22:19	59.09954	-21.20140	59.10023	-21.20390		200M
DI221	WP2-84	WP2-50	CS7	6/29/96 2:53	6/29/96 2:59	59.09947	-21.71150	59.10110	-21.71070		100M
DI221	WP2-85	WP2-500	CS7	6/29/96 3:01	6/29/96 3:08	59.10135	-21.71110	59.10254	-21.71100		100M
DI221	WP2-86	WP2-500	CS7	6/29/96 3:10	6/29/96 3:17	59.10281	-21.71110	59.10380	-21.71080		100M
DI221	WP2-87	WP2-200	CS7	6/29/96 3:19	6/29/96 3:26	59.10430	-21.71060	59.10535	-21.71000		100M
DI221	WP2-88	WP2-200		04/07/96 03:35	04/07/96 03:47	59.30952	-21.11802	59.31025	-21.12375		200M
DI221	WP2-89	WP2-200		04/07/96 03:48	04/07/96 03:55	59.31015	-21.12437	59.31018	-21.12810		100M
DI221	WP2-90	WP2-200		04/07/96 03:56	04/07/96 03:59	59.31004	-21.12842	59.31014	-21.12965		20M
DI221	WP2-91	Apstein		04/07/96 04:01	04/07/96 04:13	59.31010	-21.13053	59.31032	-21.13728		50M
DI221	WP2-92	WP2-200		05/07/96 00:05	05/07/96 00:20	57.54471	-21.11559	57.54480	-21.11757		200M
DI221	WP2-93	WP2-200		05/07/96 00:22	05/07/96 00:24	57.54508	-21.11725	57.54515	-21.11734		20M
DI221	WP2-94	WP2-200		05/07/96 12:55	05/07/96 13:05	55.84941	-20.91287	55.84964	-20.91466		200M
DI221	WP2-95	WP2-200		06/07/96 00:52	06/07/96 01:06	53.99304	-20.69918	53.99372	-20.69895		200M
DI221	WP2-96	WP2-200		06/07/96 01:07	06/07/96 01:09	53.99377	-20.69892	53.99405	-20.69928		20M
DI221	WP2-97	WP2-200		06/07/96 12:13	06/07/96 12:41	52.44145	-20.52439	52.44469	-20.52219		200M
DI221	WP2-98	WP2-200		07/07/96 00:52	07/07/96 01:05	50.33549	-20.32283	50.33614	-20.32522		200M
DI221	WP2-99	WP2-200		07/07/96 01:06	07/07/96 01:08	50.33609	-20.32522	50.33617	-20.32490		20M
DI221	WP2-100	WP2-200		07/07/96 12:20	07/07/96 12:33	48.74349	-20.16584	48.74306	-20.16545		200M
DI221	WP2-101	WP2-200		08/07/96 01:00	08/07/96 01:13	46.99788	-20.00074	46.99621	-20.00048		200M
DI221	WP2-102	WP2-200		08/07/96 01:15	08/07/96 01:21	46.99611	-20.00064	46.99549	-20.00090		100M
DI221	WP2-103	WP2-200		08/07/96 01:23	08/07/96 01:25	46.99520	-20.00071	46.99465	-20.00041		20M
DI221	WP2-104	APSTEIN		08/07/96 01:26	08/07/96 01:32	46.99436	-20.00037	46.99365	-20.00110		
DI221	WP2-105	WP2-200		08/07/96 10:25	08/07/96 10:38	46.99949	-20.00124	46.99878	-20.00121		200M

DI221	WP2-106	WP2-200	08/07/96 10:39	08/07/96 10:49	46.99891	-20.00130	46.99856	-20.00159		100M	
DI221	WP2-108	WP2-200	09/07/96 01:30	09/07/96 01:43	44.46354	-19.72957	44.46202	-19.73125		200M	
DI221	WP2-109	WP2-200	09/07/96 01:45	09/07/96 01:47	44.46176	-19.73136	44.46140	-19.73176		20M	
DI221	WP2-110	WP2-200	09/07/96 12:12	09/07/96 12:24	42.96756	-19.56779	42.96960	-19.56663		200M	
DI221	WP2-111	WP2-200	07/10/96 01:28	07/10/96 01:43	40.60551	-19.33991	40.60754	-19.34191	4,797.17	200M	
DI221	WP2-112	WP2-200	07/10/96 01:43	07/10/96 01:46	40.60754	-19.34191	40.60772	-19.34203	4,791.56	20M	
DI221	WP2-113	WP2-200	07/10/96 12:10						5,441.84	200M	
DI221	WP2-114	BONGO-200	07/11/96 01:42	07/11/96 01:55	37.00598	-18.99679	37.00624	-18.99855	4,695.27	200M	
DI221	WP2-115	WP2-200	07/11/96 01:57	07/11/96 02:06	37.00656	-18.99891	37.00692	-18.99977	4,691.67	100M	
DI221	WP2-116	WP2-200	07/11/96 02:06	07/11/96 02:09	37.00692	-18.99977	37.00717	-19.00006	4,682.91	20M	
DI221	WP2-117	WP2-500	07/11/96 05:47	07/11/96 06:03	37.00779	-19.00899	37.00646	-19.01064	4,613.90	200M	
DI221	WP2-118	BONGO-200	07/11/96 11:55	07/11/96 12:10	36.99771	-19.05478	36.99796	-19.05755	4,675.70	200M	
DI221	WP2-119	WP2-200	07/11/96 12:12	07/11/96 12:18	36.99794	-19.05786	36.99819	-19.05876	4,686.00	100M	
DI221	WP2-120	WP2-200	07/11/96 12:20	07/11/96 12:23	36.99823	-19.05883	36.99795	-19.05959	4,681.37	20M	
DI221	WP2-121	WP2-500	07/11/96 21:00	07/11/96 21:14	36.97897	-19.12027	36.97997	-19.12163	4,801.76	200M	
DI221	WP2-122	WP2-200	07/12/96 00:06	07/12/96 00:20	36.97490	-19.13007	36.97437	-19.13161	4,832.87	200M	
DI221	WP2-123	WP2-200	07/12/96 00:24	07/12/96 00:37	36.97446	-19.13198	36.97458	-19.13271	4,836.95	200M	
DI221	WP2-124	WP2-200	07/12/96 00:39	07/12/96 00:46	36.97443	-19.13299	36.97417	-19.13340	4,838.48	100M	
DI221	WP2-125	WP2-200	07/12/96 00:48	07/12/96 00:50	36.97426	-19.13343	36.97423	-19.13364	4,841.05	20M	
DI221	WP2-126	BONGO-500	07/12/96 04:59	07/12/96 05:13	36.96048	-19.16297	36.95988	-19.16498	4,966.19	200M	
DI221	WP2-127	BONGO-200	07/12/96 11:53	07/12/96 12:06	36.94547	-19.19727	36.94622	-19.19946	4,981.64	200M	
DI221	WP2-128	BONGO-200	07/12/96 12:08	07/12/96 12:15	36.94649	-19.19950	36.94643	-19.20010	4,983.70	100M	
DI221	WP2-129	BONGO-200	07/12/96 12:17	07/12/96 12:19	36.94613	-19.20013	36.94602	-19.20019	4,983.70	20M	
DI221	WP2-130	APSTEIN	07/12/96 12:22	07/12/96 12:30	36.94665	-19.20048	36.94704	-19.20150	4,985.76	50M	
DI221	WP2-131	WP2-200	07/12/96 20:57	07/12/96 21:11	36.92105	-19.21481	36.92032	-19.21553	4,802.27	200M	
DI221	WP2-132	WP2-500	13/07/96 00:05	13/07/96 00:19	36.91770	-19.22955	36.91702	-19.22932	5,040.35	200M	
DI221	WP2-132S	WP2-200	13/07/96 00:21	13/07/96 00:35	36.91700	-19.22922	36.91683	-19.22916	5,040.87	lost Bongo net	
DI221	WP2-133	WP2-200	13/07/96 00:55	13/07/96 01:09	36.92023	-19.22336	36.91966	-19.22375	5,040.87	200M	
DI221	WP2-134	WP2-200	13/07/96 01:10	13/07/96 01:19	36.91941	-19.22334	36.91884	-19.22359	5,040.35	100M	
DI221	WP2-135	WP2-500	13/07/96 05:15	13/07/96 05:28	36.90713	-19.21806	36.90815	-19.21811	4,878.64	200M	
DI221	WP2-136	WP2-200	13/07/96 11:41	13/07/96 11:55	36.88358	-19.24237	36.88383	-19.24121	5,019.75	200M	
DI221	WP2-137	WP2-200	13/07/96 11:56	13/07/96 12:03	36.88386	-19.24110	36.88349	-19.24057	5,018.21	100M	
DI221	WP2-138	WP2-200	13/07/96 12:05	13/07/96 12:12	36.88382	-19.24116	36.88461	-19.24218	5,018.21	100M	
DI221	WP2-139	WP2-200	13/07/96 12:13	13/07/96 12:15	36.88461	-19.24220	36.88464	-19.24223	5,016.66	20M	
DI221	WP2-140	WP2-500	13/07/96 21:25	13/07/96 21:40	36.83430	-19.25176	36.83472	-19.25320	4,556.22	200M	
DI221	WP2-141	WP2-500	14/07/96 00:05	14/07/96 00:20	36.83452	-19.25532	36.83491	-19.25602	4,568.58	200M	

DI221	WP2-142	WP2-200		14/07/96 00:24	14/07/96 00:36	36.83484	-19.25591	36.83520	-19.25573	4,579.91	200M	
DI221	WP2-143	WP2-200		14/07/96 00:37	14/07/96 00:42	36.83521	-19.25569	36.83516	-19.25584	4,583.00	100M	
DI221	WP2-144	WP2-200		14/07/96 00:43	14/07/96 00:50	36.83505	-19.25606	36.83487	-19.25609	4,583.00	100M	
DI221	WP2-145	WP2-200		14/07/96 00:52	14/07/96 00:55	36.83469	-19.25614	36.83482	-19.25667	4,584.03	20M	
DI221	WP2-145	net ?		14/07/96 05:05	14/07/96 05:22	36.81370	-19.23842	36.81294	-19.23966	4,533.05		
DI221	WP2-146	WP2-500		14/07/96 14:06	14/07/96 14:20	36.73912	-19.24832	36.73893	-19.24838	5,206.22	500M	
DI221	WP2-147	WP2-200		14/07/96 14:22	14/07/96 14:34	36.73873	-19.24827	36.73878	-19.24832	5,206.74	200M	
DI221	WP2-148	WP2-200		14/07/96 14:35	14/07/96 14:41	36.73860	-19.24841	36.73827	-19.24875	5,207.78	100M	
DI221	WP2-149	WP2-200		14/07/96 14:42	14/07/96 14:50	36.73830	-19.24873	36.73780	-19.24874	5,207.78	100M	
DI221	WP2-150	WP2-200		14/07/96 14:52	14/07/96 14:57	36.73794	-19.24896	36.73742	-19.24891	5,208.30	20M	
DI221	WP2-151	APSTEIN		14/07/96 14:58	14/07/96 15:05	36.73735	-19.24902	36.73755	-19.24892	5,208.82	50M	
DI221	WP2-152	WP2-500		14/07/96 20:56	14/07/96 21:11	36.70536	-19.22967	36.70454	-19.23213	5,135.63	200M	
DI221	WP2-153	WP2-200		15/07/96 00:05	15/07/96 00:27	36.68522	-19.24880	36.68065	-19.25080	5,168.26	200M	
DI221	WP2-154	WP2-200		15/07/96 00:28	15/07/96 00:35	36.68061	-19.25083	36.68045	-19.25113	5,201.02	100M	
DI221	WP2-155	WP2-200		15/07/96 00:37	15/07/96 00:43	36.68023	-19.25135	36.67971	-19.25129	5,195.30	100M	
DI221	WP2-156	WP2-200		15/07/96 00:47	15/07/96 00:48	36.67939	-19.25129	36.67922	-19.25121	5,209.86	20M	
DI221	WP2-157	WP2-500		15/07/96 04:45	15/07/96 05:00	36.68129	-19.22774	36.68061	-19.22885	5,242.10	200M	
DI221	WP2-158	WP2-500		15/07/96 11:47	15/07/96 12:03	36.63329	-19.23293	36.63336	-19.23399	5,431.94	200M	
DI221	WP2-159	WP2-200		15/07/96 12:05	15/07/96 12:18	36.63337	-19.23403	36.63314	-19.23458	5,430.90	200M	
DI221	WP2-160	WP2-200		15/07/96 12:20	15/07/96 12:26	36.63300	-19.23441	36.63276	-19.23479	5,431.42	100M	
DI221	WP2-161	WP2-200		15/07/96 12:30	15/07/96 12:34	36.63326	-19.23518	36.63277	-19.23513	5,431.42	100M	
DI221	WP2-162	WP2-200		15/07/96 12:35	15/07/96 12:37	36.63278	-19.23516	36.63291	-19.23507	5,432.46	20M	
DI221	WP2-163	WP2-500		15/07/96 20:50	15/07/96 21:05	36.55154	-19.19827	36.54977	-19.19930	5,480.62	200M	
DI221	WP2-164	WP2-200		16/07/96 00:03	16/07/96 00:16	36.52802	-19.19868	36.52587	-19.19926	5,482.68	200M	
DI221	WP2-165	WP2-200		16/07/96 00:17	16/07/96 00:23	36.52580	-19.19940	36.52423	-19.19931	5,482.16	100M	
DI221	WP2-166	WP2-200		16/07/96 00:26	16/07/96 00:32	36.52394	-19.19956	36.52282	-19.19990	5,482.16	100M	
DI221	WP2-167	WP2-200		16/07/96 00:35	16/07/96 00:36	36.52274	-19.19988	36.52255	-19.19986	5,482.16	20M	
DI221	WP2-168	WP2-200		16/07/96 00:37	16/07/96 00:56	36.52242	-19.19997	36.52014	-19.20176	5,481.65	287M	
DI221	WP2-169	WP2-500		16/07/96 05:00	16/07/96 05:14	36.47014	-19.19567	36.46867	-19.19563	5,436.10	200M	
DI221	WP2-170	WP2-500		16/07/96 11:55	16/07/96 12:12	36.43516	-19.17981	36.43132	-19.18034	5,173.46	250M	
DI221	WP2-171	WP2-200		16/07/96 12:14	16/07/96 12:30	0.50972	36.43063	36.42746	-19.18030	5,141.29	250M	
DI221	WP2-172	WP2-200		16/07/96 12:32	16/07/96 12:38	36.42664	-19.18028	36.42548	-19.18030	4,961.56	100M	
DI221	WP2-173	WP2-200		16/07/96 12:40	16/07/96 12:47	36.42514	-19.18067	36.42433	-19.18093	4,922.42	100M	
DI221	WP2-174	WP2-200		16/07/96 12:48	16/07/96 12:49	36.42424	-19.18098	36.42410	-19.18101	4,804.82	20M	
DI221	WP2-175	APSTEIN		16/07/96 12:51	16/07/96 13:00	36.42361	-19.18122	36.42221	-19.18166	4,901.82	50M	
DI221	WP2-176	WP2-500		16/07/96 20:05	16/07/96 20:25	36.37646	-19.14670	36.37365	-19.14830	5,411.66	270M	

DI221	WP2-177	WP2-200		17/07/96 00:06	17/07/96 00:19	36.32977	-19.13870	36.32819	-19.13949	5,489.89	200M
DI221	WP2-178	WP2-200		17/07/96 00:21	17/07/96 00:27	36.32786	-19.13990	36.32719	-19.14090	5,490.40	100M
DI221	WP2-179	WP2-200		17/07/96 00:29	17/07/96 00:35	36.32695	-19.14110	36.32609	-19.14198	5,490.92	100M
DI221	WP2-180	WP2-200		17/07/96 00:37	17/07/96 00:39	36.32576	-19.14186	36.32555	-19.14201	5,491.95	20M
DI221	WP2-181	WP2-500		17/07/96 04:30	17/07/96 04:45	36.30606	-19.16321	36.30475	-19.16312	5,499.67	200M
DI221	WP2-182	WP2-500		17/07/96 11:46	17/07/96 12:04	36.24414	-19.12334	36.24266	-19.12462	5,506.37	270M
DI221	WP2-183	WP2-200		17/07/96 12:07	17/07/96 12:20	36.24216	-19.12488	36.24069	-19.12613	5,506.37	200M
DI221	WP2-184	WP2-200		17/07/96 12:21	17/07/96 12:28	36.24082	-19.12614	36.23941	-19.12660	5,505.85	100M
DI221	WP2-185	WP2-200		17/07/96 12:30	17/07/96 12:36	36.23932	-19.12659	36.23917	-19.12707	5,506.37	100M
DI221	WP2-186	WP2-200		17/07/96 12:38	17/07/96 12:40	36.23878	-19.12703	36.23860	-19.12732	5,505.85	20M
DI221	WP2-187	WP2-500		17/07/96 20:00	17/07/96 20:19	36.19068	-19.11922	36.18871	-19.12096	5,497.10	270M
DI221	WP2-188	WP2-200		18/07/96 00:07	18/07/96 00:19	36.13166	-19.14592	36.13010	-19.14668	5,490.40	200M
DI221	WP2-189	WP2-200		18/07/96 00:21	18/07/96 00:27	36.12989	-19.14702	36.12896	-19.14844	5,489.89	100M
DI221	WP2-190	WP2-200		18/07/96 00:29	18/07/96 00:35	36.12893	-19.14854	36.12858	-19.14915	5,489.89	100M
DI221	WP2-191	WP2-200		18/07/96 00:37	18/07/96 00:39	36.12855	-19.14927	36.12830	-19.14971	5,488.86	20M
DI221	WP2-192	WP2-500		18/07/96 04:29	18/07/96 04:49	36.11863	-19.17924	36.11816	-19.18011	5,487.31	200M
DI221	WP2-193	WP2-200		18/07/96 11:52	18/07/96 12:06	36.07001	-19.15320	36.06786	-19.15367	5,496.07	200M
DI221	WP2-194	WP2-200		18/07/96 12:07	18/07/96 12:12	36.06805	-19.15394	36.06749	-19.15479	5,496.07	100M
DI221	WP2-195	WP2-200		18/07/96 12:14	18/07/96 12:20	36.06724	-19.15520	36.06553	-19.15630	5,496.07	100M
DI221	WP2-196	WP2-200		18/07/96 12:22	18/07/96 12:24	36.06527	-19.15664	36.06474	-19.15703	5,496.58	20M
DI221	WP2-197	APSTEIN		18/07/96 12:29	18/07/96 12:36	36.06403	-19.15797	36.06282	-19.15912	5,496.58	50M

APPENDIX 6.5

OPTICS CASTS

										WATER-DEPTH	
DI221	OPT1	light meter		05/07/96 12:45	05/07/96 13:01	55.84971	-20.91188	55.84967	-20.91361		
DI221	OPT2	light meter		06/07/96 12:17	06/07/96 12:41	52.44145	-20.52439	52.44469	-20.52219		
DI221	OPT3	light meter		07/07/96 12:23	07/07/97 12:40	48.74330	-20.16566	48.74285	-20.16529		
DI221	OPT4	light meter		08/07/96 11:58	08/07/96 12:20	46.99773	-20.00540	46.99917	-19.99644		
DI221	OPT5	light meter		09/07/96 12:12	09/07/96 12:31	42.96756	-19.56779	42.96960	-19.56663		
DI221	OPT6	light meter		07/10/96 12:16	07/10/96 12:36	39.18077	-19.21636	39.18208	-19.21870	5,443.90	
DI221	OPT7	light meter		07/11/96 10:54	07/11/96 11:19	36.99678	-19.04577	36.99823	-19.05029	4,665.92	
DI221	OPT8	light meter		07/11/96 13:43	07/11/96 14:10	36.99377	-19.07350	36.99371	-19.07619	4,735.96	
DI221	OPT9	light meter		07/12/96 12:39	07/12/96 12:56	36.94707	-19.20252	36.94671	-19.20223	4,986.28	
DI221	OPT10	light meter		13/07/96 12:21	13/07/96 13:00					5,017.69	
DI221	OPT11	light meter		14/07/96 15:09	14/07/96 15:21	36.73707	-19.24889	36.73688	-19.24888	5,209.34	
DI221	OPT12	light meter		15/07/96 12:45	15/07/96 12:59	36.63266	-19.23508	36.63343	-19.23548	5,431.94	
DI221	OPT13	light meter		16/07/96 13:08	16/07/96 13:17	36.42087	-19.18210	36.42073	-19.18259	4,901.82	
DI221	OPT14	light meter		17/07/96 12:50	17/07/96 13:12	36.23694	-19.12783	36.23605	-19.13005	5,505.34	
DI221	OPT15	light meter		17/07/96 15:16	17/07/96 15:35	36.22799	-19.13899	36.22425	-19.13864	5,502.76	
DI221	OPT16	light meter		18/07/96 12:57	18/07/96 13:25	36.06166	-19.16165	36.05870	-19.16332	5,497.10	

APPENDIX 6.6

SEASOAR TOWS (LEG 1)

			START-TIME	END-TIME	START-LAT	START-LON	END-LAT	END-LON	WATER-DEPTH	COMMENTS
DI221	SS1	SEASOAR	6/13/96 15:12	6/13/96 20:20	54.54749	-14.7696	54.96298	-15.4566		
DI221	SS2	SEASOAR	6/15/96 17:09	6/17/96 17:24	59.85161	-21.1676	59.96288	-20.3329		SeaSoar survey
DI221	SS3	SEASOAR	6/19/96 14:35	6/19/96 22:47	59.13596	-20.152	59.07693	-20.1511		
DI221	SS4	SEASOAR	6/21/96 18:10	6/21/96 23:48	59.22004	-19.4114	59.19106	-20.1722		
DI221	SS5	SEASOAR	6/23/96 15:07	6/23/96 22:56	58.96931	-20.3751	58.93481	-20.5257		
DI221	SS6	SEASOAR	6/25/96 14:35	6/25/96 23:18	59.18033	-20.5829	59.10198	-20.4663		
DI221	SS7	SEASOAR	6/29/96 9:50	6/30/96 17:18	59.13933	-21.6877	59.46234	-20.8838		

APPENDIX 6.7

UOR TOWS (LEG 2)

DI221	UOR1	UOR		03/07/96 09:00	03/07/96 16:52	62.16852	-22.84986	60.86183	-21.96846
DI221	UOR2	UOR		03/07/96 19:07	04/07/96 00:58	60.46591	-21.69882	59.61857	-21.01874
DI220	UOR3	UOR		04/07/96 13:25	04/07/96 23:33	59.46919	-21.32213	57.59371	-21.12199
DI221	UOR4	UOR		05/07/96 03:06	05/07/96 12:36	57.53792	-21.11094	55.85047	-20.91674
DI221	UOR5	UOR		05/07/96 16:11	06/07/96 00:43	55.54679	-20.84708	53.99337	-20.69856

APPENDIX 6.8

U-TOW DEPLOYMENTS

Conversion from Dates to Julian Days

Date	Julian Day
12th June 1996	164
13th June 1996	165
14th June 1996	166
15th June 1996	167
16th June 1996	168
17th June 1996	169
18th June 1996	170
19th June 1996	171
20th June 1996	172
21th June 1996	173
22th June 1996	174
23th June 1996	175
24th June 1996	176
25th June 1996	177
26th June 1996	178
27th June 1996	179
28th June 1996	180
29th June 1996	181
30th June 1996	182
01st July 1996	183
02nd July 1996	184
03rd July 1996	185
04th July 1996	186
05th July 1996	187
06th July 1996	188
07th July 1996	189
08th July 1996	190
09th July 1996	191
10th July 1996	192
11th July 1996	193
12th July 1996	194
13th July 1996	195
14th July 1996	196
15th July 1996	197
16th July 1996	198
17th July 1996	199
18th July 1996	200
19th July 1996	201
20th July 1996	202
21th July 1996	203
22th July 1996	204
23th July 1996	205

The following pages contain colour diagrams that were removed from the original report before it was scanned.

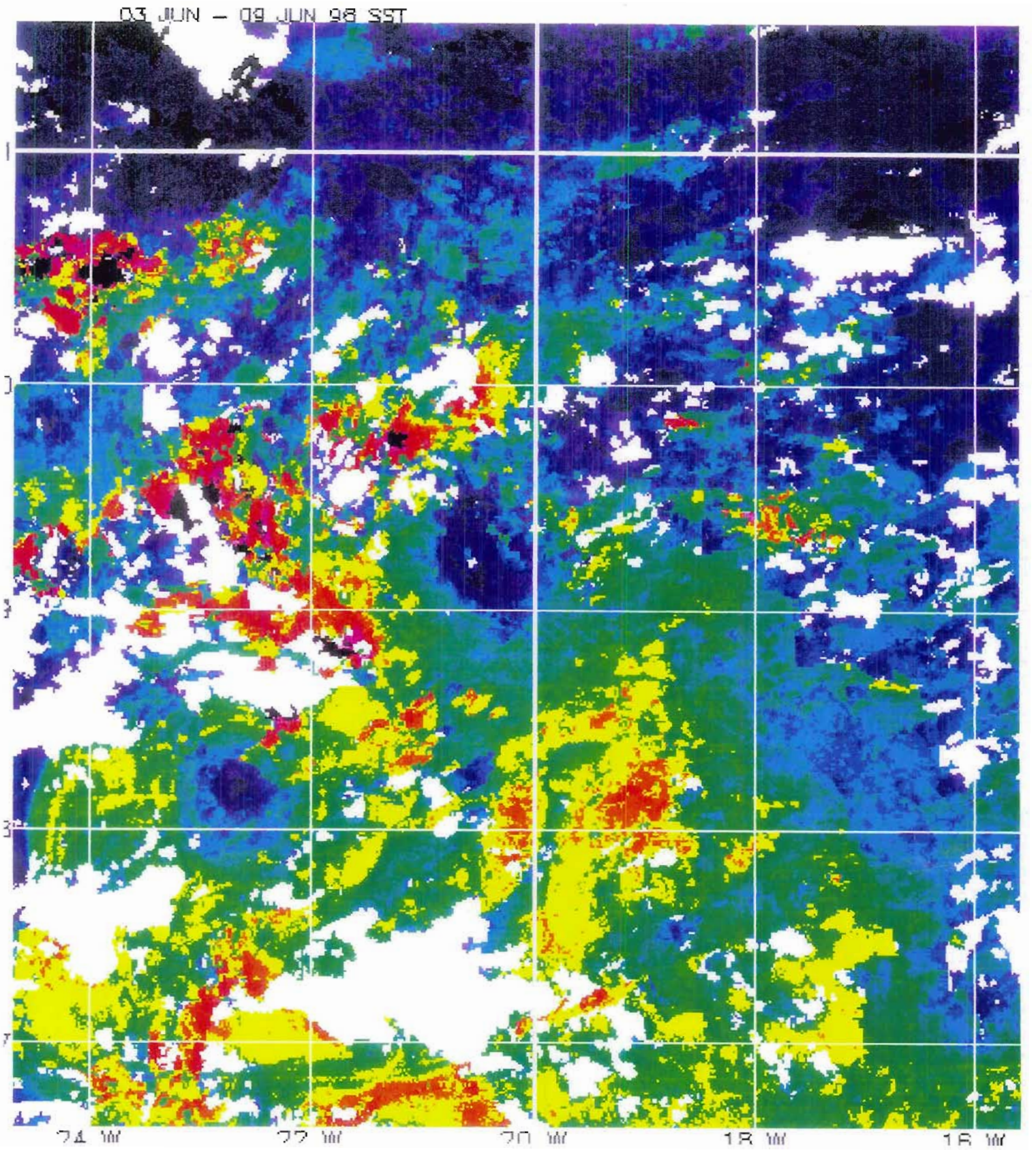


Fig. 2. Composite sea-surface temperature image derived from AVHRR images in period 3-9 June 1996. Surface cold-core eddy studied in Leg 1 of Discovery Cruise 221 located approximately 59.2°N 20.6°W. Darker areas indicate cooler water.

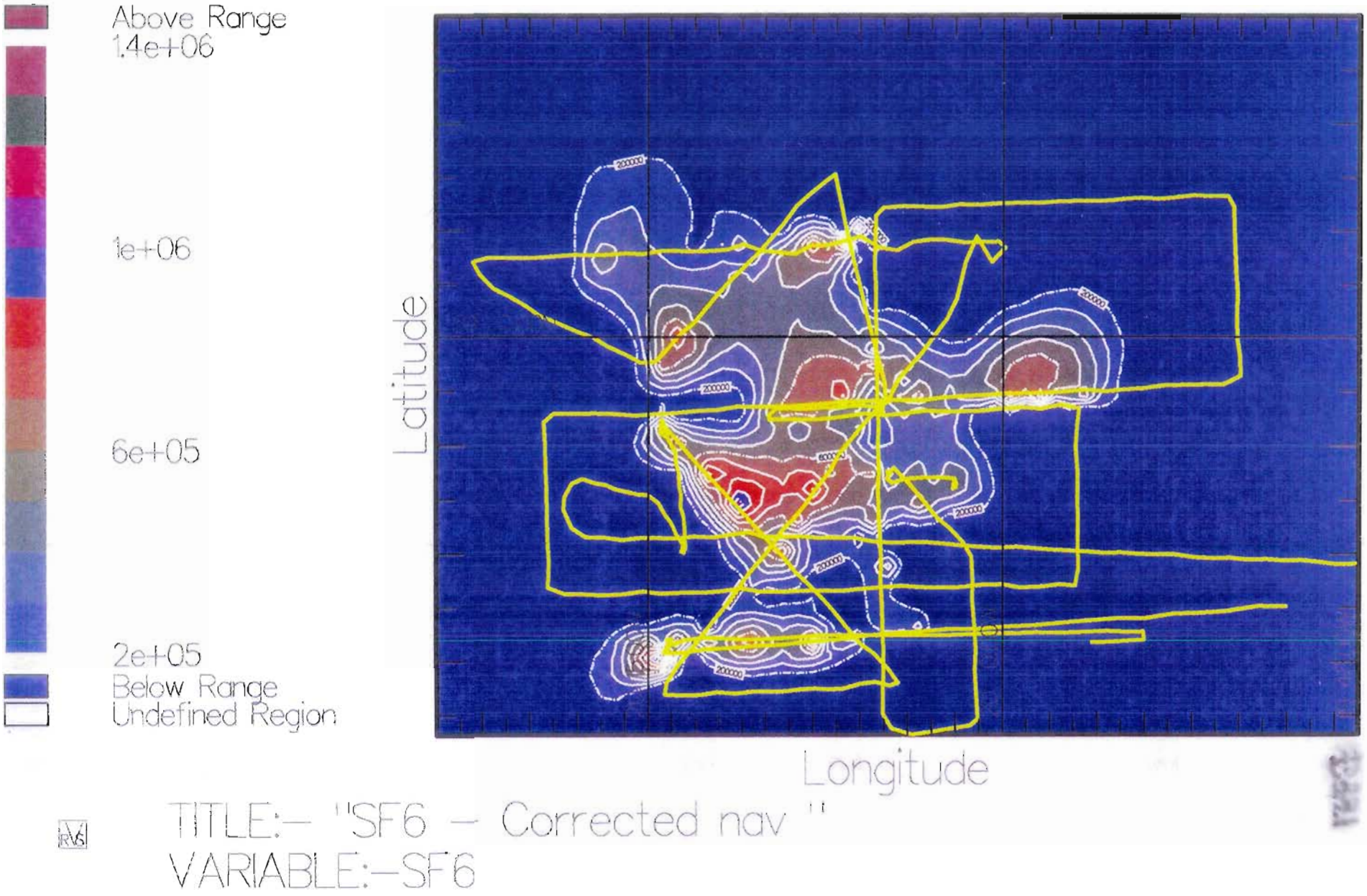


Fig. 10. Contour plot of SF_6 patch five days after initial release of SF_6.

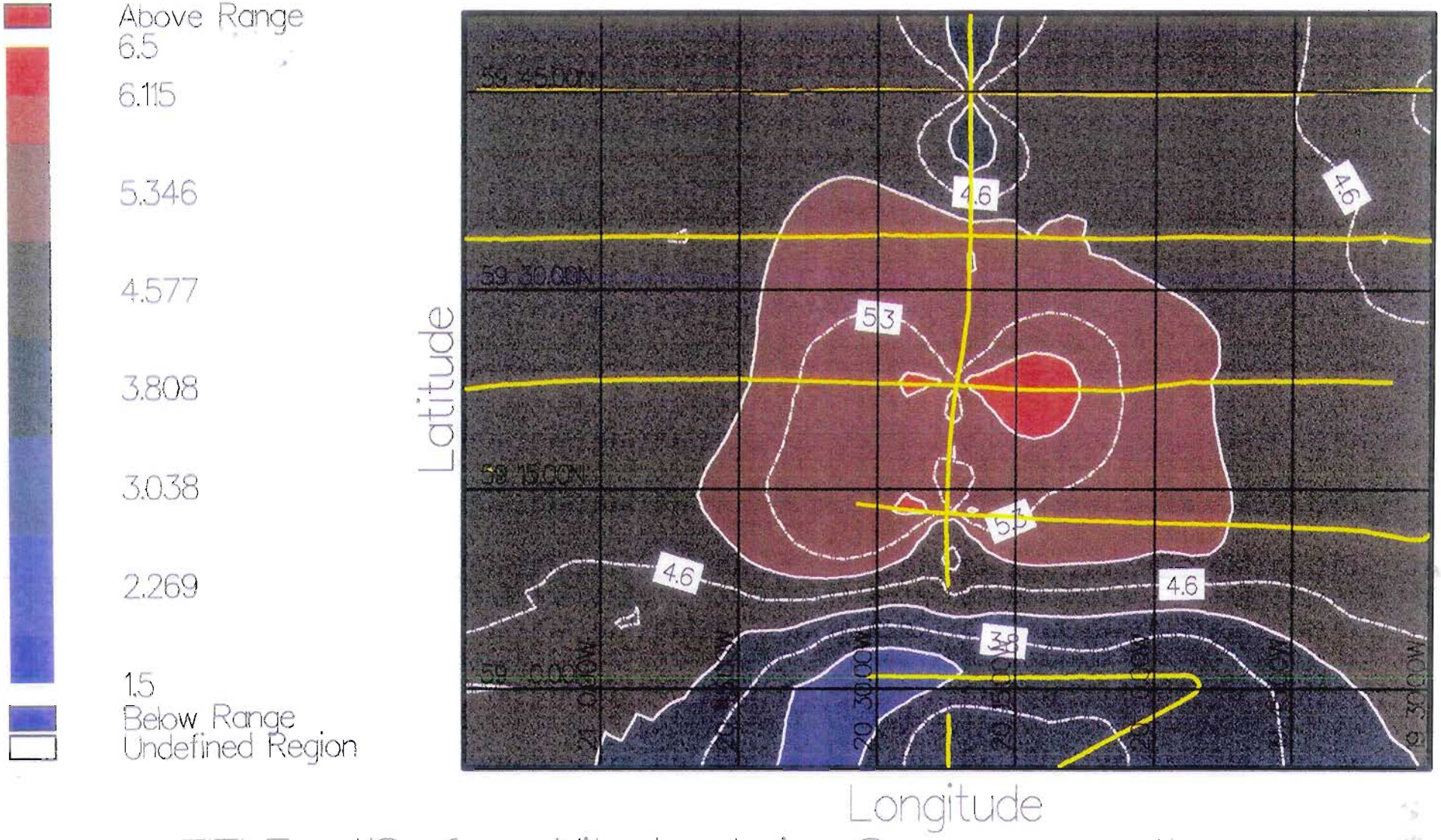


Fig. 12. Surface distribution of NO_3 during first major Seasoar survey of northern eddy, Leg 1.

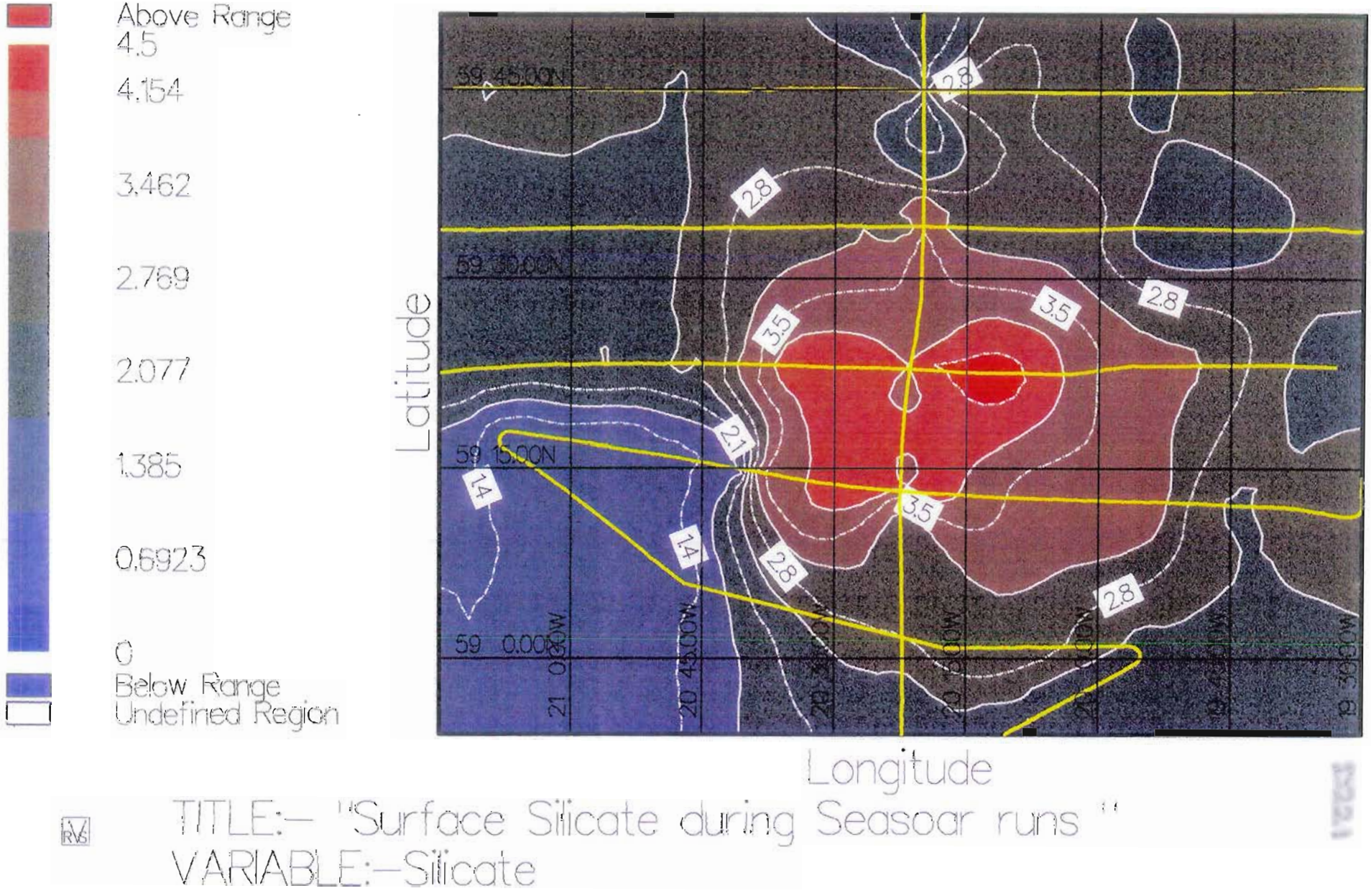
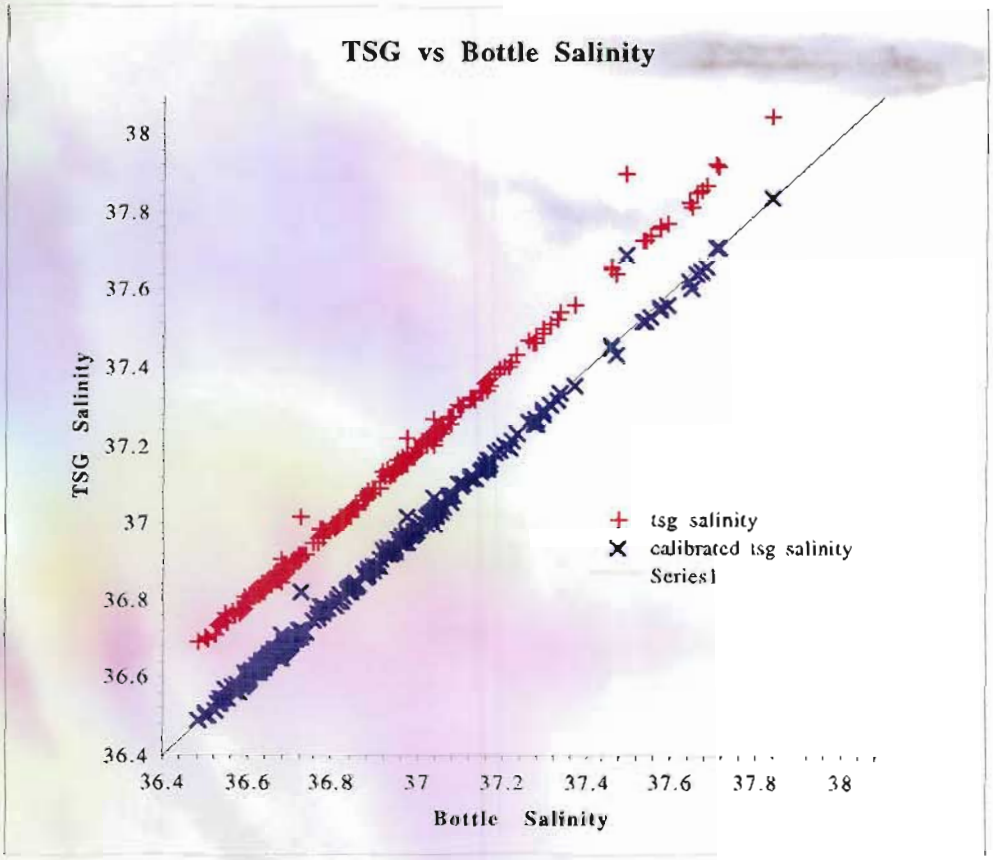


Fig. 13. Surface distribution of Si during first major Seasoar survey of northern eddy, Leg 1.



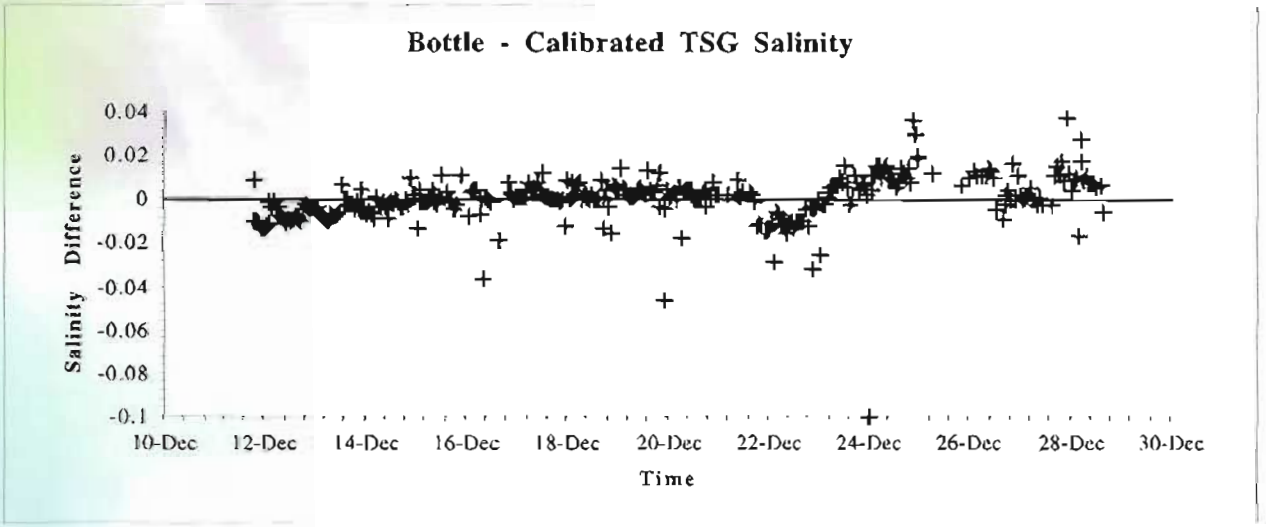


Figure 13. TSG salinities vs. bottle salinities (top) and residual noise between bottle salinities and calibrated TSG salinities (bottom), from the beginning of the first fine scale survey to the end of the cruise.

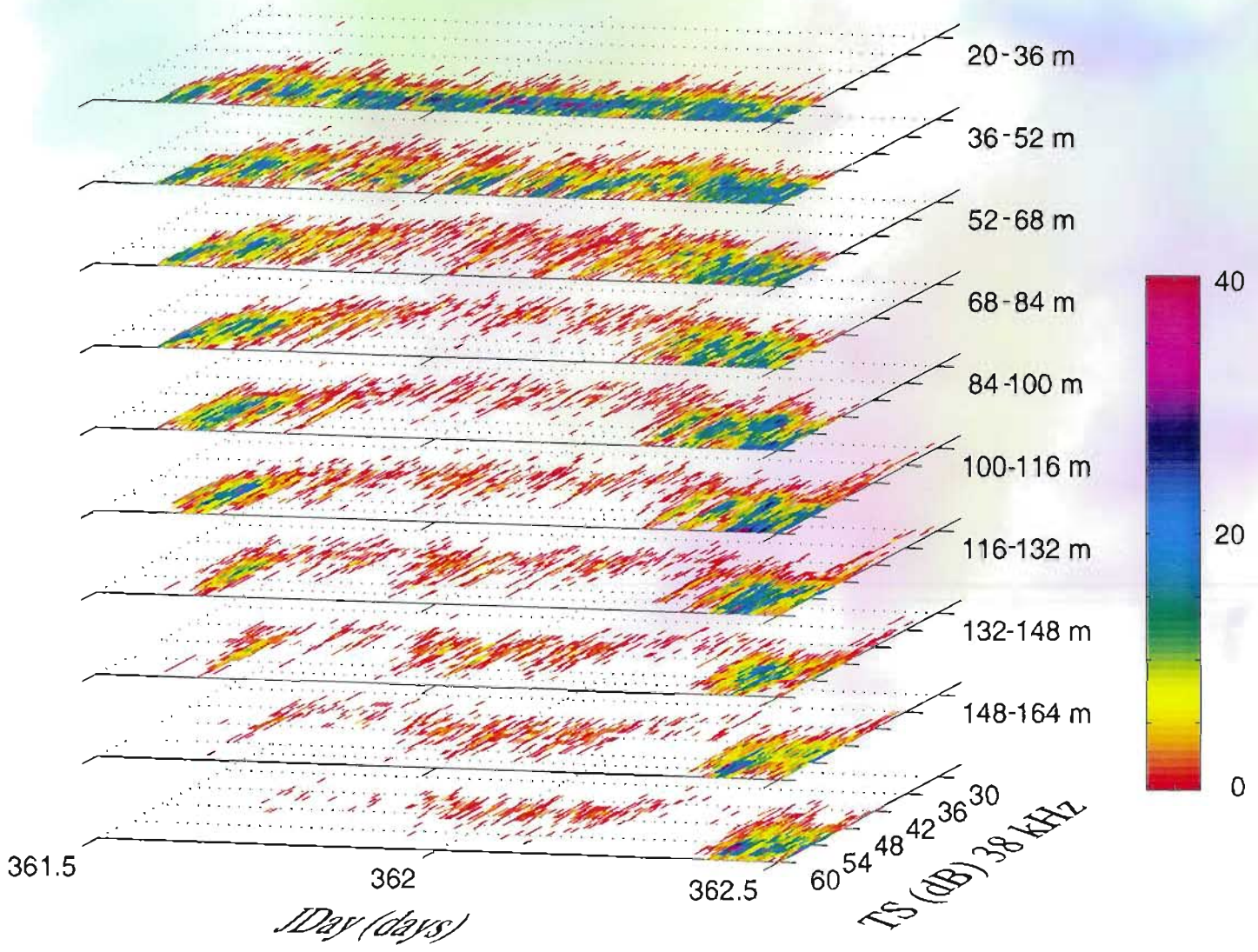


Figure 14. EK500 data. Number of detections contoured against target strength and time for specific depth layers.

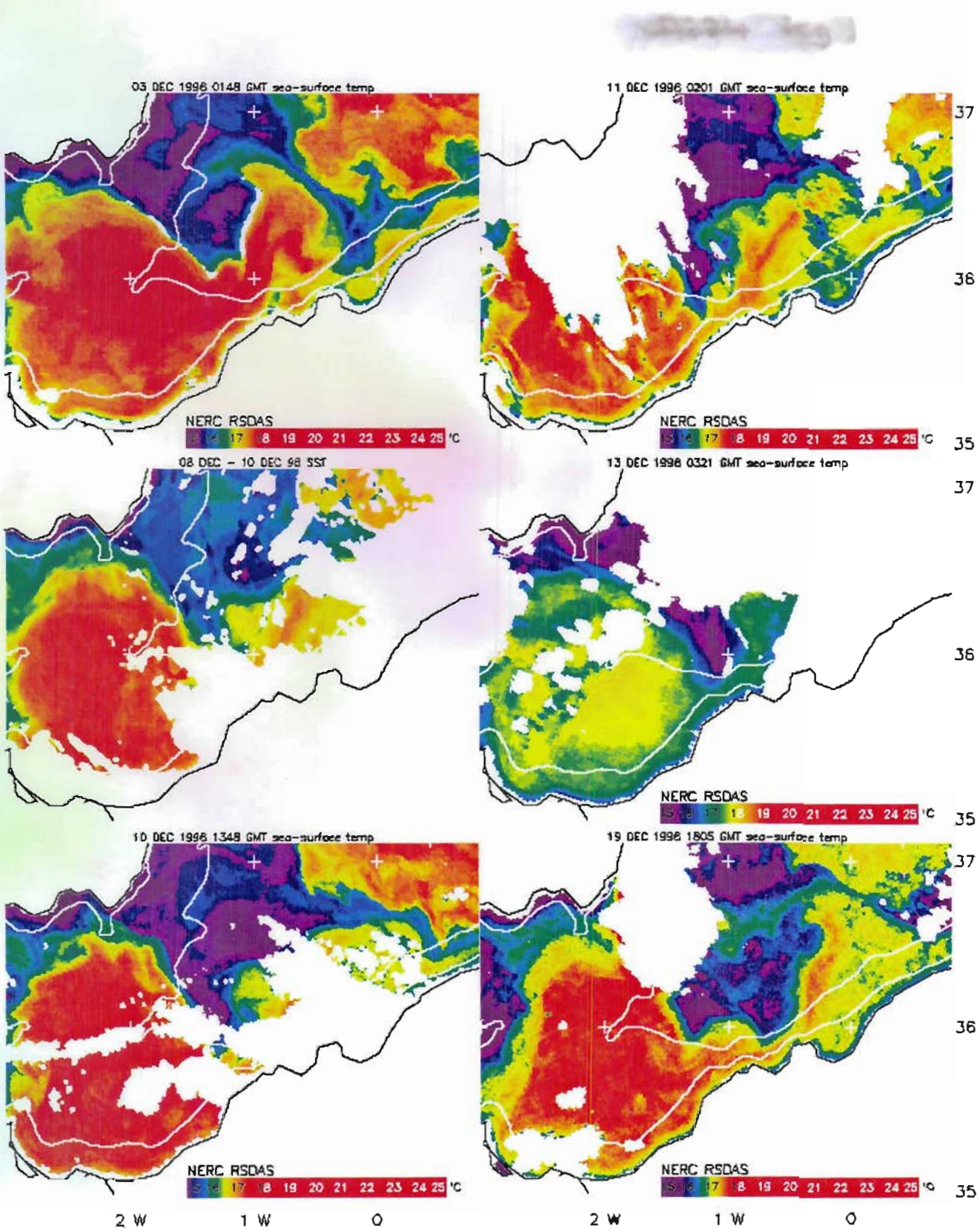


Figure 15. AVHRR images obtained in near real time via NERC's Satellite Receiving Station in Dundee and Image Analysis Unit in Plymouth.

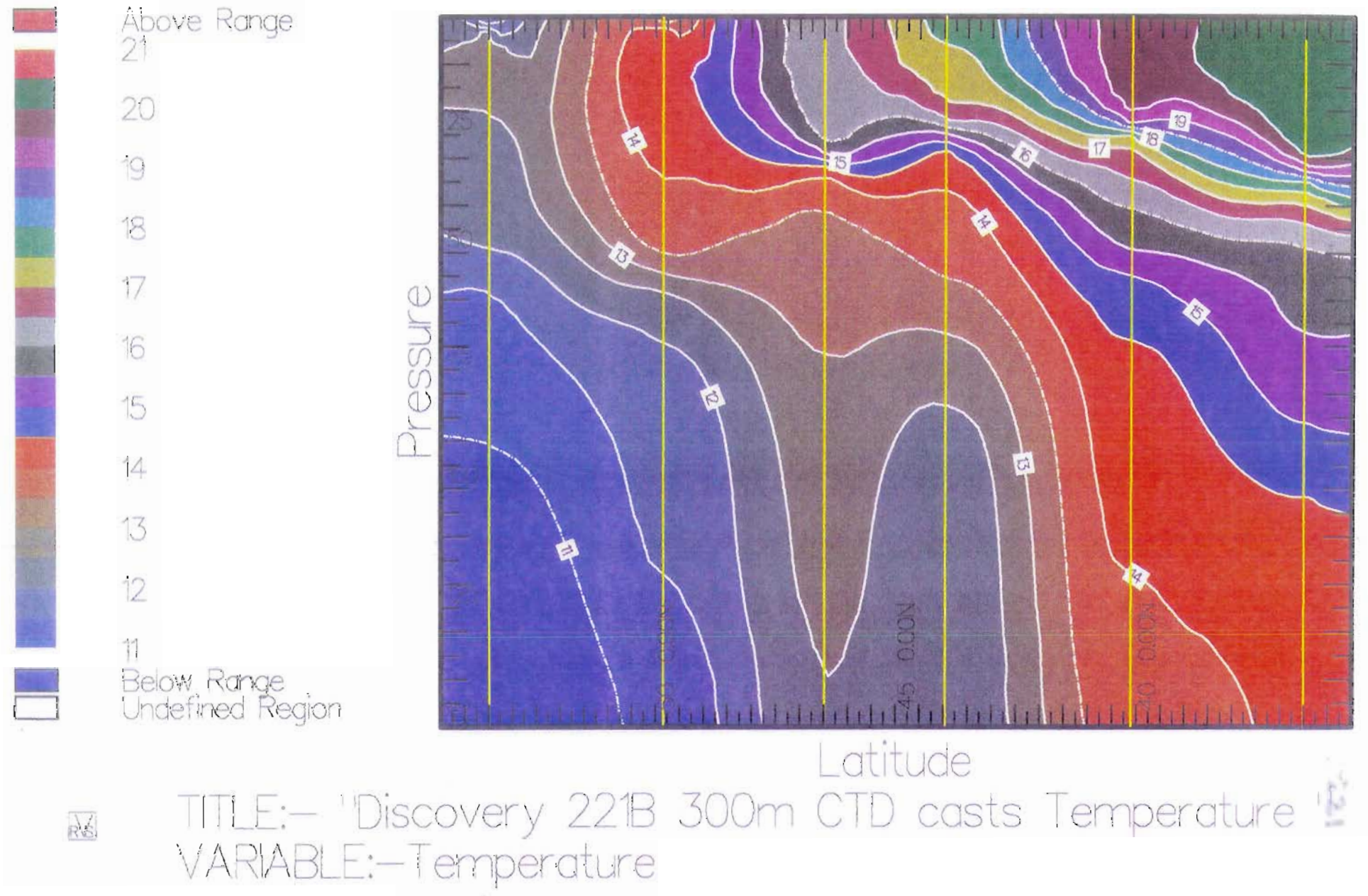


Fig. 16. Distribution of temperature (oC) in the upper 300m along transect approximately 59oN 21oW 37oN 20oW, July 1996

Fig. 17. Distribution of salinity in upper 300m along N-S transect between approximately 59^{0}N 21^{0}W 37^{0}N 20^{0}W, July 1996.

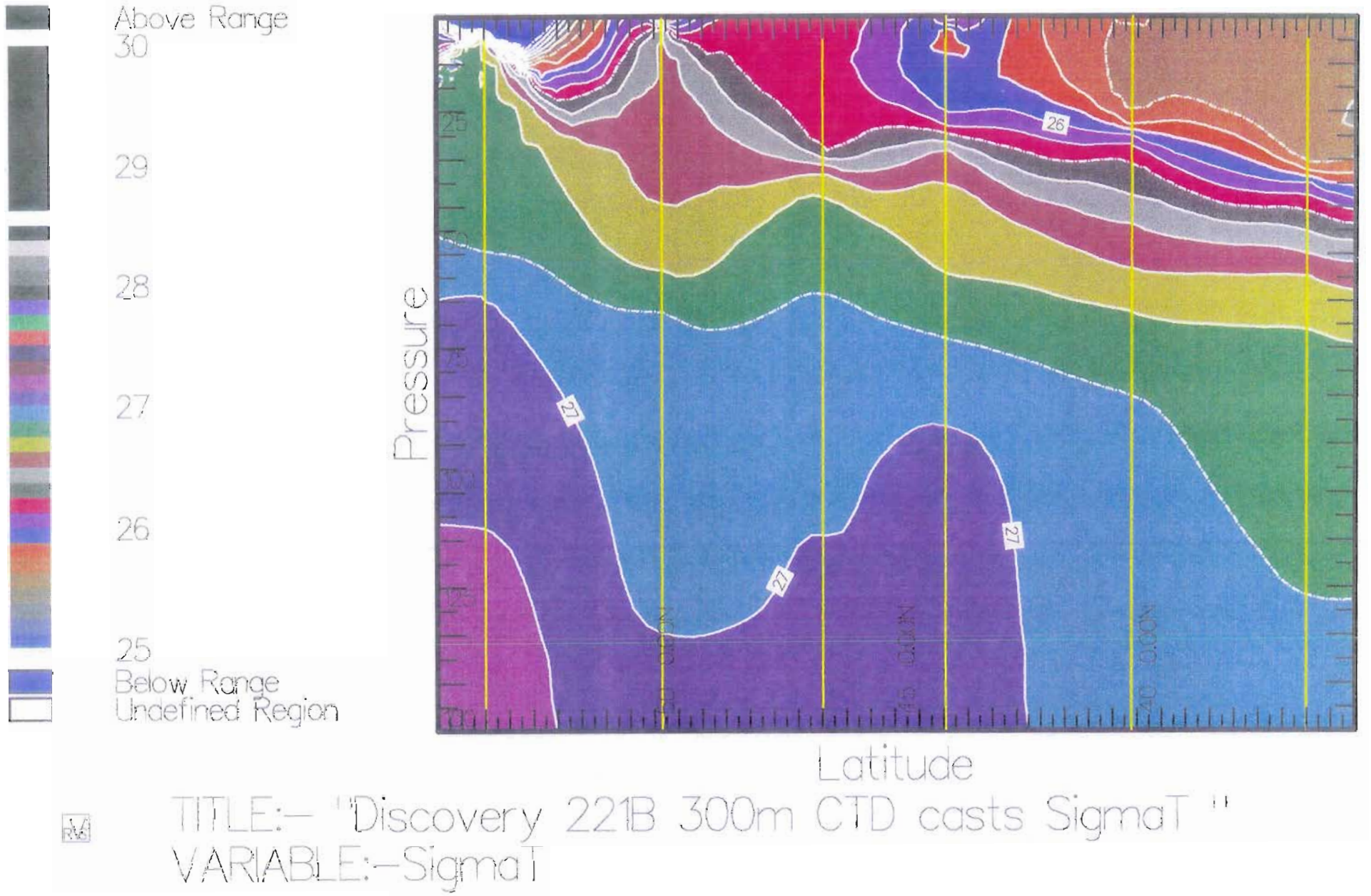


Fig. 18. Distribution of density (σ_t) in upper 300m along N-S transect between approximately 59^{0}N 21^{0}W 37^{0}N 20^{0}W, July 1996.

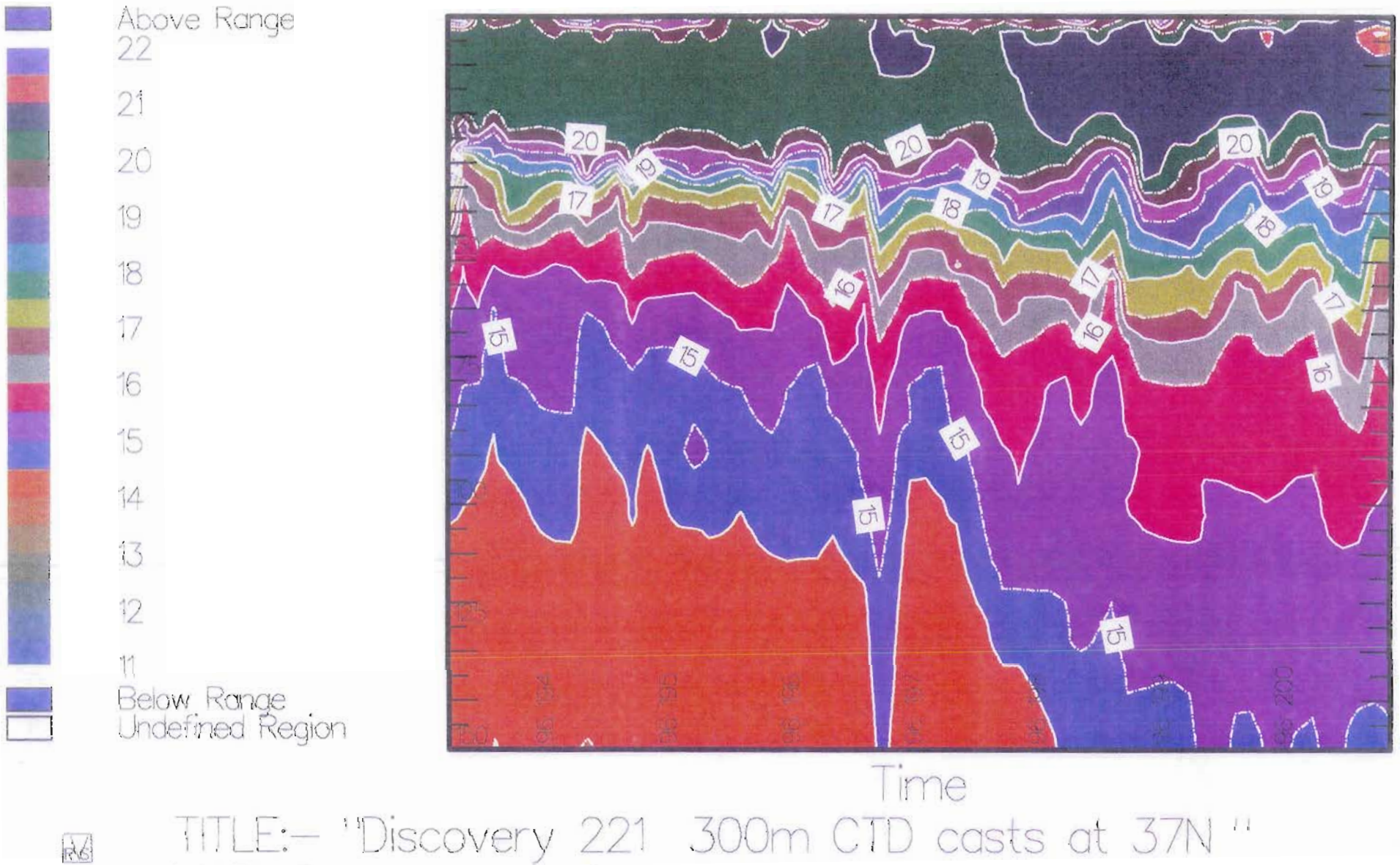


Fig. 19. Time series changes in temperature (^{0}C) in upper 150m recorded adjacent to Lagrangian buoy in vicinity of 37^{0}N 20^{0}W, July 1996.

Fig. 20. Time series changes in salinity in upper 150m recorded adjacent to Lagrangian buoy in vicinity of 37°N 20°W, July 1996.

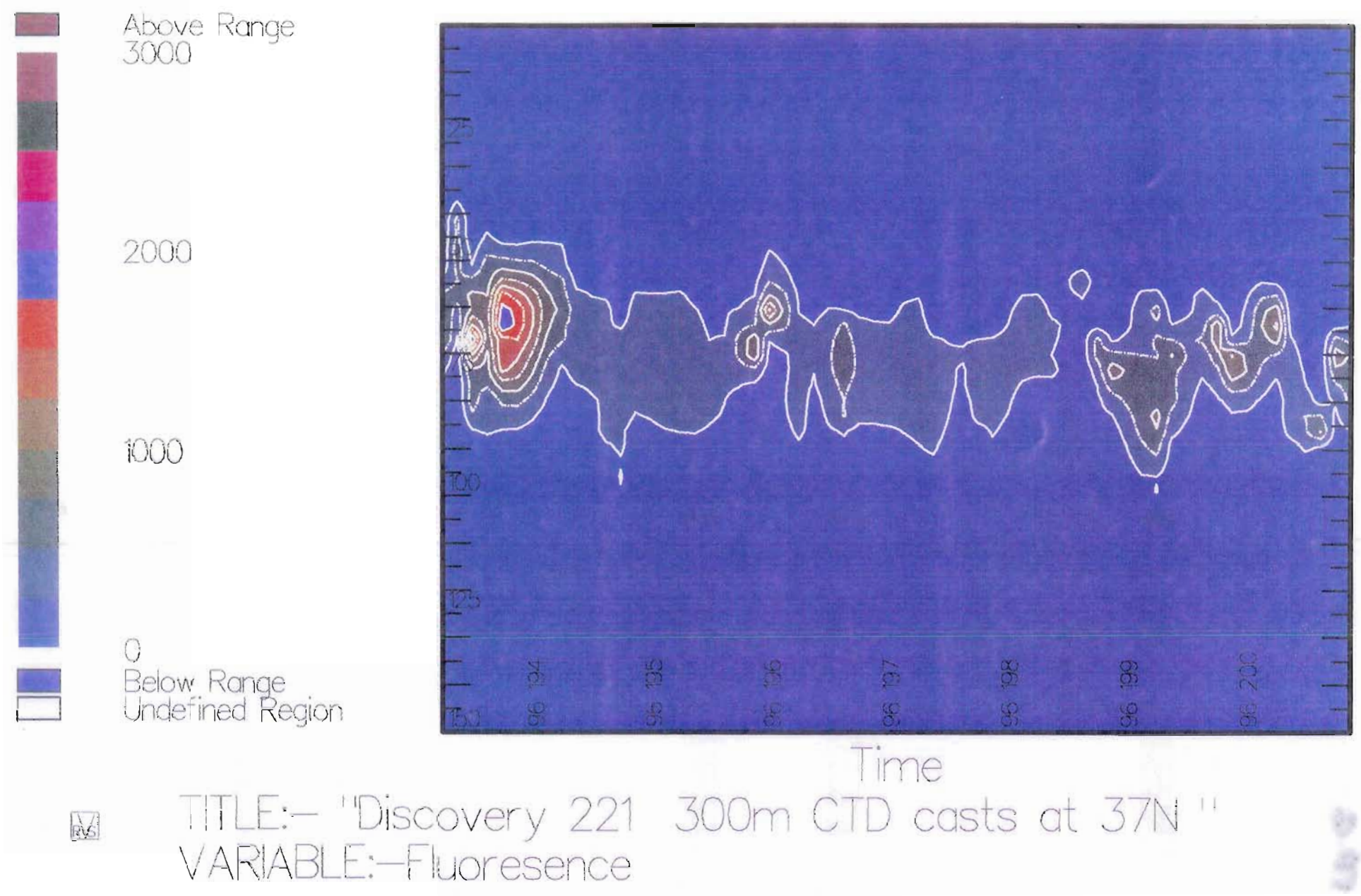


Fig. 21. Time series changes in chlorophyll *a* fluorescence (relative units) in upper 150m recorded adjacent to Lagrangian buoy in vicinity of 37^{0}N 20^{0}W, July 1996.