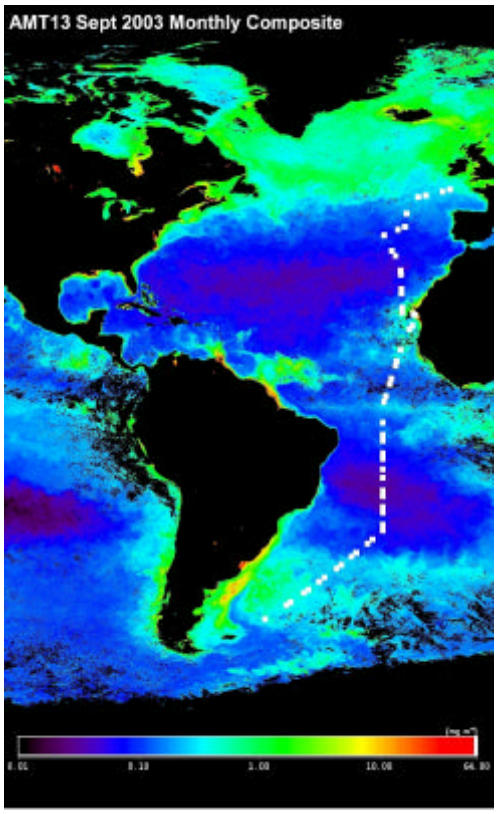
# Atlantic Meridional Transect




## AMT13 Cruise Report

**RRS James Clark Ross**

**10 September – 13 October 2003**

**Principal Scientist:**

**Carol Robinson (PML)**

Plymouth Marine Laboratory

Southampton Oceanography Centre
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

UEA NORWICH

University of Newcastle upon Tyne

THE UNIVERSITY of LIVERPOOL

University of Plymouth

University of Southampton

# RRS James Clark Ross Cruise 91
# 10 Sept – 13 Oct 2003

# Atlantic Meridional Transect (AMT) 13

## Cruise Principal Scientist


## Carol Robinson

## Plymouth Marine Laboratory
## Prospect Place
## West Hoe
## Plymouth PL1 3DH


Plymouth Marine Laboratory

# Contents

# Acknowledgements

We thank Captain Robert Paterson and his crew for their outstanding support in ensuring the success and safety of this cruise. Without their help, enthusiasm and professionalism none of the science would have been possible. We also thank Chris Hindley and the BAS personnel at Cambridge for their organisation of transport and freight and especially their work in gaining clearances to work in the EEZ of Mauritania and Senegal. Special thanks go to Simon Wright (Deck Engineer) for his patience, expertise and enthusiasm in co-ordinating our complicated deck operations. Thanks to the UKORS and BAS technical support staff Jon Short, Pete Lens and Pat Cooper whose technical excellence and commitment we rely upon. Many thanks to Dawn Ashby and Malcolm Woodward for their enormous contribution to the preparation of this cruise and Andy Rees for his professionalism during his press ganged mini cruise from Immingham to Portsmouth. Thanks to Dawn Ashby for co-ordinating communication between the ship and the outside world via the web site, and for her contribution to the completion and distribution of this report. Photographs are by Carol Robinson, Simon Wright and Glen Tarran.

As PSO I'd like to say a special thank you to all the officers, crew and scientists of AMT 13 who made this, my first attempt at being Principal Scientist, so enjoyable and rewarding. I've been particularly touched and proud to see the younger staff develop and grow into conscientious scientists and empathetic team players and the older members sensitively carry out mentoring and leadership roles. It's been a pleasure to sail with you all and an honour to be part of this overall project.

# Cruise participants

## Scientific party

| | |
|---|---|
| Carol Robinson<br>Darren Clark<br>Nicola Gist<br>Paul Hampton<br>Chris Lowe<br>Nick Millward<br>Andy Rees (Immingham to Portsmouth)<br>Elena San Martin<br>Glen Tarran<br>Malcolm Woodward | *Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, U.K.* |
| Alex Baker<br>Tom Bell<br>Andy Hind | *School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, U.K.* |
| Samantha Lavender | *School of Earth, Ocean and Environmental Sciences, University of Plymouth, Plymouth. PL4 8AA, U.K.* |
| Alex Poulton<br>Mark Stinchcombe<br>Mike Zubkov | *Southampton Oceanography Centre, Empress Dock, European Way, Southampton, SO14 3ZH, U.K.* |
| Grant Forster<br>Jenna Robinson | *Department of Marine Sciences and Coastal Management, University of Newcastle upon Tyne, Newcastle, NE1 7RU, U.K.* |
| Bernhard Fuchs | *Max Planck Institute for Marine Microbiology,*<br>*Department for Molecular Ecology, Celsiusstr. 1, 28359 Bremen, Germany* |
| Zackary Johnson | *Massachusetts Institute of Technology 48-336 MIT, 15 Vassar St., Cambridge, Massachusetts, USA* |

| | |
|---|---|
| Angelica Paz Granda<br>Eva Lopez Garcia | *University of Oviedo, Departamente BOS, Catedratico Rodrigo Uria s/n, 33071 Oviedo, Asturias, Spain* |
| Howard Waldron<br>Sandy Thomalla | *Department of Oceanography, University of Cape Town, Private Bag, Rondebosch 7701, South Africa* |
| Jon Short | *UKORS, Southampton Oceanography Centre, Empress Dock, European Way, Southampton, SO14 3ZH, U.K.* |
| Pat Cooper<br>Pete Lens | *British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, U.K..* |

## Ship's Officers and Crew

| | |
|---|---|
| Robert Paterson | Master |
| Andy Liddell | Chief Officer |
| Mike Golding | 2nd Officer |
| Calum Hunter | 3rd Officer |
| Liam Beaton | Cadet |
| Peadar Conneely | Cadet |
| Charlie Waddicor | Radio Officer |
| Dave Cutting | Chief Engineer |
| Gerry Armour | 2nd Engineer |
| Tom Elliott | 3rd Engineer |
| Steve Eadie | 4th Engineer |
| Simon Wright | Deck Engineer |
| Nick Dunbar | Electrician |
| Hamish Gibson | Purser |
| George Stewart | Bosun |
| Dave Williams | Bosun's Mate |
| Derek Jenkins | Able Seaman |
| Terry Spiers | Able Seaman |
| Lester Jolly | Able Seaman |
| Marc Blaby | Able Seaman |
| Mark Robinshaw | Motor man |
| Sid Smith | Motor man |
| Duncan Macintyre | Chief Cook |
| Ray Collins | 2nd Cook |
| Clifford Pratley | Senior Steward |
| Derek Lee | Steward |
| Jimmy Newall | Steward |
| Ken Weston | Steward |
| Emma Wilson | Doctor |

**Captain Robert Paterson searching for Venus**

**Marc Blaby, Simon Wright, George Stewart and Dave Williams wait for the CTD**

**Dave Cutting explains the controls in the engine room to Sam Lavender**

**Jimmy Newall and Derek Lee serving the end of cruise dinner**

# Introduction to AMT

**CAROL ROBINSON**
*Plymouth Marine Laboratory*

The biota of the surface ocean has a profound influence on the global budgets of climatically-active trace constituents in the atmosphere ($CO_2$, DMS, $N_2O$, $CH_4$ and aerosols) and hence climate. Our understanding of how biogeochemical cycling in the oceans affects climate, and of how changes in climate influence the structure and activity of oceanic ecosystems is still incomplete, hindering accurate predictions of the future global environment. Realistic model simulations require new observations of both the spatial and temporal variability of planktonic ecosystem structure, multi-element cycling and exchange processes between ocean and atmosphere.

The Atlantic Meridional Transect Programme (AMT) is a UK National Environment Research Council (NERC) funded project which aims to quantify the nature and causes of ecological and biogeochemical variability in the planktonic ecosystems of the Atlantic Ocean, and the effects of this variability on the biological C pump and on air-sea exchange of radiatively active gases and aerosols. The programme continues a series of 12 bi-annual transect cruises between the UK ($50^oN$) and the Falkland Islands ($52^oS$) which took place between 1995 and 2000 making measurements of hydrographic and bio-optical properties, plankton community structure and primary production. Six further cruises will take place between 2003 and 2005 to provide a unique decadal time series of spatially extensive observations on the structure and biogeochemical properties of planktonic ecosystems. The project will allow 45 investigators from 6 partner UK institutions to test nine inter-related hypotheses which fall within the following three scientific objectives :

- To determine how the structure, functional properties and trophic status of the major planktonic ecosystems vary in space and time

The first three hypotheses strive to address the question of linking plankton biodiversity with variability in biogeochemical fluxes, in particular the potential for carbon export to the deep sea and ocean / atmosphere exchange of carbon dioxide. A fourth hypothesis will develop and validate models and empirical relationships to enable the use of remote sensing to interpolate in time between the two AMT sampling periods per year and to extrapolate in space from the single track of *in situ* samples to the basin scale.

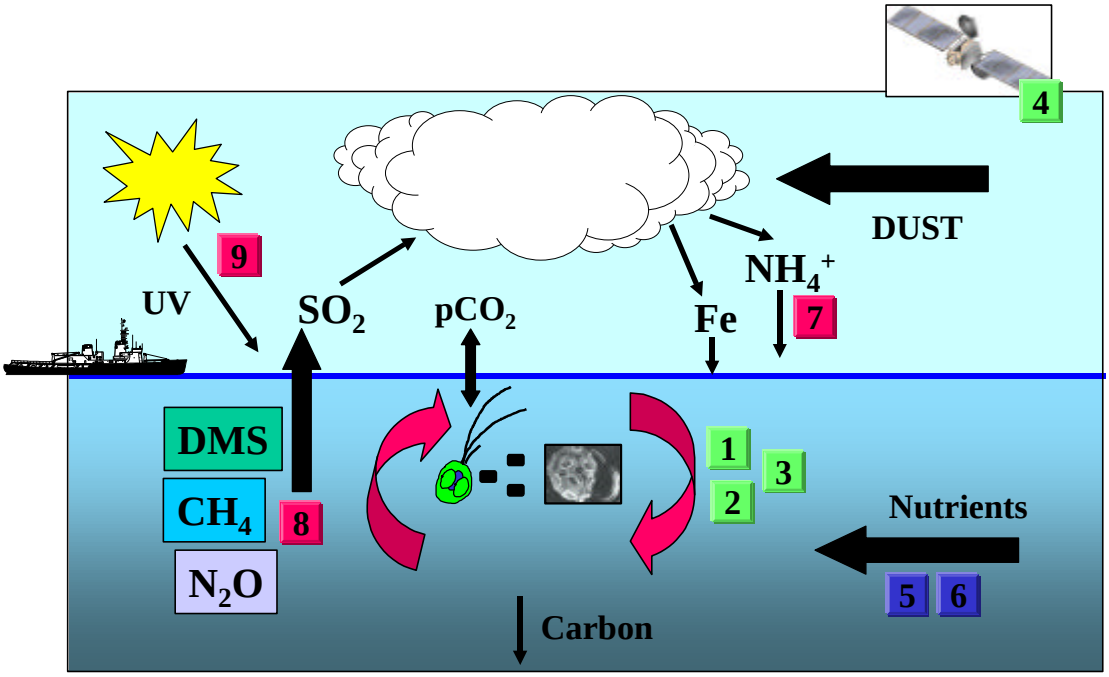
- To determine the role of physical processes in controlling the rates of nutrient supply, including dissolved organic matter, to the planktonic ecosystem

Hypothesis 5 and 6 deal with the physical supply of nutrients on two space and time scales. The programme will derive an indication of lateral transport of nutrients from upwelling regions into the gyres as well as validating models which predict the impact of atmospheric forcing functions on nutrient supply mechanisms.

- To determine the role of atmosphere-ocean exchange and photo-degradation in the formation and fate of organic matter

Hypothesis 7 assesses the impact of atmospheric input of nutrients such as inorganic nitrogen and iron, and hypothesis 8 will further investigate the link between the production of radiatively important gases and plankton community structure with a view to improving basin scale estimates of the fluxes of $CO_2$, DMS, $N_2O$ and $CH_4$. Finally hypothesis 9 will determine the magnitude and variability of the photodegradation products of coloured dissolved organic matter.

The schematic shows how the hypotheses follow a climate feedback loop, with plankton community structure and activity impacting gas emissions which influence cloud formation which in turn influence dust solubility and hence deposition of nutrients and so community structure and activity …..




The first cruise of the programme occurred in May / June 2003 and aimed to compare and contrast the functioning of the plankton in the North and South Atlantic Gyres. The research carried out on the second cruise (AMT-13) is described in this cruise report.

The website www.amt-uk.org is the main source of cruise updates, contact information and reports relevant to the project.

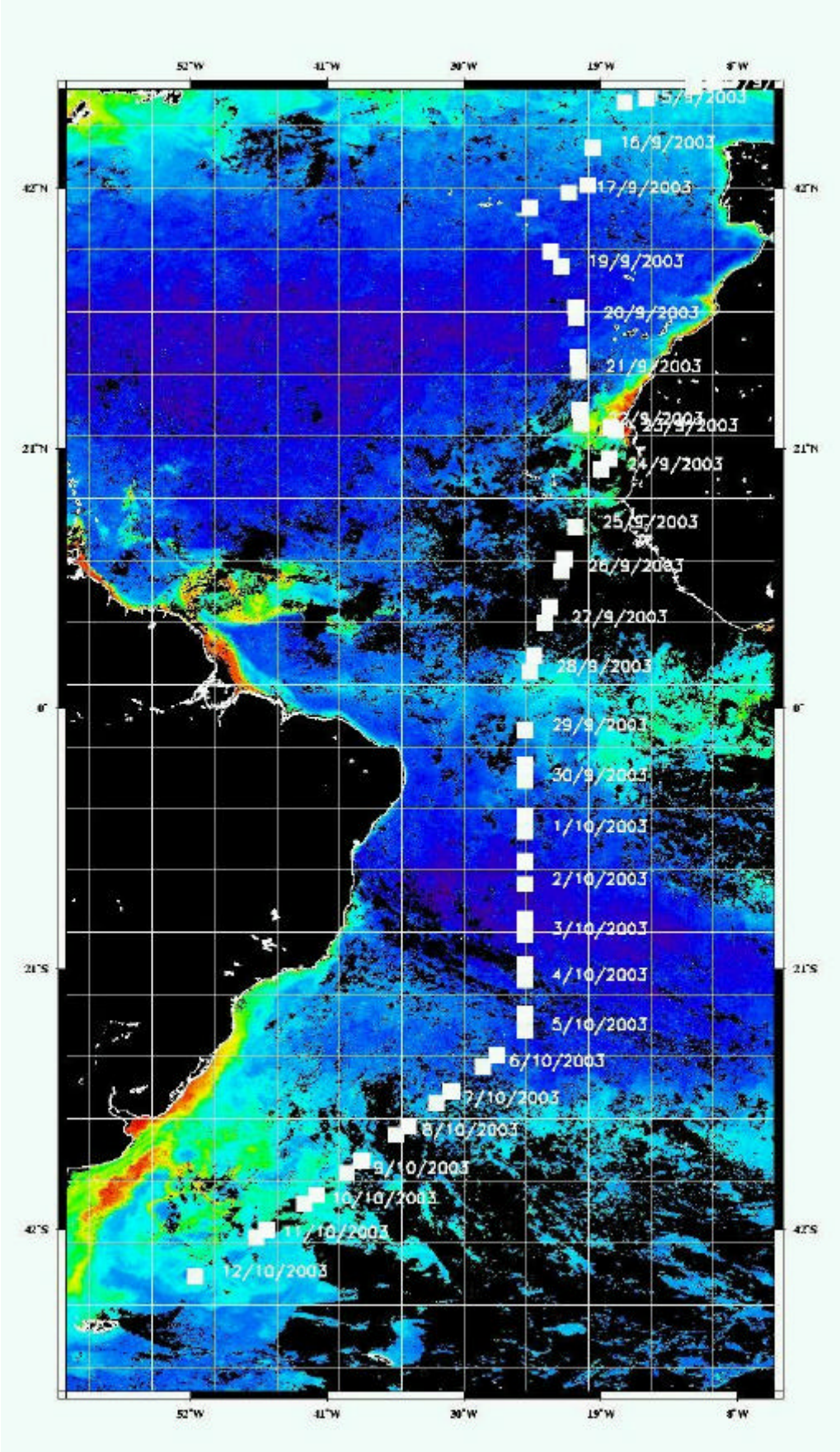



**Figure 1 Cruise track overlaid on SeaWiFS 29 August to 5 September composite**

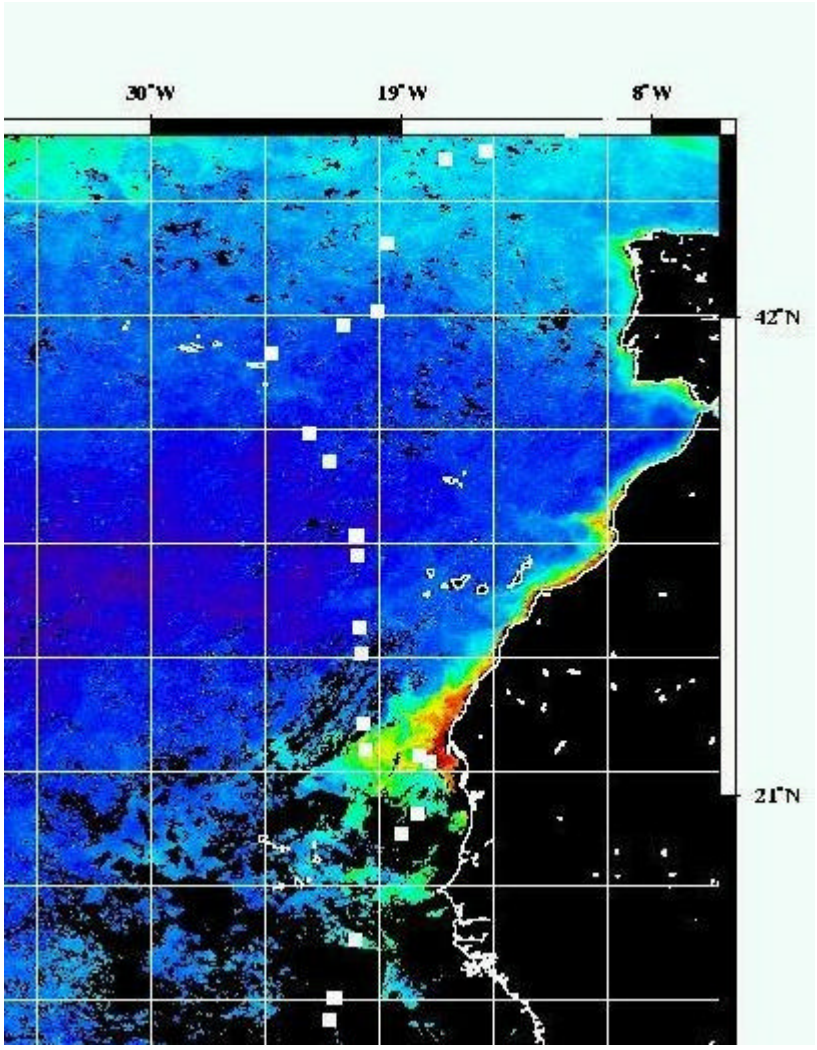



**Figure 2 SeaWiFS monthly composite of the Mauritanian upwelling in 2003**

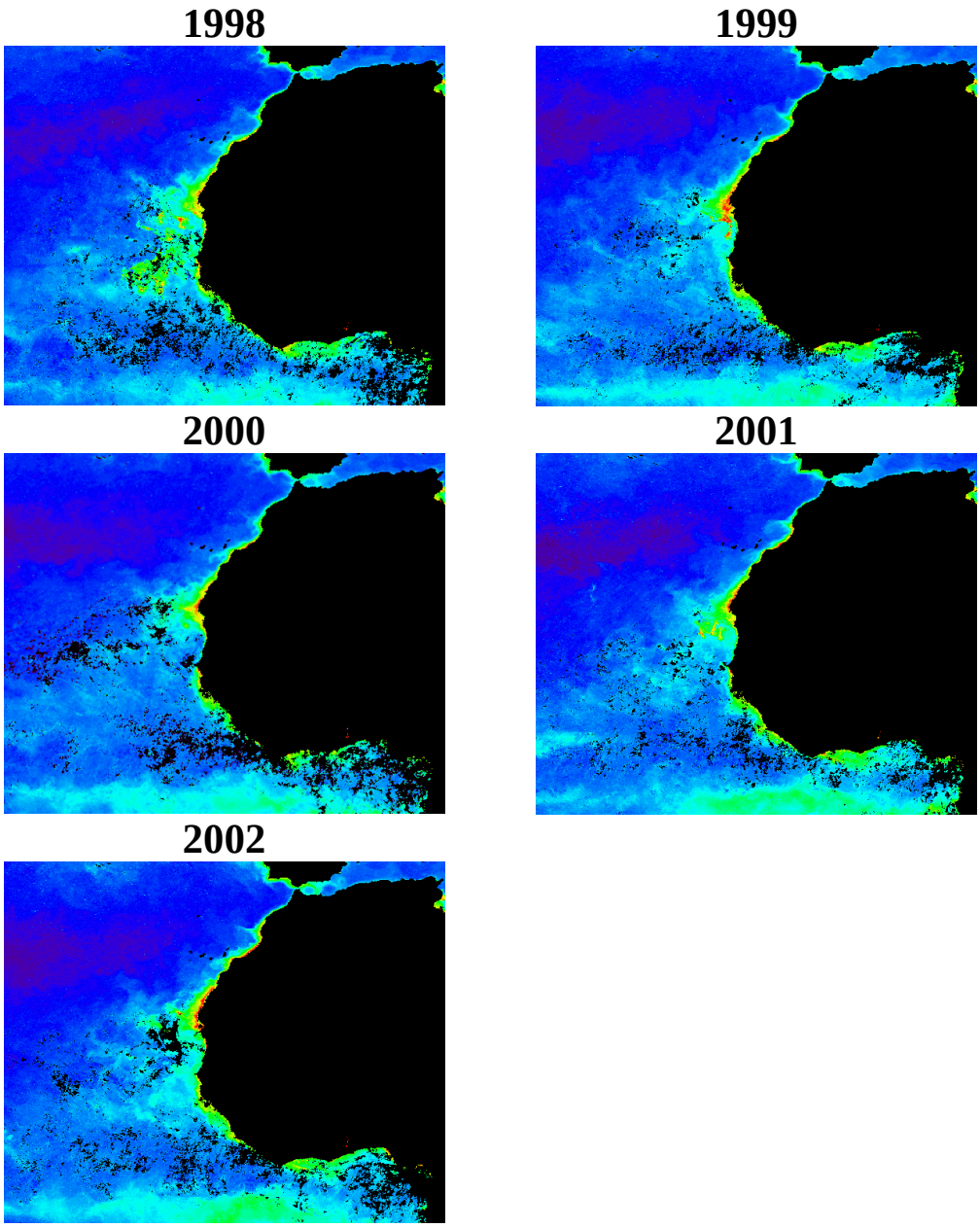



**Figure 3 SeaWiFS September monthly composites of the Mauritanian upwelling in the years 1998-2002**

# Cruise Narrative

## CAROL ROBINSON
*Plymouth Marine Laboratory*

**Thursday 11 September 2003 21:00 BST**

The journey to join the RRS James Clark Ross for AMT13 began for the Plymouth contingent at 05:30 Sunday 7 September 2003, and was memorable for its interruption for breakfast at an ostrich farm (Darren's parents' home) and the inclusion of a 20 minute detour around the Immingham container docks. It was here that the cruise very nearly lost its PSO on a ferry to Rotterdam. The loading of 474 boxes weighing over 10 tons and with an estimated value of £943,000 was achieved with the help of willing volunteers from Southampton, Plymouth and Newcastle, including Dawn Ashby, the AMT Project Officer. The change-over of the JCR Crews on Monday 8 September meant that we were unable to work onboard, but afforded an excellent opportunity for a 'school trip' to York where we bought last minute items for the cruise. Apart from the usual books, music and chocolate, this included stockings for Darren (for storage of cryovials in liquid nitrogen apparently !) and distinctive coffee mugs. Getting to know each other during this 'team building' exercise unearthed a rich seam of 'crimes' which may lead to some interesting forfeits to King Neptune during the crossing the line ceremony. Back on board on Tuesday 9 September, Nick Millward made an admirable job of creating two new benches for scientific equipment, which substantially eased the accommodation of 25 scientists and > 28 analytical instruments in the available laboratory space. Before leaving Immingham Docks on Wednesday at 16.00 BST, all equipment was tied down and all empty boxes were safely stowed. This mammoth task was only achieved through the prior planning of Malcolm Woodward, and the teamwork of all scientists, willing volunteers and crew on board. During Thursday we attended a safety brief which included the correct donning of lifejackets and immersion suits (Paul Hampton was worryingly enthusiastic at wrapping himself in a red rubber suit) and had our first science meeting to discuss our working practises and sampling schedule. We successfully tested the CTD and the optics rig and freefall rocket and are currently standing off Southampton where we will pick up the landing craft on Friday morning. Our first scientific station is planned for 02:00 BST Sunday 14 September just off the shelf break.

**Thursday 18 September 2003 11:00 GMT**

Quite an eventful week on board. Friday 12$^{th}$ September saw us sitting off Southampton waiting for the JCR launch and to say goodbye to Andy Rees who had gallantly volunteered to stay on board (= press ganged) to set up the underway methane / nitrous oxide system. We steamed along the English Channel on Friday night, passing Plymouth about 07:00 Saturday, and out to the shelf break for our first station on Sunday morning. Saturday was spent setting up a white board with magnetic coloured markers for depths and measurements (a brilliant idea of Malcolm's) and plumbing 14 square metres of incubators on the back deck including a novel water mill for Elena and a cascading water feature for the chilled 1% light productivity incubators. Many thanks to Simon Wright for his invaluable help with this. Two stations were sampled on Sunday – a 3 hr station for CTDs to 1000m and 300m, optics and nets at 02:00 BST

and a 1 hr station for a 300m CTD, optics and nets at 11:00 BST. This two station per day routine will continue for the rest of the cruise. The clocks went back 1 hr at midnight on Monday to GMT, and as dawn was getting later, we moved the pre-dawn station to 02:00 GMT. Unfortunately, on Tuesday, the CTD wire snapped, so there were no pre-dawn CTDs and two filters were lost from the optics rig. When, later that day, the MVP malfunctioned and was unable to be deployed we decided the day was unlucky and began plans to rename the cruise AMT12b rather than AMT13. The CTD wire was re-terminated and tested in time for the 11:00 cast thanks to Jon Short, Pat Cooper and the deck crew. On Wednesday we resumed our 2 station routine, now at 40N 20W with a chlorophyll maximum at 60m, surface water temperature of 22.5$^{o}$C and estimated surface chlorophyll concentrations of 0.15 mg $l^{-1}$. Unfortunately three scientists were now ill with tonsillitis, however some of our luck has returned as the DMS system, the discrete methane and nitrous oxide system and one flow cytometer were all repaired today. The Thursday pre-dawn station was brought forward to 00:00 GMT to accommodate a trip to Sao Miguel in the Azores, and was accompanied by a spectacular electrical storm. Having avoided being struck by lightening, we disembarked the Simrad engineer and picked up spare parts for the deck incubator chiller in Sao Miguel before heading back to our planned track. The proximity to land enabled enthusiastic phone calls home, but also the reminder that we may not sight land or see our nearest and dearest again for several weeks. The 11:00 am GMT station had to be cancelled due to the proximity to the islands. However, this gives everyone a chance to catch up with sleep, data analysis and analytical calibration. The two station per day routine resumes at 02:00 GMT Friday 19$^{th}$, and continues until we reach the coastal upwelling off Mauritania on Monday / Tuesday.

**Tuesday 30 September 2003 03:30 GMT**

An interesting phenomena which happens at sea, is that time can simultaneously progress incredibly quickly and tortuously slowly. So here we are, an eon and millisecond after the last narrative, apparently written 12 days ago. Last week began with a science planning meeting to discuss our sampling strategy whilst in the NW African upwelling. This was followed by three days of intensive shift work mapping the distribution of the upwelling influenced waters and the larger phytoplankton and more productive plankton communities occurring there. Chlorophyll concentrations and primary production increased 20 to 30 fold compared to the open ocean waters sampled previously. The sea changed colour from azure blue to pea green and squid, jellyfish and sharks were common. We were also close enough to Africa to be plagued by flies, butterflies and locusts and visited by owls, petrels and pigeons. Towards the end of the week, as we approached the equator, the rain clouds accumulated, the water turned steel grey and the plankton production decreased again. The science programme settled back into a predictable pattern of water collection, net hauls and optical measurements between 02:00 and 04:30 local time, analysis and incubation of samples though the morning, water collection, net hauls and optical measurements again at 11:00 local time, analysis of samples until dinner, relax and sleep. One or two scientists have chosen to work a night shift and they can be distinguished from the rest as they squint in the sunlight and are exuberant and chatty when everyone else is tired and mellow and vice versa. Sunday mornings are ‘Captain’s Inspection’, which elicits a frantic tidy up of the labs and cabins and emptying of the bins into their segregated bags – paper, plastic, tins etc. We crossed the equator at 16:31 local time on Sunday afternoon during the ritual ceremony of presenting new ‘line crossers’ to King Neptune

and Queen Amphritite. Judge Woodward read out the charges against each candidate, and 'Doctor' Alex P. and 'Barber' Alex B. dealt out the punishments with glee. The day was completed with an excellent barbecue (cooked in the galley due to the large quantities of aviation fuel and explosive gases we're carrying) and birthday celebrations for Jon Short and Alex Poulton. Tuesday morning's station was livened up with dancing and singing to Disney's Bare Necessities and Whistle While You Work, and plans are afoot for a 'themed' station on Thursday to celebrate our 50th CTD deployment. As we head south, we'll soon be sampling the crystal clear waters of the South Atlantic Gyre and look forward to comparing the results with those we collected here in May.

**King Neptune (Lester Jolly), Captain Robert Paterson & Queen Amphitrite (Carol Robinson)**

**Saturday 11 October 2003 11:30 GMT**

Just two more CTDs to go !! CTD number 76 – the last one to be deployed to 1000m – returned successfully to the surface this morning bedecked with cans of drinks suitably cooled for celebration and polystyrene cups and plates which had reduced to a tenth of their former size. As we collected this depth profile of water samples we watched as the full moonlit night turned into a pink hued dawn. All this, and we get paid too ! Over the past 10 days we've moved successively into cooler, more productive and stormier waters. We celebrated our 50th CTD with an Elvis tribute, organised a Sunday night pub quiz and held a pre-dinner drinks party in the penthouse Principal Scientist's cabin. Our first albatross was spotted on 5th October, and we're now surrounded by a wide variety of South Atlantic bird life. Several scientists have participated in an excellent 'ship's engine room' tour given by the Chief Engineer, where we learnt the ingenious ways of controlling the ship's engines, the sewage treatment plant, the ship's stabilisers and fuel centrifugation, as well as having the opportunity to climb the funnel. The ship's rodeo effect (or "rough sea and moderate following swell" as it's described in the bridge log) prevented the deployment of the optics rig on the 8th , unfortunately led to the splitting of one of the zooplankton nets and made sampling from the CTD an interesting balancing exercise. As we near the end of the sampling, the scientists are beginning to write their cruise reports and dismantling and packing their equipment. Voting forms are being distributed for the cruise awards – 'Golden Blanket' for the sleepyhead, 'Test-tube' award for the most efficient worker, 'T shirt' award for the best fashion statement, amongst others. The end of cruise dinner, when the awards will be presented, is planned for Sunday 12th October, followed by 2 days of intensive packing and a science meeting to review those results which are available.

We are due to dock at Stanley 08:00 local time 14th October, leaving enough time to sight see and buy presents before we return home on flights on 16th, 20th and 23rd October. Until next time ☺.

**Mr Fixit : Nick Millward**

**King of Comedy award to Grant Forster**

**Captain Paterson receiving framed Thank you card from AMT13 scientists to JCR Officers and Crew**

# Cruise log

## CAROL ROBINSON

*Plymouth Marine Laboratory*

**Sunday 7 September 2003**

Arrived at Immingham from mid-day onwards to begin loading 474 equipment boxes weighing over 10 tons and valued at £943,000 into the laboratories of RRS James Clark Ross. Finished work at tea time to return to various hotels in Grimsby.

**Monday 8 September 2003**

Due to the ship's crew change over, we weren't able to work onboard today. Instead we organised a 'school trip' to York followed by a Chinese meal in Grimsby. Hester Willson returned home due to family illness and Andy Rees, Dawn Ashby, Mike Lucas, Stuart Painter and Young Nam-Kim arrived to help set up the analytical equipment prior to sailing.

**Tuesday 9 September 2003**

Back on board by 08.30 to begin setting up and stowing carriage boxes. In order to accommodate 25 scientists and all our equipment, we installed an extra workbench in the rough workshop and extended one of the benches in the main laboratory. The laboratories were beginning to show signs of organisation by the end of the day. First night on board.

**Wednesday 10 September 2003**

An emergency muster exercise was undertaken at 10.30 to familiarise everyone with their relevant muster station, donning of life jackets and seating in the lifeboats. Those not sailing left the ship at 14.00. The rest of us emerged through Immingham Dock for the beginning of AMT13 at 16.00. Andy Rees volunteered to stay on board until Southampton on Friday morning to help set up the nitrous oxide and methane underway system. We were also joined by a Norwegian engineer Kjetil Aasaekjaer who will help synchronise the swathe before leaving the ship at the Azores next week.

**Thursday 11 September 2003**
Turned into English Channel ca. 08.00. Safety brief at 10.00 including donning of smoke masks and immersion suits and operation of watertight doors was followed by a science meeting at 11.00. We tested the CTD, optics rig and freefall satisfactorily at 14.00 and heard that we've received clearances for Portugal, Spain and Mauritania.

**Friday 12 September 2003**
Anchored off Southampton waiting for launch. Unfortunately, problems with the launch shipping water meant that it didn't arrive until late afternoon. Andy happily waved goodbye to return to PML. Launch finally recovered and we were underway at 18.30, about 6.5 hours later than expected. Made good time, to try and arrive at shelf edge by 02:00 14/09/03. Underway sampling group met and agreed delegation of tasks, Tom to co-ordinate. Nutrient addition / limitation team met to plan first experiments.

**Saturday 13 September 2003**
Sailed past Plymouth about 07:00 am. Last day of preparations before sampling. Unfortunately Jenna confined to bed with tonsillitis. Meeting with Bridge to discuss manpower required for simultaneous deployment of nets, CTD and optics rig. Netting team met to discuss order of play and priorities. Steak for tea.

**Sunday 14 September 2003**
Wind SE 3, slight sea, moderate swell. Air pressure 1026 mb and visibility good. First CTD at 48 21.57 N 09 51.47W in a depth of 1500m. 1000m CTD + 300m CTD + 5 net hauls + 2 optics rig deployments took 3 hours. Net line frayed and had to be re-terminated and re-measured. Interesting collection of jellyfish and ctenophores caught in the nets. All ran extremely smoothly with very few glitches. Second station of day sampled at 11:00 am BST at 47 58.60 N 11 32.04W and took 1 hour for 300m CTD + freefall optics + net + 2 optics rig deployments. Decided not to deploy the MVP as the controlling laptop continues to crash intermittently – reschedule for tomorrow. All analytical instrumentation working well, except the discrete / continuous nitrous oxide / methane, DMS and alkalinity machines and two flow cytometers. Also the chiller for the 1% and 0.1% on-deck productivity incubations belched black smoke and is unlikely to be repairable without spare parts.

**Monday 15 September 2003**
Wind S3, slight sea, moderate swell. Air pressure 1020 mb, temperature 18$^{o}$C and visibility good. CTDs 004 and 005 + 3 nets at 47 05.49N 15 17.22W with surface chlorophyll estimated at 0.2 mgl$^{-1}$ all successfully completed in 2 hr 20 mins. Second station at 11 am BST with 300m CTD 006 + optics cast and freefall rockets at 46 41.27N 17 00.36W. Surface chlorophyll still 0.2 ugl$^{-1}$ with chlorophyll maximum at 50m. Some very clean scientists on board as we're using 18 tons of fresh water a day. The usual consumption for 30 scientists is 13 – 15 tons per day, and the ship can make about 16 tons during the 20 hr per day that we're underway, so some conservation is called for.

**Tuesday 16 September 2003**
Clocks retarded 1 hour at midnight last night, so local time = GMT. Wind picked up to SSE 5, slight sea, moderate swell. Air pressure 1017 mb, temperature 19.5$^{o}$C, visibility good. CTD wire snapped during initial winching of CTD, so pre-dawn CTDs cancelled

and the wire re-terminated during the morning. Nets and optics casts were completed successfully at 02.30 GMT at 44 46.57N 19 21.53W. CTD 008 was deployed at 11.31 GMT at 43 02.56N 19 37.27W together with an optics cast and 3 freefall deployments. Surface chlorophyll dropped to 0.17 $ugl^{-1}$ with a chlorophyll maximum at 60m. MVP couldn't be deployed due to poor wire condition, and this was also re-terminated during the day. Planned sampling before and after an unscheduled visit to the Azores to drop off the Simrad engineer.

**Wednesday 17 September 2003**
Wind SE2, slight sea, long slow swell. Air pressure 1017 mb, temperature 22.6$^{o}$C and visibility good. Good day in terms of getting three more instruments operational, but not so good for the three scientists now suffering from tonsillitis. The pre-dawn station (CTDs 9 and 10) was at 40 02.83 N 20 00.96W where surface chlorophyll concentration was estimated to be 0.15 $ugl^{-1}$.

**Thursday 18 September 2003**
Wind S2, slight sea, low swell. Air pressure 1008 mb, temperature 22.1$^{o}$C and visibility good. This morning's predawn station was brought forward to midnight and restricted to 2 hours (by reducing the monster cast to a depth of 120m) in order to accommodate a boat transfer at Sao Miguel, Azores. The station was preceded and accompanied by a spectacular electrical storm which almost caused it to be cancelled for fear of being struck by lightening. Having survived the storm, the Norwegian Simrad engineer disembarked and we took on board spares for the deck incubator chiller. Black storm clouds lingered for the rest of the day enabling the atmospheric team to collect a whole cruise worth of rain samples.

**Friday 19 September 2003**
Wind NW5, moderate sea, low swell. Air pressure 1010 mb, temperature 23.7$^{o}$C and visibility good. The pre-dawn station took only 2 hr 20 mins and was accompanied by songs from the musicals Oklahoma and South Pacific. We planned our proposed track through the upwelling off the north Mauritanian coast and discussed potential changes to our sampling regime in preparation for a science meeting on Sunday. The highlight of the day was the sighting of dolphins swimming in the bow wave and the most confusing item of the day was the lack of the usual Friday fish and chips from the menu.

**Saturday 20 September 2003**
Wind WNW2, slight sea and low swell. Air pressure 1019 mb, temperature 24.3$^{o}$C and visibility good. Received clearance to work in Senegalese EEZ providing we take on board an observer at Dakar. After reviewing the SeaWiFS images of the Mauritanian upwelling for September of the last 5 years we decided to continue with our plan to sample off Cap Blanc rather than Cap Vert in Senegal. This also means we avoid the potential for piracy and so don't have to set up anti-boarding hoses as was worryingly suggested. The pre-dawn station took only 2hr 15 mins and everyone had their samples in incubators by 05:30 am (even the mysteriously dressed nun) i.e. 1.5 hr before dawn. We therefore took the decision to move the pre-dawn sampling time from 02:00 to 03:00 until dawn moves to 06:00 nearer the equator. Needless to say, the extra hour in bed was welcomed by all. The sea was as glass during the afternoon as we passed the Canary Islands, making it easy to spot turtles and shark's fins. Steak and Death by Chocolate for tea.

**Sunday 21 September 2003**
Wind NE5, slight sea and low swell. Air pressure 1021 mb, temperature 24.5$^{o}$C and visibility good. The pre-dawn station was undertaken at 26 10.23N 20 47.30W, followed by a science meeting at 08:00. Everyone present gave an update on their work and detailed any outstanding problems which still needed help to solve. Alex B. reported collecting rain and Saharan dust samples and Howard and Malcolm were pleased that their ammonia methods agree. Earlier, the student representative had collated comments from the young researchers and these were presented to and acted upon by the PSO. We discussed the extra sampling involved in traversing the upwelling region and an 'underway monitoring' team and shift system was put into place. This was to start at 11:00 am Monday, continue through Monday (low influence of upwelling) and Tuesday (high influence of upwelling) and end when we leave the upwelling influenced waters at 11:00 am on Wednesday. The highlight of Howard's day was catching 4 large squid during the pre-dawn station – almost the JCR record.

**Monday 22 September 2003**
Wind NNE6, moderate sea and swell. Air pressure 1015 mb, temperature 24.4$^{o}$C and visibility good. The pre-dawn station began at 03:00am at 21 58.02N 20 37.43W, surface chlorophyll was estimated to be 0.15 µg $l^{-1}$ with a chlorophyll maximum at 42m. Unfortunately some of the CTD Niskins leaked which caused a rapid reshuffle of water allocation from this precious and oversubscribed cast, but all worked out satisfactorily in the end. Howard caught two more squid, which the galley prepared for entre. Mike Golding (2$^{nd}$ Officer) calculated our predicted positions during the upwelling experiment which Sam Lavender could then overlay on the latest SeaWiFS ocean colour composite. Since the latest composite was dated 5 September we requested a more up to date version to enable us to direct the ship to the highest ocean colour during the upwelling experiment. Unfortunately this later image was completely obscured by cloud. Underway sampling continued throughout the night, with chlorophyll concentrations staying around 0.15 µg $l^{-1}$ as we headed east into the Mauritanian coast just south of the Moroccan / Mauritanian border.

**Tuesday 23 September 2003**
Light air, calm sea, low swell. Air pressure 1011 mb, temperature 23.7$^{o}$C, moderate visibility with a fine haze. The pre-dawn station took place at 20 36.08N 18 09.29W accompanied by numerous squid, flying fish, flies and butterflies. The surface chlorophyll was still only 0.18 µg $l^{-1}$ with a chlorophyll maximum at 35m. On leaving the station we continued inland, slowing to retrieve the moving vehicle profiler [MVP = CTD + optics + nitrate sensor in towed fish] which had developed a fault at 06:30am. At 07:50am the chlorophyll rose to 0.8 µg $l^{-1}$ and SST dropped to 22$^{o}$C. This tempting indicator of upwelled waters lasted only 10 minutes, and didn't occur again until 08:50 am. Flow cytometric analysis suggested the population in these higher chlorophyll / lower temperature waters was dominated by nanophytoplankton (small dinoflagellates and prymnesiophytes) rather than the ubiquitous picophytoplankton observed all around. We therefore turned the ship 180 $^{o}$ and returned to search for this point for the mid morning station. The sampling of this important plankton population was only achieved through the teamwork, patience and superb co-operation of the officers and crew. The bridge reported a definite green line in the sea as we crossed this front from estimated chlorophyll concentrations of 0.1 to 0.9 ug$l^{-1}$, along which they saw sharks cruising. Later analysis revealed substantial quenching of the underway fluorescence –

chlorophyll concentrations were actually 3-4 $ugl^{-1}$ of which ~ 70% was > 10 um – which tallied better with the ~ 50 µmol $O_2$ $m^{-3}$ $d^{-1}$ measured gross production. Nitrous oxide and methane concentrations soared to > 400% saturation during sampling in the vicinity of the coastal upwelling. A hammerhead shark was spotted during deployment of the CTD. The underway sampling night shift included making pirates' costumes and daggers for the pirate's party on Wednesday evening.

**Wednesday 24 September 2003**

Overcast with rain showers, rough sea and long swell. Air pressure 1014mb, temperature 26.8°C and visibility good. Wind squalling SSE8 livened up the daily deposition and retrieval of sample bottles from the deck incubators. The pre-dawn station took place at 18 00.95N 18 17.13W, surface chlorophyll concentration still 0.15µg $l^{-1}$ accompanied by numerous dorado, flying fish, squid, ctenophores and locusts ! The 11:00am station took place at 17 08.40N 19 00.91W, after which we crossed into Cape Verde EEZ waters and sampling stopped until 11:00 am Thursday as we have not received diplomatic clearance to work in these waters. The 11:00 am station revealed significant concentrations of *Trichodesmium* – an organism capable of utilising atmospheric nitrogen gas. The pirates ahoy ! fancy dress party was a great success – several scientists sported wooden legs, hooks instead of hands, tattoos, moustaches and beards as well as a variety of avian imitations on their shoulders. Gerry Armour (2nd Engineer) won the bottle of rum prize for the most authentic costume and Glen Tarran won the prize for the most innovative use of limited resources. The pirates stormed the bridge and demanded politely to be taken to a Caribbean Island forthwith – however after some negotiation they settled on East Falkland Island.

**Thursday 25 September 2003**

Wind NE2, slight sea, low swell. Air pressure 1013 mb, temperature 27.6°C and visibility good. Back in international waters at 12:30 pm – mid morning cast at 12 30.87N 20 59.59W. Baby owl found on back deck – Hedwig delivering a message to Harry Potter (Chris Lowe) no doubt. Simon Wright's birthday (Deck Eng.) gave us another excuse to have Death by Chocolate birthday cake for tea.

**Friday 26 September 2003**

Wind NE2, slight sea, low swell. Air pressure 1012 mb, temperature 27.6°C and visibility good. Howard caught 4 more squid during the pre-dawn station at 09 57.06N 21 58.31W. Humidity 85% at 04:00am. MVP deployed and retrieved again – still not communicating properly. Chlorophyll maximum deepened to 60m at the mid morning cast. Alex Poulton and Gerry Armour's birthdays – Celtic music, toffee cheesecake

and champagne to celebrate. Congratulations to Howard Waldron on his promotion to Senior Lecturer.

**Saturday 27 September 2003**
Clocks retarded 1 hour at midnight last night to GMT –1. Wind NE2, slight sea, low swell. Overcast day with prolonged rain showers. Pre-dawn station at 06 07.83N 23 03.68W and mid morning station at 04 51.00N 23 27.25W. Making steady progress south at an average 11.7 knots with 3.5 to 4.0 hr per day station time. Malfunction of CTD rosette at the mid morning station meant that the top 7 sample bottles (40 m) didn't close so we had to resort to the old 'bucket over the side' method of sampling.

**Sunday 28 September 2003**
Wind SE5, slight sea, low swell. Air pressure 1010 mb, temperature 26.8$^{o}$C, cloudy but fine, visibility good. Jon Short's birthday. Pre-dawn station at 02 09.34N 24 18.92W and mid morning station at 00 53.12N 24 42.62W. Chlorophyll maximum at 70 to 80m. King Neptune and Queen Amphitrite arrived on board at 16:00 for the traditional 'crossing the line ceremony' and we crossed the equator at 16:31 local time at 25 00.00W. Judge Woodward officiated and King Neptune was satisfied with the fines and forfeits administered (measuring the length of the ship with a sausage, singing and dancing to 'singing in the rain' etc.) to the 14 candidates requesting permission to cross his territory. The ceremony was followed by an excellent barbecue cooked in the galley to avoid the large quantities of aviation fuel stored on deck.

**Monday 29 September 2003**
Wind SE4, slight sea, low swell. Air pressure 1013 mb, temperature 26.1$^{o}$C, visibility good. Mid cruise break from 03:00 stations, mid morning station at 03 50.08S 24 59.69W. Chlorophyll maximum at 80m. Began planning logistics of packing equipment and writing cruise report.

**Tuesday 30 September 2003**
Wind ESE5, moderate sea, low swell. Air pressure 1014 mb, temperature 25.4$^{o}$C, visibility good. Pre-dawn station at 06 35.05S 24 59.89W and mid morning station at 07 50.18S 24 59.78W. Chlorophyll maximum at 90m.

**Wednesday 1 October 2003**
Wind SE4, slight sea, low swell. Air pressure 1016 mb, temperature 24.6$^{o}$C, visibility good. Pre-dawn station at 10 38.79S 24 59.7W and mid morning station at 11 56.39S 24 59.58W. Chlorophyll maximum at 130m. Drinks soiree at 19:00 to celebrate Howard's promotion to Senior Lecturer.

**Thursday 2 October 2003**
Wind SE3, slight sea, low swell. Air pressure 1016 mb, temperature 24$^{o}$C, visibility good. Pre-dawn station at 14 19.53S 24 59.68W and mid morning station at 16 09.25S 24 59.37W. Celebrated 50$^{th}$ CTD at 04:50 GMT with Elvis music, costumes and dance.

**Friday 3 October 2003**
Wind variable 1, slight sea, moderate swell, pitching gently. Air pressure 1017 mb, temperature 23.8$^{o}$C, visibility good. Chlorophyll maximum 150m – centre of South Atlantic Gyre now. Large dorado spotted swimming around CTD – but failed to take

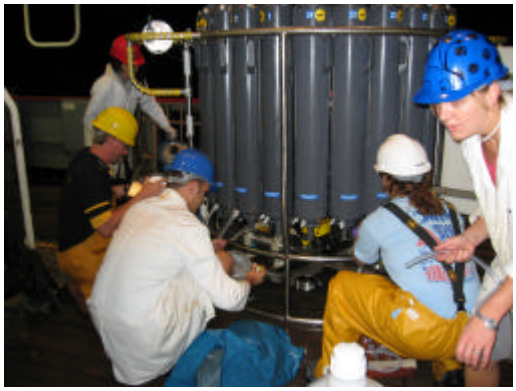
the fishing bait. Officers and crew carried out emergency drill, rescuing a dummy from a smoke filled room. Personal electrical equipment tested for electrical safety.

**Saturday 4 October 2003**
Wind ESE5, moderate sea, low swell, occasional showers. Air pressure 1019 mb, temperature 20.4$^{o}$C, visibility good. Pre-dawn station at 22 40.83S 25 00.14W and mid morning station at 23 54.39S 24 59.89W. CTD oxygen electrode showed signs of drifting, sensor changed for a spare last night, but this also showed an offset. Decided to return to the original sensor for the mid morning station, as it has the advantage of a large number of concurrent Winkler calibration samples.

**Sunday 5 October 2003**
Wind SE5, slight sea, low swell. Air pressure 1022 mb, temperature 18.8$^{o}$C, visibility good. Pre-dawn station at 22 39.05S 24 59.96W and mid morning station at 27 55.00S 24 59.72W. Turned west to the Falklands at 12:46 local time, with only 2061 miles to go – this was a significant event, marked by a visit to the bridge to watch, as we've been heading due south since we crossed the equator a week ago. Another highlight of the day was the sighting of the first albatross following the ship at 17:05. Many thanks to Jenna Robinson who organised a pub quiz for all on board this evening – an excellent time was had by all.

**Monday 6 October 2003**
Wind E2, calm sea and low swell. Cloudless sky, air pressure 1023 mb, temperature 18.7$^{o}$C, visibility good. Pre-dawn station at 29 57.10S 27 19.52W and mid morning station at 30 52.00S 28 26.23W. Spectacularly beautiful dawn elicited a cheer as the sun burst through the horizon and created some stunning photographs. Sea surface temperature 19$^{o}$C and chlorophyll maximum at 140 to 150m with estimated surface concentrations of 0.11 µg l$^{-1}$.

**Tuesday 7 October 2003**
Wind NW5, moderate sea and low swell. Overcast, though visibility good, air pressure 1020 mb and temperature 17.9$^{o}$C. Pre-dawn station at 32 52.35S 30 54.35W. At 09.20 local time (ca. 33S) we passed through a distinct front, with sea surface dropping from 18.2$^{o}$C to 16.8$^{o}$C and sea surface chlorophyll rising from 0.11 to 0.14 µg l$^{-1}$.



**Wednesday 8 October 2003**
Wind E7, rough sea and moderate following swell. Air pressure 1024 mb, temperature 14.9$^{o}$C, overcast though visibility good. No-one got much sleep due to the rodeo effect. Went ahead with CTD, but weather prevented optics deployment and ruptured one of

the plankton nets. Stayed stationary during sampling of the CTD rather than immediately getting underway due to the weather. Pre-dawn station at 35 37.18S 34 20.82W at 03:10 GMT and mid morning station at 36 23.69S 35 20.31W at 12:02 GMT. Nick Dunbar (Ship's electrician) completes the portable appliance testing (PAT) of all personal electrical equipment. The day was completed with a 'pre-dinner' drinks party in the vast penthouse suite known as the Principal Scientist's cabin.

**Thursday 9 October 2003**

Clocks went back one hour at midnight last night to GMT minus 2. Wind NNW 5-6, rough sea, low swell. Overcast with light drizzle and moderate visibility. Air pressure 1002 mb, temperature 16$^{o}$C. Pre-dawn station at 38 28.44S 38 05.88W at 04:08 GMT and mid morning station at 39 23.16S 39 19.371W at 12:59 GMT. Surface chlorophyll concentrations now 0.3 μg $l^{-1}$. Science meeting at 08:00 local time to discuss sampling on the last days of the cruise, preparation of the cruise report and requirements for raw CTD and underway data. Many thanks to Dave Cutting (Chief Engineer) for organising an excellent tour of the ship's engine room, engines, winch room, sewage treatment plant, fuel centrifugation room etc.

**Friday 10 October 2003**

Wind SSW5, rough sea, moderate swell. Bright sunny day, partly cloudy. Air pressure 1008 mb, temperature 8.7$^{o}$C, visibility good. Pre-dawn station at 41 10.11S 41 44.44W at 04:00 GMT and mid morning station at 41 53.63S 42 44.67W at 13:02 GMT. Surface temperature now 13.5$^{o}$C. Logistics meeting at 08:00 to plan packing equipment containers for a) return to PML b) return to Southampton and c) storage in the Falklands. Safety committee meeting at 16:00 to discuss safety aspects on board ship. Meeting for those requiring frozen samples transported back to UK or remaining on board at 17:30.

**Saturday 11 October 2003**

Wind SSW5, moderate sea and swell, partly cloudy with occasional showers. Air pressure 1016 mb, air temperature 7.9$^{o}$C, sea temperature 9.7$^{o}$C, visibility good. Pre-dawn station at 43 58.56S 45 43.47W at 07:00 GMT and mid morning station at 44 33.81S 46 35.21W at 13:04 GMT. Last 1000m CTD at 07:00 accompanied by polystyrene cups and plaques and canned drinks. Surface temperature 9$^{o}$C and surface chlorophyll concentration 0.36 mg $m^{-3}$.

**Sunday 12 October 2003**

Wind SW3-4, slight sea and low swell. Air pressure 1025 mb, air temperature 5.5$^{o}$C, visibility good. Last CTD (#78) at 47 46.02S 51 25.83W at 13.07 GMT. Surface temperature 6.5$^{o}$C with thermocline at ~ 90m. Packing up equipment begins in earnest. End of cruise dinner 18:30 followed by speeches from Captain and PSO and awards ceremony. Many thanks to Nick Millward for co-ordinating the production of the awards and the voting procedure. The Golden Blanket was awarded to Nick Millward, the Shark award to Chris Lowe, the Pastie award to Mark Stinchcombe, King of Comedy to Grant Forster, the Test Tube award to Niki Gist, the Star award to Chris Lowe, the Red Cross award to Jenna Robinson, the Bar Ferret to Howard Waldron, the Golden Gob award to Jenna Robinson, and the T shirt award to Chris Lowe. The PSO presented special awards : Mr Fixit (Nick Millward), Equatorial Singing (Howard Waldron) and Blue Peter (the runaway nun alias Paul Hampton).

**Monday 13 October 2003**
Clocks went back 1 hour at midnight last night to GMT minus 3. Wind NW3, slight sea and moderate swell, rolling gently. Air pressure 1011 mb, air temperature 5.9$^{o}$C, sea temperature 5.1$^{o}$C. Science meeting at 10:00 to discuss any results available, progress towards deposition of data at BODC and timing of data workshop / next cruise planning meeting. Weather and sea state incredibly kind – due into Stanley this evening rather than first thing tomorrow. Northerly gale forecast which could prevent us coming alongside on Tuesday speeded us along. PML container re-packed so that once alongside it could be craned off together with the lab container.

**Tuesday 14 October 2003**
Alongside FIPAS. Spent morning loading container with equipment for return to Southampton and container for storage of equipment at FIPAS. Tidy, clean all laboratories. Walk to Gypsy Cove to see Magellanic penguins at 3pm. Collect cruise reports, complete cruise paperwork.

**Wednesday 15 October 2003**
Nine scientists left for week's holiday in Falklands. Walk through check of laboratory space with First Officer. Afternoon off in Stanley.

**Thursday 16 October 2003**
Remaining scientists left ship. Some with 13 boxes of frozen samples to air cargo back to the UK via Ascension, others for a well earned holiday in South America.

# Cruise reports from Individual Participants or Groups

# Micro and Nano Nutrients

## E. MALCOLM S. WOODWARD
*Plymouth Marine Laboratory*

**OBJECTIVES**

To investigate the spatial and temporal variations of the micro nutrients nitrate, nitrite, phosphate, silicate and ammonium, through the contrasting oceanic regions along the cruise track between the UK and the Falklands Islands. This is the second cruise as part of the NERC AMT consortium project. The track for this cruise was to transect through the edge of the Northern Atlantic gyre, through the west African upwelling off the coast of Mauritania and then contrasting this to the 'marine desert' of the South Atlantic gyre system, with the aim of greater understanding the physical and chemical structures that make up these vastly different oceanic systems.

**METHODOLOGY**

The main nutrient analyser was a 5 channel Bran and Luebbe AAIII, segmented flow autoanalyser. The analytical chemical methodologies were based on the following: nitrate, (Brewer and Riley, 1965); nitrite, (Grasshoff, 1976); phosphate (Kirkwood, 1989); silicate (Kirkwood, 1989), and ammonium (Mantoura and Woodward, 1983). All summarised in Woodward (1994). For the entire cruise track I used a nanomolar detection limit ammonium analytical system which is an adaptation from Jones, (1991) which uses a fluorescent analysis technique following ammonia gas diffusion out of the samples, passing across a hydrophobic teflon membrane, due to pH differential chemistry. Valve problems at the start of the cruise were overcome by removing it from the system and despite a couple of reagent problems the system worked very well at a detection limit of less than 10 nanomoles.

During this cruise I also used a new three-channel nanomolar analyser for nitrate, nitrite and phosphate, combining the sensitive segmented flow colorimetric analytical techniques with a Liquid Waveguide Capillary Cell (LWCC). The nitrate and nitrite channels worked extremely well but due to time constraints the phosphate system was only used in the Southern Gyre region and beyond.

Water samples were taken from the 24 x 20 litre CTD/Rosette system (SeaBird), these were sub-sampled into acid clean 60 ml HDPE (nalgene) sample bottles and analysis for the nutrient samples was in most cases complete within 3 hours of sampling. Clean handling techniques were employed to avoid any contamination of the samples, particularly by ammonium. No samples were stored.

**CTD SAMPLES ANALYSED**

There were 3 different daily operations for the CTD samplings. There was a 'monster' cast at about 2 am for the deep water samples at 500m and 1000m, followed by the pre-dawn productivity CTD cast. During the later part of the morning there was also a 'profile' CTD. This was used as a biogeochemistry cast for nutrient and other sampling, with a number of samples taken in the region of the thermocline and nutricline to be able to use the waveguide analyser to look at the fine scale structure.

The maximum sampling depth was normally 300 metres, with the 'monster' cast deployed to 1000 metres.

| CTD | DATE | PROVISIONAL BOTTLE DEPTHS |
|---|---|---|
| AMT: 13-01 | 14.9.03 | 500 and 1000 |
| AMT: 13-02 | 14.9.03 | Surface, 5, 10, 20, 25, 35, 50, 60, 100, 200, 300 |
| AMT: 13-03 | 14.9.03 | 3,10, 15,20,35,40,45,50,60,75,100,150,200,300 |
| AMT: 13-04 | 15.9.03 | 500,1000 |
| AMT: 13-05 | 15.9.03 | 3,5,15,25,50,60,70,90,120,200,300 |
| AMT: 13-06 | 15.9.03 | 3,5,16,20,25,30,32,35,40,45,48,50,60,75,90,150,200,300 |
| AMT: 13-08 | 16.9.03 | 3,12,20,30,40,50,52,55,58,60,75,90,120,200,250,300 |
| AMT: 13-09 | 17.9.03 | 500,1000 |
| AMT: 13-10 | 17.9.03 | 3,8,15,26,45,60,75,90,120,200,300 |
| AMT: 13-11 | 17.9.03 | 3,12,20,28,40,50,55,58,60,65,80,98,40,150,200,250,300 |
| AMT: 13-13 | 18.9.03 | 3,8,15,26,50,60,75,90,120,200,300 |
| AMT: 13-14 | 19.9.03 | 500,1000 |
| AMT: 13-15 | 19.9.03 | 3,12,12,38,65,85,105,132,150,200,300 |
| AMT: 13-16 | 19.9.03 | 3,14,26,40,55,70,80,90,95,110,120,160,200,240,300 |
| AMT: 13-17 | 20.9.03 | 500,1000 |
| AMT: 13-18 | 20.9.03 | 3,18,32,56,100,130,150,195,250,275,300 |
| AMT: 13-19 | 20.9.03 | 3,14,26,40,60,80,100,110,130,150,200,250,300 |
| AMT: 13-20 | 21.9.03 | 500,1000 |
| AMT: 13-21 | 21.9.03 | 3,13,24,42,70,100,110,150,200,250,300 |
| AMT: 13-22 | 21.9.03 | 3,13,24,35,45,60,70,80,90,95,100,110,150,200,300 |
| AMT: 13-23 | 22.9.03 | 500,1000 |
| AMT: 13-24 | 22.9.03 | 3,5,18,35,42,50,65,100,200,300 |
| AMT: 13-25 | 22.9.03 | 3,5,10,20,25,35,36,37,38,39,40,50,70,100,200,300 |
| AMT: 13-26 | 23.9.03 | 500,1000 |
| AMT: 13-27 | 23.9.03 | 3,5,8,12,28,35,40,45,100,200,300 |
| AMT: 13-28 | 23.9.03 | 2,3,5,6,8,20,15,10,25,40,60,100,150,200,300 |
| AMT: 13-29 | 24.9.03 | 500,1000 |
| AMT: 13-30 | 24.9.03 | 3,4,7,12,20,30,40,55,100,200,300 |
| AMT: 13-31 | 24.9.03 | 3,5,10,20,30,32,34,36,38,40,42,50,65,100,200,300 |
| AMT: 13-32 | 25.9.03 | 3,5,10,20,25,30,34,36,38,40,45,50,65,100,200,300 |
| AMT: 13-33 | 26.9.03 | 500,1000 |
| AMT: 13-34 | 26.9.03 | 3,5,10,16,34,37,45,60,100,200,300 |
| AMT: 13-36 | 27.9.03 | 500,1000 |
| AMT: 13-37 | 27.9.03 | 3,9,17,30,55,69,80,107,150,200,300 |

| CTD | DATE | PROVISIONAL BOTTLE DEPTHS |
|---|---|---|
| AMT: 13-38 | 27.9.03 | Surface,10,20,40,46,48,50,60,68,72,76,80,85,90,100,200,300 |
| AMT: 13-39 | 28.9.03 | 500,1000 |
| AMT: 13-40 | 28.9.03 | 3,10,20,34,60,78,80,120,150,200,300 |
| AMT: 13-41 | 28.9.03 | 3,8,16,28,45,5,0,54,56,58,60,62,65,75,98,200,300 |
| AMT: 13-42 | 29.9.03 | 3,10,20,34,50,60,68,70,74,76,78,80,100,150,200,300 |
| AMT: 13-43 | 30.9.03 | 500,1000 |
| AMT: 13-44 | 30.9.03 | 5,12,24,40,80,95,100,143,200,250,300 |
| AMT: 13-45 | 2.10.03 | 5,12,24,40,50,60,70,80,84,86,88,90,93,100,140,200,300 |
| AMT: 13-46 | 1.10.03 | 500,1000 |
| AMT: 13-47 | 1.10.03 | 3,18,32,56,110,130,140,195,250,275,300 |
| AMT: 13-49 | 2.10.03 | 500,1000 |
| AMT: 13-50 | 2.10.03 | 10,22,40,140,68,100,156,180,240,150,260,300 |
| AMT: 13-51 | 2.10.03 | 7,22,40,50,68,100,120,140,148,152,154,156,160,200,300 |
| AMT: 13-52 | 3.10.03 | 500,1000 |
| AMT: 13-53 | 3.10.03 | 7,20,36,120,66,145,148,155,225,180,300, |
| AMT: 13-54 | 3.10.03 | 7,20,36,66,100,140,145,150,152,155,158,160,180,200,300 |
| AMT: 13-55 | 4.10.03 | 1000 |
| AMT: 13-56 | 4.10.03 | 7,18,34,120,60,132,137,140,200,160,300 |
| AMT: 13-58 | 5.10.03 | 500,1000 |
| AMT: 13-59 | 5.10.03 | 7,11,28,48,110,1151,120,173,200,150,300 |
| AMT: 13-60 | 5.10.03 | 7,20,36,66,100,110,120,130,140,145,148,250,160,1870,250,300 |
| AMT: 13-61 | 6.10.03 | 500,1000 |
| AMT: 13-62 | 6.10.03 | 7,20,36,135,66,145,150,160,225,180,250,300 |
| AMT: 13-63 | 6.10.03 | 7,18,32,56,80,100,110,120,125130,135,140,160,200,300 |
| AMT: 13-64 | 7.10.03 | 500,1000 |
| AMT: 13-65 | 7.10.03 | 7,17,29,52,110,118,120,180,160,250,300 |
| AMT: 13-67 | 8.10.03 | 500,1000 |
| AMT: 13-68 | 8.10.03 | 6,12,22,30,50,60,75,100,200,300 |
| AMT: 13-69 | 8.10.03 | 5,10,20,30,40,50,70,100,120,140,160,200300 |
| AMT: 13-70 | 9.10.03 | 500,1000 |
| AMT: 13-71 | 9.10.03 | 5,10,18,33,75,115,200,250,300 |
| AMT: 13-72 | 9.10.03 | 6,20,36,50,70,100,120,150,200,225,250,300 |
| AMT: 13-73 | 10.10.03 | 500,1000 |
| AMT: 13-74 | 10.10.03 | 5,10,18,33,50,75,115,170,180,200,300 |
| AMT: 13-75 | 10.10.03 | 5,18,25,40,50,60,75,80,100,115,130,150,180,200,250,300 |
| AMT: 13-76 | 11.10.03 | 5,10,20,110,34,60,80,100,120,140,160,299,250,300 500 1000 |
| AMT: 13-77 | 11.10.03 | 5,10,20,34,50,70,80,90,100,120,150,200,250,300 |

**UNDERWAY ANALYSES**

Some daily underway sampling was carried out from the surface (7m) non-toxic sea-water supply. Extra samples were taken when we were in the Mauritanian upwelling, at a frequency of up to one per hour for a couple days.

**OTHER ANALYSES**

9 zooplankton experiments were carried out in conjunction with Elena San Martin, here different selected size classes were spiked with about 15 micromoles of ammonium and 1 micromole of phosphate, the animals were left for 24 hours and the samples then re-analysed to compare the effects.

**PRELIMINARY RESULTS**

Little data analysis has been carried out, the main observation was the variation of the nutricline being shallow in the upwelling and deep to 150m in the gyre. The good operation of the waveguide analyser allowed for the detailed CTD profiles to investigate the nutricline and how sharp it was at the thermocline in its increase from the surface deplete waters above the thermocline. This was the second AMT where there were regular 1000m CTD casts that will gives more insight to the physics of the gyres in particular. Surprisingly in the upwelling waters the surface waters were still warm and nutrient deplete to the nanomolar concentrations.

**THANKS**

Sadly with the loss of Hester to the cruise the second nutrient berth stayed unfilled, but great help was given by the legendry Harry Potter who really can wash bottles in his sleep, and again to Carol our PSO who also cleaned and washed the volumetrics and collected all the samples from the CTD. Thanks to Nick and Tom and some others for help where possible within their own work schedules. Without you all as they say, none of this would have been possible. Thank You.

# Total Alkalinity and Dissolved Inorganic Carbon

## ANDREW HIND
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**INTRODUCTION**

Measurements of the carbonate system allow determination of the flux of carbon dioxide between the atmosphere and the ocean. Current increases in atmospheric carbon dioxide chiefly from burning of fossil fuels combined with the huge-scale deforestation have been linked with climate change. The oceans will eventually take up this relatively small perturbation of the system but rates of exchange are not well known. An improved understanding of the biological pump is required in order to predict the effects of a changing climate and community structure in a perturbed carbonate system. The objectives of this cruise are to measure titration alkalinity (TA) and store samples for later redetermination of TA and also dissolved inorganic carbon (DIC). This work is a direct continuation from that of Ludger Mintrop on AMT 12. Depth profiles from CTD casts will be produced, supplemented with intermediate samples from the underway non-toxic seawater supply. A total of 393 samples were taken. In addition 90 samples were taken for Dr. Andrew Dickson (Scripps Institute of Oceanography, USA) for parallel determination of alkalinity.

**METHODS**

**Total alkalinity (AT):**

Alkalinity is determined by titration of seawater with a strong acid, following the potential of a proton sensitive electrode. The titration curve shows two inflection points, characterizing the protonation of carbonate and bicarbonate, respectively. The acid consumption up to the second point is equal to the titration alkalinity. From this value, the carbonate alkalinity, which is wanted for the adequate description of the marine carbonate system, needs to be calculated by subtracting the contributions to the titration alkalinity from other ions present in seawater. These concentrations are either determined separately or can be derived from salinity and pH of the sample. On this cruise, the VINDTA (Versatile INstrument for the Determination of Titration Alkalinity, Marianda, Kiel Germany) version 3C was used as on AMT 12. It is an open cell titration system, with sample delivery by thermostated calibrated pipette. Sample handling and titration is automated. Alkalinity is calculated using a non linear curve

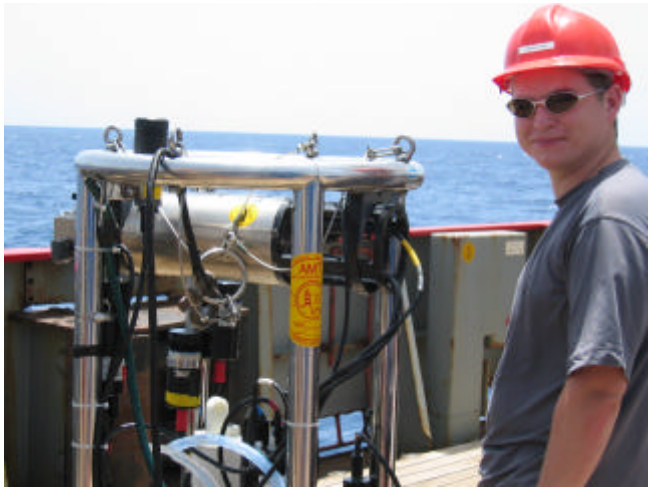
fitting approach, fitting a calculated curve to the data points and making use of the best fit coefficients.

**Dissolved Inorganic Carbon (DIC)**

DIC will be measured using the SOMMA (Single Operator Multiparameter Metabolic Analyzer) system (URI, Rhode Island, USA). The principle of the measurement is to strip the total dissolved inorganic carbon as $CO_2$ from a sample after acidification, using $CO_2$ free nitrogen as carrier gas. The liberated $CO_2$ is absorbed in an organic solution containing ethanolamine and forms an organic acid. The solution also contains a pH-indicator, which turns from blue to colourless when acidified. Using a platinum cathode and a silver anode, $OH^-$ ions are created electrolytically, that neutralize the acid. The current required for this reaction is recorded. The endpoint is determined photometrically by titrating back to the transmission value of the blue colour before $CO_2$ extraction started. The current gives a direct measure of the $CO_2$ titrated and the CT of the sample.

# Partial Pressure of $CO_2$ ($pCO_2$)

## CHRIS LOWE
*Plymouth Marine Laboratory*



The $pCO_2$ system was run continuously from September 12th until October 12th. A single pair of $CO_2$ gas standards were available which were stopped at the equator as they had reached a low pressure and some gas was required to return to the UK for post calibration of the standards. The system was still run through until the end of the cruise, however data from after the point where the gas standards were closed off must be considered qualitative only as there is no indication of how the instrument had drifted during that period.

**REMOVAL OF DATA TAKEN WHILE ON STATION**
Due to probability of contamination of the marine air supply from the ships funnel while on station records where the GPS position between consecutive records of the same group (e.g. marine air(i) – marine air(ii)) was identical were removed. Standards were not edited in this manner since they are not affected by contamination of the marine air supply.

**FLOW RATES**
Due to a requirement to clear the dead space within gas tubes prior to each reading any samples where the flow rate was measured at below 25 cycles was removed.

**GPS POSITIONS**
Positions have been decimalised from the degrees minutes and seconds format of the raw data. North and South have been replaced with positive and negative values respectively.

**GAS STANDARDS**
Two standards were used at the same time, one high and one low so as to calibrate for instrument drift.

**FURTHER PROCESSING**

The data retrieved from the system will be required to be tied in with the ship's ocean logging system to give accurate readings of the barometric pressure and sea surface temperature used for calculating the calibrated $pCO_2$.

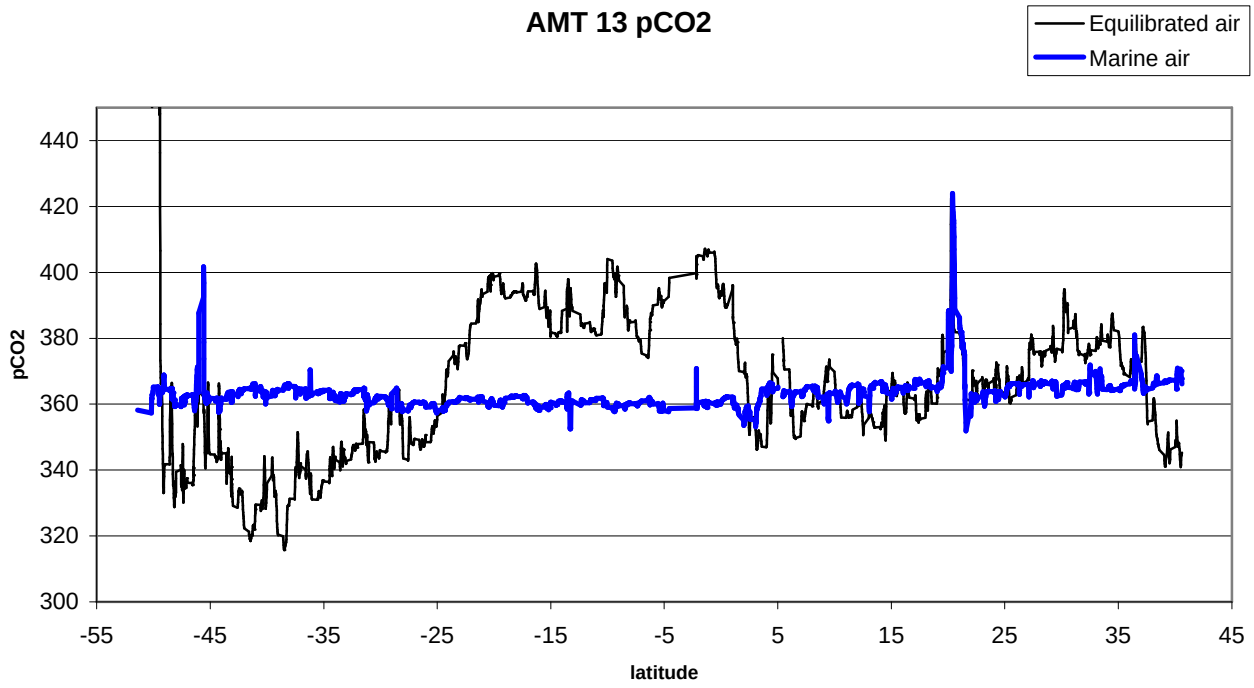



**Figure 4 Uncorrected $pCO_2$ – AMT 13, relative Partial Pressure of $CO_2$ in water and air.**

# Gross production, Net Community Production and Dark Community Respiration

## NICOLA GIST
*Plymouth Marine Laboratory*

### OBJECTIVES

- To determine the depth and latitudinal distribution of the balance of gross production (P) and respiration (R) and to relate this to community structure and nutrient supply (hypothesis 1).
- To examine the balance of gross production and respiration within the Northern Atlantic gyre, and to relate any changes in the P:R ratio to the transport of organic nutrients into the gyre (hypothesis 5).
- To study the balance of gross production and respiration in the upwelling region on the eastern edge of the Northern Atlantic gyre within the context of a possible organic carbon source for the centre of the gyre.
- To compare the P:R ratio in the Northern and Southern Atlantic gyres and relate this to atmospheric and hydrographic derived nutrient supply and to community structure (hypothesis 3).
- To measure dissolved oxygen concentration in order to calibrate the oxygen sensors on the CTDs.

### METHODS

Measurements of dissolved oxygen were made using an automated Winkler titration system with a photometric endpoint (Williams and Jenkinson, 1982). Oxygen saturation was calculated from the equations for the solubility of oxygen in seawater of Benson and Krause (1984).

Gross production (GP), net community production (NCP) and dark community respiration (DCR) were determined from *in vitro* changes in dissolved oxygen. Water was collected directly into opaque polypropylene aspirators from depths equivalent to 55%, 33%, 14%, 1% and 0.1% of surface irradiance. The water was siphoned into 125ml borosilicate glass bottles, and five zero time replicates were fixed immediately. Two further sets of replicates were incubated for 24 hours in surface water cooled deck

incubators or in temperature controlled water baths at *in situ* temperatures. One set was incubated in the dark, the other set in light of equivalent irradiance to that found at the *in situ* depth. This was controlled using polycarbonate screens incorporating neutral density acrylic of differing transmission (Joint *et al*., 1993; Watts and Owens, 1999; Maranon *et al*., 2000; Donald *et al.*, 2001). During hours of darkness, the incubators were covered with opaque screens to prevent interference from the ship's deck lights.

On three occasions, respiration was determined on a surface seawater sample which had been gravity filtered through a 0.8 µm polycarbonate filter.

Dissolved oxygen was measured for calibration of the Seabird Electronics (SBE) sensor on the CTD ($O_2$ sensor number: 43B-0363) using water collected directly from Niskin bottles by use of silicon tubing.

**PRELIMINARY RESULTS**

The metabolic balance of the oceans is investigated by measuring P and R and there is currently a debate as to whether the worlds' oceans are net autotrophic or heterotrophic, which would have serious implications for global climate (Duarte and Agusti, 1998; Williams, 1998). Measurements on AMT 6 showed that P<R (i.e. net heterotrophic) over 48% of the transect, but the carbon required for the observed respiration could not be accounted for (Robinson *et al.*, 2002). Work carried out on AMT 11 showed that in the southern Atlantic gyre, R~<P, but that the north eastern edge of the northern gyre, which shares the same chlorophyll concentration, community structure and primary production is net heterotrophic.

If this net heterotrophy is indicative of the northern Atlantic gyre as a whole, then a source of organic carbon, specific to the northern gyre, must be available. The north Atlantic gyre is cyclonic, and such gyres lead to net movement outwards from the centre. However, it is believed that organic carbon brought to the surface by upwelling on the west coast of Africa may act as a source for the centre of the gyre, probably moving in via eddy currents.

Measurements of P:R on AMT12 were made further within the northern gyre than they have ever been made previously and will allow us to learn more about it's trophic status and how it changes seasonally and from year to year. Results are currently being processed. The cruise track of AMT13 allowed sampling from a similar region to that studied on AMT6, where net heterotrophy was observed, and also to study the upwelling region on the African coast.

P:R ratios are calculated from GP and DCR, both measured in this work at various depths throughout the euphotic layer. P:R values have been calculated for each depth and will be integrated across the water column. Samples were taken from depths corresponding to 55%, 33%, 14%, 1% and 0.1% irradiance. In addition, water collected from the 55% light depth was incubated at both 55% and 97% light intensity, allowing us to take account of potential photo-inhibition to be taken into account when integrating over the entire water column.

We hope to derive representative P:R ratios for provinces traversed by the AMT 13 transect, characterised by community structure and nutrient supply. Concurrent measurements of community size spectra have been carried out (E. San Martin, A.

Poulton, M. Zubkov) and we hope to test the hypothesis that the P:R ratio can be predicted from the slope of the plankton size spectra.

Results will be processed fully on our return to the UK, but preliminary results show that gross production rates at the 55% light level ranged from 0.47 mmol $m^{-3}$ $d^{-1}$ (CTD 56) to 54.84 mmol $m^{-3}$ $d^{-1}$ (CTD 28) and that dark community respiration at the same light depth ranged from 0.5 mmol $m^{-3}$ $d^{-1}$ (CTD 68) to 15.64 mmol $m^{-3}$ $d^{-1}$ (CTD 28).

CTD 28 was a mid-morning cast within the African coastal upwelling region, where both production and respiration rates were high. However, although the lowest observed production rates were measured within the southern gyre, respiration rates were lowest south of the gyre (latitude, 35 37.17$^{o}$S), where gross production rates were relatively high.

On 20 September, the respiration rate of the 0.8µm fraction was 1.11 $\pm$ 0.14 mmol $O_2$ $m^{-3}$ $d^{-1}$ which corresponded to 100% of the whole community respiration measured at the same depth. On 1 October, the respiration rate of this fraction was 2.39 $\pm$ 0.08 mmol $O_2$ $m^{-3}$ $d^{-1}$ which corresponded to 86% of the whole community respiration measured at the same depth, and on 6 October, the respiration rate of this fraction was 0.39 $\pm$ 0.17 mmol $O_2$ $m^{-3}$ $d^{-1}$ which corresponded to 62% of the whole community respiration measured at the same depth. Flow cytometric analysis of these fractionationed samples will allow a mean respiration rate per cell to be calculated.

In-situ water samples collected for the calibration of the SBE oxygen sensor were used to calculate oxygen saturation throughout the cruise. Values varied widely at the deeper depths, with saturations as low as 19% at 300m within the upwelling region (CTDs 27 and 29) compared to ~90% at the same depth at each end of the transect.

The biannual frequency of AMT cruises means that as well as comparing the results from the northern and southern Atlantic gyres on a particular cruise and from year to year, seasonal comparisons can be made. Results from AMT 12 have not currently been fully processed, but it appears that within the southern gyre, net community production values are more negative on this cruise than on the previous one, implying a greater degree of heterotrophy at this time of the year. Future cruises will help to determine whether this is a general trend for the contrasting seasons.

Data will be processed further on our return to the UK, but we expect to be able to deposit all $O_2$, GP, NCP and DCR data at BODC by the end of 2003.

Calibration $O_2$ samples for the CTD SBE sensor have been collected. The complete calibration procedure will be undertaken at BODC, but on this cruise we have been able to carry out some preliminary calibrations ourselves. The sensor appears to “drift” after CTD 27. However, advice from BODC suggests that at the latest point at which calibration took place on-board, the residuals from the statistical analysis are low enough for the calibration to be constrained.

Examples of the depth profiles produced from the productivity incubations are attached for interest (Figure 6), but these are produced from preliminary un-processed data. Figure 5 shows how the oxygen saturation varied at each depth over the initial part of the transect.

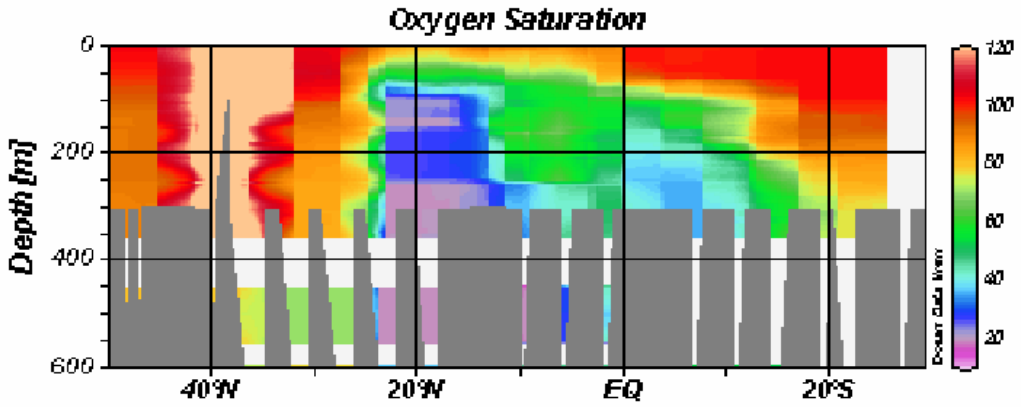



**Figure 5. Oxygen saturation over an initial section of the transect.**

## SAMPLES COLLECTED

Depth profiles of GP/DCR samples were collected daily (n=23) as well as 2 surface-only GP/DCR samples.

*In situ* oxygen for the calibration of the CTD oxygen sensor:
Samples from 8 depths collected from the pre-dawn cast on 23 occasions.
Samples from 2 depths collected from the monster cast on 22 occasions.
Samples from up to 12 depths collected from the mid-morning cast on 9 occasions.

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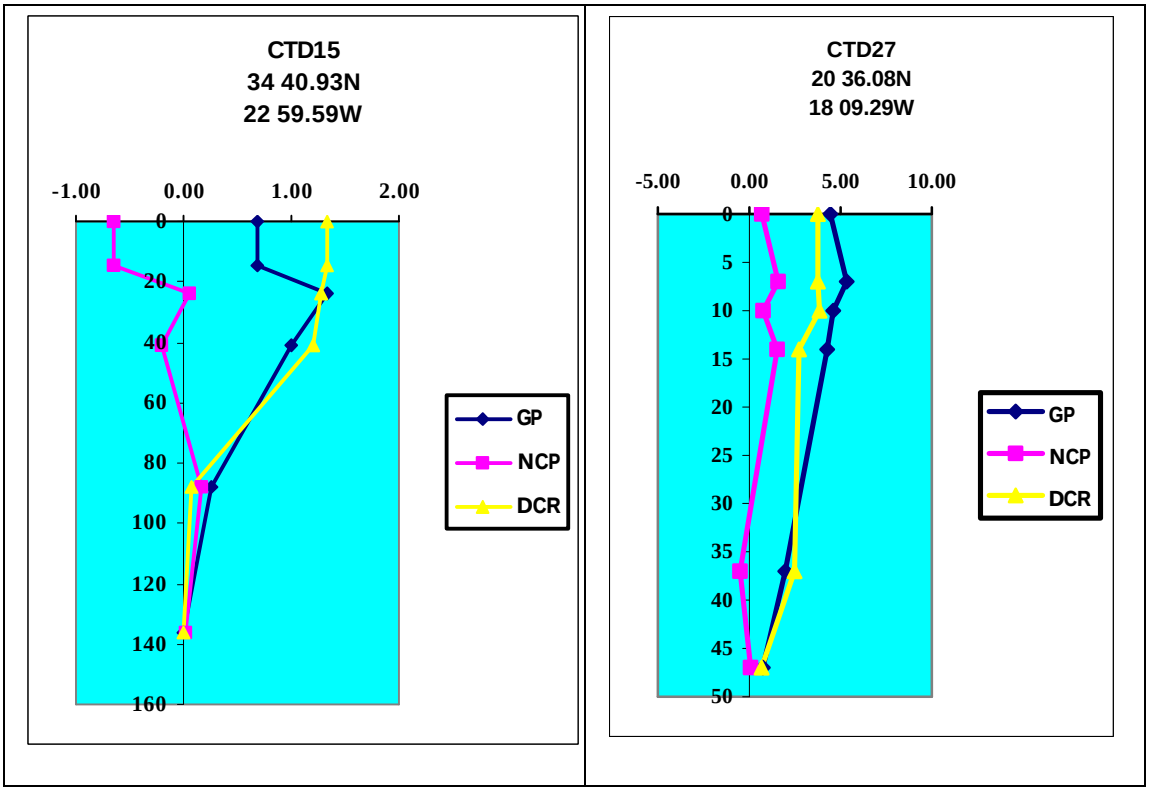
I must firstly thank the Captain and Crew of RRS James Clark Ross for all their help and support. Many thanks also to Carol Robinson, without whom I would not be on the cruise in the first place, but also without whom I would not have survived the cruise. She quietly helped me out, collecting samples and titrating when needed and giving priceless advice when called upon.

Also, thanks to Pete Lens, who spent many hours in the cold and wet shaking bottles with me. He also helped to create a user-friendly, hassle-free on-board calibration method for the oxygen sensor. Emma (Doc) was also a smiley helper with the shaking routine, and Jenna helped keep the pre-dawn cast as late as possible with her help collecting/fixing of in-situ samples. Thanks also to Sam Lavender, who produced the oxygen saturation plot.

I have been very lucky on this cruise to be surrounded by fun, energetic lab-mates and funny but supportive cabin-mates. It has been incredibly rewarding.



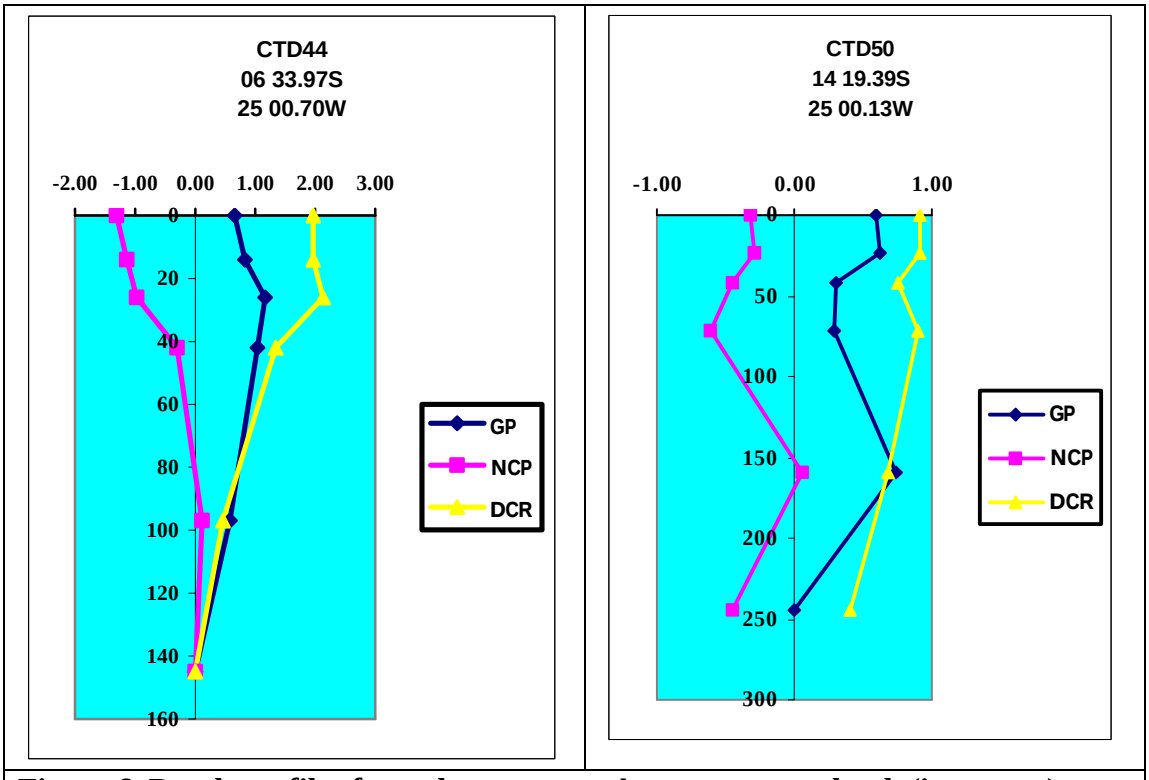



**Figure 6. Depth profiles from the transect. Axes represent depth (in metres) against rates (in mmol $m^{-3}$ $day^{-1}$).**

# Basin Scale Variability of CDOM and Photoreactivity

## JENNA ROBINSON
*University of Newcastle upon Tyne*

### OBJECTIVES

- To measure the absorbance and concentration of Chromophoric Dissolved Organic Matter throughout Atlantic Ocean provinces.
- To measure the photoreactivity of Chromophoric Dissolved Organic Matter through on deck incubations.
- To measure the consumption of oxygen during photodegradation of CDOM, and to compare this to the consumption of Oxygen during respiration.
- To measure the production of carbon dioxide from photodegradation of CDOM.

### METHODS

**Measuring CDOM Absorbance and Concentration**

The instrument used to measure CDOM absorbance is an Ultrapath UV-visible spectrometer.

1) Collect the sample in 100ml acid washed and rinsed amber glass bottles.
2) Make up a saline reference for the spectrometer. Put a measured amount of NaCl into a litre acid washed glass bottle. Fill the bottle with MilliQ water to the 1l mark. Shake the bottle gently until all of the salt is dissolved and the solution is well mixed.
3) Fill a salinity bottle with some of this reference solution so that the salinity of the reference can be taken, and this can be used at a later date to correct the analysis for refraction due to salinity.
4) Transfer 100ml of this saline reference to a 100ml acid washed glass bottle.

5) Connect a 0.2µm disposable filter to the "liquid in" tube on the waveguide.
6) Draw 20ml of the saline reference into a glass syringe, connect the syringe to the filter, and inject the sample into the waveguide.
7) Open the light source by moving the switch to open. In the Spectralys software, go to the instrument panel and click on reference, this will give you a reference for the sample. Check the instrument by running a baseline. While the reference solution is still in the waveguide, click on sample. The sample should be a straight line. If this is not the case, then the instrument is causing a shift away from this baseline. This could be due to;
    a. An instability of the light source, check that the lamps have been given adequate time to heat up and stabilise, if they haven't, leave them for the required time and repeat the dark reference, and then reference and sample.
    b. Fault with the fibre optic cables; check that they are tightened properly at the connections to the light source, the waveguide and the spectrometer. Check also that there is not a large amount of movement of the optical fibres, this can be corrected by securing the optical fibres to the casing for the spectrometer.
8) Press the reference button on the computer to take a reference scan.
9) Draw a small amount of sample into an acid washed 50ml glass syringe, rinse the syringe with this, discard, and refill the syringe with 50ml of sample.
10) Connect the syringe containing the sample to the 0.2micrometer filter, and inject the sample into the waveguide.
11) Press scan, when the time scan is finished a 3D image of the time scan will be shown.
12) If the absorbance of the sample is negative, or the absorbance spectra are obviously far different to expected spectra, then there are a number of possibilities as to why this would happen.
    a. The salinity of the reference is much lower than that of the sample, make up a new reference with a higher salinity.
    b. Contamination has been introduced into the waveguide, try using a different source of filter, particles from the filter may have been drawn in to the waveguide.
    c. The waveguide may be contaminated by CDOM being left in overnight; this can be solved by cleaning the waveguide thoroughly. First introduce waveguide cleaning solution, follow this with methanol, and then with hydrochloric acid. Flush thoroughly afterwards with pure water.
    d. There is a problem with the light source. Turn off the lamps. Disconnect the fibre optic cable which runs between the light source and the waveguide from the waveguide. Turn on the deuterium light, WARNING: NEVER LOOK INTO THE FIBRE OPTICAL CABLE! Wear appropriate protective glasses. Shine the cable onto a white surface, and check that a light is being emitted from the lamp. Next turn on the tungsten lamp, and check that there is light emitted from this lamp also. If one or both of the bulbs are not working, refer to the instruction manual for instructions on changing one or both lamps.

**Measuring CDOM photoreactivity and uptake of oxygen**

1) Take 10 litres of water from the 55% light level Niskin bottle or the 0.1% Light level Niskin bottle at the pre dawn CTD into an aspirator. Filter this sample through a 0.2µm followed by a 0.1µm filter into a second acid washed and rinsed aspirator.
2) Fill 10 120ml glass oxygen bottles and 5 100ml quartz bottles as replicates, i.e. one glass bottle, one quartz bottle and then the second glass bottle (using the quartz bottles for light incubation and the glass bottles for dark incubation and for time zero).

3) Place the 5 “dark” glass bottles into a dark incubator cooled with surface water, and the 4 quartz bottles in an uncovered light incubator cooled with surface water.
4) Fix the 5 time zero samples.
5) Leave the incubations for 12 hours (or for the duration of daylight hours).
6) At the end of the incubations remove the bottles and fix the oxygen in the samples.
7) Measure dissolved oxygen by automated Winkler titration.

## RESULTS

The samples collected were as in the following table:

| CTD no. | Photoreactivity of CDOM Consumption of Oxygen | CDOM Absorbance | Photoreactivity of CDOM Production of $CO_2$ |
|---|---|---|---|
| 2 | 1 depth 55% light | 6 depths | 0 |
| 3 | 0 | 1 depth | 0 |
| 4 | 1 depth 1% light | 0 | 0 |
| 5 | 0 | 6 depths | 0 |
| 6 | 0 | 1 depth | 0 |
| 8 | cancelled | cancelled | cancelled |
| 9 | 0 | 1 depth | 0 |
| 11 | 1 depth, 55% light | 6 depths | 0 |
| 13 | 1 depth, 55% light | 6 depths | 1 depth, 55% light |
| 15 | 0 | 6 depths | 0 |
| 18 | 2 depths, 55% & 1% light | 6 depths | 0 |
| 21 | 1 depth 1% light | 5 depths | 0 |
| 24 | 1 depth 1% light | 6 depths | 0 |
| 25 | 0 | 10 depths | 0 |
| 27 | 1 depth, 55% light | 5 depths | 0 |
| 28 | 0 | 6 depths | 0 |
| 29 | 1 depth, 55% light | 0 | 1 depth, 55% light |
| 30 | 0 | 5 depths | 0 |
| 31 | 0 | 7 depths | 0 |
| 32 | 0 | 4 depths | 0 |
| 34 | 0 | 6 depths | 0 |
| 37 | 2 depths, 55% & 1% light | 6 depths | 0 |
| 40 | 55% light | 6 depths | 0 |
| 41 | 0 | 5 depths | 0 |
| 44 | 55%light and 1% light | 6 depths | 0 |
| 45 | 0 | 6 depths | 0 |
| 47 | 0 | 7 depths | 0 |
| 48 | 0 | 8 depths | 0 |
| 50 | 55% light and 1% light | 6 depths | 0 |
| 51 | 0 | 5 depths | 0 |
| 53 | 55% light | 6 depths | 0 |
| 54 | 0 | 7 depths | 0 |
| 56 | 0 | 6 depths | 0 |
| 57 | 0 | 8 depths | 0 |
| 59 | 0 | 6 depths | 0 |
| 60 | 0 | 6 depths | 0 |
| 62 | 0 | 6 depths | 0 |
| 65 | 0 | 6 depths | 0 |

The analysis of the results from the photo reactivity experiments and the measurement of CDOM absorbance will be carried out at Newcastle University.

# DMS / DMSP


## TOM BELL

*School of Environmental Sciences, University of East Anglia*


### INTRODUCTION

During AMT-13 I have been analysing seawater samples for dimethylsulphide (DMS) and its precursor, dimethylsulphoniopropionate (DMSP) in both the particulate and dissolved form. DMS is volatile and considered climatically significant as it impacts cloud formation and hence the climate, at least on a local scale. DMSP is produced by phytoplankton and its conversion to DMS is both intra and extra cellular. These processes are complicated, involving a myriad of factors. My work on AMT-13 comes under hypothesis 8 (see below) but can be linked with every other hypothesis in some way or another.

*Hypothesis 8:*

*$pCO_2$ and trace gas exchange are a function of phytoplankton community structure and biomass and significantly influence aerosol formation over the remote oceans*

### SAMPLING METHODOLOGIES AND TIMES

I analysed both DMS and DMSP using a system termed 'Purge and Trap'. This essentially involves bubbling and inert gas through the water sample to purge out the gaseous DMS, and then trapping it onto an adsorbent surface (Tenax) at a low temperature. Having concentrated all the DMS onto the trap, I then inject it onto my gas chromatograph (GC) column by heating the trap. The GC provides me with a measurement of how much DMS was in the volume of seawater purged and, using my

own calibration curve, I am able to calculate a concentration. For DMSP, there is an initial preparation step. This simply involves adding concentrated sodium hydroxide (NaOH) to the sample (or filter paper if analysing for particulate DMSP) which cleaves DMSP into DMS and acrylic acid. In the case of dissolved DMSP (DMSPd), the resulting DMS is then purged in the same manner as before. For particulate DMSP (DMSPp), a sample of the headspace above the NaOH-filter medium is injected directly onto the GC column for direct analysis.

Throughout AMT-13, my equipment has experienced what can only be described as a large number of problems. The first three weeks were spent identifying and solving each problem one by one. Initially, all time was devoted to fixing the instrument and equipment. However, as we entered the upwelling region I began taking samples for analysis back at UEA. This essentially involves adding NaOH to a filtered sample (which is sealed and can be analysed for DMS+DMSPd); the difference between this result and the DMSPd result is an indication of the DMS concentration in the water. I took these samples for all the pre-dawn CTD profiles and also took underway samples every two hours. After leaving the upwelling, I only had enough vials available (assuming the equipment was never going to work) to take surface samples from both casts and one underway sample at 1500hrs local time.

Eventually I got all of my system working and began "normal" sampling on CTD cast 50. Normal sampling involved every pre-dawn CTD cast (approx. 0400hrs local time), generally 8 depths - the light depths plus three depths in and around the chlorophyll max). I also sampled the mid-morning CTD cast (approx. 1100hrs local time), but only the surface bottle, and took an underway sample from the underway supply at around 1500hrs (local time). To aid in any correction that might be necessary to the "DMS by difference" method, I continued with both styles of sample collection on the surface sample from the pre-dawn CTD cast.

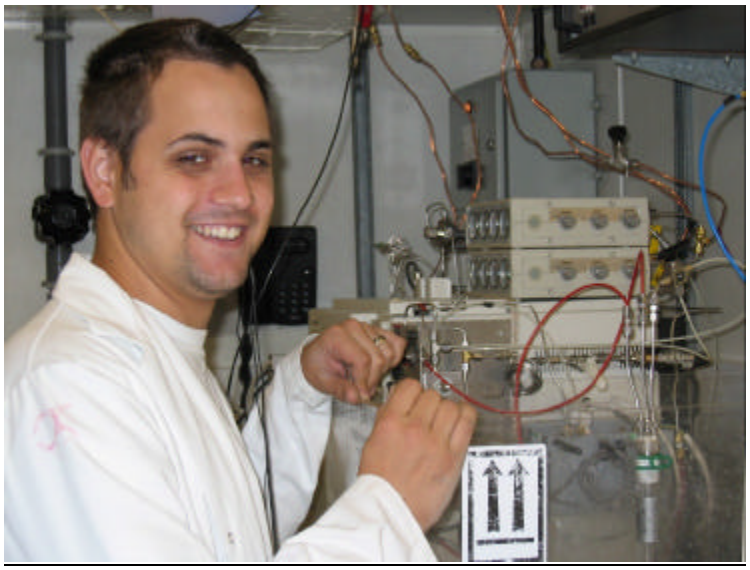
**DATA AND ANLYSIS AIMS**

Once I get back to the UK, my aims are to:

1) Quantify the DMS flux from/to the surface ocean/lower atmosphere.
2) Analyse the DMS/DMSP data in relation to spatial scale and all other data that potentially affects DMS/DMSP production.

# Nitrous Oxide and Methane concentrations in the Atlantic Ocean and stable isotopic signatures

## GRANT FORSTER
*University of Newcastle upon Tyne*



### AIMS AND OBJECTIVES

- To generate vertical profiles of nitrous oxide ($N_2O$) and methane ($CH_4$) saturations for the Atlantic Ocean on the AMT-13 (North to South) cruise track. This will utilise single-phase equilibration gas chromatography (Upstill-Goddard *et al*, 1996)).
- To generate vertical profiles of the stable isotopic signature of nitrous oxide ($^{15}N/^{14}N$, $^{18}O/^{16}O$) using isotopic ratio mass spectrometry (IRMS) to identify the source of the oceanic nitrous oxide.

### INTRODUCTION

A recent synthesis of available data and modelling results reveals an increase in the average global surface temperature of ~ 0.6°C since the late 19$^{th}$ century (IPPC, 2001). Hence concern is growing with regards to the increasing atmospheric burdens of a number of radioactively active trace gases. Nitrous oxide ($N_2O$) and methane ($CH_4$) are of particular interest because they both absorb infrared radiation more intensively than carbon dioxide (Lashof and Ahuja, 1990), together accounting for ~ 18% of enhanced radiative forcing (Hansen *et al*, 1989; Lashof and Ahuja, 1990). $CO_2$ (57%) and CFC's (25%) account for the remainder (Hansen *et al*, 1989).

In 1998, globally averaged atmospheric mixing ratios of $CH_4$ and $N_2O$ were 1,730 ppbv (Dlugokencky *et al*, 1998) and 314 ppbv (IPPC, 2001), respectively. This corresponds to total burdens of 4,850 Tg$CH_4$ and 1510 TgN (IPPC, 2001). However, these burdens are increasing by 0.25-0.31 % yr$^{-1}$ for $N_2O$ (Prinn *et al*, 1990) and 0.3 % yr$^{-1}$ for $CH_4$ (Steele *et al*, 1992; Dlugokencky *et al*, 1994). Data from Pearman and Fraser (1988) show annual increases in methane concentrations of ~0.6 % yr$^{-1}$ during

the eighties, thus the data from Steele *et al* (1992) and from Dlugokencky *et al*, (1998) show a dramatic decrease in the growth rate of methane emissions for the period 1984 to 1996. This imbalance suggests global source-sink imbalances that deserve much needed investigation.

$CH_4$ in the ocean is a source of atmospheric $CH_4$, thus it is essential to quantify this sink if the global $CH_4$ budget is to be resolved. It has been estimated that this source could contribute as little as 0.4 $Tg(CH_4)yr^{-1}$, approximately 0.1% of natural flux based on measurements from open ocean surface waters (Bates *et al*, 1996). However, larger estimates assign an oceanic source strengths as 2% and 2.5 % of natural source strength corresponding to 10 $Tg(CH_4)yr^{-1}$ and 15 $Tg(CH_4)yr^{-1}$, respectively (Fung *et al*, 1991; Lelieveld *et al*, 1998). Bange *et al* (1994) estimated a total marine flux of 15 $TgCH_4yr^{-1}$, this included estuarine and coastal shelf contribution to the marine methane source and supports other estimations (e.g. Brooks *et al*, 1981; Scranton and McShane, 1991; Scranton et al, 1993) suggesting estuarine and coastal sources are a major contributing factor to the marine $CH_4$ flux. Bange *et al* (1994) calculated 75% of all oceanic $CH_4$ is from coastal origin, an area that accounts for ~16% of the world's ocean surface.

Deep water, coastal waters and ocean upwellings are all considered to be oceanic sources of $N_2O$ to the atmosphere (Cohen and Gordon, 1979; Law and Owens, 1990; Naqvi and Norhona, 1991; Owens *et al*, 1991; Nevison *et al*, 1995; Bange *et al*, 1996abc; Bange *et al*, 1999; Patra *et al*, 1999; Dore and Karl, 1996; Dore *et al*, 1998; Morell *et al*, 2001). As a result of the large spatial and temporal variability of the $N_2O$ fluxes from the oceans (e.g. areas of intense flux such as north west Indian Ocean) and a lack of spatial and temporal coverage of the study areas, it still remains hard to assign a total oceanic source and estimates remain uncertain (Houghton *et al*, 1995). According to the IPCC (2001) assessment the major source of $N_2O$ to the atmosphere is from soils, in particular agricultural soils. Unlike $CH_4$, the ocean is considered a large source of $N_2O$ to the atmosphere (see Table 3). The total net source of $N_2O$ to the atmosphere from the oceans has been estimated ranging from approximately 17% to approximately 24% (Cline *et al*, 1987; Butler *et al*, 1989; Mosier *et al*, 1998; Olivier *et al*, 1998 Kroeze *et al*, 1999) of the total source strength. A model by Kroeze *et al* (1998) predicts greater than a 2-fold increase in $N_2O$ production form continental shelves, estuaries, and rivers from 1990 to 2050, this could have strong implication on radiative forcing.

The $^{15}N/^{14}N$ and the $^{18}O/^{16}O$ ratio of $N_2O$ produced in the oceans can hold important information with regards to the geochemical cycle of $N_2O$ (Yoshida and Matsuo, 1983) because it can provide information on whether nitrification or denitrification is the dominant $N_2O$ production mechanism. Importantly the isotopic signature from major terrestrial sources is significantly lighter than that of tropospheric $N_2O$. Although isotopic fractionation occurs during the destruction of $N_2O$ in the atmosphere, this cannot account for the high $\delta^{15}N$ of atmospheric $N_2O$. Observed atmospheric $\delta^{15}N$-$N_2O$ values have been explained by invoking an isotopically heavy source from the oceans (Kim and Craig, 1993; Prasad, 1994). A large marine source of isotopically heavy $N_2O$ is plausible considering that deep water $N_2O$ is characterised by high $\delta^{15}N$ (Kim and Craig, 1990) and the impacts of regions such as the Arabian Sea and the eastern tropical North Pacific where low oxygen and suboxic waters may be major sources of $N_2O$ to the atmosphere (Law and Owens, 1990; Naqvi and Norhona, 1991;

Codispoti et al, 1992). In recent years the formation of the isotopically 'heavy' $N_2O$ has been attributed to nitrification, denitrification, and a denitrification-nitrification couple.

## DATA AND SAMPLES COLLECTED

Data has been collected at various stations along the AMT-13 transect. These range from 9-11 depth measurements for $N_2O$ and $CH_4$. For depths and stations please see the Table below. This data was analysed same day using Single-Phase Equilibration Gas Chromatography (Upstill-Goddard *et al*, 1996) on board RRS James Clark Ross. The final data is yet to be calculated.

Also samples have been collected for $^{15}N/^{14}N$ and $^{18}O/^{16}O$ analysis. These sample have been collected and stored and will be analysed using Isotopic Ratio Mass Spectrometry (IRMS) at the University of Newcastle upon Tyne.

**Table -** ***samples collected on RRS James Clark Ross.***

| STATION | METHANE SATURATIONS | NITROUS OXIDE SATURATIONS | ISOTOPES |
|---|---|---|---|
| | | | |
| AMT13_10 | 10 depths | 10 depths | × |
| AMT13_13 | 10 depths | 10 depths | 10 depths |
| AMT13_15 | 10 depths | 10 depths | 10 depths |
| AMT13_18 | 10 depths | 10 depths | 9 depths |
| AMT13_21 | 9 depths | 9 depths | × |
| AMT13_24 | 10 depths | 10 depths | 10 depths |
| AMT13_27 | 10 depths | 10 depths | 10 depths |
| AMT13-28 | 4 depths | 4 depths | × |
| AMT13_30 | 8 depths | 8 depths | 8 depths |
| AMT13_34 | 9 depths | 9 depths | 8 depths |
| AMT13_37 | 9 depths | 9 depths | × |
| AMT13_40 | 9 depths | 9 depths | 9 depths |
| AMT13_44 | 8 depths | 8 depths | × |
| AMT13_50 | 9 depths | 9 depths | 9 depths |
| AMT13_53 | 9 depths | 9 depths | 9 depths |
| AMT13_56 | 9 depths | 9 depths | 9 depths |
| AMT13_59 | 9 depths | 9 depths | 9 depths |
| AMT13_62 | 9 depths | 9 depths | 9 depths |
| AMT13_65 | 9 depths | 9 depths | 9 depths |
| AMT13_68 | 9 depths | 9 depths | 9 depths |
| AMT13_71 | 9 depths | 9 depths | 9 depths |
| AMT13_74 | 9 depths | 9 depths | 9 depths |

## OBSERVED TRENDS

Date to be analysed and calculated. IR-MS will be carried out at University of Newcastle upon Tyne.

$N_2O$ and $CH_4$ saturations are still to be calculated. However, observed trends are enhanced production with depth for $N_2O$, this is enhanced in the upwelling regions. $CH_4$ vertical profiles need more work before any trend can be reported.

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# Measurements of autotrophic community structure and primary production


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**OBJECTIVES**

1. To provide an understanding of the autotrophic community structure (taxa, size spectra, physiological) on a basin-scale with reference to spatial and temporal changes.
2. To collect samples for measurements of particulate and dissolved organic carbon and nitrogen.

**Table of measurements:**

| Measurement(s) | No. Stations | Analysis method(s) | Person(s) Responsible |
|---|---|---|---|
| Total Chlorophyll<br>(Size-fractionated Chlorophyll[1]) | 57<br>(16) | Welschmeyer (1994) | Mark S, Alex P |
| Pigments[2] (HPLC) | 57 | Barlow et al., (1997) | Sandy T |
| C-uptake:<br>Simulated In-Situ<br>Photosynthesis vs. Irradiance | <br>19<br>9 | Maranon et al., (2000) | Alex P, Mark S |
| DOC, DON, DOP[3] | 24 | Knap et al., (1996) | Mark S |
| POC / PON | 25 | Knap et al., (1996) | Sandy T |
| Phytoplankton species (Microscope) | 25 | Hasle, (1975); Poulton (2002) | Mark S |

Notes;
[1] - Size-fractions were 0.2 - 2-µm, 2 - 5-µm, 5-10-µm (polycarbonate filters; Poretics, UK). Filters were treated identically to those for total chl (GF/F): extracted in

10-ml 90%-acetone (HPLC grade) for 20-24 hrs and read on a TD-700 Turner Fluorometer which was calibrated with pure chl-a extract (Sigma, UK).
[2] - Samples stored at -80$^{o}$C (freezer) until transfer of one set of replicates (set A) into liquid-N for the trip back to UK whilst other set of replicates (B) were left in the freezer until return of JCR to UK in 2004. Sarah Root (SOC) is in charge of HPLC analysis.
[3] - Replicate DOC samples were collected and preserved with phosphoric acid, while replicate DON and DOP samples were frozen (-20$^{o}$C) and returned to the UK in dry ice for analysis.

**SUMMARY**

Core measurements relating to the structure and dynamics of the autotrophic community were collected successfully from all stations, with primary production measurements ($^{14}$C-uptake) from 19 stations (SIS and PvsE). In addition to the measurements collected during AMT-12 (May, 2003) DOC samples were successfully collected as well as the addition of size-fractionated chlorophyll measurements (thanks to Mark S) from the 3 - 4-am pre-dawn CTD casts. Pigment (replicates) and POC samples were also collected from all pre-dawn stations (thanks to Sandy T), as well as pigment samples and further total chlorophyll measurements from the 11-am optics cast (thanks to Sam Lavender). Calibration of the TD-700 (Turner Designs) fluorometer was carried out using a Sigma Chl standard during the cruise with the concentration of the standard rechecked in Southampton and hopefully available to the AMT community with 1-2 months of return to the UK.

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# Estimates of new and regenerated production using labelled $^{15}N$ and $^{13}C$ salts with special reference to "spike" response and bottle effects.

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### INTRODUCTION

This study continues the work completed on previous AMT expeditions to investigate the assimilation of nitrogen and carbon by primary producers in the primarily oligotrophic systems that dominate AMT transects. Although most of the research work was conducted in the gyres of the north and south Atlantic, the cruise track also enabled studies to be made at the edge of the north west African upwelling, the equatorial upwelling and waters to the south of the sub-tropical convergence. Nitrogen uptake experiments provide a wealth of information relating to primary production because they partition the production between the different sources of nitrogen. Primary production based on the uptake of nitrate is termed "new production" (NP) and that based on the uptake ammonium and urea is termed "regenerated production" (RP). Water column dynamics and biogeochemical cycling dictate that NP is equivalent to export production over appropriately long time scales. This is important with respect to the sequestration of carbon below the permanent thermocline and has special relevance to global carbon sink estimates. The relative contributions of NP and RP to the total primary production is conveniently expressed as the "f" ratio (NP / NP + RP). High "f" ratios are likely in eutrophic systems (e.g. upwelling regions) during early bloom stages. Low "f" ratios may characterize later stages of the same bloom event and also oceanic systems dominated by the smaller size classes of phytoplankton. This "uptake signature" relates mainly to nutrient availability and assimilative energy efficiency. A further estimate of total primary production was made possible by the addition of $^{13}C$ to our sampled water.

There were several keystone objectives in the planning for AMT 13:

- Estimate hourly new and regenerated production over the nominal euphotic zone for different oceanic provinces in respect of the total phytoplankton community and within different size classes.
- With special relevance to oligotrophic systems, investigate the impact of nitrogen-15 spike additions on nitrogen uptake rate.
- Investigate the effect of incubation period on hourly nitrogen uptake rate.
- Compute a daily nitrogen uptake rate by incubating over an abbreviated day/night cycle.

**EXPERIMENTAL DESIGN AND METHODS**

There were three CTD deployments each day at approximately 02h00, 04h00 and 11h00. Water was obtained for nitrogen-15 work from the 04h00 cast so that samples could be prepared for a dawn commencement of incubation. Exceptions to this routine occurred when an "abbreviated day" incubation was planned. In these events water was obtained from the 02h00 cast so that incubations could commence pre-dawn and expose the samples to a *pro rata* period of dark and light.

There were six types of experiment designed to address the objectives given above. Emphasis was placed on experiments dealing with "spike response":

- Standard Experiment

Water was obtained from the 55%, 33%, 14%, 1% and 0,1% light levels. Separate sub-samples were spiked with $^{13}C$ and $^{15}N$ labelled salts of $N0_3$-N, $NH_4$-N and urea-N and incubated on deck at the equivalent light level for approximately 10 hours from dawn until late afternoon. Dark bottles were also deployed at each light depth. Incubations were terminated by filtration onto 25mm Whatman GFFs. Nutrient concentrations for nitrate and ammonium will be provided post-cruise and frozen samples have been stored for the determination of urea. This type of experiment should yield the uptake rate of the different N nutrients and the ammonium regeneration rate. The latter may be problematic since it proved difficult to reliably determine ammonium at nanomolar concentrations at the end of each experiment using the manual OPA method..

- Size-fractionation experiments

Similar methodology to that described above, however larger sub-samples were prepared and spiked and post-incubation filtering should provide nitrate, ammonium, urea and carbon uptake rates in the <2μm, 2-10μm and >10μm phytoplankton size fractions.

- Spike response experiments

When doing $^{15}N$ work it is the norm to spike sub-samples with labelled salts at about 10% of the ambient nutrient concentration. This level of addition is thought to maintain the sub-sample's nutrient status quo while providing sufficient $^{15}N$ for subsequent analysis. When working in the oligotrophic environments of the North and South Atlantic, nutrient concentrations are so low that spiking at 10% will provide insufficient $^{15}N$ for post-filtration analysis. It is recognised that spike addition has to be greater than 10% of ambient, therefore experiments were designed to spike sub-samples over a wide range of concentrations from 10nm/litre up to 500nm/litre. In this way, a model can be produced to adjust for nutrient perturbation of the sub-sample. This type of experiment also yields the same information as that for the Standard Experiment i.e. N and C uptake rates at different light levels. Ammonium regeneration measurements were excluded.

- Effect of incubation time on hourly uptake rate

This type of experiment was designed to address the potential problem of "bottle effect" which may occur over the time scale of an incubation. Nitrate was targeted as the pivotal nutrient for these experiments and a bulk water sample was obtained from a specific light depth. Sub-samples were prepared and incubated for 6 hours, 12 hours and 24 hours respectively. Post-cruise analyses should provide information on the impact of incubation time on nitrogen uptake rate.

- Abbreviated day experiments

Daytime incubations provide an hourly uptake rate for the different nitrogenous nutrients, they exclude, however, the nitrogen uptake that may occur during hours of darkness. This is important when one wishes to extrapolate to daily uptake rates. A standard experiment and a size-fractionation experiment were conducted over the time period of an abbreviated day. This means that samples were placed in the incubators a number of hours pre-dawn and the experiment was terminated when they had been exposed to an equivalent period of daylight. In this way, the nitrogen uptake over the period of the experiment integrated both night and day processes. This approach helps to mitigate the "bottle effect" that may occur during 24 hour incubations.

- Additional work

A further experiment was conducted opportunistically with E. San Martin as part of her zooplankton grazing research. It became apparent that the hourly uptake rate of ammonium-nitrogen by phytoplankton in the mesocosms would be a useful variable in interpreting net processes following the addition of excess ammonium. Spike additions of $^{15}NH_4$-N were added to the mesocosms and post-incubation filtration of 500ml should permit the estimation of $NH_4$-N uptake.

The following table gives a breakdown of the experiments conducted during the course of this research cruise:

| Station Reference | CTD number | Experiment Type |
|---|---|---|
| 1 | 2 | Standard (dawn-dusk) |
| 2 | 8 | Size-fractionation (24h) |
| 3 | 13 | Standard (abb. day) |
| 4 | 15 | Spike response ($NH_4$) |
| 5 | 18 | Spike response ($NO_3$) |
| 6 | 21 | Spike response (Urea) |
| 7 | 24 | Standard (dawn-dusk) |
| 8 | 27 | Incubation time impact |
| 9 | 34 | Spike response ($NH_4$) |
| 10 | 37 | Spike response ($NO_3$) |
| 11 | 39 | Size-fractionation (abb. day) |
| 12 | 44 | Spike response (Urea) |
| 13 | 47 | Spike response ($NH_4$) |
| 14 | 50 | Spike response ($NO_3$) |
| 15 | 53 | Spike response (Urea) |
| 16 | 56 | Spike response ($NH_4$) |
| 17 | 59 | Spike response ($NO_3$) |
| 18 | 62 | Spike response (Urea) |
| 19 | 65 | Spike response ($NH_4$) |
| 20 | 68 | Spike response ($NO_3$) |
| 20a | 69 | Zooplankton grazing - ϕpl uptake of $NH_4$ |
| 21 | 72 | Spike response (Urea) |
| 22 | 75 | Incubation time impact |

## RESULTS

The results of $^{15}N$ and $^{13}C$ work conducted on this cruise will not be available until post cruise analyses have been performed on the mass spectrometer and $^{15}N$ analyser at SOC or PML. These results should be available in 2004.

## CONCLUSIONS / CONJECTURES

In the absence of results this section of the report leans heavily on conjecture. The research cruise passed through several different types of marine system *viz* North and South Atlantic gyres, the Ekman-driven north-west African upwelling system, the divergent equatorial upwelling and waters to the south of the sub-tropical convergence. The latter three systems were familiar in terms of their relatively high biomass, most of my previous work having been conducted in the Benguela upwelling system, however the oligotrophic waters of the sub-tropical gyres were a revelation. I was expecting the oceanographic equivalent of the Atacama desert and this was true except for the bustling phytoplankton community living at the 1% light level. The filters were brightly coloured with a thriving algal biomass that sit happily on the boundary between famine and feast i.e. the nutricline. It is likely that their nutrient supply stems from a diffusion of nitrate from the underlying reservoir in combination with metabolically recycled ammonium and urea, however, there was evidence of other vertical mixing processes. When wind conditions were appropriate, the observation of surface slicks indicated the passage of progressive internal waves. The shear at the pycnocline would provide a turbulent as opposed to diffusive mechanism for the vertical transport of phytoplankton nutrients. A future research initiative could investigate the dynamics of vertical transport in oligotrophic systems.

## ACKNOWLEDGEMENTS

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# Carbon and Nitrogen export estimated from $^{234}$Thorium and $^{238}$U disequilibria

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Biological activity in surface waters drives the oceanic particle cycle, which in turn controls the scavenging of trace metals and sedimentation to the sea floor. Carbon fixation and carbon export is central to understanding oceanic productivity, and its long term effect on atmospheric $CO_2$ concentration. The particle- reactive radioisotope $^{234}$Th (half life 24.1 days) is often in disequilibrium with its parent nuclide $^{238}$U in surface ocean waters. This occurs because $^{234}$Th but not $^{238}$U partitions strongly onto particle surfaces and its removal on the sinking flux of material leads to radioactive disequilibrium. Consequently $^{234}$Th/$^{238}$U disequilibrium is potentially a powerful tool to study the downward flux of carbon in the ocean via sinking particles.

Knowledge of the integrated disequilibrium in the water column combined with a steady-state assumption and with the decay constant of $^{234}$Th yields an estimate for the flux of $^{234}$Th from the surface ocean caused by settling particles. To calculate the POC flux from the surface ocean, the ratio of POC to $^{234}$Th on sinking particles is multiplied by the estimated $^{234}$Th flux.

For budget calculations of $^{234}$Th, it is essential to consider all processes that control $^{234}$Th activity in a given volume of water. For dissolved $^{234}$Th these are $^{238}$U decay (i.e. $^{234}$Th production), radioactive decay of $^{234}$Th and loss of $^{234}$Th to the particulate $^{234}$Th pool. For particulate $^{234}$Th the controlling processes are input from the dissolved pool, radioactive decay and loss through particles settling out of the given volume of water.

**METHODS**

Samples for thorium analysis were collected from a designated CTD cast every 2 days (see Table below for station positions). Twenty litre water samples were collected from seven depths (surface, 25m, 100m, 200m, 300m, 500m and 1000m). The sampling distribution is concentrated in the surface 300m where a significant export of thorium on settling particles is expected to result in radioactive disequilibrium between thorium and uranium. The sample at 1000m represents radioactive equilibrium between $^{234}$Th and $^{238}$U.

Total uranium is calculated from salinity and does not have to be measured separately.

Particulate $^{234}$Th is measured by filtering the 20litre sample through 142mm 0.4µm polycarbonate filters. These filters are folded in a reproducible way, wrapped in mylar foil and counted directly in a beta counter using appropriate corrections for self-absorption of radiation due to the filter and for detector efficiencies <100%, and corrections for $^{234}$Th decay and $^{234}$Th in growth from $^{238}$U decay since sampling.

Dissolved thorium is measured by adding potassium permanganate ($KMnO_6$), manganese dichloride ($MnCl_2$), and concentrated ammonia ($NH_3$) to the already filtered water sample. Dissolved $^{234}$Th is precipitated from the filtered water as $MnO_2$ precipitate within 8 hours. This precipitate is filtered onto 142mm 0.8µm polycarbonate filters which are then processed in an analogous way as filters for particulate $^{234}$Th. The extraction efficiency of the precipitate was tested on the last CTD by collecting the filtered sea water after the $MnO_2$ precipitate had been filtered out and adding the chemicals again. After letting the water stand for 8 hours the precipitate was once again filtered out and processed and the filters counted to see if any dissolved thorium was still present in the water.

$^{234}$Th decays via beta decay to $^{234}$Pa. $^{234}$Pa has higher energy betas than $^{234}$Th. It has a short half life of 1.2 minutes and therefore always in radioactive equilibrium with $^{234}$Th. Hence, what actually is measured by the beta counter is $^{234}$Pa decaying via beta decay to $^{234}$U.

The replicate sample taken at 1000m helps assess the precision of the sampling process. This was also done on the last CTD where three 20litre samples were collected from the surface and five from 1000m. These samples are all processed in the same way to test the reproducibility of the sampling methods. Accuracy may be assessed by comparing the determined activity of total $^{234}$Th with the $^{238}$U activity at depth (i.e. 500 or 1000m).

Detector drift (which usually is negligible) is monitored by repeated measurements of a standard sample having a known amount of $^{238}$U in equilibrium with $^{234}$Th.

At each of the seven thorium depths, a 4litre sample was filtered onto GFF filters for particulate organic carbon (POC) and particulate organic nitrogen (PON). Filters were placed into plastic petri dishes and frozen at -20$^{o}$C in a dark room for future analysis at the Southampton Oceanography Centre.

The large particulate thorium fraction >50µm was sampled using a 50µm zooplankton net which is raised through the water column from a depth of 100m. A flow metre was

attached to the top of the net in order to more accurately determine the actual volume of water passing through the net. The net sample is then filtered through a 200µm mesh in order to eliminate the zooplankton or swimmers from the sample. Following which the sample is split using a Fulsam sample splitter. 6/8$^{ths}$ of the sample is filtered onto 142mm 0.4µm polycarbonate filters which are then processed and counted in the beta counter. 1/8$^{th}$ of the sample is filtered onto GFF filters for POC and PON analysis and stored in the -20 degree freezer.

**Table of Thorium station positions**

| CTD | Latitude | Longitude |
|---|---|---|
| **1** | 48 21.57N | 09 51.74W |
| **9** | 40 02.83N | 20 00.96W |
| **14** | 34 41.10N | 22 59.70W |
| **20** | 26 10.23N | 20 47.30W |
| **26** | 20 36.08N | 18 09.29W |
| **33** | 09 57.06N | 21 58.31W |
| **39** | 02 09.34N | 24 18.92W |
| **43** | 06 35.05S | 24 59.89W |
| **49** | 14 19.53S | 24 59.68W |
| **55** | 22 40.83S | 25 00.14W |
| **61** | 29 57.10S | 27 19.52W |
| **67** | 35 37.18S | 34 20.82W |
| **70** | 38 28.44S | 38 05.88W |
| **73** | 41 10.11S | 41 44.44W |

# Dinitrogen Fixation in the Atlantic Ocean

## NICK MILLWARD
*Plymouth Marine Laboratory*

### OBJECTIVES

- To develop an acetylene reduction gas chromatographic method for use with marine oligotrophic water samples as an indirect measure of dinitrogen fixation
- To further develop the $^{15}N$ stable isotope method for atmospheric dinitrogen fixation.
- To make measurements of dinitrogen fixation, by means of the acetylene reduction technique.
- To make measurements of dinitrogen fixation, by means of the $^{15}N$ stable isotope incorporation technique.
- To further develop protocols for both the $^{15}N$ and acetylene reduction techniques in a research vessel environment.

### METHODS

**Acetylene reduction:** Dinitrogen fixation was measured indirectly by means of the acetylene reduction technique. This technique is based upon the biodegradation of acetylene to ethylene, by means of the triple bond in the acetylene being broken by the nitrogenase enzyme. This enzyme is only present in organisms that possess the ability to fix atmospheric dinitrogen, and it therefore a reliable measure of the dinitrogen fixing natural biota.

Water was collected each morning from the pre-dawn CTD from 3 depths equivalent to ( 33%, 55% and 97%) of surface irradiance. The samples were incubated in 250 ml gas tight bottles for 12hrs in on-deck incubators, with the appropriate light filters. The required light depths were calculated from PAR data from the previous day's data. The samples were removed after incubation and stored in a dark box, the headspace of the bottles was then equilibrated and analysed by gas chromatography (flame ionisation detection).

**$^{15}$N stable isotope technique:** This technique is a direct measure of the uptake of $^{15}$N by the dinitrogen fixing organisms. $^{15}$N was introduced as a gas into the cubitainers and any uptake of $^{15}$N labelled nitrogen, therefore must be as a result of atmospheric /dinitrogen fixation.

Water was collected each morning from the pre-dawn CTD from 2 depths equivalent to 1% and 55% of surface irradiance. This was then transferred into 8 gas tight cubitainers, 4 for each depth.

To each set of cubitainers the following inoculations were carried out:

| Cubitainers No | light level | Addition | incubation time |
|---|---|---|---|
| 1,5 | 1% and 55% | $^{15}$N | 0 hr |
| 2,6 | 1% and 55% | $^{14}$N (Air) | 0 hr |
| 3,7 | 1% and 55% | $^{15}$N | 24hr |
| 4,8 | 1% and 55% | $^{14}$N (Air) | 24hr |

These were incubated for the appropriate time in on deck incubators with the appropriate light filters, removed and filtered on to glass fibre filters (GFFs), placed in to small petri dishes, sealed and dried..

**PRELIMINARY RESULTS**

Due to the time required to process the data I can not supply preliminary results at this time.

**CONCLUSION**

The acetylene reduction technique proved to be somewhat troublesome. The 250ml incubation bottles with gas tight septa caps proved to be ineffective. It was found that the needle gauge needed to inoculate the sample whilst displacing the excess sea water was found to be very large. This caused one serous problem, the septa would not reseal after puncture by the large gauge needle. So this problem was overcome by setting up a bottle with fixed injection ports, capped with 3 way luer lock valves.

This proved to be effective and the subsequent experiments went ahead without problems. However due to lack of luer lock valves I was only able to sample 3 depths on each CTD for the acetylene reduction technique.

# Planktonic size spectra & zooplankton feeding experiments

**ELENA SAN MARTIN**
*Plymouth Marine Laboratory*

The main aim of this component of AMT-13 is to determine plankton size spectra along the Atlantic Meridional Transect and carry out size fractionated zooplankton feeding experiments. I will compare latitudinal variation in the spectral slope of plankton in the size range between 10 µm and 4 mm. This will hopefully contribute towards understanding the export of carbon to the atmosphere and deep ocean. The main purpose is to resolve whether plankton community size structure can be used as a predictive tool in large-scale oceanic regions. The grazing experiments will further help to understand the complex trophic interactions between this plankton size range.

## OBJECTIVES

- To determine phytoplankton and microzooplankton size spectra.
- To obtain depth integrated mesozooplankton size spectra from vertical net hauls.
- To produce “complete plankton size spectra” for each station by compiling both of the above data sets.
- To obtain size fractionated zooplankton biomass.
- To conduct mesozooplankton feeding experiments and observe the grazing activity of a mixed size fractionated zooplankton population over a mixed prey (phytoplankton and microzooplankton) population.
- Observe the occurrence of large phytoplankton in 50 µm net samples in collaboration with Professor Patrick Holligan and Dr Alex Poulton.

**METHODS**

Vertical 200 and 50 µm bongo net hauls were towed up at 30 m $min^{-1}$ from both 200 and 50 m depths at each pre-dawn station. Each 50 µm sample was fixed in both Lugol's iodine and formalin for later microscopic examination. Time allowing, size fractionated zooplankton biomass sub-samples (> 1000 µm; > 500 µm; > 200 µm) were taken from the 200 µm net samples and dried for later C and N analysis. The rest of the sample was fixed in formalin for later examination.

Phytoplankton and microzooplankton samples were collected from the pre-dawn CTD cast at every depth and fixed in both Lugol's iodine and formalin. FlowCam, which is an instrument that instantaneously counts and sizes particles in the 10 µm – 4 mm range, will be used to count and size all of the preserved plankton samples.

The zooplankton feeding experiments were conducted every three days from mid-morning casts. The mesozooplankton were collected from vertical plankton net hauls made with a 50 µm mesh net towed at 10 m $min^{-1}$. The animals were fractionated into 50-200 µm and > 200 µm sizes. The experimental water containing the mixed prey for grazing assessment was collected from the CTD at the depth of the chl *a* maximum. 24-hour incubations were set up in an on-deck plankton wheel with a screen simulating 1% surface irradiance. In total there were two initial bottles (t=0), 3 controls (no zooplankton), 3 experimental bottles with the smaller size fraction of zooplankton (50-200 µ) and 3 experimental bottles with the larger zooplankton fraction (> 200µ).

An excess of nutrients (15 µM ammonia and 1 µM phosphate) was added to all the experimental water to stop zooplankton excretion having an effect on phytoplankton. In other words, allowing nutrient concentration to be a non-limiting factor. Nevertheless, nutrient analysis from each of the bottles was performed to observe whether concentrations had changed significantly before and after the experiment and how significant the presence of the animals were.

Microzooplankton samples from the initial bottles were fixed in Lugol´s iodine and formalin and chlorophyll *a* quantification by fluorometry was carried out using GF/F and >5 µm filters. The remaining water in the initials was filtered onto a GF/F filter for later HPLC analysis. Mesozooplankton initial aliquots were filtered onto ashed GF/C glass filters and dried for assessment of biomass (dry weight) and some were fixed in a small bottle with formalin for later taxonomic assessment and sizing. After 24 hours the size fractionated animals from the experimental bottles were collected and fixed with formalin for later examination. As for the initials, samples from each bottle were taken for microzooplankton, chlorophyll *a* and HPLC analysis.

## SAMPLES COLLECTED

### *Plankton Size Spectra*

| CTD | Date | Depths | Bongo nets – 200 & 50 µm (200 & 50 m) | Size fractionated Zooplankton Biomass |
|---|---|---|---|---|
| 2 | 14/09/2003 | 11 | Y | Y |
| 5 | 15/09/2003 | 11 | Y | Y |
| 11 | 17/09/2003 | 11 | Y | |
| 13 | 18/09/2003 | 11 | Y | |
| 15 | 19/09/2003 | 11 | Y | Y |
| 18 | 20/09/2003 | 11 | Y | |
| 21 | 21/09/2003 | 11 | Y | |
| 24 | 22/09/2003 | 11 | Y | Y |
| 27 | 23/09/2003 | 11 | Y | |
| 30 | 24/09/2003 | 11 | Y | |
| 34 | 26/09/2003 | 11 | Y | |
| 37 | 27/09/2003 | 11 | Y | |
| 40 | 28/09/2003 | 11 | Y | Y |
| 44 | 30/09/2003 | 11 | Y | |
| 47 | 01/10/2003 | 11 | Y | Y |
| 50 | 02/10/2003 | 11 | Y | |
| 53 | 03/10/2003 | 11 | Y | |
| 56 | 04/10/2003 | 11 | Y | |
| 59 | 05/10/2003 | 11 | Y | |
| 62 | 06/10/2003 | 11 | Y | |
| 65 | 07/10/2003 | 11 | Y | |
| 68 | 08/10/2003 | 11 | Y | |
| 71 | 09/10/2003 | 11 | Y | |
| 74 | 10/10/2003 | 11 | Y | Y |

### *Mesozooplankton Feeding Experiments*

| Feeding Experiment | CTD | Date |
|---|---|---|
| 1 | 3 | 14/09/2003 |
| 2 | 12 | 17/09/2003 |
| 3 | 19 | 20/09/2003 |
| 4 | 28 | 23/09/2003 |
| 5 | 35 | 26/09/2003 |
| 6 | 42 | 29/09/2003 |
| 7 | 51 | 02/10/2003 |
| 8 | 60 | 05/10/2003 |
| 9 | 69 | 08/10/2003 |

**PRELIMINARY RESULTS**

There are no results to discuss at present as all analysis is performed back in the laboratory. The only qualitative observation that can be made was that there was a significant difference in the amount of plankton found in the nets in the different oceanic regions. There were fewer and generally smaller animals in the oligotrophic regions compared to a more abundant and apparent diverse sample in mesotrophic and eutrophic waters.

I have no "real" phytoplankton biomass results from the feeding experiment as the chlorophyll (total and > 5μm) fluorometer readings have yet to be calibrated. In general though, there was a decrease in the total chlorophyll between the controls and the smaller zooplankton size fraction (50-200 μm) suggesting consumption of phytoplankton by these animals. The bottles containing the larger zooplankton size fraction (>200 μm) appeared to exhibit either no obvious difference with the controls or a significant increase in phytoplankton biomass. This may be as a result of not only the preferential mesozooplankton feeding on microzooplankton over phytoplankton but the removal of the predators of phytoplankton, both the smaller zooplankton (50-200 um) and the microzooplankton.

The size fractionated zooplankton biomass samples and HPLC will be analysed at Plymouth Marine Laboratory. The phytoplankton and microzooplankton samples from the CTD, as well as the 200 μm zooplankton net samples will be sized and counted using FlowCam at AZTI in late Autumn 2003. The 50 μm net samples will be investigated for the presence of large phytoplankton at Southampton Oceanography Centre.

# Microzooplankton grazing

## ANGELICA PAZ GRANDA
*Universidad de Oviedo*

The main aim of this component of AMT13 was to determine the microzooplankton grazing along the transect carrying out grazing experiments following the method of dilution of natural water proposed by Landy. There is not information about grazing rates along the transect we studied. I hope to ascertain whether there is a latitudinal variation in grazing rate and whether differences exist in the grazing rate between the surface and the deep chlorophyll maximum. My other aim was to study nanoflagellate abundance along the transect analysing water from the underway supply.

**METHODS**

The microzooplankton grazing experiments were conducted every day alternating surface and DCM water samples. The experiments were carried out following the recommendations of Quevedo and Anadon (2001). Water was collected from the CTD pre-dawn cast at approximately 0300 hours. 24-hour incubations, involving bottles containing sea water diluted at 20%, 40%, 60%, 80% and 100% control bottles were set up in an on-deck incubator with a screen simulating 1% and surface irradiance. Micro zooplankton samples from the initial bottle (t=0) were fixed in Lugol's iodine and chlorophyll *a* quantification by fluorometry was carried out using 0.2 µm and >5 µm filters. After 24 hours samples from each bottle were taken for chlorophyll *a* analysis and samples from non-diluted bottles were collected for microzooplankton analysis. Samples for analysis of nanoflagellates (NF) picoplankton and bacteria were taken from each bottle, fixed with glutaraldeyde and frozen at –80°C.

The nanoflagellate distribution, focused principally on HNF, was conducted collecting water from the underway every 4 hours. Samples were fixed with glutaraldehyde and stored in the freezer at –80°C to be analysed by flow cytometry.

**Table of Samples Collected for Grazing Experiments**

| CTD | Date | Water collected from |
|---|---|---|
| 1 | 14/09/03 | Surface |
| 4 | 15/09/03 | DCM |
| 9 | 17/09/03 | DCM |
| 12 | 18/09/03 | Surface |
| 14 | 19/09/03 | DCM |
| 17 | 20/09/03 | Surface |
| 20 | 21/09/03 | DCM |
| 23 | 22/09/03 | Surface |
| 26 | 23/09/03 | DCM |
| 33 | 26/09/03 | DCM |
| 39 | 28/09/03 | DCM |
| 43 | 30/09/03 | Surface |
| 46 | 01/10/03 | DCM |
| 49 | 02/10/03 | Surface |
| 55 | 04/10/03 | Surface |
| 58 | 05/10/03 | DCM |
| 61 | 06/10/03 | Surface |
| 64 | 07/10/03 | DCM |
| 67 | 08/10/03 | Surface |
| 70 | 09/10/03 | DCM |

**PRELIMINARY RESULTS**

There are no results to discuss at present as all analysis is performed back in the laboratory. The only observation that can be made after measuring *chl a* is that the experiments seem to be good results as they fit well to a regression line. Microscopy on the microzooplankton Lugol's fixed samples will be carried out in Spain. Frozen samples were taken from grazing experiments to determine NF, picoplankton and bacteria by flow cytometry in Spain. Analysis on frozen samples taken from the underway supply will be conducted by flow cytometry in Spain.

# Ingestion rates and abundance of copepod larval stages

**EVA LOPEZ GARCIA**
*University of Oviedo, Spain*

The main aim was to study the autotrophic and heterotrophic ingestion rates of copepod larval stages (nauplii and copepodites) and to determine their abundance along the transect. Historically, very few experiments have been carried out with this objective and there is not enough data to estimate the importance of this group in the carbon fluxes in oligotrophic regions of the ocean. With the development of feeding experiments (on deck incubations) and the measurements of chlorophyll gut contents and gut evacuation rates I hope to obtain data that could start to explain their role in carbon fluxes.

**OBJECTIVES**

- To determine nauplii and copepodites, belonging to microzooplankton, abundance and the abundance of the main taxonomic groups of mesozooplankton.
- To determine their autotrophic ingestion rates by measuring chlorophyll gut contents and obtaining gut evacuation rates that could be related to temperature in the different oceanic regions sampled.
- To conduct nauplii and copepodites feeding experiments and observe any latitudinal pattern in their grazing activity over a mixed prey (small microplankton, nanoplankton and picoplankton) population.

**METHODS**

Vertical 53 µm WP2 net (with 30 µm mesh cod ends) hauls were towed up at 20 m $min^{-1}$ from 200 m depth at each monster station. One of the cod end contents was fractionated (<200 µm and >200 µm ) and fixed in formalin (final concentration 4%) for later examination. One sample was fractionated, filtered through 30 µm and 200 µm filters and frozen for later chlorophyll gut contents analysis with a Turner Designs 700 fluorometer. The rest of the sample was held in filtered sea water and used for gut evacuation experiments and feeding experiments. I alternated carrying out these two experiments, one each day.

The zooplankton feeding experiments were conducted every two days. The microzooplankton and prey were collected from net hauls and CTD casts after the monster cast at approximately 0330 hours. The experimental water containing the mixed prey for grazing assessment was collected from the CTD at the depth of the chl *a* maximum. 24-hour incubations, involving experimental and control bottles were set up in an on-deck incubator with a screen simulating 1% surface irradiance and at the maximum of chlorophyll depth temperature. Water was pre-screened with 30 µm filters and a nutrient mixture was added to compensate for nutrient enrichment due to zooplankton excretion. Groups of nauplii were separated under a stereomicroscope. Bottles of 1 litre were filled with the water and animals were added to experimental bottles, they were sealed with plastic to avoid air bubbles. At the beginning, two subsamples of 500 ml were taken for chlorophyll analysis and filtered onto 5 µm and 0.2 µm filters, two 250 ml subsamples were preserved with acidic lugol iodine solution for ciliate enumeration and two 5ml subsamples were preserved with glutaraldehyde and frozen for flagellate and bacteria enumeration with flow cytometry.

When the incubation finished the content of the bottles was gently filtered through a 30µm filter and samples were taken and treated as described above. The zooplankton remaining in the filter was transferred to a petri dish and counted under a stereomicroscope.

In the evacuation experiment, zooplankton <200 µm were placed in a cool box containing filtered (0.2 µm) surface sea water, and kept in darkness at surface water temperature. They were subsampled every two minutes during the first ten minutes and then every five minutes until half an hour, filtered and frozen for gut contents analysis.

**TABLE OF SAMPLES COLLECTED**

| | NUMBER |
|---|---|
| Gut content analysis | 72 |
| Gut evacuation rate | 120 |
| Microzooplankton abundance | 24 |
| Mesozooplankton abundance | 24 |
| Lugols (feeding experiments) | 96 |
| Chlorophylls (feeding experiments) | 192 |
| Flow cytometry (feeding experiments) | 96 |

**PRELIMINARY RESULTS**

There are no preliminary results as all analysis is going to be performed back in the laboratory. I expect to have all the analyses done by May 2004.

**ACKNOWLEDGEMENTS**

Thanks to everybody on the ship for their patience with my spanenglish language and their help with everything I have needed during this cruise. I want to especially thank Elena for her translations and for being always inclined to help me. And to Niki for teaching me good English, for her efforts to make me feel comfortable everyday and for telling me: “Eva, when you are not very happy remember why you have studied marine science and why you have chosen this job: the sea, the sunsets and sunrises,…” and then the work looked less hard and the incubation problems less frustrating.

Finally thanks to Ricardo Anadon (my “boss”) for having made it possible that I could come to this cruise (it was not easy) and for his blind trust in everything I do.

# Bio-Optics

**CHRIS LOWE and SAM LAVENDER**
*Plymouth Marine Laboratory and University of Plymouth*

One of the objectives of the AMT is the interpretation of optical remote sensing at the basin scale. Key to this interpretation of global data are the bio-optical models used for the interpretation of satellite remotely sensed observations of ocean colour. Traditionally, algorithms have been developed from empirical relationships between optical measurements (reflectance) and in water constituents, primarily chlorophyll concentration. The primary objective of the bio-optics measurements on AMT 13 has been to develop models that enable the determination of all the biologically active constituents of the water column. Simply the reflectance, allowing for the effects of pure water, is a non-linear ratio of the backscatter to absorbance, where the absorbers, pigments DOC and detrital material (non photosynthetic particles), and the backscatters are detrital material and phytoplankton. Of the absorbing pigments Chlorophyll *a* (Chla) is only one of a large number of phytoplankton pigments, including chlorophylls *b* and *c*, carotenoids and phycobilliproteins (PBs). Chlorophyll-*a* is normally less than 50% of the total pigment biomass, and can be only 30% in oligotrophic areas; it has a limited impact on the spectrum of absorbed light with bands at 440nm and 670nm. The carotenoids absorb in a broad band 400-550 and the PBs, 550-600 nm, and dominate the surface oligotrophic waters. Full bio-optical models, which relate the water absorption spectrum to all the constituents of the water column to their Inherent Optical Properties (IOPs) of absorption and backscatter, have been developed than can derive CDOM, carotenoids and detrital and potential province classification. These models together with simple atmospheric models enable the determination of the spectral column scalar light field that is the primary driving input to productivity. Inversion of inherent optical properties into the packaged absorption of photosynthetically active pigments, photoprotectant pigments and gelbstoff (ODOM) enables the determination of the photosynthetically useful photon flux. The characteristic absorption spectra of the different phytoplankton pigments give potential information as to the photo-adaptive state of the phytoplankton assemblage. These

models have largely been developed from data collected during previous AMTs. The experience of these AMTs has pointed out gaps in knowledge of primary bio-optical variables and problems in instrumentation. With this experience the bio-optical sampling and instrumentation was specified for AMT13.

**INSTRUMENTATION**

1) Satlantic free falling optical profiler that measured the optical properties of the upper euphotic zone. The profiler measured the wavelengths corresponding to the MERIS sensor on ENVISAT (412,443,490,510,560,620, 665 and 685nm). The sensor had matching surface sensors for normalization to incident light. The free fall profiler and its surface sensors were calibrated daily with the SeaWiFS Quality Monitor (SQM), which after post calibration at PML will give a radiometric accuracy of better than 1%.
2) Wetlabs AC/9 absorption and attenuation meter. This is a multiband spectrophotometer that measures at 9 wavelengths (412, 440, 488, 510, 532, 555, 650, 676 & 715nm). It is coupled to a SBE 19+ CTD. The CTD data is used to correct the ac/9 data for the effects in the changes in the optical properties of pure water with temperature and salinity. The system has flow cells to ensure proper operation of the instruments and to correct for any time lags in sampling. It is also capable of measuring chlorophyll absorption and 676 nm as a biomass indicator. Additionally at 10 stations the instrument was used with a 0.2 micron supercap filter that enabled the determination of CDOM.
3) Wetlabs VSF. This is a backscatter meter that measures scattering at three discrete angles (100, 125 and 150 degrees). The measurement of the change in angular scattering is key to relating water reflectance at the different sun and view angles that are found in ocean colour observations.
4) Phycoerythrin and phycocyanin fluorometers. These have been developed in association with Chelsea Instruments and are modified minitracker fluorometers. The specifications were developed from a bench instrument that was used on AMT4.
5) Fast repetition rate fluorometer (FRRF). This can measure the absorption cross-section of photosystem II, the quantum yield and the rate of photosynthetic electron transport. During the cruise the instrument was calibrated with a number of blanks from 1000m CTD water.
6) UV spectrometer. A Trios spectrophotometer was deployed on the rig before the equatorial stations. After this point possible weaknesses in the head were identified at PML and the decision was made not to use the instrument unless the data was of particular interest.
7)

**INSTRUMENT PERFORMANCE AND PRELIMINARY RESULTS**

In contrast with AMT 12 instruments were deployed twice a day, the optics rig was deployed at either 2am or 3am local time to coincide with the first deep water CTD cast, and secondly at 11am local time, where a freefall optical profile was also taken.
This system was adopted for three reasons.

1) It enables measurements of changes in Inherent Optical Properties during the diel cycle.
2) It increases the data density of measurements taken along the cruise track.
3) It allowed further experiments to be carried out which could not be performed during the relatively short mid morning cast. Namely double casts which were required for CDOM/phytoplankton absorption comparisons with the AC/9.

In general the optical instrumentation, with the exception of the free-fall, was working at or near its performance limits in the gyre waters.

A total of 47 FRRF casts and 35 AC9 casts were completed on the main optics rig, with FRRF casts on 34 of the main CTD rosette casts. The FRRF was not used on the 1000m main CTD rosette casts since the pressure sensor is not rated to below 500m.

The FRRF data shows the large scale patterns which would be expected on an AMT cruise, the fv/fm maxima starting shallow in the temperate North Atlantic, going deeper as the North Atlantic Gyre was crossed, shallowing and intensifying through the upwellings in the equatorial region, deepening again in the South Atlantic Gyre and finally raising again as the waters became mixed in the Argentine basin.

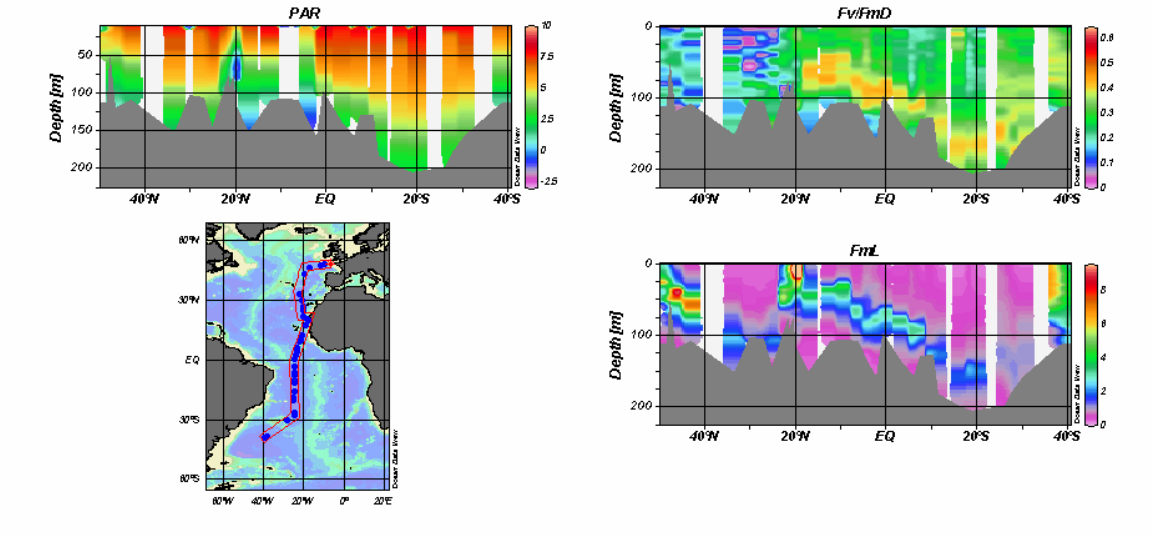



**Figure 7: Some photosynthetic parameters taken from the optics rig FRRF. This data will be amalgamated with FRRF data from the main CTD once calibration files for processing are available.**

On twelve stations, the AC/9 was fitted with two 0.2micron supercap filters which had been altered to remove the covering and inlet allowing for greater flow rates. Twin casts were made at each station, where this methodology was used to determine CDOM using the filters. The CDOM profile was also subtracted from the second profile, which was made without filters, to give the phytoplankton absorption spectrum. These double profiles were carried out such that pre dawn and mid morning casts were concurrent, the effects of sunlight, particularly UV can therefore be examined. As has been noted, potential damage to the UV spectrometer meant that deployment of this instrument was limited, it was therefore only used when double casts were carried out in the mid morning station. Due to time constraints, the mid morning casts had to be of a shallower depth than would normally be the case if a single profile were to be performed and were therefore limited to 100m. The pre dawn casts did not have this problem and as such the full depth casts were used and went to approximately 20m below the chlorophyll maximum.

The AC9 data has yet to be fully processed, however an experimental cast with the filtration system is presented below. These data have yet to be salinity and temperature corrected but show the viability of this method. These measurements will be used in tandem with particulate absorption spectra to investigate the viability of using this methodology to derive profiles of phytoplankton absorption spectra using the AC9.

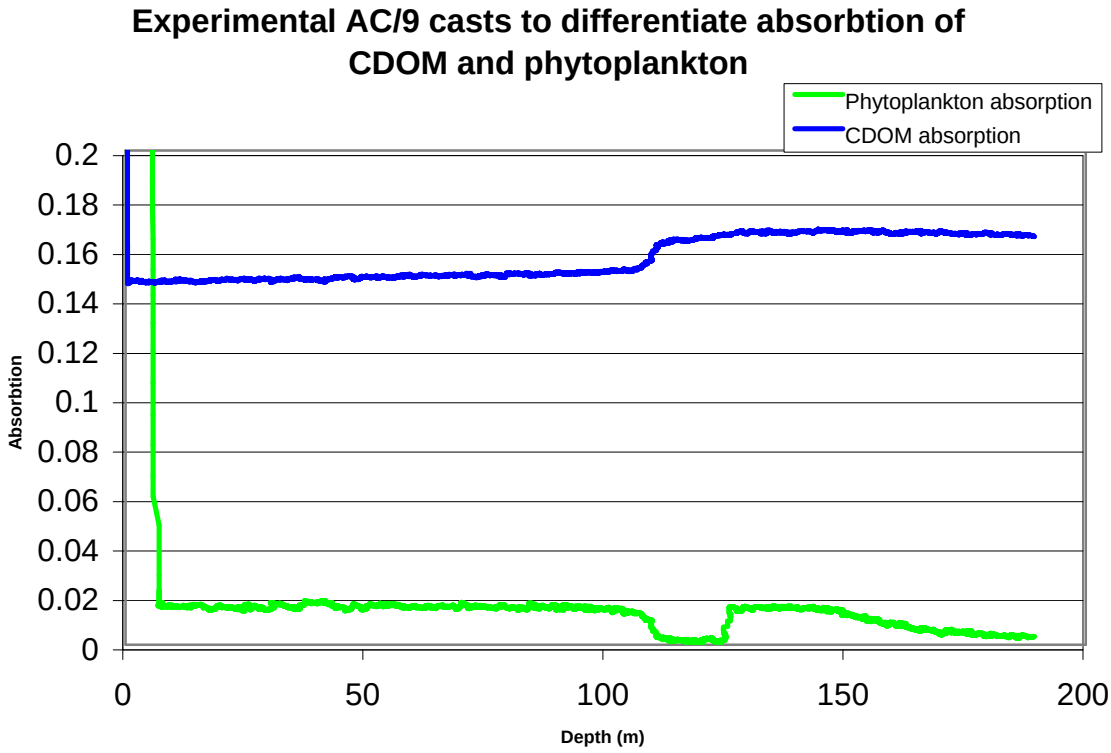



**Figure 8. Results of a twin cast with the AC/9 (with and without filters), where subtraction of the filtered (CDOM) absorption from the total equals the absorption of the phytoplankton.**

A number of issues were encountered during the cruise:
The AC9 and VSF began to fail in the interface between the Northern Atlantic Gyre and the upwelling region, the instrument would appear to work and not log to its internal memory or fail to initialise once turned on. A number of faults in the power supply and connection to the computer were discovered and fixed however the AC9 from this point on was unreliable and would only work sporadically resulting in a much reduced number of casts. The instrument became more reliable again in the Southern Gyre, so the data density is greater in this region.

The Trios spectrometer worked while deployed, however a weakness in the instrument used in PML was discovered during the cruise and communicated to us on the ship. It was therefore decided to only use this instrument for profiling when the data would be of particular use. Therefore the frequency at which this was deployed was much reduced, however the sensor was used on deck by Paul Hampton in conjunction with his work.

The CTD and fluorometers worked without flaw throughout the cruise.

Apart from one telemetry failure, the freefall (rocket) performed faultlessly throughout the cruise.

The FRRFs used for profiling in general functioned well. Two were used for this purpose, serial numbers 460039 and 460041. The PAR sensor supplied with SN 460041 was marked as being faulty and as such was replaced with a spare. The pressure sensor used with SN 460039 on the main CTD frame failed on 20th September and was not replaced until 24th September. The data for the casts in this period is therefore viable, but must be tied into the main CTDs pressure sensor via time stamps in order to be useful.

The FRRFs themselves in general worked well, however the gain setting in the northern hemisphere was set to level 1 and as such data from within this region should be considered potentially saturated, this issue was remedied at 5°N and as such other data should be viable.

Filtered seawater from the ships pure water system and water from the CTD rosette at 1000m were measured in both the AC/9 and FRRF on 4 occasions to act as blanks and to track instrument drift

## Satlantic Free Falling Optical Profiler

The Satlantic free faller measures the upwelling radiance and downwelling irradiance in eight wavebands corresponding to the wavebands of active satellite ocean colour missions (such as SeaWiFS and MERIS). The data can be extrapolated to the surface and provide a means of validating the satellite measured signal measured when there is a contemporaneous overpass.

The instrument was deployed prior to the 11am optics cast, as the JCR was slowing, so that it would be carried away from the vessel and hence avoid ship shadow. Between 1 and 3 casts were deployed depending on the time available and prevailing conditions. This data was processed daily and provided estimates of $K_d$(PAR), the diffuse attenuation coefficient for the Photosynthetically Available Radiation, that could be used to predict euphotic levels for the following pre-dawn CTD cast. See Table below for a summary of the data collected, where there is a $K_d$ estimate but no free fall cast the estimate was made using the Fast Repetition Rate Fluorometer (FRRF) PAR sensor.

**Table: Summary of data collected using the Satlantic Free Falling Optical Profiler.**

| CTD | Date | Time (GMT) | Latitude | Longitude | No. of casts taken | No. of casts processed | Sea state | Cloud (octals) | $K_d$ (PAR) |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 14/09/03 | 10:07:00 | 47 58.60N | 11 32.04W | 1 | 1 | 2 | 0 | 0.091 |
| 6 | 15/09/03 | 11:06:00 | 46 41.27N | 17 00.36W | 3 | 3 | 2 with long swell | 8 | 0.077 |
| 8 | 16/09/03 | 11:31:00 | 43 02.56N | 19 37.27W | 2 | 2 | 2 to 3 | 1 | 0.076 |
| 11 | 17/09/03 | 11:04:00 | 39 26.45N | 21 32.70W | 2 | 1 | 2 | 3 | 0.052 |
| 16 | 19/09/03 | 11:01:00 | 33 29.69N | 22 06.58W | 2 | 2 | 2 to 3 | 3, but clear overhead | 0.044 |
| 19 | 20/09/03 | 11:03:00 | 29 21.26N | 20 53.75W | 3 | 3 | 1 | 2 | 0.039 |
| 22 | 21/09/03 | 11:06:00 | 25 05.08N | 20 44.53W | 2 | 1 | 2 to 3 | 3 | 0.045 |
| 25 | 22/09/03 | 11:01:00 | 20 48.52N | 20 34.86W | 3 | 2 | | | 0.083 |
| 28 | 23/09/03 | 12:33:00 | 20 19.69N | 17 46.36W | 3 | 3 | 2 | 2 | 0.204 |
| 31 | 24/09/03 | 11:11:00 | 17 08.40N | 19 00.91W | 0 | 0 | | | |
| 32 | 25/09/03 | 12:40:00 | 12 30.87N | 20 59.59W | 3 | 1 | 1 to 2 | 3 | 0.087 |
| 35 | 26/09/03 | 11:11:00 | 09 00.03N | 22 08.30W | 3 | 3 | 1 to 2 | 3 | 0.065 |
| 38 | 27/09/03 | 12:10:00 | 04 51.00N | 23 27.25W | 2 | 2 | 1 to 2 | 8 and rain | 0.044 |
| 41 | 28/09/03 | 12:04:00 | 00 53.12N | 24 42.62W | 2 | 1 | 2 | 3, but clear overhead | 0.042 |
| 42 | 29/09/03 | 12:05:00 | 03 50.08S | 24 59.69W | 2 | 2 | 2 | 2, but clear overhead | 0.038 |
| 45 | 30/09/03 | 12:03:00 | 07 50.18S | 24 59.78W | 0 | 0 | | | |
| 48 | 01/10/03 | 12:03:00 | 11 56.39S | 24 59.58W | 3 | 2 | 2 | 1, but clear overhead | 0.031 |
| 51 | 02/10/03 | 12:06:00 | 16 09.25S | 24 59.37W | 2 | 2 | 1 | 3 | 0.030 |
| 54 | 03/10/03 | 11:58:00 | 20 14.65S | 25 00.16W | 2 | 2 | 1 with long swell | 2 | 0.029 |
| 57 | 04/10/03 | 12:01:00 | 23 54.39S | 24.59.89W | 2 | 1 | 2 to 3 | 8 | 0.047 |
| 60 | 05/10/03 | 12:02:00 | 27 55.00S | 24 59.72W | 1 | 1 | 2 to 3 | 3, but clear overhead | 0.035 |
| 63 | 06/10/03 | 12:07:00 | 30 52.00S | 28 26.23W | 3 | 1 | 2 | 4 with high cirrus | 0.039 |
| 66 | 07/10/03 | 12:06:00 | 33 48.60S | 32 04.25W | 2 | 2 | 3 | 8 | 0.054 |
| 69 | 08/10/03 | 12:02:00 | 36 23.69S | 35 20.31W | 0 | 0 | 4 | 8 | 0.060 |
| 72 | 09/10/03 | 12:59:00 | 39 23.16S | 39 19.71W | 0 | 0 | 5 | 8 | |
| 75 | 10/10/03 | 13:02:00 | 41 53.63S | 42 44.67W | 0 | 0 | 3 with long swell | 4 | 0.063 |
| 77 | 11/10/03 | 13:04:00 | 44 33.81S | 45 43.47W | 2 | 1 | 2 | 4 | 0.082 |
| 78 | 12/10/03 | 13:07:00 | 47 46.02S | 51 25.83W | 0 | 0 | | | |

The sensors were checked daily using the SeaWiFS Quality Monitor (SQM) so that drifts in the calibration could be monitored and post-corrected for. During the casts, data was also logged from downwelling solar irradiance sensors (8 wavebands) and a GPS. Underway solar spectral irradiance data has also been logged on a daily basis.

Overall the instrument performed well and should provide a high quality data set.

**DATA AVAILABILITY**

1) Satlantic free falling optical profiler: The data will be available after normalization for the SQM calibrations. An integrated PAR Kd and profile will be generated. At present there is some doubt as to how BODC will store the spectral data. It will be available locally from PML.
2) Wetlabs AC/9 absorption and attenuation meter. The data requires checking for blanks and salinity / temperature correction.
3) Wetlabs VSF. An integrated depth resolved spectral backscatter will be available.
4) Phycoerythrin and phycocyanin fluorometers. These are experimental, and require further testing with standards. Raw data is available any time from PML. The timescale of final validation is uncertain. Data is potentially available for all optics casts.
5) Fast repetition rate fluorometer (FRRF). The data with the standard CI (corrected) calibration will be processed on receiving calibration files. As soon as a blanks procedure and processing is developed then the data will be updated.
6) UV spectrometer. At present this is experimental and work is in progress with the calibration of the spectrometer. It is hoped to provide underwater UV flux, and attenuation by the end of 2003. This should be available at BODC. If spectral data is required then this should be available from PML.

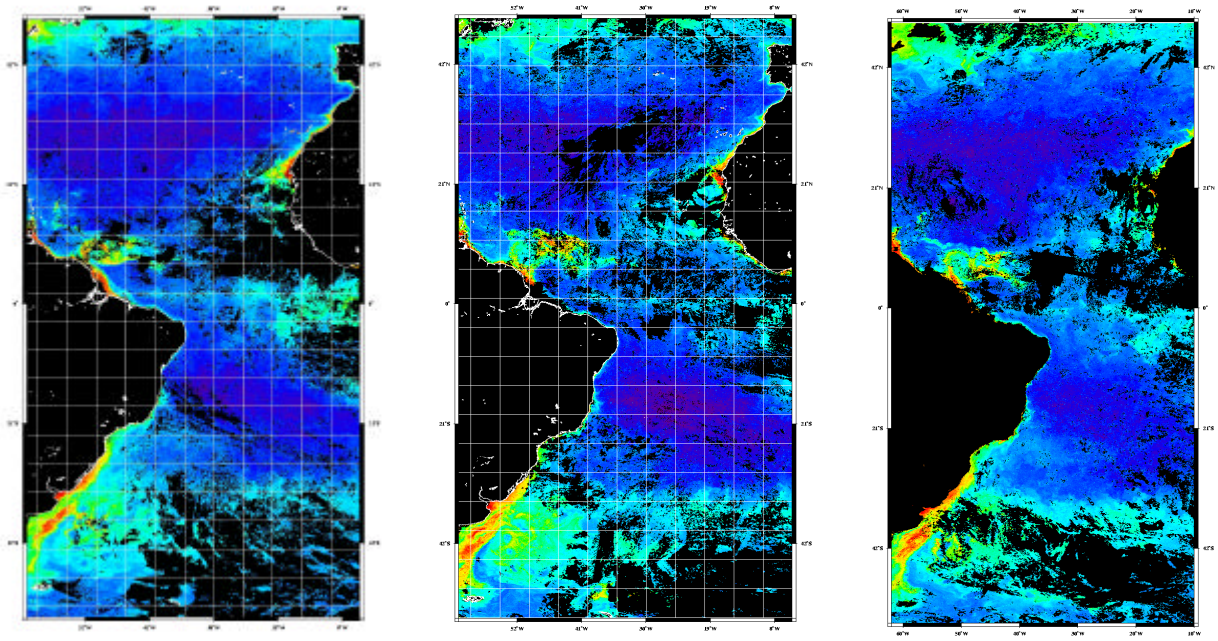
**ACKNOWLEDGEMENTS**

Thanks to the crew for deploying the optics rig at some unsociable hours and sometimes in some very unsociable weather. To Jon Short for running and fixing the FRRF on the main CTD rosette and providing replacement parts if things fell apart, and to Gerald Moore at PML for providing suggestions on how to fix them when they did.

# Remote Sensing

**SAMANTHA LAVENDER and CHRIS LOWE**
*University of Plymouth and Plymouth Marine Laboratory*

SeaWiFS imagery was supplied by the PML Remote Sensing and Data Analysis Service (RSDAS) before the cruise, and while AMT13 was in the UK (Dundee) receiving stations range. For the rest of the cruise, and as an overview of the whole Atlantic, NASA SIMBIOS provided SeaWiFS 8-day chlorophyll composite images



**a)** **b)** **c)**

***Figure 9: SeaWiFS 8-day chlorophyll composite images for a) 29 August to 5 September b) 6 to 13 September c) 22 to 29 September.***

Imagery were transmitted to the Radio Officer on the JCR using the "AMT_IMAGE" subject line so that they were not delayed because of the large attachment sizes. IDL programs were written so that the cruise stations could be predicted (from the noon position, average speed of the vessel and future waypoints), and the predicted cruise stations could be overlaid on the imagery. Printouts were produced regularly and placed on the science notice board.

NASA will also have recorded onboard LAC (1-km resolution) over the predicted cruise stations. The predictions had to be made several days in advance so that there was time to upload them to the SeaWiFS satellite. Onboard LAC is the only method for gaining full resolution imagery when SeaWiFS is outside of any receiving stations range. Data from local receiving stations will also be available for north of the Azores (Dundee), and probably the African upwelling region and Falklands shelf. If LAC is not available then GAC (4-km resolution) will have been recorded.

The actual station positions have been plotted on the 29$^{th}$ August composite for the cruise report. Post-cruise the monthly composite will be downloaded and overlaid with the cruise stations, and the LAC data will also be downloaded and analysed.

# Atmospheric Sampling

ALEX BAKER
*University of East Anglia*

The atmospheric sampling campaign aims to determine atmospheric deposition fluxes of key nutrients (N, P and Fe) along the AMT track and to use this information to assess the importance of atmospheric nutrient supply and its contribution to the nutrient limitation of primary productivity. In addition to determining fluxes, our work aims to identify the sources of these nutrients using air-parcel back trajectories and inter-element and isotopic relationships. In addition sampling aims to help determine the role of marine emissions in regulating atmospheric chemistry, particularly in terms of the formation of aerosol S and N compounds. This objective is shared with groups measuring trace gas emissions.

An additional aim for AMT13 was to determine the chemical speciation of iodine in Atlantic aerosol. In the gas phase, iodine can be involved in ozone destruction in the troposphere. Eventually this iodine is incorporated into aerosol particles, where it may or may not be able to re-enter the gas phase, depending on its chemical form. The published literature currently contains only a single determination of iodine speciation in marine aerosol. Data from AMT13 should significantly enhance our understanding of iodine and ozone cycling in the marine atmosphere.

Atmospheric sampling was conducted on the JCR's monkey island when wind conditions permitted, i.e. apparent wind direction was forward of the monkey island ensuring no contamination from the ship's stacks.

Three high volume (approximately $1m^3$/min) aerosol samplers were deployed. One was for major ions and used conventional Whatman 41 filter substrates. The second was for trace metals and used acid-cleaned Whatman 41 filters. A third system provided by the University of Liverpool (M. Preston) was for trace organic analysis and used pre-ashed glass fibre filters. One of the collectors gave some electrical problems initially, but this was quickly cured by Nick, JCR's Electrical Officer. All three collectors operated

continuously throughout almost the entire cruise. Filters were changed in a laminar flow cabinet and subsequently frozen. Cascade impactors were used for major ion and trace metals sampling, to separate aerosol particles at a diameter of 1µm. Samples for organic analysis were not size segregated.

It was also planned to use a filter pack air sampling system for the analysis of ammonia gas concentrations during AMT13. However, the pump for this system was found to be faulty during mobilisation at Immingham. It was not possible to replace the pump, and so no samples were collected.

Two rain samplers (for major ions and trace metals sampling) were deployed when the opportunity presented itself. The funnels were deployed at the end of a boom extended ~1.5m forward of the monkey island screen in order to minimise contamination of the samples by "bounce-off" from the ship's superstructure. The samples collected were processed in a laminar flow cabinet and subsequently frozen.

A voltammetric analysis system was used to determine iodide ($I^-$) concentrations in the (major ion) aerosol samples collected on board. It was initially intended to analyse every major ion sample, but several days work on the voltammeter were lost due to an obscure electrical problem. A subset of the samples were extracted and analysed on board (Figure 10), the remainder will be analysed on return to UEA. All other analysis (other iodine species, soluble Fe, nitrogen and phosphorus species, etc) will take place at UEA.

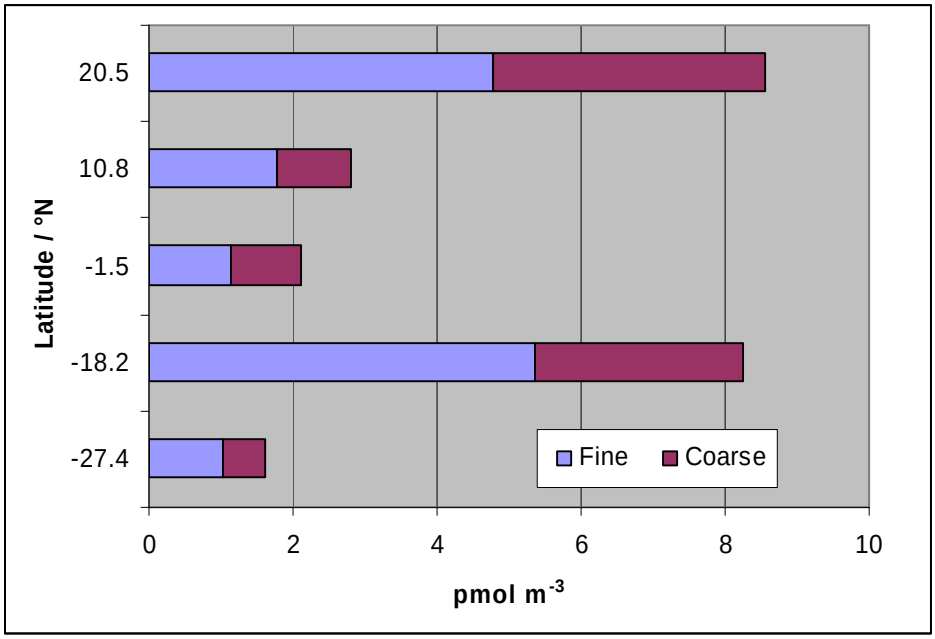



**Figure 10. Preliminary data showing iodide concentrations in the fine (<1µm) and coarse (>1µm) particles of 5 aerosol samples collected during AMT13.**

Visual inspection of the aerosol filters after collection indicated that Saharan dust was sampled over a broad latitude range (43°N to 5°N), with very high concentrations encountered just off the coast of Mauritania. Aerosols from tropical southern hemisphere air appeared to contain significant quantities of black material, which may indicate the presence of southern African biomass burning products.

A log of atmospheric samples collected is in the appendix.
Note JCR standard meteorological system was logging throughout the cruise.

Seawater samples were also collected for Dr Peter Statham (SOC), using his "chuck-it bucket" sampler on a string (for dissolved Fe determination) and for Dr Jonathan Williams (Max Planck Institute, Mainz) from the underway supply (for semi-volatile organics determination). The SOC samples were collected daily at the start of the 11am station, MPI Mainz samples were taken at the 3pm underway sampling point.

**THANKS**
Many thanks to PSO Carol for overseeing an efficient, relaxed and productive cruise and Malc W for sorting out the logistics. The mates (Andy, Mike and Callum) cheerfully and happily woke me up whenever rain appeared in the night. Thank you! Thanks to Simon for constructing the rain boom and to Nick for his help in sorting out the aerosol collectors.

## Atmospheric Samples Collected

| Date 2003 | Major Ion | Metals | Organics | Start Position, °N | Comments | Rain Samples |
|---|---|---|---|---|---|---|
| 13-14/9 | **(X)** | **(X)** | **(X)** | | Blanks | |
| 14-15/9 | **X** | | **X** | 48.0 | | |
| 15-16/9 | **X** | **X** | **X** | 46.7 | | |
| 16-17/9 | **X** | **X** | **X** | 43.1 | Dust | 1 |
| 17-18/9 | **(X)** | **(X)** | **(X)** | 39.4 | Blanks | 1 |
| 18-19/9 | **X** | **X** | **X** | 37.2 | | |
| 19-20/9 | **X** | **X** | **X** | 33.5 | | |
| 20-21/9 | **X** | **X** | **X** | 29.4 | Dust | |
| 21-22/9 | **X** | **X** | **X** | 25.1 | Dust | |
| 22-23/9 | **X** | **X** | **X** | 20.8 | Dust | |
| 23-24/9 | **X** | **X** | **X** | 20.2 | Dust | |
| 24-25/9 | **X** | **X** | **X** | 17.2 | Dust | |
| 25-26/9 | **X** | **X** | **(X)** | 12.5 | Dust | |
| 26-27/9 | **X** | **X** | **X** | 9.0 | Dust | 2 |
| 27-28/9 | **X** | **X** | **X** | 4.9 | | 3 |
| 28-29/9 | **X** | **X** | **X** | 0.9 | | |
| 29-30/9 | **X** | **X** | **X** | -3.8 | | |
| 30/9-1/10 | **X** | **X** | **(X)** | -7.8 | | |
| 1-2/10 | **X** | **X** | **X** | -11.9 | | |
| 2-3/10 | **X** | **X** | **X** | -16.2 | | |
| 3-4/10 | **X** | **X** | **(X)** | -20.3 | | 1 |
| 4-6/10 | **X** | **X** | **X** | -23.9 | | |
| 6-8/10 | **X** | **X** | **X** | -30.9 | | 1 |
| 8-10/10 | **X** | **X** | | -37.2 | | 2 |
| 10-11/10 | **(X)** | **(X)** | | | Blanks | |

# CTD and MVP deployments


## JON SHORT

*UKORS, Southampton Oceanography Centre*


CTD Operations

1) A total of 78 CTD casts were undertaken on the cruise. The stainless steel frame configuration was as follows;

Sea-Bird 9/11 *plus* CTD system
24 by 20L Ocean Test Equipment External Spring water samplers
Sea-Bird 43 Oxygen sensor
Chelsea MKIII Aquatracka Fluorometer
Chelsea MKII Alphatracka 25cm path Transmissometer
RD Instruments Workhorse 300 KHz Lowered ADCP (downward-looking configuration)
RD Instruments Workhorse 300 KHz Lowered ADCP (upward-looking configuration)
OED LADCP pressure case battery pack
Chelsea FRRF/battery pack/pressure sensor
Chelsea PAR Sensor (Upwelling)
Chelsea PAR Sensor (downwelling)

The pressure sensor is located 15cm from the bottom of the water samplers, and 132 cm from the top of the water samplers. Deep cast configuration was the same with the exception of the removal of the Chelsea PAR sensors and the FRRF pressure sensor for the 1000m casts

2) The Sea-Bird CTD configuration was as follows:

SBE 9 *plus* Underwater unit s/n 09P-24680-0598
Frequency 0—SBE 3P Temperature sensor s/n 03P-4105 (primary)
Frequency 1—SBE 4C Conductivity sensor s/n 03P-2571 (primary)
Frequency 2—Digiquartz temperature compensated pressure sensor s/n 78958
Frequency 3—SBE 3P Temperature sensor s/n 03P-2674 (secondary)

Frequency 4—SBE 4C Conductivity sensor s/n 03P-2231 (secondary)
SBE 5T submersible pump s/n 05T-3090
SBE 5T submersible pump s/n 05T-3088
SBE 32 Carousel 24 position pylon s/n 32-31240-0243
SBE 11 *plus* deck unit s/n 11P-24680-0588

3) The auxiliary A/D output channels were configured as below:

V2---SBE 43 Oxygen s/n 43B-0013
V3--- Chelsea MKIII Aquatracka Fluorometer s/n 088242
V4--- Chelsea MKII Alphatracka 25cm path Transmissometer s/n 161-2642-03
V5--- Chelsea PAR Sensor (UWIRR) s/n 08
V6--- Chelsea PAR Sensor (DWIRR) s/n 12

4) The additional self-logging instruments were configured as follows:

Chelsea FRRF s/n 182039
Druck pressure sensor s/n 1265910 with PDM cable s/n 001
RDI Workhorse 300 KHz Lowered ADCP (downward-looking configuration) s/n 1855
RDI Workhorse 300 KHz Lowered ADCP (upward-looking configuration) s/n 1881
OED LADCP pressure case battery pack s/n 1935-B-L

Moving Vessel Profiler
1) A total number of 44 profiles were conducted during the cruise. The sensor configuration was as below:

MVP300-1700 s/n 10014, with MSFFF:
AML Micro Sensor CTD s/n 7027
WETLabs Flash Lamp Fluorometer s/n FLF-362D
Sea-Bird/YSI 23-01Y Dissolved Oxygen sensor s/n 23-0960
Satlantic OCR 507-ICSW Irradiance sensor s/n 0104
Satlantic OCR 507-R10W Irradiance sensor s/n 0055
PML Tilt and Roll sensor
SATLANTIC nutrients sensor

A report on the observations and impressions of the performance of the MVP is attached.

**MISCELLANEOUS**
1) Salinometer - An Autosal 8400B (BAS) salinometer was used on this cruise to process 60 CTD water bottle samples and 13 TSG underway samples. The salinometer worked well for the first batch of samples but failed to keep a constant reading later in the cruise, it was decided to return the samples to the UK to run them on a UKORS salinometer. The salinometer was located in the Prep Laboratory and operated at 24C bath temperature and 21C to 24C ambient lab temperature. All samples were processed according to WOCE standards and protocols.

**MOVING VESSEL PROFILER**

This was the first cruise where the new large multi-sensor freefall fish (MSFFF) was used. The increase in size is to accommodate the new nutrient sensor supplied by Satlantic. The remaining sensors in the fish are the same as those used in the small MSFFF. It was not possible to test the new fish as thoroughly as would have been liked due the delivery date of the new fish being very close to the sailing date (~ 1 week). The large MSFFF was built and the sensors were added at the SOC and the fish was shipped with the sensors in-situ.

A total of 44 casts were performed by the MVP system, with the longest continuous period of operation being 12 hours. The fish was deployed using one of the ships fitted cranes as the new fish was too long to allow the MVP winch to lift over the bulwarks, and to heavy for the fish to be man handled.

The problems encountered with the MVP system on AMT-12 were not in evidence during AMT-13, however there were a host of new problems:

1) Before the first deployment the tow cable was reterminated due to damage sustained by the cable where loose turns had been “pinched” in the frame of the MVP winch.
2) It was discovered during the first deployment that the MVP winch would only take the weight of the MSFFF whist the winch was being driven, this was caused by the brake not being applied whilst the power pack was running. Fault finding on the system identified the problem as a faulty hydraulic valve which was stuck in the open position, this was changed and the problem was cured.
3) The fish was brought close to the surface whilst the ship was on station for CTD deployments, after the first of these the MVP system was restarted only for the deck unit to stop receiving CTD data on the upcast. The CTD data is vital for correct operation of the MVP as it measures the correct depth of the fish. The fish was brought in board and it was discovered that one of the conducting cables between the telemetry module and the CTD had gone open circuit. This was swapped with a cable from the spare (small) MSFFF which corrected the problem for two deployments but the spare cable also failed and was changed for another (brand new) spare. This solved the problem.
4) After the longest deployment (12 hours) the fish was brought to the surface and it was noted that all communication with the fish had ceased. This was eventually discovered to be due to a failed “tail” which had short circuits between three of the four conducting cores. The tow cable was reterminated with a new tail. At this point it became clear that the telemetry module had suffered some damage due to this short circuit as the system would no longer start properly. This operation was hampered somewhat by problem 5 (see below)
5) It was necessary to re-terminate the tow cable in the ships scientific workshop so cable had to be pulled of the winch. During this operation the emergency stop light on the winch came on for no obvious reason. At this point help was sought from the manufacturers of the MVP (Brooke Ocean Technology), via e-mail. It was discovered that there was a faulty watchdog timer in the electronics of the control system, this was bypassed as there was no spare on board. Unfortunately due to Halifax, Nova Scotia (where BOT are based) being hit by

Hurricane Juan this problem took much longer to identify than was anticipated and further deployments were impossible.

# Engineering Technology Section

## PAT COOPER

*British Antarctic Survey*

Thankfully this was a very “quiet” cruise and all BAS instrumentation worked without fault.

The CTD wire parted in the winch room at the start of the cruise. This happened just as the weight was taken by the winch and the CTD dropped a short distance to the deck. The CTD suffered no damage but the cable had to be re-terminated. I noted that the cable appeared to be quite old and there was a great deal of corrosion/debris embedded between the outer layers. Initially I thought that an old cable had been used to replace the previous drum but eventually discovered that the cable was brand new.

Subsequent discussion about the problem seemed to point to a build up of tension in the wire during the Celtic cruise. The log shows that around 200 casts were made, most to about 80m. The tension caused the cable to lift from a groove on a traction winch sheeve and become lodged between the sheeve and a roller designed to keep it in place. The twisting tension in the cable must have been considerable for this problem to occur and it is (in my experience) the first time it has happened.

Around 50m of cable was removed before a new termination was made. In hindsight I feel that removal of say 200m would have been better to eliminate the cable that has been “damaged” by tension build-up. A small price to pay to help prevent future CTD damage. Naturally we cannot keep removing cable after the end of each cruise but 200 shallow drops in 4 weeks is not “normal use” by our standards.

The only other problem occurred toward the end of the cruise when the CTD wire “loop” above the termination was drawn over the gantry roller. Unfortunately the loop was underneath the main wire and was pressed into the roller groove. This caused a sharp bend in the loop but did not part the cable. The loop is not a stressed component and suffered only superficial damage. I did not deem it necessary to remake the termination at this time.

# Information Technology Section

## PETE LENS
*British Antarctic Survey*

The following is something I shall be bringing up in Cambridge and wish to be included in future AMT cruise planning meetings. It's directed at situations where a computer used for running a scientific instrument is also required for Groupwise, virus scanners and to play games or DVD's. I'd love to say this is possible, but scientific software is notoriously demanding and unstable and needs to be treated as if it is the only software installed on the machine. It may work, then again it may fail as is sometimes the case and personally I don't want to be placed in the situation where having installed the Netware client, the users science fails because they did not bring proper drivers for the instrument. I will be refusing to work on machines that are intended for running instruments in the future unless they have a problem which stops them from doing the job they were intended. I recommend that other IT staff do the same.

I have drawn up the following guidelines which I shall be asking to be included in the cruise memorandum of understanding for future cruises:

(a) Any computer that controls scientific hardware will not be installed with BAS applications such as GroupWise or the Novell client.

(b) A machine which controls scientific hardware must be correctly configured before the cruise begins and an image backup taken of the hard drive.

(c) All drivers and recovery disks provided when the machine was purchased should be brought onboard.

(d) Data backup via the ships LAN is not recommended; either backup locally or use the underway SCS logging system which requires NMEA standard data from an RS232 serial port or TCPIP sockets.

A SplitCast program has been written to separate a CTD ASCII data file into up and down casts. This is to allow scientists to load the data in Excel which has a 64000 data point limit. A filter is also provided so that particular depths can be cut out of the data or long surface waits can be removed. There is help within the program and it can be installed from appinst. You will need to install the .NET framework first, also via appinst.

# Microbial community abundance, structure and dynamics

**MIKE ZUBKOV[1], GLEN TARREN[2] and BERNHARD FUCHS[3]**

*[1]Southampton Oceanography Centre, [2]Plymouth Marine Laboratory, [3]Max Planck Institute, Bremen*

## AIM

To compare abundance and metabolic activities of dominant microbial groups in different planktonic communities of the Atlantic Ocean.

## OBJECTIVES

**1)** To determine the vertical distribution, abundance and community structure of nano- and picoplankton in the top 300 m by flow cytometry using several vital and fixed cell staining techniques.

**2)** To collect samples for analyses of bacterioplankton community composition in the top 300 m water using molecular approach including fluorescence in situ hybridisation.
**3)** To estimate the turnover of different organic nutrients and phosphorus, to assess microbial competition for these compounds and to relate the latter with community composition.
**4)** Underway sampling from the uncontaminated seawater supply: a) To assess microbial spatial variability at ten km scale; b) To estimate growth of cyanobacterial populations using cell cycle analyses; d) To collect preserved seawater samples (formalin) for post-cruise analysis of phytoplankton community structure and abundance to verify the underway flow cytometry.
**5)** To test the capability of the CytoSub & CytoSense flow cytometers for automated underway analysis and to determine the distribution, abundance and community structure of phytoplankton (approx. 1 – 1000µm) in surface waters.

## METHODS

Water samples were collected and analysed live and preserved for determination of microbial concentration, biomass and composition. Fresh seawater samples were collected in clean 250 ml polycarbonate bottles from a Seabird CTD system containing 24 x 20 L Niskin bottles from predawn and late morning (11:00 local time) CTD casts. Samples were stored in a refrigerator and analysed within 1-2 hours of collection. Fresh samples were measured using a Becton Dickinson FACSort instrument, which characterised and enumerated Prochlorococcus spp. and Synechococcus spp. (cyanobacteria), picoeukaryotes, cryptophytes, coccolithophores and other nanophytoplankton based on their light scattering and autofluorescence properties. Microorganisms were preserved with paraformaldehyde (1% final) and then stained with SYBR Green I nucleic acid stain. The samples were then left in the dark at room temperature for at least 1 hour before enumeration of bacterioplankton by a flow cytometer. Table 1 summarises the CTD casts sampled and analysed during the cruise. Samples were also collected for later molecular identification of microorganisms using fluorescence in situ hybridisation. Samples were taken from the daily mid-morning CTD cast down to 300 metres from every depth available. 50 ml of each sample were fixed with paraformaldehyde solution (1% v/v) for 2-6h at room temperature. Fixed samples were filtered onto polycarbonate filters (0.22µm pore size), air dried and frozen. From 23 casts and from the underway non toxic seawater supply (10 days) samples were taken for vital staining and analysed by flow cytometry (see lists for details). The flow cytometric data were immediately stored on disk and will be analysed back in the UK. Microbial metabolic activities, production as well as the compound turnover rates were determined on board by incubating samples with isotopically labelled precursor molecules: $^{3}$H-leucine, $^{35}$S-methionine, $^{3}$H-tyrosine, $^{3}$H-glucose, $^{3}$H-glucosamine and $^{33}$P-phosphate.

Microbial concentration varied 100 fold, from $20\times10^{6}$ cells $l^{-1}$ at 1000m depth to $5\times10^{9}$ cells $l^{-1}$ in the surface up-welled waters. Scintillation counts were done on board the ship and a wide range of rates of microbial activity was observed. Detailed analysis of the data will be done back in the UK. The molecular analysis will be done after the cruise. When completed the data set will allow estimation of the rates of bacterioplankton metabolic activity and production as well as linkage between bacterial function, composition and hydrological structure of the water column.

**Table: CTD casts sampled for phytoplankton & bacterial community structure & abundance**

| Date | Time (GMT) | CTD # | Lat (+N, -S) | Long (W) | Depths analysed |
|---|---|---|---|---|---|
| 14-Sep | 3:03 | 2 | 48.38 | 9.87 | 3 5 15 20 25 35 50 60 100 200 300 |
| 14-Sep | 10:09 | 3 | 47.98 | 11.53 | 3 6 10 12 15 20 22 35 40 45 50 60 75 100 120 150 200 250 300 |
| 15-Sep | 2:50 | 5 | 47.10 | 15.30 | 3 5 15 20 25 50 60 70 90 120 200 300 |
| 15-Sep | 10:00 | 6 | 46.69 | 17.01 | 3 5 6 12 16 20 22 25 30 32 35 40 45 48 50 60 75 90 120 150 180 200 250 300 |
| 16-Sep | 11:32 | 8 | 43.04 | 19.62 | 3 8 12 14 20 26 30 40 50 52 55 58 60 75 90 100120 150 200 250 275 300 |
| 17-Sep | 4:10 | 10 | 40.06 | 20.00 | 3 8 15 20 26 45 60 75 90 120 200 300 |
| 17-Sep | 11:17 | 11 | 39.44 | 21.55 | 3 8 12 16 20 28 35 40 45 50 55 58 60 65 80 98 120 150 200 250 300 |
| 18-Sep | 1:06 | 13 | 38.17 | 24.69 | 3 8 15 20 26 50 60 75 90 120 200 300 |
| 19-Sep | 3:47 | 15 | 34.69 | 23.00 | 3 12 21 30 35 65 85 105 132 150 200 300 |
| 19-Sep | 11:05 | 16 | 33.50 | 22.11 | 3 14 20 26 30 40 48 55 60 70 80 90 95 100 110 120 160 180 200 220 240 260 280 300 |
| 20-Sep | 3:42 | 18 | 30.76 | 20.96 | 3 18 32 45 56 100 130 150 195 250 275 300 |
| 20-Sep | 11:05 | 19 | 29.35 | 20.89 | 3 14 26 30 40 48 60 70 80 100 110 130 150 160 180 200 225 250 275 300 |
| 21-Sep | 5:03 | 21 | 26.17 | 20.79 | 3 13 24 30 42 70 100 110 150 200 250 300 |
| 21-Sep | 11:05 | 22 | 25.08 | 20.74 | 3 13 24 30 35 42 45 50 60 70 80 90 95 100 110 150 155 160 180 200 250 275 300 |
| 22-Sep | 4:40 | 24 | 21.97 | 20.62 | 3 5 10 15 18 35 42 50 65 100 200 300 |
| 22-Sep | 11:00 | 25 | 20.81 | 20.58 | 3 5 10 15 18 20 25 35 36 37 38 39 40 50 65 70 80 100 120 170 200 300 |
| 23-Sep | 4:55 | 27 | 20.60 | 18.15 | 3 5 8 10 12 28 35 40 45 100 200 300 |
| 23-Sep | 12:38 | 28 | 20.32 | 17.77 | 2 5 6 8 10 15 20 25 40 60 80 100 150 200 300 |
| 24-Sep | 4:34 | 30 | 18.02 | 18.28 | 3 4 7 10 12 20 30 40 55 100 200 300 |
| 24-Sep | 11:11 | 31 | 17.14 | 19.02 | 3 5 10 15 18 20 25 30 32 34 36 38 40 42 50 55 65 80 100 200 250 300 |
| 25-Sep | 12:43 | 32 | 12.52 | 20.99 | 3 5 10 15 18 20 22 25 28 30 32 34 36 38 40 45 50 65 80 100 150 200 300 |
| 26-Sep | 4:50 | 34 | 9.95 | 21.97 | 3 5 10 12 16 34 37 45 60 100 200 300 |
| 26-Sep | 11:13 | 35 | 9.00 | 22.14 | 3 6 15 20 25 30 40 50 55 60 70 80 95 100 120 160 180 200 250 300 |
| 27-Sep | 4:45 | 37 | 6.13 | 23.06 | 3 9 17 25 30 55 69 80 107 150 200 300 |
| 27-Sep | 12:10 | 38 | 4.85 | 23.45 | 3 10 20 30 36 40 46 48 50 60 64 68 72 76 80 85 90 100 110 120 200 250 300 |
| 28-Sep | 4:50 | 40 | 2.16 | 24.32 | 3 10 20 28 34 60 78 80 100 120 200 300 |
| 28-Sep | 12:07 | 41 | 0.89 | 24.71 | 3 8 16 28 45 50 52 54 56 58 60 62 65 75 80 90 98 120 150 200 250 300 |
| 29-Sep | 12:05 | 42 | -3.83 | 24.99 | 3 6 10 20 34 50 60 68 70 74 76 78 80 100 120 150 200 250 300 |
| 30-Sep | 4:45 | 44 | -6.58 | 25.00 | 5 12 24 40 80 95 100 143 200 250 300 |

| Date | Time (GMT) | CTD # | Lat (+N, -S) | Long (W) | Depths analysed |
|---|---|---|---|---|---|
| 30-Sep | 12:03 | 45 | -7.84 | 25.00 | 5 12 24 30 40 50 60 70 75 80 82 84 86 88 90 93 100 120 140 160 200 250 300 |
| 1-Oct | 4:35 | 47 | -10.64 | 25.00 | 3 18 32 40 56 110 130 140 195 250 275 300 |
| 1-Oct | 12:08 | 48 | -11.94 | 24.99 | 6 18 32 40 56 80 90 100 110 120 125 132 136 140 150 160 180 195 220 250 300 |
| 2-Oct | 4:50 | 50 | -14.32 | 25.00 | 10 22 40 68 100 140 150 156 180 240 260 300 |
| 2-Oct | 12:10 | 51 | -16.15 | 24.99 | 7 22 40 50 68 80 100 120 130 148 152 154 156 160 180 200 240 300 |
| 3-Oct | 4:35 | 53 | -19.04 | 25.00 | 7 20 36 66 120 148 155 180 225 250 300 |
| 3-Oct | 12:03 | 54 | -20.24 | 25.00 | 7 20 36 66 80 100 120 126 140 145 150 152 155 158 160 180 200 225 250 300 |
| 4-Oct | 4:40 | 56 | -22.68 | 25.00 | 7 18 34 60 120 132 137 140 160 200 250 300 |
| 4-Oct | 12:02 | 57 | -23.91 | 25.00 | 7 18 34 50 60 70 80 90 100 110 120 130 142 150 160 170 180 190 200 220 250 300 |
| 5-Oct | 4:38 | 59 | -26.65 | 25.01 | 1 16 28 48 110 115 120 140 173 200 250 300 |
| 5-Oct | 12:02 | 60 | -27.92 | 25.00 | 7 20 36 66 100 110 120 130 140 145 148 150 160 180 225 250 300 |
| 6-Oct | 4:57 | 62 | -29.95 | 27.32 | 7 20 36 66 135 145 150 160 180 225 250 300 |
| 6-Oct | 12:07 | 63 | -30.87 | 28.44 | 7 18 32 56 80 100 110 120 125 130 135 140 150 160 170 180 190 200 250 300 |
| 7-Oct | 4:40 | 65 | -32.88 | 30.94 | 7 17 29 40 52 110 118 120 160 180 250 300 |
| 7-Oct | 12:06 | 66 | -33.81 | 32.07 | 5 9 30 40 50 55 60 62 64 75 80 90 105 110 120 160 200 250 300 |
| 8-Oct | 4:46 | 68 | -35.62 | 34.35 | 6 12 18 22 30 50 60 75 100 200 300 |
| 8-Oct | 12:02 | 69 | -36.44 | 35.34 | 5 10 20 30 40 50 65 70 80 90 100 110 120 130 140 150 160 200 300 |
| 9-Oct | 5:46 | 71 | -38.48 | 36.12 | 5 10 18 26 33 60 75 85 115 200 250 300 |
| 9-Oct | 12:59 | 72 | -39.39 | 39.33 | 6 10 20 36 50 66 70 80 90 100 110 120 130 140 150 180 200 210 225 250 300 |
| 10-Oct | 5:30 | 74 | -41.15 | 41.71 | 5 10 18 26 33 50 75 115 170 180 200 300 |
| 10-Oct | 13:02 | 75 | -41.89 | 42.74 | 5 10 18 25 33 40 50 60 75 80 90 100 115 130 150 160 180 190 200 220 250 300 |
| 11-Oct | 7:02 | 76 | -43.98 | 45.72 | 5 10 20 34 60 80 100 110 120 130 140 160 180 200 250 300 500 1000 |
| 11-Oct | 13:04 | 77 | -44.56 | 46.59 | 5 10 20 28 34 40 50 60 70 80 90 100 110 120 140 150 160 180 200 250 300 |

Note - Underlined depths indicate samples, in which microbial activity was estimated.

For live staining the following underway samples were taken hourly (ship local time): 30.9. (16:00 - 24:00); 1.10. (01:00; 18:00-24:00); 2.10. (01:00; 18:00-24:00); 3.10. (01:00; 18:00-24:00); 4.10. (01:00; 18:00-24:00); 5.10. (01:00; 18:00-24:00); 6.10. (01:00; 20:00-24:00); 7.10. (01:00; 18:00-24:00); 8.10. (01:00; 18:00-24:00); 9.10. (01:00; 18:00-24:00); as well as from the following CTDs: 21, 22, 24, 25, 27, 28, 30, 31, 32, 34, 35, 37, 38, 40, 42, 45, 48, 51, 54, 57, 60, 63, 66, 69, 72, 75, 77.

**Automated underway sampling with the CytoSub & CytoSense flow cytometers**
CytoSub is a unique submersible flow cytometer, capable of autonomously quantifying phytoplankton from approx. 1-1000-µm. It has data storage capacity for approx. 200 sample files and can be pre-programmed to sample at set time intervals from 10

minutes to days and if, attached to a mains power supply should be able to operate indefinitely. CytoSense is a nonsubmersible version of the same instrument, equipped with a 488 nm laser. During the cruise there were two main objectives: to test the capability/reliability of CytoSub/CytoSense instruments to take samples over prolonged periods of time and to analyse phytoplankton distributions and abundance at regular 1 h and 10-15 min intervals, respectively. The instruments were housed in the chemistry lab close to the primary inlet of the uncontaminated seawater supply (pumped from a depth of 6.5 m). The table below provides details of the sampling schedule for the CytoSub during the cruise. The CytoSense was routinely sampling at 10-15 min intervals throughout the cruise. Interpretation of the collected data will be carried out back in the UK.

**Table: Details of CytoSub trials**

| Trial | Start (GMT) | End (GMT) | No. samples |
|---|---|---|---|
| 1 | 13 Sep 1600 | 18 Sep 1500 | 120 |
| 2 | 18 Sep 1800 | 23 Sep 1700 | 120 |
| 3 | 23 Sep 1800 | 28 Sep 1800 | 120 |
| 4 | 29 Sep 1100 | 4 Oct 1100 | 120 |
| 5 | 4 Oct 1300 | 9 Oct 1300 | 120 |
| 6 | 9 Oct 1400 | 12 Oct 1000 | 88 |

To verify samples analysed by CytoSub, 100mL seawater samples were collected periodically from the uncontaminated seawater supply and preserved with approx.1% formalin (final conc.) for post-cruise analysis by flow cytometry back in the UK.

Live sample analysis was carried out periodically to help with the verification of CytoSub samples, to provide greater spatial resolution for small phytoplankton along the Amt 13 transect. Details of underway sampling for fresh and preserved samples are given in the Table below. All data will be analysed back in the UK.

**Table: Underway samples and locations. CS = formalin fixed sample. U = sample analysed live**

| Sample | Date | Time (GMT) | Lat (+N, -S) | Long (W) |
|---|---|---|---|---|
| CS1 | 13-Sep | 16:05 | 48.980 | 7.255 |
| CS2 | 13-Sep | 20:01 | 48.522 | 8.421 |
| CS3 | 14-Sep | 5:01 | 48.305 | 10.130 |
| CS4 | 14-Sep | 11:00 | 47.984 | 11.544 |
| CS5 | 14-Sep | 17:00 | 47.609 | 13.134 |
| CS6 | 14-Sep | 19:02 | 47.470 | 13.672 |
| CS7 | 15-Sep | 5:00 | 47.000 | 15.684 |
| U001 | 15-Sep | 5:00 | 47.000 | 15.684 |
| U002 | 15-Sep | 6:00 | 46.935 | 15.956 |
| U003 | 15-Sep | 7:00 | 46.875 | 16.219 |
| U004 | 15-Sep | 8:00 | 46.814 | 16.488 |
| CS8 | 15-Sep | 9:00 | 46.746 | 16.764 |
| U005 | 15-Sep | 9:00 | 46.746 | 16.764 |
| U006 | 15-Sep | 12:00 | 46.631 | 17.266 |
| U007 | 15-Sep | 13:00 | 46.562 | 17.537 |
| CS9 | 15-Sep | 13:00 | 46.562 | 17.537 |

| Sample | Date | Time (GMT) | Lat (+N, -S) | Long (W) |
|---|---|---|---|---|
| CS10 | 15-Sep | 20:00 | 45.963 | 19.203 |
| CS11 | 16-Sep | 8:00 | 43.811 | 19.510 |
| CS12 | 16-Sep | 11:00 | 43.129 | 19.600 |
| U008 | 16-Sep | 13:00 | 42.955 | 19.627 |
| U009 | 16-Sep | 14:00 | 42.727 | 19.656 |
| U010 | 16-Sep | 15:00 | 45.510 | 19.680 |
| CS13 | 16-Sep | 16:00 | 42.267 | 19.723 |
| U011 | 17-Sep | 6:00 | 39.956 | 20.282 |
| U012 | 17-Sep | 7:00 | 39.850 | 20.535 |
| CS14 | 17-Sep | 7:00 | 39.850 | 20.535 |
| U013 | 17-Sep | 8:00 | 39.753 | 20.799 |
| U014 | 17-Sep | 13:02 | 39.342 | 21.811 |
| CS15 | 17-Sep | 13:02 | 39.342 | 21.811 |
| U015 | 17-Sep | 14:00 | 39.237 | 22.063 |
| U016 | 17-Sep | 15:00 | 39.134 | 22.322 |
| CS16 | 17-Sep | 19:00 | 38.705 | 23.378 |
| U017 | 18-Sep | 3:00 | 37.946 | 24.871 |
| CS17 | 18-Sep | 3:00 | 37.946 | 24.871 |
| U018 | 18-Sep | 4:00 | 37.757 | 25.014 |
| CS18 | 18-Sep | 6:00 | 37.667 | 25.444 |
| CS19 | 18-Sep | 10:00 | 37.441 | 25.430 |
| CS20 | 18-Sep | 14:00 | 36.856 | 24.656 |
| CS21 | 18-Sep | 18:00 | 36.116 | 24.086 |
| CS22 | 18-Sep | 21:00 | 35.559 | 23.663 |
| CS23 | 19-Sep | 6:00 | 34.415 | 22.780 |
| U019 | 19-Sep | 6:00 | 34.415 | 22.780 |
| CS24 | 19-Sep | 8:00 | 34.051 | 22.515 |
| U020 | 19-Sep | 8:00 | 34.051 | 22.515 |
| U021 | 19-Sep | 9:00 | 33.865 | 22.377 |
| U022 | 19-Sep | 10:00 | 33.678 | 22.241 |
| CS25 | 19-Sep | 17:00 | 32.567 | 21.410 |
| CS26 | 19-Sep | 19:00 | 32.197 | 21.144 |
| CS27 | 20-Sep | 6:00 | 30.400 | 20.944 |
| U023 | 20-Sep | 6:00 | 30.400 | 20.944 |
| U024 | 20-Sep | 7:00 | 30.195 | 20.931 |
| U025 | 20-Sep | 8:00 | 29.985 | 20.922 |
| CS28 | 20-Sep | 10:00 | 29.550 | 20.907 |
| CS29 | 20-Sep | 14:00 | 28.956 | 20.883 |
| U026 | 20-Sep | 14:00 | 28.956 | 20.883 |
| U027 | 20-Sep | 15:00 | 28.747 | 20.875 |
| U028 | 20-Sep | 16:00 | 28.536 | 20.868 |
| CS30 | 20-Sep | 18:00 | 28.103 | 20.843 |
| CS31 | 21-Sep | 6:00 | 26.149 | 20.797 |
| U029 | 21-Sep | 6:00 | 26.149 | 20.797 |
| U030 | 21-Sep | 7:00 | 25.932 | 20.777 |
| U031 | 21-Sep | 8:00 | 25.717 | 20.767 |
| U032 | 21-Sep | 9:05 | 25.485 | 20.753 |
| U033 | 21-Sep | 10:00 | 25.287 | 20.750 |
| CS32 | 21-Sep | 10:00 | 25.287 | 20.750 |

| Sample | Date | Time (GMT) | Lat (+N, -S) | Long (W) |
|---|---|---|---|---|
| U034 | 21-Sep | 11:00 | 25.083 | 20.739 |
| U035 | 21-Sep | 13:00 | 24.889 | 20.761 |
| CS33 | 22-Sep | 5:00 | 21.961 | 20.630 |
| U036 | 22-Sep | 6:12 | 21.811 | 20.625 |
| U037 | 22-Sep | 7:00 | 21.642 | 20.617 |
| CS34 | 22-Sep | 13:00 | 20.815 | 20.520 |
| U038 | 22-Sep | 13:00 | 20.815 | 20.520 |
| U039 | 22-Sep | 14:00 | 20.784 | 20.424 |
| U040 | 22-Sep | 15:00 | 20.753 | 20.244 |
| CS35 | 22-Sep | 17:00 | 20.724 | 19.983 |
| CS36 | 22-Sep | 20:00 | 20.687 | 19.490 |
| CS37 | 23-Sep | 5:00 | 20.597 | 18.160 |
| U041 | 23-Sep | 6:00 | 20.596 | 18.136 |
| U042 | 23-Sep | 7:00 | 20.566 | 17.994 |
| U043 | 23-Sep | 7:55 | 20.410 | 17.879 |
| U044 | 23-Sep | 8:00 | 20.397 | 17.869 |
| CS38 | 23-Sep | 8:00 | 20.397 | 17.869 |
| U045 | 23-Sep | 8:45 | 20.267 | 17.781 |
| U046 | 23-Sep | 9:00 | 20.224 | 17.753 |
| U047 | 23-Sep | 10:08 | 20.029 | 17.595 |
| CS39 | 23-Sep | 14:00 | 20.242 | 17.849 |
| U048 | 23-Sep | 14:00 | 20.242 | 17.849 |
| U049 | 23-Sep | 15:00 | 20.124 | 17.975 |
| CS40 | 23-Sep | 17:01 | 19.813 | 18.262 |
| CS41 | 24-Sep | 5:00 | 18.004 | 18.285 |
| U050 | 24-Sep | 6:00 | 17.908 | 18.384 |
| U051 | 24-Sep | 7:00 | 17.746 | 18.529 |
| U052 | 24-Sep | 8:00 | 17.594 | 18.670 |
| CS42 | 24-Sep | 8:00 | 17.594 | 18.670 |
| U053 | 24-Sep | 9:00 | 17.442 | 18.794 |
| U054 | 24-Sep | 13:04 | 17.026 | 19.109 |
| CS43 | 25-Sep | 10:00 | 12.813 | 20.912 |
| U055 | 25-Sep | 14:00 | 12.484 | 20.975 |
| CS44 | 25-Sep | 14:00 | 12.484 | 20.975 |
| U056 | 25-Sep | 15:00 | 12.292 | 21.064 |
| U057 | 25-Sep | 16:00 | 12.103 | 21.138 |
| U058 | 25-Sep | 17:00 | 11.899 | 21.202 |
| CS45 | 26-Sep | 5:00 | 9.957 | 21.857 |
| U059 | 26-Sep | 6:00 | 9.931 | 21.868 |
| U060 | 26-Sep | 7:00 | 9.739 | 21.908 |
| U061 | 26-Sep | 7:53 | 9.569 | 21.940 |
| CS46 | 26-Sep | 9:00 | 9.360 | 22.015 |
| CS47 | 26-Sep | 12:00 | 9.000 | 22.138 |
| U062 | 26-Sep | 12:00 | 9.000 | 22.138 |
| U063 | 26-Sep | 13:00 | 8.867 | 22.181 |
| U064 | 26-Sep | 14:00 | 8.664 | 22.246 |
| CS48 | 26-Sep | 16:00 | 8.261 | 22.375 |
| CS49 | 27-Sep | 5:00 | 6.136 | 23.064 |
| U065 | 27-Sep | 6:00 | 6.030 | 23.087 |

| Sample | Date | Time (GMT) | Lat (+N, -S) | Long (W) |
|---|---|---|---|---|
| U066 | 27-Sep | 7:00 | 5.834 | 23.148 |
| CS50 | 27-Sep | 9:00 | 5.445 | 23.271 |
| U067 | 27-Sep | 13:00 | 4.850 | 23.454 |
| CS51 | 27-Sep | 14:00 | 4.699 | 23.509 |
| U068 | 27-Sep | 14:00 | 4.699 | 23.509 |
| U069 | 27-Sep | 15:00 | 4.497 | 23.573 |
| CS52 | 28-Sep | 5:00 | 2.157 | 24.317 |
| U070 | 28-Sep | 6:00 | 2.080 | 24.343 |
| U071 | 28-Sep | 7:00 | 1.878 | 24.406 |
| CS53 | 28-Sep | 8:00 | 1.678 | 24.469 |
| U072 | 28-Sep | 14:00 | 0.700 | 24.777 |
| CS54 | 29-Sep | 10:00 | -3.435 | 25.001 |
| U073 | 29-Sep | 12:48 | -3.831 | 24.997 |
| U074 | 29-Sep | 13:00 | -3.823 | 24.999 |
| CS55 | 29-Sep | 13:00 | -3.823 | 24.999 |
| U075 | 29-Sep | 14:15 | -4.077 | 24.999 |
| U076 | 29-Sep | 15:00 | -4.229 | 25.000 |
| CS56 | 30-Sep | 5:00 | -6.564 | 25.013 |
| U077 | 30-Sep | 6:00 | -6.219 | 25.007 |
| U078 | 30-Sep | 7:00 | -6.821 | 25.004 |
| U079 | 30-Sep | 8:00 | -7.026 | 25.001 |
| CS57 | 30-Sep | 8:00 | -7.026 | 25.001 |
| U080 | 30-Sep | 13:00 | -7.834 | 25.002 |
| CS58 | 30-Sep | 13:00 | -7.834 | 25.002 |
| U081 | 30-Sep | 14:00 | -8.008 | 25.001 |
| U082 | 30-Sep | 15:00 | -8.214 | 25.000 |
| U083 | 30-Sep | 16:00 | -8.418 | 25.000 |
| CS59 | 1-Oct | 5:00 | -10.635 | 24.999 |
| U084 | 1-Oct | 6:00 | -10.744 | 24.996 |
| U085 | 1-Oct | 7:00 | -10.943 | 25.000 |
| CS60 | 1-Oct | 10:00 | -11.551 | 25.006 |
| CS61 | 1-Oct | 13:00 | -11.938 | 25.002 |
| U086 | 1-Oct | 14:00 | -12.105 | 25.000 |
| U087 | 1-Oct | 15:00 | -12.311 | 25.000 |
| CS62 | 1-Oct | 16:00 | -12.520 | 25.000 |
| CS63 | 2-Oct | 5:00 | -14.823 | 25.003 |
| U088 | 2-Oct | 6:00 | -14.902 | 25.000 |
| U089 | 2-Oct | 7:00 | -15.109 | 25.001 |
| CS64 | 2-Oct | 10:00 | -15.743 | 25.000 |
| U090 | 2-Oct | 13:00 | -16.153 | 24.998 |
| U091 | 2-Oct | 15:00 | -16.555 | 25.000 |
| CS65 | 2-Oct | 15:00 | -16.555 | 25.000 |
| CS66 | 3-Oct | 5:00 | -19.033 | 25.000 |
| U092 | 3-Oct | 6:00 | -19.144 | 25.000 |
| U093 | 3-Oct | 7:00 | -19.341 | 24.998 |
| CS67 | 3-Oct | 9:00 | -19.712 | 25.000 |
| CS68 | 3-Oct | 12:00 | -20.242 | 25.003 |
| U094 | 3-Oct | 14:00 | -20.361 | 25.000 |
| CS69 | 3-Oct | 15:00 | -20.537 | 25.000 |

| Sample | Date | Time (GMT) | Lat (+N, -S) | Long (W) |
|---|---|---|---|---|
| U095 | 3-Oct | 15:00 | -20.537 | 25.000 |
| U096 | 3-Oct | 16:00 | -20.720 | 25.002 |
| CS70 | 4-Oct | 5:00 | -22.694 | 25.016 |
| U097 | 4-Oct | 6:00 | -22.776 | 25.004 |
| U098 | 4-Oct | 7:00 | -22.965 | 25.002 |
| CS71 | 4-Oct | 8:00 | -23.158 | 25.001 |
| U099 | 4-Oct | 8:00 | -23.158 | 25.001 |
| U100 | 4-Oct | 14:00 | -24.086 | 25.000 |
| CS72 | 4-Oct | 14:00 | -24.086 | 25.000 |
| U101 | 4-Oct | 15:00 | -24.278 | 25.000 |
| CS73 | 4-Oct | 19:00 | -25.062 | 24.994 |
| CS74 | 5-Oct | 5:00 | -26.645 | 25.008 |
| U102 | 5-Oct | 6:00 | -26.720 | 25.004 |
| U103 | 5-Oct | 7:00 | -26.922 | 25.003 |
| CS75 | 5-Oct | 9:00 | -27.328 | 25.000 |
| U104 | 5-Oct | 14:15 | -28.071 | 25.084 |
| U105 | 5-Oct | 15:00 | -28.184 | 25.218 |
| U106 | 6-Oct | 6:00 | -29.978 | 27.350 |
| CS76 | 6-Oct | 6:00 | -29.978 | 27.350 |
| U107 | 6-Oct | 7:00 | -30.122 | 27.534 |
| U108 | 6-Oct | 8:00 | -30.280 | 27.721 |
| U109 | 6-Oct | 8:11 | -30.305 | 27.751 |
| CS77 | 6-Oct | 9:00 | -30.428 | 27.902 |
| CS78 | 6-Oct | 13:00 | -30.869 | 28.448 |
| U110 | 6-Oct | 15:00 | -31.151 | 28.775 |
| CS79 | 7-Oct | 5:00 | -32.884 | 30.927 |
| U111 | 7-Oct | 6:00 | -32.939 | 30.981 |
| CS80 | 7-Oct | 9:00 | -33.387 | 31.527 |
| CS81 | 7-Oct | 12:00 | -33.811 | 32.071 |
| U112 | 7-Oct | 12:50 | -33.807 | 32.071 |
| U113 | 7-Oct | 14:00 | -33.930 | 32.211 |
| U114 | 7-Oct | 15:00 | -34.075 | 32.394 |
| U115 | 7-Oct | 15:15 | -34.114 | 32.444 |
| U116 | 7-Oct | 15:30 | -34.149 | 32.486 |
| U117 | 7-Oct | 15:45 | -34.190 | 32.534 |
| U118 | 7-Oct | 16:00 | -34.224 | 32.578 |
| U119 | 7-Oct | 16:15 | -34.259 | 32.623 |
| U120 | 7-Oct | 16:30 | -34.293 | 32.668 |
| U121 | 7-Oct | 16:45 | -34.327 | 32.713 |
| CS82 | 8-Oct | 5:00 | -35.620 | 34.355 |
| U122 | 8-Oct | 6:00 | -35.620 | 34.346 |
| U123 | 8-Oct | 7:00 | -35.743 | 34.515 |
| U124 | 8-Oct | 9:00 | -36.014 | 34.849 |
| U125 | 8-Oct | 14:00 | -36.521 | 35.500 |
| CS83 | 8-Oct | 14:00 | -36.521 | 35.500 |
| U126 | 8-Oct | 15:00 | -36.651 | 36.679 |
| CS84 | 8-Oct | 17:00 | -36.938 | 36.059 |
| CS85 | 9-Oct | 6:00 | -38.482 | 38.118 |
| U127 | 9-Oct | 7:00 | -38.530 | 38.188 |

| Sample | Date | Time (GMT) | Lat (+N, -S) | Long (W) |
|---|---|---|---|---|
| U128 | 9-Oct | 8:00 | -38.686 | 38.383 |
| U129 | 9-Oct | 10:00 | -38.975 | 38.767 |
| U130 | 9-Oct | 11:00 | -39.131 | 38.977 |
| U131 | 9-Oct | 14:00 | -39.397 | 39.360 |
| CS86 | 9-Oct | 14:00 | -39.397 | 39.360 |
| U132 | 9-Oct | 15:00 | -39.550 | 39.539 |
| U133 | 9-Oct | 16:00 | -39.693 | 39.729 |
| CS87 | 10-Oct | 6:00 | -41.149 | 41.705 |
| U134 | 10-Oct | 7:00 | -41.215 | 41.788 |
| U135 | 10-Oct | 8:00 | -41.330 | 41.962 |
| CS88 | 10-Oct | 11:00 | -41.670 | 42.447 |
| U136 | 10-Oct | 15:00 | -41.985 | 42.884 |
| CS89 | 10-Oct | 15:00 | -41.985 | 42.884 |
| U137 | 10-Oct | 16:00 | -42.103 | 43.047 |
| CS90 | 11-Oct | 7:00 | -43.976 | 45.724 |
| U138 | 11-Oct | 9:00 | -44.037 | 45.820 |
| U139 | 11-Oct | 10:00 | -44.170 | 46.010 |
| U140 | 11-Oct | 14:00 | -44.559 | 46.588 |
| CS91 | 11-Oct | 14:00 | -44.559 | 46.588 |
| U141 | 11-Oct | 15:00 | -44.686 | 46.761 |
| U142 | 11-Oct | 16:00 | -44.825 | 46.964 |

# Nitrification and its contribution to 'new' production.

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## OVERVIEW

To date, only limited insights into the role of nitrification in relation to biogeochemical N-cycles exist. Nitrification is the sequential oxidation of ammonium through to nitrate via nitrite, and is mediated by two groups of bacteria – the ammonium and nitrite oxidising bacteria. Consequently, nitrate (conceptually referred to as 'new nitrogen') is derived from a 'regenerated' form of nitrogen (ammonium). 'New' and 'regenerated' production are related in the f-ratio which itself is a measure of nitrate dependant productivity and can, under certain conditions, be related to the exportable production in a given system. Significant rates of nitrification would lead to overestimations of new production and would introduce errors in various other indices derived from new production estimates.

While significant advances have been made in the measurement of nanomolar nutrient concentrations typical of oligotrophic oceans, such measurements give no indication of the *flux* of nutrients through a given system. Microbially mediated N cycles in oligotrophic oceans are, by their very nature, tightly coupled and perpetually low nutrient concentrations conceal this flux. In the present study, changes in $^{15}N$ enrichment and dilution of dissolved inorganic nitrogen (DIN; as ammonium, nitrite and nitrate) will be used to estimate the rates of ammonium regeneration, ammonium and nitrite oxidation and nitrate enrichment by solid phase extraction and Gas-Chromatography Mass Spectrometry (GC-MS). Isotope Ratio Mass Spectrometry (IRMS) of particulate organic nitrogen will be used to measure N-assimilation by the phytoplankton assemblage. Collectively, the data should enable an estimation of the significance of nitrification in relation to N-assimilation.

## OBJECTIVES

1. To determine the rate of $^{15}$N-ammonium and $^{15}$N-nitrite oxidation in a series of incubations in seawater collected from the chlorophyll maximum and 55 % surface PAR. From these the overall nitrification rate can be estimated.
2. To determine the rate of $^{15}$N-nitrate assimilation by the phytoplankton assemblage in seawater collected from the chlorophyll maximum and 55 % surface PAR.
3. From 1 and 2 above, an estimation of the significance of nitrification in relation to nitrate assimilation can be made.
4. To determine the rate of ammonium regeneration by the dilution of $^{15}$N ammonium during the incubations described above.
5. To collect samples for molecular biology analysis – primarily to test a molecular probe chip developed to probe for the expression of genes associated with N-assimilation.

## CTD numbers from which samples were taken.

CTD # 1, 4, 7, 9, 12, 17, 20, 23, 26, 29, 33, 36, 43, 46, 52, 55, 58, 64

## METHODS

1. 20L was collected (pre-dawn monster cast) from the chlorophyll maximum and 55 % surface PAR. Seawater from each depth was treated as follows:
    a. 3 x initial $NH_4^+$ samples (concentration & 15-N natural abundance) collected by derivitisation forming indo-phenol, and retained by solid phase extraction.
    b. 3 x $NO_2$ samples (concentration & 15-N natural abundance) collected by derivatisation forming the azo dye sudan-1, and retained by solid phase extraction.
    c. 3 x $NO_3$ samples (concentration & 15-N natural abundance) exposed to cadmium reduction to $NO_2$ and collected as for 'b' above.
    d. 3 x 'Ammonium Oxidising Bacteria' incubations, spiked with $^{15}$N-$NH_4$ and used to examine $^{15}NH_4$ dilution (i.e. $NH_4$ regeneration rate) and $NO_2$ enrichment (i.e. ammonium oxidation rate).
    e. 3 x 'Nitrite Oxidising Bacteria' incubations, spiked with $^{15}$N-$NO_2$ and used to examine $^{15}NO_2$ dilution (i.e. a second method of estimating $NH_4$ oxidation rate) and $NO_3$ enrichment (i.e. nitrite oxidation rate).
    f. 3 L of seawater spiked with $^{15}$N-$NO_3$ - PON samples taken before and after deck incubations to determine $NO_3$ assimilation rate.
2. $NH_4$, $NO_2$ and $NO_3$ standards generated and collected for GC-MS analysis.
3. A series of $NO_2$ and $NO_3$ standards collected to monitor the efficiency of the cadmium column reduction method used.
4. 3 L was filtered onto RNA/DNA clean filters and frozen in dry-shipper.
5. At the PML, $NH_4$-indophenol samples will be eluted from the SPE columns and derivatised with Sylon prior to GC-MS analysis. Sudan-1 derived from $NO_2$ and $NO_3$ will be eluted from SPE's and derivatised with MTBSTFA prior to GC-MS.

## RESULTS

All results will be generated post-cruise and data made available to BODC within 6 months of the cruise end.

# Atlantic Microzooplankton: community composition and the role of UV in carbon flux


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**AIMS AND OBJECTIVES:**

- Profile surface solar UVR along the AMT.
- Quantify the effect of UVR on microzooplankton community and taxa specific growth rates in relation to latitude.
- Quantify the effect of UVR on a 'control culture' growth rate in relation to latitude.
- Quantify the effect of UVR exposure on species diversity within the microzooplankton population.
- Quantify the effect of UVR intensity on microzooplankton growth rates.
- Identify the species composition in relation to latitude by vertical profiling.
- Quantify the effect of latitude related temperature on microzooplankton cell size.
- Identify heterotrophic and autotrophic flagellates using epifluorescence staining of filters.

This study has four interrelated parts: i. assess microzooplankton biomass and abundance in the water column and convert this to production. Integration of this with other work being conducted by the Atlantic Meridional Transect study will provide an assessment of the role of microzooplankton in food webs along the transect; ii. assess if there is a 'global presence' of all microzooplankton taxa and how the environment may influence species composition; iii. experimental research on the effects of UVR on surface microzooplankton growth rates along the transect to assess how increased UVR levels may affect microzooplankton; iv. assess affects of latitude-related temperature on the microzooplankton size.

## INTRODUCTION:

Microzooplankton play an important biogeochemical role in the microbial loop (Landry & Hassett 1982, Archer *et al*. 2000, Stelfox-Widdicombe *et al*. 2000), which is intrinsically linked with the classical food web (Azam *et al* .1983). Understanding the role of microzooplankton is essential to assess the role of the ocean as a carbon sink (Steele 1974, Landry & Hassett 1982, Azam *et al.* 1983). With predicted global climate changes, including increased UV radiation and raised sea temperature affecting marine organisms, an understanding of trophic interactions is needed to predict consequences. This study will assess the role of microzooplankton in the food webs of the Atlantic Ocean, along the AMT, extending from northern temperate to southern temperate waters, and specifically it will assess the impact of UV radiation, which varies along this transect, on the microzooplankton in those food webs. Finally, as microzooplankton size will influence food web dynamics (Menden-Deuer & Lessard 2000), a further sub-set of this investigation will study the effect of the latitudinal changes in sea temperature on protist cell size. This will assess if their size is temperature dependent (Mayr 1956, from: Bergmann 1847).

## EXPERIMENTAL DESIGN AND SETUP

***The effect of UVR on microzooplankton community, specific taxa and cultured sample growth rates and on species diversity.***

Water samples were collected from 25 stations from along the AMT tract, chosen to represent a general gradient of varying UV exposures. These samples, along with 150 ml cultures of the heterotrophic dinoflagellate, *Oxyrrhis marinas*, were incubated under ambient light in on-deck incubators for two days under differing regimes of UVR exposure (see section below). Growth rates will be determined assuming an exponential increase over a 2-day period, and diversity of the collected samples will also be determined.

The latitudinal variation of the experiment sites will allow a comparison of treatment effects at varying UV intensities and upon differently adapted communities and taxa.

### Incubators

Within the incubators are three compartments that are vented to allow through flow of seawater. Each compartment has a specific cut-off filter lid to control the UVR exposure. The exposure treatments will be: i. PAR+UVA+UVB (280-700 nm) treatment with no filters i.e., exposed to ambient sunlight; ii. PAR+UVA (320-700 nm); iii. PAR only (400-700 nm) treatment. The incubators were covered with UV transparent neural density screening to reduce the intensity of the ambient sunlight, simulating the sampling depth of 5 m.

### Radiation Statistics

In the field solar radiation was monitored using an on deck multiwavelength sensor (Ramses-ACC-UV hyperspectral radiometer, TriOS GmbH, Oldenburg, Germany ) that takes readings at 5 minute intervals. This recorded the incidence of specific wavelengths of ambient light that irradiated the incubators and will allow calculation of entire daily radiation exposure and daily wavelength ratios using the TriOS multispectral radiometer software. The same sensor allowed in-incubator assessment of the shielding properties of the neutral density screening.

**Sample collection and incubation**

Samples were collected from the CTD after passing through a 200 µm mesh to remove larger predators. Acid washed 750 ml Whirlpak® polyethylene bags (Nasco, Fort Atkinson, USA) were used as culture vessels as they transmit solar radiation (>220 nm) (Smith *et al*. 1992, Holm-Hansen & Helbling 1993).

*Oxyrrhis marina* was cultured on-board using filtered seawater containing rice grains to stimulate bacterial growth as a source of prey. 150 ml samples were incubated in acid washed 150 ml Whirlpak® polyethylene bags.

Triplicates of both natural and cultured samples were immersed in each of the three incubator compartments. $T_0$ readings for the natural samples were taken by fixing a 250 ml sample from the seawater source in 2% Lugol's solution. $T_0$ readings for the cultured sample were taken using 2 ml of the sample analysed in a Becton Dickinson FACSort flow cytometer (American Laboratory Trading LLC, Connecticut, USA) to assess *Oxyrrhis marina* numbers.

250 ml was removed from each culture bag containing natural samples after a one day incubation ($T_{24}$) and fixed in 2% Lugol's solution. The culture vessels were then replaced in the incubator for a further day's incubation, after which 250 ml was again fixed in 2% Lugol's solution ($T_{48}$). All fixed samples will be returned to the laboratory for analysis. The cultured samples of *Oxyrrhis marina* were analysed using 2 ml samples taken from the culture bags at $T_{24}$ and $T_{48}$ and counted in the flow cytometer.

Community, dominant taxa, and cultured sample growth rates will be estimated, assuming exponential growth over the incubation period, from 3 data points ($T_0$, $T_{24}$, $T_{48}$). If the growth rate is not constant over the 48 h period, then the 24 h incubation will only be used. The fixed samples from the UVR experiments will be analysed using an inverted microscope at 200×magnification to identify and enumerate microzooplankton from 100 ml samples that will have been settled for 48 h. (Gifford & Caron 2000). Diversity indices will be estimated using the collected samples prepared above.

***Vertical Profiling***

To assess the microzooplankton biomass and abundance in the water column, 500 ml water samples were fixed in 2% Lugol's solution directly from CTD, at 10 depths from the pre-dawn cast. A total of 5 of these depths will be analysed aiming to be representative of the water column. These are likely to be chosen from: i. the surface layer (97% surface irradiance); ii. near surface (55 % surface irradiance) ; iii. at mid-way in the mixed layer (20-30 m for a 50 m mixed layer depth (MLD) or 40-50 m for a 100 m MLD); iv. at 33% of surface irradiance; v. at 1% light level (the chlorophyll *a* maximum in gyres and equatorial waters); vi. at 0.1% light level, the bottom of the photic zone and vii. below the thermocline.

100 ml from each of the fixed samples will be settled for 48 h and then examined using an inverted microscope at 200×magnification (Gifford & Caron 2000) to identify and enumerate microzooplankton taxa (>20 µm). Estimations of biomass will be made with an image-analysis system attached to the inverted microscope to estimate size, assuming standard geometric shapes (Hillebrand et al. 1999) and by using carbon to volume conversions: pg C $cell^{-1} = 0.22 \times (\mu m^3)^{0.939}$ for ciliates and pg C $cell^{-1} = 0.76 \times (\mu m^3)^{0.819}$ for dinoflagellates (Menden-Deuer & Lessard, 2000). Both biomass and abundance will be integrated through the water column.

Assessment of the presence of heterotrophic and autotrophic flagellates will be achieved using an ultraviolet inverted microscope to analyse the epifluorescent slides prepared from 6 different depths in the water column.

***Effect of temperature on cell size***

Using the surface samples from the vertical profiling (above), 30 individuals from each of 5 selected key species will be measured and volumes will be calculated from the assumption of standard geometric shapes (Hillebrand et al. 1999). These species specific cell sizes will be related to surface sea temperatures at their site of collection.

## DATA

Daily UV experiments were performed from the 14$^{th}$ September 2003 until 11th October with the exception of 16$^{th}$, 25$^{th}$ and 29$^{th}$ of September. Daily data generated was 9 samples from each incubator at $T_{24}$ and $T_{48}$ (with a $T_0$ of 3 samples). 9 daily samples were collected from the *Oxyrrhis marina* cultured experiments which were analysed in the flow cytometer. 10 daily samples were collected for vertical profiling and 6 epifluorescent slides created for each profile.

## PROBLEMS

The UV sensor was a replacement item as the original was damaged before the cruise. This replacement is not fully calibrated, has a noisy reception and had errors in recording a full days data. It is hoped that sufficient data will be retrieved to allow a reasonable guide to solar UV irradiance.

## ADDITIONAL PROJECT

At 3 stations, 5 duplicate 250 ml samples were taken from each of 2 depths (surface and chlorophyll max). These samples were fixed in 2 and 10% Lugol's solution respectively. It is hoped that comparison of microzooplankton assemblages in terms of numbers and size under the differing fixative concentrations will allow assessment of cell shrinkage and cell loss (apparent carbon loss) under these conditions. This will, in turn, allow a more accurate assessment of carbon flow within the microbial web.

## ANALYSIS

The completion of data and deposition at BODC will be dependent on analysis of collected samples at the Plymouth Marine Laboratory. Analysis will start at the beginning of December and will continue until AMT14, at which point the majority of analysis will be completed. Analysis of the epifluorescent slides will be by Elaine Fileman at the PML.

## CTD CASTS USED FOR INVESTIGATIONS

| CTD # | Date | Time (GMT) | Experiment | Lat. | Long. | TSG temp | TSG sal | TSG chl | Chl max depth |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 14/09/03 | 01:10 | UV | 48 21.57N | 09 51.74W | 17.6 | 35.6 | 0.306 | 35 |
| 2 | 14/09/03 | 03:03 | Profile | 48 22.90N | 09 52.11W | 17.5 | 35.6 | 0.32 | 35 |
| 4 | 15/09/03 | 01:05 | UV | 47 05.49N | 15 17.22W | 18.35 | 35.65 | 0.231 | 65 |
| 5 | 15/09/03 | 01:50 | Profile | 47 06.07N | 15 17.70W | 18.29 | 35.65 | 0.23 | 60 |
| 9 | 17/09/03 | 02:13 | UV | 40 02.83N | 20 00.96W | 22.47 | 36.11 | 0.152 | 80 |
| 11 | 17/09/03 | 11:04 | Profile | 39 26.45N | 21 32.70W | 23.09 | 36.21 | 0.148 | 65 |
| 12 | 18/09/03 | 00:07 | UV | 38 10.34N | 24 41.49W | 23.45 | 36.15 | 0.144 | 58 |
| 13 | 18/09/03 | 01:03 | Profile | 38 10.09N | 24 41.96W | 23.45 | 36.15 | 0.153 | 60 |
| 14 | 19/09/03 | 02:04 | UV | 34 41.10N | 22 59.70W | 25.12 | 36.59 | 0.14 | 88 |
| 15 | 19/09/03 | 03:47 | Profile | 34 40.93N | 22 59.59W | 25.15 | 36.56 | 0.132 | 85 |
| 17 | 20/09/03 | 02:02 | UV | 30 15.56N | 20 57.51W | 25.06 | 37.19 | 0.129 | 137 |
| 18 | 20/09/03 | 03:45 | Profile | 30 15.06N | 20 56.55W | 25.10 | 37.18 | 0.132 | 130 |
| 20 | 21/09/03 | 03:27 | UV | 26 10.23N | 20 47.30W | 25.42 | 37.14 | 0.122 | 102 |
| 21 | 21/09/03 | 05:01 | Profile | 26 10.23N | 20 47.30W | 25.44 | 37.14 | 0.133 | 100 |
| 23 | 22/09/03 | 03:00 | UV | 21 58.02N | 20 37.43W | 24.78 | 36.54 | 0.149 | 42 |
| 24 | 22/09/03 | 04:32 | Profile | 21 57.75N | 20 37.77W | 24.75 | 36.55 | 0.148 | 42 |
| 26 | 23/09/03 | 03:03 | UV | 20 36.08N | 18 09.29W | 26.23 | 36.23 | 0.184 | 35 |
| 27 | 23/09/03 | 04:48 | Profile | 20 36.08N | 18 09.29W | 26.17 | 36.23 | 0.186 | 35 |
| 28 | 23/09/03 | 12:23 | Lugol's | 20 19.69N | 17 46.36W | 22.54 | 35.83 | 0.633 | 10 |
| 29 | 24/09/03 | 02:59 | UV | 18 00.95N | 18 17.13W | 27.60 | 35.97 | 0.153 | 30 |
| 30 | 24/09/03 | 04:36 | Profile | 18 00.95N | 18 17.13W | 27.79 | 35.98 | 0.151 | 30 |
| 33 | 26/09/03 | 03:00 | UV | 09 57.06N | 21 58.31W | 28.27 | 35.22 | 0.141 | 35 |
| 36 | 27/09/03 | 03:06 | UV | 06 07.83N | 23 03.68W | 28.65 | 34.87 | 0.125 | 71 |
| 37 | 27/09/03 | 04:37 | Profile | 06 08.12N | 23 03.84W | 28.61 | 34.90 | 0.131 | 69 |
| 39 | 28/09/03 | 03:03 | UV | 02 09.34N | 24 18.92W | 27.77 | 35.51 | 0.135 | 83 |
| 40 | 28/09/03 | 04:48 | Profile | 02 09.36N | 24 19.00W | 27.71 | 35.58 | 0.134 | 78 |
| 43 | 30/09/03 | 02:59 | UV | 6 35.05S | 24 59.89W | 26.20 | 36.17 | 0.122 | 90 |
| 44 | 30/09/03 | 04:48 | Profile | 06 33.97S | 25 00.70W | 26.15 | 36.20 | 0.122 | 95 |
| 46 | 01/10/03 | 02:58 | UV | 10 38.79S | 24 59.77W | 25.83 | 36.27 | 0.111 | 130 |
| 47 | 01/10/03 | 04:33 | Profile | 10 38.22S | 24 59.87W | 25.76 | 36.26 | 0.116 | 130 |
| 49 | 02/10/03 | 03:08 | UV | 14 19.53S | 24 59.68W | 25.13 | 36.83 | 0.111 | 158 |
| 52 | 03/10/03 | 02:57 | UV | 19 02.27S | 25 00.12W | 24.27 | 37.00 | 0.120 | 150 |
| 53 | 03/10/03 | 04:31 | Profile | 19 02.02S | 25 00.04W | 24.29 | 37.02 | 0.113 | 148 |
| 54 | 03/10/03 | 12:03 | Lugol's | 20 14.65S | 25 00.16W | 23.92 | 36.99 | 0.116 | 155 |
| 55 | 04/10/03 | 03:02 | UV | 22 40.83S | 25 00.14W | 22.96 | 36.80 | 0.120 | 133 |
| 56 | 04/10/03 | 04:40 | Profile | 22 40.83S | 25 00.14W | 22.89 | 36.87 | 0.106 | 137 |
| 58 | 05/10/03 | 03:03 | UV | 26 39.05S | 24 59.96W | 20.70 | 36.37 | 0.123 | 120 |
| 59 | 05/10/03 | 04:35 | Profile | 26 38.80S | 25 00.44W | 20.74 | 36.40 | 0.122 | 115 |
| 61 | 06/10/03 | 03:21 | UV | 29 57.10S | 27 19.52W | 19.23 | 35.94 | 0.117 | 137 |
| 62 | 06/10/03 | 04:57 | Profile | 29 57.03S | 27 19.26W | 19.13 | 35.94 | 0.114 | 150 |
| 64 | 07/10/03 | 03:00 | UV | 32 52.35S | 30 54.35W | 18.26 | 35.87 | 0.112 | 118 |
| 65 | 07/10/03 | 04:40 | Profile | 32 52.90S | 30 56.36W | 18.25 | 35.88 | 0.115 | 118 |
| 67 | 08/10/03 | 03:10 | UV | 35 37.18S | 34 20.82W | 15.66 | 35.61 | 0.291 | No max |
| 68 | 08/10/03 | 04:46 | Profile | 35 37.17S | 34 21.24W | 15.58 | 35.62 | 0.281 | No max |
| 70 | 09/10/03 | 04:08 | UV | 38 28.44S | 38 05.88W | 14.01 | 35.36 | 0.317 | No max |
| 71 | 09/10/03 | 05:46 | Profile | 38 28.84S | 38 06.90W | 14.05 | 35.35 | 0.317 | No max |
| 73 | 10/10/03 | 04:00 | UV | 41 10.11S | 41 44.44W | 13.29 | 35.28 | 0.294 | No max |
| 74 | 10/10/03 | 05:30 | Profile | 41 09.27S | 41 42.81W | 13.25 | 35.28 | 0.299 | No max |
| 78 | 12/10/03 | 13:07 | Lugol's | 47 46.02S | 51 25.83W | 6.50 | 34.03 | 0.217 | 38 |

**Experiment definition: UV:** Sample used in UV experimentation
**Profile:** Samples taken from ten depths (always including irradiance levels of 97%, 55%, 33%, 14%, 1% and 0.1% and the maximum depth of 300 m) .
**Lugol's:** Samples taken for the investigation into the effect of various Lugol's concentration on cell shrinkage and loss.

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# Genetic Diversity of *Prochlorococcus* spp.

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Marine cyanobacteria account for approximately 50% of the biomass and primary production in oligotrophic waters and are a significant component of total phytoplankton community structure in mesotrophic waters. The *Prochlorococcus* group, one of the major components of the cyanobacteria melange, is genetically diverse with different genotypes co-occurring throughout the water column. Distinct genotypes have been shown to have significantly different physiologies with respect to light level and nutrient uptake, among other properties. Thus, understanding the presence and abundance of the different clades of *Prochlorococcus* and their relationships to environmental variables will help our understanding of the role that *Prochlorococcus* plays in microbial food webs and in the global carbon cycle.

On AMT-13 our group sampled all of the CTD profile casts (53 total) from approximately 10 representative depths from the upper 200m. The water samples were filtered to isolate phytoplankton, preserved with an EDTA-based preservation solution and stored at -80$^{o}$C for later analyses. In the laboratory, we will isolate DNA from the filtered samples and use a quantitative PCR protocol to quantify the number of cells from each of the six known clades of *Prochlorococcus*. These estimates of *Prochlorococcus* abundance will be compared to flow cytometry and HPLC-estimates as well as with environmental variables such as nutrients, temperature, light level and mixing. Using the same DNA extractions, for select samples, we also plan on searching for new types of *Prochlorococcus* by creating clone libraries. We will screen the clones using either the 16S/inter-trascribed region of rDNA or psbA gene and sequencing or using a terminal restriction fragment length polymorphism protocol (T-RFLP).

# Appendices

## Appendix 1 : List of CTDs

| CTD # | Date | Time (GMT) | Lat. | Long. | TSG temp | TSG sal | TSG chl | Chl max depth |
|---|---|---|---|---|---|---|---|---|
| **1** | 14/09/03 | 01:10 | 48 21.57N | 09 51.74W | 17.6 | 35.6 | 0.306 | 35 |
| **2** | 14/09/03 | 03:03 | 48 22.90N | 09 52.11W | 17.5 | 35.6 | 0.32 | 35 |
| **3** | 14/09/03 | 10:07 | 47 58.60N | 11 32.04W | 17.9 | 35.6 | 0.235 | 50 |
| **4** | 15/09/03 | 01:05 | 47 05.49N | 15 17.22W | 18.35 | 35.65 | 0.231 | 65 |
| **5** | 15/09/03 | 01:50 | 47 06.07N | 15 17.70W | 18.29 | 35.65 | 0.23 | 60 |
| **6** | 15/09/03 | 11:06 | 46 41.27N | 17 00.36W | 18.40 | 35.62 | 0.21 | 50 |
| **7** | 16/09/03 | 02.20 | 44 46.57N | 19 21.53W | Cancelled – wire snapped | | | |
| **8** | 16/09/03 | 11.31 | 43 02.56N | 19 37.27W | 19.8 | 35.83 | 0.165 | 60 |
| **9** | 17/09/03 | 02:13 | 40 02.83N | 20 00.96W | 22.47 | 36.11 | 0.152 | 80 |
| **10** | 17/09/03 | 04:13 | 40 03.72N | 20 00.08W | 22.5 | 36.10 | 0.160 | 60 |
| **11** | 17/09/03 | 11:04 | 39 26.45N | 21 32.70W | 23.09 | 36.21 | 0.148 | 65 |
| **12** | 18/09/03 | 00:07 | 38 10.34N | 24 41.49W | 23.45 | 36.15 | 0.144 | 58 |
| **13** | 18/09/03 | 01:03 | 38 10.09N | 24 41.96W | 23.45 | 36.15 | 0.153 | 60 |
| **14** | 19/09/03 | 02:04 | 34 41.10N | 22 59.70W | 25.12 | 36.59 | 0.14 | 88 |
| **15** | 19/09/03 | 03:47 | 34 40.93N | 22 59.59W | 25.15 | 36.56 | 0.132 | 85 |
| **16** | 19/09/03 | 11:01 | 33 29.69N | 22 06.58W | 25.26 | 36.84 | 0.133 | 110 |
| **17** | 20/09/03 | 02:02 | 30 15.56N | 20 57.51W | 25.06 | 37.19 | 0.129 | 137 |
| **18** | 20/09/03 | 03:45 | 30 15.06N | 20 56.55W | 25.10 | 37.18 | 0.132 | 130 |
| **19** | 20/09/03 | 11:03 | 29 21.26N | 20 53.75W | 25.36 | 37.14 | 0.125 | 110 |
| **20** | 21/09/03 | 03:27 | 26 10.23N | 20 47.30W | 25.42 | 37.14 | 0.122 | 102 |

| CTD # | Date | Time (GMT) | Lat. | Long. | TSG temp | TSG sal | TSG chl | Chl max depth |
|---|---|---|---|---|---|---|---|---|
| **21** | 21/09/03 | 05:01 | 26 10.23N | 20 47.30W | 25.44 | 37.14 | 0.133 | 100 |
| **22** | 21/09/03 | 11:06 | 25 05.08N | 20 44.53W | 25.02 | 36.95 | 0.133 | 100 |
| **23** | 22/09/03 | 03:00 | 21 58.02N | 20 37.43W | 24.78 | 36.54 | 0.149 | 42 |
| **24** | 22/09/03 | 04:32 | 21 57.75N | 20 37.77W | 24.75 | 36.55 | 0.148 | 42 |
| **25** | 22/09/03 | 11:01 | 20 48.52N | 20 34.86W | 25.58 | 36.19 | 0.216 | 40 |
| **26** | 23/09/03 | 03:03 | 20 36.08N | 18 09.29W | 26.23 | 36.23 | 0.184 | 35 |
| **27** | 23/09/03 | 04:48 | 20 36.08N | 18 09.29W | 26.17 | 36.23 | 0.186 | 35 |
| **28** | 23/09/03 | 12:33 | 20 19.69N | 17 46.36W | 22.54 | 35.83 | 0.633 | 10 |
| **29** | 24/09/03 | 02:59 | 18 00.95N | 18 17.13W | 27.60 | 35.97 | 0.153 | 30 |
| **30** | 24/09/03 | 04:36 | 18 00.95N | 18 17.13W | 27.79 | 35.98 | 0.151 | 30 |
| **31** | 24/09/03 | 11:11 | 17 08.40N | 19 00.91W | 28.60 | 35.97 | 0.172 | 42 |
| **32** | 25/09/03 | 12:40 | 12 30.87N | 20 59.59W | 28.38 | 35.52 | 0.14 | 40 |
| **33** | 26/09/03 | 03:00 | 09 57.06N | 21 58.31W | 28.27 | 35.22 | 0.141 | 35 |
| **34** | 26/09/03 | 04:49 | 09 57.33N | 21 51.34W | 28.26 | 35.28 | 0.14 | 37 |
| **35** | 26/09/03 | 11:11 | 09 00.03N | 22 08.30W | 28.29 | 35.79 | 0.13 | 60 |
| **36** | 27/09/03 | 03:06 | 06 07.83N | 23 03.68W | 28.65 | 34.87 | 0.125 | 71 |
| **37** | 27/09/03 | 04:37 | 06 08.12N | 23 03.84W | 28.61 | 34.90 | 0.131 | 69 |
| **38** | 27/09/03 | 12:10 | 04 51.00N | 23 27.25W | 28.45 | 34.10 | 0.127 | 85 |
| **39** | 28/09/03 | 03:03 | 02 09.34N | 24 18.92W | 27.77 | 35.51 | 0.135 | 83 |
| **40** | 28/09/03 | 04:48 | 02 09.36N | 24 19.00W | 27.71 | 35.58 | 0.134 | 78 |
| **41** | 28/09/03 | 12:04 | 00 53.12N | 24 42.62W | 26.75 | 35.87 | 0.124 | 65 |
| **42** | 29/09/03 | 12:05 | 03 50.08S | 24 59.69W | 26.08 | 36.11 | 0.117 | 78 |
| **43** | 30/09/03 | 02:59 | 06 35.05S | 24 59.89W | 26.20 | 36.17 | 0.122 | 90 |
| **44** | 30/09/03 | 04:48 | 06 33.97S | 25 00.70W | 26.15 | 36.20 | 0.122 | 95 |

| CTD # | Date | Time (GMT) | Lat. | Long. | TSG temp | TSG sal | TSG chl | Chl max depth |
|---|---|---|---|---|---|---|---|---|
| **45** | 30/09/03 | 12:03 | 07 50.18S | 24 59.78W | 26.12 | 36.14 | 0.132 | 93 |
| **46** | 01/10/03 | 02:58 | 10 38.79S | 24 59.77W | 25.83 | 36.27 | 0.111 | 130 |
| **47** | 01/10/03 | 04:33 | 10 38.22S | 24 59.87W | 25.76 | 36.26 | 0.116 | 130 |
| **48** | 01/10/03 | 12:03 | 11 56.39S | 24 59.58W | 25.64 | 36.38 | 0.107 | 132 |
| **49** | 02/10/03 | 03:08 | 14 19.53S | 24 59.68W | 25.13 | 36.83 | 0.111 | 158 |
| **50** | 02/10/03 | 04:50 | 14 19.39S | 25 00.13W | 25.11 | 36.85 | 0.108 | 156 |
| **51** | 02/10/03 | 12:06 | 16 09.25S | 24 59.37W | 24.86 | 37.18 | 0.116 | 156 |
| **52** | 03/10/03 | 02:57 | 19 02.27S | 25 00.12W | 24.27 | 37.00 | 0.120 | 150 |
| **53** | 03/10/03 | 04:31 | 19 02.02S | 25 00.04W | 24.29 | 37.02 | 0.113 | 148 |
| **54** | 03/10/03 | 12:03 | 20 14.65S | 25 00.16W | 23.92 | 36.99 | 0.116 | 155 |
| **55** | 04/10/03 | 03:02 | 22 40.83S | 25 00.14W | 22.96 | 36.80 | 0.120 | 133 |
| **56** | 04/10/03 | 04:40 | 22 40.83S | 25 00.14W | 22.89 | 36.81 | 0.106 | 137 |
| **57** | 04/10/03 | 12:02 | 23 54.39S | 24 59.89W | 22.03 | 36.63 | 0.120 | 142 |
| **58** | 05/10/03 | 03:03 | 26 39.05S | 24 59.96W | 20.70 | 36.37 | 0.123 | 120 |
| **59** | 05/10/03 | 04:38 | 26 38.79S | 25 00.45W | 20.69 | 36.38 | 0.122 | 115 |
| **60** | 05/10/03 | 12:02 | 27 55.00S | 24 59.72W | 19.86 | 36.15 | 0.128 | 150 |
| **61** | 06/10/03 | 03:21 | 29 57.10S | 27 19.52W | 19.23 | 35.94 | 0.117 | 137 |
| **62** | 06/10/03 | 04:57 | 29 57.03S | 27 19.26W | 19.13 | 35.94 | 0.114 | 150 |
| **63** | 06/10/03 | 12:07 | 30 52.00S | 28 26.23W | 18.47 | 35.84 | 0.110 | 130 |
| **64** | 07/10/03 | 03:00 | 32 52.35S | 30 54.35W | 18.26 | 35.87 | 0.112 | 118 |
| **65** | 07/10/03 | 04:40 | 32 52.90S | 30 56.36W | 18.25 | 35.88 | 0.115 | 118 |
| **66** | 07/10/03 | 12:06 | 33 48.60S | 32 04.25W | 16.86 | 35.67 | 0.138 | 70 |
| **67** | 08/10/03 | 03:10 | 35 37.18S | 34 20.82W | 15.66 | 35.61 | 0.291 | No max |
| **68** | 08/10/03 | 04:46 | 35 37.17S | 34 21.24W | 15.58 | 35.62 | 0.281 | No max |

| CTD # | Date | Time (GMT) | Lat. | Long. | TSG temp | TSG sal | TSG chl | Chl max depth |
|---|---|---|---|---|---|---|---|---|
| **69** | 08/10/03 | 12:02 | 36 23.69S | 35 20.31W | 15.06 | 35.60 | 0.282 | No max |
| **70** | 09/10/03 | 04:08 | 38 28.44S | 38 05.88W | 14.01 | 35.36 | 0.317 | No max |
| **71** | 09/10/03 | 05:46 | 38 28.84S | 38 06.90W | 14.05 | 35.35 | 0.317 | No max |
| **72** | 09/10/03 | 12:59 | 39 23.16S | 39 19.71W | 15.71 | 35.77 | 0.222 | No max |
| **73** | 10/10/03 | 04:00 | 41 10.11S | 41 44.44W | 13.29 | 35.28 | 0.294 | No max |
| **74** | 10/10/03 | 05:30 | 41 09.27S | 41 42.81W | 13.25 | 35.28 | 0.299 | No max |
| **75** | 10/10/03 | 13:02 | 41 53.63S | 42 44.67W | 13.53 | 35.35 | 0.225 | No max |
| **76** | 11/10/03 | 07:02 | 43 58.56S | 45 43.47W | 9.11 | 34.39 | 0.362 | No max |
| **77** | 11/10/03 | 13:04 | 44 33.81S | 46 35.21W | 9.08 | 34.40 | 0.275 | No max |
| **78** | 12/10/03 | 13:07 | 47 46.02S | 51 25.83W | 6.50 | 34.03 | 0.217 | 38 |

# Appendix 2: Estimated Time of Sunrise and Sunset for predicted positions during AMT13

| Date | Sunrise (GMT) | Sunset (GMT) |
|---|---|---|
| 13th September 2003 | - | 18:48 |
| 14th September 2003 | 06:17 | 19:11 |
| 15th September 2003 | 06:43 | 19:31 |
| 16th September 2003 | 07:00 | 19:26 |
| 17th September 2003 | 07:02 | 19:30 |
| 18th September 2003 | 07:08 | 19:43 |
| 19th September 2003 | 07:18 | 19:26 |
| 20th September 2003 | 07:11 | 19:24 |
| 21st September 2003 | 07:12 | 19:22 |
| 22nd September 2003 | 07:12 | 19:18 |
| 23rd September 2003 | 07:09 | 19:12 |
| 24th September 2003 | 07:01 | 19:06 |
| 25th September 2003 | 07:14 | 19:20 |
| 26th September 2003 | 07:15 | 19:26 |
| 27th September 2003 | 07:22 | 19:32 |
| 28th September 2003 | 07:27 | 19:34 |
| 29th September 2003 | 07:27 | 19:35 |
| 30th September 2003 | 07:26 | 19:35 |
| 1st October 2003 | 07:24 | 19:36 |
| 2nd October 2003 | 07:22 | 19:37 |
| 3rd October 2003 | 07:21 | 19:39 |
| 4th October 2003 | 07:16 | 19:42 |
| 5th October 2003 | 07:18 | 19:53 |
| 6th October 2003 | 07:22 | 20:00 |
| 7th October 2003 | 07:32 | 20:19 |
| 8th October 2003 | 07:42 | 20:36 |
| 9th October 2003 | 07:56 | 20:53 |
| 10th October 2003 | 08:05 | 21:16 |

**Very many thanks to Mike Golding (2nd Officer) for these estimations.**

# Appendix 3 : Sampling requirements

| Monster Dawn Cast | (to 1000 m) (0200) | | | | |
|---|---|---|---|---|---|
| | | | | | |
| **Bottle** | **Depth** | **Volume** | **Water Requirements (litres)** | **Required** | **Excess** |
| 1 | Surface 97% | 20 | Sandy (20) every other day alternates with FRRF nutrient addition expts | 20 | 0 |
| 2 | Surface 97% | 20 | Nick (20) | 20 | 0 |
| 3 | Surface 97% | 20 | Nick (10), Sandy POC (5), Alex (5) | 20 | 0 |
| 4 | Surface 97% | 20 | Paul H (20) | 20 | 0 |
| 5 | Chl max | 20 | Eva (20) alternates day 1 Sandy 1000m, day 2 Eva chl max | 20 | 0 |
| 6 | Surface 97% / Chl max | 20 | Angelica (20) alternates surface and chl max | 20 | 0 |
| 7 | Surface 97% / Chl max | 20 | Angelica (20) alternates surface and chl max | 20 | 0 |
| 8 | Surface 97% / Chl max | 20 | Angelica (10) alternates surface and chl max | 10 | 10 |
| 9 | 10 m 55% | 20 | Darren (20) | 20 | 0 |
| 10 | 25m fixed depth | 20 | Sandy POC (5) every other day | 5 | 15 |
| 11 | 25m fixed depth | 20 | Sandy (20) every other day | 20 | 0 |
| 12 | ~ 30m 14% | 20 | Nick (20) | 20 | 0 |
| 13 | ~ 30m 14% | 20 | Nick (10) | 10 | 10 |
| 14 | 100m (Chla max) | 20 | Darren (20) | 20 | 0 |
| 15 | 100m fixed depth | 20 | Sandy (20) every other day alternates with Howard size fractionated 15N at chl max | 20 | 0 |
| 16 | 100m fixed depth | 20 | Sandy POC (5) every other day Alex (5) Chl max | 10 | 10 |
| 17 | 200m fixed depth | 20 | Sandy (20) every other day | 20 | 0 |
| 18 | 200m fixed depth | 20 | Sandy POC (5) every other day | 5 | 15 |
| 19 | 300m fixed depth | 20 | Sandy (20) every other day | 20 | 0 |
| 20 | 300 m fixed depth | 20 | Sandy POC (5) every other day | 5 | 15 |
| 21 | 500m fixed depth | 20 | Sandy (20) every other day | 20 | 0 |
| 22 | 500m fixed depth | 20 | Niki oxygen (0.5), nutrients (0.8), Andy Hind DIC (0.8), Sandy POC (5) | 7.1 | 12.9 |
| 23 | 1000m / 10m | 20 | Sandy (20) / Jenna (20) alternate days | 20 | 0 |
| 24 | 1000m fixed depth | 20 | Niki oxygen (0.5), nutrients (0.8), Andy Hind DIC (0.8), FRRF (1), Sandy POC (5) | 8.1 | 11.9 |

| **Pre-dawn (0300) Cast to 300m** | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| **Bottle** | **Hypothetical Depth** | **Volume** | **Water Requirements (litres)** | **Required** | **Excess** |
| 1 | Surface 97% | 20 | Grant (2.5), Tom (1), Nuts (0.8), Andy Hind (0.8), Nick (2), Elena (1), Mike Z (1), Glen (0.25), Zackary (0.5), Paul H (1) | 10.85 | 9.15 |
| 2 | 10 m 55% | 20 | Chla (0.5), HPLC (8.5), Lugols SOC (0.4), Mike Z (4), Elena (1), UKHORS (0.5), Zackary (0.5), Paul H (1) | 16.6 | 3.4 |
| 3 | 10m 55% | 20 | Oxygen (8), Jenna R (10), Nick M (2 ) | 20 | 0 |
| 4 | 10 m 55% | 20 | Grant (2.5), Nuts (0.8), 15N (12), Particle abs (4.5), | 19.8 | 0.2 |
| 5 | 10 m 55% | 20 | Tom (1), DOC (1), Alex P (4), Andy H (0.8), Glen (0.25), Zackary (6.0), Alex POC/N (4.2) | 17.25 | 2.75 |
| 6 | 25 m 33% | 20 | Oxygen (6), Jenna (0.1), HPLC (8.5), Chla (0.5) Alex P (4), Andy Hind (0.8) | 19.9 | 0.1 |
| 7 | 25 m 33% | 20 | Nuts (0.8), 15N (12), Lugols SOC (0.4), Nick M (2), Elena (1), Zackary (0.5), Paul H (1) | 17.9 | 2.1 |
| 8 | 25 m 33% | 20 | Grant (2.5), Tom (1), DOC (1), Particle abs (4.5), Mike Z (1), Glen (0.25), Alex POC/N (4.2) | 14.45 | 5.55 |
| 9 | 35m | 20 | Mike Z (3) | 4.5 | 15.5 |
| 10 | 50 m 14% | 20 | Oxygen (6), Jenna (0.1), HPLC (8.5), Chla (0.5) Alex P (4), Andy Hind (0.8) | 19.9 | 0.1 |
| 11 | 50 m 14% | 20 | Nuts (0.8), 15N (12), Lugols SOC (0.4), Nick M (2), Elena (1), Zackary (0.5), Paul H (1) | 17.9 | 2.1 |
| 12 | 50 m 14% | 20 | Grant (2.5), Tom (1), DOC (1), Particle abs (4.5), Mike Z (1), Glen (0.25), Alex POC/N (4.2) | 14.45 | 5.55 |
| 13 | 80m, Upslope Chlor Max | 20 | Grant (2.5), Tom (1), Nuts (0.8), Chla (0.5), Andy Hind (0.8), Elena (1), Mike Z (1), Glen (0.25), Zackary (0.5), Paul H (1) | 9.35 | 10.65 |
| 14 | 100 m (Fmax, 1 %) | 20 | Oxygen (7), HPLC (8.5), Chla (0.5), Alex P (4) | 20 | 0 |
| 15 | 100 m (Fmax, 1 % ) | 20 | Jenna R (10), Elena (1), Mike Z (4), Paul H (1) | 16 | 4 |
| 16 | 100 m (Fmax, 1 % ) | 20 | Nuts (0.8), 15N (12), Nick M (2), Lugols SOC (0.4), Zackary (0.5) | 15.9 | 4.1 |
| 17 | 100 m (Fmax, 1 % ) | 20 | Grant (2.5), Tom (1), DOC (1), Particle abs (4.5), Andy H (0.8), Glen (0.25), Alex POC/N (4.2) | 14.25 | 5.75 |
| 18 | 120m, Downslope Chlor Max | 20 | Grant (2.5), Tom (1), Nuts (0.8), Chla (0.5), Andy Hind (0.8), Elena (1), Mike Z (1), Glen (0.25), Zackary (0.5), Paul H (1) | 9.35 | 10.65 |
| 19 | 150 m (0.1% ) | 20 | Oxygen (6), Jenna (0.1), HPLC (8.5), Alex P (4), Paul H (1) | 19.6 | 0.4 |
| 20 | 150 m (0.1% ) | 20 | 15N (12), Lugols SOC (0.4), Mike Z (1), UKHORS (0.5), particle abs (4.5), Chla (0.5) | 18.9 | 1.1 |
| 21 | 150 m (0.1% ) | 20 | Grant (2.5), Tom (1), Nuts (0.8), DOC (1), Andy Hind (0.8), Elena (1), Glen (0.25), Zackary (0.5), Alex POC/N (4.2) | 12.05 | 7.95 |
| 22 | 175 m | 20 | Grant (2.5), Tom (1), Oxygen (4), Nuts (0.8), Chla (0.5), Andy Hind (0.8), Elena (1), Mike Z (1), Glen (0.25), Zackary (0.5), Paul H (1) | 13.35 | 6.65 |
| 23 | 200 m | 20 | Grant (2.5), Tom (1), Oxygen (0.5), Nuts (0.8), Chla (0.5), Andy Hind (0.8), Elena (1), Mike Z (1), Glen (0.25), Zackary (0.5) | 8.85 | 11.15 |
| 24 | 300 m | 20 | Grant (2.5), Tom (1), Oxygen (4), Jenna (0.1), Nuts (0.8), Chla (0.5), Andy Hind (0.8), Elena (1), UKHORS (0.5), Mike Z (1), Glen (0.25), Zackary (0.5), Paul H (1) | 13.95 | 6.05 |

| Mid-morning CTD (1030/1100 am) to 300 m at same time as Optics cast x 2 (plus rocket as come onto station) | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| **Bottle** | **Hypothetical Depth** | **Volume** | **Water Requirements (litres)** | **Required** | **Excess** |
| 1 | Surface 97% | 20 | Oxygen (0.5), Nuts (0.8), Andy Hind (0.8), Chris/Alex chl (0.25), Carole L (1), Tom (1), Mike Z (1), Glen (0.25), Zackary (0.5), Jenna (0.1) | 6.1 | 13.9 |
| 2 | 10 m 55% | 20 | Oxygen (0.5), Nuts (0.8), DOC/DON (1), Andy Hind (0.8), Chris/Alex HPLC (5), Carole L (1), Chris (4), Mike Z (1), Glen (0.25), Zackary (0.5), PvsE 14C/FRRF Alex (2), Jenna (0.1) | 16.85 | 3.15 |
| 3 | 20m | 20 | Nuts (0.8), Glen (0.25), Jenna (0.1) | 1.05 | 18.95 |
| 4 | 25 m 33% | 20 | Oxygen (0.5), Nuts (0.8), DOC/DON (1), Andy Hind (0.8), Carole L (1), Mike Z (1), UKORS (0.5), Glen (0.25), Zackary (0.5) | 6.35 | 13.65 |
| 5 | 30m | 20 | Nuts (0.8), Glen (0.25), Jenna (0.1) | 1.05 | 18.95 |
| 6 | 40m | 20 | Nuts (0.8), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 3.35 | 16.65 |
| 7 | 50 m 14% | 20 | Oxygen (0.5), Nuts (0.8), DOC/DON (1), Andy Hind (0.8), Carole L (1), Chris/Alex HPLC (5), Chris (4), Mike Z (1), Glen (0.25), Zackary (0.5), Jenna (0.1) | 14.85 | 5.15 |
| 8 | 60m | 20 | Nuts (0.8), Glen (0.25) | 1.05 | 18.95 |
| 9 | 70m | 20 | Nuts (0.8), Glen (0.25), Jenna (0.1) | 1.05 | 18.95 |
| 10 | 80 m | 20 | Oxygen (0.5), Nuts (0.8), Andy Hind (0.8), Carole L (1), Mike Z (1), Glen (0.25), Zackary (0.5) | 4.85 | 15.15 |
| 11 | 90m | 20 | Nuts (0.8), Glen (0.25), Jenna (0.1) | 1.05 | 18.95 |
| 12 | 100 m (Chl max) 1% | 20 | Elena (20) EVERY THIRD DAY | 20 | 0 |
| 13 | 100 m (Chl max) 1% | 20 | Elena (20) EVERY THIRD DAY | 20 | 0 |
| 14 | 100 m (Chl max) 1% | 20 | Elena (20) EVERY THIRD DAY | 20 | 0 |
| 15 | 100 m (chla max) 1% | 20 | Oxygen (0.5), Nuts (0.8), DOC/DON (1), Andy Hind (0.8), Carole L (1), Chris/Alex chl (5), Chris (4), UKORS (0.5), Mike Z (1), Glen (0.25), Zackary (0.5), PvsE 14C/FRRF Alex (2), Jenna (0.1) | 17.35 | 2.65 |
| 16 | 120 m | 20 | Oxygen (0.5), Nuts (0.8), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 3.85 | 16.15 |
| 17 | 150 m 0.1% | 20 | Oxygen (0.5), Nuts (0.8), DOC/DON (1), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 4.85 | 15.15 |
| 18 | 175 m | 20 | Nuts (0.8), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 3.35 | 16.65 |
| 19 | 200 m | 20 | Oxygen (0.5), Nuts (0.8), Andy Hind (0.8), UKHORS (0.5), Mike Z (1), Glen (0.25), Zackary (0.5), Chris (0.25) | 4.6 | 15.4 |
| 20 | 225 m | 20 | Nuts (0.8), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 3.35 | 16.65 |
| 21 | 250 m | 20 | Oxygen (0.5), Nuts (0.8), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 3.85 | 16.15 |
| 22 | 275 m | 20 | Oxygen (0.5), Nuts (0.8), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 3.85 | 16.15 |
| 23 | 300 m | 20 | Oxygen (0.5), Nuts (0.8), Andy Hind (0.8), Mike Z (1), Glen (0.25), Zackary (0.5) | 3.85 | 16.15 |
| 24 | | | | | |

# Nets

## Pre-dawn (during CTDs ~ 02.00am)

| | |
|---|---|
| **1 haul 50 µm mesh 0-250 m** | **Sandy Thomalla** |
| **1 haul Bongo net** | **Paul Hampton** |
| **2 hauls with triple net of 30 µm mesh from below chl max** | **Eva Lopez** |
| **2 hauls with bongo nets of 200 µm and 50 µm down to 200-0 and 50-0** | **Elena San Martin** |

## Late morning (during CTD ~ 11.30 am)

| | |
|---|---|
| **1 haul with single net of 200 µm down to 100-0m** | **Elena San Martin** |

## Underway sampling

### Continuous from non-toxic seawater supply

| | |
|---|---|
| **pCO2** | **Andy Hind** |
| **N2O / CH4** | **Hester** |
| **50 µm phytoplankton** | **Alex** |
| **Cytobuoy** | **Glen** |
| **Cytosense** | **Mike Z** |

### Continual from non-toxic seawater supply

| | | |
|---|---|---|
| **Ammonia / pH** | **Malcolm / Andy Hind** | **3pm** |
| **Alkalinity / salinity** | **Andy Hind / Andrew Dickson** | **3pm and 7pm** |
| **DMS** | **Tom** | **3pm** |
| **TChl 0.25l to calibrate fluorometer** | **Mark Stinchcombe** | **3:00 AM** |
| **Salinity to calibrate TSG** | **Jon Short** | **Once per day at 3pm to calibrate (Tom)** |
| **Eva 20 l every day** | **Eva** | **Before the nets** |
| **Picoplankton diurnal cycle** | **Mike, Glen, Bernhard** | **Every hour between 3pm and 3 am** |
| **Heterotrophic Nanoflagellates (HNF)** | **Angie** | **Every two hours to coincide with 3pm** |
| **CDOM** | **Jenna** | **3pm and 7pm (collected by Andy Hind)** |

**Continuous over side deployment**

| | | |
|---|---|---|
| **MVP** | **towed between stations possible watch system** | **Malcolm Woodward** |

**Continuous atmospheric sampling**

| | |
|---|---|
| **Air samplers located on monkey island** | **Alex Baker** |

# Appendix 4 : Work schedules

| WORK SCHEDULES AMT13 | | | | | | | WORK | | REST | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Elena** | **Nick** | **Malcolm** | **Hester** | **Paul** | **Alex** | **Mark** | **Howard** | **Sandy** | **Tom** | **Jenna** |
| MIDNIGHT | | | | | | day1/3 day 2 | day 1/3 day 2 | | | | |
| 01:00 | | | | | | | | | | | |
| 02:00 | | | | | | | | | | | |
| 03:00 | | | | | | | | | | | |
| 04:00 | | | | | | | | | | | |
| 05:00 | | | | | | | | | | | |
| 06:00 | | | | | | | | | | | |
| 07:00 | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** |
| 08:00 | | | | | | | | | | | |
| 09:00 | | | | | | | | | | | |
| 10:00 | | | | | | | | | | | |
| 11:00 | | | | | | | | | | | |
| 12:00 | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** |
| 13:00 | | | | | | | | | | | |
| 14:00 | | | | | | | | | | | |
| 15:00 | | | | | | | | | | | |
| 16:00 | | | | | | | | | | | |
| 17:00 | | | | | | | | | | | |
| 18:00 | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** |
| 19:00 | | | | | | | | | | | |
| 20:00 | | | | | | | | | | | |
| 21:00 | | | | | | | | | | | |
| 22:00 | | | | | | | | | | | |
| 23:00 | | | | | | | | | | | |

| WORK SCHEDULES AMT13 | | | | | | | | WORK | | REST | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Niki** | **Sam** | **Chris** | **Glen** | **Mike** | **Bernhard** | **Zackary** | **Grant** | **Eva** | **Angelica** | **Andy** | **Alex B.** | **Carol** |
| MIDNIGHT | | | | | | | | | | | | | |
| 01:00 | | | | | | | | | | | | | |
| 02:00 | | | | | | | | | | | | | |
| 03:00 | | | | | | | | | | | | | |
| 04:00 | | | | | | | | | | | | | |
| 05:00 | | | | | | | | | | | | | |
| 06:00 | | | | | | | | | | | | | |
| 07:00 | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** | ***Breakfast*** |
| 08:00 | | | | | | | | | | | | | |
| 09:00 | | | | | | | | | | | | | |
| 10:00 | | | | | | | | | | | | | |
| 11:00 | | | | | | | | | | | | | |
| 12:00 | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** | ***Lunch*** |
| 13:00 | | | | | | | | | | | | | |
| 14:00 | | | | | | | | | | | | | |
| 15:00 | | | | | | | | | | | | | |
| 16:00 | | | | | | | | | | | | | |
| 17:00 | | | | | | | | | | | | | |
| 18:00 | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** | ***Dinner*** |
| 19:00 | | | | | | | | | | | | | |
| 20:00 | | | | | | | | | | | | | |
| 21:00 | | | | | | | | | | | | | |
| 22:00 | | | | | | | | | | | | | |
| 23:00 | | | | | | | | | | | | | |

# Appendix 5 : Underway sampling

| Date | Time | Lat | Long | Salinity | Sal. Cal. | Chl | Chl Cal | Temp | Stemp | PAR | Nut | CDOM | Alk | AD | LHC | DMS | AFC | scs | pic | Angie |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14/09/2003 | 1400 | 47.78999 | 12.33438 | 35.5991 | | 0.205 | | 18.47 | 18.5 | 1461.905 | y | | y | y | y | | | | y | |
| 14/09/2003 | 1825 | 47.51339 | 13.50716 | 35.6213 | | 0.212 | | 18.02 | 18.39 | 101.7316 | | | y | y | | | | | | |
| 15/09/2003 | 500 | 47.00242 | 15.68859 | 35.5766 | | 0.216 | | | | | | | y | | | | | | | |
| 15/09/2003 | 1400 | 46.49601 | 17.80828 | 35.7044 | #161 | 0.19 | | | 18.53 | 722.29 | y | | y | y | y | | | | y | |
| 15/09/2003 | 1830 | 46.19585 | 19.05206 | 35.7376 | | 0.241 | | | | | | | y | y | | | | | | |
| 16/09/2003 | 0830 | 43.70594 | 19.52269 | 35.8202 | | 0.176 | | | | | | | y | y | | | | | | |
| 16/09/2003 | 1500 | 42.2953 | 19.4124 | 35.763 | #162 | 0.171 | | 21.28 | 20.31 | 1364.069 | y | | y | y | y | | | | y | |
| 16/09/2003 | 1930 | 41.47891 | 19.83798 | | | 0.148 | | | | | | | y | y | | | | | | |
| 17/09/2003 | 0300 | 40.0283 | 20.0096 | 36.1 | | 0.152 | | | 21.56 | | | | | | | | | | | y |
| 17/09/2003 | 0525 | 40.0283 | 20.0809 | 36.1 | | 0.195 | | | 22 | | | | | | | | | | | y |
| 17/09/2003 | 0904 | 39.3823 | 21.0443 | 36.17 | | 0.148 | | | 22.8 | | | | | | | | | | | y |
| 17/09/2003 | 1100 | 39.2603 | 21.3267 | 36.21 | | 0.148 | | | 23.03 | | | | | | | | | | | y |
| 17/09/2003 | 1300 | 39.2051 | 21.4865 | 36.26 | | 0.143 | | | 23.41 | | | | | | | | | | | y |
| 17/09/2003 | 1500 | 39.13452 | 22.3223 | 36.2688 | #163 | 0.149 | | 23.7 | 23.5 | 1622.944 | y | | y | y | y | | | | y | |
| 17/09/2003 | 1513 | 39.0649 | 22.2315 | 36.3 | | 0.15 | | | 23.67 | | | | | | | | | | | y |
| 17/09/2003 | 1710 | 38.508 | 22.543 | 36.58 | | 0.147 | | | 24.5 | | | | | | | | | | | y |
| 17/09/2003 | 1910 | 38.4102 | 23.2886 | 36.55 | | 0.142 | | | 24.3 | | | | | | | | | | | y |
| 18/09/2003 | 0106 | 38.1007 | 24.4199 | 36.15 | | 0.145 | | | 23.45 | | | | | | | | | | | y |
| 18/09/2003 | 0215 | 38.08393 | 24.7619 | 36.1994 | | 0.147 | | | | | | | y | y | | | | | | |
| 18/09/2003 | 0302 | 37.5624 | 24.5665 | 36.11 | | 0.147 | | | 23.34 | | | | | | | | | | | y |
| 18/09/2003 | 0732 | 37.426 | 25.3757 | 36.14 | | 0.23 | | | 22.58 | | | | | | | | | | | y |
| 18/09/2003 | 0900 | 37.58977 | 25.61357 | 36.3234 | | 0.156 | | | | | | | y | y | | | | | | |
| 18/09/2003 | 1104 | 37.1737 | 25.1274 | 36.33 | | 0.152 | | | 23.95 | | | | | | | | | | | y |
| 18/09/2003 | 1318 | 36.5869 | 24.4504 | 36.26 | | 0.143 | | | 24.04 | | | | | | | | | | | y |
| 18/09/2003 | 1500 | 36.6692 | 24.50654 | 36.3711 | | 0.146 | | 23.18 | 24.67 | 1754.113 | | | y | y | y | | | | | |
| 18/09/2003 | 1511 | 36.63792 | 24.48622 | 36.416 | #164 | 0.146 | | 23.17 | 24.89 | 1780.519 | | y | | | | | | | | |
| 18/09/2003 | 1704 | 36.1714 | 24.1319 | 36.48 | | 0.147 | | | 24.97 | | | | | | | | | | | y |
| 18/09/2003 | 1901 | 35.5548 | 23.5595 | 36.52 | | 0.149 | | | 25.24 | | | | | | | | | | | y |
| 18/09/2003 | 1930 | 35.83737 | 23.86615 | 36.5609 | | 0.143 | | 23.38 | 25.24 | 18.18182 | | | y | y | | | | | | |

| Date | Time | Lat | Long | Salinity | Sal. Cal. | Chl | Chl Cal | Temp | Stemp | PAR | Nut | CDOM | Alk | AD | LHC | DMS | AFC | scs | pic | Angie |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19/09/2003 | 0308 | 34.6282 | 22.9915 | 36.56 | | 0.154 | | | 25.15 | | | | | | | | | | | y |
| 19/09/2003 | 0504 | 34.62 | 22.929 | 36.56 | | 0.14 | | | 25.2 | | | | | | | | | | | y |
| 19/09/2003 | 0710 | 34.2029 | 22.638 | 36.43 | | 0.146 | | | 25.1 | | | | | | | | | | | y |
| 19/09/2003 | 0930 | 33.7672 | 22.30623 | 36.8135 | | 0.132 | | 24.02 | 25.19 | 971.645 | | | y | y | | | | | | |
| 19/09/2003 | 1104 | 34.4945 | 22.1096 | 36.84 | | 0.136 | | | 25.22 | | | | | | | | | | | y |
| 19/09/2003 | 1258 | 33.3062 | 21.9576 | 36.75 | | 0.125 | | | 25.38 | | | | | | | | | | | y |
| 19/09/2003 | 1500 | 32.92783 | 21.68238 | 36.7218 | #167 | 0.134 | | 23.74 | 25.13 | 495.0216 | y | | y | y | y | | | | y | |
| 19/09/2003 | 1500 | 32.9307 | 21.6823 | 36.75 | | 0.137 | | | 25.16 | | | | | | | | | | | y |
| 19/09/2003 | 1729 | 32.4793 | 21.3441 | 37.01 | | 0.146 | | | 25.28 | | | | | | | | | | | y |
| 19/09/2003 | 1910 | 32.1654 | 21.1236 | 37.02 | | 0.135 | | | 25.06 | | | | | | | | | | | y |
| 19/09/2003 | 1930 | 32.10254 | 21.08361 | 37.0674 | | 0.134 | | 23.08 | 25.05 | 8.874499 | | | y | y | | | | | | |
| 20/09/2003 | 0300 | 30.7541 | 20.9554 | 37.18 | | 0.127 | | | 25.14 | | | | | | | | | | | y |
| 20/09/2003 | 0630 | 30.29825 | 20.93713 | 37.0608 | | 0.135 | | 24.06 | 24.97 | 2.380952 | | | y | y | | | | | | |
| 20/09/2003 | 0908 | 29.7406 | 20.9122 | | | 0.099 | | | 25.04 | | | | | | | | | | | y |
| 20/09/2003 | 1102 | 29.3545 | 20.8954 | 37.14 | | 0.134 | | | 25.28 | | | | | | | | | | | y |
| 20/09/2003 | 1301 | 29.1681 | 20.8868 | 37.14 | | 0.124 | | | 25.5 | | | | | | | | | | | y |
| 20/09/2003 | 1500 | 28.74 | 20.87 | 37.2088 | | 0.129 | | 24.88 | 25.61 | 1850.9 | | | y | y | y | | | | | |
| 20/09/2003 | 1510 | 28.71226 | 20.87326 | 37.219 | #4 | 0.123 | | 24.86 | 25.79 | 1797.9 | y | | | | | | | | | |
| 20/09/2003 | 1718 | 28.2542 | 20.84643 | 37.245 | | 0.128 | | 24.89 | 25.86 | | | | | | | | | | | y |
| 20/09/2003 | 1930 | 27.782 | 20.832 | 37.0838 | | 0.137 | | 24.55 | 25.7 | 5.884 | | | y | y | | | | | | |
| 21/09/2003 | 1000 | 25.287 | 20.75 | 37.1259 | | 0.129 | | 24.51 | 25.22 | 1283.117 | | | y | y | | | | | | |
| 21/09/2003 | 1310 | 24.853 | 20.756 | 37.09 | | 0.124 | | | 25.14 | | | | | | | | | | | y |
| 21/09/2003 | 1500 | 24.471 | 20.716 | 37.09 | #7 | 0.123 | | 24.69 | 25.18 | 1856.71 | | | y | y | y | | | | | |
| 21/09/2003 | 1510 | 24.433 | 20.714 | 37.09 | | 0.13 | | 24.63 | 25.04 | | | | | | | | | | | y |
| 21/09/2003 | 1900 | 23.62 | 20.682 | 36.99 | | 0.139 | | 24.76 | 25.16 | | | | | | | | | | | y |
| 21/09/2003 | 1930 | 23.517 | 20.677 | 37.0162 | | 0.134 | | 24.75 | 25.23 | 4.54 | | | y | y | | | | | | |
| 22/09/2003 | 0715 | 21.587 | 20.614 | 36.15 | | 0.212 | | 23.96 | 24.01 | | | | | | | | | | | y |
| 22/09/2003 | 0830 | 21.321 | 20.601 | 36.1646 | | 0.222 | | 24.35 | 25.29 | 315.15 | | | y | y | | | | | | y |
| 22/09/2003 | 0900 | | | | | | HPLC | | | | | | | | | | | | | |
| 22/09/2003 | 1056 | 20.808 | 20.583 | 36.188 | | 0.21 | | 24.81 | 25.6 | | | | | | | | | | | y |
| 22/09/2003 | 1300 | 20.81482 | 20.51937 | 36.18 | | 0.197 | HPLC | 25.09 | 25.62 | 1856 | | | | | | | | | | y |
| 22/09/2003 | 1500 | 20.752 | 20.244 | 36.1888 | #19 | 0.247 | HPLC | 24.92 | 25.69 | 1469 | y | y | y | y | y | y | | | | |

| Date | Time | Lat | Long | Salinity | Sal. Cal. | Chl | Chl Cal | Temp | Stemp | PAR | Nut | CDOM | Alk | AD | LHC | DMS | AFC | scs | pic | Angie |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22/09/2003 | 1700 | | | | | | HPLC | | | | | | | | | | | | | |
| 22/09/2003 | 1708 | 20.72 | 19.96 | 36.2 | | 0.275 | | 24.74 | 25.78 | | | | | | | | | | | y |
| 22/09/2003 | 1930 | 20.689 | 19.577 | 36.2255 | | 0.214 | | 19.58 | 25.88 | 3.03 | | | y | y | | | | | | |
| 22/09/2003 | 2100 | | | | | | HPLC | | | | y | y | | | | y | | | | |
| 22/09/2003 | 2200 | | | | | | | | | | y | | | | | | | | | |
| 22/09/2003 | 2300 | | | | | | HPLC | | | | y | y | y | | | y | | | | |
| 23/09/2003 | 0000 | | | | | | | | | | y | | | | | | | | | |
| 23/09/2003 | 0100 | | | | | | HPLC | | | | y | y | y | | | y | | | | |
| 23/09/2003 | 0800 | 20.397 | 17.869 | 35.8519 | | 0.538 | | 24.18 | 22.44 | | | | y | y | | | | | | |
| 23/09/2003 | 0900 | | | | | | HPLC | | | | | | | | | | | | | |
| 23/09/2003 | 1158 | | | | | | | | | | | | y | | | | | | | |
| 23/09/2003 | 1503 | 20.11588 | 17.98448 | 36.1152 | #8 | 0.164 | | 26.15 | 27.39 | 1699.4 | | y | y | y 50 | | y | | | | |
| 23/09/2003 | 1700 | 19.816 | 18.26 | 36.1492 | | 0.156 | | 27.44 | 27.8 | 912.99 | y | y | y | | | y | | | | y |
| 23/09/2003 | 1930 | 19.34 | 18.593 | 36.1438 | | 0.146 | | 26.79 | 27.85 | 2.6 | | | y | y 57 | | | | | | |
| 23/09/2003 | 2105 | | | | | HPLC | | | | | y | y | y | | | y | | | | |
| 23/09/2003 | 2212 | 18.88402 | 18.37119 | | | | | | | | y | | | | | | | | | |
| 23/09/2003 | 2300 | | | | | HPLC | | | | | y | y | y | | | y | | | | |
| 24/09/2003 | 0000 | | | | | | | | | | y | | | | | | | | | |
| 24/09/2003 | 0102 | | | | | HPLC | | | | | y | y | y | | | y | | | | |
| 24/09/2003 | 0700 | 17.746 | 18.529 | 35.898 | | 0.159 | | 25.5 | 27.76 | 3.03 | | | y | y 55 | | | | | | |
| 25/09/2003 | 1501 | 12.2859 | 21.0674 | 35.14 | | 0.162 | | 28.17 | 28.68 | | | | y | y 59 | | | | | | |
| 25/09/2003 | 1930 | 11.407 | 21.336 | 35.865 | | 0.135 | | 27.81 | 28.3 | | | | y | y 60 | | | | | | |
| 26/09/2003 | 0831 | 9.452 | 21.982 | 35.506 | | 0.148 | | 27.17 | 28.37 | | | | y | y 61 | | | | | | |
| 26/09/2003 | 1500 | 8.465 | 22.13 | 35.645 | | 0.126 | | 28.13 | 28.64 | | | | | | y | | | | | |
| 27/09/2003 | 0600 | 6.03 | 23.087 | 34.879 | | 0.126 | | 26.38 | 28.71 | | | | | y 62 | | | | | | |
| 27/09/2003 | 1240 | | | | | HPLC | | | | | | | | | | | | | | |
| 27/09/2003 | 1400 | 4.699 | 23.509 | 33.727 | | 0.146 | | 24.41 | 28.15 | 191.99 | | | | y 63 | | | | | | |
| 27/09/2003 | 1600 | 4.298 | 23.636 | 33.884 | | 0.148 | | 24.15 | 28.01 | 49 | | | y | y | y | y | | | | |
| 27/09/2003 | 2000 | | | | | | | | | | | | y | y 65 | | | | | | |
| 28/09/2003 | 0600 | 2.079 | 24.342 | 35.638 | | 0.125 | | 26.26 | 27.59 | 2.38 | | | | y 66 | | | | | | |
| 28/09/2003 | 1100 | 1.073 | 24.66 | 35.82 | | 0.131 | | 26.28 | 26.82 | | | | | y 67 | | | | | | |
| 29/09/2003 | 1600 | 4.423 | 25 | 36.093 | | 0.123 | | 25.73 | 26.04 | | y | | y | y 68 | y | y | | | | |

| Date | Time | Lat | Long | Salinity | Sal. Cal. | Chl | Chl Cal | Temp | Stemp | PAR | Nut | CDOM | Alk | AD | LHC | DMS | AFC | scs | pic | Angie |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30/09/2003 | 0700 | | | | | | | | | | | | | y | | | | | | |
| 30/09/2003 | 1100 | 7.645 | 25 | 36.134 | | 0.125 | | 25.43 | 26.14 | | | | y | | | | | | | |
| 30/09/2003 | 1600 | 8.418 | 24.999 | 36.215 | | 0.119 | | 25.48 | 26.15 | | | | y | y 71 | y | y | | | | |
| 30/09/2003 | 2000 | 9.244 | 25.001 | 36.138 | | 0.117 | | 25.3 | 25.91 | 2.38 | | | | y 72 | | | | | | |
| 01/10/2003 | 0800 | 11.146 | 24.998 | 36.29 | | 0.111 | | 24.83 | 25.7 | 151.94 | | | y | y 74 | | | | | | |
| 01/10/2003 | 1600 | 12.52 | 25 | 36.651 | | 0.109 | | 24.93 | 25.47 | 1743 | | | y | y 75 | y | y | | | | |
| 01/10/2003 | 1606 | | | 36.6323 | #136 | | | | | | | | | | | | | | | |
| 02/10/2003 | 1501 | 16.55 | 25 | 37.16 | | 0.111 | | 23.72 | | | | | | | | | | | | y |
| 02/10/2003 | 1600 | 16.76 | 24.99 | 37.1577 | #140 | 0.111 | | 23.82 | | 1622.9 | y | | | y79 | y | y | | | | |
| 02/10/2003 | 1904 | 17.41 | 24.99 | 37.158 | | 0.114 | | 24.32 | | | | | | | | | | | | y |
| 03/10/2003 | 0347 | 19.03 | 25 | 37.016 | | 0.114 | | 22.82 | | | | | | | | | | | | y |
| 03/10/2003 | 0600 | 19.14 | 25 | 37.086 | | 0.138 | | 22.7 | 24.19 | 1.94 | | | | y80 | | | | | | |
| 03/10/2003 | 1000 | 19.89 | 25 | 36.9632 | | 0.122 | | 22.88 | 23.84 | 1232.68 | | | | y81 | | | | | | |
| 03/10/2003 | 1301 | 20.24 | 25 | 36.99 | | 0.111 | | 23.17 | 24.37 | | | | | | | | | | | y |
| 03/10/2003 | 1600 | 20.72 | 25 | 36.954 | #141 | 0.112 | | 22.79 | 24.62 | 1909.1 | | y | y | y82 | y | y | | | | |
| 03/10/2003 | 1920 | 21.32 | 24.99 | 36.97 | | 0.119 | | 23.06 | 24.35 | | | | | | | | | | | y |
| 03/10/2003 | 1930 | 21.539 | 25 | 36.92 | | 0.45 | | 22.5 | 23.97 | 1.73 | | | | y83 | | | | | | |
| 03/10/2003 | 2100 | 21.69 | 25 | 36.93 | | 0.123 | | 22.51 | 23.79 | | | | | | | | | | | y |
| 04/10/2003 | 0354 | 22.68 | 25.01 | 36.81 | | 0.107 | | 20.91 | 22.94 | | | | | | | | | | | y |
| 04/10/2003 | 0600 | 22.77 | 25 | 36.81 | | 0.111 | | 20.72 | 22.99 | 1.298 | | | | y84 | | | | | | |
| 04/10/2003 | 1019 | 23.59 | 25 | 36.64 | | 0.115 | | 19.47 | 22.18 | | | | | | | | | | | y |
| 04/10/2003 | 1600 | 24.47 | 25 | 36.596 | #144 | 0.111 | | 20 | 21.77 | 987.8 | | | | y85 | y | y | | | | |
| 04/10/2003 | 1608 | 24.49 | 25 | 36.61 | | 0.112 | | 20 | 21.77 | | | | | | | | | | | y |
| 04/10/2003 | 1800 | 26.86 | 24.99 | 36.57 | | 0.117 | | 19.68 | 21.66 | 10.6 | | | | y86 | | | | | | |
| 04/10/2003 | 1951 | 25.23 | 24.99 | 36.49 | | 0.12 | | 19.29 | 21.32 | | | | | | | | | | | y |
| 04/10/2003 | 2000 | 25.26 | 24.99 | 36.451 | | 0.119 | | 19.24 | 21.29 | 1.73 | | | | y87 | | | | | | |
| 05/10/2003 | 0353 | 25.65 | 25 | 36.37 | | 0.122 | | 17.91 | 20.73 | | | | | | | | | | | y |
| 05/10/2003 | 0600 | 26.71 | 25 | 36.36 | | 0.208 | | 17.76 | 20.79 | 1.29 | | | | y88 | | | | | | |
| 05/10/2003 | 0854 | 27.31 | 25 | 36.2 | | 0.123 | | 18.03 | 20.16 | | | | | | | | | | | y |
| 05/10/2003 | 1000 | 27.52 | 24.99 | 36.22 | | 0.127 | | 17.91 | 20.3 | 1396.3 | | | | y89 | | | | | | |
| 05/10/2003 | 1355 | 28.02 | 25.02 | 36.18 | | 0.111 | | 17.77 | 19.95 | | | | | | | | | | | y |
| 05/10/2003 | 1400 | 28.03 | 25.04 | 36.159 | | 0.114 | | 17.97 | 19.92 | 2120 | | | | y90 | | | | | | |

| Date | Time | Lat | Long | Salinity | Sal. Cal. | Chl | Chl Cal | Temp | Stemp | PAR | Nut | CDOM | Alk | AD | LHC | DMS | AFC | scs | pic | Angie |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 05/10/2003 | 1600 | 28.335 | 25.399 | 36.2026 | #128 | 0.113 | | 17.54 | 20.24 | 1687 | | | y | y91 | y | y | | | | y |
| 05/10/2003 | 1827 | 28.7 | 25.83 | 36.93 | | 0.115 | | 17.41 | 19.07 | | | | | | | | | | | y |
| 05/10/2003 | 2000 | 28.93 | 26.11 | 35.77 | | 0.117 | | 17 | 18.33 | 2.59 | | | | y92 | | | | | | |
| 05/10/2003 | 2114 | 29.11 | 26.32 | 35.93 | | 0.115 | | 17.08 | 19.15 | | | | | | | | | | | y |
| 06/10/2003 | 0346 | 29.95 | 27.32 | 35.93 | | 0.116 | | 17.38 | 18.97 | | | | | | | | | | | y |
| 06/10/2003 | 0500 | 29.95 | 27.32 | 35.94 | | 0.113 | | 17.29 | 19.14 | 1.08 | | | | y93 | | | | | | |
| 06/10/2003 | 1347 | 30.97 | 28.55 | 35.83 | | 0.108 | | 17.97 | 18.57 | | | | | | | | | | | y |
| 06/10/2003 | 1410 | 31.02 | 28.62 | 35.85 | | 0.104 | | 18.09 | 18.68 | 1788 | | | | y94 | | | | | | |
| 06/10/2003 | 1600 | 31.29 | 28.95 | 35.93 | #146 | 0.108 | | 18.14 | 18.91 | 1825 | | | | | y | y | | | | y |
| 06/10/2003 | 1808 | 31.59 | 29.32 | 35.95 | | 0.114 | | 18.33 | 18.96 | | | | | | | | | | | y |
| 06/10/2003 | 1910 | 31.74 | 25.5 | 35.94 | | 0.115 | | 18.2 | 18.87 | 170.7 | | | | y95 | | | | | | |
| 06/10/2003 | 2022 | 31.91 | 29.72 | 35.92 | | 0.118 | | 18.16 | 18.63 | | | | | | | | | | | y |
| 07/10/2003 | 0353 | 32.87 | 30.91 | 35.87 | | 0.113 | | 17.78 | 18.25 | | | | | | | | | | | y |
| 07/10/2003 | 0600 | 32.93 | 30.98 | 35.82 | | 0.122 | | 17.68 | 18.09 | 1.29 | | | | y96 | | | | | | |
| 07/10/2003 | 0853 | 33.68 | 31.5 | 35.79 | | 0.12 | | 17.54 | 17.75 | | | | | | | | | | | y |
| 07/10/2003 | 1308 | 33.8 | 32.07 | 35.68 | | 0.135 | | 17.13 | 16.88 | | | | | | | | | | | y |
| 07/10/2003 | 1400 | 33.93 | 32.21 | 35.65 | | 0.161 | | 16.96 | 16.67 | 682 | | | | y97 | | | | | | |
| 07/10/2003 | 1557 | 34.21 | 32.56 | 34.64 | #148 | 0.258 | | 16.74 | 16.1 | 331.17 | | | | y98 | y | y | | | | y |
| 07/10/2003 | 1800 | 34.5 | 32.92 | 33.64 | | 0.29 | | 16.43 | 16.2 | 162.5 | | | y | | | | | | | |
| 07/10/2003 | 1933 | 34.7 | 33.19 | 35.6 | | 0.332 | | 13.39 | 16.19 | | | | | | | | | | | y |
| 07/10/2003 | 2030 | 34.82 | 33.34 | 35.6 | | 0.268 | | 13.45 | 16.26 | 2.38 | | | | y99 | | | | | | |
| 08/10/2003 | 0348 | 35.61 | 34.34 | 35.6 | | 0.258 | | 13.73 | 15.61 | | | | | | | | | | | y |
| 08/10/2003 | 0600 | 35.61 | 34.34 | 35.63 | | 0.266 | | 14.17 | 15.43 | 0.649 | | | | y100 | | | | | | |
| 08/10/2003 | 0911 | 36.04 | 34.87 | 35.67 | | 0.292 | | 14.29 | 15.61 | | | | | | | | | | | y |
| 08/10/2003 | 1351 | 36.5 | 35.47 | 35.61 | | 0.238 | | 15.71 | 15.23 | | | | | | | | | | | y |
| 08/10/2003 | 1415 | 36.55 | 35.54 | 35.57 | | 0.274 | | 15.39 | 15.14 | 0.274 | | | | y101 | | | | | | |
| 08/10/2003 | 1600 | 36.79 | 35.87 | 35.56 | #147 | 0.272 | | 15.66 | 15.14 | 0.851 | | | | y102 | y | y | | | | |
| 08/10/2003 | 1653 | 36.9 | 36.03 | 35.58 | | 0.273 | | 15.59 | 15.06 | | | | | | | | | | | y |
| 08/10/2003 | 1928 | 37.29 | 36.51 | 35.65 | | 0.237 | | 15.49 | 15.29 | 116 | | | | y103 | | | | | | |
| 09/10/2003 | 0506 | 38.47 | 38.1 | 35.35 | | 0.31 | | 15.06 | 14.03 | | | | | | | | | | | y |
| 09/10/2003 | 0710 | 38.55 | 38.22 | 35.44 | | 0.247 | | 14.98 | 14.42 | 1.08 | | | | y104 | | | | | | |
| 09/10/2003 | 0935 | 38.91 | 38.68 | 35.63 | | 0.218 | | 15.4 | 15.2 | | | | | | | | | | | y |

| Date | Time | Lat | Long | Salinity | Sal. Cal. | Chl | Chl Cal | Temp | Stemp | PAR | Nut | CDOM | Alk | AD | LHC | DMS | AFC | scs | pic | Angie |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 09/10/2003 | 1110 | 39.14 | 39 | 35.62 | | 0.212 | | 15.58 | 15.04 | 487 | | | | y105 | | | | | | |
| 09/10/2003 | 1617 | 39.73 | 39.77 | 35.65 | | 0.279 | | 12.66 | 15.38 | | | | | | | | | | | y |
| 09/10/2003 | 1700 | 39.82 | 39.9 | 35.61 | #149 | 0.248 | | 13.77 | 15.1 | 256 | | | | y106 | | y | | | | |
| 09/10/2003 | 2017 | 40.25 | 40.47 | 35.6 | | 0.315 | | 13.98 | 15.22 | | | | | | | | | | | |
| 09/10/2003 | 2030 | 40.28 | 40.51 | 35.7 | | 0.273 | | 14.05 | 15.35 | 48.91 | | | | y107 | | | | | | |
| 10/10/2003 | 0700 | 41.21 | 41.78 | 35.23 | | 0.287 | | 8.55 | 13.03 | | | | | y108 | | | | | | |
| 10/10/2003 | 1520 | 42.02 | 42.94 | 35.12 | | 0.253 | | 7.75 | 12.84 | 1958 | | | | y109 | | | | | | |
| 10/10/2003 | 1845 | 42.43 | 43.52 | 34.45 | | 0.292 | | 7.31 | 10.14 | 891 | | | | y110 | | | | | | |
| 10/10/2003 | 2045 | 42.67 | 43.88 | 34.47 | | 0.466 | | 6.93 | 10.17 | 82.4 | | | | y111 | | | | | | |
| 10/10/2003 | 2300 | 42.95 | 44.26 | 34.46 | | 0.458 | | 6.68 | 10.09 | -0.64 | | | | y112 | | | | | | |
| 11/10/2003 | 0915 | 44.07 | 45.87 | 34.4 | | 0.344 | | 6.72 | 8.94 | 215 | | | | y113 | | | | | | |
| 11/10/2003 | 1130 | 44.5 | 46.5 | 34.46 | | 0.257 | | 6.55 | 9.18 | 1217 | | | | y114 | | | | | | |
| 11/10/2003 | 1525 | 44.74 | 46.84 | 34.41 | | 0.266 | | 6.8 | 9.22 | 1909 | | | | y115 | | | | | | |
| 11/10/2003 | 2200 | 45.65 | 48.19 | 34.4 | | 0.596 | | 6.38 | 9.2 | -0.6 | | | | y116 | | | | | | |
| 12/10/2003 | 1302 | 47.76 | 51.42 | 34.03 | | 0.215 | | 5.59 | 6.54 | 964 | | | | y117 | | | | | | |
| 12/10/2003 | 1455 | 47.89 | 51.6 | 34.06 | | 0.198 | | 6.05 | 6.7 | 1730 | | | | y118 | | | | | | |
| 12/10/2003 | 1655 | 48.18 | 52.05 | 34.6 | | 0.217 | | 6.51 | 9.22 | 1560 | | | | y119 | | | | | | |
| 12/10/2003 | 1750 | 48.32 | 52.26 | 34.51 | | 0.213 | | 7.35 | 8.86 | 1357 | | | | y120 | | | | | | |

# Appendix 6: Optics deployment log

P = Pre dawn cast
M = Mid day cast

AC9 Filtered = with 0.2 microm filters
= no optics profiles taken, CTD FRRF data normally available

| CTD # | Date [sdy] | Time | Depth [m] | FRRF optics | FRRF ctd | AC9 | CTD | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | 257 | P | 100 | v | | Filtered | v | |
| | 257 | P | 100 | v | | Unfiltered | v | |
| 2 | | | | | | | | No FRRF data from main CTD frame |
| 3 | 257 | M | 70 | v | | Filtered | v | |
| | 257 | M | 40 | v | | Unfiltered | v | |
| 4 | | | | | | | | No FRRF data from main CTD frame |
| 5 | | | | | | | | No FRRF data from main CTD frame |
| 6 | 258 | M | 100 | v | | Unfiltered | v | |
| 7 | 259 | P | 150 | v | | *Failed* | v | CTD wire sheered, filters lost |
| 8 | 259 | M | 100 | v | | Unfiltered | v | |
| 9 | | | | | v | | | |
| 10 | | | | | v | | | |
| 11 | 260 | M | 100 | v | | *Failed* | v | |
| 12 | | | | | v | | | |
| 13 | | | | | v | | | |
| 14 | | | | | | | | |
| 15 | | | | | v | | | |
| 16 | 262 | M | 150 | v | | Unfiltered | v | |
| 17 | 263 | P | 150 | v | | *Failed* | v | CTD not turned on, use from previous cast |
| | 263 | P | 100 | v | | Filtered | *Failed* | |
| 18 | 263 | P | 100 | v | v | Unfiltered | v | FRRF pressure sensor on CTD broken |
| 19 | 263 | M | 100 | v | | Filtered | v | |
| | 263 | M | 100 | v | | Unfiltered | v | TRIOS sensor removed |
| 20 | | | | | | | | No FRRF data from main CTD frame |
| 21 | | | | | | | | No FRRF data from main CTD frame |
| 22 | 264 | M | 120 | v | | *Failed* | v | VSF worked |

| CTD # | Date [sdy] | Time | Depth [m] | FRRF | | AC9 | CTD | Comments |
|---|---|---|---|---|---|---|---|---|
| 23 | 265 | P | 70 | v | | Unfiltered | v | |
| 24 | | | | | | | | No FRRF data from main CTD frame |
| 25 | 265 | M | 80 | v | v | Unfiltered | v | FRRF pressure sensor on CTD replaced |
| 26 | 266 | P | 70 | v | | *Failed* | v | |
| 27 | | | | | v | | | |
| 28 | 266 | M | 80 | v | | *Failed* | v | Gain changed on FRRF from 1 to 64 |
| 29 | 267 | P | 100 | *Failed* | | *Failed* | v | Programming error on FRRF |
| 30 | | | | | | | | |
| 31 | 267 | M | 100 | v | v | *Failed* | v | |
| 32 | 268 | M | 100 | v | v | *Failed* | v | |
| 33 | 269 | P | 100 | v | | Unfiltered | v | |
| 34 | | | | | v | | | |
| 35 | 269 | M | 100 | v | | *Failed* | v | |
| 36 | 270 | P | 100 | v | | *Failed* | v | |
| 37 | | | | | v | | | |
| 38 | 270 | M | 140 | v | v | Unfiltered | v | |
| 39 | 271 | P | 150 | v | | Unfiltered | v | |
| 40 | | | | | v | | | |
| 41 | 271 | M | 100 | v | v | *Failed* | v | |
| 42 | 272 | M | 140 | v | v | *Failed* | v | |
| 43 | 273 | P | 150 | v | | *Failed* | v | |
| 44 | | | | | v | | | |
| 45 | 273 | M | 120 | v | | Unfiltered | v | |
| 46 | 274 | P | 130 | v | | *Failed* | v | |
| 47 | | | | | v | | | |
| 48 | 274 | M | 180 | v | v | *Failed* | v | |
| 49 | 275 | P | 200 | v | | *Failed* | v | |
| 50 | | | | | v | | | |
| 51 | 275 | M | 200 | v | | Unfiltered | v | |
| 52 | 276 | P | 200 | v | | *Failed* | v | |
| 53 | | | | | v | | | |
| 54 | 276 | M | 200 | v | | *Failed* | v | |

| CTD # | Date [sdy] | Time | Depth [m] | FRRF | | AC9 | CTD | Comments |
|---|---|---|---|---|---|---|---|---|
| 55 | | | | | | | | No CTD FRRF cast either |
| 56 | | | | | v | | | |
| 57 | 277 | M | 200 | *Failed* | v | Unfiltered | v | FRRF file corrupted |
| 58 | 278 | P | 200 | v | | Filtered | v | |
| | 278 | P | 200 | v | | Unfiltered | v | |
| 59 | | | | | v | | | |
| 60 | 278 | M | 170 | v | v | Filtered | v | |
| | 278 | M | 170 | v | | *Failed* | v | |
| 61 | 279 | P | 200 | *Failed* | | Filtered | v | |
| | 279 | P | 200 | *Failed* | | Unfiltered | v | |
| 62 | | | | | v | | | |
| 63 | 279 | M | 150 | v | v | *Failed* | v | |
| 64 | 280 | P | 160 | *Failed* | | *Failed* | v | |
| 65 | | | | | v | | | |
| 66 | 280 | M | 100 | v | v | Filtered | v | |
| | 280 | M | 100 | v | | Unfiltered | v | |
| 67 | | | | | | | | No optics casts due to weather |
| 68 | | | | | v | | | |
| 69 | | | | | v | | | |
| 70 | 282 | P | 100 | v | | Filtered | v | Filters fell off during profile |
| 71 | | | | | | | | No optics casts due to weather |
| 72 | 282 | M | 100 | v | | Unfiltered | v | |
| 73 | 283 | P | 60 | *Failed* | | Unfiltered | v | |
| 74 | | | | | v | | | |
| 75 | 283 | M | 50 | *Failed* | v | *Failed* | v | Flat battery? |
| 76 | 284 | P | 60 | v | | Filtered | v | |
| | 284 | P | 60 | v | | Unfiltered | v | |
| 77 | 284 | M | 60 | *Failed* | | Filtered | v | |
| | 284 | M | 60 | *Failed* | | Unfiltered | v | |
| 78 | 285 | M | 100 | *Failed* | v | Filtered | v | |
| | 285 | M | 100 | *Failed* | | Unfiltered | v | |

**Dawn on 6 October 2003 at 29°S 27°W**