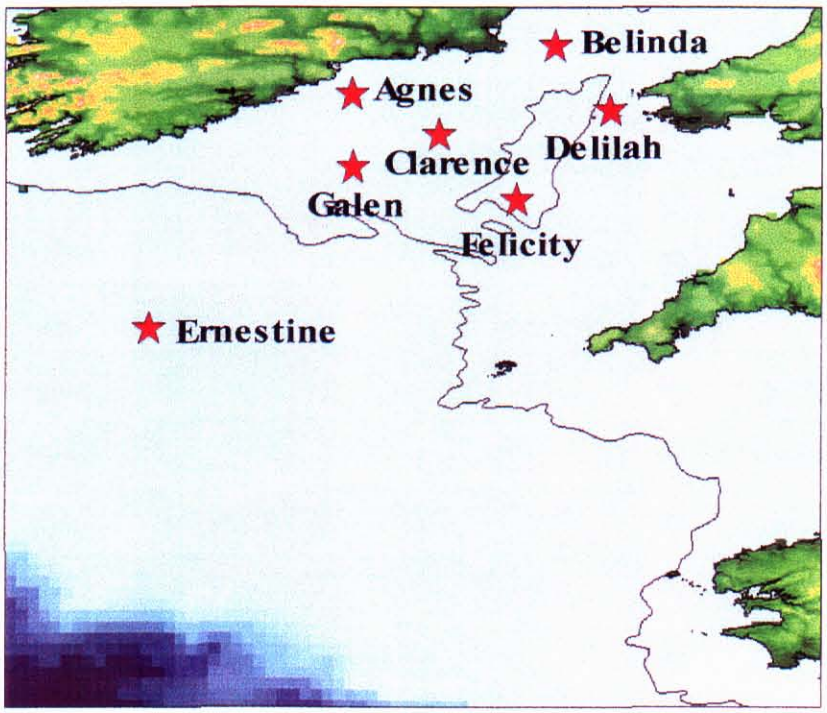
RRS DISCOVERY Cruise 246 Report

Production and Physical Interactions in the Euphotic Zone

PROPHEZE

Dynamics of Marine Ecosystems (DYME) CS Research Programme



15th - 30th May 2000

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Executive Summary

PROPHEZE was an integrated, multidisciplinary study of the interactions between physical processes and biological production in contrasting pelagic shelf waters. These interactions are required for subsequent ecosystem modelling. Specific objectives of PROPHEZE were a) to quantify light fields, turbulence, vertical advection and diffusion in waters of contrasting physical status; b) to study the community structure and biogeochemical function of pelagic populations of phytoplankton, bacteria and protozoa in relation to physical and other ambient environmental conditions; c) to relate remote sensing to pelagic community structure and function; and d) to model the interactions of physical forcing and the dynamics of pelagic production and test control mechanisms.

The objectives were met by working at seven stations, whose physical and biological characteristics varied, in the Celtic Sea. These stations were each occupied for ca 24h. The water column at Clarence, Ernestine, Felicity and Galen was stratified, while at Agnes it was partially stratified and Belinda it was well mixed. Delilah was situated on the Celtic Sea front. Tidal currents were strong at Belinda and Delilah and weak at the other stations. Nutrient concentrations were lowest at Galen (<0.01μM NO_3, <0.02 nM Fe^{++}) and highest at Delilah (4 μM NO_3, 10nM Fe^{++}). Phytoplankton populations varied with a healthy mixed bloom of diatoms (*Nitzschia*) and dinoflagellates (*Scripsiella*) exhibiting primary production rates of ca 370 mgC m^{-2} d^{-1} at Galen. The population at Ernestine was reaching post-bloom condition and comprised small dinoflagellates and some large diatoms (*Rhizosolenia*). The primary production there was 330 mgC m^{-2} d^{-1}. Production was lowest (110 mgC m^{-2} d^{-1}) at Agnes where nutrients were low (<0.1 μM NO_3) and so was the photosynthetic potential/efficiency. The range of physical, chemical and biological conditions are being analysed after the cruise to quantify the interactions between physical processes and biological production in contrasting pelagic shelf waters.

An important goal of the cruise was to map the tidal front situated in the St George's Channel using pre-operational model simulations to plan the ship's track for UOR tows, CTD profiles and station selection. Three Acoustic Doppler Current Profilers (ADCPs) were deployed (two at Belinda and 1 at Clarence).

This research involved 28 scientists and technicians from 14 separate institutions situated in 5 countries. The study formed part of CCMS' Core Strategic Research Programmes of the *Dynamics of Marine Ecosystems* (DYME) and the EC MAST AIMS *project (Automated Identification and Characterisation of Microbial Populations* MAS3-CT97-0080). PROPHEZE was funded principally by NERC through Core Strategic and Responsive Mode Grant and by the EU through MAST.

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1 BACKGROUND

PROPHEZE was mounted to tackle objectives within two complementary research programmes: the first of these was one of CCMS' Core Strategic Research Programmes and the second, a project in one of the EU MAST programmes.

CCMS' Core Strategic Research Programme on *Dynamics of Marine Ecosystems (DYME)* has a central aim to "understand the mechanisms controlling biological production, particularly those mechanisms involving biological-physical interactions". To address this, the response of microbial populations to a range of different physical forcing was selected for study in PROHEZE. The physical forcing fields ranged from a highly stratified region in the central Celtic Sea through to the dynamic, well-mixed region of the tidal front that extends across the St George's Channel.

Within the EU MAST AIMS (Automated Identification and Characterisation of Microbial Populations MAS3-CT97-0080) project, procedures had been developed for characterising microbial populations and their intrinsic (C, N, chl-a) cellular properties in the laboratory and within mesocosms. PROPHEZE allowed these procedures involving novel techniques, including molecular probes to algal and bacterial taxa, flow cytometric protocols for *in-situ* analyses, neural-net applications for algae and bacteria and the characterisation of algal optical and physiological properties, to be addressed and verified at sea.

PROPHEZE also addressed physical processes central to DYME. These included microscale turbulence in contrasting regimes and the dynamics of fronts. The cruise addressed the controls of biological production in algal, bacterial and protozoa populations in waters of contrasting physical forcing. The data generated will be used in models of biological, physical and biophysical dynamics within DYME.

2 AIM and OBJECTIVES

PROPHEZE's aim was to quantify the interactions between physical processes and biological production in contrasting pelagic shelf waters. These interactions are required for subsequent modelling. Specific objectives of PROPHEZE were:

1) to quantify light fields, turbulence, vertical advection and diffusion in waters of contrasting physical status;
2) to study the community structure and biogeochemical function of pelagic populations of phytoplankton, bacteria and protozoa in relation to physical and other ambient environmental conditions;
3) to relate remote sensing to pelagic community structure and function;
4) after the cruise, to model the interactions of physical forcing and the dynamics of pelagic production and test control mechanisms.

MODUS OPERANDI

The objectives were tackled by a multidisciplinary team of 28 physical, chemical and biological oceanographers as well as a specialist in neural net development. The team comprised scientists drawn from 14 institutions situated in Canada, Ireland, Netherlands, Spain as well as eight institutions in the UK (see Section 3).

The cruise involved two legs, with a change of 3 personnel, and while the science carried out on each was similar, priorities and the main focus varied between the legs. On Leg 1, the main focus was to map the tidal front of the St George's Channel and work stations in, or adjacent to, the front. This included the deployment of ADCP instruments on the seabed. On Leg 2, the focus was given to the microbial biogeochemistry in stations situated away from the front as well as the recovery of one ADCP instrument.

ACHIEVEMENTS

All cruise objectives were accomplished including

1) mapping the tidal front of St George's Channel,
2) deploying three ADCP's and the recovery of one of these, as planned.
3) 574 profiles of turbulence microstructure were made throughout the cruise;
4) 11 UOR tows were completed covering 677 miles to survey the physical optical and biological structure of the Celtic Sea;
5) 72 CTD casts were made during the cruise focussing on seven major stations;
6) measurement of water column chemistry (nitrate, nitrite, ammonia, silicate, phosphate, iron and oxygen) worked well:
7) a wide range of biological measurements were made with a primary focus of phytoplankton (taxonomy, pigments, flow cytometry, molecular probes, physiology and absorption) and their dynamics (primary production, O_2 respiration and production);
8) a wide range of measurements were made on bacteria and protozoa and their dynamic properties (herbivory and production).

A preliminary summary of the results is shown in Table 2.1

	Agnes	*Belinda*	*Clarence*	*Delilah*	*Ernestine*	*Felicity*	*Galen*
Physics							
stratification	partial	mixed	Strong – 2°C top - bottom	on front	stratified internal waves with 20m amplitude	stratified (salinity)	stratified
currents	weak	strong (>1m s^{-1})		strong currents	weak	weak	weak
Chemistry							
NO_3 (μM)	<0.1	4	0.5	4	<0.05		0.01
NH_3 (μM)	<0.1	2	1	4	<0.25		<0.1
Fe^{++} (nM)	5-60	3-10	5-60	3-10			<0.02
Biology							
AFC (clusters)	4	3	5				
taxonomy			dinos		"post bloom" diatoms coccolitho-phores		"healthy" diatoms dinos
fl efficiency	low		high				
bacter prod	high	high	Lowest	low			
primary production ($mgCm^{-2}d^{-1}$)	110	288	174	136	330		370

Fig 2.1. Surface mixed layer properties at each station; preliminary data deduced on-board ship.

3 PERSONNEL

a) Scientists

Person	Responsibility	Legs
Peter Burkill (CCMS/PML)[1]	Chief Scientist	1&2
John Howarth (CCMS/POL)[2]	Deputy Chief Scientist: Physical oceanography - turbulence, ADCP	1&2
Roger Procter (CCMS/POL)[2]	Physical oceanography and modelling	1
John Humphery (CCMS/POL)[2]	Physical oceanography ADCP	1
Andy Vile (CCMS/POL)[2]	Physical oceanography	1&2
Chris MacKay (Sytech, Canada)[3]	Turbulence	1&2
Jim Aiken (CCMS/PML)[1]	Optics and FRRF	1&2
Tim Smyth (CCMS/PML)[1]	Optics – Bulk	1&2
Andy Rees (CCMS/PML)[1]	Nutrients – nanomolar and urea	1&2
John Stephens (CCMS/PML) [1]	Nutrients – autoanalysis	1&2
Toby Holland (UoP)[4]	Iron chemistry	1&2
Denise Cummings (CCMS/PML)[1]	HPLC/POC/nutrients	1&2
Richard Geider (Essex)[5]	Phytoplankton physiology; particulate absorption	1&2
Katherine Woods (SOC/CCMS)[1,6]	Primary production	1&2
Glen Tarran (CCMS/PML)[1]	Flow cytometry (Logistics)	1&2
Richard Jonker (Amsterdam, NL)[7]	CytoBuoy and CytoWave	1&2
Tracy Anning (MBA)[8]	Molecular probes	1&2
Mike Zubkov (CCMS/PML)[1]	Bacterial community	1&2
Andreas Reul (Malaga, ES)[9]	Microbial community	1&2
Elaine Fileman (CCMS/PML)[1]	Microzooplankton	1&2
Jason Mallard (UoL)[10]	Protozoa and fine-resolution sampling	1&2
Linda Gilpin (Napier)[11]	Oxygen respiration and production	1&2
Georgina McDermott (Galway, Ir)[12]	Irish Observer – phytoplankton	1&2
Malcolm Wilkins (Cardiff)[13]	Neural nets	2
Andy Jones (RVS)[14]	Electronics	1&2
Dave Jolly (RVS)[14]	Electronics	1&2
Colin Day (RVS)[14]	Mechanical engineering and Technical Liaison Officer	1&2
Darren Young (RVS)[14]	Mechanical engineering	1&2
Gareth Knight (RVS)[14]	Computing	1&2

Addresses

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12 University College Galway, Department of Oceanography, Galway, Ireland
13 University of Wales, Cardiff, School of Biosciences, Cardiff CF1 3TL
14 Research Vessel Services, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH

b) Ship's Officers and Crew

Name	*Rank*	*Institution*
Robin Plumley	Master	RVS – Marine, UK
Richard Warner	Chief Officer	RVS – Marine, UK
Philip Oldfield	Second Officer	RVS – Marine, UK
Titus Owoso	Third Officer	RVS – Marine, UK
Ian McGill	Chief Engineer	RVS – Marine, UK
Jim Royston	Second Engineer	RVS – Marine, UK
Stuart Cumming	Third Engineer	RVS – Marine, UK
Kevin Wilson	Third Engineer	RVS – Marine, UK
Dave Stewart	ETO	RVS – Marine, UK
Mike Trevaskis	Deck CPO	RVS – Marine, UK
Iain Thomson	Deck PO	RVS – Marine, UK
Philip Allison	Seaman Grade 1A	RVS – Marine, UK
Bob Johnson	Seaman Grade 1A	RVS – Marine, UK
Stuart Cook	Seaman Grade 1A	RVS – Marine, UK
Bob Dickingson	Seaman Grade 1A	RVS – Marine, UK
Mark Moore	Seaman Grade 1A	RVS – Marine, UK
Peter Searle	Motorman	RVS – Marine, UK
Clive Perry	Catering Manager	RVS – Marine, UK
John Haughton	Chef	RVS – Marine, UK
Andy Morton	Mess Steward	RVS – Marine, UK
Jeff Orsborn	Steward	RVS – Marine, UK
Mick Stephen	Steward	RVS – Marine, UK

4 a) Scientific Log of Activities

Date	Time (BST)	Event	Position	Event	Station
Wednesday 10th May		Commence mobilising for cruise D246			
Thursday 11th May		Mobilisation. Scientific party join vessel			
Friday 12th May		Mobilisation			
Saturday 13th May		Mobilisation; some scientific staff join vessel			
Sunday 14th May		Mobilisation; remainder of scientific staff join vessel			
Monday 15th May	0900	Safety briefing for non RVSM personnel			
	1050	Pilot on board			
	1107	Clear of berth			
	1117	Clear of Empress Dock			
	1222	Pilot away			
	1336	Clear of Needles Channel			
	1400-1435	Cruise Planning meeting			
	1448-1506	CTD test	50°28.5'N 01°53.6'W	15/01	
	1536-1640	CTD test	50°26.7'N 02°00.0'W		
	1615-1630	Emergency Drill and Boat Muster			
Tuesday 16th May	0930-1034	Land's End TSS			
	1050-1118	CTD test	50°11.0'N 05°57.6'W	16/01	
	1248	UOR deployed	50°22.2'N 06°06.1'W	16/02	
	1845	UOR recovered	51°10.7'N 06°50.5'W		
	1903-1940	CTD	51°11.0'N 06°50.2'W	16/03	
	1953	UOR deployed	51°11.4'N 06°50.2'W	16/04	
Wednesday 17th May	0200	UOR recovered	51°55.3'N 07°29.5'W		
	0248-0304	CTD	51°59.8'N 07°32.9'W	17/01	
	0403-0440	CTD	51°57.0'N 07°29.1'W	17/02	"Agnes"
	0523-0545	CTD	51°53.0'N 07°23.6'W	17/03	
	0638-0653	CTD	51°49.1'N 07°18.0'W	17/04	
	0758-0811	CTD	51°45.6'N 07°13.1'W	17/05	
	1003-1014	CTD	51°54.9'N 07°02.5'W	17/06	
	1147-1155	CTD	52°02.6'N 06°54.0'W	17/07	
	1252-1311	Optics casts	52°06.2'N 06°50.2'W	17/08-09	
	1321-1345	CTD	52°06.1'N 06°50.1'W	17/10	
	1533-1545	CTD	52°00.1'N 06°40.3'W	17/11	
	1545-1852	Reposition towards ADCP site St. George's Channel			
	1635	XBT	52°01.1'N 06°28.7'W	17/12	
	1700	XBT	52°01.8'N 06°21.2W	17/13	
	1730	XBT	52°02.9'N 06°12.5'W	17/14	
	1800	XBT	52°04.4'N 06°05.0'W	17/15	
	1834	XBT	52°08.2'N 06°56.0'W	17/16	
	1905-1922	CTD	52°10.5'N 05°51.9'W	17/17	
	2000	ADCP D4 deployed	52°10.3'N 05°52.5'W	17/18	"Belinda"
	2008	ADCP D2 deployed	52°10.6'N 05°52.3'W	17/19	"Belinda"
	2020-2045	CTD	52°10.6'N 05°52.3'W	17/20	"Belinda"
Thursday 18th May	0131- 0215	FLY deployments	52°10'N 05°52'W	18/01	
	0440-0506	GoFlo	52°09.5'N 05°52.8'W	18/02	"Belinda"
	0525-0555	CTD	52°09.1'N 05°53.4'W	18/03	"Belinda"
	0700	UOR deployed	52°10.5'N 05°52.6'W	18/04	
	1247	UOR recovered	51°50.0'N 06°19.8'W		
	1306-1321	Optics cast	51°49.7'N 06°19.7'W	18/05	
	1555-1624	CTD	51°45.1'N 06°44.8'W	18/06	

	1640-1646	Plankton net	51°45.0'N 06°45.4'W	18/07	
	1700-1717	MGS	51°45.0'N 06°45.6'W	18/08-09	
	1726	ADCP D1 deployed	51°45.1'N 06°45.7'W	18/10	
	1807-1828	CTD	51°45.4'N 06°46.0'W	18/11	
	1857	FLY deployments	51°45.1'N 06°45.4'W	18/12-15	
	2306	FLY deployments end	51°50.3'N 06°47.0'W		
Friday 19th May	0016-0351	FLY deployments	51°45.5'N 06°46.1'W	19/01	"Clarence"
	0410-0420	GoFlo	51°46.8'N 06°49.9'W	19/02-03	"Clarence"
	0443-0515	CTD	51°46.9'N 06°50.2'W	19/04	"Clarence"
	0606	UOR deployed	51°45.7'N 06°47.0'W	19/05	
	0709	XBT	51°38.6'N 06°36.4'W	19/06	
	0930	XBT	51°40.7'N 06°07.1'W	19/07	
	1206	XBTx2	51°49.8'N 05°43.1'W	19/08-09	
	1215	UOR recovered	51°49.6'N 05°42.0'W		
	1230-1249	Optics cast	51°49.5'N 05°41.6'W	19/10	
	1303-1333	CTD	51°49.4'N 05°41.7'W	19/11	"Delilah"
	1341-1350	Plankton net	51°49.1'N 05°42.1'W	19/12	"Delilah"
	1400-1425	Series of MGS casts	51°48.3'N 05°42.7'W	19/13-15	"Delilah"
	1516-1540	CTD	51°48.9'N 05°42.4'W	19/16	"Delilah"
	1628-1738	FLY profiling	51°49.1'N 05°41.4'W	19/17	"Delilah"
	1746-1807	CTD	51°48.7'N 05°40.4'W	19/18	"Delilah"
	1822-1932	FLY profiler	51°48.4'N 05°40.8'W	19/19	"Delilah"
	2222-	FLY profiler	51°49.3'N 05°41.3'W	19/20	"Delilah"
Saturday 20th May	0320	FLY profiler	51°50.2'N 05°38.2'W	20/01	"Delilah"
	0410-0412	GoFlo	51°50'N 05°38.8'W	20/02	"Delilah"
	0419-0447	CTD	51°48.8'N 05°39.7'W	20/03	"Delilah"
	0605	UOR deployed	51°50.8'N 05°39.2'W	20/04	
	1142	UOR recovered	52°12.8'N 05°51.8'W		
	1325	ADCP D4 recovered		20/05	"Belinda"
	1346-1416	CTD	52°10.0'N 05°52.6'W	20/06	"Belinda"
	1428-1504	Optics series	52°09.0'N 05°53.3'W	20/07-08	"Belinda"
	1508-1515	Plankton net	52°08.5'N 05°54.0'W	20/09	"Belinda"
	1523-1551	MGS series	52°08.0'N 05°55.0'W	20/10-12	"Belinda"
	1747-1800	CTD	52°09.0'N 05°52.8'W	20/13	"Belinda"
	2012-	FLY profiler	52°10.4'N 05°51.4'W	20/14	"Belinda"
Sunday 21st May	0322	FLY profiler	52°10.0'N 05°52.0'W		"Belinda"
	0354-0404	CTD	52°08.1'N 05°56.8'W	21/01	"Belinda"
	0404	Proceed towards Martin's Haven			
	0805	V/l stopped off Martin's Haven			
	0900-0924	Ship's RIB away to shore to disembark two scientists and embark one scientist			
	0933	All secure, v/l holding position for results of scientific planning meeting			
	1147	Proceed towards new work area			
	1302	UOR deployed	51°39.2'N 05°29.0'W	21/02	
	2006	UOR recovered	51°39.0'N 07°22.7'W		
	2045	UOR deployed	51°58.9'N 07°25.8'W	21/03	
Monday 22nd May	0357	UOR recovered	51°30.0'N 07°19.8'W		
	0416-0420	GoFlo	51°30.1'N 07°19.7'W	22/01-02	"Galen"
	0440-0500	CTD	51°30.3'N 07°19.8'W	22/03	"Galen"
	0513-0607	Optics cast	51°30.4'N 07°19.8'W	22/04	"Galen"
	0619-0724	FLY series	51°32.4'N 07°20.6'W	22/05	"Galen"
	0730-0740	CTD	51°32.4'N 07°20.6'W	22/06	"Galen"
	0830-0855	Optics	51°28.8'N 07°19.4'W	22/07	"Galen"
	0920-0935	FLY	51°29.5'N 07°19.0'W	22/08	"Galen"
	1032-1100	Optics/FRRF	51°30.0'N 07°19.5'W	22/09	"Galen"
	1115-1225	FLY	51°30.4'N 07°19.6'W	22/10	"Galen"
	1256-1334	CTD	51°30.8'N 07°19.7'W	22/11	"Galen"
	1345-1428	Optics	51°30.4'N 07°20.1'W	22/12	"Galen"

	1432-1453	Plankton net series	51°30.4'N 07°20.1'W	22/13-14	"Galen"
	1508-1613	MGS series	51°30.5'N 07°19.5'W	22/15-17	"Galen"
	1621-1700	FLY	51°30.0'N 07°20.0'W	22/18	"Galen"
	1703-1725	CTD	51°29.4'N 07°20.5'W	22/19	"Galen"
	1734-1803	Optics	51°29.3'N 07°20.6'W	22/20	"Galen"
	1815-1907	FLY	51°28.9'N 07°20.6'W	22/21	"Galen"
	1911-1922	CTD	51°28.0'N 07°21.5'W	22/22	"Galen"
	1927-1946	Optics	51°28.0'N 07°21.5'W	22/23	"Galen"
	2004	UOR deployed	51°27.0'N 07°21.3'W	22/24	
Tuesday 23rd May	0359	UOR recovered	51°29.7'N 07°19.4'W		
	0419-0430	GoFlo	51°29.5'N 07°19.2'W	23/01-02	"Galen"
	0451-0523	CTD	51°29.0'N 07°19.0'W	23/03	"Galen"
	0558-0639	FLY	51°28.1'N 07°18.6'W	23/04	"Galen"
	0642-0700	CTD	51°27.1'N 07°18.6'W	23/05	"Galen"
	0724-0948	FLY series	51°26.6'N 07°18.2'W	23/06-07	"Galen"
	0955-1012	CTD	51°28.6'N 07°20.7'W	23/08	"Galen"
	1137-1159	FLY	51°29.9'N 07°20.7'W	23/09	"Galen"
	1234-1259	CTD	51°30.0'N 07°21.0'W	23/10	"Galen"
	1310-1321	Plankton net	51°30.1'N 07°21.1'W	23/11	"Galen"
	1336-1407	MGS series	51°30.2'N 07°21.4'W	23/12-14	"Galen"
	1440-1520	FLY	51°30.0'N 07°20.5'W	23/15	"Galen"
	1534-1551	CTD	51°30.2'N 07°22.3'W	23/16	"Galen"
	1604-1623	Optics	51°30.2'N 07°22.6'W	23/17	"Galen"
	1632-1910	FLY series	51°29.9'N 07°22.3'W	23/18-19	"Galen"
	1915-1932	CTD	51°30.4'N 07°21.4'W	23/20	"Galen"
Wednesday 24th May	0404-0413	GoFlo	51°29.9'N 07°20.0'W	24/01-02	"Galen"
	0428-0501	CTD	51°29.8'N 07°20.3'W	24/03	"Galen"
	0531-0618	FLY	51°29.7'N 07°21.3'W	24/04	"Galen"
	0632-0650	CTD	51°29.7'N 07°24.2'W	24/05	"Galen"
	0650-0736	FLY	51°29.7'N 07°24.2'W	24/06	"Galen"
	0830-0906	Optics/FRRF	51°30.3'N 07°20.9'W	24/07	"Galen"
	0915-0924	CTD	51°30.8'N 07°20.9'W	24/08	"Galen"
	0939-1030	FLY	51°30.7'N 07°21.2'W	24/09	"Galen"
	1040-1100	CTD	51°29.9'N 07°23.1'W	24/10	"Galen"
	1115-1142	Optics	51°29.8'N 07°23.3'W	24/11	"Galen"
	1151-1232	FLY	51°30.1'N 07°23.1'W	24/12	"Galen"
	1236-1300	CTD	51°29.5'N 07°24.3'W	24/13	"Galen"
	1311-1347	Optics	51°29.3'N 07°24.7'W	24/14	"Galen"
	1349-1409	Plankton Net	51°29.6'N 07°24.7'W	24/15-16	"Galen"
	1414-1442	MGS series	51°29.7'N 07°24.7'W	24/17-19	"Galen"
	1450-1539	FLY	51°29.9'N 07°24.5'W	24/20	"Galen"
	1559-1615	CTD	51°29.9'N 07°22.4'W	24/21	"Galen"
	1618-1700	FLY	51°29.7'N 07°22.4'W	24/22	"Galen"
	1708-1730	Optics	51°29.7'N 07°20.5'W	24/23	"Galen"
	1752-1838	FLY	51°29.6'N 07°20.2'W	24/24	"Galen"
	1844-1901	CTD	51°28.6'N 07°20.5'W	24/25	"Galen"
	1924	UOR deployed	51°27.1'N 07°23.1'W	24/26	
Thursday 25th May	0416	UOR recovered	50°10.8'N 08°34.9'W		
	0425-0433	GoFlo	50°10.7'N 08°35.4'W	25/01-02	"Ernestine"
	0439-0510	CTD	50°10.7'N 08°35.6'W	25/03	"Ernestine"
	0533-0634	FLY	50°10.9'N 08°36.7'W	25/04	"Ernestine"
	0634-0658	CTD	50°11.0'N 08°38.5'W	25/05	"Ernestine"
	0806-0909	FLY	50°11.9'N 08°37.7'W	25/06	"Ernestine"
	0915-0936	CTD	50°11.9'N 08°37.9'W	25/07	"Ernestine"
	0942-1039	FLY	50°11.6'N 08°38.6'W	25/08	"Ernestine"
	1045-1109	CTD	50°11.2'N 08°40.3'W	25/09	"Ernestine"
	1115-1205	FLY	50°10.8'N 08°40.7'W	25/10	"Ernestine"
	1236-1306	CTD	50°10.0'N 08°39.0'W	25/11	"Ernestine"
	1333-1351	Optics	50°09.6'N 08°38.8'W	25/12	"Ernestine"
	1352-1409	CTD	50°09.4'N 08°39.0'W	25/13	"Ernestine"

	1418-1426	Plankton Net	50°09.2'N 08°39.2'W	25/14	"Ernestine"
	1440-1527	MGS series	50°08.8'N 08°39.5'W	25/15-18	"Ernestine"
	1533-1641	FLY	50°08.6'N 08°39.7'W	25/19	"Ernestine"
	1641-1706	CTD	50°08.1'N 08°42.2'W	25/20	"Ernestine"
	1710-1800	FLY	50°08.0'N 08°42.2'W	25/21	"Ernestine"
	1800-1832	CTD	50°06.9'N 08°42.5'W	25/22	"Ernestine"
	1832-1846	FLY	50°06.5'N 08°42.2'W	25/23	"Ernestine"
	1846-2015	CTD	50°06.3'N 08°42.5'W	25/24	"Ernestine"
	2030-2215	Reposition to Ernestine.			
Friday 26th May	0409-0424	GoFlo	50°10.1'N 08°35.0'W	26/01-02	"Ernestine"
	0430-0501	CTD	50°09.9'N 08°35.5'W	26/03	"Ernestine"
	0656-0720	CTD	50°10.0'N 08°35.0'W	26/04	"Ernestine"
	0809-0824	CTD	50°10.1'N 08°34.9'W	26/05	"Ernestine"
	0921-1021	FLY	50°10.6'N 08°35.1'W	26/06	"Ernestine"
	1030-1051	CTD	50°10.6'N 08°36.7'W	26/07	"Ernestine"
	1056-1200	FLY	50°10.6'N 08°37.0'W	26/08	"Ernestine"
	1240-1307	CTD	50°09.9'N 08°34.5'W	26/09	"Ernestine"
	1321-1401	Optics	50°09.6'N 08°34.7'W	26/10	"Ernestine"
	1403-1410	Plankton net	50°09.2'N 08°34.7'W	26/11	"Ernestine"
	1414-1428	Optics	50°09.1'N 08°34.7'W	26/12	"Ernestine"
	1440-1532	FLY	50°08.9'N 08°34.9'W	26/13	"Ernestine"
	1547-1604	CTD	50°08.7'N 08°37.5'W	26/14	"Ernestine"
	1615-1655	Emergency Drill and Boat Muster			
	1705	UOR deployed	50°08.7'N 08°38.2'W	26/15	
	1944	UOR recovered	50°23.8'N 08°06.5'W		
	2021	UOR deployed	50°25.6'N 08°02.7'W	26/16	
Saturday 27th May	0358	UOR recovered	51°14.0'N 06°23.8'W		
		Unable to reach nominal position due to intense fishing activity			
	0415-0421	GoFlo	51°13.2'N 06°23.2'W	27/01-2	"Felicity"
	0440-0505	CTD	51°12.9'N 06°23.4'W	27/03	"Felicity"
	0531-0629	FLY	51°12.3'N 06°24.0'W	27/04	"Felicity"
	0650-0708	CTD	51°11.8'N 06°23.3'W	27/05	"Felicity"
	0708-0803	FLY	51°11.5'N 06°23.3'W	27/06	"Felicity"
	0845-0855	CTD	51°11.8'N 06°23.7'W	27/07	"Felicity"
	0904-0915	CTD	51°11.6'N 06°23.9'W	27/08	"Felicity"
	0922-1015	FLY	51°11.6'N 06°23.9'W	27/09	"Felicity"
	1028-1048	CTD	51°12.1'N 06°23.3'W	27/10	"Felicity"
	1124-1207	FLY	51°12.7'N 06°23.0'W	27/11	"Felicity"
	1234-1301	CTD	51°12.8'N 06°22.8'W	27/12	"Felicity"
	1312-1343	Optics	51°12.8'N 06°22.4'W	27/13	"Felicity"
	1347-1359	Plankton net	51°13.0'N 06°22.0'W	27/14	"Felicity"
	1408-1447	MGS series	51°13.3'N 06°21.7'W	27/15-17	"Felicity"
	1456-1548	FLY	51°13.4'N 06°21.1'W	27/18	"Felicity"
	1555-1624	Optics	51°12.3'N 06°21.9'W	27/19	"Felicity"
	1637-1725	FLY	51°11.9'N 06°21.8'W	27/20	"Felicity"
	1733-1751	CTD	51°10.9'N 06°22.8'W	27/21	"Felicity"
	1805-1843	FLY	51°10.7'N 06°22.9'W	27/22	"Felicity"
	1854-1912	CTD	51°09.8'N 06°23.8'W	27/23	"Felicity"
	1912-1953	FLY	51°09.7'N 06°23.9'W	27/24	"Felicity"
	1953-2018	CTD	51°08.8'N 06°24.5'W	27/25	"Felicity"
Sunday 28th May	0409-0436	CTD	51°12.1'N 06°27.8'W	28/01	"Felicity"
	0532-0624	FLY	51°11.9'N 06°24.2'W	28/02	"Felicity"
	0630-0648	CTD	51°12.5'N 06°26.2'W	28/03	"Felicity"
	0721-0747	FLY	51°12.5'N 06°22.2'W	28/04	"Felicity"
	0824-0845	CTD	51°12.3'N 06°24.0'W	28/05	"Felicity"
	0854-1000	FLY	51°12.3'N 06°24.7'W	28/06	"Felicity"
	1045-1100	CTD	51°12.6'N 06°22.7'W	28/07	"Felicity"
	1109-1200	FLY	51°12.2'N 06°32.2'W	28/08	"Felicity"
	1234-1300	CTD	51°12.5'N 06°22.5'W	28/09	"Felicity"
	1312-1336	Optics	51°12.6'N 06°22.1'W	28/10	"Felicity"

	1353-1436	FLY	51°12.5'N 06°22.4'W	28/11	"Felicity"
	1449-1503	CTD	51°12.1'N 06°23.5'W	28/12	"Felicity"
	1511-1551	FLY	51°12.1'N 06°23.7'W	28/13	"Felicity"
	1613-1632	CTD	51°11.7'N 06°24.8'W	28/14	"Felicity"
	1632-1704	FLY	51°11.5'N 06°25.0'W	28/15	"Felicity"
	1718	End of science. All secure. Proceed towards Southampton			
	2255-0057	Transit Land's End TSS			
Monday 29th May					
	0900-1020	Debrief Meeting			
	1715	Entering Needles Channel			
	1844	Pilot on board			
	2030	All secure starboard side at 27 Berth, Empress Dock			

Table 4.1. Scientific log of activities

b) Positions of the Principal Stations

The nominal positions and dates of occupancy of the seven principal stations, are given below.

Station	Latitude	Longitude	Dates
Agnes	51° 57'N	07° 29'W	17th May
Belinda	52° 10'N	05° 52'W	17th - 18th and 20th - 21st May
Clarence	51° 47'N	06° 50'W	19th May
Delilah	51° 50'N	05° 40'W	19th - 20th May
Ernestine	50° 10'N	08° 35'W	25th - 26th May
Felicity	51° 12'N	06° 24'W	27th - 28th May
Galen	51° 30'N	07° 20'W	22nd - 24th May

Table 4.2. Positions of the principal stations

5 RESULTS

5.1 Measurements of current profiles (John Howarth, John Humphery and Andy Vile)

Objectives

1) To deploy a 150 kHz and a 1200 kHz Acoustic Doppler Current Profiler (ADCP) at a well mixed site (Belinda) and a 150 kHz ADCP at a stratified site (Clarence).

2) To recover the 1200 kHz ADCP.

Three bottom frames were deployed at two locations. Each frame contained an Acoustic Doppler Current Profiler (ADCP), Bottom Pressure Recorder (BPR) and Minilogger (Temperature). The two 150 kHz ADCPs were set up to sample every 10 minutes, profiling the entire water column in 4 m bins. They were recovered on June 17, after a month, by RV Prince Madog. The 1200 kHz ADCP was set up to continuously record 2 second samples profiling the bottom 10-20 m of the water column in 0.5 m bins, and was successfully recovered after 3 days. The data from all three ADCPs were of good quality.

Deployments were made over the side using the ship's crane fitted with a slip hook which was released when the frame was in the water. There were no problems with the recovery of the frame and its ballast weight which was conducted at slack water.

DEPLOYMENT NUMBER	1
Rig	D4
Type	RDI Workhorse ADCP + BPR
Date/Time Entered Water	17-May-2000 19:59
Location	52° 10.27' N, 5° 52.53' W

Instrument Type	Serial Number	Start Date/Time (BST)
RDI 1200 kHz Workhorse ADCP	0572	14-May-2000 16:00
BPR	445	12-May-2000 15:51
Minilogger	2417	14-May-2000 15:00

Recovery	
Date/Time	: 20-May-2000 12:59
Location	: 52° 10.2' N, 5° 52.5' W
Water Depth	: 93 m

All data were downloaded satisfactorily, and look good. Full analysis to be done in lab.

DEPLOYMENT NUMBER :	2
Rig	D2
Type	50 kHz ADCP + BPR
Date/Time Entered Water	17-May-2000 20:07
Location	52° 10.64' N, 5° 52.27' W

Instrument Type	Serial Number	Start Date/Time (BST)
150 kHz ADCP	1148	14-May-2000 15:00
BPR	444	12-May-2000 16:04
Minilogger	2421	14-May-2000 15:00

DEPLOYMENT NUMBER :	3
Rig	D1
Type	150 kHz ADCP + BPR
Date/Time Entered Water	18-May-2000 17:26
Water Depth	74m
Location	51° 45.07' N, 6° 45.73' W

Instrument Type	Serial Number	Start Date/Time (BST)
150 kHz ADCP	1149	14-May-2000 15:30
BPR	1042	12-May-2000 12:01
Minilogger	2424	14-May-2000 15:30
Minilogger	2419	14-May-2000 14:40

5.2 Turbulence dissipation measurements (John Howarth, Chris MacKay and Andy Vile)

A FLY microstructure profiler was operated at all the main sites except Agnes.

Objectives

1) On the first leg of the cruise to obtain three sets of detailed 13 hour dissipation measurements at a well-mixed site (Belinda), a stratified site (Clarence) and a frontal site (Delilah). The purpose was to study dissipation profiles in a stratified and frontal region (combined with measurements of current profiles and of the density field) to test numerical model predictions.

2) On the second leg the emphasis shifted to combining the dissipation measurements at the three sites (Ernestine, Galen and Felicity) with the biogeochemistry measurements, particularly by the Fast Repetition Rate Fluorometer, to obtain a better understanding of the surface layer and mixing across the thermocline.

The system consisted of a free-fall probe, winch and a line-puller mounted at the stern and was hired from SyTech, Canada. Shears are measured at 280 Hz and are transmitted to the ship via a Kevlar and conducting cable. To take measurements the probe is allowed to free-fall at about 0.75 m s^{-1}, with the winch and line-puller paying out line faster than the probe descends, whilst the ship is steaming ahead at about 1 knot. The probe hits the sea bed and is then pulled back to the surface, when another profile can be obtained. Ideally profiles are recorded in blocks of eight to ten, which took up to an hour at the deeper stations (100 – 120 m water depth, Ernestine, Felicity, Delilah and Belinda). A CTD profile is then recorded or the ship repositioned and then another block of microstructure profiles obtained. A measurement period should last at least 13 hours to cover a tidal cycle. Inevitably in a multi-disciplinary cruise the ideal pattern cannot be obtained to accommodate biogeochemical measurements which required long CTD and water sampling operations at 04.00 and 12.00 each day. There were, in addition, insufficient people to maintain 24 hour coverage of the FLY system.

Five sets of measurements (13-17) were obtained at Belinda, 6 at Clarence (1-6), 6 at Delilah (7-12), 10 at Ernestine (36-45), 18 at Galen (18-35) and 15 at Felicity (46-60), see Table 5.2.1. A variety of problems were encountered initially leading to data of varied quality, but these problems were overcome by set 31 so that the data quality appears to be uniformly high for the last 30 sets. A learning curve was also involved since the system is new to CCMS. No detailed data processing was attempted on board ship but the data were processed up to estimating dissipation profiles with the SPIDER software, obtained from the School of Ocean Sciences, Menai Bridge, to check on the data quality after each set.

Whilst objective (2) was clearly achieved, the uncertain quality of the data recorded on the first leg mean that objective (1) was not fully met. However the data from the second leg can also be applied to objective (1) since the three sites were in stratified and possibly frontal (Felicity) water.

Set	Drops	Time GMT	Day in May	Latitude (N)	Longitude (W)	Depth (m)	Sensors
1	1	01.00	18	52 9.8	5 52.4	95	506 518
1	6	19.00	18	51 45.7	6 45.9	75	506 518
2	4	19.36	18	51 47.4	6 45.9	73	508 121
2	10	21.29	18	51 49.4	6 46.5	71	141 121
3	10	23.20	18	51 45.5	6 46.2	72	141 121
4	10	00.15	19	51 46.1	6 47.3	71	141 121
5	10	01.23	19	51 46.9	6 49.5	71	141 121
6	10	02.18	19	51 46.3	6 48.8	72	141 121
7	10	15.30	19	51 49.1	5 41.1	111	508 121
8	10	17.24	19	51 48.5	5 40.7	102	137 121
9	5	21.23	19	51 50.8	5 41.3	107	137 121

10	10	22.23	19	51 51.5	5 42.5	109	116	121	
11	10	00.01	20	51 50.9	5 39.8	100	116	121	
12	10	01.30	20	51 50.9	5 38.1	89	116	121	
13	10	19.11	20	52 10.5	5 51.4	97	116	121	
14	10	20.54	20	52 11.1	5 51.4	95	116	121	
15	11	22.39	20	52 11.4	5 50.7	92	116	121	
16	10	00.18	21	52 10.6	5 52.3	93	116	121	
17	11	01.34	21	52 10.1	5 52.6	93	116	121	
18	16	05.20	22	51 30.9	7 20.0	82	116	121	**
19	2	08.21	22	51 29.5	7 19.1	84	120	508	
19	15	10.14	22	51 30.4	7 19.3	82	116	508	
20	9	15.20	22	51 30.2	7 19.8	80	121	508	
21	10	17.17	22	51 28.9	7 20.6	83	121	508	
22	10	04.54	23	51 28.2	7 18.6	83	121	508	
23	11	06.23	23	51 26.6	7 18.2	84	121	508	
24	8	08.09	23	51 29.1	7 19.5	84	116?	508	
25	4	10.37	23	51 29.9	7 20.2	83	116?	508	
26	9	13.41	23	51 30.0	7 20.5	81	116	508	
27	10	15.34	23	51 29.9	7 22.4	81	141	508	
28	10	17.22	23	51 30.1	7 19.9	83	141	508	
29	10	04.37	24	51 29.7	7 21.6	82	141	508	
30	10	05.55	24	51 29.7	7 23.8	83	141	508	
31	10	08.44	24	51 30.7	7 21.2	84	141	508	
32	10	10.51	24	51 30.1	7 23.1	82	141	508	
33	10	13.52	24	51 29.9	7 24.5	81	141	508	
34	8	15.28	24	51 29.7	7 22.1	82	141	508	
35	10	16.53	24	51 29.6	7 20.2	82	141	508	
36	10	04.36	25	50 10.8	8 36.8	125	141	508	
37	10	07.10	25	50 12.0	8 35.5	118	141	508	
38	9	08.44	25	50 11.6	8 38.1	114	141	508	
39	8	10.17	25	50 10.8	8 40.8	116	141	508	
40	10	14.37	25	50 08.6	8 39.8	120	141	508	
41	8	16.11	25	50 08.0	8 42.2	116	141	506	
42	10	17.42	25	50 06.4	8 42.2	129	141	506	
43	10	08.21	26	50 10.7	8 35.1	130	141	506	
44	11	09.57	26	50 10.6	8 37.0	123	141	506	
45	9	13.40	26	50 08.9	8 34.9	128	121	506	
46	10	04.42	27	51 12.1	6 24.5	98	141	506	
47	10	06.15	27	51 11.4	6 23.5	102	141	506	
48	10	08.24	27	51 11.6	6 24.0	101	141	506	
49	8	10.25	27	51 12.6	6 23.0	104	141	506	
50	10	13.57	27	51 13.4	6 21.1	107	141	506	
51	10	15.38	27	51 11.9	6 21.8	104	141	506	
52	7	17.06	27	51 10.7	6 22.9	100	141	506	
53	8	18.16	27	51 09.6	6 23.9	98	141	506	
54	10	04.36	28	51 12.0	6 24.3	99	141	506	
55	4	06.26	28	51 12.5	6 22.3	104	141	506	
56	10	08.08	28	51 12.0	6 25.2	98	141	506	
57	10	10.10	28	51 12.2	6 23.1	104	141	506	
58	8	12.54	28	51 12.5	6 22.4	106	141	506	
59	8	14.12	28	51 12.1	6 23.8	103	141	506	
60	6	15.36	28	51 11.4	6 25.1	100	141	506	

*Table 5.2.1. Information on FLY deployments. Note ** The temperature probe was changed for drop 18.*

5.3 Modelling and detection of the tidal front (Roger Proctor, Leg 1)

Objectives

1) Utilise 3D baroclinic model output and AVHRR/SEAWIFS imagery to detect frontal position and regions of thermally stratified water in Celtic Sea to aid deployment of fixed instrumentation and physical-biological station measurements.
2) Map northern transition of Celtic Sea front.

Initial planning for ADCP/FLY deployments in the first leg were made using AVHRR image and model output (SST, surface-bottom temperatures, 2 temperature cross-sections 20 nm apart between Scilly Isles and Cork) for 10 May. Model output is 24-hour average from the POL 3D model running pre-operationally at the UK Met. Office. This is run in near real time with results available 1 day in arrears. Original planning for this cruise anticipated this model being operational from mid-April, i.e. part of the MO forecasting suite and thus providing 36 hour forecasts. However, the operational implementation has been delayed so no forecasts were available before or during the first leg of the cruise. It is hoped that forecasts will be available for the second leg but no guarantee can be given.

Following commencement of cruise, weather changed on approaching Celtic Sea from sustained high pressure and sunshine with light easterly winds, to falling pressure, winds SW force 6/7 and waves with maximum of 5 m and significant wave height 3 m. Model output was faxed daily to the ship, but, being one day behind, still showed effects of recent good weather and therefore showed different vertical structure to that shown by CTD's and UOR (tows 1, 2) on passage across Celtic Sea (model showed linear stratification in upper 30 m whereas observations showed well-mixed upper 25 m and sharp (5-10 m) thermocline. UOR also showed upper mixed layer deepening to 30-35 m towards the Irish coast). It is unfortunate that the weather changed just before we were able to measure the stratification under the stable conditions.

Zigzag eastwards track followed on 17th May to identify northern extent of front. CTD's (CTD stations 17/1-17/7, 17/10, 17/11) approx. every 10 nm along 50 nm followed by XBT's (XBT stations 1-5) at 5 nm intervals on 30 nm NE track to northern ADCP position. CTD and XBT measurements showed front sharply left Irish coast at approx. 52 10N, 6 50W, with stratified water to west, well-mixed water to east. Two ADCP's deployed, FLY deployment unsuccessful.

UOR tow 3 on 18th May from well-mixed ADCP site towards planned stratified ADCP site. XBT6 showed water well-mixed. Eastward track with XBT every 5 nm (XBT 7-10) located front, ADCP deployed in stratified (1.5° C) water at 51° 45N, 6° 45W. Model results for 17th May suggested model 2° C stratification contour lined up with observed frontal position on 17/18th May so this was used to plan next days UOR to zigzag front. Successful FLY deployment.

UOR tow 4 on 19th May planned using model stratification of 17th May, adjusted for 18th May observations. Five point zigzag crossed front 5 times, supported by XBT's 11 and 12. End of UOR close to Welsh coast at 51 49N 5 40W where CTD showed strong haline stratification, marking presence of coastal freshwater (presumably outflow from Bristol Channel) in surface waters. Successful FLY deployment.

UOR tow 5 on 20th May to identify northern extremity of front. Four point zigzag north/south/north to northern ADCP site located front at southernmost excursion, all water northwards was well-mixed. Frontal position to western side of St George's Channel appears strongly related to northern part of the Celtic Deep with most northerly frontal position at 52N 6W. ACDP recovered.

XBT no.	LOGGED	Time BST	Date	Lat N	Lon W	Comment
1	17/12	1630	17May	52° 01	6° 28	Well mixed
2	17/13	1700	17May	52° 02	6° 21	Well-mixed
3	17/14	1730	17May	52° 03	6° 13	Well-mixed
4	17/15	1800	17May	52° 04	6° 05	Well-mixed
5	17/16	1833	17May	52° 08	5° 56	Well-mixed
6	-	1330	18May	51° 50	6° 20	Well-mixed
7	-	1415	18May	51° 50	6° 30	Well-mixed
8	-	1445	18May	51° 50	6° 40	1° stratification
9	-	1500	18May	51° 50	6° 45	1° stratification
10	-	1545	18May	51° 45	6° 45	1.5° stratification
11	19/6	0715	19May	51° 38.5	6° 37	1.5° stratification
12	19/7	0930	19May	51° 40	6° 06	1° stratification
13	-	1150	19May	50° 51	5° 46	Unreliable (UOR snagged)
14	-	1200	19May	50° 51	5° 45	Unreliable (UOR snagged)

Table 5.3.1: XBT drops

Summary

1) Model output proved useful in helping to define cruise plans, both before cruise and during cruise. That model output was always a hindcast (one day behind) which was less satisfactory than a forecast would have been, particularly as the weather pattern changed immediately the cruise had started. However, the weather conditions prevented the production of any useful AVHRR/SEAWIFS images during the first leg, so at least the model was able to provide an indication of change.

2) The northern location of the Celtic Sea front was quite well located. Northern limit of front in St George's Channel at 52° N 6° W. Stratification south of the front showed between 2-3° C surface to bottom temperature difference with surface mixed layer between 20 and 30 m deep, with UOR showing layer thickness increasing towards the Irish coast. Surface temperatures between 11-13.5° C, bottom temperatures between 9 and 10° C.

5.4 Undulating Oceanographic Recorder (UOR) (Jim Aiken and Tim Smyth)

The UOR was used to survey the coupled physical, biological structure throughout the Celtic Sea and S. Irish Sea region and characterise the variability of structures around the experimental stations. The UOR was towed at speeds between 9 and 11 knots (16 to 20 km/h) undulating from 5 to 40 or 50 m in depth, with sensors for Depth, Temperature, Conductivity and Chlorophyll fluorescence, logged internally.

There were 11 UOR tows (see Tow log xx1) covering a total distance of ca 677 miles (71 h tow time). There were no instrumentation failures, but some data were lost at the end of tow 9 due to data overflow.

a) Bio-optics; Optical Profiling Sensors (OPS)

The OPS was profiled on station from the A-frame mid-ships, to determine the Apparent Optical Properties of the water column: the diffuse attenuation coefficients Kd(l) and water leaving radiance Lw(l) at the 6 SeaWiFS wavelengths + 1 (412, 443, 490, 510, 555, 670 and 620 nm). The measurements, with the measurements of phytoplankton absorption (Geider) will be used to validate bio-optical and productivity models and derive algorithms for the interpretation of remotely sensed observations of water colour. When appropriate (clear, cloudless sky at solar noon) the data could be used for match-up validation of SeaWiFS. Besides the Radiometers and Irradiometers the OPS had a C-T-D-Fl instrument package and a beam transmisometer (670 nm); data were logged with a battery powered Solid State Data Logger (SSDL) in situ. For the mid-day casts in leg 2, the FRRF and PAR sensors were attached to the OPS frame.

There were 23 deployments of OPS, most with double casts to 60 m.

Data analysed on board

Objectives

- Take "sea-truth" optical measurements for SeaWiFS ocean colour validation and algorithm development.
- Take measurements of marine aerosols to improve SeaWiFS atmospheric correction algorithms.
- Provide remote sensing data analysis.

Method

A SIMBAD radiometer (on loan from Laboratoire d'Optique Atmospherique) was used to derive properties of marine atmospheric aerosols. The instrument has five wavelengths in the optical and near infra-red (443, 490, 560, 670 and 870nm) and is operated by pointing the instrument directly at the sun when the sun's disk is un-obscured by clouds. SIMBAD measures direct sunlight intensity and, by knowing an accurate calibration for the instrument and using algorithms found in the literature, the contribution to the total atmospheric absorption at the five wavelengths by aerosols can be calculated.

Ocean Colour and SST satellite imagery was sent via email from the Plymouth Marine Laboratory Remote Sensing Group (RSG). The RSG possesses the capability of receiving and processing satellite data in near-real time; the imagery being ready for dissemination to the RRS Discovery about 1 hour after the satellite overpass time.

Results

Aerosols

During the cruise 195 (see table 1 for summary) separate SIMBAD measurements were taken. The first few days of the cruise were affected by aerosols of a terrestrial rather than a marine origin. This can be seen in figure 1, which shows the atmospheric absorption due to aerosols at 490nm. Terrestrial aerosols are distinguishable from marine aerosols by their higher values of τ_a. This is because of their higher concentrations and chemical composition; marine aerosols are dominated by sea-salt rather than sulphate or silicon compounds.

Remote Sensing

The four images sent to the RRS Discovery by Peter Miller of the PML Remote Sensing Group were vital in planning the location of sampling stations particularly during the second week of the cruise. The imagery sent out to the ship gave the location of a large bloom to the south of Ireland that was sampled on the 25th and 26th May and also enabled the position of the oligotrophic region over the Celtic deep to be pinpointed. This was sampled on the 27th and 28th May.

Figures and Tables

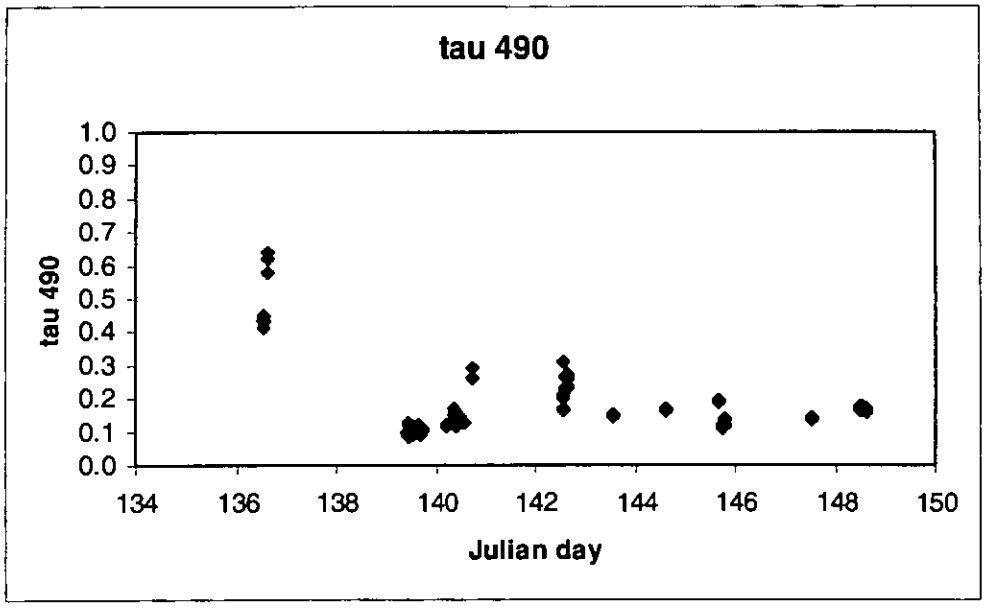


Figure 5.4.1: Variation of the absorption coefficient due to aerosols at 490nm for the duration of D246. Data are summarised in Table 5.4.1.

Julian	hour	Latitude	Longitude	Tau 443	tau 490	tau 560	tau 670	tau 870
136	7.825	50.892	-1.395	1.108	1.153	1.083	1.057	0.934
136	12.653	50.633	-1.641	0.350	0.449	0.348	0.328	0.144
136	14.772	50.445	-1.997	0.501	0.577	0.491	0.458	0.280
139	10.299	51.716	-6.522	-0.044	0.096	0.068	0.116	0.032
139	10.784	51.747	-6.576	-0.060	0.089	0.062	0.109	0.025
139	10.803	51.748	-6.571	-0.061	0.089	0.060	0.109	0.024
139	11.103	51.772	-6.491	-0.023	0.124	0.094	0.138	0.045
139	11.484	51.808	-6.395	-0.065	0.092	0.062	0.115	0.028
139	11.621	51.821	-6.362	-0.059	0.098	0.069	0.120	0.034
139	12.806	51.831	-6.355	-0.070	0.090	0.061	0.113	0.026
139	15.657	51.750	-6.757	-0.005	0.110	0.079	0.117	0.047
139	15.730	51.750	-6.757	0.013	0.123	0.089	0.125	0.052
139	16.264	51.750	-6.761	-0.005	0.095	0.067	0.099	0.035
139	17.389	51.760	-6.766	0.040	0.105	0.078	0.096	0.044
140	5.687	51.703	-6.695	0.097	0.120	0.105	0.115	0.095
140	8.800	51.704	-6.092	0.026	0.135	0.108	0.142	0.075
140	9.306	51.784	-6.078	0.054	0.172	0.139	0.177	0.102
140	9.785	51.859	-6.041	-0.007	0.125	0.093	0.137	0.058
140	10.180	51.870	-5.955	-0.020	0.121	0.091	0.135	0.056
140	10.676	51.851	-5.830	-0.028	0.119	0.084	0.135	0.049
140	10.945	51.838	-5.762	0.001	0.146	0.110	0.155	0.069
140	11.626	51.825	-5.694	-0.020	0.136	0.100	0.152	0.064
140	12.483	51.820	-5.700	-0.017	0.140	0.105	0.155	0.068
140	13.755	51.817	-5.698	-0.025	0.125	0.091	0.142	0.057
140	17.796	51.818	-5.671	0.215	0.265	0.240	0.250	0.207
142	13.173	51.650	-5.802	0.016	0.164	0.122	0.166	0.062
142	13.584	51.649	-5.916	0.059	0.200	0.153	0.188	0.081
142	14.094	51.649	-6.059	0.098	0.228	0.178	0.208	0.102
142	14.568	51.650	-6.189	0.146	0.267	0.215	0.240	0.135
142	15.091	51.649	-6.335	0.119	0.233	0.187	0.215	0.120
143	13.765	51.507	-7.334	0.004	0.153	0.115	0.161	0.073
144	14.676	51.504	-7.374	0.038	0.172	0.134	0.174	0.085
145	16.216	51.496	-7.342	0.096	0.191	0.152	0.172	0.093
145	17.768	51.478	-7.343	0.067	0.123	0.096	0.105	0.053
145	18.399	51.454	-7.382	0.080	0.116	0.092	0.095	0.052
145	18.6469	51.433	-7.436	0.082	0.112	0.090	0.091	0.053
145	18.8178	51.419	-7.474	0.095	0.118	0.095	0.093	0.055

145	19.0508	51.401	-7.526	0.124	0.138	0.112	0.105	0.067
145	19.3511	51.379	-7.593	0.130	0.137	0.111	0.101	0.067
147	12.9711	50.153	-8.578	-0.016	0.141	0.105	0.153	0.055
147	13.3172	50.152	-8.578	-0.022	0.135	0.100	0.146	0.049
148	12.2389	51.213	-6.372	0.006	0.161	0.123	0.165	0.056
148	12.470	51.215	-6.37	0.017	0.173	0.135	0.174	0.070
148	12.6172	51.216	-6.368	0.017	0.173	0.136	0.175	0.072
148	13.0067	51.220	-6.363	0.018	0.172	0.133	0.172	0.067
148	14.3819	51.215	-6.358	0.024	0.165	0.131	0.167	0.072
148	15.0392	51.205	-6.364	0.037	0.166	0.133	0.167	0.076
148	15.1775	51.204	-6.363	0.032	0.159	0.129	0.159	0.073

Table 5.4.1: Summary of aerosol measurements taken using the SIMBAD radiometer. Julian is the Julian day of 2000 and tau is the aerosol absorption coefficient at each of the five wavelengths.

Cast No	Date	Time (GMT)	Event	Lat (N), Lon (W)	Depth
PD50001	15/5	14.41	In	50 26.7, 01 59.7	
(15/01)		15.50	out		20
PD50002	17/5	11:53:45	In	52 06.2, 06 50.2	
		11:58:00	25m		25
(17/08)		12:02:00	Out		
PD50003	17/5	12:04:55	In	52 06.2, 06 50.2	
		12:06:40	10m		10
(17/09)		12:09:07	Out		
PD50004	18/5	12:08:10	In	51 49.7, 06 19.7	
		12:11:20	60m		60
(18/05)		12:17:28	Out		
PD50005	19/5	11:32:00	In	51 49.5, 05 41.6	
		11:37:02	60m		60
(19/10)		11:42:00	Out		
		11:42:28	In		
		11:45:03	40m		40
		11:48:21	Out		
PD50006	20/5	13:30:48	In	52 09.3, 05 53.0	
		13:35:15	40m		40
(20/07)		13:39:25	Out		
		13:42:02	In	52 09.0, 05 53.3	
		13:45:13	40m		40
		14:03:00	Out		
PD50007f	22/5	04:13:00	In	51 30.4, 07 19.8	
(22/04)			55m		55
		04:40:00	Out		
		04:40:00	In		
			55m		55
		05:05:00	Out		
PD50008f	22/5	07:30:00	In	51 28.8, 07 19.4	
(22/07)			45m		45
07:57:00			Out		
PD50009f	22/5	09:32:30	In	51 30.0, 07 19.5	
(22/09)		09:40:42	60m		60
09:47:39			Out		
LOG contd. P2					
OPTICS CAST		09:49:45	In		
		09:54:16	45m		45
		10:03:23	Out		
PD50010f	22/5	12:46:00	In	51 30.4, 07 20.2	
(22/12)		12:54:45	60m		60
		13:06:28	Out		
		13:06:44	In		
		13:16:43	50m		50
		13:21:45	Out		

PD50011f	22/5	16:35:02	In	51 29.3, 07 20.6	
(20/20)		16:42:16	60m		60
		16:50:05	Out		
		16:50:50	In		
		16:54:45	40m		40
		17:00:37	Out		
PD50012f	22/5	18:29:20	In	51 28.0, 07 21.5	
(22/23)		18:36:12	60m		60
		18:43:30	Out		
PD50013	23/5	15:06:59	In	51 30.2, 07 22.6	
(23/17)			65m		65
		15:23:03	Out		
PD50014f	24/5	07:31:36	In	51 31.3, 07 20.4	
(24/07)		07:42:25	60m		60
		07:55:59	0m		
		08:03:00	30m		30
		08:06:03	Out		
PD50015f	24/5	10:14:35	In	51 29.8, 07 23.3	
(24/11)		10:21:45	50m		50
		10:30:52	0m		
		10:35:48	40m		40
		10:38:54	Out		
PD50016f	24/5	12:12:12	In	51 29.3, 07 24.8	
(24/14)		12:14:48	0m		
		12:20:12	60m		60
		12:34:17	0m		
		12:37:55	40m		40
		12:46:26	Out		
PD50017f	24/5	16:10:35	In	51 29.7, 7 20.5	
(24/23)		16:13:15	40m		40
		16:16:50	0m		
		16:19:50	40m		40
		16:21	15md		
		16:23:45	35m		35
		16:29:13	Out		
PD50018f	25/5	12:33	In	50 09.6, 08 38.8	
(25/12)		12:40:25	60m		60
		12:50:	Out		
PD50019f	26/5	12:21:50	In	50 09.6, 08 34.7	
(26/10)		12:23:28	30m		30
		12:25:00	0m		
		12:29:44	60m		60
		12:41:13	0m		
		12:44:02	40m		40
		12:55:12	0m		
		12:57:08	30m		30
		13:00:00	Out		
PD50020f	26/5	13:13:35	In	50 09.1, 08 34.7	
(26/12)		13:20:00	45m		45
		13:26:46	Out		
PD50021f	27/5	12:12:24	In	51 12.9, 06 22.8	
(27/13)			12:17:24	60m	60
			12:26:10	0m	
			12:30:40	60m	60
			12:42:27	Out	
PD50022f	27/5	14:56:07	In	51 10.9, 06 22.8	
(27/21)			15:00:50	40m	40
			15:05:04	0m	
			15:09:20	60m	60
		15:17:05	0m		
		15:09:20	40m		40
		15:24:10	Out		
PD50023f	28/5	12:13:24	In	51 12. , 06 24	

(28/10)	12:19:41	65m	65
	12:27:47	0m	
	12:31:00	40m	40
	12:35:30	Out	

Table 5.4.2. PROPHEZE CRUISE, May 2000 (D500xx) Optics cast log

Tow No (Event No)	Date	Time (GMT)	Tow event	Lat (°N) Lon (°W)	Tow time	No of Unds.	Depth range	Tow miles
D50001	16/5	11.45	L	50 22.2, 06 06.1				
(16/02)	16/5	17.30	R	51 10.7, 06 50.5	5.45	63	5-40	67
D50002	16/5	18.50	L	51 11.4, 06 50.2				
(16/03)	17/5	01.00	R	51 55.3, 07 29.5	6:10	57	6-42	52
D50003	18/5	06.04	L	52 10.5, 05 52.6				
(18/04)	18/5	11.47	R	51 50.0, 06 19.8	5:43	81	5-38	69.5
D50004	19/5	05.14	L	51 45.7, 06 47.0				
(19/05)		06.20	AC	51 38.0, 06 34.4				
		08.46	AC	51 42.1, 06 05.6				
		09.58	AC	51 52.6, 06 00.3				
	19/5	11.14	R	51 49.6, 05 42.0	6:00	52	5-50	59
D50005	20/5	05.02	L	51 50.8, 05 39.2				
(20/04)		06.17	AC	52 02.2, 05 38.0				
		06.38	AC	52 03.6, 05 45.9				
		08.31	AC	51 52.8, 05 01.0				
	20/5	10.40	R	52 12.8, 05 51.8	5:38	54	5-49	58.5
D50006	21/5	12.03	L	51 39.2, 05 29.3				
(21/01)	21/5	19.06	R	51 39.0, 07 22.7	7:03	69	5-48	60.
D50007	21/5	19.43	L	51 38.9, 07 25.8				
(21/02)		22.06	AC	51 39.0, 08.00.0				
		23.11	AC	51 30.0, 08 14.3				
	22/5	02.56	R	51 30.0, 07 19.8	7:13	61	5-52	68
D50008	22/5	18.59	L	51 27.0, 07 21.3				
(22/23)		20.00	AC	51 20.0, 07 19.0				
		21.49	AC	51 21.1, 07 09.6				
		22.20	AC	51 34.1, 07 13.0				
	23/5	00.49	AC	51 20.2, 07 29.7				
		02.14	AC	51 32.8, 07 30.0				
		02.59	R	51 29.7, 07 19.4	8:00	53	5-56	76.5
D50009	24/5	18.10	L	51 28.4, 07 20.5				
(24/26a)		20.21	AC	51 18.2, 07 48.5				
	25/5	03.15	R	50 10.8, 08 34.9	9:05	88	5-50	97
D50010	26/5	16.03	L	50 08.6, 08 38.6				
(26/15)		18.58	R	50 24.5, 08 04.5	2:55	21	5-50	26.5
D50011	26/5	19.22	L	50 25.6, 08 02.7				
(26/16)		21.15	AC	50 37.0, 07 41.0				
27/5		02.57	R	51 14.0, 06 23.8	7:19	78	1-50	

Table 5.4.3. PROPHEZE CRUISE, May 2000 (D500xx): UOR Tow log. Total of 11 tows totalling 70h 51min over a distance of 677 miles

5.5 Nutrient Analysis (Andy Rees and John Stephens)

Objectives

1) To determine the concentration and vertical distribution of dissolved nutrient species at a number of oceanographic stations showing diverse hydrodynamical conditions.

2) To utilise sensitive analysis techniques for the determination of nanomolar concentrations of nitrate, nitrite and ammonium.

3) To investigate the viability of freezing samples for urea analysis.

4) To compare the analysis of dissolved NH_4 by manual and autoanalytical techniques.

5) To participate in experiments to determine the simultaneous rates of microzooplankton grazing, phytoplankton nitrogen uptake and microbial nitrogen regeneration using ^{15}N as a tracer.

Methods

Seawater samples were collected from the ship's CTD bottle rosette at times and dates listed below. The concentrations of dissolved nitrate, nitrite, ammonium, silicate and phosphate were determined using a five channel segmented flow autoanalyser which has been described in detail by Woodward *et al.* (1996). Ammonium concentrations were determined using both the phenol-hypochlorite reaction (nominal detection limit 0.1 μM) and O-phthaldehyde reaction (nominal detection limit 10nM). A chemiluminescent technique for the analysis of nanomolar concentrations of dissolved nitrate and nitrite was due to be employed but the detection system was found to be faulty during set-up. To provide nitrate concentrations at the oligotrophic stations the autoanalyser was pushed to it's analytical limits to return a detection limit in the order of 10nM.

Historically samples have been taken and frozen for subsequent laboratory analysis of dissolved urea utilising the reaction with di-acetyl monoxime. During this cruise the opportunity was taken to collect seawater samples to compare urea concentrations in fresh (onboard) and frozen (laboratory) samples analysis using spectrophotometer absorbance at 520 nm.

The concentration of ammonium was determined simultaneously by manual (phenol-hypochlorite reaction at 630 nm) and autoanalytical methods to compare the relative precision and sensitivities.

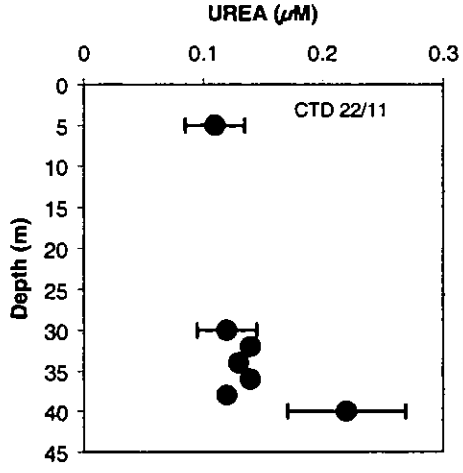


Figure 5.5.1: Depth profile of urea concentration.

Twenty-four hour dilution experiments to determine microzooplankton grazing rates (Elaine Fileman) were amended with ^{15}N- nitrate, ammonium and urea. Sub-samples were collected at T_0 and T_{24} for the analysis of dissolved nutrients, and at T_{24} only for the determination of ^{15}N enrichment. It is envisaged that estimates will be made from single samples of; chlorophyll, particulate nitrogen and carbon and dissolved nutrient concentration and rates of microzooplankton grazing, and microbial nitrogen uptake and regeneration.

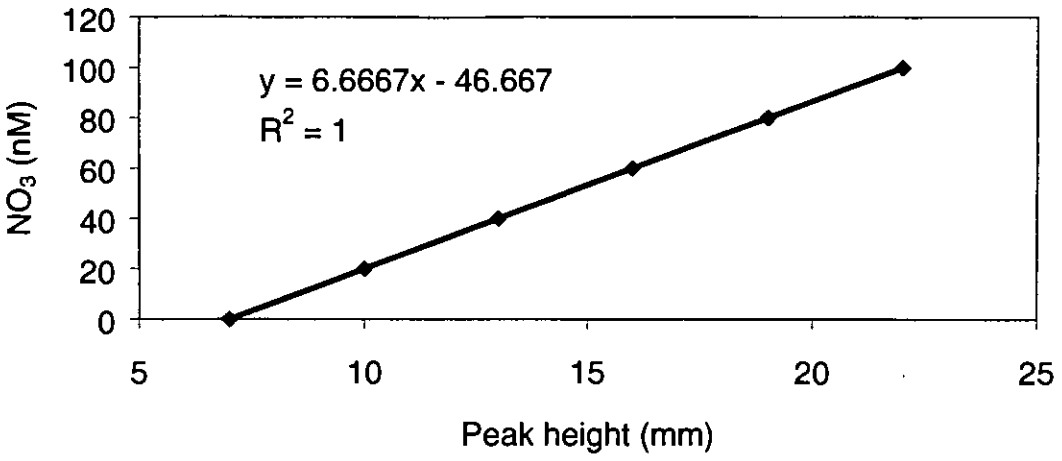


Figure 5.5.2: Typical calibration curve for nitrate concentration in the range 20 – 100 nM

Results

Few calibrated data are available at present; instrument output is on the chart paper and final analysis requires a labour intensive period in the laboratory. However, it is hoped that the analysis of nutrient concentrations will be complete within 2 months of the cruise ending and this data will be made available to cruise participants via either the B.O.D.C. or the principal scientist. ^{15}N analysis will be completed within 6 months.

Date	CTD No	Autoanalyser	No. depths/samples
16 May	16/04	Autoanalyser	6
		Nanoamm	6
17 May	17/02	Autoanalyser	11
		Nanoamm	11
	17/10	Autoanalyser	6
		Nanoamm	6
		Urea	4
18 May	18/03	Autoanalyser	10
		Nanoamm	10
		Diln. Expt	4
	18/06	Autoanalyser	7
		Nanoamm	7
		Urea	3
19 May	19/04	Autoanalyser	10
		Nanoamm	10
		Diln. Expt	15
	19/11	Autoanalyser	7
		Nanoamm	7
		Urea	3
20 May	20/03	Autoanalyser	10
		Diln. Expt	18
	20/06	Autoanalyser	7
		Urea	3
21 May		Diln Expt.	10
		Autoanalyser – continuous	11 hours
22 May	22/03	Autoanalyser	10
		Nanoamm	10
		Diln. Expt	4
	22/11	Autoanalyser	12
		Nanoamm	12
		Urea	7
		MSG	8

23 May	23/03	Autoanalyser	10
		Nanoamm	10
		Diln. Expt.	14
	23/10	Autoanalyser	7
		Nanoamm	7
		Urea	3
24 May	24/03	Autoanalyser	10
		Diln. Expt.	14
	24/13	Autoanalyser	12
		Urea (frozen only)	12
25 May	25/03	Autoanalyser	10
		Diln. Expt.	10
	25/11	Autoanalyser	13
26 May	26/03	Autoanalyser	11
		Nanoamm	11
		Diln. Expt.	18
	26/09	Autoanalyser	12
		Nanoamm	12
27 May	27/03	Autoanalyser	10
		Nanoamm	10
		Diln. Expt.	18
	27/12	Autoanalyser	12
		Nanoamm	12
28 May	28/01	Autoanalyser	12
		Diln. Expt.	10
	28/09	Autoanalyser	12

Table 5.5.1. Sample date and station number.

5.6 Iron Speciation (Toby Holland)

Aim

The aim of this work was to measure iron speciation (dissolved iron(II), total dissolved iron and total particulate iron) in waters of the Celtic Sea. The data produced will be used to elucidate the iron biogeochemistry of the tidal front region of the Southern Irish Sea and the strongly stratified thermocline of the central Celtic Sea. This will be achieved by correlation of results with data generated on the cruise, particularly that for the distribution of chemotaxonomic pigments.

Methods

Seawater was collected in acid-washed Teflon-lined Go-Flo bottles. On deck, water was transferred form these into acid-washed 1 litre high-density polythene (HDPE) bottles. Seawater was filtered through 0.4 μM pore size polycarbonate Cyclopore track etched membrane filters for the dissolved iron measurements. Dissolved iron(II) was then measured immediately using a flow-injection chemiluminescence iron analyser. This measured iron(II) concentrations using the chemiluminescence reaction of luminol, which is catalysed by iron(II). Total dissolved iron was measured after sample acidification and addition of a reducing agent to reduce all iron to iron(II). All dissolved iron measurements were made on board ship. Unfiltered samples were acidified to pH 1.8 and will be left for at least one month before determination of particulate iron in the laboratory at Plymouth, also using flow-injection chemiluminescence.

Samples were also taken for other researchers at the University of Plymouth to measure trace metals including copper.

Samples taken

Station	Iron species determined/to be determined
Station 17/10	Dissolved iron(II), total dissolved iron
Station 18/06	Dissolved iron(II), total dissolved iron
Station 19/11	Dissolved iron(II), total dissolved iron and total particulate iron

Station 20/06	Dissolved iron(II), total dissolved iron and total particulate iron
Station 22/11	Dissolved iron(II), total dissolved iron and total particulate iron
Station 23/10	Dissolved iron(II), total dissolved iron and total particulate iron
Station 24/03	Dissolved iron(II), total dissolved iron
Station 26/09	Dissolved iron(II), total dissolved iron and total particulate iron
Station 28/09	Dissolved iron(II), total dissolved iron

Example results

Full data analysis will be carried out on return to Plymouth. The following figure shows a preliminary result for Station 22/11:

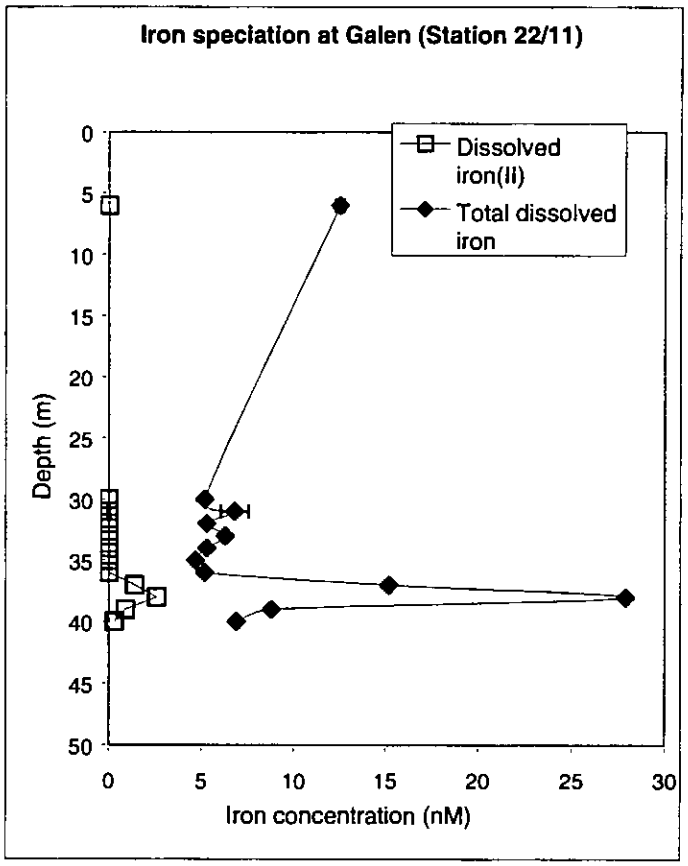


Fig 5.6.1. Vertical profile of iron at Galen.

5.7 Oxygen Respiration and Production (Linda Gilpin and Graham Savidge)

The aim of this work is to study microbial respiration at high vertical resolution especially across the thermocline under a variety of stratified regimes.

Specific objectives carried out during the cruise were:

To collect regular *in-situ* oxygen samples from the biogeochemistry casts in order to calibrate the oxygen probe.

1) To obtain respiration data from up to 6 depths at each station; depths selected according to the profile and the strategy for the station (high vertical resolution in the thermocline or 'normal' distribution of equally spaced samples).

2) To obtain production estimates from one depth at regular stations for comparison with data obtained for ^{14}C production, grazing rates and bacterial activity.

Methodology

Samples for the determination of the *in-situ* oxygen concentration were the first to be collected from the rosette following copious rinsing of the bottles. The temperature was noted, the samples pickled, shaken well and stored under water until analysis. Six litres of water from up to six depths were decanted gently into carboys for respiration and production measurements. Quadruplicate bottles were filled for time zero, dark incubations and light incubations (10 m only) respectively. The time zero bottles were pickled immediately and again stored under water until analysis. Bottles for respiration determination were incubated in black bags either in an on-deck system with continuous flow through of non-toxic seawater or in a tank in the constant temperature lab according to the in situ temperature at the depth from which the water was collected. Samples for the estimation of production were incubated on-deck under simulated in situ light conditions. Both light and dark incubations were terminated after 24hrs by again pickling the samples and storing under water.

The oxygen concentration for all bottles was determined by the standard Winkler titration using an SIS Microtitrator system with automatic endpoint detection.

Date	Name	Stn	In situ conc depths	Respiration depths
18.5.00	Belinda	18/03	2 – 60m	4,12,22,32,42,62
19.5.00	Clarence	19/04	2 – 60m	4,28,33,36,43,63
20.5.00	Delilah	20/03	2 – 75m	2,30,50,75
22.5.00	Galen	22/03	2 – 60m	2,10,25,30,40,60
		22/11	6 – 40m	
		22/19	2 – 40m	
23.5.00	Galen	23/03	2 – 60m	10,35,60
24.5.00	Galen	24/03	26 – 38m	26,28,30,32,34,38
		24/23	5 – 40m	
		24/25	5 – 30m	
25.5.00	Ernestine	25/03	2 – 100m	10,30,40,50,100
		25/11	5 – 70m	
26.5.00	Ernestine	26/03	20 – 60m	
		26/09	5 – 100m	
27.5.00	Felicity	27/03	2 – 60m	2,12,22,37,42,62
		27/12	2 – 60m	
28.5.00	Felicity	28/01	10 – 60m	

Table 5.7.1. Samples collected during D246 were as follows.

Following initial teething problems, the system worked well and collation of the data will ensue.

It is hoped that the data may be interpreted both in relation to the detailed microbial population information collected by colleagues as well as the fine scale physical turbulence measurements made during this cruise.

5.8 Chemotaxonomic assessment of phytoplankton (Denise G Cummings)

Background

The photosynthetic pigments, particularly chlorophyll *a* (*Chl a*) have long been recognised as unique molecular markers of phytoplankton biomass. Whilst the distribution of *Chl a* has typically been studied by spectrophotometry or fluorimetry, these methods suffer from inaccuracies associated with spectral interferences from chlorophyll *b* (*Chl b*), carotenoids and *Chl a* degradation products. These degradation products include chlorophyllides, phaeophytins and phaeophorbides which may occur during senescence, grazing, sedimentation, and re-suspension of phytoplankton. The use of high performance liquid chromatography (HPLC) allows a more accurate estimate of *Chl a* to be obtained and also the rapid separation and quantification of up to 50 additional chloropigments and carotenoids in extracts of marine plankton.

Many of these pigments exhibit strong chemotaxonomic associations which may be used to characterise the distribution and composition of phytoplankton assemblages. For example:

Pigment	Key marker for:
Phycobiliproteins**	Cyanobacteria
Peridinin	Dinoflagellates
Fucoxanthin	Diatoms
19'-Hexanoyloxyfucoxanthin	Prymnesiophytes
Alloxanthin	Crypyophytes
Zeaxanthin	Cyanobacteria
Lutein	Green Algae
Divinyl chlorophyll a	Prochlorophytes

*Table 5.8.1. Chemotaxonomic pigments markers for algal groups. **At present, we do not have a method to detect phycobiliproteins (PhBP's), but a few samples were filtered for future analysis at the lab (using capillary electrophoresis). In addition to their photosynthetic and photoprotective function, PhBP's are also important in nitrogen cycling and can incorporate up to 60% of cellular N in N-fixing cyanobacteria.*

The analysis of phytoplankton pigments by HPLC and the exploitation of their chemotaxonomic relationships provides us with information on the composition of the phytoplankton community as well as the biomass abundance. In addition, pigment degradation products can be used as indicators of transformation processes such as grazing and bacterial degradation that contribute significantly to the turnover of phytoplankton carbon and subsequent sedimentation processes.

Methodology

Samples were collected on-board by vacuum filtering of seawater through 25mm GF/F filters. Filters were preserved in liquid nitrogen. Back at the lab, pigments will be extracted in methanol and analysed using reverse phase HPLC with diode array detection. Pigments will be identified through co-elution with authentic standards and confirmed using spectral evaluation. Concentrations will be calculated using an internal standard method.

Objectives

Pigment data will be used towards the following objectives:

1) To chemotaxonomically track the spatial and temporal evolution of the phytoplankton community.
2) To estimate the contribution of the major taxonomic groups to the total phytoplankton biomass from measured concentrations of phytoplankton pigments.
3) To integrate microscopy, flow cytometry, nutrients, phytoplankton physiology and HPLC data to fully characterise algal characteristics.
4) To relate with Remote sensing, Optics and calibrate the FRRF
5) To relate with Iron Chemistry (analysed by Toby Holland).

POC/N samples were taken for later analysis at the lab. This will give an estimate of carbon and nitrogen biomass which can be related to other onboard measurements.

DOC samples were taken and analysed onboard using a spectrophotometer, the results of which will be interpreted by Gerald Moore at PML.

Date	CTD	Pigs	POC	DOC
16/5/00	16/04	6	6	
17/5/00	17/02	8	8	
17/5/00	17/10	6	6	1
18/5/00	18/03	8	8	
18/5/00	18/06	7	7	1
18/5/00	18/11	5		
19/5/00	19/04	8	8	
19/5/00	19/11	7	7	1
20/5/00	20/03	8	8	
20/5/00	20/06	7	7	1
22/5/00	22/03	8	8	
22/5/00	22/11	8	8	
22/5/00	22/19	6	6	
23/5/00	23/03	8	8	
23/5/00	23/10	7*	7	
24/5/00	24/03	7	7	

24/5/00	24/10	4	4	
24/5/00	24/13	7	7	1
24/5/00	24/25	4	4	
25/5/00	25/03	7	7	
25/5/00	25/11	6	6	
25/5/00	25/13	3	3	1
25/5/00	25/24	3	3	
26/5/00	26/03	7*	7	
26/5/00	26/09	7	7	1
27/5/00	27/03	8	8	
27/5/00	27/10	3	3	
27/5/00	27/12	8	8	1
27/5/00	27/23	3	3	
28/5/00	28/03	8	8	
28/5/00	28/09	7	7	

*Table 5.8.1. Summary of number of samples collected for pigments, POC/N and DOC. *plus samples for phycobiliproteins.*

Acknowledgements: Thanks to those who helped with the collection of samples!!

5.9 **Phytoplankton** (Georgina McDermott)

Methodology

- 50 ml was taken from the CTD water bottles from various depths.
- Samples were then preserved with Lugol's Iodine and kept cool and in the dark until further analysis.
- Vertical plankton tows using a 32 μm mesh were taken from a depth of 45 m or just below the thermocline.

Objectives

- Phytoplankton cells in each sample will be identified and counted. From this the biomass of each species will be estimated.
- The net haul samples will give a qualitative account of large phytoplankton species in the water column.

Preliminary Results

- 'Galen' was dominated by the armoured dinoflagellate *Scripsiella sp.* and the diatom *Nitzschia SP* and had high species diversity of dinoflagellates.
- 'Ernestine' had high numbers of the diatoms *Rhizoslenia SP* and *Corethron sp.*
- 'Felicity' had very few diatoms but mainly consisted of armoured dinoflagellates especially *Gonyaulax* sp and *Protoperidinium sp* species.

Station	Sample Depths (m)	Vertical Plankton Hauls (m)
16/04	2, 12, 27, 32, 43	
17/02	10, 23, 31, 41	
17/10	5, 17	
18/03	7, 17, 27	
18/06	6, 11, 21, 32, 36	45
19/04	5, 18, 33	
19/11	5, 15, 30	35
20/03	4, 11, 27, 52	
20/06	7, 17, 32	40
22/03	5, 13, 23, 33, 43	
22/11	6, 30, 33, 37, 40	45
23/03	5, 18, 27, 37	

23/10	7, 12, 32, 37	45
24/03	10, 28, 34, 40	
24/13	5, 20, 30, 32, 40	45
25/03	8, 17, 32, 42	
26/03	8, 32, 47	
26/09	7, 17, 23, 32, 42	50
27/03	4, 12, 22, 32, 42	
27/12	4,12, 22, 32, 47	50
28/01	12, 22, 32, 38, 42, 52	
28/09	7, 17, 27, 42, 52	

Table 5.9.1. Samples taken for algal analysis

5.10 Phytoplankton identification using fluorescent *in-situ* hybridisation (FISH) (Tracy Anning)

Background

The work was carried out within the objectives of the EC-AIMS (Automatic identification and characterisation of marine microbial populations) project aiming at identification of microbial populations using flow cytometry.

To ensure accurate identification of cell populations during flow cytometric analysis oligonucleotide DNA probes specific to evolutionary conserved regions of ribosomal 18S rRNA gene were developed. These probes range from a higher group level (e.g. prymnesiophytes and dinoflagellates) down to the species level (*Gymnodinium mikimotoi*). Six of these probes were used during the cruise to identify a) phytoplankton populations from concentrated seawater by fluorescence microscopy, b) verify by fluorescence microscopy distinct populations that were identified and sorted by flow cytometry, c) identify distinct phytoplankton groups using FISH in conjunction with flow cytometry.

Collaboration was with Glen Tarran, Richard Jonker, Malcolm Wilkins, Andy Reul, Richard Geider and Georgina McDermott.

Methodology

Forty litres of water (integrated from different depths) was collected daily from above the thermocline (Table 5.10.1). Two litres of water were filtered onto a 3 um polycarbonate filter. The filtrate was filtered onto a 0.2 um polycarbonate filter. Both filters were stored at -20°C and will be used for DNA amplification in the laboratory (Rene Groben, Alfred-Wegener Institute (AWI)). The remaining water was concentrated to 100 ml by gravity filtration through a 0.2 um gasket filter. It was necessary to concentrate each water sample to ensure sufficient cell numbers for flow cytometry identification and sorting of cell populations.

2 x 5 ml of concentrate were collected onto 0.2um polycarbonate filters and fixed in ethanol for one hour. One filter was stored at 4°C for further *in-situ* hybridisation using additional probes (Rene Groben, AWI). The second filter was used during the cruise for identification of the phytoplankton community using the fluorescent probes in conjunction with fluorescence microscopy. Filters were hybridised with each of the six probes at 50°C. The filters were washed with SET buffer at the same temperature for five minutes and placed onto a new slide. 30 ul of DAPI/citifluor was added and the filters viewed under the microscope. Live cells were identified by DAPI fluorescence and positive hybridisation of the probes by green fluorescence. Images were captured on video.

6 ml of concentrate was further concentrated by centrifugation and the pellets combined in 0.5 ml of ethanol fixative. The cells were fixed for one hour. Subsamples were hybridised with each of the probes using the conditions described above but all hybridisations were carried out in solution. Following hybridisation the cells were resuspended in SET buffer, the cell suspension placed on a microscope slide and viewed by light and fluorescent microscopy. The remaining cell suspension was analysed by flow cytometry using green fluorescence (from the resulting hybridisations) and side scatter as the parameters to distinguish distinct populations.

Additional samples were taken from the concentrate for total RNA, protein, POC, chlorophyll and optical measurements.

Source ID	Sampling type	Station	Longitude (N)	Latitude (W)	Date/Time (BST)
17/02	CTD	Agnes	51°57'07	7°29'26	17-May-00 04:10
18/03	CTD	Belinda	52°09'01	5°53'40	18-May-00 04:30
19/04	CTD	Clarence	51°46'09	6°50'46	19-May-00 04:55
20/03	CTD	Delilah	51°49'06	5°39'08	20-May-00 04:20
22/03	CTD	Galen	51°30'19	7°19'48	22-May-00 04:52
23/03	CTD	Galen	51°28'54	7°18'62	23-May-00 04:03
24/03	CTD	Galen	51°29'75	7°21'06	24-May-00 04:49
25/03	CTD	Ernestine	50°10'79	8°35'96	25-May-00 04:52
26/03	CTD	Ernestine	50°09'69	8°36'50	26-May-00 04:40
27/03	CTD	Felicity	51°12'56	6°23'49	27-May-00 03:55
27/10	CTD	Felicity	51°13'07	6°21'94	27-May-00 12:45
28/01	CTD	Felicity	51°12'20	6°22'80	28-May-00 04:50

Table 5.10.1: Stations where samples were collected for analysis

Preliminary results and observations

Identification of phytoplankton by fluorescence microscopy.

There was limited success in identifying phytoplankton cells collected and hybridised on filters. Fluorescence was detectable under the microscope but was difficult to capture on video, and was of insufficient intensity to discriminate between populations. It was also difficult to verify the specificity of a probe as it was not possible to identify the cells by light microscopy.

Samples hybridised in solution showed a higher level of fluorescence, and although this was often masked by autofluorescence, it was possible to capture fluorescent images on video. The advantage of this method is the ability to capture a light image of the fluorescent cells and therefore verify probe specificity. Further analysis of video images will be undertaken at the laboratory.

It has not been possible during the cruise to identify cell populations that had been collected after flow cytometric sorting. On average there were only 5000-10000 cells collected in 25 ml of sheath fluid. Consequently cells were lost during concentration (necessary for *in-situ* hybridisation in solution) and were not detected under the microscope. It may be possible to identify sorted populations that were concentrated on a 0.2 um filter (as opposed to concentration by centrifugation) although problems encountered using filters (as described above) may occur. This analysis will be carried out in the laboratory (Rene Groben, AWI).

Identification of phytoplankton populations using FISH and flow cytometry

Initial analysis suggests that different cell populations can be identified using this method when analysing concentrated water samples. A distinct prymnesiophyte population was observed from Galen, 2603 and further analyses are underway.

5.11 Microplankton abundance and distribution in the Celtic Sea (Jason Mallard)

Aims

To assess the abundance and distribution of micro- and nanoplankton in waters varying in hydrographic properties in the Celtic Sea. Variation in microscale (cm) distribution of micro- and nanoplankton between mixed and stratified waters will also be examined. Taxa identification and enumeration will take place post-cruise, as will image analysis for biovolume, cell carbon content and potential ciliate gross production calculations.

Methods

Sampling: Table 5.11.1 lists the Rosette/CTD station and haul along with the range of depths sampled on each specific date. Samples were taken at all depths within the range noted, and fixed with Lugol's iodine (2% final concentration).

Microscale gradient sampler (MGS) high resolution sampling regime can be seen in Table 5.11.2.

Taxa identification and enumeration: All ciliates and dinoflagellates will be identified to genera and species level where possible. These will be enumerated by settling 25 ml sub-samples of the original 150 ml for 24 h following the Utermohl method (Hasle, 1978) and will be identified using a Ziess Axiovert inverted microscope. Nanoplankton (5 -20 μm) abundance will be estimated by counting >100 cells in random fields of the settling chamber. Flagellates will be separated into one of three size classes (5 to 10 μm, 11 to 15 μm and 15 to 20 μm).

Biovolume, cell carbon content and potential ciliate gross production: Using image analysis (Scion Image, Scion Corp), ciliate biovolume will be determined from linear measurements applied to basic geometric shapes. Cell carbon content of ciliate morphotypes will be estimated from mean biovolume (>30 cells) following Putt and Stoecker (1989).

Potential ciliate production will be calculated by estimating maximum growth rate (μ_{max}) from cell volume and ambient temperature.

Microscale sampling: High resolution sampling (10 samples over 2 m, spaced 15cm apart) was undertaken in both stratified and mixed regions. To estimate 'patchiness' and therefore variation between regions, replication (x3) of micro-sampler hauls within a mixed and a stratified region were undertaken. To statistically strengthen this, two sites within each region were also sampled. Adding further interest to this study we also sampled at two different depths, ~1 m and ~10 m (3 x replication x 2 regions x 2 places x 2 depths).

Multiple hauls of the MGS throughout the water column were also used to examine change across the thermocline.

Date	Station	Location	Range of Depths
16/5/00	16/4	51 10 9N 6 50.2W	62 -3
17/5/00	17/2	51 57N 7 29.1W	46 - 4
	17/10		27 - 5
18/5/00	18/3	52 09N 5 53.5W	62 - 4
	18/6	51 45 04N 6 44.8W	50 - 2
19/5/00	19/4	51 46 98N 6 50.35W	63 - 5
	19/11	51 48 16N 5 41.42W	62 - 7
20/5/00	20/3	51 49 20N 5 39.2W	75 - 4
22/5/00	22/3	51 30 14.9N 7 19 45W	62 -2
	22/11		40 - 6
23/5/00	23/3	51 28 46N 7 19.01W	62 - 5
23/5/0	23/10	51 30N 7 21W	52 - 7
24/5/00	24/3	57 29.8N 7 20.4W	40 -28
	24/13	51 29.8N 7 23.6W	40 - 5
25/5/00	25/3	50 13.7N 8 35.7W	

Table 5.11.1. CTD/Rosette station, location and depth range sampled between 16/5/00 and 27/5/00

Date	Station	Location	Range of depths (10 samples over 2 m)
19/5/00	19/13	51 46.8N 6 50.2W	2.35 -1
	19/14		same
	19/15		same
20/5/00	20/10	52 7 59.6N 5 54.39W	10 - 8.65
	20/11		same
	20/12		same
23/5/00	23/12	57 28. 96N 7 19.01W	10 - 8.65
	23/13		same
	23/14		same
24/5/00	24/	51 29.8N 7 23.6W	2.35 - 1

	24/		same
	24/		same
25/5/00	25/15	50 59.3N 7 38.9W	50 - 48.65
	25/16		30 - 28.65
	25/17		10 - 8.65
27/5/00	27/17	51 12.9N 6 22.8W	10 - 8.65
	27/18		same
	27/19		same

Table 5.11.2. MGS station, location and depth range.

5.12 **Microplankton** (Andreas Reul)

Objectives

a) To estimate the biomass (biovolume) of photoautotrophic microplankton (>20µm), not covered by flow cytometry, to evaluate their contribution to total phytoplankton biomass.

b) Elaboration of the microplankton size-spectra and, if possible, of the whole phytoplanktonic community in junction with flow cytometry measurements.

Methods

Two to four litre samples were taken from all depths of each CTD-rosette cast during the cruise. Sampling sites are shown in Table 4.1. Each sample was processed as follows:

i) 2-4 litres of each sample were filtered through a 20 µm pore mesh by gravity.

ii) The retained particles were recovered by washing the mesh with filtered seawater into 125 ml glass bottles.

iii) The concentrated samples were fixed with non-acetic Lugol solution (f.c. 2%).

At selected depths near the thermocline, additional subsamples were taken from the concentrates before fixing to analyse them with the Cytobuoy (Richard Jonker) and afterwards with the inverted microscope (see preliminary results by Georgina McDermott).

When possible, seven litres from each depth were filtered through 20µm mesh to better estimate the integrated microplankton biomass. More detailed analysis in terms of phytoplankton size-spectra will be carried out by image analysis (Image Pro and Vids IV) in the laboratory.

List of samples not considered in the standard sample design:

a) Integrated and concentrated samples: Stations 20/06, 23/10 and 27/12

b) Concentrated samples analysed with the Cytobuoy.

Station	Depth (m)
22/11	32
23/03	27
24/03	34
25/03	13
26/03	32
27/03	17
28/01	40

Table 5.12. Samples analysed with the Cytobuoy

In collaboration with Glen Tarran, I was involved in the framework of flow cytometry analysis, charged to carry out the sorting on the FACSort for further analysis (see Report Glen Tarran).

Possible future collaboration:

a) Flow Cytometry with Glen Tarran (PML): a) to compare the contribution of pico-, nano-, and microplankton to total phytoplanktonic biomass in the different sample sites; and b) to determine size-spectra for the whole phytoplanktonic community.

b) Cytobuoy with Richard Jonker (Aquasense): a) to compare of cell size (>20μm) measured by image analysis with light scatter measurements from the CytoBuoy carried out on natural samples, as a first step towards an automated measurement of natural microplankton size distribution.

c) Turbulence with John Howarth (CCMS/POL) and Chris MacKay (Sytech) and nutrients with Andy Rees and John Stephens (CCMS/PML): a) to study the coupling between hydrodynamics (turbulence), nutrient availability and phytoplankton size-spectra, a key factor for the pathways of phytoplankton biomass flux through the pelagic food web, and/or its export towards the seafloor.

5.13 Microbial Community Structure by Flow Cytometry (Glen Tarran)

The primary objectives of the cruise were to study phytoplankton communities in waters of contrasting physical status throughout the Celtic Sea region from standard CTD rosette casts and high resolution (15 cm) casts. It was hoped that the different physical regimes would result in differing phytoplankton communities, providing a suitable focus to test techniques and technology developed within the EC MAST AIMS project (Automated Identification and Characterisation of Microbial Populations MAS3-CT97-0080).

Specific objectives and collaborations

These are shown in Table 5.13.1 below

Objective	Activity	Collaboration
1	Quantification of phytoplankton (<1μm - ~50μm) – Spatial and vertical studies from Level 1 CTD's and underway	Richard Jonker with CytoBuoy flow cytometer
2	Quantification of phytoplankton (<1μm - ~50μm) – over fine scales (15 cm resolution) using Microscale Gradient Sampler (MGS)	Jason Mallard Richard Jonker
3	Analysis, sorting and preservation of concentrated seawater samples for oligonucleotide probe development, neural network and microscopic verification.	Tracy Anning Andreas Reul Malcolm Wilkins Richard Jonker Elaine Fileman
4	Microscopic analysis and video recording of live concentrated seawater samples for phytoplankton identification.	Tracy Anning
5	Analysis of probed seawater samples by flow cytometry	Tracy Anning

Table 5.13.1. Objectives and collaborations

Methods

Samples for phytoplankton quantification were collected from the CTD in 125 ml polycarbonate bottles and were then kept in the dark at 4°C until analysed (< 1h). Samples for analysis from the Microscale Gradient Sampler (MGS) (sampler methods elsewhere) were collected in 15 ml polypropylene tubes and stored in the same way as CTD samples. Samples were analysed for 3 minutes on a Becton Dickinson FACSort flow cytometer, modified to analyse at a flow rate of approx. 95 μl min^{-1} (determined with beads of known concentration). Measurements of light scatter and auto-fluorescence were collected and stored on disk as listmode data for subsequent quantification of coccolithophores, small (<50 μm) dinoflagellates, picoeucaryotes, cyanobacteria (*Synechococcus* sp.) and other phytoplankton. These analyses will compliment analyses made by Richard Jonker using the CytoBuoy flow cytometer which specialises in quantifying larger phytoplankton.

Cell sorting for AIMS-related activities was carried out using samples concentrated by gravity filtering 12 – 60 l of seawater (Tracy Anning and Elaine Fileman). Concentration was carried out using Gelman 0.22 μm capsule filters. A small volume of seawater was retained in the filter before

running dry; the filter was shaken and the retentate (40 – 100 ml) was then poured into a 250 ml polycarbonate bottle and stored in the refrigerator. Phytoplankton groups were sorted for oligonucleotide probing by Tracy Anning and Rene Groben (Alfred Wegener Institute, Germany) and microscopic verification of preserved samples. Some probed samples were also analysed on the flow cytometer to see if they had been successful using a combination of side scatter and green fluorescence emitted from the probe. This aspect of the work is outlined further in this report by Tracy Anning.

Samples of live concentrated material were also analysed by microscopy in a 3 ml settling chamber base (x60 objective, x1.5 magnifier) and videoed to provide information on community structure which could not be achieved from preserved material, particularly as some species are best identified by seeing how they swim.

Summary of research

Date	Time (BST)	Cast	Operation	Station	Latitude (°N)	Longitude (°W)	Depths (m)
16-17 May	1300-0130		Non-toxic supply	Underway	50.35 – 51.86	6.13 – 7.45	4
16-May	19:37	16/04	CTD	G	51.18	6.84	3-62
17-May	4:36	17/02	CTD	Agnes	51.95	7.49	4-46
17-May	13:47	17/10	CTD		52.10	6.84	5-27
17-May	21:00	17/21	MGS		52.21	5.86	0.70-2.05
18-May	5:55	18/03	CTD	Belinda	52.15	5.89	4-62
18-May	16:23	18/06	CTD	Clarence	51.76	6.75	2-52
18-May	17:00	18/08	MGS	Clarence	51.75	6.76	33.65-35.00
19-May	5:15	19/04	CTD	Clarence	51.78	6.84	5-63
19-May	13:36	19/11	CTD	Delilah	51.82	5.70	7-62
19-May	14:01	19/13	MGS	Delilah	51.81	5.01	0.90-2.25
20-May	4:49	20/03	CTD	Delilah	51.83	5.65	4-75
20-May	14:15	20/06	CTD	Belinda	51.17	5.87	7-53
20-May	15:24	20/10	MGS	Belinda	52.13	5.91	5.65-7.00
22-May	5:03	22/03	CTD	Galen	51.50	7.33	5-62
22-May	13:38	22/11	CTD	Galen	51.52	7.33	6-40
22-May	15:40	22/15	MGS	Galen	51.51	7.33	38.65-40.00
23-May	5:03	23/03	CTD	Galen	51.47	7.32	5-62
23-May	13:03	23/10	CTD	Galen	51.50	7.35	7-52
23-May	13:39	23/12	MGS	Galen	51.50	7.36	8.65-10.00
24-May	5:05	24/03	CTD	Galen	51.50	7.34	7-40
24-May	13:04	24/13	CTD	Galen	51.50	7.39	5-40
24-May	14:15	24/17	MGS	Galen	51.50	7.41	8.65-10.00
25-May	5:15	25/03	CTD	Ernestine	50.18	8.60	5-102
25-May	13:08	25/11	CTD	Ernestine	50.17	8.65	7-72
25-May	14:46	25/15	MGS	Ernestine	50.15	8.66	8.65-10.00
26-May	5:02	26/03	CTD	Ernestine	50.17	8.59	8-63
26-May	13:02	26/09	CTD	Ernestine	50.16	8.58	7-102
27-May	5:06	27/03	CTD	Felicity	51.22	6.39	4-62
27-May	13:04	27/12	CTD	Felicity	51.22	6.38	4-62
27-May	14:10	27/17	MGS	Felicity	51.22	6.36	8.65-10.00
28-May	4:38	28/01	CTD	Felicity	51.20	6.38	12-62
28-May	12:05	28/09	CTD	Felicity	*51.2*	*6.38*	*7-92*

Table 5.13.2. Underway sampling and CTD's

Comments

Objectives for the cruise were met successfully. Stations studied covered a range of physical regimes, from well mixed to strongly stratified waters with diverse phytoplankton communities associated with them. An important aspect of the post-cruise analysis will be to characterise and quantify the phytoplankton species associated with the different stations. This will be achieved, partly through the analysis of preserved samples of concentrated seawater and cells sorted by flow cytometry. An additional method will be the analysis of approx. 2.5 hours of video recording which will be used to identify nanoflagellate species. I would like to thank Elaine Fileman for access to

the microscope and for providing the video tape which will enhance our understanding of the phytoplankton community structure present during the cruise.

5.14 **CytoSense** (Richard Jonker)

Objectives and collaborations

CytoSense analysis was carried out in the framework of the EC-AIMS project, aiming at identification and characterisation of microbial subpopulations using flow cytometry.

Analysis with the CytoSense was performed with the following specific objectives:

- Analyse flow cytometrically the size range of particles from 1µm - 1 mm;
- Identification of subpopulations within the phytoplankton using the standard flow cytometric parameters (light scatter and fluorescence of individual particles);
- Intercalibration with other flow cytometers, in this case the FACSort flow cytometer;
- Identification of particle profiles of individual cells;
- Building of a database of pulse profiles from various species, focusing on diatoms and dinoflagellates;
- Provide data for artificial neural net analysis and optical characterisation of phytoplankton.

Collaboration was with the other AIMS research activities, including Glen Tarran (flow cytometry, FACSort), Andy Reul (size distributions), Tracy Anning (taxon-specific probes), Richard Geider (optical measurements) and Malcolm Wilkins (artificial neural net analysis), as well as with Georgina McDermott (phytoplankton analysis) and Jason Mallard (microgradient analysis).

Methods

The CytoSense is an autonomous flowcytometer, designed for *in-situ* analysis of phytoplankton and other particles. It was developed in the EC project CytoBuoy (Dubelaar *et al.*, 1999, Cytometry 37, 247-254). The CytoSense has a 5 µm laser focus, through which the cells traverse in a fluid stream. The signals (forward scatter, side scatter, red- and orange fluorescence) were digitised at high frequency (3 MHz), resulting in pulse profiles of the individual particles. The pulses were both converted into standard flow cytometric parameters and available for morphological analysis, i.e., individual cells in colonies of diatoms can be easily picked up, as well as dividing cells. The resolution of the details is limited by the focus of the laser beam (5µm).

The CytoWave software was used for analysis of the data, including transformation of data, automated analysis and pulse profile analysis of CytoSense data.

Summary of research

In table 1 an overview is given of CTD- and microgradient samples (MGS) casts from which samples were analysed with the CytoSense. Samples were analysed from all depths. Samples were also analysed from concentrates that were made by Andy Reul (>20µm, from 18/06 till end), Tracy Anning and Elaine Fileman (both cartridge filters), when available, as well as from Georgina McDermott (plankton net, 18, 19, 22 May).

During the return to Southampton (28-29 May) CytoSense has performed on-line measurements on the non-toxic supply every 10 minutes.

Comments and preliminary results

Preliminary analysis of the CytoBuoy data showed that the quality of the profiles allows for identification of some dinoflagellates and diatoms. Since the amount of analysed volume per measuring cycle is rather low (ca. 300 - 600 µl) and the concentration of the fraction of the plankton larger then 20µm is low, measurements were carried out in triplicate, both to collect more data and to have triplicate concentration measurements.

Clusters of the analysed samples could be identified as cyanobacteria, cryptophytes, coccolithophores, other eukaryotes, small dinoflagallates, large dinoflagellates/diatoms, Nitschia-like diatoms and large diatom colonies. The detection level of the CytoSense is around 2 µm, so that detection of small cyanobacteria and other small cells is limited.

Examples of CytoSense profiles of *Nitschia* sp. and *Dinophysis* sp. are depicted in figure 5.14.1 and 5.14.2. A depth profile of some groups is depicted in figure 5.14.3. It shows the chlorophyll maximum, resulting mainly from diatoms. Further analysis will be focused on identifying species, analysis of the morphological information of the pulse (cells size, localisation of chlorophyll in the cells etc.) and intercalibration with image analysis and the FACSort flow cytometer.

Source ID	Sampling type	Station	Longitude (N)	Latitude (W)	Date/Time (BST)
17/02	CTD	Agnes	51°57'07	7°29'26	17-May-00 04:10
17/10	CTD		52°06'02	6°50'20	17-May-00 12:30
18/03	CTD	Belinda	52°09'01	5°53'40	18-May-00 04:30
18/06	CTD	Clarence	51°45'06	6°44'90	18-May-00 12:30
19/04	CTD	Clarence	51°46'09	6°50'46	19-May-00 04:55
19/11	CTD	Delilah	51°49'04	5°41'70	19-May-00 13:05
20/03	CTD	Delilah	51°49'06	5°39'08	20-May-00 04:20
20/06	CTD	Belinda	52°10'12	5°52'12	20-May-00 14:00
22/03	CTD	Galen	51°30'19	7°19'48	22-May-00 04:52
22/11	CTD	Galen	51°30'41	7°20'09	22-May-00 13:03
22/15	MGS	Galen	51°30'51	7°19'60	22-May-00 15:40
22/16	MGS	Galen	51°30'34	7°19'60	22-May-00 16:08
23/03	CTD	Galen	51°28'54	7°18'62	23-May-00 04:03
23/10	CTD	Galen	51°30'00	7°21'00	23-May-00 12:43
23/12	MGS	Galen	51°30'19	7°21'57	23-May-00 13:52
24/03	CTD	Galen	51°29'75	7°21'06	24-May-00 04:49
24/13	CTD	Galen	51°29'52	7°24'70	24-May-00 13:04
24/17	MGS	Galen	51°29'78	7°24'68	24-May-00 14:15
25/03	CTD	Ernestine	50°10'79	8°35'96	25-May-00 04:52
25/11	CTD	Ernestine	50°09'47	8°38'91	25-May-00 12:49
26/03	CTD	Ernestine	50°09'69	8°36'50	26-May-00 04:40
26/09	CTD	Ernestine	50°09'26	8°34'59	26-May-00 13:02
27/03	CTD	Felicity	51°12'56	6°23'49	27-May-00 03:55
27/12	CTD	Felicity	51°13'07	6°21'94	27-May-00 12:45
27/17	MGS	Felicity	51°13'58	6°21'25	27-May-00 14:30
28/01	CTD	Felicity	51°12'20	6°22'80	28-May-00 04:50

Table 5.14.1. CytoSense measurements performed during the PROPHEZE cruise

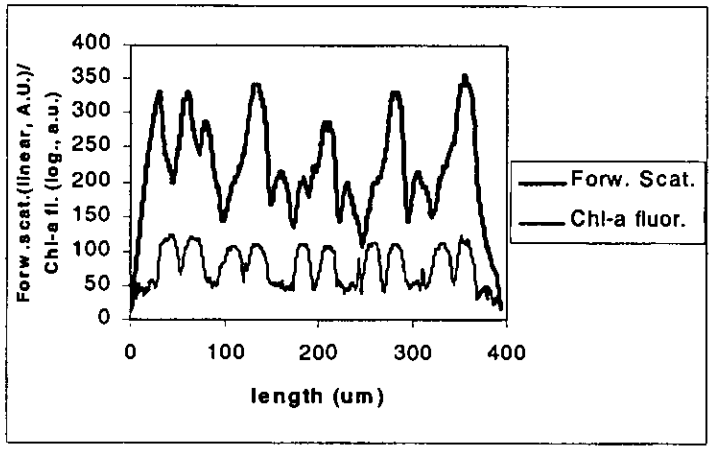


Figure 5.14.1. CytoSense profile of Nitschia sp. *Signals of forward scatter and red chl-a fluorescence are depicted as a function of time, converted to particle length.*

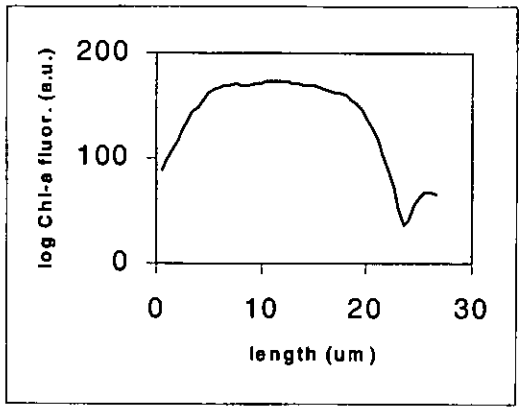


Figure 5.14.2. CytoBuoy profile of Dinophysis sp. Signals of forward scatter and red chl-a fluorescence are depicted as a function of time, converted to particle length.

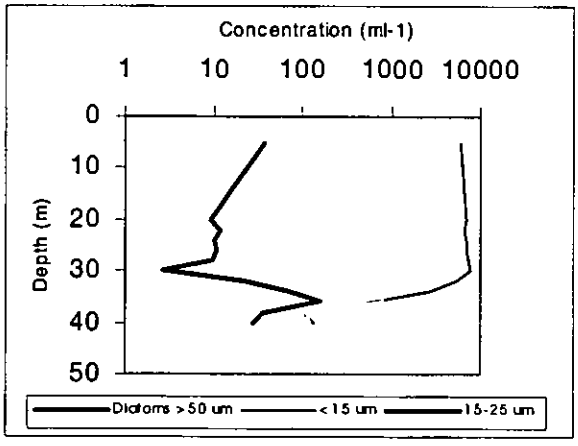


Figure 5.14.3. Profile of 24/03, station Galen, with a well developed chlorophyll maximum at 34 m.

5.15 Particulate Absorption (Richard Geider)

Light absorption by phytoplankton is key to understanding primary productivity in the sea and to the interpretation of ocean colour images. The particulate absorption measurements will be employed in conjunction with optical characterisation (Aiken, Smyth) and HPLC pigment measurements (Cummings) to determine the impact of phytoplankton on the optical properties of coastal waters. These measurements will also be employed in conjunction with fast repetition rate fluorescence (FRRF) measurements to estimate primary productivity (Geider, Aiken). Finally, the measurements will be used in conjunction with flow cytometry to partition light absorption amongst the dominant groups of phytoplankton.

Methodology

Samples were collected on glass fibre filters (Whatman GF/F) and stored at -80 °C for particulate absorption measurements. Particle absorption will be measured with a Hitachi U3000 spectrophotometer fitted with an integrating sphere, with correction for "detrital" absorption after bleaching pigments. Cast numbers and sampling depths are as follows.

Cast Number	Depths (m)
17/10	15, 10, 5, 2
18/03	30, 25, 20, 15, 10, 5, 2
18/06	30, 20, 10, 5, 2
19/04	30, 25, 20, 15, 10, 5
19/11	30, 20, 15, 10, 5
20/03	30, 25, 20, 10, 5
20/06	30, 20, 15, 10, 5
22/03	30, 25, 20, 15, 10, 5, 2
22/11	30, 6
22/19	30, 25, 20, 15, 10, 5, 2
23/03	60, 35, 30, 25, 20, 10, 5
23/10	20, 15, 10, 5
24/03	20, 10
24/10	20, 20, 10, 5
24/13	30, 20, 5
24/25	30, 20, 10, 5
25/03	30, 25, 20, 15, 10, 5, 2
25/11	50, 40, 30, 20
25/13	15, 10, 5
25/24	20, 10, 5
26/03	30, 25, 20, 5
26/09	30,25, 20, 15, 10, 5
27/03	30, 25, 20, 15, 10, 5, 2
27/12	30, 25, 20, 15, 10, 5, 2
27/23	20, 10, 5
28/01	30, 5
28/09	30, 25, 20, 15, 10, 5

Table 5.15.1. Cast numbers and sampling depths

5.16 Fast Repetition Rate Fluorescence (FRRF) (Richard Geider and Jim Aiken)

FRRF allows the rapid, *in-situ* assessment of several variables related to the cross-section and efficiency of photosystem II (PSII), from which PSII-specific photosynthesis rates (strictly, electron transfer rates) can be calculated. The absolute values of fluorescence of dark-adapted cells can also be used as an index of pigment concentration in much the same way as conventional fluorometers. However, this index suffers from fluorescence quenching in bright light. Together with measurements of chlorophyll *a* concentration, and an assumption of the chl *a*:PSII ratio, chl *a*-specific photosynthesis rates can be calculated. In addition, changes of fluorescence variables throughout the day can be used to assess the responses of the photosynthetic apparatus to changing irradiance.

Methodology

FRR fluorescence was measured with a Chelsea Instruments FAST-TRACKA (Ser No182018), operated with version 1.10 control software. The acquisition sequence consisted of 100 saturation flashes and 20 relaxation flashes, with 10 ms sleeptime between acquisitions. The flash duration was set to either 4 or 8. Depth and irradiance (Chelsea Instruments hemispherical PAR sensor Ser No 046024) were measured and logged in conjunction with each FRRF acquisition. The internal clock was set to GMT. The instrument was operated in the autogain mode. The data was logged on the internal flashcard, downloaded and analysed using the software provided by Chelsea Instruments analysis and definition file 18210.2000120. Data flagged by error codes of 1 or value codes of 1 or 2 were deleted from the processed files, as were data that showed saturation of the photomultiplier.

The FRR fluorometer was operated either on the CTD, in which case the instrument was oriented vertically with the LED array facing upwards, or on an optical rig in which case it was oriented horizontally with the LED array facing towards the side. FRRF measurements made in conjunction

with a CTD cast are designated by the suffix c in the attached table, whereas those made in conjunction with an optical cast are designated by the suffix o.

Results

All results presented in this report are based on a preliminary analysis of the FRRF data. They are indicative, but absolute values may change with further analysis of the data.

Dark or low-light adapted values. Dark-adapted values of σ_{PSII} and F_v/F_m (Table 5.16.1) were obtained from averaging the values over the mixed layer for early-morning stations in which solar mediated near-surface fluorescence quenching was not evident. The phytoplankton photosynthetic characteristics determined from FRRF fell into two categories. The stations that were well mixed to the bottom (casts 1720, 1803, 2003 and 2101) were characterised by low values of the functional cross-section of PSII (i.e., σ_{PSII} of about 300 A^2). The other stations were characterised by higher values of σ_{PSII}. The ratio of variable to maximum fluorescence of dark-adapted cells fell within a narrow range (F_v/F_m = 0.39 - 0.46), the lowest value being observed on cast 2403.

Cast No	Depths	F_v/F_mD		σ_{PSII}		τ	
		Light	Dark	Light	Dark	Light	Dark
1720	2-80	0.461	0.464	310	310	1363	1452
		(0.068)	(0.038)	(26)	(27)	247	160
1803	2-80	0.464	0.464	300	306	1507	1490
		(0.068)	(0.050)	(23)	(23)	281	166
1904	5	0.420	0.429	461	478	1732	1763
		(0.011)	(0.010)	(11)	(19)	107	216
2003	2-25	0.461	0.447	298	295	1628	1623
		(0.051)	(0.039)	(28)	(29)	214	253
2101	2-80	0.428	0.450	307	293	1759	1684
		(0.062)	(0.037)	(26)	(30)	243	255
2204	2-20	0.423	0.438	502	518	2187	1884
		(0.021)	(0.014)	(20)	(21)	224	134
2403	2-20	0.387	0.393	526	530	2189	1975
		(0.015)	(0.012)	(17)	(17)	227	260
2503	2-20	0.428	0.427	482	491	2002	1881
		(0.022)	(0.015)	(13)	(14)	132	127
2603	2-20	0.422	0.423	500	503	1856	1760
		(0.024)	(0.016)	(27)	(19)	144	131
2703	2-20	0.434	0.437	480	484	1949	1845
		(0.012)	(0.013)	(20)	(18)	203	150
2801	2-40	0.418	0.408	498	497	1838	1882
		(0.025)	(0.034)	(24)	(28)	(411)	(199)

Table 5.16.1: Mean and standard deviation (in parentheses) of fast repetition rate fluorescence parameter values for low-light or dark acclimated samples (no trend within mixed layer).

Fluorescence quenching. Near-surface quenching of both the maximal fluorescence, F_m, and of F_v/F_m was evident at most stations. The extensive wire time that was made available for FRRF measurements provides an extensive data base for evaluation of the photophysiological responses of phytoplankton to changing light and mixing regimes during the day.

Photosynthetic parameters. We derived the parameters of the photosynthesis-irradiance (PI) response curve from measurements of the variables F_v/F_mL and σ_{PSII}. The light-saturation parameter, I_K, was estimated by fitting observations of F_v/F_mL to the function; $A[1-\exp(-I/I_K)]/I$, where $A = [F_v/F_mL(MAX)]\ I_K$. The numerical values of σ_{PSII} were converted to σ_{chl} as follows; $\sigma_{chl} = 0.013498\ \sigma_{PSII}$. The constant in this equation is based on the assumption of a photosynthetic unit size of 500 chl/PSII. It also includes conversion factors of 10^{20} A^2/m^2; 892 g chl *a*/mol chl *a*, and 6.02 10^{23} molecules/mol. This allowed the conversion of σ_{PSII} (with units of A^2/photon = A^2/RCII) to σ^{chl} (with units of m^2/g chl). The initial slope of the PI curve was then calculated as $\alpha^{chl} = 2.5\ \sigma_{chl}$ $[F_v/F_m(MAX)/0.65]$. The factor of 2.5 (i.e., 2.5 = 0.25 12/1.2) arises from two processes and a conversion from mol C to g C. First, 4 photons must be delivered to RCII in order to evolve 1 O_2,

hence a factor of 0.25 O_2/photon. Second, a photosynthetic quotient of 1.2 O_2/CO_2 was assumed. Finally, this factor also includes the molecular weight of carbon (12 g C/mol C). The term [F_v/F_m(MAX)/0.65] accounts for the decline in quantum efficiency due to "inactive" photosystems. Thus, α^{chl} has units of (gC/mol photons)(m^2/g chl). The light-saturated photosynthesis rate was calculated as P_m^{chl} =0.0036 α^{chl} I_K, where the factor of 0.0036 accounts for the conversion of seconds to hours and mol photons to µmol photons.

Date	σ_{PSII}	σ_{chl}	F_v/F_m	α^{chl}	I_K	P_m^{chl}
17-May	305	4.12	0.46	7.32	-	-
18-May	303	4.09	0.46	7.30	-	-
19-May	470	6.34	0.42	10.35	-	-
20-May	297	4.00	0.45	6.99	-	-
21-May	300	4.05	0.44	6.84	-	-
22-May	510	6.88	0.43	11.4	59.8	2.45
23-May	519	7.01	0.41	11.1	33.4	1.33
24-May	528	7.13	0.39	10.7	53.2	2.05
25-May	487	6.57	0.43	10.8	49.7	1.93
26-May	502	6.77	0.42	11.0	53.0	2.10
27-May	482	6.51	0.44	10.90	47.9	1.88
28-May	493	6.65	0.41	10.56	46.4	1.76

Table 5.16.2: Summary of FRRF and derived photosynthesis-irradiance (PI) curve parameters. Note that F_v/F_m and σ_{PSII} were derived from the pre-dawn casts (except for 23 May which was based on mean of 22 May and 24 May data for the same station), whereas I_K was derived from the composite of day-light casts. Units are as follows: σ_{PSII}, A^2/PSII; σ_{chl}, m^2/g chl; F_v/F_m, dimensionless; α^{chl}, (m2/gchl)(gC/mol photons); I_K, µmol photons m^{-2} s^{-1}; P_m^{chl}, gC/(g chl h).

5.17 Neural networks (Malcolm Wilkins)

Objectives

These were to evaluate the use of RBF ANNs in analysis of AFC data collected during the cruise, and to validate the results as far as possible by means of microscopic analysis of concentrates and sorted concentrate fractions. A two-fold approach was adopted: training a network on previously-collected data from laboratory cultures, and training a network using clusters of data manually extracted from the data collected during the cruise.

Pure culture network

The network, designated PC, was trained using 5-parameter FACS data (FSC-H, SSC-H, FL1-H, FL2-H, FL3-H) obtained for 46 species in pure culture from an experiment conducted between 03-07 April at PML (data was also obtained for *Synechococcus* by analysis of a sample obtained from Plymouth harbour). This network had 66 HLNs and correctly identified 60.3% of the training data. 25.6% of the training data was rejected as unidentifiable, but 81.1% of the remaining data were correctly identified; data was deemed unidentifiable if the highest-valued network output was less than 0.2 or the difference between the highest and second-highest network outputs was less than 0.1.

In applying this network to the cruise data, two problems were encountered. The first was that the flow cytometer signatures, as determined by standard beads, had shifted between the date of the April experiment and the cruise. This was addressed by using CytoWave software to apply a linear offset to the cruise data prior to analysis by the network, an approach which had previously been found to be reasonable during the mesocosm experiment; this linear offset of the logarithmic data corresponds to a multiplicative scaling of the original data. The size of the offset was selected so as to move the mean of the PROPHEZE bead cluster to the position of that at the time of the April data collection. The second problem was that typically over 90% of the data was rejected by the above rejection criteria leading to unrealistically low concentration estimates, even for species found by microscopic examination to be present. This is an indication of the extent of the difference

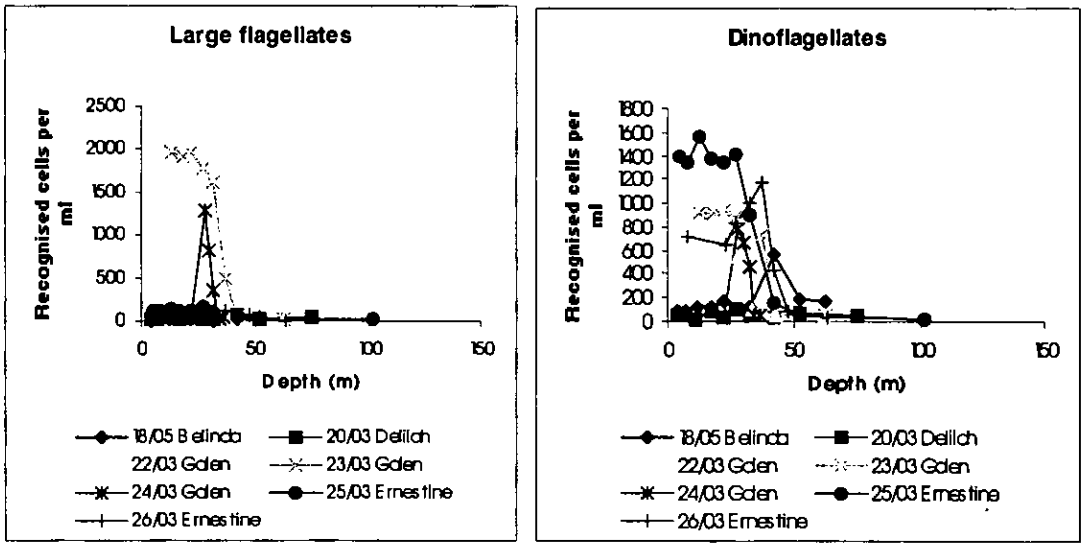
between the AFC distribution of a species in culture and the corresponding distribution in the field. For data points falling far from any training data distribution, the outputs of the HLNs of an RBF tend to zero; however the outputs tend towards small, but non-zero, values, due to the presence of a "bias node" within the hidden layer for which the output is always held at 1.0. Beyond a certain distance, the effect of the bias HLN was found to be masking the small contribution from the remaining HLNs, preventing identification being made. This problem was addressed in two ways: firstly combining species from the April data set into 14 groups on the grounds of flow cytometric similarity, to force identifications to be made at a genus or group level rather than a species level; secondly by modifying the RBF algorithm to exclude the effect of the bias node, allowing tentative identification to be made even where output values are close to zero. To facilitate comparison of the data clusters, the data dimensionality was reduced by omitting the FL1-H parameter (depolarised light scatter).

The revised network (designated G2) had 40 HLNs and 15 outputs (an extra group having been added to represent flowset beads). Using a weaker rejection threshold of 0.05 on the maximum network output value, G2 correctly identified 81.0% of an independent test set of data.

Field sample network

Eight principal clusters were identified and sorted by 2D gates within the AFC data from the concentrate of 22/03 (Galen), with the exception of the coccolithophores, which came from 26/03 (Ernestine), and the sort data collected. The clusters were assigned provisional names based on their likely identity (coccolithophores, cryptophytes, cyanobacteria, dinoflagellates, large, medium and small flagellates, and *Micromonas pusilla*). The raw sort data frequently contained minor distinct sub-populations (probably attributable to the inclusion within the sort gates of populations overlapping the desired population in 2D projection); the data were cleaned up by 3D principal component analysis to remove these. This procedure revealed two distinct subpopulations within the large and medium flagellate clusters distinguished by differing forward scatter, which were therefore assigned to separate classes. A flowset bead class and a "noise" class representing data with low red fluorescence were also added, giving a total of 12 classes. A network (designated FS) was trained on this data; the resulting network had 30 HLNs and performed extremely well (>99.4% overall) on the corresponding test data.

Preliminary results



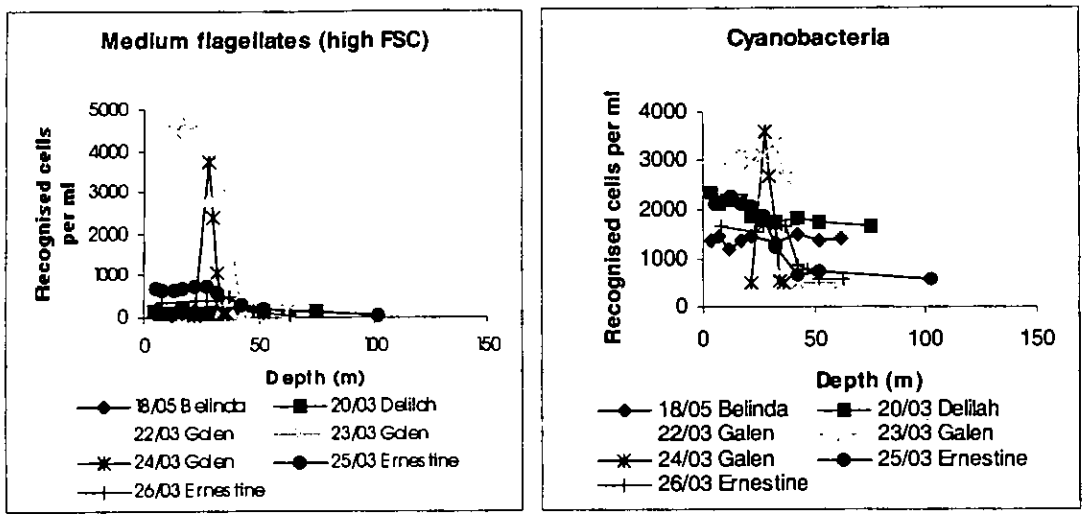


Fig 5.17.1. Sample results of analysis by FS. No unknown rejection criterion was applied to the network outputs.

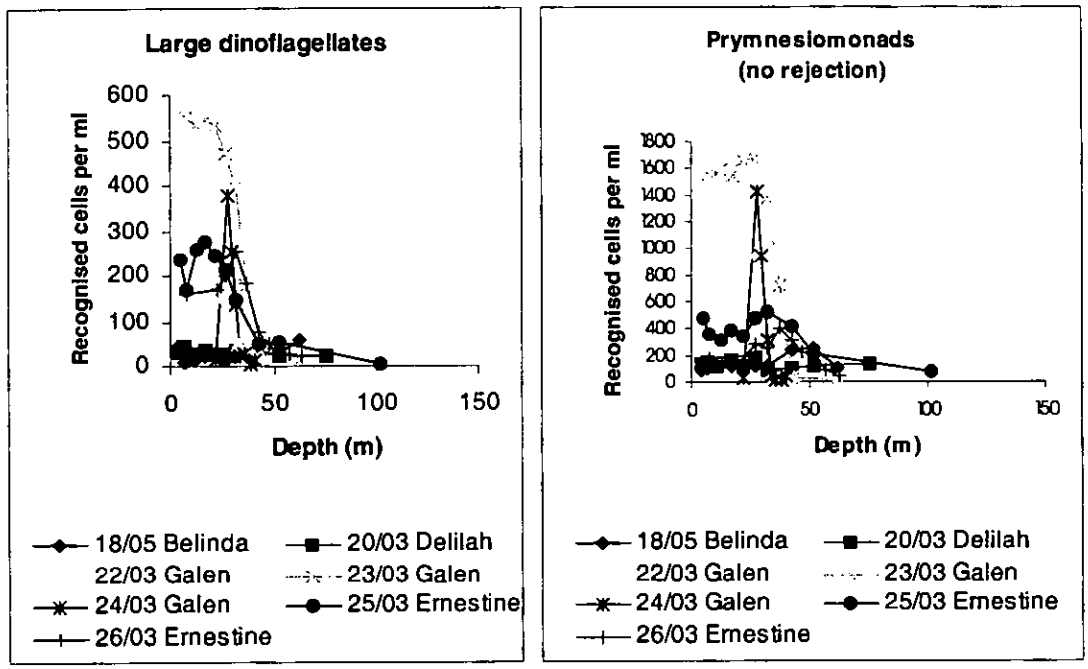


Fig 5.17.2. Sample results of analysis by G2. No rejection criterion was applied to the network outputs.

The concentrations found for the prymnesiomonad class identified by G2 corresponded closely to those for the large flagellate class identified by FS. The cyanobacteria concentrations found by FS closely matched those of the *Synechococcus* class found by G2 (however the *Synechococcus* data used by G2 was actually obtained from a field sample). Other classes did not match: G2 appeared to show surface concentrations of *E. huxleyi* around 2500 cells/ml at Galen, while FS found no coccolithophores. Full results will be available at a later date.

Discussion

Software. The cruise highlighted a number of areas of the AimsNet software where there is room for improvement. For example, DSF data files need to optionally include a "calibration file", for example a bead run file, to which the actual data is relative. This would allow much easier recalibration of data to remove the effects of shifts (for instance due to cytometer settings, or, where two corresponding clusters are found in field samples, to changing abiotic conditions). There are other minor changes and enhancements to the interface which would greatly ease the task of the operator.

Algorithm. The RBF algorithm used within AimsNet is fairly sensitive to deviations from the training data. Where the object is maximal discrimination of multiple data clusters with no cluster shift, this

approach is ideal. With even fairly moderate cluster shift, the result is that most of the data shows very low identification values (>0.01) and may be rejected as unknown. One approach is simply to accept all identifications made by the network, no matter how tenuously; however variants of the RBF algorithm (normalised RBF) are designed specifically to allow identifications to be made across the whole data space and may generalise more reliably.

Proportion estimates. The proportion estimation algorithm developed at Cardiff requires the assumption that the probability distribution of the classes in the training data used to calibrate the algorithm is representative of that in the sample to be analysed. This assumption is grossly violated in analysis of field samples, and the algorithm therefore cannot be used in its present form to give useful proportion estimates for this data. The only results possible are concentrations of recognised particles per unit volume.

Further work

Short term The results of these analyses must be validated against the output of a traditional microscopic analysis of the sort fractions and concentrates. Specifically the names of the classes used by the field sample network need to be verified, and lists obtained of species present in significant numbers; if at all possible combined with estimates of relative abundance of the different identifiable species groups. The ANN analysis procedure can then be verified by analysing sort fractions of a different set of data (e.g. different day, different station, different depth) from that used in training the network.

It should be possible to use the field sample analysis network in a "bootstrap mode", progressively incorporating the results of analysis back into the training data and thereby improving the identification reliability; however some changes to AimsNet will be needed for this to be practical.

Long term The cruise has highlighted the requirement for a cluster tracking algorithm (performing correspondence analysis between sets of clusters in different data sets). Data sets normalised by such an algorithm would be much more amenable to automated ANN analysis. Development of such an algorithm is not trivial, requiring as a first step a reliable method of cluster extraction from AFC data: this is currently under research at Cardiff.

5.18 Primary production and photosynthetic parameter determination (Katharine Woods)

Aims:

There were two main aims of the work. The first was to measure variability in primary production over the study area. The second aim was to compare the values of photosynthetic parameters in the surface waters measured at dawn and at midday. This will be achieved by the creation of photosynthesis-irradiance (P-E) curves. An additional aspect was the creation of P-E curves with water from depth at midday. This will allow a comparison between photosynthetic parameters over the water column.

Table 5.18.1 shows the details of dates, sites and depths sampled. A total of 10 primary production measurements were made over 7 sites. Water was collected before dawn to prevent light shock to the phytoplankton. Six depths were sampled, roughly corresponding to the 97%, 55%, 20%, 14%, 5% and 1% of surface light levels. The depth of the 1% level was determined by the midday optics cast of the previous day and the stratification of the water observed during the dawn cast. Water from each depth was used to fill four 80 ml Nalgene bottles each of which was then spiked with 100 µl of ^{14}C bicarbonate. The same volume of ^{14}C bicarbonate was added to 10 ml of Carbosorb to check the radioactivity added to each bottle.

Date	Station	Time of day	Depths (m) sampled for primary production	Depths (m) sampled for photosynthetic parameters
17/05/00	17/02	Dawn	4, 6, 10, 14, 29 & 31	
18/05/00	18/03	Midday	2, 5, 10, 15, 20 & 30	
19/05/00	19/04	Dawn	2, 5, 10, 15, 25 & 36	
20/05/00	20/03	Midday	4, 6, 10, 14, 19 & 31	
22/05/00	22/03	Dawn	2, 5, 10, 15, 25 & 35	5

	22/11	Midday		6	30
23/05/00	23/03	Dawn	2, 5, 10, 15, 25 & 35	5	
	23/10	Midday		5	36
24/05/00	24/05	Dawn	5, 10, 10, 20, 26 & 34	5	
	24/13	Midday		5	34
25/05/00	25/03	Dawn	2, 5, 10, 15, 20 & 30	5	
	25/11	Midday		35	
	25/13	Midday		5	
26/05/00	26/03	Dawn	5, 5, 20, 20, 25 & 40	5	
	26/09	Midday		5	30
27/05/00	27/03	Dawn	2, 5, 16, 20, 30 & 40	5	
	27/12	Midday		5	40
28/05/00	28/	Dawn		10	34
	28/	Midday			

Table 5.18.1. Stations from which samples were taken

Samples were incubated for 24 hours in an on-deck incubator consisting of 8 polycarbonate tubes encased in filters. Six of the filters created light inside the tubes corresponding to the respective depths of the samples. The other two tubes were black to give a measurement of photosynthesis in the dark. Three bottles from each depth were incubated in the respective tube whilst the fourth was incubated in the dark tube. The incubator was connected to the on-deck non-toxic water supply to maintain the samples at sea surface temperature. At nightfall the incubator was covered to prevent the ship's lights affecting the measurements. The following dawn the samples were removed and replaced with the next day's bottles.

Samples were filtered through 0.2 μm pore size polycarbonate filters and placed for a few minutes in a dessicator with fuming HCl. Filters were then moved to labelled scintillation vials and left to dry overnight before 2.5 ml of scintillation cocktail was added. To each of 5 scintillation vials, 1 ml of the spiked Carbosorb was added as well as 2.5 ml of scintillation cocktail. The samples were run through a scintillation counter and primary production in each bottle calculated from the returned values.

Photosynthesis-irradiance curves were constructed for the sites on leg 2 of the cruise in order to derive the values of photosynthetic parameters. Each day one curve was constructed using water from the dawn CTD cast and two from the midday cast. At both dawn and midday, water was taken from roughly 5 m and at midday an additional experiment was carried out using water from around 30 m depending on the depth of the thermocline.

Fifteen 80 ml Nalgene bottles were filled with water from each site and spiked with ^{14}C bicarbonate in the same way as for the primary production measurements. A two column, indoor light gradient incubator, cooled with running water was used for the experiments. Samples were incubated for four hours. The light at each position in the incubator was measured at the end of each experiment using a light meter with a fibre optic probe. To do this, the probe was placed in a spare bottle filled with seawater and used to sequentially replace each experimental bottle to get a light reading at each position. After the incubation, samples were treated as for the primary production experiments. The results will be used to estimate values for photosynthetic parameters which will then be normalised to chlorophyll.

The table below shows preliminary values for depth integrated primary production.

Station	Primary production (mg C m^{-2} d^{-1})	Station	Primary production (mg C m^{-2} d^{-1})
17/02	110	22/03	441
18/03	288	23/03	305
19/04	174	24/05	176
20/03	136	25/03	330

Table 5.18.2: Depth integrated primary production

5.19 Bacterioplankton dynamics in the water column of contrasting stratification (Mike Zubkov)

Aim

To relate observed variability of bacterioplankton community functioning and composition with hydrological stratification of the Celtic Sea water column.

Methods

Water samples were collected and fixed for subsequent analysis of bacterioplankton concentration and composition using flow cytometry and *in-situ* hybridisation. Bacterioplankton metabolic activity and production were determined on-board by incubating samples with radioactively labelled precursor molecules: ^{3}H-leucine, ^{3}H-glucose, ^{35}S-methionine and ^{3}H-thymidine. Dilution culture growth experiments were done to determine empirical factors to convert rates of activity into bacterioplankton production. Rates of bacterivory were estimated in dilution experiments using ^{3}H-leucine as a tracer.

St. No.	Concentration	Production	Bacteriovory
16/04	11 depths	-	-
17/02	11 depths	5 depths	-
18/03	10 depths	5 depths	-
19/04	10 depths	6 depths	-
20/03	10 depths	5 depths	-
22/03	10 depths	6 depths	13 m
22/11	12 depths	6 depths (thermocline)	-
23/03	10 depths	6 depths (thermocline)	-
24/03	12 depths	6 depths (thermocline)	10 m
24/13	12 depths	-	-
25/03	10 depths	6 depths (thermocline)	13 m
25/11	11 depths	-	-
26/03	10 depths	6 depths (thermocline)	32 m
26/09	12 depths	-	-
27/03	10 depths	6 depths	12 m
27/12	12 depths	-	-
28/01	11 depths	6 depths (thermocline)	-
28/09	12 depths	-	-

Table 5.19.1 Logging of collected samples and bacterioplankton analyses made

Results

Preliminary scintillation counts were done on board the ship and a wide range of rates of bacterial activity was observed. Accurate counts will be done in the laboratory after adequate extraction of labelled material from filters. Concentrations of bacterioplankton will be determined by flow cytometry back in the laboratory. The molecular analysis will also be done after the cruise. The data set will allow estimation of rates of production and mortality of bacterial community and to link bacterial function and composition with hydro-physical structure of the water column.

5.20 Microzooplankton herbivory and community structure (Elaine Fileman and Jason Mallard)

Microzooplankton are classically defined as heterotrophic organisms, which pass through a 200μm mesh. This broad category comprises both the protozoa and some smaller metazoa. Identification of microzooplankton is complex but cells generally fall into one of three categories: the heterotrophic nanoplankton, heterotrophic microplankton or metazoa. Microzooplankton are capable of controlling the biomass of both bacteria and phytoplankton and are in turn consumed by larger animals, therefore providing a link through to higher trophic levels. They are also important remineralisers of organic matter and nutrients.

Objectives

a) to determine the abundance, biomass and vertical distribution of the heterotrophic nanoplankton size fraction (2-20μm)
b) to determine rates of herbivory by the total microzooplankton community (2-200μm) and the heterotrophic nanoplankton community (2-20μm) in surface waters and at the thermocline.
c) to determine rates of bacterivory by the heterotrophic nanoplankton.
d) to use microzooplankton herbivory experiments to look at nitrogen uptake by phytoplankton and microbial regeneration of nitrogen using ^{15}N as a tracer

Methods

Microzooplankton community

Water samples were collected from 6-8 depths within the water column from all dawn CTD biogeochemistry casts. Samples were treated as follows:-

20-40 ml water samples were fixed in 1% glutaraldehyde, dual-stained with DAPI and proflavine (final concentration 5 $\mu g\ ml^{-1}$) and filtered onto 0.8μm black polycarbonate filters. The filters were mounted onto slides and frozen. Heterotrophic nanoplankton abundance and biomass will be determined from these samples by inverted fluorescence microscopy.

To compliment these, further samples were collected and fixed in Lugol's Iodine (see cruise report by Jason Mallard).

Herbivory

A total of 9 microzooplankton grazing experiments were carried out using the dilution technique described by Landry & Hassett in 1982 (*Mar Biol* 67: 283-288) and these are summarised in Table 5.20.1. Experimental water to make up the filtrate was collected pre-dawn from surface waters (10m) or from the depth of the thermocline (30m) using a 30 litre Go-Flo bottle. This water was gravity filtered through a 0.2 μm Gelman Criticap filter that had been pre-soaked in Milli-Q water overnight. The first 2-3 litres of the filtered seawater was discarded. Further experimental water was collected by the CTD from the relevant depth and pre-screened using a 200 μm mesh bag to exclude larger predators. For size fractionated experiments, water was further screened through a 20 μm mesh. A series of triplicate dilutions were made up by gently combining the screened water with the 0.2 μm filtered water in 1 or 2 litre polycarbonate bottles.

All incubations were carried out over a 24 hour period in an ambient temperature-cooled deck incubator screened to the 33% light level for 10m experiments and 1% for 30m experiments. Sub-samples were taken at T_0 and T_{24} for the determination of (i) chlorophyll concentration (ii) microzooplankton and HNAN biomass and community structure and (iii) nutrient concentration. In addition, occasionally 1.5 ml sub-samples were taken at T_0 and T_{24} fixed in 1% glutaraldehyde and frozen. These will be analysed by flow cytometry in order to determine grazing on the picoplankton. All chlorophyll samples were extracted with 90% acetone and analysed on board by fluorometry. The heterotrophic nanoplankton community will be enumerated at PML whilst Lugol's fixed heterotrophic microplankton will be enumerated at Port Erin.

Bacterivory

Bacterivory experiments were carried out in conjunction with Mike Zubkov. For 6 of the experiments sub-samples were collected at T_0, T_{12} and T_{24} fixed in 1% paraformaldehyde and frozen. These samples will be analysed back in the lab by flow cytometry to determine bacterivory.

Nitrogen uptake and microbial regeneration

For all experiments, to prevent any potential effects of nutrient limitation within the bottles each bottle was enriched with a nutrient mixture of NH_4, NO_3 and urea. The concentrations added varied depending on ambient nutrient concentrations. Three controls were also set up containing 100% seawater with no nutrient enrichment. In addition, for each dilution replicate one of the added nutrients was substituted by either ^{15}N-nitrate, ammonium or urea. See cruise report by Andy Rees for further details. Sub-samples were taken at T_0 and T_{24} to determine nutrient concentrations. Nutrient analyses were carried out by Andy Rees, John Stephens and Denise Cummings.

Date	Station	Depth (m)	Chl <200μm	Chl <20μm	AFC-pico <200μm	AFC-bact <20μm
18/5	B	10	✓	✓		
19/5	C	10	✓	✓		✓
20/5	D	10	✓			✓
22/5	G	10	✓	✓	✓	✓
23/5	G	30	✓			✓
24/5	G	10	✓			✓
25/5	E	10	✓	✓	✓	
26/5	E	30	✓	✓	✓	
27/5	F	10	✓	✓	✓	✓

Table 5.20.1. Sampling details. Chl= chlorophyll; pico= picoplankton; bact = bacterivory; AFC = flow cytometry

Results

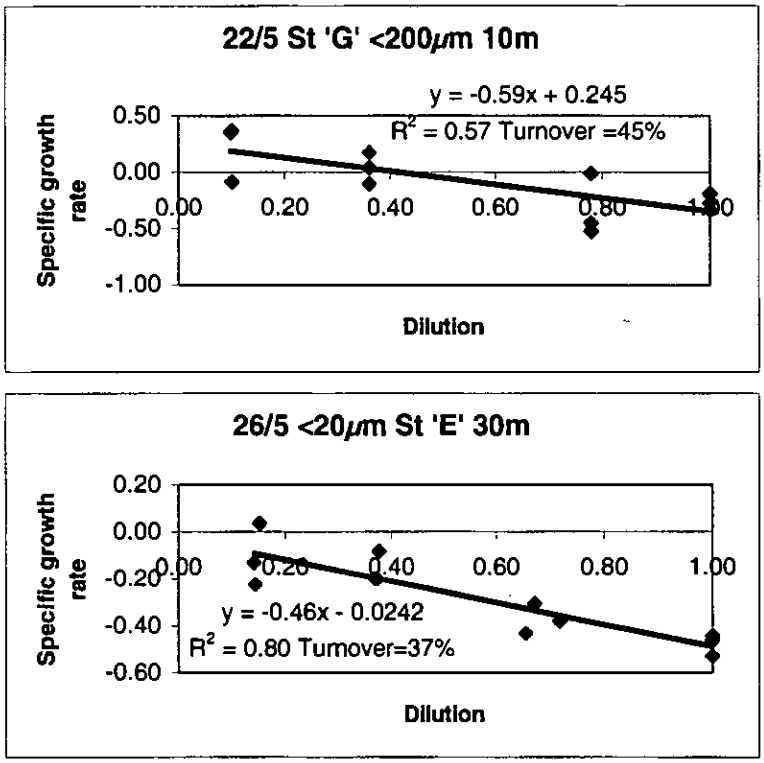


Figure 5.20.1: Examples of preliminary results obtained from microzooplankton grazing experiments carried out at station 'G' and 'E'. Turnover = amount of chlorophyll turned over by the microzooplankton day^{-1}; Slope (m) = phytoplankton mortality due to microzooplankton grazing; Y axis intercept = specific phytoplankton growth in the absence of grazers.

5.21 Shipboard Computing (Gareth Knight)

Data Logged

The following data were logged using the ISG ABC System: Chernikeef Log, Ship's Gyro, Trimble GPS, Ashtec ADU, Ashtec Glonass GPS, Surface and Metl data, CTD, Echo-Sounder, Analogue nutrient data, Bottle firing data

Level B: The level B data logging system operated without incident for the whole of the cruise.

Computing

Each of the seventy-three CTD casts was processed into an individual data file each filename indicating its cast number. The cruise data was recorded onto a data CD and passed to BODC for verification and distribution. Calibration files used are also available on the CD in a cal directory as are CTD PostScript plots of all CTD casts and cruise track in directory post. Data from CTD bottle firing is available in the RVS data file bottles and extracted CTD values are present as ascii text in

directory bott. Backup of PC directories for transect ADCP data, Shipborne Wave Recorder and XBT data were created in adcp, sbwr and xbt respectively. The ADCP PC showed no time drift over the cruise. The Shipborne Wave Recorder was set to BST and had drifted 5min and 17 sec. Several computer systems installed in the scientific lab space for 246 were networked to the ships computing network for mail access and data exchange. Navigation data was provided to a laptop in the Principal Scientist's cabin.

5.22 SEG Technical Report (Colin Day and Darren Young)

Equipment used included the following:

Starboard Gantry

Gantry system functioned without problem during all equipment deployments. The gantry and auxiliary winches were operated from both the cab and Stbd deck stations. During the cruise a fault developed with the auxiliary winch hydraulic powerpack, which was traced to a faulty relay on the main powerpack starter control circuit. The fault caused the pump motor to cut out intermittently, this occurred on approximately 8 occasions over a three-day period (until the fault was traced and rectified).

Speed control on the auxiliary winches is poor. The winch response to the potentiometer control is unpredictable; the hydraulic and electrical control circuit needs to be examined for fault. The Fwd pendulum ram gaiter has broken into two pieces and requires changing as the cylinder is now exposed to the elements.

Stern Gantry

The gantry system and associated powerpacks were operated without problem from the control cab and remote operating positions during the cruise.

10T Storage System, including 37KW Power Pack, Inboard Compensator and Diverter Sheaves

During preparation for the first CTD deployment a fault was noted and traced to the CTD drum slip ring assembly. After examination and testing the slip ring assembly was removed for stripping and servicing. The assembly required thorough cleaning. The slip ring bearing is worn and needs to be replaced. It should be discussed which group has responsibility for planned maintenance of this equipment so work could be programmed into refit and re-certification schedules.

10T and 20T Cable Hauler Assemblies and Power Pack

Haulers operated well during all CTD operations. There is an oil leak on the '2nd from Aft' top roller output shaft. If the hauler is to be removed to change the oil seal it would be useful to fit an oil filler plug, level plug and a drain plug. There is also no level plug or drain plug on the 20T haulers.

Non Toxic Water System

The system worked well throughout the cruise but on starting up was found to be very contaminated. Although the system was extensively used during the last cruise and was therefore well flushed there may be a requirement to flush the system on a regular basis with Decon90. If this is to be the case it may be necessary to modify the system to more easily facilitate the entry and drainage of chemical flushing agents, especially if this work is to be carried out with the vessel along side. Additionally we could modify the system to allow the system to be fully fresh water filled when not in use.

Millipore Water System

The MilliPore system operated throughout the cruise with no problems. The current non-standard membrane has been found to be as effective as the previously fitted type.

Seametrix System

In general the monitoring system worked very well during all operations. The wire rate display requires calibrating as it was assessed, it is reading overspeed. There was a problem with logging the winch monitoring data to the ships computer system during the cruise, which needs to be addressed.

Ship fitted Fume hood

The new re-circulating fume hood worked well during the cruise with no problems although the limitation of headroom and the inability to secure equipment to the base of the hood is a problem. A PTFE or GRP pallet could be located in the fume hood working area which could have screw eyes fitted to allow users to secure their equipment.

Flow Cytometer/RadioNuclide containers

Both these containers require significant investment if they are to continue to be useful for any future sea-going duties. The age and structural condition would bring into question whether either container will be available beyond the year 2000 cruise programme.

Both containers functioned well during the cruise with only a few minor faults on the RN container electrical system and AC unit. A 16Amp breaker on the RN container lighting circuit failed during the cruise, which was replaced, but the replacement needs itself to be replaced with an exact match of the failed component.

5.23 Scientific Instrumentation Group (David Jolly and Andy Jones)

1 Surfmet

The Surfmet system was powered and running before the beginning of the cruise until the last day 29/5/00. Displayed data are calibrated but logged to the level B system uncalibrated but mostly in engineering units.

Met Sensors: The wind sensors were changed before the cruise to a new configuration which points the zero heading if the vane is in a forward direction. Wind from starboard is thus indicated by 90 degrees, aft 180 degrees and port is 270 degrees. This change is in common with the Charles Darwin system which has also been changed recently to remove the 90 offset to port.

The Starboard PAR sensor was not working for the duration of the cruise. It was observed before the cruise that this sensor had been hit or knocked in some way as the gimbal mount had become bent, leaving the sensor attached only by its cable.

Action: Starboard PAR needs replacing.

Surface Sensors: The non-toxic seawater supply to the TSG and flow through sensors was opened at 18:15Z. Flow was approx. 45 litre/min input to the system, 2 litre/min controlled flow through transmissometer and fluorometer and approx. 12 litre/min debubbler waste.

A step increase in the housing temperature, compared to the remote was observed on 25/5/00 of approx. 1.5 degrees, above the usual difference of approx. 0.4 deg. The conductivity cell also showed a step increase at this point, the result of which meant that measured salinity was not affected. The cause of the step change was not obvious. Heating in the pipe system seems unlikely as the flow remained at 45-50 litre/min. Electrical noise was a possibility since there were several AC powered water pumps being used in the water-bottle annex, none of the pumps were started or stopped at the time of the step change. The transmissometer showed a small "blip" at the time the other parameters stepped which may indicate a water cause. A movement on or off station would presumably have been shown in the remote temperature, rather than a difference between the two.

Whilst investigating the above problem, it was discovered that the surface data was not being logged, and had not been up until that point in the cruise. This was because the Surfmet configuration had been used from the previous cruise where surface instruments were not run. It is unclear whether the Surfmet system was stopped between the cruises, thus a new configuration was not required for the system to appear to be logging, or whether the old configuration was simply selected for the current cruise.

The software does indicate in the Numeric Display whether a parameter is "Selected" or "Not Selected" which determines if it is logging or not, but this is not as obvious as an indicator (red or

green for example) might be, which would perhaps be noticed when viewing the graphs. The two halves of the system are often run separately. One system only may be used for a cruise but also non-toxic seawater is not available at the start of a cruise when there is no problem running Met. instruments. It may be worthwhile having separate logging facilities for the two parts of the system, even if performed on the same machine as presently done.

Action: Surfmet software needs to be changed to prevent future loss of data in the way has happened this cruise. Suggest options for Surface on or off and Met on or off, removing the option to select individual sensors and to make the operation mode more obvious. Create a fixed system checklist that would include:

a) When each system is started/stopped

b) Tick box after checked that being correctly logged to computing system.

c) Other comments or periodic checks.

This type of checklist would also make the writing of cruise reports a more straightforward task, would ensure consistency in the means of recording and would provide a useful record for future use.

2 EA500 Echosounder.

The system was operated using the Port Hull Transducer at 10kHz. The PES fish was not deployed and reduced power was used throughout the cruise as maximum depth was < 150m. The printer, thermal linescan recorder, beam steering unit and audio interface were not used.

3 Vessel Mounted Acoustic Doppler Current Profiler.

This system was operated from midday on 16/5/00 until midday 29/5/00. Transect software was used. The PC clock did not drift from the ship's clock during the cruise. Data was transferred by floppy disk to the computing system after logging was stopped.

4 Ship-borne Wave Recorder.

The shipborne wave recorder was run throughout the cruise. Data were transferred by floppy disk to the computing system after the logging was stopped.

5 XBT

Fourteen XBT probes were launched during the first half of the cruise. The new system was operated without problem.

6 CTD

The CTD used was a Neil Brown Mk3C, horizontally mounted in a large 24way frame, with a General Oceanics 1016 (24way) rosette pylon. The CTD contains the following sensors:

Pressure (with pressure temperature), Temperature, Conductivity, Fast Temperature, Oxygen Current and Oxygen Temperature. The auxiliary A/D channels of the CTD were used to interface a SeaTech 20cm transmissometer, Chelsea Instruments Mk2 Aquatracka fluorometer and 2 off PML designed PAR irradiance sensors. The transmissometer and fluorometer were mounted horizontally at the same level as the CTD, down-welling PAR was mounted on a pole above the rosette pylon and up welling PAR was mounted below the centre of the lower part of the frame.

The oxygen sensor was generating "noise" due to the rolling of the ship. Whether this is due to the consumption of oxygen as the system is lowered at a varying speed, or due to the pressure differences on the membrane which this varying speed of lowering would cause is not clear. Either way, this noise might have been reduced by the use of a SeaBird pump attached to the oxygen sensor receptacle. When the CTD is mounted horizontally it is not possible to achieve vertical alignment of the oxygen sensor and the main sensor head, making it even more essential that a pumped system is used on a cruise where high resolution oxygen profiles are required.

Action: SeaBird pump should be available for all Neil Brown CTDs.

The 1016 rosette performed well throughout the cruise with only two unexplained misfires which were repeated without problem. The second misfire occurred due to battery failure. Because of the

in-operation of the Continuous Power Module (CPM) the rosette power is partly derived from a battery module. The lifetime of a battery is not known and use is difficult to measure due to arming and firing needs varying with each bottle set-up. The battery failed on cast 046 and was replaced. A second cast was necessary at the station to fire 2 remaining bottles (+ 1 extra).

Action: Method needed to determine the remaining life of a battery.

Sampling bottles used were:

12 off 30-L Teflon-lined Niskin bottles

24 off 10-L externally-sprung Niskin bottles (X-Niskins)

Twelve of the X-Niskins were acid washed, before the cruise, for trace metal work. These bottles also had their external springs coated with "Plastic Protective Coating" spray. The bottles were used interchangeably, sometimes all of one size and sometimes a combination of the two, depending on the requirements for trace-metal work, higher resolution of sampling or larger volume of water. One of the 30l bottles was fired on deck when the arm was moving to the "home" position, this was probably due to the plunger not returning to it's fully out position when cocking the bottle. The handle on the bottom endcap was broken off rendering the bottle out of action for one cast where needed. A repair was made by SEG (Darren) using a steel pin and has been in use since.

All bottles rinsed with fresh water before repacking.

Action: Spare 30 litre Niskin end caps needed for support box.

A total of 72 casts were made, numbered DY46D000 to DY46D071. The first cast was a test of both the CTD equipment and the water sampling procedures. A cross reference of CTD cast number to station number is provided. All data were logged to the computing system but data files from the operating PC are also retained.

8 Autosal

The salinometer was located in the Stable Lab and used to measure the wet samples for calibrating the CTD and TSG data. The UPS was used in the power line to smooth any power fluctuations which may cause unstable readings. The readings were stable in Standby and Read modes. The softsal Standardise procedure was followed to adjust the Rs trim. This was done successfully but after the first crate had been run, another ampoule of SSW was run as a check. This second standard had a rising measurement (approx. 0.001 psu every flush) and no reading could be taken. This happened again with a second ampoule. The standard seawater is from a recent batch dated April 2000.

Two crates still to be run.

9 Go-Flo Bottles

These bottles were used to collect water samples before CTD casts. The first bottle to be used failed to close its bottom ball valve properly. Another 2 bottles were used for the rest of the cruise. One of these had to have the rubber tightened to ensure correct operation. As the sampling depth was usually 10m, we found it necessary to lower the bottle to approx. 20m, then return to 10m to drop the messenger, to ensure that the pressure opening release operated correctly so that a full sample was taken. The very first bottle sample was delayed because insufficient weight was used to make the bottle sink. All bottles rinsed with fresh water before rebagging and boxing.

Action: Documented procedure needed to ensure efficient sampling can be undertaken, along with a suggested weight and set-up for the line.

10 CTD Winch Slip-ring

During setting up and testing of the CTD system there was a short in the cabling between the lab and the end of the conducting cable. This was traced to the slip ring where inspection revealed a clear, thick, oil-like substance, which appeared to contain graphite powder from the brushes. After cleaning with spray solvent the circuit was still giving an unacceptably low insulation between core and ground. The whole slip-ring assembly was removed from the winch and the brushes removed

checked and cleaned. The whole system when checked with a 'Megger' gave an insulation of 50MΩ, well above the required 15MΩ and the system worked without further problem. The cable, which has been two core mains for several years, from winch to junction box was replaced with 50Ω coax.

Action: The CTD winch slip ring requires a scheduled maintenance program as a preventative measure against further problems. This could be associated with SEG servicing of the winch or an interval set by Instrumentation Group such as every 4 months, with a check every cruise as currently practised. The cover is difficult to remove and install, inspection would be made easier with a different securing system, perhaps with s/s bolts that went through the cover and mounting plate, secured with nuts on the back. Better still would be a system of quick fit clips as space is restricted for spanner/ratchet.

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6 Acknowledgements

It is a pleasure to thank Captain Robin Plumley and the crew of DISCOVERY for their shipboard support for this research. Our thanks also go to Dr Glen Tarren, Mr Malcolm Woodward and Mrs Julia Crocker for ensuring the cruise logistics planned out.

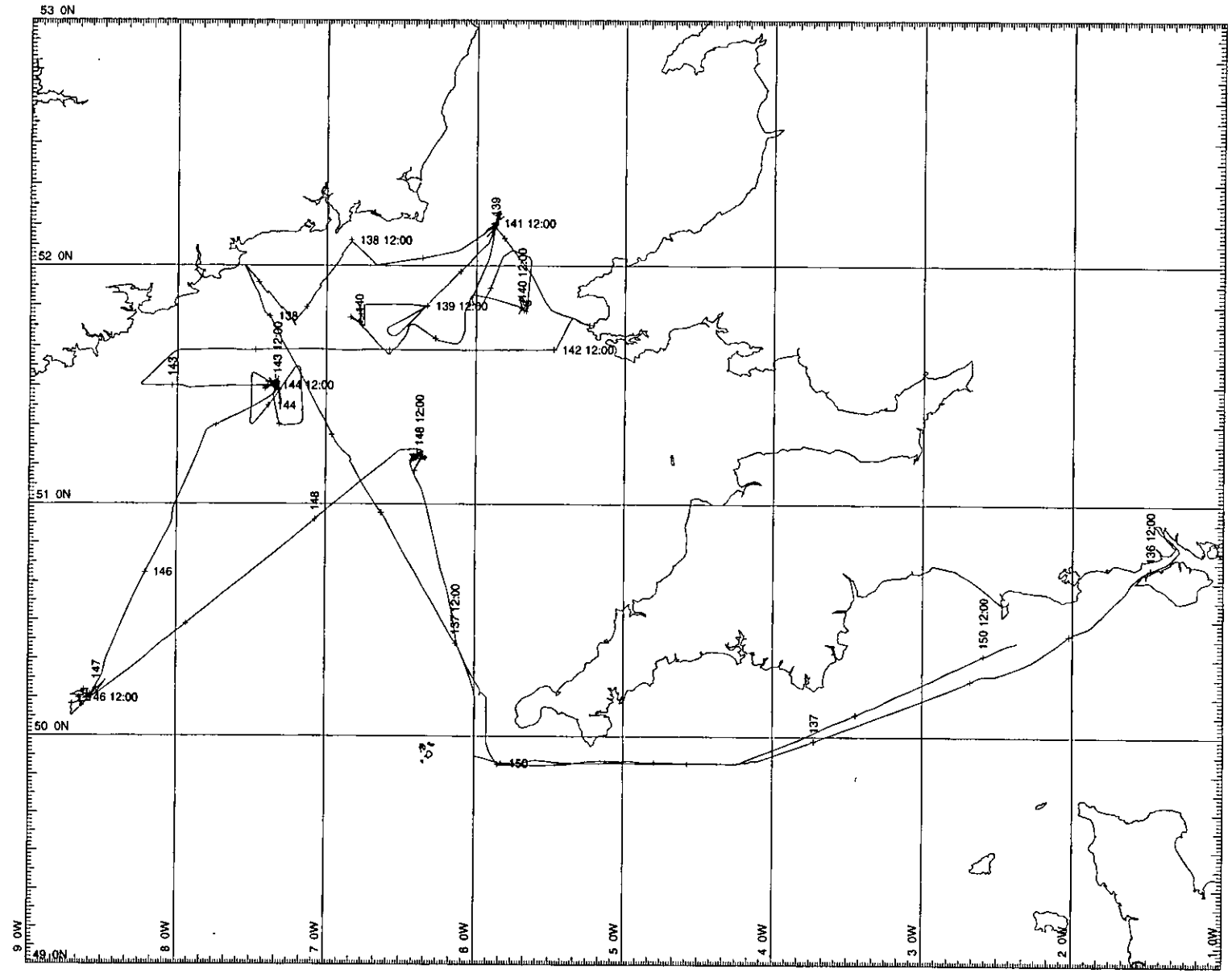
The scientists acknowledge gratefully the financial support from NERC, the European Union as well as the input from PML's Remote Sensing Group for satellite details.

The research forms a component of the CCMS Core Strategic Research Programme and the EU MAST Programme.

PROPHEZE Cruise Report

Annex 1

Chart showing cruise track



MERCATOR PROJECTION

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

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 0

GRID NO 1

— Track plotted from bestnav

PROPHEZE Cruise Report

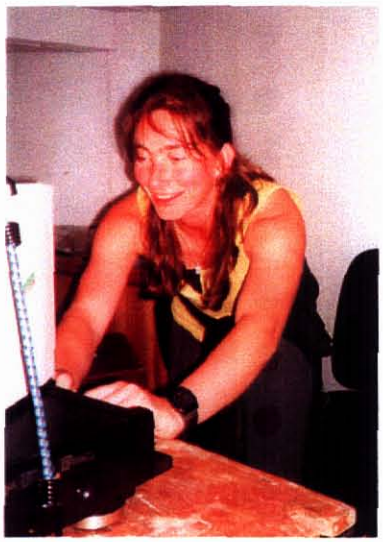
Annex 2

Photo section

PROPHEZE CRUISE PHOTO SECTION

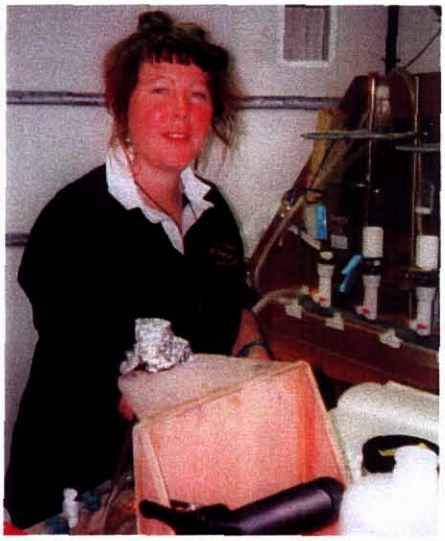
Scientists

Jim Aiken setting up optics equipment

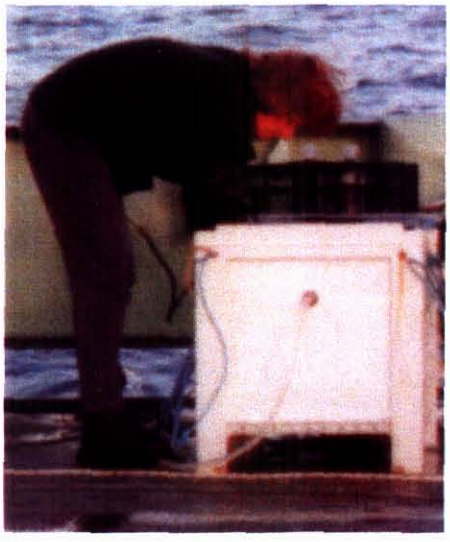


Tracy Anning in the microscopy lab.

Peter Burkill (right) welcomes Malcolm Wilkins aboard for Leg 2



Denise Cummings with filtering equipment

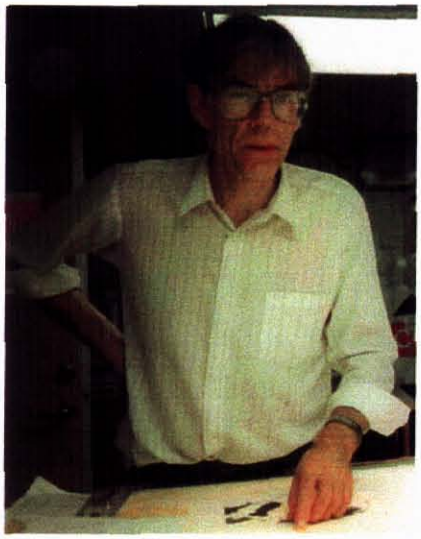


Elaine Fileman checks a deck incubator

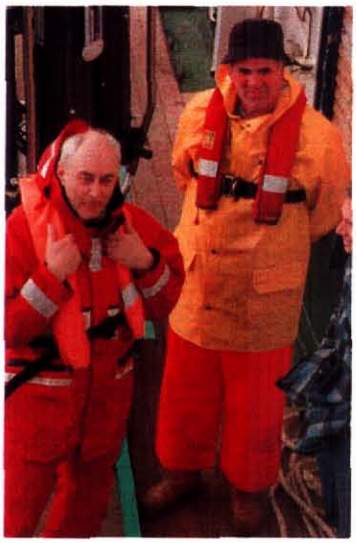
Richard Geider watching an optics rig deployment

Linda Gilpin fills oxygen bottles

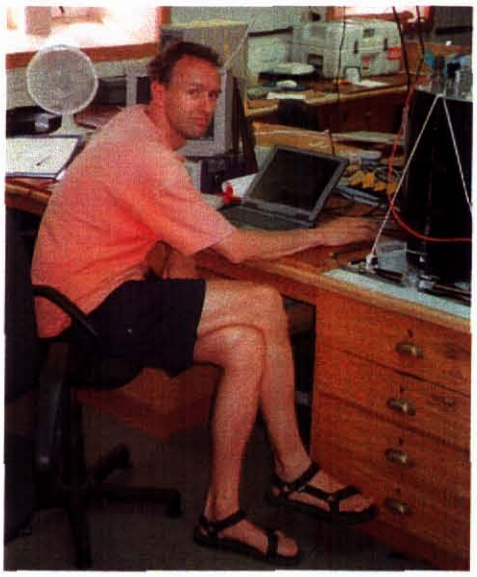
Toby Holland (right) preparing to take water from the CTD



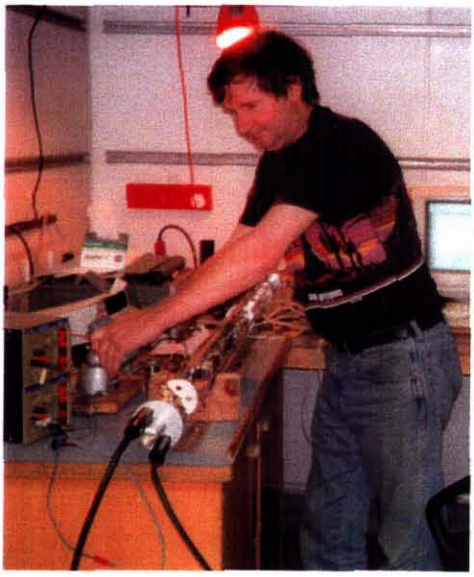
John Howarth in the plot



John Humphrey (right) ready for boat transfer at the end of Leg 1



Richard Jonker analysing CytoBuoy data



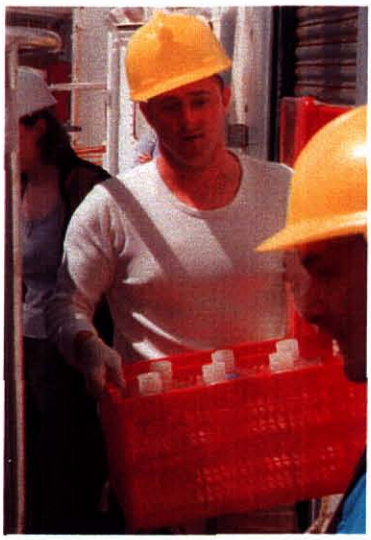
Chris MacKay setting up the FLY probe

Jason Mallard taking microzooplankton samples from the CTD

Georgina McDermott oversees a plankton net deployment

Roger Proctor in the plot

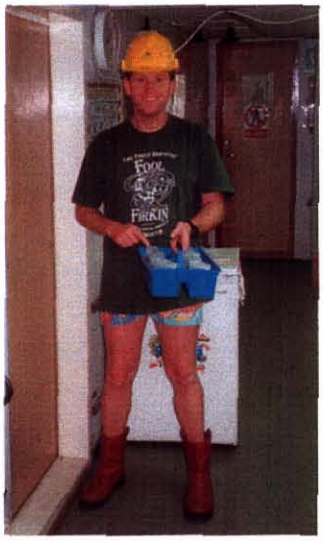
Andy Rees at the CTD



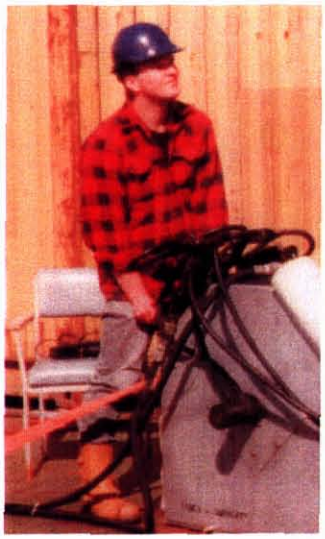
Andy Reul takes seawater to filter microzooplankton

Tim Smyth with his sun photometer

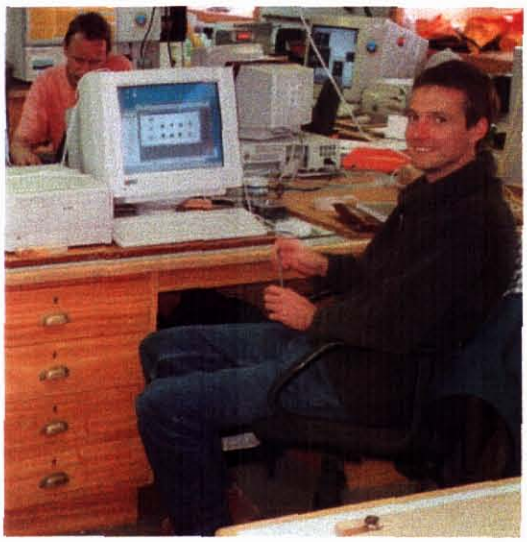
John Stephens takes seawater samples for nutrient analysis



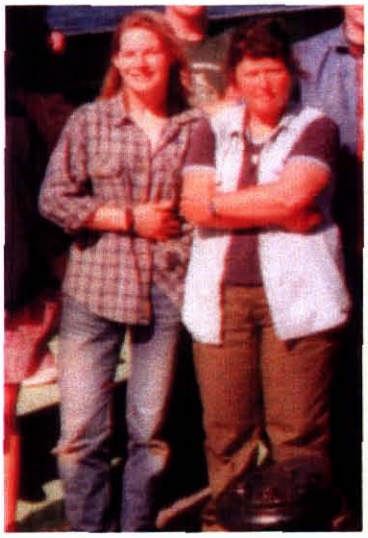
Glen Tarran with samples for phytoplankton analysis by flow cytometry



Andy Vile operating the FLY turbulence probe winch



Malcolm Wilkins setting up a neural network for phytoplankton identification



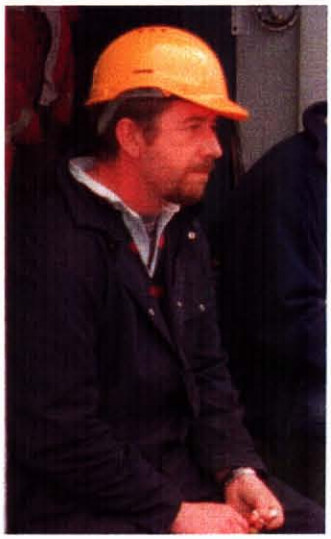
Kathy Woods (left) in the group photo at the end of the cruise

Mike Zubkov in the radiochemistry container lab.

RVS Technicians

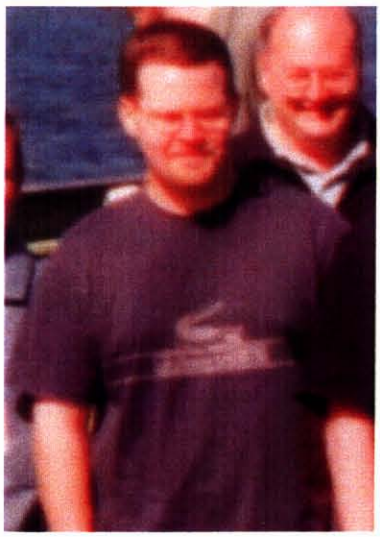
Colin Day ready to board the lifeboat during emergency drill

Dave Jolly working on one of the CTD modules



Andy Jones at the muster station during emergency drill

Gareth Knight in the computer room



Darren Young in the group photo at the end of the cruise