PARENT

Water Sample Data Documentation

HOME

Introduction

During the PRIME cruise, mesocosm experiment and studies centring on Ocean Weather Station India, over 100 different parameters were measured on water samples by 15 principal investigators using a wide range of protocols. The aim of this document is to allow the protocol used to obtain any particular data value within the BOTDATA table to be determined with ease.

To help you find the information you require quickly, the document is subdivided into sections that describe groups of closely related parameters. These are listed below as a series of hot links. Each section starts with the definition of the parameter codes covered, followed by a list of who measured one or more of those parameters. Next, there is a protocol section describing the methods used by each principal investigator. Finally, there may be comments on data quality that have been noted by BODC or have come to our attention.

<TIP> If you want to find out how a particular parameter was measured and know the parameter code then the fastest way to find the information you require is to use the *Acrobat* 'find' tool to search for the parameter code.

Document Index

Bacteria Data

Bacterial abundance and biomass data.

Dissolved Organic Carbon and Total Nitrogen

High temperature catalytic oxidation measurements.

Particulate Organic Carbon and Nitrogen

Those parameters loosely described as ‘POC’ and ‘PON’

Nutrients

Nitrate + nitrite, nitrite, phosphate and silicate data.

Carbon Stable Isotopes

$\delta^{13}C$ of different forms of inorganic and organic carbon.

Pigments

Chlorophyll-a determined by a range of techniques, including data derived from calibrated *in situ* fluorometers.

Dissolved Tracers

Concentrations of sulphur hexafluoride (SF_6).

Dissolved Oxygen

Winkler titration and calibrated CTD data.

Hydrography

Temperature, salinity, density and attenuance data that have been derived from the CTD and its calibration data.

Irradiance

Light meter data at bottle firing depths.

Microzooplankton Biomass

Microzooplankton abundance and biomass data together with data on heterotrophic and photosynthetic nanoflagellate abundances.

Phytoplankton Species Counts

Abundance, surface area, volume and carbon biomass of phytoplankton taxa.

AFC Counts

Abundance and biomass of broad taxonomic groupings as defined by Automated Flow Cytometry.

OPC Counts

Abundance of thirteen size categories as defined by the Optical Plankton Counter

Mesozooplankton Biomass and Egg Production

Biomass and egg production of major mesozooplankton.

Photosynthesis and Calcification

Rate measurements of photosynthesis and calcification by the PvI incubation technique.

Oxygen Production and Respiration

Data from whole community and size-fractionated light/dark bottle oxygen incubation experiments.

Trace Metals

Concentrations of zinc and iron together with data on their ligand associations.

Genetic Markers

Presence/absence and relative hybridisation of genes coding for proteins associated with photosynthetic apparatus or with transporting phosphate into the cell under limiting conditions.

References

Full references for the papers cited in the protocol descriptions.

Bacteria Data

Parameter Code Definitions

TBCCMIPZ	Total bacterial cell numbers per ml Optical microscopy of stained samples
SFTBMDPA	Size-fractionated (0.2-200 μm) bacterial cell numbers per ml Optical microscopy of DAPI stained samples
TBBMMDPZ	Total bacterial biomass as mg carbon per m^3 Optical microscopy of DAPI stained samples

Originator Code Definitions

142	Dr.M. Zubkov	CCMS Plymouth Marine Laboratory

Originator Protocols

Dr. M. Zubkov

Samples were collected from 10 depths corresponding to 97%, 55%, 32.6%, 19.9%, 13.8%, 6.9%, 4.6%, 3%, 2.1% and 1% of surface irradiance, using pre-dawn CTD casts. Size-fractionation of bacteria was used to estimate the median cell diameter of populations. Samples were filtered through Nuclepore filters with pore size 0.4, 0.6, 0.8 and 1μm and the filtrate fixed for subsequent analysis by flow cytometry and epifluorescence microscopy.

Bacterial abundance

Samples were fixed with 2.5% by volume, 0.2 micron filtered, electron microscope grade glutaraldehyde, stained immediately with DAPI (4'6-diamidino-2-phenylindole) as described by Porter and Feig (1980) and filtered.

Samples were either examined immediately or stored frozen at -20°C until being examined back at the laboratory. Fluorescent bacteria were counted with an epifluorescence microscope by the method of Hobbie et al. (1977). The microscope used was a Leitz Ortholux II equipped with a 50W HBO light source, Ploempak 2.2 fluorescence vertical illuminator with filter block A and an NPL Fluorotar 100/1.32 oil objective lens.

Dissolved Organic Carbon and Total Nitrogen

Parameter Code Definitions

CORGCOD1	Dissolved organic carbon (µM) High temperature platinum catalytic oxidation (GF/F filtered)
NTOTCOD1	Dissolved total nitrogen (µM) High temperature platinum catalytic oxidation (GF/F filtered)
SEOCCOD1	Dissolved organic carbon standard error (µM) High temperature platinum catalytic oxidation (GF/F filtered)
SETNCOD1	Dissolved total nitrogen standard error (µM) High temperature platinum catalytic oxidation (GF/F filtered

Originator Code Definitions

13	Dr. A.E.J. Miller	CCMS Plymouth Marine Laboratory

Originator Protocols

250 ml samples were taken from the CTD rosette and filtered through GF/F filters. Ultra-clean handling techniques were used throughout. Duplicate aliquots were sealed in glass ampoules and stored in the dark at 4°C prior to transfer to PML for analysis.

The analytical technique involves the direct injection of acidified and decarbonated sea water onto a platinised alumina catalyst at high temperature (680-900°C) under an atmosphere of oxygen or high purity air. Quantitative production of CO_2 gas allows DOC concentrations to be determined using a CO_2-specific infrared gas analyser (IRGA).

Analyses were undertaken using a Shimadzu TOC-5000 HTCO analyser fitted with a LiCor Li6252 IRGA.

Great care was taken to quantify blank signals generated at all stages of the analytical procedure and to correct the data for them.

A more detailed description of the protocols followed may be found in Miller et al (1993).

For total dissolved nitrogen (TDN), the analytical technique involves the direct injection of acidified and decarbonated seawater onto a platinised alumina catalyst at high temperature (680-900°C) under an atmosphere of oxygen or high purity air. Quantitative production of the nitric oxide radical allows total dissolved nitrogen concentrations to be determined using a nitrogen-specific chemiluminescence detector.

Analyses were undertaken using a Shimadzu TOC-5000 HTCO analyser fitted with an Antek 705-D chemiluminescence detector. The combustion products travelled through a Drierite trap (97% $CaSO_4$, 3% $CoCl_3$) and a membrane (permeation tube) drier to remove any trace of water. The dried nitric acid radical was then reacted with ozone to produce

the excited chemiluminescent nitrogen species and passed to the detector. Each sample was injected four times with each injection cycle taking 5.5 minutes.

POC and PON

Parameter Code Definitions

CORGCAP1	Particulate organic carbon (acidified) Acid fumed then C/N analyser (GF/F filtered)	µM
NTOTCNP1	Particulate total nitrogen (“PON”) Carbon/nitrogen analyser (GF/F filtered)	µM

Originator Code Definitions

39	Mr. Bob Head	CCMS Plymouth Marine Laboratory

Originator Protocols

Mr. Bob Head

Replicate 500 ml water samples were taken. After an initial screening through a 200 micron mesh to prevent spurious results caused by large zooplankton, the samples were filtered through 25mm GF/F filters. Samples were frozen at -20°C until analysis back at the laboratory.

The samples were acidified with sulphur dioxide to remove carbonates and then dried at 50°C for 2 days. The samples were then encapsulated in squares of pre-combusted aluminium foil in a 4.5mm press.

The samples were analysed in a Carlo Erba NA1500 elemental analyser at a reactor temperature of 1030°C and a helium carrier flow rate of 120 ml per minute. Calibration was effected with standards of acetanilide assayed on a calibrated Cahn 25 balance. Filter and seawater blanks were analysed and used to correct the data.

Nutrients

Parameter Code Definitions

NTRIAAD1	Nitrite concentration Colorimetric autoanalysis (GF/F filtered)	µM
NTRIAADZ	Nitrite concentration Colorimetric autoanalysis (filtration unknown)	µM
NTRZAAD1	Nitrate + nitrite concentration Colorimetric autoanalysis (GF/F filtered)	µM
NTRZZZXX	Nitrate + nitrite concentration Unspecified methodology	µM
PHOSAAD1	Phosphate concentration Colorimetric autoanalysis (GF/F filtered)	µM
PHOSZZXX	Phosphate concentration Unspecified methodology	µM
SLCAAAD1	Silicate concentration Colorimetric autoanalysis (GF/F filtered)	µM
SLCAZZXX	Silicate concentration Unspecified methodology	µM

Originator Code Definitions

62	Mr. E.M.S. Woodward	CCMS Plymouth Marine Laboratory
127	PRIME Project Office	University of Wales, Bangor

Originator Protocols

Mr. E.M.S. Woodward

Standard autoanalyser methods were used as described in Rees et al. (1995) for the measurement of nitrate + nitrite, nitrite, phosphate, and silicate.

Carbon Stable Isotopes

Parameter Code Definitions

D13CMIAX	Carbon dioxide ^{13}C enrichment Mass spectrometry	per mil
D13CMICX	Carbonate ^{13}C enrichment Mass spectrometry	per mil
D13CMIHX	Bicarbonate ^{13}C enrichment Mass spectrometry	per mil
D13CMITX	Total carbon ^{13}C enrichment Mass spectrometry	per mil
D13CMOPC	Particulate organic carbon ^{13}C enrichment Mass spectrometry	per mil

Originator Code Definitions

44	Dr. Hilary Kennedy	University of Wales, Bangor

Originator Protocols

Samples for POC $\delta^{13}C$ determination were decarbonated by acidification and then oven dried at 55°C. The material was ground into a fine powder and vacuum sealed. It was then heated at 550°C for a day to complete combustion of organic matter. The carbon dioxide generated was cryogenically trapped by liquid nitrogen. $\delta^{13}C$ was determined on a mass spectrometer using certified CO_2 gas as an intermediate standard. Routine measurements were reported as accurate to within 0.3 parts per thousand.

Pigments

Parameter Code Definitions

CPHLFLP1	Fluorometric chlorophyll-a Fluorometric assay of acetone extract (GF/F filtered)	µg/litre
CPHLFLP2	Fluorometric chlorophyll-a Fluorometric assay of acetone extract (0.4/0.45 µm pore filtered)	µg/litre
CPHLFLP5	Fluorometric chlorophyll-a Fluorometric assay of acetone extract (0.2 µm pore filtered)	µg/litre
CPHLPR01	In-situ fluorometer chlorophyll Calibrated in-situ fluorometer	µg/litre
CPHLZZXX	Chlorophyll-a Unspecified methodology	µg/litre
PHAEFLP1	Fluorometric phaeopigments Fluorometric assay of acetone extract (GF/F filtered)	µg/litre
PHAEFLPZ	Fluorometric phaeopigments Fluorometric assay of acetone extract (filter unspecified)	µg/litre
SCHLFLPA	Size-fractionated fluorometric chlorophyll-a Fluorometric assay of acetone extract (>5 µm fraction)	µg/litre
SCHLFLPC	Size-fractionated fluorometric chlorophyll-a Fluorometric assay of acetone extract (2-5 µm fraction)	µg/litre
SCHLFLPD	Size-fractionated fluorometric chlorophyll-a Fluorometric assay of acetone extract (1-5 µm fraction)	µg/litre
SCHLFLPL	Size-fractionated fluorometric chlorophyll-a Fluorometric assay of acetone extract (GF/F-20 µm fraction)	µg/litre

Originator Code Definitions

2	Dr. Duncan Purdie	Southampton Oceanography Centre
16		British Oceanographic Data Centre
36	Dr. Roger Harris	CCMS Plymouth Marine Laboratory
39	Mr. Bob Head	CCMS Plymouth Marine Laboratory
127		PRIME Project Office
136	Dr. Graeme Hays	University of Wales, Swansea

Originator Protocols

Mr. Bob Head and Dr. Roger Harris

Samples (100 ml) were taken from the non-toxic supply and filtered, either through GF/F or pore filters for the size-fractionated work. Pigments were extracted on board ship using 90% acetone and assayed fluorometrically before and after the addition of acid on a Turner 111 bench fluorometer. The fluorometer was calibrated using known concentrations of chlorophyll *a* standard in 90% acetone.

Dr. Duncan Purdie

Samples of 1-2 litres were filtered, extracted into 10 ml acetone for 24-72 hours and assayed on a Turner bench fluorometer.

British Oceanographic Data Centre

Calibrated fluorometer values from the CTD **downcasts** at depths corresponding to the bottle firings have been determined by BODC and stored in the database. A Chelsea Instruments Aquatracka fluorometer was used, calibrated against fluorometric chlorophyll-*a* data by BODC.

Dissolved Sulphur Hexafluoride

Parameter Code Definitions

DSF6GCDX Dissolved sulphur hexafluoride (SF_6) femtomoles/litre
Gas chromatography- electron capture detection (unfiltered)

Originator Code Definitions

106 Dr. C. Law CCMS Plymouth Marine Laboratory

Originator Protocols

Water samples were collected from the CTD casts using syringes. The samples were then injected into the sparge tower of the gas chromatograph under a vacuum (500mm Hg) and mixed with sparge gas (oxygen-free nitrogen). Degassing of SF_6 from the sample was accelerated by the drawing in and rapid expulsion of the sample through 0.5mm orifices. The sparged SF_6 was then passed through magnesium perchlorate followed by a Nafion drier to absorb any water vapour and then directed through a cryogenically cooled Porapak Q trap (Upstill-Goddard et al. 1991) to be stripped. The trap containing the sparged SF_6 was then isolated and raised out of the propanol, being heated from -70°C to 80°C in 25 seconds and the sparged SF_6 was transported to the chromatographic column where it was eluted after 50 seconds and passed to the electron capture detector. Oxygen and similar eluents were retained by molecular sieve columns.

Calibration was by reference to standards prepared by pressure dilution (Upstill-Goddard et al., 1991) of 0.1% SF_6 in nitrogen mixture (Spantech Products Ltd., UK) in 9.4 litre bottles. Calibration precision for each GC unit showed a mean standard deviation of 2.5% or better.

Dissolved Oxygen

Parameter Code Definitions

DOXYPR01	Calibrated CTD Beckmann oxygen probe micromoles/litre Beckmann probe calibrated against Winkler samples
DOXYWITX	Dissolved oxygen concentration micromoles/litre Winkler titration
OXYSBB01	Dissolved oxygen saturation (%) Benson & Krause algorithm from Beckmann probe data

Originator Codes

127	PRIME Project Office	University of Wales, Bangor
16		British Oceanographic Data Centre

Originator Protocols

PRIME Project Office

The technique used was the standard automated Winkler titration, as described in Williams and Jenkinson (1982).

British Oceanographic Data Centre

The oxygen probe concentrations and saturations in table BOTDATA have been obtained by extracting the data from the CTD **downcasts** corresponding to the bottle firing depths. The CTD system used was a Neil Brown Mk3B with a non-pulsed membrane Beckmann oxygen sensor. Oxygen data were calibrated against the PRIME Project Office water bottle data.

Oxygen saturations were computed using calibrated temperature and salinity data and the algorithm of Benson and Krause (1984).

Hydrography

Parameter Code Definitions

ATTNZR01	Red light attenuance (per metre) 660nm transmissometer
POTMCV01	Potential temperature (degrees Celsius) Computed from CTD data using UNESCO function POTEMP
PSALBSTX	Bench salinometer salinity (PSU) Guildline Autolab salinometer
PSALST01	CTD salinity (PSU) Derived from CTD conductivity and temperature measurements
PSALZZXX	Salinity (PSU) Unspecified methodology
SIGTPR01	CTD sigma-theta (kg/m^3) Computed using UNESCO function SVAN
TEMPRTNX	Reversing thermometer temperature (degrees Celsius) Digital SIS reversing thermometers, mounted on CTD bottle
TEMPST01	CTD temperature (degrees Celsius) CTD platinum resistance thermometer
TEMPZZXX	Temperature (degrees Celsius) Unspecified methodology
TOKGPR01	Micromolar to micromoles/kg conversion factor Calculated from CTD data

Originator Code Definitions

1		Research Vessel Services
16		British Oceanographic Data Centre
127	PRIME Project Office	University of Wales, Bangor

Originator Protocols

British Oceanographic Data Centre

The data values present in the bottle database have been obtained by BODC software, which extracts CTD **downcast** data corresponding to the bottle firing depths. This ensures an internally consistent data set across all cruises regardless of whether or not the upcast data were made available. The method is prone to errors if significant changes occur to

water column structure during the cast. In all cases, further details about the CTD data may be obtained from the CTD document for the relevant cruise.

The conversion factor TOKGPR01 is 1000/(1000+sigma-theta). This was included to allow the conversion of sample data stored per litre into per kilogram. Other computed values (potential temperature and sigma-theta) were obtained using the standard UNESCO algorithms.

CTD data were taken by a Neil Brown MK 3 CTD. Data were screened on a graphics workstation to accurately delimit the downcast and flag out any spikes. Temperatures were checked against SIS digital reversing thermometers. Salinity was calibrated against bench salinometer data.

The attenuance data were obtained using a SeaTech 25cm path length red light (661 nm) transmissometer fitted to the CTD cage. Data were corrected for source decay using the air readings during the cruise and the air reading taken from the instrument with a new source.

Further details of CTD data processing and quality control procedures may be found in the CTD data documentation.

Research Vessel Services

Temperature measurements were made using SIS digital reversing thermometers. Two or three instruments were mounted together in a reversing cage to provide duplicate data and an indication of occasions when the cage failed to reverse cleanly. Each thermometer was periodically calibrated at the RVS laboratory facility and a correction, in the form of a third order polynomial, determined. These corrections were routinely applied. Data in the database are the averages of the readings from all thermometers in the cage after fliers (such as caused by the reading being written down incorrectly) had been eliminated.

Salinity samples were taken in medicine bottles. After rinsing, the bottle was filled up to the shoulder, carefully dried off and then sealed with a plastic stopper under the cap. Salinities were determined by taking triplicate readings on a Guildline Autosal bench salinometer as soon as the samples had come to laboratory temperature (generally 24-36 hours after sampling). The instrument was standardised against OSI standard seawater.

Irradiance

Parameter Code Definitions

IRRDPP01	Downwelling 2-pi PAR scalar irradiance (microEinsteins/square metre/second) Hemispherical photodiode light meter mounted on CTD frame
IRRUPP01	Upwelling 2-pi PAR scalar irradiance (microEinsteins/square metre/second) Hemispherical photodiode light meter mounted on CTD frame

Originator Code Definitions

16	British Oceanographic Data Centre

Originator Protocols

The data presented in the BOTDATA table are derived from CTD **downcast** data at the bottle firing depths. Note that the interpolation was done on log transformed data to allow a linear interpolation technique to be used.

The data were collected by Plymouth Marine Laboratory designed light meters based on a photodiode under a hemispherical translucent white plastic cap. The sensors were designed to collect light across the visible portion of the spectrum.

The light meters were fitted to the CTD frame with the downwelling instrument projecting above the top of the bottle rosette and the upwelling instrument attached to the base of the cage. This gave a physical separation of approximately two metres.

The data were logged as voltages and converted to W/m^2 using laboratory calibrations. The calibrations used were over five years old. The data were converted to $\mu E/m^2/s$ using an empirically derived conversion factor of 3.75.

Microzooplankton Biomass

Parameter Code Definitions

MZBCMITX	Microzooplankton biomass as carbon (mg/m^3) Calculated from cell numbers determined by optical microscopy
MZBNMITX	Microzooplankton abundance (cells/ml) Optical microscopy
P400E00A	Autotrophic nanoflagellates (2-20 µm) (cells/ml) Epifluorescence microscopy with DAPI/proflavine stain
P400E00B	Heterotrophic nanoflagellates (2-20 µm) (cells/ml) Epifluorescence microscopy with DAPI/proflavine stain
C400E00B	Heterotrophic nanoflagellate (2-20 µm) biomass as carbon (mg/m^3) Epifluorescence microscopy with DAPI/proflavine stain

Originator Code Definitions

84	Dr. P.H. Burkill	CCMS Plymouth Marine Laboratory
137	Elaine Fileman	CCMS Plymouth Marine Laboratory

Originator Protocols

Water samples were obtained from water bottles deployed on a CTD rosette. These were fixed with 1% Lugol's iodine and the microzooplankton were counted using an image analysis system coupled to an inverted microscope. Fixed samples were gently mixed and sub-samples of 30-100 ml were concentrated overnight in sedimentation chambers. Each sample was examined at a magnification of x300 and all grazers > *circa* 10 microns were counted. Cells were identified to genus level whenever possible.

Live video work together with fluorescence microscopy at sea enabled the separation of heterotrophic dinoflagellates from phototrophic forms. All ciliates were assumed to be heterotrophic. In order to obtain a more accurate identification of some ciliates, Protargol silver staining was carried out on a number of samples.

The biomass was determined using methods detailed in JGOFS protocols (Burkill et al., 1994). The image analysis system was used to generate data on the surface area of each cell. These were converted to cell volume using geometric formulae and standard volume to carbon conversion factors were applied for different taxa. Individual cell carbon volumes were integrated for discrete taxa to determine the biomass of those taxa in each water sample.

Samples were also collected for the determination of nanoplankton (2-20 micron) abundance and biomass. Samples were fixed in 0.3% glutaraldehyde, dual stained with DAPI and proflavine and filtered onto 0.4 micron black polycarbonate filters. Cells were

counted by epifluorescence microscopy. Heterotrophs were distinguished from autotrophs by the presence or absence of chlorophyll autofluorescence. 1-200 flagellate cells were counted per filter and cell dimensions were measured with an ocular micrometer. Flagellate cell volumes were calculated assuming they were ellipsoids. Biovolumes were converted to biomass using appropriate carbon conversion factors.

Phytoplankton

Parameter Code Definitions

A034M00Z	*Coscinodiscus* spp. surface area Optical microscopy	Square micrometres per ml
A073M20Z	*Navicula directa* surface area Optical microscopy	Square micrometres per ml
A074M00Z	*Nitzschia* spp. surface area Optical microscopy	Square micrometres per ml
A093M22Z	*Rhizosolenia shrubsolei* surface area Optical microscopy	Square micrometres per ml
A111M00Z	*Thalassiosira* spp. surface area Optical microscopy	Square micrometres per ml
A118M00Z	*Tropodoneis* spp. surface area Optical microscopy	Square micrometres per ml
A197M00Z	*Pseudo-nitzschia* spp. surface area Optical microscopy	Square micrometres per ml
A205M00Z	*Amphidinium* spp. surface area Optical microscopy	Square micrometres per ml
A213M08Z	*Ceratium furca* surface area Optical microscopy	Square micrometres per ml
A213M09Z	*Ceratium fusus* surface area Optical microscopy	Square micrometres per ml
A213M15Z	*Ceratium lineatum* surface area Optical microscopy	Square micrometres per ml
A228M17Z	*Gonyaulax polygramma* surface area Optical microscopy	Square micrometres per ml
A229M50Z	*Gymnodinium splendens* surface area Optical microscopy	Square micrometres per ml
A230M00Z	*Gyrodinium* spp. surface area Optical microscopy	Square micrometres per ml
A230M99A	*Gyrodinium* spp. B (heterotrophic) surface area. Optical microscopy	Square micrometres per ml

A257M00Z	*Prorocentrum* spp. surface area Optical microscopy	Square micrometres per ml
A349M01Z	*Oxytoxum scolopax* surface area Optical microscopy	Square micrometres per ml
A358M00Z	*Protoperidinium spp* surface area Optical microscopy	Square micrometres per ml
A360M01Z	*Ptychodiscus noctiluca* surface area Optical microscopy	Square micrometres per ml
A370M00Z	*Torodinium* spp. surface area Optical microscopy	Square micrometres per ml
A999M01Z	*Diplopeltopsis* cyst surface area Optical microscopy	Square micrometres per ml
C000M00Z	Diatom carbon content Optical microscopy	mg C/m^3
C034M00Z	*Coscinodiscus* spp. carbon content Optical microscopy	mg C/m^3
C073M20Z	*Navicula directa* carbon content Optical microscopy	mg C/m^3
C074M00Z	*Nitzschia* spp. carbon content Optical microscopy	mg C/m^3
C093M22Z	*Rhizosolenia shrubsolei* carbon content Optical microscopy	mg C/m^3
C111M00Z	*Thalassiosira* spp. carbon content Optical microscopy	mg C/m^3
C118M00Z	*Tropodoneis* spp. carbon content Optical microscopy	mg C/m^3
C197M00Z	*Pseudo-nitzschia* spp. carbon content Optical microscopy	mg C/m^3
C200M00A	Autotrophic dinoflagellate carbon content Optical microscopy	mg C/m^3
C205M00Z	*Amphidinium* spp. carbon content Optical microscopy	mg C/m^3
C213M08Z	*Ceratium furca* carbon content Optical microscopy	mg C/m^3

C213M09Z	*Ceratium fusus* carbon content Optical microscopy	mg C/m^3
C213M15Z	*Ceratium lineatum* carbon content Optical microscopy	mg C/m^3
C228M17Z	*Gonyaulax polygramma* carbon content Optical microscopy	mg C/m^3
C229M50Z	*Gymnodinium splendens* carbon content Optical microscopy	mg C/m^3
C230M00Z	*Gyrodinium* spp. carbon content Optical microscopy	mg C/m^3
C230M99A	*Gyrodinium* spp. B (heterotrophic) carbon content. Optical microscopy	mg C/m^3
C257M00Z	*Prorocentrum* spp. carbon content Optical microscopy	mg C/m^3
C349M01Z	*Oxytoxum scolopax* carbon content Optical microscopy	mg C/m^3
C358M00Z	*Protoperidinium spp* carbon content Optical microscopy	mg C/m^3
C360M01Z	*Ptychodiscus noctiluca* carbon content Optical microscopy	mg C/m^3
C370M00Z	*Torodinium* spp. carbon content Optical microscopy	mg C/m^3
C999M01Z	*Diplopeltopsis* cyst carbon content Optical microscopy	mg C/m^3
P000M00Z	Diatom abundance Optical microscopy	per ml
P034M00Z	*Coscinodiscus* spp. abundance Optical microscopy	per ml
P039M01Z	*Dactyliosolen antarctica* abundance Optical microscopy	per ml
P039M03Z	Dactyliosolen mediterraneus abundance Optical microscopy	per ml
P052M00Z	*Fragilaria* spp abundance Optical microscopy	per ml

P052M01Z	*Fragilaria nana* abundance Optical microscopy	per ml
P073M10Z	*Navicula planamembranacea* abundance Optical microscopy	per ml
P073M20Z	*Navicula directa* abundance Optical microscopy	per ml
P074M00Z	*Nitzschia* spp. abundance Optical microscopy	per ml
P074M14Z	*Nitzschia closterium* abundance Optical microscopy	per ml
P074M18Z	*Nitzschia delicatissima* abundance Optical microscopy	per ml
P074M61Z	*Nitzschia seriata* abundance Optical microscopy	per ml
P093M02C	*Rhizosolenia alata indica* abundance Optical microscopy	per ml
P093M02H	*Rhizosolenia alata inermis* abundance Optical microscopy	per ml
P093M22Z	*Rhizosolenia shrubsolei* abundance Optical microscopy	per ml
P093M23Z	*Rhizosolenia stolterfothii* abundance Optical microscopy	per ml
P110M01Z	*Thalassionema nitzschiodes* abundance Optical microscopy	per ml
P111M00Z	*Thalassiosira* spp. abundance Optical microscopy	per ml
P112M02Z	*Thalassiothrix longissima* abundance Optical microscopy	per ml
P118M00Z	*Tropodoneis* spp. abundance Optical microscopy	per ml
P197M00Z	*Pseudo-nitzschia* spp. abundance Optical microscopy	per ml
P200M00A	Autotrophic dinoflagellate abundance Optical microscopy	per ml

P205M00Z	*Amphidinium* spp. abundance Optical microscopy	per ml
P213M08Z	*Ceratium furca* abundance Optical microscopy	per ml
P213M09Z	*Ceratium fusus* abundance Optical microscopy	per ml
P213M13Z	*Ceratium horridum* abundance Optical microscopy	per ml
P213M15Z	*Ceratium lineatum* abundance Optical microscopy	per ml
P228M17Z	*Gonyaulax polygramma* abundance Optical microscopy	per ml
P228M22Z	*Gonyaulax turbynei* abundance Optical microscopy	per ml
P229M00D	*Gymnodinium* spp. (heterotrophic) abundance Optical microscopy	per ml
P229M50Z	*Gymnodinium splendens* abundance Optical microscopy	per ml
P230M00Z	*Gyrodinium* spp. abundance Optical microscopy	per ml
P230M99A	*Gyrodinium* spp. B (heterotrophic) abundance Optical microscopy	per ml
P257M00Z	*Prorocentrum* spp. abundance Optical microscopy	per ml
P315M00Z	*Cochlodinium* spp. abundance Optical microscopy	per ml
P349M00Z	*Oxytoxum* spp. abundance Optical microscopy	per ml
P349M01Z	*Oxytoxum scolopax* abundance Optical microscopy	per ml
P358M00Z	*Protoperidinium* spp abundance Optical microscopy	per ml
P360M01Z	*Ptychodiscus noctiluca* abundance Optical microscopy	per ml

P370M00Z	*Torodinium* spp. abundance Optical microscopy	per ml
P490M00Z	Coccolithophore abundance Optical microscopy	per ml
P500M17Z	Ciliate abundance Optical microscopy	per ml
P510M01Z	Bodonid abundance Optical microscopy	per ml
P520M04Z	Tintinnid abundance Optical microscopy	per ml
P999M01Z	*Diplopeltopsis* cyst abundance Optical microscopy	per ml
V034M00Z	*Coscinodiscus* spp. volume Optical microscopy	μm^3/ ml
V073M20Z	*Navicula directa* volume Optical microscopy	μm^3/ ml
V074M00Z	*Nitzschia* spp. volume Optical microscopy	μm^3/ ml
V093M22Z	*Rhizosolenia shrubsolei* volume Optical microscopy	μm^3/ ml
V111M00Z	*Thalassiosira* spp. volume Optical microscopy	μm^3/ ml
V118M00Z	*Tropodoneis* spp. volume Optical microscopy	μm^3/ ml
V197M00Z	*Pseudo-nitzschia* spp. volume Optical microscopy	μm^3/ ml
V205M00Z	*Amphidinium* spp. volume Optical microscopy	μm^3/ ml
V213M08Z	*Ceratium furca* volume Optical microscopy	μm^3/ ml
V213M09Z	*Ceratium fusus* volume Optical microscopy	μm^3/ ml
V213M15Z	*Ceratium lineatum* volume Optical microscopy	μm^3/ ml

V228M17Z	*Gonyaulax polygramma* volume Optical microscopy	μm^3/ ml
V229M50Z	*Gymnodinium splendens* volume Optical microscopy	μm^3/ ml
V230M00Z	*Gyrodinium* spp. volume Optical microscopy	μm^3/ ml
V230M99A	*Gyrodinium* spp. B (heterotrophic) volume Optical microscopy	μm^3/ ml
V257M00Z	*Prorocentrum* spp. volume Optical microscopy	μm^3/ ml
V349M01Z	*Oxytoxum scolopax* volume Optical microscopy	μm^3/ ml
V358M00Z	*Protoperidinium* spp. volume Optical microscopy	μm^3/ ml
V360M01Z	*Ptychodiscus noctiluca* volume Optical microscopy	μm^3/ ml
V370M00Z	*Torodinium* spp. volume Optical microscopy	μm^3/ ml
V999M01Z	*Diplopeltopsis* cyst volume Optical microscopy	μm^3/ ml

Originator Codes

104	Mr. Glen Tarran	CCMS Plymouth Marine Laboratory
127	PRIME Project Office	University of Wales, Bangor

Originator Protocols

Water samples were taken from bottles deployed on the CTD and preserved in Lugol's Iodine. Back in the laboratory, sedimented samples were examined by optical microscopy and the dominant species in the >5 micron size fraction were quantified. Diameters were measured by reference to a graticule. Surface areas and volumes were calculated according to simple equations of spheres or solid cylinders, according to species. Carbon biomasses were calculated from the species cell counts and species-specific values of typical carbon content per cell.

Automated Flow Cytometry

Parameter Code Definitions

C400A00A	Flagellate (2μm) biomass as carbon Automated flow cytometry	mg/m^3
C400A00B	Flagellate (4μm) biomass as carbon Automated flow cytometry	mg/m^3
C400A00C	Flagellate (20μm) biomass as carbon Automated flow cytometry	mg/m^3
C419A00Z	*Coccolithus* spp. biomass as carbon Automated flow cytometry	mg/m^3
C490A00Z	Coccolithophore biomass as carbon Automated flow cytometry	mg/m^3
C700A90Z	*Synecchococcus* spp. biomass as carbon Automated flow cytometry	mg/m^3
C701A90Z	*Prochlorococcus* spp. biomass as carbon Automated flow cytometry	mg/m^3
CYEUAFTX	Eukaryotic cell biomass as carbon Automated flow cytometry	mg/m^3
CYPKAFTX	Prokaryote biomass as carbon Automated flow cytometry	mg/m^3
P400A00A	Flagellate (2μm) abundance Automated flow cytometry	per ml
P400A00B	Flagellate (4μm) abundance Automated flow cytometry	per ml
P400A00C	Flagellate (20μm) abundance Automated flow cytometry	per ml
P419A00Z	*Coccolithus* spp. abundance Automated flow cytometry	per ml
P490A00Z	Coccolithophore abundance Automated flow cytometry	per ml
P700A90Z	*Synecchococcus* spp. abundance Automated flow cytometry	per ml

P701A90Z	*Prochlorococcus* spp. abundance Automated flow cytometry	per ml
PYEUAFTA	Large eukaryotic cell abundance Automated flow cytometry	per ml
PYEUAFTB	Small eukaryotic cell abundance Automated flow cytometry	per ml
PYEUAFTX	Eukaryotic cell abundance Automated flow cytometry	per ml
PYPKAFTX	Prokaryotic cell abundance Automated flow cytometry	per ml

Originator Code Definitions

104	Mr. Glen Tarran	CCMS Plymouth Marine Laboratory

Originator Protocols

400 microlitre water samples were injected into a Becton Dickinson FACSort cytometer. Sensitivity was sufficient to determine cellular light scatter and fluorescences from prochlorophytes (0.6 micron size, approximate chlorophyll-a content 1 femtogram) in surface waters. Protocols based on light scatter and fluorescence were used to characterise and quantify total phytoplankton concentrations and those of individual taxa (Carr et al., 1996).

OPC Counts

Parameter Code Definitions

ZV00C00E Zooplankton abundance (parts per billion by volume) as measured by OPC. 250-354 micron size fraction

ZV00C00F Zooplankton abundance (parts per billion by volume) as measured by OPC. <500 micron size fraction

ZV00C00G Zooplankton abundance (parts per billion by volume) as measured by OPC. <707 micron size fraction

ZV00C00H Zooplankton abundance (parts per billion by volume) as measured by OPC. <1000 micron size fraction

ZV00C00I Zooplankton abundance (parts per billion by volume) as measured by OPC. <1414 micron size fraction

ZV00C00J Zooplankton abundance (parts per billion by volume) as measured by OPC. <2000 micron size fraction

ZV00C00K Zooplankton abundance (parts per billion by volume) as measured by OPC. <2828 micron size fraction

ZV00C00L Zooplankton abundance (parts per billion by volume) as measured by OPC. <4000 micron size fraction

ZV00C00M Zooplankton abundance (parts per billion by volume) as measured by OPC. <5657 micron size fraction

ZV00C00N Zooplankton abundance (parts per billion by volume) as measured by OPC. <8000 micron size fraction

ZV00C00P Zooplankton abundance (parts per billion by volume) as measured by OPC. <11312 micron size fraction

ZV00C00Q Zooplankton abundance (parts per billion by volume) as measured by OPC. <16000 micron size fraction

Originator Code Definitions

141 Dr. Chris Gallienne CCMS Plymouth Marine Laboratory

Originator Protocols

A laboratory OPC and video system was used in flow-through mode, sampling the ship's non-toxic supply at approximately 20 litres a minute via a de-bubbling device. An in-line flow meter was installed to give a record of volume of water passing through the OPC. Abundances were derived for zooplankton in the size range 0.25 - 16 mm in equivalent spherical diameter. Although the initial sampling rate was 2 Hertz, data were integrated over 30 seconds to give enough animals for a reasonable description of community size

structure. Validation was by means of a lab calibration against spherical glass beads of known size. Further details are given in Gallienne et al. (1996).

Mesozooplankton Biomass and Egg Production

Parameter Code Definitions

MSBCMITX	Total mesozooplankton biomass Computed from cell counts	mg/m^3
MSEPMITX	Total mesozooplankton egg production Optical microscopy	per female per day
SDMEMITX	Total mesozooplankton egg production standard deviation. Optical microscopy.	per female per day

Originator Code Definitions

36	Dr. Roger Harris	CCMS Plymouth Marine Laboratory

Originator Protocols

Mesocosm bags were sampled daily with a WP-2 200 micron mesh zooplankton net, taken together with water samples for pigment analysis. Biomass was determined using JGOFS protocols.

A sub-sample of the catch was examined by optical microscopy and the adult females were counted and separated. They were incubated for 24 hours and the number of eggs produced determined by optical microscopy.

Photosynthesis and Calcification

Parameter Code Definitions

ALPBPIP2	Calcification quantum yield (alphaB) PvI incubation (0.45 μm Nuclepore filtered)	mg C/(μE/m^2/sec)/mg chl/hour
ALPHPIP2	Quantum yield (alpha) PvI incubation (0.45 μm Nuclepore filtered)	mg C/(μE/m^2/sec)/mg chl/hour
CMAXPIP2	Calcification maximum (cmax) PvI incubation (0.45 μm Nuclepore filtered)	mg C/mg chl/hour
PMAXPIP2	Photosynthetic maximum (pmax) PvI incubation (0.45 μm Nuclepore filtered)	mg C/mg chl/hour
SEABPIP2	Standard error of alphaB PvI incubation (0.45 μm Nuclepore filtered)	mg C/(μE/m-2/sec)/mg chl/hour
SEALPIP2	Standard error of alpha PvI incubation (0.45 μm Nuclepore filtered)	mg C/(μE/m-2/sec)/mg chl/hour
SECXPIP2	Standard error of cmax PvI incubation (0.45 μm Nuclepore filtered)	mg C/mg chl/hour
SEPXPIP2	Standard error of pmax PvI incubation (0.45 μm Nuclepore filtered)	mg C/mg chl/hour
TCUPRIPZ	Carbon uptake Radiotracer in situ incubation	mg/m^3/day
TCUPROPZ	Carbon uptake Radiotracer natural light incubation	mg/m^3/day

Originator Code Definitions

2	Dr. Duncan Purdie	Southampton Oceanography Centre
46	Dr. Mike Wyman	University of Stirling
127	PRIME Project Office	University of Wales, Bangor

Originator Code Protocols

Dr. Duncan Purdie

Photosynthesis and calcification versus irradiance incubations were performed in polycarbonate bottles in an artificial light gradient in a constant temperature bath maintained by circulating fjord water (mesocosm experiments). Incubation times were

short, generally of the order of 6 hours. The data were parameterised following the procedures in Platt et al. (1980).

Dr. Mike Wyman and PRIME Project Office

Production was measured using the ^{14}C radiotracer on samples collected pre-dawn to avoid light shock. Incubations were initiated by transferring aliquots of water from each sampling depth into triplicate 60ml clear polycarbonate bottles and two 60ml black polycarbonate bottles prior to inoculation with 10 μCi $NaH^{14}CO_3$. Incubations were for 24 hours; either *in situ* in the case of the mesocosm experiment or on deck using natural light incubators on cruise DI221. The on deck incubators consisted of a series of plastic boxes covered with neutral density filters to give a simulated ambient light profile. Samples were maintained at ambient temperature by pumping seawater from the ship's non-toxic supply through the system. The *in situ* incubations were carried out by suspending the sample bottle in the mesocosm bags, or by using a free-floating rig for bag 9 (the surrounding fjord water). Incubations were terminated by filtration onto polycarbonate filters. The filters were then placed in scintillation vials prior to counting of incorporated material using an onboard/on-site scintillation counter.

Oxygen Production and Respiration

Parameter Code Definitions

GOXPLDPX	Gross oxygen production Light dark bottle incubation	µmol/litre/hour
NOXPLDPX	Nett oxygen production Light dark bottle incubation	µmol/litre/hour
RESPLDPX	Respiration Light dark bottle incubation	µmol/litre/hour
SEGPLDPX	Standard error of gross oxygen production Light dark bottle incubation	µmol/litre/hour
SENPLDPX	Standard error of nett oxygen production Light dark bottle incubation	µmol/litre/hour
SERPLDPX	Standard error of respiration Light dark bottle incubation	µmol/litre/hour
SRSPLDPK	Size-fractionated respiration Light dark bottle incubation (53 µm screened)	µmol/litre/hour
SESRLDPK	Standard error of respiration Light dark bottle incubation (53 µm screened)	µmol/litre/hour
SRSPLDPL	Size-fractionated respiration Light dark bottle incubation (20 µm screened)	µmol/litre/hour
SESRLDPL	Standard error of respiration Light dark bottle incubation (20 µm screened)	µmol/litre/hour
SRSPLDPM	Size-fractionated respiration Light dark bottle incubation (5 µm screened)	µmol/litre/hour
SESRLDPM	Standard error of respiration Light dark bottle incubation (5 µm screened)	µmol/litre/hour
SRSPLDPN	Size-fractionated respiration Light dark bottle incubation (2 µm screened)	µmol/litre/hour
SESRLDPN	Standard error of respiration Light dark bottle incubation (2 µm screened)	µmol/litre/hour

SRSPLDPP	Size-fractionated respiration Light dark bottle incubation (0.8 μm screened)	μmol/litre/hour
SESRLDPP	Standard error of respiration Light dark bottle incubation (0.8 μm screened)	μmol/litre/hour

Originator Code Definitions

2	Dr. Duncan Purdie	Southampton Oceanography Centre
33	Prof. P.J. Williams	University of Wales, Bangor

Originator Protocols

Prof. P.J. Williams

Water was sampled from the mixed layer at an approximate depth of 10 metres and size-fractionated aliquots were produced using Nuclepore filters or mesh screens. Coulter Counter data were used to confirm that the fractionating meshes and filters were working effectively. A sub-sample was left unfractionated to measure whole community respiration.

Dissolved oxygen concentrations were measured using the automated Winkler titration technique at the start of the experiment and after 24 hours incubation in the dark. The respiration rates were then determined from the difference in oxygen concentration between the time zero sample and the equivalent incubated sample.

Dr. Duncan Purdie

Gross and nett oxygen production and respiration were measured using light and dark bottle incubations. Oxygen concentrations were determined using an automated Winkler titration technique.

Trace Metals

Parameter Code Definitions

FEINCVDX	Dissolved inorganic total iron Cathodic stripping voltammetry	nM
FELGCVDX	Dissolved total iron complexed by ligands Cathodic stripping voltammetry	nM
FELSCVZZ	Dissolved total iron ligand binding strength (log K'Fe) Cathodic stripping voltammetry	dimensionless
FEXXCVDX	Dissolved total iron Cathodic stripping voltammetry	nM
LGFECVDX	Conc of iron-complexing organic ligands Cathodic stripping voltammetry	nM
LGZNCVDX	Conc of zinc-complexing organic ligands Cathodic stripping voltammetry	nM
SDFECVDX	Dissolved total iron standard deviation Cathodic stripping voltammetry	nM
SDFLCVZZ	Standard deviation of log K'Fe Cathodic stripping voltammetry	dimensionless
SDLFCVDX	Iron-complexing organic ligand std deviation Cathodic stripping voltammetry	nM
SDLZCVDX	Zinc- complexing organic ligand std deviation Cathodic stripping voltammetry	nM
SDZLCVZZ	Standard deviation of log K'Zn Cathodic stripping voltammetry	dimensionless
SDZNCVDX	Dissolved total zinc standard deviation Cathodic stripping voltammetry	nM
ZNINCVDX	Dissolved inorganic zinc Cathodic stripping voltammetry	nM
ZNLGCVDX	Dissolved zinc complexed by ligands Cathodic stripping voltammetry	nM
ZNLSCVZZ	Diss zinc ligand binding strength (log K'Zn) Cathodic stripping voltammetry	dimensionless

ZNXXCVDX	Dissolved zinc concentration Cathodic stripping voltammetry	nM

Originator Code Definitions

110	Dr. C.M.G van den Berg	University of Liverpool

Originator Protocols

Dr. C.M.G. van den Berg

Samples were collected using acid-cleaned Teflon-coated Go-Flo bottles for vertical profiles, or using a peristaltic pump (flow rate 3-4 litres per minute) attached to a 2cm diameter PVC hose for surface underway samples. Samples were decanted into acid-cleaned HDPE sample bottles (500ml). Some were stored frozen at –20°C until analysis back in the laboratory, others were acidified with quartz-distilled hydrochloric acid to pH 2.8 – 3.0 and stored at room temperature to test the effects of storage on organic speciation determination. Sample manipulations were carried out in a class 100 clean container at room temperature.

Analysis was carried out at Liverpool University using Autolab voltammeters (Eco Chemie, Netherlands) attached to a hanging mercury drop (HMDE, from Metrohm 663 VA, drop surface area 0.38 mm^2). The voltammetric cell was made of glass and solutions in the cell were stirred using a rotating PTFE rod (Metrohm electrode). Potentials were given with respect to a double junction, Ag/AgCl reference electrode (saturated AgCl in 3M KCl) with the salt bridge filled with 3M KCl and with a graphite rod as a counter electrode. Each system was controlled with an IBM-compatible PC using GPES33 software from Eco Chemie. UV-digestion of samples was carried out in Teflon capped silica tubes using a 500 Watt high-pressure mercury-vapour lamp (home-built).

The organic complexation of iron and zinc was determined by means of titrations using ligand competition against an added specific ligand with detection by cathodic stripping voltammetry. The added ligand was PDC (pyrrolidine-dithiocarbamate) for zinc and NN (1-nitroso-2-naphtol) for iron.

For further details see Boye et al., Leal and van den Berg and Daniels et al. (all papers were in review at the time of going to press).

Genetic Markers

Parameter Code Definitions

RBHYGMPR Proportion of hybridised prymnesiophyte RuBisCO mRNA %
Genetic marker

RBHYGMDI Proportion of hybridised diatom RuBisCO mRNA %
Genetic marker

RBHYGMDP Proportion of hybridised deep-adapted *Prochlorococcus spp*. %
RuBisCO mRNA
Genetic marker

RBHYGMSP Proportion of hybridised shallow-adapted *Prochlorococcus spp*. %
RuBisCO mRNA
Genetic marker

RBHYGMP2 Proportion of hybridised RuBisCO mRNA %
Genetic marker

NMCLGMSP Number of clones for shallow-adapted *Prochlorococcus spp* dimensionless
Genetic marker

NMCLGMDP Number of clones for deep-adapted *Prochlorococcus spp* dimensionless
Genetic marker

PSTSGMSP Expression of phosphate-limitation protein (PSTS) in dimensionless
shallow-adapted *Prochlorococcus spp*
Genetic marker and Western dot blot

PSTSGMDP Expression of phosphate-limitation protein (PSTS) in dimensionless
deep-adapted *Prochlorococcus spp*
Genetic marker and Western dot blot

Originator Code Definitions

46	Dr. Mike Wyman	University of Stirling
140	Dr. Nyree West	University of Warwick

Originator Protocols

Dr. M. Wyman

Samples were collected either from the ship's non-toxic supply or from Go-Flo water bottles fired at an approximate depth of two metres. RNA, DNA and proteins were extracted as described in Wyman et al. (in revision). The relative abundance of rbcl (a gene coding for RuBisCO) transcripts was examined using a group specific probe for rbcl as described in Wyman et al. (in revision).

Dr. Nyree West

Samples were collected either from the ship's non-toxic supply or from the CTD rosette Go-Flo water bottles fired at a number of depths down to 110 metres. *Prochlorococcus* community structure was examined using the polymerase chain reaction to amplify a region of the 16S rRNA to look at the changes in genotypes with depth through the water column. The phosphate status of these organisms was assayed by collecting large volume samples and concentrating to approximately 250ml by tangential flow filtration using a 0.3µm filter and cell pellets collected by centrifugation. The protein marker PstS a periplasmic phosphate-binding protein, induced only under limiting phosphate conditions was used. Antibodies raised against this protein were analysed by Western dot blotting. Further details of these techniques are given in Scanlan et al. (1996).

References

Benson, B.B., Krause D. 1984. The concentration and isotopic fractionation of oxygen dissolved in fresh water and seawater in equilibrium with the atmosphere. ***Limnol.Oceanogr***., 29, 620-632.

Boye, M., Sarthou, G., van den Berg, C.M.G. (in review). Organic speciation of iron and zinc in the North-Eastern Atlantic Ocean. ***Marine Chemistry***

Burkill, P.H., Edwards, E.S., Landry, M., Paranjape, M., Reckermann, M., Sieracki, Sleigh, M.A., Stoecker, D.K. and Verity, P., 1994. Microzooplankton biomass. In: Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. Ed: A.H. Knap. Intergovernmental Oceanographic Commission Manual & Guides 29, 147-151. UNESCO, Paris.

Carr, M.R., Tarran, G.A. and Burkill, P.H., 1996. Discrimination of marine phytoplankton species through the statistical analysis of their flow cytometric signatures. ***Journal of Plankton Research,*** 18:7, 1225-1238

Daniels A., Baker, A.R. and van den Berg C.M.G. (in review). Sequential flow analysis coupled with ACSV for on-line monitoring of trace elements in the marine environment***.*** ***Frensenius Journal of Analytical Chemistry***

Gallienne, C.P., Robins, D.B., and Pilgrim, D.A., 1996. Measuring abundance and size distribution of zooplankton using the OPC-1L in underway mode. ***Underwater Technology***, 21, 15-22.

Hobbie, J.E., Daley, R.J. and Jasper, S., 1977. Use of Nuclepore filters for counting bacteria by epifluorescence microscopy***. Applied and Environmental Microbiology*** 33, 1225-1228.

Leal F. and van den Berg C. M. G. (in review) Determination of copper(I) complexation by titrations with copper(II) and detection with CSV. ***Marine Chemistry***

Law, C.S., Watson A.J., Liddicoat M.I., 1994. Automated vacuum analysis of sulphur hexafluoride in seawater: derivation of the atmospheric trend (1970-1993) and potential as a transient tracer. ***Marine Chemistry***, 48, 57-69

Miller, A.E.J., Mantoura, R.F.C., Preston, M.R. and Suzuki, Y., 1993. Preliminary study of DOC in the Tamar Estuary, UK, using UV-persulphate and HTCO techniques. ***Marine Chemistry***., 41, 223-228.

Platt, T., Gallegos, C.L. and Harrison, W.G., 1980. Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton***. J. Mar. Res***., 38, 687-701.

Porter, K.G. and Feig, Y.S., 1980. Use of DAPI for identifying and counting aquatic microflora. ***Limnology and Oceanography***, 25, 943-948.

Rees, A.P., Owens, N.J.P. and Woodward, E.M.S., 1995. Phytoplankton nitrogen assimilation at low nutrient concentrations in the NW Mediterranean Sea. Water Pollution Research Report 32 in EROS 2000 ed J-M Martin and Barth, European Commission, 141-148.

Scanlan D.J., Silman N.J., Donald K., Wilson W.H., Joint I.R., Mann N.H. and Carr N.G., 1996. A molecular marker for the phosphate status of photosynthetic picoplankton. Abstract. Vth European Marine Microbiology Symposium. Bergen. Norway. 11 - 15 August 1996.

Scanlan D.J., Silman N.J., Donald K.M., Wilson W.H., Carr N.G., Joint, I.R. and Mann N.H. (in press). An immunological approach to detect phosphate stress in populations and single cells of photosynthetic picoplankton. ***Applied and Environmental Microbiology***.

Simon, M. and Azam, F., 1989. Protein content and protein synthesis rates of planktonic marine bacteria. ***Marine Ecology Progress Series*** 51, 201-213.

Strickland, J.D.H., Parsons, T.R. 1972. A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***., 167-311.

Upstill-Goddard, R.C., Watson, A.J., Liss, P.S., Liddicoat, M.I., 1990. Gas transfer velocities in lakes measured with SF_6. ***Tellus Ser B*** 42, 364-377

Upstill-Goddard, R.C., Watson, A.J., Liddicoat, M.I., Wood, J., 1991. Sulphur hexafluoride and Helium-3 as seawater tracers: deployment techniques and continuous underway analysis of SF_6 by purge and trap ECGC. ***Analytica Chimica Acta*** 249, 555-562.

Urbach E., Scanlan D.J., Distel D.L., Waterbury J.B. and Chisholm S.W. (in review). Rapid diversification of marine picophytoplankton infrerred from sequences of *Prochlorococcus* and *Synechococcus* cyanobacteria. ***Journal of Molecular Evolution***

Wyman M., Davies J.T., Weston K., Crawford D.W. and Purdie D.A. (in revision) Ribulose-1,5-bisphosphate carboxylase/oxygenase (RubisCO) gene expression and photosynthetic activity in nutrient enriched mesocosm experiments. ***Estuarine, Coastal and Shelf Science***. Special Issue.