Indexed JAR.

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CRUISE PROGRAMME
IMER Cruise: Index I
RVS: CD 16/86
(Prep'd 23 February 1986)

VESSEL RRS Charles Darwin

PERIOD 5 September - 9 October 1986

PERSONNEL
Dr R Fauzi C Mantoura (Principal Scientist) (UK)
Dr Nicholas J P Owens (1st Scientist) (UK)
Dr Peter H Burkill (UK)
Mr Bob Williams (UK)
Mr Malcolm S-Woodward (logistics) (UK)
Mr Robin J Howland (UK)
Mrs Jenne Morris (UK)
Miss Carole A Llewellyn (UK)
Mr Cliff Law (UK)
Mr Ian Bellan (UK)
Mr Ray Leakey (UK) and/or Omani Observer Scientist
Dr Hein J W de Baar (U. of Cambridge & Netherlands)
Dr Hugh W Ducklow (U. of Maryland, USA)
Prof Bernt Zeitzschel (U. of Kiel, W. Germany)

RVS Winch Support 1 (UK)
RVS Winch Support 2 (UK)
RVS CTD Engineer (UK)
RVS Computer Engineer (UK)

ITINERARY
Wednesday 11 June : latest date for arrival at IMER of US, Kiel Cambridge equipment.

Saturday 14 June 1986
Millbay Dock; am unload RRS Frederick Russell and transfer all equipment to IMER for recommissioning, repacking ready for transfer to Index Equipment Pool.

Sunday 15 June
IMER - all equipment (IMER, Kiel, Maryland, Cambridge) must be packed, palletized, box numbered and colour coded, and stacked at designated forecourt ready for containerization.

Monday 16 June
0700 IMER complete HM Custom Clearance and loading of equipment into IMER container No 1 sealing by 1230. Winch container onto lorry (1330) for transporation to Falmouth Dock (ETA 1630) and transfer to RRS Charles Darwin.

Tuesday 17 June
1000 Load container No 2 ready for transfer to RVS for eventual trans shipment to Patras, Greece.
1700 RRS Charles Darwin depart Falmouth for Gibraltar,

Patras, (27 June) Port Said ( ) Jeddah ( ) Perim and thence Seychelles (Victoria, ETA 1300 local time, 7 August.

9-31 August. Leg 1 (Cambridge, Southampton) Victoria to Victoria

Tuesday 2 September
Latest possible flight departing UK to Paris to Seychelles

Wednesday 3 September
Arrival of latest possible flight from UK.
Report to PS and Officer on Watch on RRS Charles Darwin by 1400 or earlier.Commence equipment installation, deck plumbing, verify operation. Meals/accommodation in hotel. Debriefing on progress, problems.

Thursday 4 September
0900 Complete equipment preparation, check satisfactory operation and calibration of all hardware, rigs, traps, etc. Victualling and berthing O/B.

Friday 5 September
Note: all times are approximate and subject to alteration.
0900 Depart Victoria set course for St001 (00°00'N 67°00'E) 740 nm at 11 knots ETA 0400 Monday 8 September. When off Seychelle Bank, Shakedown deployment of CTD Rosette hydrocast to 1500 m.sampling for nutrients oxygen NOx and chlorophyll.

Saturday 6 September
In passage to St 1. 1200 when at 03°00'S (~ 1200), CTD profiling 1500. Deploy UOR 20-150 m then resume passage and commence continuous surface S, T. Fluor and hourly discrete NO_3, NO_2, PO_4, Si, NH_3 chlorophyll and particulate sampling, batching for analyses at St 1.

Sunday 7 September
In passage continue monitoring. Deck assembly of sediment trap and *in situ* incubation rigs.

Monday 8 September
Full State and Rate Variables Hydrocast, consisting of:
1 computer-controlled CTD/Rosette/O_2, Fluor down haul profiling, uphaul sampling 1000, 800, 600, 400, 300, 200, 150, 100, 75, 50, 30, 10. Analyses of dissolved and particulate state variables (Table 1 para m. 3-15 2nd shallow hydrocast for additional samples and trace metals. UOR vertical profile LHPR oblique tow 1000 m.

Tuesday 9 September
Pre-dawn. Hydrocast for microbiol rate measurements: ^{14}C, ^{15}N, ΔO_2.

Dawn: deploy *in situ* incubation rig near sediment traps for

24 h incubation. Size-fractionated respiration. N_2 fixation, denitrification, bacterial production and µzp grazing experiments.

Wednesday 10 september
Dawn Recovery in situ rigs and sample processing. Recovery of sediment traps. ~ 1200 depart St 1 steam for St 2 (ETA 1000 11.9.86) UOR and monitoring continuously S, T, fluorescence and discrete hourly samples for NO_3, NO_2, Si, PO_4, NH_3, chlorophyll and particulate sampling, batching for analyses at St 2 ("Standard monitoring").

Thursday 11 September
1000 ETA St 2. Full computer-CTD hydrocast double hydrocast (24 Rosette samples) to 3000 m, concentrating on chemocline ~ 110 m region. Sampling for State Variable parameters (Table 1, sections I, II, III) only. Optional shipboard incubation for rate measurements. Depart St 2 1800 steam for St 3.

Friday 12 September
ETA St 3 1500. Repeat hydrocasts, measurements, experiments and deployments as per St 1 (4000 m).

Saturday 13 September
On St 3.

Sunday 14 September
1500 depart St 3 proceed to St 4, standard monitoring.

Monday 15 September
1300 ETA St 4, repeat measurements St 2 ETD 1900 proceed to St 5 with standard monitoring.

Tuesday 16 September
1600 ETA St 5. Repeat hydrocasts, measurement equipment and deployment as per St 1, 3. (3800 m).

Wednesday 17 September
on St 5.

Thursday 18 september
1800 Depart St 5 proceed to St 6 standard monitoring.

Friday 19 September
1500 ETA St 6 repeat hydrocasts, measurements as in St 2, 4. Depart St 6 2100 proceeding to St 7 standard monitoring.

Saturday 20 September
2100 ETA ST 7. Repeat CTD hydrocast, measurements and deployments of equipment as in St 1, 3, 5 but traps deployed for 24 hours.

Sunday 21 September
On St 7 recover sediment traps, rigs etc by 2400. Proceed

to St 8 standard monitoring.

Monday 22 September
1600 ETA St 8 repeat hydrocast, measurements as per St 2, 4, 6. depart St 8 2200 proceed to St 9. Standard monitoring.

Tuesday 23 September
1000 ETA St 9 repeat CTD hydrocast, measurements deployments as in St 1, 3, 5, 7 with 24 h trap deployment.

Wednesday 24 September
1400 depart St 9 proceed to St 10 (ETA 2100) thence St 11 (1000 25 September 1986) and carry out state variable measurements by hydrocasts and measurements as per St 2, 4, 6, 8 with standard monitoring between.

Thursday 25 September
Mid cruise exchange of scientists with Omani observer (to be confirmed) at Qaboos .Proceed to St 12 (standard monitoring).

Friday 26 September
0800 ETA ST 12. CTD-profiling for state variables as per St 2, 4. Depart 1300 for St 13. Commence continuous monitoring of surface S, T, NO_3, NO_2, PO_4, Si, NH_4, fluorescence with pigments, bacterial counts, O_2, and other particulate state variables for the whole of S Oman upwelling track.

Saturday 27 september
0300 ETA St 13. STandard hydrocast. Depart 0800 proceed to St 14. 2100 ETA St 14. Deploy sediment trap etc as per St 1, 3, 5.

Sunday 28 September
On St 14 pre-dawn biological water sampling. dawn deployment of _in situ_ rig. Complete analyses and rate experiments.

Monday 29 September
Dawn recovery of sediment trap and incubation rig. Depart 1000 proceed to St 15 ETA 2000. Standard hydrocast. Depart 2400 proceed to St 16 (Gulf of Masirah)

Tuesday 30 September
1000 E%TA St 16. Launch sediment traps. Commence final comp. rosette fluor O_2 hydrocast state and rate variables.

Wednesday 1 October
Pre-dawn: Hydrocast biological water samples for _in situ_ incubation experiments. Dawn: Deploy _in situ_ incubation rig. Grazing experiments, bacterial productivity. Recover sediment traps (1800).

Thursday 2 October

Dawn: Recover *in situ* rig proceed to 17, 18 .... 22 with standard monitoring.

Friday 3 October
In passage to St 22.

Saturday 4 October
In passage to St 22.

Sunday 5 October
0600 ETA St 22. Proceed to St 12 cease monitoring at Masira Island.

Monday 6 October
Proceed to Qaboos. Commence packing equipment excepting display items and demonstrations.

Tuesday 7 October
Programme contingency day.

Wednesday 8 October
Arrive Qaboos mid day.Recontaining equipment, transfer perishable samples to refrigerators, pm formal reception of Senior Politicians, Administrators and Scientists from Oman and Gulf States.

Thursday 9 October
Scientists to disembark. Containers may be off loaded perishable frozen samples to be custom cleared and air freighted. (Travel details to follow).

SCIENTIFIC BACKGROUND TO IMER'S INDIAN OCEAN EXPEDITION

The chemical forms of nitrogen and their microbiological transformation exert a major control on oceanic productivity and biogeochemistry. Our current studies into nitrogen cycling have concentrated on UK estuaries, embayments and shelf waters which are relatively rich in nitrogen (NO_3^-, NO_2^-, NH_4^+ > 1.0 µm - Nl^{-1}). We propose to extend these studies into the contrasting environments of the oligotrophic (0.01 - 0.50 µm - Nl^{-1}) and deoxygenated waters of the Indian Ocean.

The dynamics and mechanisms of nitrogen cycling in oligotrophic waters are tightly coupled between consumers (phytoplankton) and recyclers (bacteria, microzooplankton). But oligotrophic levels of nutrients have usually escaped detection and so the cycles are poorly understood. The North Western Indian Ocean (NWIO; 02-20°N, 50-70°E, see Fig 1) is characterized, as in other Ocean systems, by a large oligotrophic gyre but, unlike other ocean systems, includes seasonal upwelling of nutrient-rich bottom water along the Somali and SE Arabian coastline during the SW monsoons (April-September). The resultant off-shore gradients in nutrients (eg PO_4^{3-} —> 0.15 µM - PL^{-1}) and primary production (> 1000 mg C m^{-2} day^{-1} —> < 50 mg C m^{-2} day^{-1}) are prominent over relatively short distances (~ 400 nautical miles).

Another unique feature of the NWIO is the presence of an oxygen depleted zone (ODZ; O_2 < 0.1% saturation) at 200 - 2000 m depth below the whole Indian Ocean. The ODZ is particularly pronounced in the Arabian Sea (Fig. 2). Within the ODZ, nitrogen regeneration pathways switch from oxidative mechanisms (eg nitrification) to reductive mechanisms in which No_3^- replaces O_2 as terminal electron acceptor for the microbial oxidation or organic matter. The ODZ of the NWIO is one of only three permanent denitrifying environments (Eastern Tropical North Pacific and Coastal Peru), in which NO_3^- is bacterially reduced to N_2, thus comprising a major route for returning N_2 to the atmosphere.

We propose to use novel sensitive analytical and microbiological techniques together with sedimentation traps to investigate the sources, fluxes and transformation of nitrogen in upwelling, oligotrophic and o_2-depleted zones of the NWIO.

SPECIFIC OBJECTIVES

1 - To determine the vertical distribution and hydrochemistry of nitrogen compounds ($NO_3^=$, NO_2^-, N_2O, NH_4^+, urea $R\text{-}NH_2$, MA), oxygen and particulate nitrogen (detrital, phytoplankton, pigments) along off-shore sections of 11 stations from Gulf of Oman in SE Arabia to the Central oligotrophic gyre (05°N, 67°E) and equatorial waters.

2 - To quantify the rates of nitrogen assimilation by size-fractionated phytoplankton in relation to their ecophysiology (Nitrogen preference, kinetics, light dependence).

3 - To estimate bacterial and microzooplanktonic recycling of nitrogen using ^{15}N isotope dilution techniques, grazing dilution and precision respirometry, in euphotic and oxygen-depleted zones (ODZ) of the NWIO.

4 - To quantitate rates of denitrification in the ODZ and N_2 fixation in surface oligotrophic waters.

5 - To quantitate sedimentation rate of biogenic N and C and rates of new production sustained by diapycnic fluxes in oligotrophic waters and upwelling in coastal Arabian waters.

6 - To assess the impact of the upwelling regime on primary and secondary production and fisheries potential in the Arabian Sea.

SCIENTIFIC METHODOLOGY

1 - Vertical hydrocasts (down to 200 m) using Rosette bottle array and shipboard computerized CTD will be deployed to obtain water samples for nutrients, O_2, pigments and bacterial biomass estimates. Normal (< 1 µm) levels of nutrients (NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, Si) will be estimated by conventional auto Analyzer, trace levels of NO_3^- and NO_2^- will be determined by a new chemiluminescence procedure; N_2O and CH_4 will be measured by GC. Separate dedicated bottles hydrocasts will be used for trace metals and REE.

2 - Microbial nitrogen transformation rates on vertical samples from

stations shown in Table 1 will be measured by *in situ* or shipboard incubations using (a) ^{15}N for phytoplankton assimilation of NO_3^-, NO_2^-, NH_4^- and N_2 fixation, and microheterotrophic regeneration of NH_4^-; (b) ^{14}C phytoplankton production; (c) precision O_2 respiration and photosynthetic production in response to N enrichment; (d) N_2 fixation estimates by C_2H_2 reduction.

3 - The net transformation rates of nitrogen in euphotic waters will be followed over the short term (two days) using ^{15}N 'pulse chase' experiments and trace nutrients analyses.

4 - Nutrients, salinity, temperature, o_2, *in vivo* fluorescence, and near surface vertical variability of chlorophyll S, T will be continuously monitored between stations and in the upwelling waters off SE Arabia.

5 - Free drifting triple sedimentation trap array will be deployed over periods of 1 - 25 days to quantitate sedimentation, losses from the euphotic chemocline and suboxic aphotic regions of the water column.

EQUIPMENT (IMER + Collaborators)

A complete listing of all IMER equipment, reagents and glassware, their size weight and value is listed in separate IMER EQUIPMENT MANIFEST.

EQUIPMENT to be supplied by RVS

1 6 x 30 l Niskin bottles + spares + rack + messengers

2 12 x 7.1 l modified 'NTO' bottles + spares + racks to be fitted on outer bulk head of wet laboratory (S/B)

3 12 x 2.5 l Std NIO bottles + messengers

4 CTD-Rosette-Computer System
  - 12 x 10 l GO Teflon-coated bottles
  - Beckman O_2 sensor + 1/F
  - Aquatracka Fluorescence Probe + 1/F
  - the above sensors multiplexed and interphased with shipboard computer for data logging, viewing and printing
  - Software development to allow 1) calibration correction of C, T, D. O_2, Fluor data 2) subsequent addition of chemical and biological data on up to 22 variables obtained from bottle samples 3) hydrographic section contouring package 4) general purpose data plotting. We would also require computer logging of ship's position, speed, time, and analogue signals from Plessy salinograph (salinity, temperature), light meter (IMER provided) and capacity for later manual imput of discrete chemical/biological data (12 variables) obtained in passage between stations.

5 Chemistry Container

6 Fume hood (mobile) for handling low level ^{14}C and ^{3}H isotopes in main lab

7 Additional benching in CT, main and wet laboratories and Plot Room as in cruise 5/85 RRS Charles Darwin, 23 July - 3 August (see my letter 24.6.85 regarding the above cruise)

8 External gas bottle rack for 6 bottles situated near main and Ct labs (see letter 24.6.85 regarding CD 5/85

9 PES III Transducer + Dolphin

10 PES III Transducer + paper + spares

11 XBT recorder + launcher paper spares + 25 deep blue XBT probes

12 Thermosalinograph 6000T + paper + spares plumbed with siphon feed

13 2 pumps poles + shoes

14 1 Zodiac + outboard + VHF hand sets

15 Salinometer for calibrating CTD

Prepared by: RFC Mantoura 24 February 1986

Approved by: Brian L. Bayne
Dr B L Bayne

CIRCULATION:

Internal

AW MORRIS
B.L. BAYNE
J. AIKEN

I.R. JOINT
CRUISE PERSONNEL
NOTICE BOARD
FILE VES 11.1

P.N. CLARIDGE

External

NERC HQ SWINDON:	D. PUGH
	S. WHITE
IOS WORMLEY:	Mrs P. EDWARDS (MIAS)
DAFS:	McINTYRE
RVS:	SKINNER (2)
MBA:	DENTON
UNIVERSITY OF DUNDEE:	STEWART

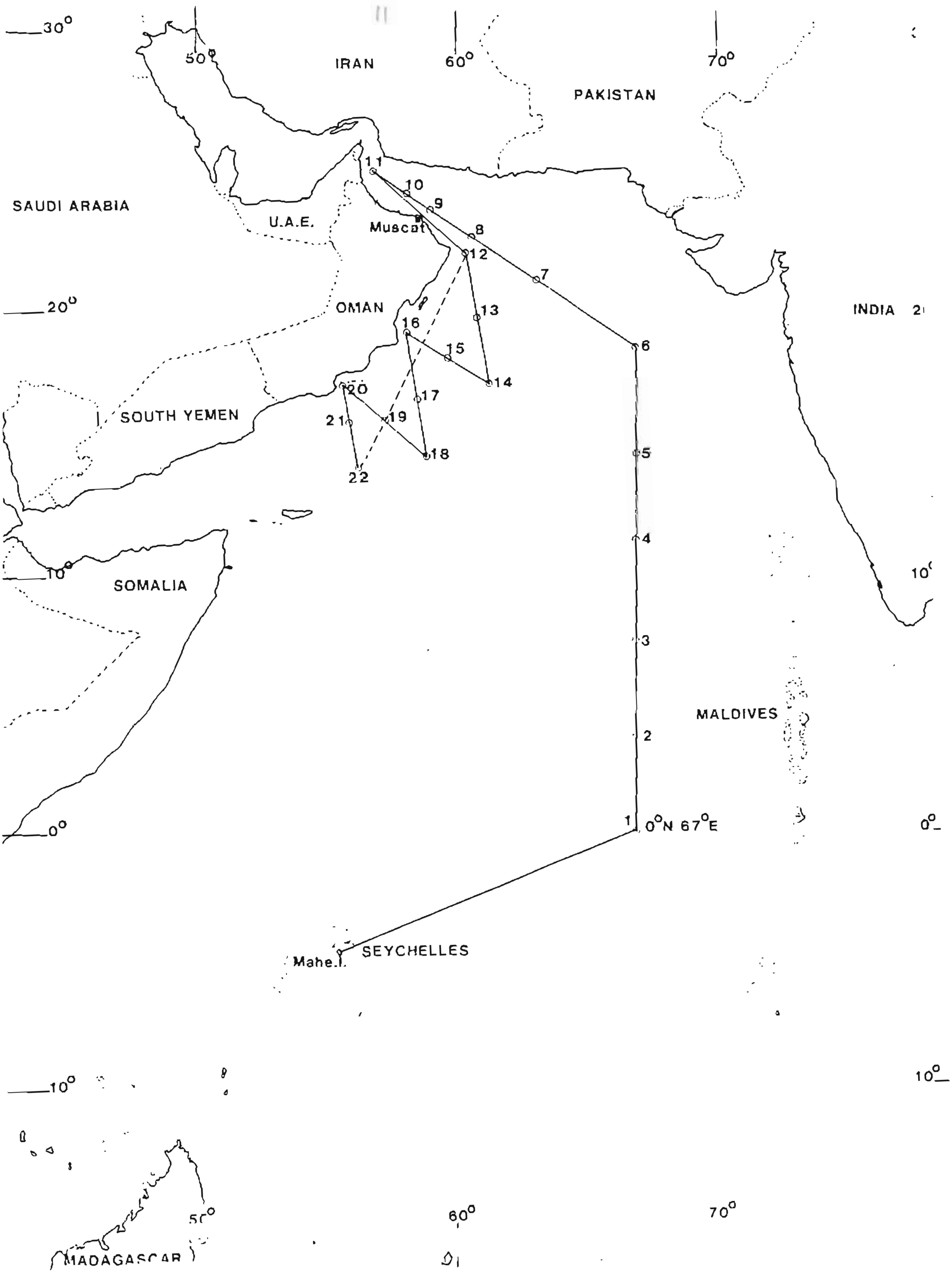
Table 1

Parameter	Methodology	Responsibility	Station No / Depth
I <u>Rosette/Sensor Hydrocast</u>			
1 Computer-controlled CTD-O_2/Fluorescence/rosette 12x10 l - real time data loging/ display real time data display and archiving on shipboard computer		Mantoura, de Baan, Winch, CTD Comp. Engineer	All ≥ 22 Stn usually 1500 m
2 UOR sensor (light, depth, T. fluorescence) vertical profiling <		Bellan, Winch engineers	All ~ 22 Stn, < 150 m
II <u>Dissolved State Variables</u> (samples from CTD rosette)			
3 NO_3, NO_2, Si, PO_4	Technicon auto analyzer	Howland/Woodward	All @ 24 samples per Stn
4 NH_4, urea	Automatic analyzer	S-Woodward/Howland	As in 3
5 Trace NO_3, NO_2	NO_x chemilliminescence	S-Woodward	Surface ~ 8 samples St 1-12
6 O_2 profiles + CTD calibration	Winkler autotitration	Morris/Burkill	As in 3
7 CTD-calibrating salinities	Hytech conductivity	CTD engineer	All, @ ~ 4 depth
8 Cr, Cu, Cd, Ag + rare earths	Ultra clean filtration acid storage	de Baar/Howland	As in 3
9 N_2O, CH_4	GC analyses	Law/Owens	Stn 1-12, occn 13-22
10 Alkalinity, pH	Metrohm autotitrator	Bellan/Mantoura	As in 3
III <u>Particulate State Variables</u> (samples from CTD rosette)			
11 Coulter Volume	Coulter Counter TAII-Apple	Williams/Zeitschel	As in 3
12 POC/N tot chlorophyll	Filtration ashed GF/F (<200 µm)	Howland, Woodward, Llewellyn, Law (rota)	As in 3
13 Size-fractionated chlo/carotenoid	0.2, 0.8, 5 µm, HPLC	Lewellyn	St 1-6, 8, 11, 14-16, 20-22
14 Phycobiliprotein	Fluorescence	Burkill, Llewellyn	As in 3
15 Cyanobacterial counts	Epifluorescence microscopy	Burkill, Zeitschel	As in 3
16 Bacterial counts	AO Epifluor microscopy	Morris	As in 3
17 Quant taxonomy, SEM	Glut, preservation	As in 10	As in 3
18 Macrozooplankton	LHPR (>22 µm, >200 µm)dr. wt.	Williams/Bellan	1 hydrocast ~ 500 m/station
19 Surface, sediment sampling			
IV <u>Rate variables</u>			
20 O_2 production/respiration	L/D bottles, <u>in situ</u> incubation rig	Burkill/Morris	Rate station 1, 3, 5, 7, 9, 14, 16
21 Size fractionated respiration	CT dark <u>incubation</u>	Burkill/Morris	?
22 ^{14}C-primary production	as 17 + O/B liqu. scintillation	Owens/Law	1, 3, 5, 7, 9, 14, 16
23 ^{15}N-NO_3 NH_4 phyto assimilation	as 17, filtration	Owens/Law	1, 3, 5, 7, 9, 14, 16
24 N_2 fixation		Law	1-6
25 Dinitrification	ΔN_2O ~ GC analyses	Lawl, 3, 5, 7, 9	
26 Bacterial production	^3H thymidine	Ducklow	1, 3, 5, 7, 9, 14, 16
27 Microzooplankton grazing	Graz. dilution, Δ pigments, Δ ^{14}C	Burkill/Llewellyn	?
28 Macrozooplankton grazing		Williams	?
29 Sedimentation	< 2 d deployment, sediment traps	Zeitzschel/Bellan	1, 3, 5, 7, 14, 15, 16

Table 2

Station Positions for Nitrogen Cycling Cruise, RRS Charles Darwin
4 September - 8 October 1986

Station	Region	Latitude	Longitude	Depth (m)
1	Equator	00°00'N	67°00'E	1300
2		04°00'N	67°00'E	3200
3	N W Indian Ocean	08°00'N	67°00'E	4200
4		12°00'N	67°00'E	4300
5		16°00'N	67°00'E	3900
6		19°00'N	67°00'E	3200
7	Arabian Sea	21°15'N	63°15'E	3100
8		22°40'N	60°40'E	3300
9		23°40'N	59°05'E	3000
10	Gulf of Oman	24°20'N	58°10'E	2200
11		25°15'N	56°45'E	200
12		22°00'n	60°25'E	2800
13		20°00'N	60°45'E	3000
14		17°25'N	61°20'E	3900
15		18°15'N	59°45'E	3600
16	S Oman Coast	19°20'N	58°00'E	200
17	Arabian Sea	16°35'N	58°20'E	3000
18		14°40'N	58°40'E	2900
19		16°10'N	57°15'E	3700
20		17°30'N	55°40'E	200
21		17°00'N	55°55'E	3100
22		14°20'N	56°10'E	2500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