

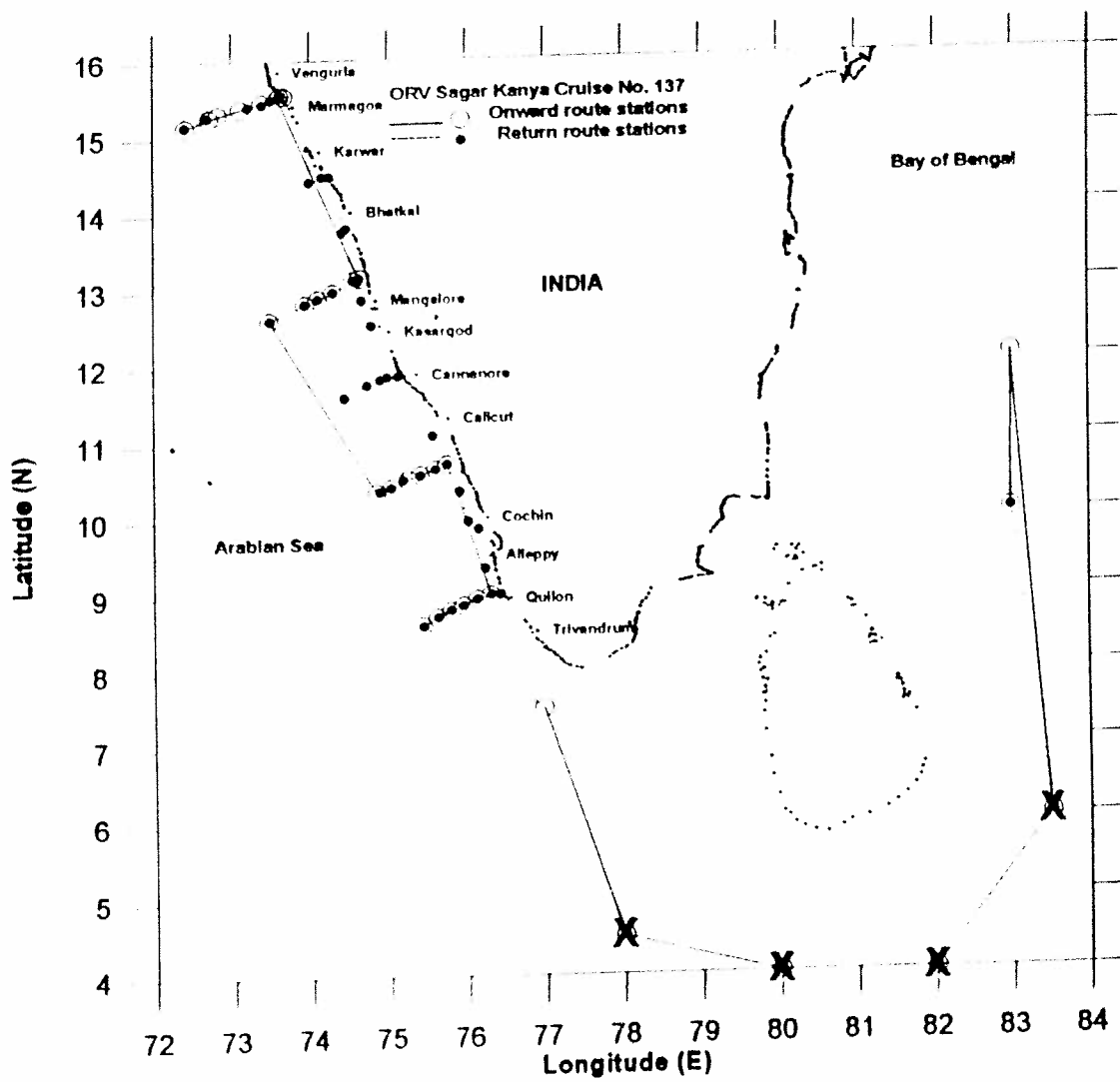
Report of Sagar Kanya Cruise 137
(20 July to 17 August 1998)
From Mormugao to Mormugao

REPORT ON 137TH OCEANOGRAPHIC CRUISE OF O.R.V. SAGAR KANYA

CONTENTS

1. Cruise track
2. Cruise summary
3. Participants
4. Cruise Schedule
5. Objectives
6. Sampling and On-board Analysis/Processing:
7. Significant Finding
8. Acknowledgement

Annexure I



2. Cruise Summary

The major objective of the cruise was to investigate the effect of upwelling on biogeochemical cycling in the coastal zone off the central and southwestern coasts of India. The work undertaken comprised observations at a total of 73 stations. Six short, cross-shelf sections were worked of which four were occupied twice. The intervening period between the two sets of observations was utilised to make some new measurements in the Bay of Bengal. In addition to the collection of routine hydrographical (temperature and salinity) and hydrochemical (oxygen and nutrients) data, specialised studies carried out during the cruise covered primary production and chlorophyll *a*, zooplankton biomass, activities of the electron transport system and nitrate reductase, particulate and dissolved organic carbon, dissolved gases (nitrous oxide, methane and dimethyl sulphide), natural abundance of stable isotopes in dissolved nitrogen species, and incubation experiments for quantifying the rate of denitrification. Bottom samples were collected through sediment coring at 15 stations and by using a grab at 10 stations. These were used for porewater nutrient profiling and/or processed for rock magnetic/paleoclimatic measurements. Finally, geophysical (bathymetric, gravity and magnetic) data were collected almost throughout the cruise. The highlight of the cruise was the observation of strong upwelling off Kerala coast, which led to the development of strongly reducing conditions in the water column. Also, "red tides" caused by blooms of the dinoflagellate *Noctiluca* were observed off Kerala. These were associated with severe fish mortality off Cochin.

3. Participants

National Institute of Oceanography, Goa

Dr. M.D. George, Chief Scientist
Dr. S.W.A. Naqvi
Dr. P.V. Narvekar
Dr. (Mrs) S. Sardesai
Dr. M.S. Shailaja
Mr. D.A. Jayakumar
Mr. V.V.S.S. Sarma
Mr. D.M. Shenoy
Ms. Hema Naik
Mr. H.S. Dalvi

Regional Centre of NIO, Cochin

Mr. P.A. Maheswaran
Mrs. K. Krishna Kumari
Mr. G. Rajesh
Mr. A.K. Sudhir
Miss. M.S. Binu

University of Cochin

Mr. A.K. Purushotham

University of Mangalore

Mr. C.N. Prabhu

NORINCO

Mr. Rohit Hermon

Mr. P Mohanan

Mr. P Bhoopathy

Mr. P S Manmohan

4. Cruise Schedule

All the participants except Dr. S.W.A. Naqvi signed on 17.7.98 as the vessel was scheduled to sail on 19.7.98. However, the sailing was delayed by a day as one of engineers suddenly fell sick and his replacement had to be flown in from Mumbai. Dr. S.W.A. Naqvi joined the cruise on 8.8.98 at the outer anchorage off Cochin. The vessel returned to Mormugao on 17 August 1998, as scheduled.

5. Objectives

Of the three centres of seasonal (southwest monsoon) upwelling in the northwestern Indian Ocean, located off the coasts of Somalia, Arabia and Southwest India, the one off the Indian coast has been least investigated in spite of its unique physical forcing and unusual hydrography. Studies undertaken by us during the monsoons of 1995 and 1997 had revealed some extremely interesting features concerning the biogeochemical cycling in this region. The 137th cruise of *Sagar Kanya* was planned to investigate some of the previously observed phenomena in detail. The work plan consisted of the following components:

(a) Investigation on the sub-seasonal variability of upwelling in view of the evidence for regular fluctuations in sea level on such time scales based on altimetry data: two sets of observations were planned for this purpose.

(b) Evaluation of the levels of primary and secondary production: incredibly, there are no reliable published estimates of the rate of primary production from this supposedly eutrophic environment.

(c) Quantification of the extent of denitrification, observed for the first time during August 1997 in shallow, open coastal waters. This system is not linked to the perennial mid-depth denitrification regime of the central Arabian Sea. Besides collecting data on concentrations of nitrogenous nutrients, the specialised measurements planned included (i) nitrogen/argon ratio in water; (ii) ratios between the stable isotopes (natural

abundance) of nitrogen ($^{15}\text{N}/^{14}\text{N}$) in molecular nitrogen (N_2) and nitrate (NO_3^-), and of both nitrogen and oxygen ($^{18}\text{O}/^{16}\text{O}$) in nitrous oxide (N_2O); (iii) incubation experiments on board ship utilising ^{15}N -labelled substrates (NO_3^- and NH_4^+); and (iv) enzymatic measurements of the activities of the respiratory electron transport system and nitrate reductase.

(d) Determination of the levels of particulate and dissolved organic matter particularly the transparent exopolymer particles in water.

(e) Estimation of concentrations of climatically important gases such as carbon dioxide (CO_2), N_2O , methane (CH_4) and dimethyl sulphide (DMS) and their fluxes across the air-sea interface.

(f) Porewater profiling of nutrients to investigate their exchange across the sediment water interface.

(g) Isotopic measurements ($^{15}\text{N}/^{14}\text{N}$ in NO_3^- and both $^{15}\text{N}/^{14}\text{N}$ and $^{18}\text{O}/^{16}\text{O}$ in N_2O) in the Bay of Bengal.

In addition to the water column work, seabed sampling (surficial collections as well as gravity/spade coring) was planned for studying the major rock magnetic properties and for paleoceanographic and paleochemical reconstructions. Lastly, geophysical (bathymetric, gravity and magnetic) data were to be acquired for studying the geology of the continental margin.

6. Sampling and On-board Analysis/Processing:

Observations along the central and southwest coasts of India were undertaken in two phases. In the first phase, four sections located off Mormugao, Mangalore, Ponnani and Quilon were worked before the vessel sailed for the Bay of Bengal. Two stations were occupied in the Bay of Bengal after which the vessel returned for the second phase of observations in the Arabian Sea. In the second phase, besides reoccupying the sections sampled during the first phase, two more sections (off Cannanore and Karwar) were added. Observations were also made at several other stations that did not form these cross-shelf sections. The cruise tracks including station locations are shown in the figure. A summary of all observations is given in the performance chart (Annexure I).

Water samples were collected at all the stations using 1.8, 10 and 20 litre Niskin/Go-flo bottles mounted on the CTD rosette. Analyses were performed on board ship shortly after collection for dissolved oxygen, nutrients (NO_3^- , NO_2^- , NH_4^+ , silicate and phosphate), N_2O , CH_4 and DMS. Oxygen was estimated titrimetrically. Two Skalar autoanalysers were used for nutrient measurements. DMS, CH_4 and N_2O were analysed by gas chromatography.

Samples were collected at seven stations for determining the ETS and nitrate reductase activities. These were filtered and the enzymes were extracted from the particulate matter for estimation of their activities on board ship following standard procedures.

Incubation experiments were carried out using N-15 labelled NO_3^- and NH_4^+ as substrates to quantify the rates of denitrification and to determine the fate of ammonia during denitrification. Denitrification experiments were conducted on deck (time series at 9 stations) drawing water from the subsurface suboxic layer having secondary nitrite. After incubations samples were collected for the analysis $^{15}\text{N}/^{14}\text{N}$ in N_2 in the shore laboratory.

Water samples were collected for the shore-based analysis of $^{15}\text{N}/^{14}\text{N}$ in NO_3^- at 15 stations and of $^{15}\text{N}/^{14}\text{N}$ in N_2 at 9 stations. At 6 stations, water samples were taken with modified 20-l Go-flo bottles and the dissolved N_2O was extracted with the aid of a specially-designed extraction apparatus and adsorbed on MS 5A. In the shore laboratory N_2O will be thermally desorbed, purified and analysed for determining its dual isotopic composition.

Samples at several stations were analysed to quantify the abundance of transparent exopolymer particles (TEP) in the water column. Aliquots of these samples were preserved for microscopic and bacteriological analyses of TEP in the shore laboratory. Water samples were also collected and preserved for the analysis of dissolved organic carbon in order to understand its transport across the margins and its involvement in chemical and microbiological processes. For the analysis of particulate organic carbon, known volumes of samples were filtered on board ship.

Samples were collected at 17 stations for measurements of primary productivity (PP) and chlorophyll concentrations. PP was measured through deck incubations following the ^{14}C technique, while samples for chlorophyll were preserved for analysis in the shore laboratory.

Sediment sampling involved grab operation at 10 stations and coring with a spade corer at 9 stations and with a gravity corer at 6 stations. The spade (box) core samples were squeezed for porewaters using a whole core squeezer. The porewater samples were analysed for N_2O and nutrients, while the sediment was subsampled for geochemical and magnetic measurements. The gravity core samples were subsectioned for paleo-oceanographic and magnetic studies, and the grab samples would be used only for the latter measurements.

Geophysical (bathymetric, magnetic and gravity) data were collected almost throughout the cruise. However the magnetic data were collected only along two sections.

7. Significant Finding

Fairly intense upwelling was observed all along the southwestern coast. However, the upwelled water was generally overlain by a lens of low salinity <10 m thick. At some stations located close to the coast, the upwelled water reached the surface leading to high surface nitrate levels. A very significant observation was the occurrence of water column denitrification at the most inshore stations, including the onset of sulphate reduction off Mangalore and Karwar. To our knowledge such a feature has not been previously reported from the Arabian Sea so far. Also, we observed the highest concentrations of nitrous oxide ever found in seawater. Our observations highlight the diversity of biogeochemical transformations and their sensitivity to small changes in the environmental conditions.

Frequent blooms of the dinoflagellate *Noctiluca* were observed in coastal waters (depth less than 40 m) off Kerala from Cochin to Calicut during 8-10 August 1998. The most intense blooms occurred off Cochin and were associated with severe mortality of fish. The dead fish, almost entirely comprising of the pink perch (*Nemipterus japonicus*), was found floating in large numbers (estimated conservatively as 1 animal per 100 square metres). As the near-bottom waters were suboxic and reducing, and even at the sea surface the oxygen content was quite low (1.25 ml/l), oxygen deficiency could have resulted in the mortality of the demersal fish. However, in view of the striking accumulation of dead fish around patches of the bloom, the presence of some other toxin-producing organism cannot be ruled out.

8. Acknowledgement

The cruise participants record their sincere thanks to the Master, officers and crew of ORV *Sagar Kanya* for their unreserved assistance without which the cruise would not have been a success.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1
55	74.1110	12.8730	110	12/8/98	1905	2005	✓																					55
56	74.3017	12.9542	55	12/8/98	2200	2245	✓																					56
57	74.7909	12.5149	35	13/8/98	0600	0900	✓ (4)																					57
58	74.6683	12.8483	33	13/8/98	1310	1400	✓																					58
59	74.6323	13.1270	25	13/8/98	1705	2115	✓ (3)																					59
60	74.5917	13.1000	35	13/8/98	2155	2310	✓																					60
61	74.5576	13.1019	40	13/8/98	2340	2400	✓																					61
62	74.4178	13.7310	35	14/8/98	0630	0745	✓																					62
63	74.4740	13.7821	26	14/8/98	0840	1030	✓ (2)																					63
64	74.2509	14.4672	22	14/8/98	1730	1845	✓																					64
65	74.1697	14.4669	33	14/8/98	1950	2100	✓																					65
66	74.0044	14.3976	44	14/8/98	2300	2325	✓																					66
67	72.4130	15.1471	1800	15/8/98	1405	1700	✓ (2)																					67
68	72.6907	15.2679	900	15/8/98	1900	2030	✓																					68
69	73.4053	15.4245	56	16/8/98	0630	1230	✓																					69
70	73.6034	15.5035	28	16/8/98	1430	1630	✓ (2)																					70
71	73.6258	15.5295	24	16/8/98	1705	1740	✓																					71
72	73.5109	15.4790	41	16/8/98	1900	1950	✓																					72
73	73.2197	15.3909	80	16/8/98	2240	2320	✓																					73

Other Operation 1) Hydrosweep was operated at most of the stations

- 2) Magnetometer was run between stations 24-26 and 53-54
- 3) Gravity was measured at all stations except Sta 31, 32, 38, 42, 44, 45, 56, 60, 68-73
- 4) Grab Stations: 32, 35, 48, 49, 55, 57, 59
- 5) Spade Corer Stations: 8, 9, 21, 36, 38, 43, 47, 59, 69
- 6) Gravity Corer Stations: 3, 36, 38, 43, 47, 59
- 7) Wave Recorder at all stations
- 8) ADCP till station no. 55
- 9) Deck incubations were carried out at stations for N₂ isotopes
- 10) Nutrients include phosphate, nitrate, nitrite, ammonia and silicate