NATIONAL INSTITUTE OF OCEANOGRAPHY GOA-INDIA

ANNUAL REPORT 1977

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13

1977

NATIONAL INSTITUTE OF OCEANOGRAPHY
(Council of Scientific & Industrial Research)
DONA PAULA-403 004
GOA, INDIA

contents

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general introduction

During the year under report maximum emphasis was given to the utilization of technology available at the Institute for the users in the country. The Institute also continued its work on 18 institutional projects and these indicate the total R & D efforts during the year. The newly formed regional centre at Waltair and the Ocean Engineering Division at the headquarters were further strengthened to undertake R & D work along with their participation in sponsored projects.

Research Vessel *Gaveshani* completed 14 cruises during the year 1977. Of these 9 cruises were undertaken for the institutional R & D projects and 5 cruises for sponsored projects mainly for the Oil and Natural Gas Commission. During the 14 cruises, the ship covered more than 18,000 line kilometres and worked at 430 stations spread all over the Arabian Sea and Bay of Bengal.

The Institute undertook 18 sponsored projects at a cost of about Rs. 54 lakhs paid to the Institute by the sponsors. Thus the earning during the year amount to about 30 percent of the total annual budget of the Institute.

The Institute organized a Seminar on 'Coastal Engineering' in March 1977· About 76 technical papers were presented at the seminar. These helped a great deal in developing an understanding of the coastal problems and coastal engineering activities in India.

The Institute extended its cooperation to the International organizations such as the Intergovernmental Oceanographic Commission (IOC) of UNESCO and United Nations Environment Programme (UNEP) by participating in their activities.

The development in the Institute's campus included the speedy construction of a meteorological tower for housing storm/cyclone warning radar and the construction of 32 additional staff quarters.

DIRECTOR

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research activities

2.0 Oceanographic cruises of Research Vessel *'Gaveshani'*

During the year *Gaveshani* undertook 14 oceanographic cruises covering over 430 stations and 18,000 line km cruise tracks. Of these, 10 were undertaken in the Arabian Sea and 4 in the Bay of Bengal. Data and samples collected during these cruises are being analysed.

Gaveshani cruises in the Arabian Sea

Of the 10 cruises undertaken in the Arabian Sea, one was devoted largely to pollution studies along the west coast from Bombay to Trivandrum. Two cruises were undertaken for a detailed sampling of sediments (coring, dredging, grab, snapper samples) from 175 stations in the continental shelf from Mormugao to Cape Camorin and from 139 stations in the continental shelf and slope from Vengurla to Mangalore. One cruise was undertaken for rectifying the defects in the Satellite Navigation System. The remaining six cruises were undertaken for the ONGC on surveys of the pipeline route from Bombay High to Bombay.

Gaveshani cruises in the Bay of Bengal

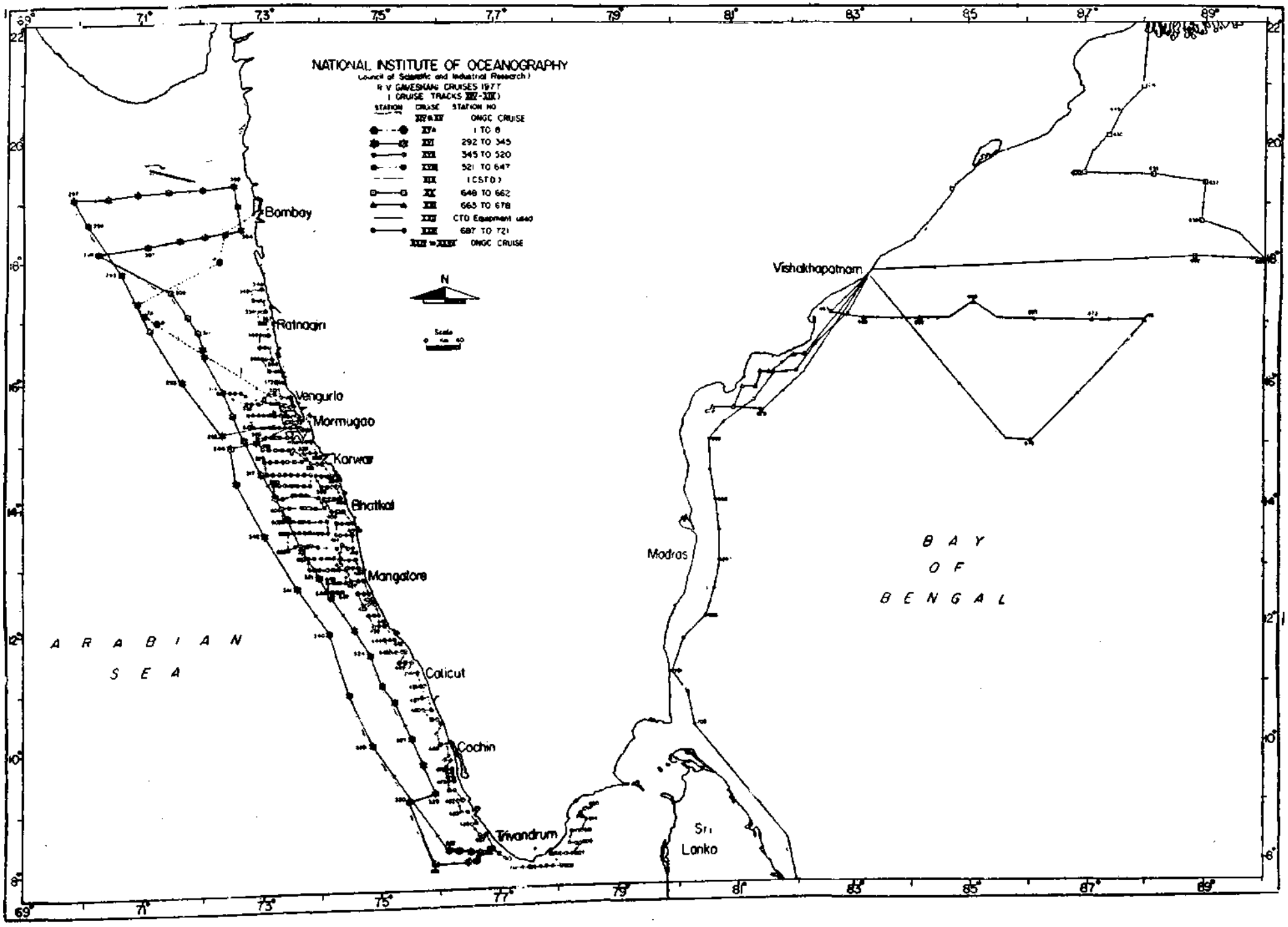
Two of the four cruises undertaken in the Bay of Bengal were devoted to physical, chemical and biological oceanography from Calcutta to Machilipatnam. One of the cruises was undertaken for testing the newly installed shipborne wave recorder and the stabilization tanks of *Gaveshani.* One cruise was undertaken for pollution studies from Visakhapatnam to Cape Camorin and enroute to Mormugao.

A brief account of all the cruises is given below:

Fourteenth Cruise

This cruise was undertaken from 3 to 26 January to carry out the various specified jobs for the Oil and Natural Gas Commission. These arc: (1) Survey of the proposed submarine pipeline route from Bombay High to Bombay, (2) Shallow seismic survey in the Bombay High Oilfield for deciphering the sea bed condition for designing production platforms and (3) Sea bed survey for jacking up of the Drilling Vessel *Sagar Samrat* on Angria Bank.

During this cruise a 1036 line km of bathymetric, 534 line km of side scan sonar and 332 line km of shallow seismic (boomer) surveys were carried out. Shoran was used as a position fixing aid throughout these surveys and on certain occasions satellite navigation system was also used. In the Bombay High area, the depth of water ranged between 70-90m. The topography was uneven and irregularities of the order of 2-5 m were common. In some areas pinnacles of about 10 m were also


NATIONAL INSTITUTE OF OCEANOGRAPHY
(Council of Scientific and Industrial Research)
R V GAVESHANI CRUISES 1977
(CRUISE TRACKS XV-XIX)
STATION
CRUISE
STATION NO
XV & XVI
ONGC CRUISE
XVA
1 TO 8
XVI
292 TO 345
XVII
345 TO 520
XVIII
521 TO 647
XIX
(CSTD)
XX
648 TO 662
XXI
665 TO 678
XXII
CTD Equipment used
XXIII
687 TO 721
XIII to XIV
ONGC CRUISE
N
Scale
Bombay
Ratnagiri
Vengurla
Marmugao
Karwar
Bhatkal
Mangalore
Calicut
Cochin
Trivandrum
Sri
Lanka
Madras
Vishakhapatnam
A R A B I A N
S E A
B A Y
O F
B E N G A L

noticed. Preliminary side scan sonar surveys did not indicate any appreciable movement of the sand waves during monsoon. These sand waves were recorded during earlier surveys.

The shallow seismic surveys carried out at Bombay High showed that the sub-bottom profile, on the lines are broadly comparable. The northern lines indicate a thin clay cover of 5-10 m which becomes thinner towards the west and the south. The clays are underlain by sandy strata. There are two very prominent reflectors in this zone between 10-20m and about 25-30 m.

Fifteenth Cruise

The survey of the pipeline route from Bombay High to Bombay was continued during this cruise from 4 to 23 February. In the Bombay High area, R.V. *Gaveshani* carried out 1200 line km of bathymetric, 350 line km of side scan sonar and 1005 line km of shallow seismic surveys.

Five lines were surveyed for the selection of a suitable pipeline route from Bombay High to Bassein. The depth in this area ranged from 54 to 78 m. The area of uneven topography and a periodic bedform was found to decrease along the northern lines. The south eastern area was covered by over 15 m thick clay. In the north-western region the thickness of clay decreased and the sea bottom in the area was found to be covered with sand.

The studies indicate that the northern lines are more suitable than the southern lines for routing the pipeline.

A number of lines at a spacing of about one kilometre were surveyed in the Bombay High for designing of platforms.

The heat flow measurements on the continental shelf and slope were carried out during the return journey from Bombay to Mormugao at the request of NGRI and as a part of the Indo-Soviet programme for cooperation in scientific research.

Sixteenth Cruise

This cruise undertaken from 3 to 17 March was largely devoted to pollution studies along the west coast of India from Bombay to Trivandrum. Samples were collected from 54 stations for the analysis of petroleum, chlorinated hydrocarbons and heavy metals. Observations were also made for the oil slicks and other floating pollutants as a part of Marine Pollution (Petroleum) Monitoring Pilot Project (MAPMOPP) of the IGOSS. Besides, hydrographic data were also collected at all the stations.

The magnitude of pollution in the Arabian Sea was found to be insignificant. The difference in BOD_2 and BOD_5 values indicated that the oxidation of organic matter in the upper layers near the coast almost reaches a steady state within the first two days.

Seventeenth Cruise

The 15-day cruise from 22 March to 5 April was organised with the sole purpose of understanding the bottom topography, sediment distribution pattern, microfaunal abundance, biological productivity and microbiological activity in the shelf region.

In all 175 stations were covered and 8 dredging operations were made from geological and biological studies. Bathymetric survey of the track was also done using echosounders.

Eighteenth Cruise

This cruise (13-23 April) was devoted to study the surficial geology of the hitherto unsurveyed parts of the continental shelf and slope between Vengurla and Mangalore.

During the cruise, snapper samples were collected from 127 stations and dredge samples from 5 stations. Samples for benthic studies were collected from 54 stations and BT data were collected from 65 stations. Ambient noise and acoustic reverberation studies were conducted at 10 stations.

Continuous echosounding was carried out throughout the cruise resulting in 1220 km of echosounding records.

Nineteenth Cruise

This cruise was undertaken on 10-12 May for rectifying the defects of satellite navigation system with a consultant from Canadian International Development Agency (ClDA) on board. During this cruise data on bottom profiles of the inner shelf region between Port Vengurla and Cape de Rama were also collected.

Twentieth Cruise

The 10-day cruise originally planned had to be cut short to 4 days from 31 July to 3 August due to cyclonic weather in the Bay of Bengal. During this cruise data on physical, chemical and biological parameters were collected at 15 stations in the northern Bay of Bengal for studying thermal structure, circulation, water-mass characteristics, distribution of oxygen, nutrients and heavy metals, rates of primary productivity and the distribution of plankton during the south-west monsoon season.

Twentyfirst Cruise

This cruise was undertaken from August 22 to September 3, 1977 to investigate the general oceanographic conditions in southern Bay of Bengal between Visakhapatnam and Madras. Data on physical, chemical, biological and geological parameters were collected at 14 stations.

The main objectives of this cruise were to study the circulation, water-mass characteristics, distribution of oxygen, nutrients, heavy metals and pesticides in the water and plankton, rates of primary productivity, phytoplankton abundance, chlorophyll, pheophytin and particulate organic carbon during the southwest monsoon period. These investigations were also intended to check and confirm the earlier observations made in this area.

Twentysecond Cruise

This cruise was undertaken on 10 September for testing the newly installed ship-borne wave recorder and the P.D.C. Anti-Rolling tanks. For the installation of

the wave recorder and conducting a training programme on its maintenance procedure, Mr. Haine from the Institute of Oceanographic Sciences, U.K. came to Visakhapatnam where the wave recorder was installed under his supervision by the Hindustan Shipyard Ltd. During trial fairly good records of waves were obtained. Trial of the P.D.C. tanks was conducted by an expert deputed by Mierform of Switzerland. The Swiss Company had provided the design of the tank and the trial was a part of the package deal. The functioning of the P.D.C. tanks was found to be upto the mark.

Twentythird Cruise

This cruise was undertaken from 23 September to 5 October and was largely devoted to chemical oceanography with special reference to pollution studies along the east coast of India from Waltair to Point Calimere and along the west coast of India from Tuticorin to Goa. Samples were collected at 34 stations for the analysis of petroleum and chlorinated hydrocarbons and heavy metals in water, organisms and sediments. Sampling for oil slicks and other floating pollutants were also carried out and hydrographic observations were made throughout the cruise. The main objectives of this cruise were: (1) to initiate investigations on a study on the *Health of the Bay of Bengal,* (2) to survey oil pollution along the tanker route from south of Sri Lanka to the head of the Strait of Malacca and (3) to collect further information on the ongoing study of the *Health of the Arabian Sea.*

The information collected clearly shows that the seas around India are fairly clean. All other details will follow when the analysis of the samples is over.

Twentyfourth Cruise

This cruise was undertaken from 17 October to 10 November for the ONGC sponsored project on the survey of the selected submarine pipeline route from Bombay High Oilfield to Bombay (bathymetry, side scan sonar, sub-bottom profiling and coring). More than 200 line km of echosounding, side scan sonar and shallow seismic profiling were carried out during this cruise and 9 cores were collected to substantiate the findings of the earlier surveys conducted by the Institute.

Twentyfifth Cruise

The 15-day cruise from 13 to 28 November 1977 was undertaken at the request of ONGC to carry out the final survey of the approved pipeline route and also to complete the shallow seismic survey of the southern Bombay High area for deciphering the sea bed conditions for designing production platforms. The work involved surveys for about 400 line km of echosounding, 200 line km of side scan sonar and sub-bottom profiling, 500 line km of magnetics and collection of 6 cores from different locations.

The surveys of the selected pipeline route supported the findings of the earlier surveys but the cores collected for the first time along this route indicated a hard bottom in certain areas and it was recommended that utmost care should be exercised while laying the pipeline in that region.

The survey of the Bombay High also indicated a number of topographic plateaues or highs, soms of which may have to be further explored to assess their suitability for the location of platforms.

Twentysixth Cruise

This cruise was also undertaken for a period of 15 days from 9 to 23 December 1977 at the request of ONGC to survey the proposed new pipeline route from Bassein to Tarapur and Hazira in Gujarat. During this cruise about 880 line km of echosounding, 780 line km of side scan sonar, 780 line km of shallow seismic and 880 line km of magnetics were carried out on the various routes between Bassein to Tarapur and Hazira. In addition to this work echosounding and shallow seismic surveys were also carried out at the proposed site for jacking up D.V. *Sagar Samrat* on the South Tapti stratum and echosounding along two lines on the proposed route from Bombay High to Bombay.

This survey was one of a reconnoitry nature along the lines spaced at about 2 km to help in selecting a route for which another survey spaced at 250 - 500 m would be required to be undertaken subsequently.

Twentyseventh Cruise

This cruise was undertaken as a follow-up work of the previous cruise proposed by the ONGC. The 9-day cruise from 27 December 1977 to 4 January 1978 was devoted mainly for hydrographic surveys at 5 selected stations on the proposed pipeline routes between Bassein, Tarapur and Hazira. The work involved observations on temperature, salinity, currents etc., at the surface and bottom at every 30 minute interval for 24 hours at each station.

Geological and geophysical works including the collection of samples by grab, echosounding, side scan sonar and shallow seismic surveys along 82 line km were also included in this survey.

2.1

physical oceanography

2.1.1 *Studies on ocean-atmosphere interaction with special reference to the seas around India (Project No.701)*

1. Prediction of storm surges at various places along the east coast
2. Studies on wind driven circulation in the Indian Ocean
3. Studies on heat storage and transfer processes
4. Shore protection through wave energy utilization
5. Advection-diffusion phenomenon in the Indian Ocean

2.1.2 *Studies on physical processes occurring in the seas around India (Project No.* 702)

2.1.3 *Studies on land-sea interaction and nearshore circulation with application to coastal zone management (Project No.* 703)

1. Studies on the beaches of Goa
2. Studies on the beaches of Kerala
3. Currents off Bombay coast
4. Studies on the oil spill movement in the Bombay High region
5. Hydrographic survey off Karwar
6. Oceanographic studies off Mangalore coast

The special features of the scientific work of the Physical Oceanography Division during 1977 are : (i) a sophisticated wave recording instrument (ship-borne wave recorder) installed on R. V. *Gaveshani* during the year and the collection of valuable wave data from the Arabian Sea and Bay of Bengal; (ii) continuous profiles of salinity and temperature against depth, upto a depth of about 1200 m in the seas around India during the cruises of R. V. *Gaveshani* using the newly installed precision instrument, the CSTD (Conductivity/Salinity, Temperature and Depth measuring) System; (iii) testing and designing of two Prime Mover Systems for the shore protection through wave energy utilisation in the field to study the performance of the systems under actual wave conditions. Based on these tests further development in its design is being undertaken.

Details of the work under different projects are as follows:

2.1.1 Studies on ocean-atmosphere interaction with special reference to the seas around India

1. Prediction of storm surges at various places along the east coast

(a) Under this investigation, evaluation of storm surges at several places along the east coast of India associated with the cyclonic storms occurring in Bay of Bengal has been continued.

(b) An analysis of wind distribution over the Bay of Bengal during the periods of intense cyclonic activity has been carried out. Computations of wind stresses were made to relate the wind stress with the storm surges associated with cyclonic storms.

2. Studies on wind driven circulation in the Indian Ocean

(a) Wind stress for each 1° square grid in the Arabian Sea has been computed for the south-west monsoon period and the wind stress curl distribution has been evaluated for studying the wind driven circulation.

(b) An analysis of the wind stress and its relations to the vertical motion has been carried out for the Arabian Sea. These studies have shown that the level of no meridional motion in open sea area varies considerably.

3. Studies on heat storage and transfer processes

A new programme aimed at studying the heat storage and transfer processes in the upper 250-300m of the Indian Ocean through analysis of BT data has started.

4. Shore protection through wave energy utilisation

Under this investigation, two Prime Mover Systems were designed and tested in the field to study the performance of these systems under actual wave conditions. Based on these tests, further development in the design of prime mover is being undertaken. Simultaneously, the energy/power transfer systems to be coupled with the prime mover systems are being developed. Relevant data on wave climate along the east and west coasts of India are being collected. A feasibility report on this is being prepared.

5. Advection-diffusion phenomenon in the Indian Ocean

Under these studies, diffusion diagrams for the Persian Gulf and Red Sea water masses have been drawn. With a view to study the processes of transformation of water masses, the static stability has been computed for about 500 stations covering the Indian Ocean.

2.1.2 Studies on physical processes occurring in the seas around India

The installation of a sophisticated ship borne wave recorder on R.V. *Gaveshani* has enabled the scientists to collect valuable data on waves in the seas around India. Studies on time variation of currents, sea temperature and other hydrographic parameters near the buoy stations worked out during Indo-Soviet Monsoon Experiment have been completed. A study of sound velocity structure in the waters of the northern Arabian Sea has been initiated. Investigations on circulation in the northern Indian Ocean through model studies have also been initiated.

Physical oceanographic data were collected on board R.V. *Gaveshani* during four oceanographic cruises (cruise Nos. 16, 20, 21 and 22) from the shelf region off the Arabian Sea and Bay of Bengal. In all 128 stations were worked. At most of these stations, bathythermograph and hydrocast were operated. CSTD system was operated at 12 stations in the Bay of Bengal during the period of south-west monsoon and continuous profiles of salinity and temperature against depth upto 1200 m were obtained. Data collected during these cruises are being processed for studying the physical oceanographic aspects like temperature distribution, microscale and macroscale features of temperature and salinity structures, circulation, wave characteristics, etc.

Studies on time series data on currents and hydrographic parameters, collected at a buoy station on the equator near 60°E meridian during the SW monsoon period revealed some interesting features. A complex vertical structure of horizontal currents with predominant easterly components at 75 m and 100 m depth and. predominant westerly components at 200 m, 300 m, 500 m and 800 m depths were observed. At 150 m depth, the currents were found to be oscillatory with a period of oscillation of about 2 hours. The currents were rather strong even at deeper levels particularly at depths of 200m and 800m where westward jets with speeds of the order of 35 cm/sec and 40 cm/sec respectively were encountered. A significant fall in temperature (about 2°C) and a slight decrease in salinity in the surface layer were noticed during the one month interval between the two series of hydrographic observations (May/June-June/July).

Short period variations of temperature in the upper layers of the sea at a station in the northeast Arabian Sea were studied using the data from two series of repeated BT lowerings for the premonsoon and monsoon periods by computing and analysing mean temperature differences and auto-correlation coefficients. These studies have indicated maximum changes of temperature in the upper part of the thermocline during premonsoon and monsoon periods, the maximum changes for monsoon season, in general, being more than those for the premonsoon period. Auto-correlation values have revealed significant correlation (1% level) in the upper part of the mixed layer for more than 3 hours, the feature being more prominent during the monsoon period. Within the thermocline, significant correlation was found around 170 m depth for more than 3 hours during the monsoon period. No definite relationship was seen between the magnitude of change in temperature and the degree of correlation.

A critical study of the continuous profiles of temperature and salinity against depth obtained with STD recorder from the northern Arabian Sea has revealed the presence of fine structures which are characterised by homogeneous layers separated by interfaces. The fluctuations of temperature and salinity were maximum (being about 0.5°C and 0.2‰) in the thermocline. Temperature showed an increase in the fine structure with the formation of seasonal thermocline. Deeper waters below the thermocline showed the fine structures with a less magnitude of fluctuation and a larger layer of thickness.

2.1.3 Studies on land-sea interaction and nearshore circulation with application to coastal zone management

Under this project, investigations were carried out at several places along the Indian coastline. Details of the work carried out are as follows:

1. Studies on the beaches of Goa

In order to understand the magnitude of seasonal changes in the beach profile near the mouth of Mandovi estuary, data on beach profiles at 13 stations were collected at fortnightly intervals since June 1977. The data are being processed and analysed.

2. Studies on the beaches of Kerala

The analysis of the beach profile data collected during the past has revealed the following in respect of the coastline from Cochin to Alleppey.

(i) The coast from Alleppey Pier to Purakkad can be considered as a single physiographic unit. (ii) The stability of this section of the coast depends more on the presence, absence or migration of the offshore mud banks. It has been observed that the lee-ward side of the mud bank gets accreted and the beach widens. (iii) The construction of the sea walls has not been very helpful at all places regulating the beach changes. In certain cases due to fringe effects, the nearby beaches have been affected very adversely as in the case of Vypeen and Purakkad. This is because the sea walls or groins on the coastline affect the littoral transport in the breaker zone, creating an imbalance in the material budget and causing erosion and accretion in that particular section of the coast. (iv) At present Narakkal section of the coast appears to be stable.

3. Currents off Bombay coast

An analysis of current measurements recorded continuously for about 24 hours at a few stations off Bombay coast during March 1976 has revealed the dominance of periodic tidal flow on the current pattern. The frequency distribution of flow direction has been observed to be bimodal. The vertical mean residual current is directed offshore in the surface layers (upto 20 m depth) and onshore at relatively deeper levels. Further, an analysis of the wind and current fluctuations has shown a fairly good correlation between them.

4. Studies on oil spill movement in the Bombay High region

Oil spill movement in the Bombay High region has been studied using available data on winds and currents. The studies indicate that the threat to the coastline is mainly from May to September, when the oil patches are expected to reach the coast in about 15 days after their release. From October to March, the oil patches will drift offshore. In April, the oil patch will very slowly approach the coast far south of Bombay.

5. Hydrographic survey off Karwar

Monthly hydrographic surveys off Karwar indicated the presence of cool, low salinity, low oxyty water near the coast during the period September/October. This water has been identified as the upwelled water. Temperature near the bottom during the period was as low as 20°C.

***6.* Oceanographic studies off Mangalore coast**

Investigations carried out on the shoreline and the adjoining sea off Mangalore have indicated that the beach shows large scale variation in sand cover throughout

the year. The maximum variation in sand cover occurs during the monsoon period. The beach is characterised by a double berm which shifts as the extent of wave activity changes The breaker zone is around 110-120 m from the reference point during the fair weather season and 150 m during the monsoon season.

The littoral currents are northerly from November to February and southerly during the rest of the year.

The water column is fairly stable throughout the year, except for a slight instability in the surface layers during the month of February.

The temperature of the surface waters in the area vary from 26.0°C to 30.4°C and the salinity from 32·8‰ to 36.8‰. The bottom waters show a variation of 24.8°C to 30.1°C in temperature and 33.0‰ to 36.7‰ in salinity. The variation in pH is 7.5 to 8.2, but no seasonal pattern in its fluctuation was noticed. The dissolved oxygen content was fairly high (4 ml/1) throughout the year.

The influence of tides on currents decreases offshore and at a distance of 2 km from the coast, it is found to be practically negligible. Beyond 2 km, the speed of the currents, in general increases as we go offshore and the current directions become mostly parallel to the shore or offshore. Minimum velocities (about 5 cm/sec) were encountered in December and the maximum (about 50 cm/sec) in May. Seasonal currents have been found to be southerly from March to September and northerly from October to February.

The bottom contours are roughly parallel to the shore. The bottom is free from rocks and has a fairly gentle slope. In the depth range 0-6 m the bottom is sandy while beyond the 6 m depth contour, it is made up of a soft greyish deposit with a high clay content .

The tides are of semi-diurnal mixed type with an average of 1.4 m. The maximum spring tide range is 1.85m while the minimum range is 0.2 m.

The predominant waves and winds are from directions between N and NW during the fair weather season and N and SW during the monsoon season.

2.2

chemical oceanography

2.2.1 *Chemical oceanographic studies in the Arabian Sea and Bay of Bengal {Project No.* 301)·

1. Chemistry of pharmacologically active constituents from marine flora and fauna.
2. Cycle of phosphorus, nitrogen and some biologically active trace metals in the estuarine and offshore waters along the west coast of India
3. Studies on the interrelationships between nutrients and oxygen with special reference to water masses in the Bay of Bengal
4. Distribution of oxygen in the offshore and coastal waters of the Arabian Sea and Bay of Bengal
5. Carbon dioxide system in the offshore and coastal waters of the Arabian Sea and Bay of Bengal
6. Carbohydrates in the estuarine, coastal and offshore waters of the west coast of India
7. Arsenic cycle in the coastal and offshore waters of the Bay of Bengal
8. Studies on calcium phosphate saturation in sea water
9. Calcium carbonate precipitation in sea and estuarine water
10. Regeneration of nutrients in marine and estuarine environments

2.2.2 *Desalination of sea water (Project No.303)*

Investigations carried out in the Chemical Oceanography Division during the year 1977 are under three main projects: (1) Chemical studies in the coastal and offshore waters in the Arabian Sea and Bay of Bengal (Project 301), (2) Protection of marine environment and monitoring of pollutants which form a part of Task Force No. 101; the progress of this is reported separately under Task Force and (3) Investigations on the desalination of sea water (Project 303).

Studies undertaken under these projects include: (i) distribution and interrelationship of inorganic and organic constituents of the estuarine, coastal and offshore waters along the east and west coasts of India, (ii) chemistry of pharmacologically active components of marine plants and animals and (iii) design and improvements of solar desalination units.

2.2.1 Chemical oceanographic studies in the Arabian Sea and Bay of Bengal

These studies are based on observations made during the various oceanographic cruises of R.V. *Gaveshani* in the coastal and offshore regions of Arabian Sea and Bay of Bengal. The data is being processed and analysed to understand the horizontal and vertical profiles of the chemical constituents and their interrelationships in relation to physical and biological processes in the sea.

Observations in the coastal and offshore waters in the Bay of Bengal during the south-west monsoon period (July to September) indicate that the nutrient concentrations in offshore regions are very low and marked increase in the levels could be noticed in the coastal regions. The nutrient profiles indicate coastal upwelling and this feature is more marked along the Andhra coast. The concentrations near the head of the Bay are extremely low followed by a gradual increase towards the south.

Investigations on silicon in the coastal and offshore waters of the Bay of Bengal were made during the south-west monsoon period. The surface concentrations in the coastal waters were always higher (1 to 2 μg at./l) than those in the offshore waters (0.4 to 1 μg at/l). Though fairly higher values were found at the surface (>1 μg at/l) in coastal waters, the depletion of silicon upto 0.4 μg at/l was noticed between 30 and 50 m depth which is believed to be the effect of biological utilization. Variations in the concentrations with depth between surface and 1000 m were from 0.4 to 51.6 μg at/l and the maximum value was at 1000 m.

1. Chemistry of pharmacologically active constituents from marine flora and fauna

(a) *Pharmacological screening of marine plants and animals:* About 50 marine organisms have been tested for a wide variety of biological activity. Out of the species examined, the following have been found to show promising results. *Hypnea musciformis* (CNS stimulant, diuretic, anti-inflamatory); *Caulerpa racemosa, Chondrus* sp., *Pocillopora domicornis* and *Gemmaria* sp. I (hypotensive); *Padina tetrastomatica, Melitodes ornata* and *Corallina* sp. (spasmogenic); *Codium elongatum* (antiviral); Cuvierian glands of sea cucumber (antifertility). *Gemmaria* sp. II and sedentary polychaetes on a sea anemone *(Anthopleura panikkarii)* were found to be extremely toxic. Of these, the extracts of only two species, namely, *Hypnea musciformis* and *Gemmaria* sp. I have been fractionated and the activity was confirmed in fractions. Further work is in progress.

(b) *Chemical investigation on Dictyota dumosa and Gracilaria corticata:* Chemical investigations on some of the marine plants were undertaken and several compounds have been isolated from the neutral fraction of *Dictyota dumosa*. One of the compounds isolated on the basis of spectral data, appears to be new and related to paradictyol isolated from some other species of Dictyota. Finalisation of this new compound is in progress.

Cholesterol was isolated from the neutral fraction of *Gracilaria corticata* and it has been found to be the major constituent of the algae.

(c) *Distribution of iodine in marine algae of Goa region:* Determination of iodine was carried out in twenty species of marine algae (red, brown and green). Low contents were observed in brown algae as compared to the red and green-

The iodine content was found to vary from 0.014% to 0.74% in red algae, from 0.054% to 0.168% in brown algae and from 0.031% to 0.489% in green algae (dry weight basis).

2. Cycle of phosphorus, nitrogen and some biologically active trace metals in the estuaries and along the west coast of India

(a) *Estuarine and coastal waters of Goa :* Studies on phosphorus and nitrogen compounds in the Bay of Bengal were undertaken between July and September. It was found that the concentration of these compounds are very low in the upper 75 m which is the most productive zone. Below the thermocline, phosphates and nitrates show rapid increase with increasing depth. No definite phosphate or nitrate maxima were observed in the upper 1000 m. It is significant to note that nitrite concentrations are extremely low in the Bay of Bengal which is in contrast to the Arabian Sea. The concentrations tend to be slightly higher at the thermocline top.

(b) *Nearshore waters and backwaters of Cochin:* Phosphorus and nitrogen cycles in the nearshore and backwaters of Cochin were carried out during the year. Inorganic phosphate levels in the backwaters showed monthly variation between 1 and 4 µg at/1. High concentrations of organic phosphorus were present during certain months of year. The values varied between 2 and 20 µg at/1. Particulate organic phosphorus formed the major organic phosphorus fraction. High organic phosphorus concentration observed in the backwaters is believed to be due to the discharge of phosphorus through other sources. A distinct seasonal variation in the distribution of phosphorus was absent. Interstitial phosphate in the sediment samples varied between 4 and 6 µg/1 of mud.

Nitrate levels in the waters varied between 0.1 and 5 µg at/1. Nitrate concentration showed very high variability with values ranging from less than 1 to 45 µg at/1. Ammonia concentrations varied from 0.1 to 28 µg/1. None of these constituents showed any definite seasonal rhythm, probably indicating that there is discharge of nutrients in the environment through other sources.

Monthly variations in the organic carbon content in the mud at various stations showed a variation between 2 and 30 mg/g of mud. Total nitrogen varied from 0.9 *to* 5.7 mg/g of mud and total phosphorus varied from 0.8 to 2.9 mg/g of mud. Total iron showed a vatiation between 0.9 and 17.9 mg/g of mud.

Heavy metal like iron, manganese, copper, zinc, cobalt and nickel were estimated in the particulate matter at various different stations in the Cochin backwaters and the nearshore region. Iron concentration varied between 1257 and 4686 µg/1 at the surface and 2286 and 4686 µg/1 at the bottom. High values were observed at the mouth of estuary. Manganese content varied between 5.7 and 64 µg/1 and 4.8 and 97 µg/1 at the surface and bottom respectively. Particulate copper values varied from 0.8 to 5.9 µg/1 at the surface and 0.87 to 13.7µg/1 at the bottom. Higher values were observed in the harbour area. Zinc levels in the backwaters varied between 2.3 and 111.2 µg/1 at the surface and 3.1 and 83.6 µg/1 at the bottom. Measurement of cobalt and nickel in the particulate matter showed very low or non detectable concentrations in the particulate matter.

3. Studies on the interrelationships between nutrients and oxygen with special reference to water masses in the Bay of Bengal

The interrelationship between apparent oxygen utilization and changes in nitrate-nitrogen and phosphate-phosphorus in the western Bay of Bengal was studied using the data collected during VII, VIII and IX cruises of R.V. *Gaveshani*. The following atomic ratios were obtained:

$$\Delta AOU : \Delta N : \Delta P = 260 : 124 : 1$$

These ratios were used for the calculation of "reserved" phosphate, which in association with delta-t was used for the classification of various subsurface water masses in the south-western Bay. The different waters thus classified are:

(i) Indian Equatorial Water lying below 150-200m;

(ii) A mixture of Persian Gulf and Red Sea Waters lying between 350 and 550 m and having low P_r ;

(iii) North Indian Deep Water below 1000 m characterised by P_r and oxygen.

Two oxygen minima were observed in Southern Bay at 150-250 and 400-600 m separated by a maximum at 250-350 m. This has been attributed to advection of oxygen rich waters from the Equatorial region- North of 17° N latitude, however, only one minimum was obsersved.

Vertical profiles of oxygen indicated the occurrence of upwelling along the coast.

4. Distribution of oxygen in the offshore and coastal waters of Arabian Sea and Bay of Bengal

A study of vertical profiles of oxygen in the Bay of Bengal during south-west monsoon period revealed the presence of two oxygen minima in the Southern Bay, first between 100-250 m and the second between 400-600 m. These minima are separated by a layer of relatively high oxygen at about 300 m depth. The upper oxygen minimum observed in the present study is probably caused by the oxidation of organic matter that sinks down from the surface and accumulates in the density discontinuity layer. The oxygen content at this minimum layer is controlled by the supply of organic matter. Off Madras, low oxygen values were found to be associated with high nutrient concentrations. This reflects the effect of large quantities of sewage discharged into the sea from the city depleting oxygen from the water column. An interesting feature observed during these studies was that the second oxygen minimum almost coincided with the salinity maximum which was invariably observed at all the positions. The depth of the second oxygen minimum and salinity maximum was in the depth range reported for the Persian Gulf and Red Sea waters.

5. Carbon dioxide system in the offshore and coastal waters of the Arabian Sea and Bay of Bengal.

Data collected during the cruises of R.V. *Gaveshani* in the coastal and offshore waters of Bay of Bengal are being processed and analysed to study the carbon dioxide system.

6. Carbohydrate in the estuarine, coastal and offshore waters of the west coast of India

Distribution of dissolved carbohydrates (DCHO) was studied in the coastal and offshore waters of the Arabian Sea. Surface values varied from 0.75 to 2.5 mg/1. More or less uniform concentration was found in deep waters. In the coastal waters, the concentration of DCHO was always higher and varied from 0.8 mg/1 to 3.2 mg/1. In the offshore waters the concentration of DCHO varied from 0.75 to 1.5 mg/1 at the surface water. From 400 to 800 m, the concentration of DCHO was very high ranging between 2.0 to 4.0 mg/1. Off Ratnagiri, the DCHO concentration was found to be uniform, varying mostly between 1.0 to 2.0 mg/1. In the coastal waters, the variation in the concentration of DCHO within 24 hours was 1.8 to 2.8 mg/1.

The concentration of carbohydrate in the surface sediment, collected from Arambol beach (Goa) at high water, mid water and low water levels varied from 66 to 264, 148 to 423 and 33 to 385 g/gm respectively. High concentration was observed at the mid tide level and still higher values were at the high tide level during the monsoon. The concentrations of particulate carbohydrate in the surface water varied from 0.37 to 0.66 mg glucose/litre as against 0.8 to 3.3 mg glucose/litre in the monsoon. The core samples at 15 cm depth showed higher values in all the three tidal levels than in the sediments taken from the surface indicating that most of the surface carbohydrate percolates to deeper layers.

7. Arsenic cycle in the coastal and offshore waters of the Bay of Bengal

Studies on the total arsenic content of some of the shelf and slope sediments (surface) along the east coast of India were made between Visakhapatnam and Madras. The distribution showed marked variation with the texture of the sediments. Major portion of the arsenic appeared to be concentrated in the clay fraction. In general, the inner shelf sediment contained higher concentrations with a slight decreasing trend towards the slope region. The concentrations over the entire area ranged between 0.2 and 8.7 ppm. High values were found to be concentrated around Visakhapatnam extending down to the region of Godavari. There was a marked decrease in arsenic concentration in the sediments off Krishna river.

8. Studies on calcium phosphate saturation in sea water

The degree of calcium phosphate saturation was studied in the waters of the Bay of Bengal. It was observed that these waters are undersaturated with calcium phosphate. Though the total inorganic phosphate concentration is higher in this area as compared to the Gulf of Kutch and Bombay High waters, low pH causes a lower fraction of the total inorganic phosphate to be present in the form of trivalent phosphate ion. As a result, the solubility products gets decreased. Further processing of the data is in progress.

The degree of saturation of sea water so far established is based on the solubility product value (4.0×10^{-20}) as calculated by Pytowitcz and Kester. Future plan includes laboratory experiments to study the equilibrium conditions of calcium phosphate to establish the solubility product constants at different salinity and temperature conditions in sea water.

9. Calcium carbonate precipitation in sea and estuarine water

Data collected during all the cruises of R.V. *Gavesheni* in the coastal and offshore waters of Bay of Bengal were pooled for processing and analysis, to study the calcium carbonate saturation profiles.

10. Regeneration of nutrients in marine and estuarine environments

Laboratory experiments on the regeneration of phosphorus from the sediments have been carried out using radioisotope phosphorus (P^{32}). Samples of sediments collected from the estuarine regions consist of sand, silty sand, sandy silt and clay. Millipore filtered water was used as controls with sufficient quantity of antibiotics added to check bacterial activity. The initial activity added was 40 μCi P^{32} as sodium orthophosphate in aqueous buffered solution. There was a remarkable loss of the added activity during the first two days which ranged from 24% to 80%. From third day onwards, release of phosphate was noticed and within twelve days about 70% of the phosphate was released to the water column. Sandy silt was found to be more efficient than any other type of sediments.

2.2.2 Desalination of sea water

A prototype of the modified design of solar still was fabricated and subjected to field trials for about three months. These trials showed that though the fresh water output from the still was fairly good (3.6 litres per square metre per day) the water contained dissolved copper (0.25-0.53 mg/1). This impurity in water was mainly caused by the condensate channels of the still which were made out of copper sheet. To obtain water of highest purity further work on replacing copper sheets with cheaper materials, such as aluminium or synthetic polymer is in progress.

2.3

geological oceanography

2.3.1 *Geological and geophysical surveys to assess the petroleum and mineral prospects of the western continental margin of India {Project No.* 501)

2.3.2 *Geochemistry of the sediments of the western continental margin of India (Project No.* 502)

2.3.3 *Sediments of the western continental margin of India (Project No.* 503)

2.3.4 *Foraminifera as indicators of high organic carbon and pollution in the marine environment (Project No.* 504)

The Geological Oceanography Division was fully engaged in the geological, sedimentological and palaeontological studies of the seas around India. The four main projects are continued and the progress achieved during the year is as follows:

2.3.1 Geological and geophysical surveys to assess the petroleum and mineral prospects of the western continental margin of India

(a) Bathymetric, side Scan sonar and shallow seismic surveys on the inner shelf between Vengurla and Cape de Ramas were carried out on board R.V. *Gaveshani.* The echogram and the side scan sonar records indicated a smooth topography. The inner shelf is underlain by clay varying in thickness from 10 to 15 m.

(b) *Geomorphology of the Gulf of Kutch :* The echograms from the Gulf of Kutch reveal that the topography of the gulf is complex and the Gulf can be divided into three physiographic units, i.e., of even, uneven and rough topography. The even surface to the east is principally due to the land derived sediments. The mouth and centre of the Gulf is uneven and rough and the bottom is rocky. The central region of the Gulf has several scarps of 6 to 32 m.

(c) Three equipments were designed, developed and fabricated namaly (i) Piston gravity corer, (ii) Deep Sea Peterson's Grab and (iii) Fluorescent tracer release drum.

2.3.2 Geochemistry of the sediments of the western continental margin of India

Studies on the chemistry of the sediments of the Gulf of Kutch have revealed that the consolidated sediments in the Gulf are generally terrigenous in nature. High concentration of elements such as Al, Fe, Mn, Ti, Ni, Cu, Co and Zn were associated with a fine grained sediments. While the calcium carbonate in these sediments is biogenic, all other elements seem to be terrigenous. The similarity that exists between the

sediments of the Gulf of Kutch with those from the adjacent shelf region north of the Gulf in their chemistry indicates that the sediments coming from the north are brought into the Gulf.

Environmentally, the outer shelf, region between Dabol and Gulf of Cambay demands a detailed exploration from the point of view of the search for phosphatic sands/ rocks.

Trace elments partition studies in the sediments of the Deep Sea Drilling Project (DSDP) Site 219 revealed that the rhyolitic tuffs and sediments in association with the montmorillonite and authigenic clays such as phillipsite and clinoptilolite constitute an important geochemical environment for the accumulation of trace elements.

2.3.3 Sediments of the western continental margin of India

Distribution of the various components of the sediments of the Gulf of Kutch indicates that the predominant control of sedimentary processes is associated with high tidal velocities and that one of the important sources for the sediments is River Indus. A sediment distribution map of the Gulf has been prepared.

Gypsum has been found in the inner shelf sediments off Maharashtra. The maximum content of gypsum is 22.5% by weight in the coarse fraction which is generally less than 5% by weight of the bulk sediment.

130 samples collected during the 17th and 18th cruises of R.V. *Gaveshani* were analysed for sand, silt and clay content. 63 samples selected after preparation of surface sediment distribution map, were analysed for grain size distribution and light and heavy mineralogy. Results of the analyses show that the outer continental shelf off the coast from Vengurla to Mangalore is a source of quartz and heavy mineral sand.

A live coral bank, named *"Gaveshani Bank"* was discovered off Mangalore at a distance of 100 km from the coast at a depth of 80m.

Scanning electron microscopy of nannofossils from core samples of the continental slope of south west coast of India was completed. The state of preservation of biogenic components has resulted in the confirmation of the existence of old shorelines on the western shelf. These old shorelines represent zones of heavy mineral accumulation.

2.3.4 Foraminifera as indicators of high organic carbon and pollution in the marine environment

175 bottom samples collected from the inner western shelf (from Dabhol to Tuticorin) during the 17th cruise and samples collected during the second cruise from the Gulf of Kutch of R.V. *Gaveshani* were analysed for their organic carbon content. The findings based on laboratory work, are as follows:

(a) The lowest value was 0.18% at 31 m depth south of Calicut whereas the highest value was 3.77% at 20 m depth of Cochin.

(b) The organic carbon from the Gulf of Kutch ranges from 0.138% to as high as 0.529 % at 39 and 32 m depth indicating that its distribution pattern is erratic.

(c) 38 grab samples from a depth of 4.5 m to 89 m collected between Ratnagiri to Bombay and Bombay area were also analysed for organic carbon content in the sediment which indicated a very high value between Ratnagiri to Bombay reaching a peak of 2.90% at 26.5 m off Ratnagiri.

(d) In the Gulf of Kutch, the foraminiferal number is the highest in fine clays and these are thin walled, hyaline, and of meiofaunal size, whereas the thick walled, porcellaneous and large types occur in silt and sand. The agglutinated and planktonic species are rare.

(e) *Hyalina balthica* which is a characteristic indicator of Pliocene-Pleistocene boundary is found in the sediments of the Gulf of Kutch.

Samples for foraminifera, as indicators of the organic carbon content, are being processed.

2.4

biological oceanography

2.4.1 *Studies on primary, secondary and tertiary levels of the food chains (Project No.* 201)

1· Biological productivity of the Indian Ocean

2· Primary production

3· Extracellular products of planktonic algae

4· Secondary production

5. Benthic production

6· Biochemical investigations

7· Ecology of estuaries

8· Uses of mangroves

9· Ecology, production and related aspects of sandy beaches of Goa

10. Studies on *Trichodesmium* blooms in the Arabian Sea

2.4.2 *Coastal aquaculture (Project No.* 202)

1.· Aquaculture in the waters of Goa

2. Aquaculture in the waters of Cochin

3. Aquaculture in the waters of Bombay

4. Laboratory and field studies on bioenergetics of some marine and estuarine animals

2.4.3 *Biogeography of the zooplankton of the Indian Ocean (Project No.203)*

2.4.4 *Ecological, developmental and experimental studies on plankton (Project No.* 204)

2.4.1 Studies on primary, secondary and tertiary levels of the food chains

1. Biological productivity of the Indian Ocean

Oceanographic data largely collected during the International Indian Ocean Expedition (IIOE), are used to study the biological productivity of the Indian Ocean. The factors studied are light, nutrients and the rates of production at the primary, secondary and tertiary levels of the food chain. The euphotic zone or the compensation'

depth (1% of the surface illumination) has been determined. Similarly values of phosphate-phosphorus and nitrate-nitrogen up to 100 m depth are integrated and plotted for the entire Indian Ocean. Euphotic zone varies between 40 m and 120 m. Both phosphorus and nitrogen show a similar pattern of distribution. Rates of primary production for the surface (1 m depth) and column (up to the depth of 1% illumination) are calculated separately. Surface production per unit area in the Bay of Bengal is higher than that of the Arabian Sea. This is probably because of greater cloud cover over the Bay of Bengal during the year than that of the Arabian Sea. The Bay of Bengal also seems to receive a high load of nitrate-nitrogen from the riverine system which enhances the nitrogen concentration at the surface resulting into a greater primary production. Column production in the Arabian Sea, on the other hand, is much greater than that of the Bay of Bengal. The total column production for the Indian Ocean amounts to 4.42 x 10^9 tonnes of carbon/yr or 94 tonnes of carbon/km^2 / yr or 258 mgC/m^2/day. Secondary production computed from the zooplankton biomass gives the value of 69.27 x 10^6 tonnes of carbon/yr. From the primary and secondary production rates, tertiary production of the potential exploitable yield for the Indian Ocean has been estimated as 15 and 17 million tonnes/yr respectively. Transfer coefficient for the Indian Ocean or the ratio between the yield from one trophic level to the other is much lower than 10%. Potential yield for the Indian Ocean based on published data of catch and effort is estimated to be about 14.25 million tonnes. The reliability of various estimates has been discussed. Recent figures of pelagic, demersal and crustacean resources from the different regions indicate that the annual catch for the Indian Ocean is about 3 million tonnes. Hence to bring the catch close to the potential yield, nearly 3-4 times increase is possible annually.

2. Primary production

The data collected on primary productivity and related parameters at 14 stations in an area between Karwar and Cape Camorin were analysed. The average daily surface productivity was 10.07 mgC with a high variability from 0.67-42.23 mgC/m^3/day. The average daily column productivity was found to be in the range of 0.045-1.17 gC/m^2. In the column, chlorophyll-a varied from 3.84-18.86 mg/m^2 (av. 9.96 mg/m^2); pheophytin from 1.35-15.98 mg/m^2 (av. 7.12 mg/m^2) and particulate organic carbon (POC) from 1.97-14.75 g/m^2 (av : 7.2 g/m^2).

During August-September 1977, primary productivity and related parameters were measured at 14 stations in the Bay of Bengal. Primary productivity at the surface varied from 2.04-84.64 mgC/m^3/day with a daily average of 21.36 mgC/m^3 and in the coulmn from 0.14-1.19 gC/m^2 day with an average of 0.64 gC/m^2/day. An exceptionally high productivity value of 495 mgC/m^2/day at the surface and 5.6 gC/m^2/day in the column, associated with high pigment and POC values was encountered at station No. 657 (Latitude 19°30' and Longitude 89°0'). This, however, was found due to dense patch of phytoplankton.

Chlorophyll-*a* in the column varied from 2.11-23.6 mg with an average of 7.91 mg and pheophytin from 1.7-15.73 mg with an average of 4.85 mg. The above findings show that the south-west monsoon is relatively a more fertile season in the Bay of Bengal.

The qualitative and quantitative analyses of phytoplankton collected during these cruises are in progress.

Productivity studies between Dabhol on the west coast and Tuticorin on the east coast in an area of about 43000 km^2 within the 50 m depth region indicated that primary production was at the rate of 5 million tonnes carbon/year and secondary production was 2.56 million tonnes carbon/year. The maximum sustainable yield of fish was estimated to be 0.8 million tonnes against the present yield of 0.6 million tonnes.

3. Extracellular products of planktonic algae

Seasonal studies on extracellular products in Dona Paula Bay, Goa, showed that they varied from 0 to 22.1 mgC/m^3/hour and thus represented 0-40% of particulate fixation. Nannoplankton were major contributors.

In the mangrove environment, phosphates (0.8-5.5 µg at/l) and nitrates (2.5-3.7 µg at/l) were high. Seasonal differences in carbon assimilation averaged 1.4 gC/m^3/day (C^{14} method) and 0.81 gC/m^3/day (oxygen method). The higher values encountered in C^{14} method are attributed to bacterial photosynthesis.

Data collected from the Bay of Bengal and the Arabian Sea are being analysed.

4. Secondary production

Analysis of the samples collected during August to October 1976 from the Bay of Bengal indicated the richness of zooplankton in the nearshore region. Biomass showed an increasing trend from north to south from 1 to 30 ml/ $100m^3$. Richest grounds for decapod larvae, fish eggs and fish larvae were found along the south-east coast.

A dense swarm of the pteropod, *Cresseis acicula* was observed off Krishna estuary, in September 1977. The biomass, mostly contributed by this species, was found to be 3.7 times higher than the highest ever recorded from the Bay of Bengal.

In the Arabian Sea, the biomass showed an increase towards the north with maximum value of 124 ml/100 m^3 off Bombay. Copepods, chaetognaths, fish eggs and fish larvae had higher population density in the northwestern region. Decapod larvae were abundant in the oceanic waters with maximum population around Lakshadweep atolls.

A comparison of zooplankton production during postmonsoon period indicates that the Arabian Sea is twice as productive as the Bay of Bengal.

An unusual aggregation of sergested shrimp, *Acetes johni* was observed off Maharashtra coast in February.

Analysis of chaetognath samples collected from three stations along the south-west coast of India showed that the species diversity increased from inshore region to offshore region. The following zones could be demarcated on the basis of the spatial preference of different species:

(i) an inner shelf zone constituted by six species,

(ii) an outer shelf zone composed of three species, and

(iii) slope zone comprising of six species.

200 chaetognath samples from the stratified depth up to 100 m collected by U.S. ship *Anton Bruun* from the Bay of Bengal were also analysed.

5. Benthic production

Collection and analysis of samples from different parts of the Arabian Sea and Bay of Bengal were completed. The findings are given below:

(i) Quantitative distribution of macro benthos in the shallow regions (below 15 m depth) of central west coast of India (between 16° and 12°N latitudes) indicated the richness of fauna (average biomass varying from 62.15 to 762.35 g/m^2) and also revealed the importance of bottom communities in demersal fisheries and nearshore living resources.

(ii) Studies on the benthos of Bay of Bengal indicated the richness of meiofauna in the nearshore regions with a clear relationship between the type of sediments and the numerical abundance of organisms. Decreasing population density of both micro and meiofauna was noticed with the increasing depth, the average biomass being 9.223 g/m^2.

(iii) The quantitative and the qualitative distribution of macro and meiofauna in Arabian Sea upto 2000 m depth revealed the dominance of detritus feeding organisms.

6. **Biochemical investigations**

Blood serum proteins of a flat fish, *Psettodes erumei* were analysed by electrophoresis. Comparison between the blood serum proteins of *P. erumei, Brachiurus orientalis* and *Pseudorhombus arsuis* has shown species to specific patterns. Commercially important fishes like *Pampas argenteus, Parastromateus niger, Rastrelliger kanagurta, Lactarius lactarius* and *Hemirhampus georgii* were also studied for blood serum protein composition. Immunological studies on the eye lens proteins of fishes were undertaken for studying the antigenic components and immunological relationship.

7. Ecology of estuaries

Studies on the distribution of prawn larvae were carried out in Mandovi and Zuari estuaries of Goa. Breeding periodicity of *Metapenaeus dobsoni, Penaeus merguiensis, P. indicus, Parapenaeopsis stylifera, Metapenaeus monoceros, M. affinis* and *Metapenaeus* sp. has been studied. The larvae and the post larvae of *M. dobsoni* are the most abundant while the post larvae of other prawns are available in large numbers during the premonsoon season especially in February. The larvae and post larvae of these species are most abundant in the catches during night and during the flood tide period.

8. Uses of mangroves

Leaf content of mangrove plant *Bruguiera passiflora* showed depressent activity on the blood pressure of cat, thus indicating presence of cholinergic compounds. This work was carried out in collaboration with the Pharmacology Department, Goa Medical College, Panaji.

Experiments on the growth of mangrove seedlings in fresh water showed less mortality in contrast to that in the mangrove swamp.

9. Ecology, production and related aspects of sandy beaches of Goa

Data collected on various beaches were analysed and the following findings are reported from Baina beach, Goa.

(i) Peak biomass was recorded in November (36.144 g/m^2).

(ii) *Emerita holthuisi, Donax incarnatus* and *D. spiculum* are the dominant inhabitants.

(iii) Macrofaunal production was almost nil during monsoon.

(iv) Species diversity was small as a result of considerable human interference.

(v) The beach is severely eroded during monsoon.

(vi) Particulate organic carbon in sand was high; the highest value of 16 mg/g was recorded in August.

(vii) The beach had a high population of terrestrial and marine bacteria, showing maximum number in August and November respectively. The bacterial population showed a highly significant relation (0.1% level of significance) with particulate organic carbon.

10. Studies on *Trichodesmium* blooms in the Arabian Sea

Blooms of *Trichodesmium erythraeum* were studied during the 1977 season in the Arabian Sea (nearshore waters of Goa, west coast of India). These blooms appear every year with a marked periodicity from Fabruary to April when the sea is calm with little wave action and has high temperature, high salinity and maximum period of sunshine. High phosphate-phosphorus, ammonia-nitrogen and nitrate-nitrogen were found in the sea associated with the blooms. The values of all these nutrients went up with every pulse of the bloom. The bloom was massive and occupied several square kilometres of the nearshore water. It was generally spread out in long bands probably because of convective circulation prevailing in the region during the premonsoon months.

During the season the density of the bloom was found to be highly variable. Bloom patches kept appearing and disappearing with the state of the sea. Slightly turbulent conditions made the bloom disappear from the surface and calm conditions made it reappear. In its early stages, the bloom had the appearance of sprinkled saw dust over the sea surface, but as it advanced in age it began to impart reddish brown colour to the water.

Towards the end of *Trichodesmium* bloom, the diatom *Asterionella japonica* begins to appear in great profusion. In the bloom patches, zooplankton organisms were just as abundant as in non-bloom areas. Many zooplankton organisms were found to be living in patches of dense bloom. Fish catches taken in areas of the bloom were largely composed of 'trash fish' showing no marked dissimilarity from those of the non-bloom areas. *Trichodesmium* is not much favoured as food by the fishes or other animals although the bloom is totally non-toxic. No mortality of fish or any other animal was ever found in association with the bloom. Laboratory experiment with natural blooms

gave a clear evidence that *Trichodesmium* plays a very important role in the enrichment of tropical seas with phosphorus and nitrogen. The ability of *Trichodesmium* to fix nitrogen enhances its role in enrichment. With death and decay of the bloom, ammonia-nitrogen become very high in water.

2.4.2 Coastal aquaculture

Experimental studies on aquaculture were carried out in Goa, Cochin and Bombay.

1. Aquaculture in the waters of Goa

Experimental work on the culture of mussels, oysters, fish, shrimps and seaweed was continued as per the following details:

(i) *Mussel culture*: Investigations initiated in previous year were continued on different aspects of raft culture. It is observed that the rope culture of green mussel *(M. viridis)* on floating rafts is economical even on a small scale because it gives a high return of 181%.

The work on the biology of a barnacle, *Balanus amphitrite* which is an important fouling animal of cultured green mussel, indicated that the species is a prolonged breeder and the recruitment to the population is almost continuous. The intensity of fouling can be considerably reduced by exposing the mussel ropes to atmosphere for 8-12 hrs/ week.

Studies on the ecology and growth of weaving mussel, *Modiolus metcalfei* grown on the floating raft and in sub-tidal habitat, has indicated that the growth in sub-merged population is 25% more than that on the raft. Possibilities of ground culture by relaying the spat, were explored.

(ii) *Oyster culture*: Spat of giant oyster *(Crassostrea gryphoides)* collected from the natural bed was transplanted in plastic trays and grown by handing the trays in a fish farm. Growth, as assessed from the increase in dorso-ventral height and total weight, was 12.8 mm and 5.27 g/month respectively. Further experiments are in progress.

(iii) *Pearl oysters:* A resource survey of natural beds at Port Okha, Sankodar Beyt, Pirotan Island and Deda Reef in the Gulf of Kutch, was carried out in November 1977. Most of the beds in these areas are heavily depleted due to dredg-ing operations.

A natural bed of pearl oyster has been found in Goa waters and detailed investi-gations are in progress.

(iv) *Fish farming:* A survey on the 'State-of-art' of traditional fish farming in Goa, initiated during 1976, was completed in the current year. Important findings are as follows :

(a) More than 200 hectares of brackish water ponds are under actual use for fish farming and more than 1700 hectares of low lying areas are available for development.

Experimental culture of oyster in plastic trays.

(b) Three types of fish farming, namely, permanent farms, salt-pans-cum-fish farming, and paddy-cum-fish culture are commonly practised.

(c) Composite culture from wild stocks of shrimps, mullets and pearl spot is commonly undertaken.

(d) Annual yield varies from 560-1150 kg/ha.

(e) In spite of traditional ways of farming, the profit margin varies from 47% (in salt-pans-cum-fish) to 100% (in permanent fish farms).

(v) *Fish culture at Siridao farm:* Larvae and fingerlings of mullet *(Mugil cephalus)* and pearl spot *(Etroplus suratensis)* stocked in July 1976 in Siridao fish farm were harvested in February 1977. Growth was found to be as follows:

	Length (mm/month)	Weight (gm/month)
M. cephalus	12.83	7.55
E. suratensis	8.41	3.20

The rate of growth was 40% and 25% more than that reported for *M. cephalus* and *E. suratensis* respectively from the natural habitat.

(vi) *Shrimp culture:* Experimental culture of *Macrobrachium rosenbergii* was carried out in the Laboratory.

The larvae were reared up to VIII zoea stage. Salinity of the rearing medium largely affects the survival and growth of the larvae. The salinity at 15‰ was found to be optimum for maximum growth and survival rate. Sudden decrease or increase in salinity adversely affects the larvae.

The diet of egg-custard was found to be the most preferred food by the larval stages.

(vii) *Seaweeds—survey, utilisation and culture*

(a) *Seaweed survey of Maharashtra coast:* Phase I of this survey was completed during this year. Luxuriant seaweed growth was observed at Redi Port, Malwan, Ratnagiri and Vijayadurg, but the remaining coast was influenced by industrial pollution resulting in decrease in the seaweed stock. Agarophytes and alginophytes are available in harvestable quantities from southern part of the Maharashtra coast. Further work is in progress.

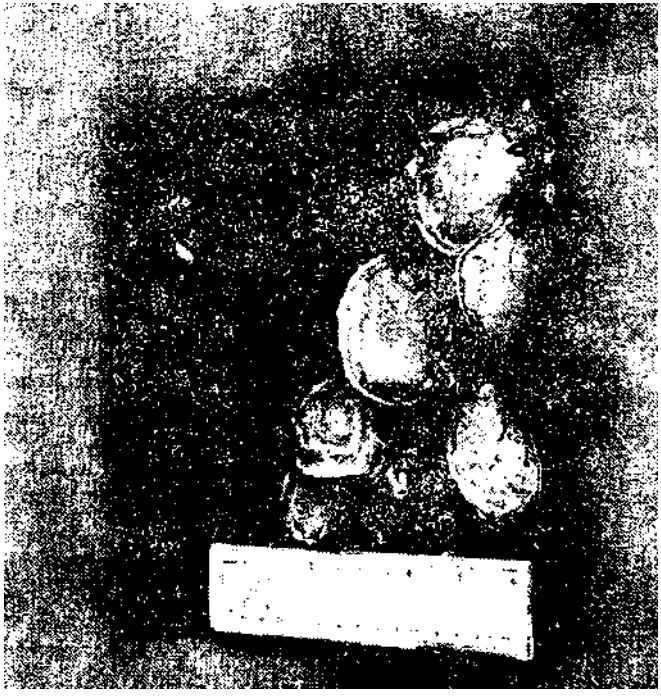
(b) *Seaweed liquid fertilizer:* Experimental studies on the effect of seaweed liquid fertilizer were continued. Seaweed extract of *Spathoglossum* sp., *Ulva* sp. and *Enteromorpha* sp. in 1 and 5% concentrations gave high yield in maize. It promoted general growth also. *Hydrangia* sp. - an ornamental plant showed an increase in leaf size by spraying seaweed extract. Lower concentrations of seaweed extract favoured a high germination rate.

(c) *Seaweed culture:* Laboratory culture of *Ulva reticulata* was undertaken to study the various developmental stages and also the effect of desiccation on it. It was observed that this species has a greater tolerance to exposure to air and can survive even after the exposure of 3 hours. This property is helpful for its culture.

2. Aquaculture in the waters of Cochin

(i) Experimental studies on the feeding of *Penaeus indicus* and *Metapenaeus dobsoni* indicated that both are voracious feeders especially when *Apseudes chilkensis* (Fam.Tenaidaceae) and two amphipods, *Eriopsa chilkensis* and *Mera orthonides* are used as food. Among these *A. chilkensis* is the most preferred food. The polychaete *Dendronereis aestuarina* was also highly preferred by the prawn. Another tanaidacean, *A. gymnophobia* was avoided by both *P. indicus* and *M. dobsoni.* One noteworthy feature of the sampling locality is that these few prey species especially the tanaidacean and the two amphipods were extremely abundant but the total number of species of macrobenthos observed in the mud samples was very limited. Experiments on feeding limit showed that these prawns fed more or less continuously with only short breaks which tended to support the view that ingestion and digestion rates are nearly equal in actively feeding prawns.

The prawns could be seen searching for these organisms. Hence they do not appear to be primarily detritus feeders or scavengers. They seem to depend very largely on their chelate legs than on the eyes for searching their food and this together with the nature of their habitat which is often muddy, seem to have made them adopt browsing as the main mode of searching their food.



Growth of *Crassostrea madrasensts* being cultured in Cochin Back waters.

Apseudes chilkensis cultured in laboratory for food of prawns.

Experiments repeated during the monsoon period seem to indicate that it is the clay that adversely affects preying efficiency more than the silt.

Feeding experiments on shrimps *Penaeus monodon, Metapenaeus monoceros* and *Metapenaeus dobsoni* using various diets such as commercial cattle feeds, compounded diets and slaughter house waste were carried out for a period of 3 months. Of these, the growth obtained from cattle feeds was not satisfactory (less than 0.35 mm/day) but the compound diet using trash fish meal, tapioca powder and rice bran was found to be superior to that formulated using shrimp waste and tapioca flour. The former gave a growth increment of 0.5 mm/day in *Metapenaeus dobsoni* whereas the later gave only 0.35 mm/day. Slaughter house wastes (cooked and minced) were fed to *Penaeus monodon* for a period of 2 months but the growth was not very fast though the animal remained healthy.

(ii) *Mass culture of animals:* During the current year, experiments were conducted on mass culture of a Tanaidacean *Apseudes chilkensis* and on a bivalve *Paphia* sp. available in Cochin backwaters. These species were found to be euryhaline and eurythermal. Being an essential prerequisite for the culture, their biology and ecology are being studied in detail. *Apseudes chilkensis* is highly esteemed as food by prawns cultured in the laboratory tanks. Mass culture of these organisms could be raised in the laboratory tanks using natural water from the backwaters. Soft sediment, rich in organic matter (5.25% organic carbon) was used as food as well as a substratum. Organisms initially introduced in the culture trays at a density of 800/m^2 grew to 23240/m^2 in 8 weeks. This works out to be about 32 gm/m^2 of live food resources which is available to predator organisms.

Life cycle of *Apseudes chilkensis* involves an intraovarian stage, an intramarsupian stage and a free living stage. Newly maturing females, measuring 5.6 mm have 12-20 eggs in the marsupium and older females measuring 7-9 mm have about 20-45 eggs. Newly born individuals measuring 1.5 mm attain maturity in 30-35 days and liberate free living young ones from their marsupium in another 10-15 days, thus taking about 50 days as generation time. Largest individuals among the population had a length of 10 mm and they were mostly males. The life span of these organisms does not seem to exceed 90 days. The comparatively short-lived nature associated with a faster rate of reproduction and growth makes this species an ideal animal at the secondary level of the food chain.

(iii) *Investigations on edible oyster Crassostrea madrasensis:* These oysters occur both in the intertidal and subtidal regions in the Cochin backwaters. The annual fluctuations in the salinity during the monsoon govern the sustenance and survival of the intertidal population. The subtidal specimens are 3 to 4 times bigger than the intertidal specimens due to availability of better food and survival conditions at that level. However, the average meat weighr was found to be higher in the intertidal population. Among the different substrata used for the collection of spats, the tiles were found to be most efficient. Growth measurement of settled spat during the period January-July showed that a maximum of 67 mm (average of 61.25 mm) was attained in 5.5 months. Period of maximum growth was January-March (14.7 mm/month), the medium growth was during, April-May (9.4 mm month) and the minimum during June-July (2.8 mm/month). The lowering of the salinity to 0.2%o during July-August resulted in heavy mortality of growing animals.

3. Aquaculture in the waters of Bombay

Bioecology of certain selected groups of sedentary animals like oysters, clams, barnacles etc. was studied. Periodical measurements were made on the population density and growth.

4. Laboratory and field studies on bioenergetics of some marine and estuarine animals

(i) Conversion efficiency and relative growth of *Metapenaeus monoceros* were high when fed on a diet containing 60% protein. Average dry weight loss/day by moulting/shrimp amounted to 0.83 mg and was equivalent to 0.57% of its mean dry weight.

(ii) Conversion efficiency of different feeds in *Etroplus suratensis* has indicated that food compound from purified ingredients gave a maximum conversion.

(iii) Biochemical constituents in *Meretrix casta* did not show significant variation with respect to sex. Average calorific value was found to be 4.1 kcal/gm ash free dry weight.

(iv) Seasonal variations in calorific value of detritus from the Dona Paula Bay in relation to bacterial population and physico-chemical parameters are being investigated.

(v) Results of the field studies on the culture of *Artemia salina* have indicated a potential yield of 36 kg/ha of its cysts which is equivalent to a return of Rs. 3000/ha/yr.

2.4.3 Biogeography of the zooplankton of the Indian Ocean

Specimens of *Haloptilus sp.* (Copepoda) from 512 IIOE stations were examined. Systematic account and distribution of 12 species with the appropriate figures were completed and presented with a key to the identification of Indian species of the genus based on adult specimens. Of the 12 species recorded, 5 are new to Indian Ocean. These are *H. paralongicirrus, H. austini, H. bulliceps, H. fertilis* and *H. fons.* Most of the species are cosmopolitan in distribution. *H. longicornis* was the dominant species. Highest density of most of the species was noticed in the upwelling areas of the ocean.

The most dominant species of the genus, *H. longicornis* showed a more or less uniform distribution upto 30° S and maximum density between 5-10°N latitude. Maximum density of the species *H. spiniceps* and *H. ornatus* was noticed between 15-20°N. Even though *H. paralongicirrus* is distributed from 35°S-20°N, maximum number was observed between 5-10°S. *H. oxycephalus* and *H. mucronatus* showed preference to northern most latitudes between 15-20°N and 20-25°N respectively.

Contrary to this *H. acutifrons* showed preference to southern latitude between 25-30°S.

Data obtained on the occurrence of siphonostomes (Copepoda-Cyclopoida) were analysed and this little known group of copepods was studied. Siphonostomes which are rarely planktonic, are represented by 2 genera, *Ratania* and *Pontoeciella,* each is represented by one species in the Indian Ocean, *Ratania flava* and *Pontoeciella abyssicola.* These species are totally absent in the samples taken from the northern most areas of the Arabian Sea and are almost absent in the Bay of Bengal. Wherever recorded, these are represented by not more than 10 specimens per standard haul. *Pontoeciella abyssicola,* obtained from about 25% of samples examined and *Ratania flava* from only about 5% of the samples.

The species of copepod genera *Arietellus* and *Phyllopus* are bathypelagic and are very sparse in the IIOE collections. Out of 300 copepod samples analysed, *Phyllopus* was present at 25 stations and *Arietellus* at 14 stations. *Phyllopus helgae, P. muticus* and *P. bidentatus* are the three species indentified. Arietellidae was represented by *Aretellus setosus* and *Arietellus giesbrechti. Phyllopus* is distributed along the equatorial belt and *Arietellus giesbrechti. Phyllopus* is distributed along the equatorial belt and *Arietellus* in the southern Indian Ocean (south of 10°S).

The copepod *Corycaeus (Monolorycaeus) robustus* occurs in a small percentage in the IIOE samples, represented at a few stations mainly along the equatorial belt.

Comparative study on the zooplankton in the surrounding seas and the lagoons of Kavaratti, Agatti and Suheli atolls showed a most strikingly high abundance in the sea as compared to the lagoon, 72.5% in Agatti lagoon compared to the surrounding sea (14 times and twice as high respectively in the sea considering the biomass). It was 55 to 66% in Suheli lagoon. From the relative percentage of occurrence of the major groups at various areas it could be seen that the copepod constituted the dominant component except in Kavaratti lagoon where molluscs dominated.

While examining the zooplankton collected from the seas around Agatti Atoll of Lakshadweep, a species of *Acartia* hitherto undescribed was encountered. The new species *Acartia dweepi* could be ascribed to the sub-genus Acanthacartia. It showed close relationship with the species *A. fossae* and differed in the ornamentation of abdomen and in the structure of its fifth leg in males. The new species is named after Lakshadweep.

As compared to other copepod genera, harpacticoids were generally poorly represented, and when present, they were few in the IIOE collections. Only five species, *viz., Miracia efferata, Macrosetella gracilis, Microsetalla norvegica, Clyternnestra scutellata* and *Aegistus* sp. were seen in the samples. *Miracia efferata* were more abundant in the northern Indian Ocean and occurred in fairly large numbers along the west coast of India and in the tropical belt north of equator. It was also found along Java and Australian coasts and was totally absent in the north-eastern Indian Ocean. *Macrosetalla gracilis* showed almost the same trend of distributions as *Miracia efferata* but occurred in more collections. They were scantily represented along the African coast. *Clyternnestra scutellata* was widely distributed over the geographical area being more abundant between 90° and 115°E. *Microsetella norvegica* and *Aegisthus* sp. occurred only in a few samples. All these species showed slightly greater abundance during the day than at night.

Morphology and taxonomy of flatfish larvae belonging to 7 genera of Bothid family from Naga Expedition Collections were studied and these were compared with the IIOE material. An examination of flat-fish larvae from the Indian and Pacific Oceans revealed the occurrence of the same species in both the oceans. The access to the material (fish larvae) collected during Naga Expedition was helpful to link the life history stages of many species of flatfishes which were rarely represented in IIOE collections and to determine proper distinguishing characters for *Engyprosopon prethina, Crassorhombus, Grammatobothus, Asterorhombus* and *Bothus* belonging to the subfamily Bothinae.

2.4.4 Ecological, developmental and experimental studies on plankton

Ecological: Studies on ecological aspects of zooplankton of the Cochin Backwaters based on year round data have been completed. Factor analysis techniques have shown

salinity to be the major factor controlling zooplankton abundance. Abundance, being high during the high saline premonsoon period. Vertical migration of zooplankton showed a higher abundance at the bottom layers during the day time. During night the tendency was for part of the population to spread upward (near the surface). The presence of low salinity water at the surface inhibited the vertical migration of marine forms living in highly saline water. The average zooplankton production in the estuary was estimated as 31.8 mg dry weight/m^3/day.

An incidence of swarming of *Noctiluca miliaris* was noticed in August 1977 off Cochin. Detailed observations were made on the swarms which lasted for about a week. It preceded the monsoon diatom bloom and completely dominated the zooplankton samples. No deleterious effect on aquatic life were noticed as a result of this organism.

Studies were conducted at seven stations in Cochin backwaters on light penetration transparency, chlorophyll *a, b* and *c,* phaeophytin, particulate organic carbon, dissolved and particulate carbohydrate and detritus. Particulate organic matter including the detrital and living particulate matter was measured in view of their importance as a source of food to marine organisms at different trophic levels. These varied from the premonsoon (Feb-May) value of 0.9 gm/m^3 to the monsoon (June-Sept) 8.3 gm/m^3 in 1977. The inorganic portion of particulate detritus amounted to more than 72%. Carbohydrate in particulate organic matter found to be in the range of 0.26 to 0.72 mg/litre. Carbohydrate was found to be fluctuating between 51 to 636 µg/gm in sediments of Cochin backwaters, dissolved organic matter was found to be 2.8 to 24.2 mg/l. High degree of diurnal and seasonal variations were noted.

Organic carbon content in zooplankton samples collected during *Gaveshani* cruises VII, VIII and IX was analysed in order to calculate the quantity of calories available in the secondary trophic level. Carbon content varied considerably from 70% to 50% of dry weight of the zooplankton.

Sediment samples collected from the slope region of the Arabian Sea during IV, V and VI cruises of I.N.S. *Darshak* were analysed for pelagic foraminifera. Percentage of planktonic forms present in the samples studied varied from 78.6 to 98.2. It was observed that the lower continental slope sediments were richer in foraminifera than the upper slope sediments. Dissolution effect on forms was observed in the samples collected from the deeper regions of the Arabian Sea. Species which are resistant and susceptible to dissolution were also studied.

Twentyone grab sediment samples were collected from the lagoons of Kavaratti, Agatti and Suheli for the study of benthic foraminifera. Preliminary studies reveal the occurrence of the following dominant species:

(a) *Sorites marginalis* (Lamarck)
(b) *Amphistegina radiata* (Fichtel and Moll)
(c) *Peneroplis pertusus* (Forskal)
(d) *Planorbulina mediterranensis* (D' Orbigny)
(e) *Calcarina calcar* (D' Orbigny) and
(f) *Cymbaloppretta sqamosa* (D' Orbigny)

Developmental: Studies to prove the occurrence of resting eggs of copepods, a key factor in the repopulation of Cochin backwaters after the monsoonal wash out have produced some results. Lowering of salinity has shown to produce eggs that 'rest'. Although their viability for longer periods is yet to be conclusively established. This is a major break through in the ecological problems of tropical estuaries.

The closed sea-water circulating system developed in the laboratory, functioned well for rearing animals under laboratory conditions and making experimental studies on behaviour, breeding and life-history. Two species of amphipods *Quadrivisio bengalensis* and *Melita* sp. and an isopod, *Cirolana fluviatilis* collected from the Cochin backwaters were successfully reared. They took 3 to 4 months to complete their life-cycles. Once in four months about 60 animals (adults) of the above species could be removed from each rearing tank, which was almost the maximum capacity of each tank.

Experimental: Major biochemical constituents in some of the dominant benthic-estuarine forms were estimated and their caloric values calculated. The animals showed highest concentrations of the various biochemical constituents during the period of their maximum occurrence in the environment. The isopod *Cirolana fluviatilis* had the highest lipid content (64.8 %) and hence their caloric value was the highest (6764 cal/g).

Experiments were conducted on the changes in the physiological activities (respiration and excretion) and the biochemical composition in the isopod *Cirolana fluviatilis* under starvation. Upto the 6th day of starvation, there was a decline in oxygen consumption and excretion, but afterwards, the values were fluctuating. Among the bio-chemical constituents, protein was the first to be broken down, followed by lipid. The fluctuation in the values in advanced stages of starvation (up to 46 days) was probably due to the cannibalistic habit of the isopods.

Among phytoplankton *Tetraselmis, Monochrysis, Chlorella* and *Nitzschia* were isolated and their mass cultures were maintained and used for various studies. Different media involving nutrients, salinity, etc. were tested on these species.

2.5

ocean engineering

2.5.1 *Coastal engineering studies with reference to the development of rural areas along the Indian coast {Project No.* 901)

2.5.2 *Ocean engineering and marine technology development for the effective exploitation of living and non-living resources of the seas around India (Project No.* 902)

The Institute has entered into a new and important phase of its development during the year by starting a new Division called the Ocean Engineering Division. This was done in recognition of the fact that there is an urgent need in the country for the development of technological and engineering capabilities in the marine sector.

The main objectives of the Division are (a) to apply the knowledge and experience of the seas around India for the development of indigenous know-how and appropriate technology relevant to Indian conditions and to provide suitable solutions to various coastal and offshore engineering problems and (b) to assist the scientists in developing suitable ocean engineering systems and to expedite their data collection and analysis programmes.

The main activities carried out during the year are summarized as follows :

2.5.1 Coastal engineering studies with reference to the development of rural areas along the Indian coast

Preliminary data on waves, currents, tides, storms, bottom sediments, etc. were collected from certain coastal segments of Goa, Kerala, Madras and Andhra Pradesh using different sources.

Attempts were made to conduct feasibility studies for the development of salt pans along certain coastal waste-lands and swampy areas.

2.5.2 Ocean engineering and marine technology development for the effective exploitation of living and non-living resources of the seas around India

Ocean engineering and technology is an area of threshold technology for the country, which would find its application to various offshore engineering activities.

This project is aimed at developing indigenous technology and expertise for the exploration and exploitation of the ocean resources, harbour development, pollution control, coastal protection, etc., leading to the welfare of the people and improving their socio-economic conditions.

Efforts have been made to develop expertise and infrastructural facilities for carrying out studies in marine soil mechanics and foundation engineering problems associated with

design and construction of coastal structures, offshore platforms, offshore terminals, seabed anchors and submarine pipelines.

Available literature pertaining to wave and tidal power development was collected. Feasibility studies on wave and tidal power development at certain sites in India are in progress.

2.6

oceanographic instrumentation

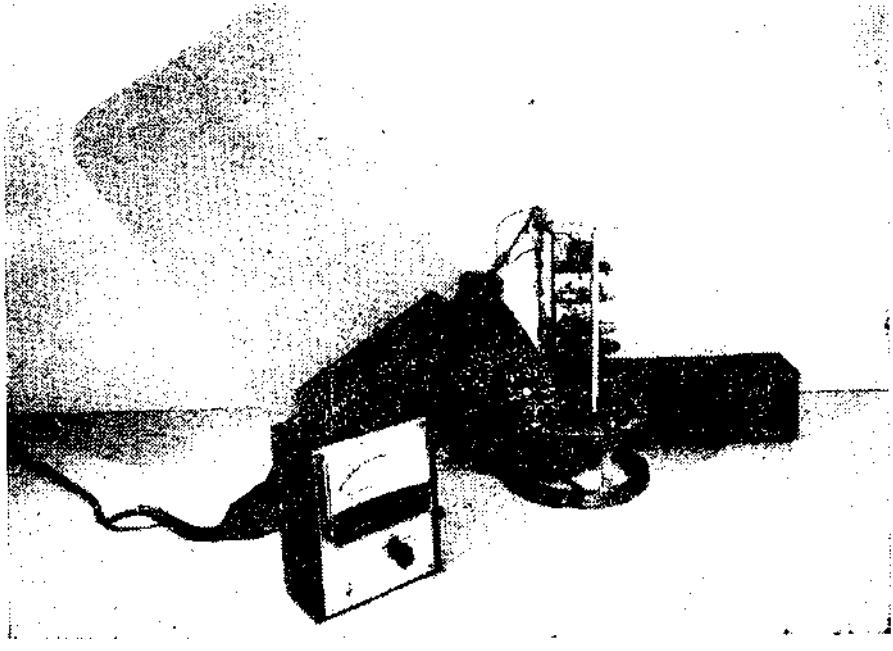
2.6.1 *Development of marine instrumentation systems (Project No.* 601)

2.6.2 *Development of calibrating and testing facility including service, maintenance and workshop (Project No.* 602)

Progress of the above two projects has been extremely good during the year under report and this can be summarised as follows:

2.6.1 Development of marine instrumentation systems

(a) Development of buoy telemetry system: Further improvements were made on the signal display system of the shore unit and in the existing multiplexer part of the system. Based on the sensors developed and the signal conditioning system perfected, a line tele-



Electro-magnetic current meter developed by the Institute.

metering system has been fabricated for transmitting about six parameters from nearby Dona Paula bay. The receiving station has also been developed for this purpose.

(b) Development of current meter: An electromagnetic current meter (Model No· CM-01) was fully developed and after field trials the model was calibrated in the tow-tank of Central Water and Power Research Station, Poona. All sub-units were fabricated in the Institute's workshop. Action has been initiated to fabricate five prototype models of the same.

(c) Development of salinometer: Regarding the development of Inductive Salinometer for the laboratory use, further studies on the behaviour of the inductive core with temperature proved that the NPL cores were not suitable for this particular purpose. Hence, electrode type conductivity cells were substituted in the design and the instrument is nearing completion.

(d) Development of sedimentation balance: An electronic sedimentation balance to weigh accurately and instantaneously the sediments settled at the bottom of a long settling tube has been developed. The information recorded on a strip chart recorder against time gives the total quantity of settled material which indirectly gives the properties of the material, namely, rate of settlement and size and quantity of particles. In the absence of such an equipment, the mesurement of the rate of settlement was found to be very tedious, time consuming and inaccurate. This sedimentation balance has solved several problems.

2.6.2 Development of calibration and testing facility including service, maintenance and workshop

During the year, calibration and testing facility were developed for the current meter. Four *in-situ* salinity temperature meters were fabricated. The design details of the B.T. calibration rig and calibration of wave rider buoys have been worked out.

The service and maintenance provided good support to various Divisions of the Institute during the year. They participated in almost all major sponsored projects. They had also maintained sophisticated geological and geophysical equipments such as Magnetometer, Side Scan Sonar, Sub-Bottom Profiler, etc., on board R.V. *Gaveshani.* In addition, instruments belonging to different Divisions of the Institute as well as from various outside organizations (public and private sectors) were serviced and repaired.

New facilities like glass blowing and electroplating were started in the workshop. The glass blower fabricated different items as per the requirements of the Institute. Anodising and dying of front panels and plates were attended to by electroplating group.

The workshop carried out various types of jobs as per the requirements of the Institute. These jobs included fabrication of wave energy oscillator, multiplexer for telemetering system, windwave for current meter and vibrocoder. During the year the workshop building was extended to provide extra space.

Drawing and photography groups were expanded and they were able to cope up with the increasing work load of the different Divisions of the Institute.

2.7

planning, publications, information and data

2.7.1 *Planning*

2.7.2 *Publications*

2.7.3 *Information*

2.7.4 *Acquisition, processing, evaluation and management of oceanographic data*

The different activities in the Planning and Data Division, namely, Planning, Publications, Information and Data were continued during the year and the account of the work undertaken is summarised as under:

2.7.1 Planning

Monitoring and evaluation of the R & D projects, initiated in previous year, were carried out. Periodical reports and project budget 1976-77 (RE) and 1977-78 (BE) were sent to the Planning Division of CSIR and a close liaison was maintained with the CSIR and with the Project Leaders. Project costing was also initiated.

Towards the end of the year, proposals for the 'Sixth Five Year Plan' of the Institute were formulated and sent to CSIR. These included recasting of the projects according to priorities and needs and a major thrust was given on work related to rural development and resources of the sea.

2.7.2 Publications

During the year, *Mahasagar* - Bulletin of the Institute completed its 10th year of publication. To improve the quality and standard of papers, an Editorial Board consisting of 10 leading scientists in the different disciplines of oceanography, was formed. All the papers received are refereed as a routine before accepting them for publication.

The following publications were brought out by the Division:

(i) *Mahasagar* - Bulletin of the National Institute of Oceanography. Vol. 9, Nos. 1 to 4.

(ii) Annual Report—1976.

(iii) Collected Reprints, Vol.3 of 1972.

(iv) Cruise Reports of R.V. *Gaveshani* (Cruise 14-27).

Volumes 4 and 5 of the Collected Reprints of the Institute have been compiled and these are ready for distribution.

Book binding facility: During this year, book binding facility has been started by this Division. Necessary equipment and staff are now available. In reprography services, a Gestetner Machine which can print double of the foolscap size has been added.

2.7.3 Information

During the year, numerous visiting parties from different parts of the country were shown the activities of the Institute. These included distinguished scientists and citizens of the country, research scholars, trainees from various institutions and colleges and school parties. The number of the students and parties visiting the Institute showed a sharp increase over the past years. Different types of mass media including newspapers, news bulletins, radio, etc. were used for the popularisation of oceanography and its relevance to the applied problems facing the country. A number of technical enquiries were also attended to in consultations with the concerned scientists.

Progress reports, monthly summaries and relevant information pertaining to various activities of the Institute were sent to CSIR from time to time.

Since the declaration of the Institute as 'IOC Depository Centre', the responsibility of cataloguing accessions and dissemination of information has increased considerably. A consolidated list of publications and documents is being prepared for circulation to all marine-based organisations in the country. Apart from the documents for Depository Centre, many selected publications from the Division of Marine Sciences of UNESCO and other agencies were also procurred for the Institute. Reprographic service as an aid to R & D work was continued.

Collected reprints; Volume 3 of the Collected Reprints of the Institute for the year 1971 was completed and Volume 4 (1972) was sent for binding. The compilation of Volumes 5, 6 and 7 (1973, 1974 and 1975) was taken up during the year.

Indian National Directory of Marine Scientists (INDMS): This Directory was published last year and during the current year it was updated as several new institutions have provided more informations for inclusion in the Direcetory.

Indian National Directory of Marine Research Projects (INDMRP). The information collected from marine based institutes in India, regarding research projects currently in operation, has been transferred to punch cards. The Directory so compiled consists of 200 projects pertaining to about 25 institutes in the country.

2.7.4 Acquisition, processing, evaluation and management of oceanographic data

All the physical, chemical, mechanical bathythermograph (MBT), X bathythermograph (XBT) data and geological/ geophysical data available at the World Data Centre 'A' and NODC Washington D.C. were procured on eight magnetic tapes.

The following jobs were carried out during the year for the processing and management of oceanographic data.

(1) Development of computer programmes

The following programmes for the Dec-10 system were developed for processing and computation of oceanographic data:

(i) ***STBLTY:*** This programme computes the stability of water masses using oceanographic tables. Input parameters are depth, temperature and salinity.

(ii) ***SUNVEL:*** This programme developed in 1976, was modified, corrected and checked during this year. It computes sound velocity using Wilson's Formulae.

The following programmes were developed and preserved on magnetic cards for the DCM 1101 Micro System:

		Programme No.
(i)	Computation of sound velocity using Wilson's Formulae	7.01
(ii)	Computation of raw estimate spectral density from the values of auto-correlation coefficient .	7.04
(iii)	Computation of auto-correlation	7.03
(iv)	Computation of cosine and sine coefficients of Fourier series	7.06
(v)	Computation of multiple regression coefficients	1.05
(vi)	Computation of statistical parameters of grain size data using graphic method	5.06
(vii)	Computation of salinity from pressure, conductivity and temperature	6.01
(viii)	Computation of salinity from conductivity and temperature	6.02
(ix)	Computation of linear regression coefficients	2.01
(x)	Computation of tidal height .	7.09

In addition, the following programmes were developed and tested by Geological Oceanography Division for the analysis and interpretation of marine magnetic data:

(i) ***MAGANOM:*** This programme computes the magnetic anomalies using the subroutine for the computation of international geophysical reference field (IGRF) using spherical coordinate system. This programme is exclusively written for the data when the navigation fixes during the collection of the data were done at discrete intervals.

(ii) ***SEAMAG:*** This programme also computes magnetic anomalies using sub-routine IGRF when the navigation data is given for each point of magnetic data which can normally be obtained when there is continuous data logging system on board the ship.

(iii) ***MAGDEPTH:*** This programme was developed to compute the depth to the basement layer from the magnetic anomalies using maximum entropy and the predictive error filters.

(iv) ***ANSIG:*** This programme computes the depth to the basement layer, using the property of analytical signal. In this programme the depths are computed only at the corners of the two dimensional bodies that are assumed as models to fit the observed magnetic anomalies.

In addition to the above main programmes, the following subroutines were also developed and tested for the analysis and interpretation of marine magnetic data :

(i) ***RFFT & RFFTI:*** These programmes are used for the Fourier transformation and their inverse transformation of time series data.

(ii) ***HILBERT:*** This programme computes the HILBERT transformation for the given time series data.

(iii) ***INTERPO:*** This programme interpolates the data at equal distances.

(iv) ***BANDPARSS:*** This programme is used for filtering out either low frequency components or high frequency components in the frequency domain as desired for the analysis of the data.

(v) ***WINDOW:*** This programme is used for smoothening the given data in time or space domain.

(2) Processing of fish catch data

Fish catch data from the Exploratory Fisheries Project, Bombay were processed on the computer and a variety of listings were prepared as per their requirements.

(3) MONEX data

MONEX data consisting of physical, chemical and meteorological parameters collected by USSR during 1973 was received and transferred to 40,000 punch cards for storage and further use.

(4) Processing of pollution data

Various oceanographic and hydrographic data collected off Bombay in connection with the project sponsored by Bombay Municipal Corporation for studies on pollution and water quality were processed and transferred on to punch cards. Computation for the average, minimum and maximum was carried out on DCM-Micro System 1101 for the different parameters. Computer listings ware provided as per the requirements.

(5) Computation of stabilities for the Indian Ocean water masses

At the request of POD, a computer programme was developed for the computation of stabilities for the ocean and print outs were taken on 625 pages.

(6) Processing of primary productivity data

A special format suiting the specific requirements of the scientists was developed and the available data were transferred on to the punch cards and computer listings were produced.

(7) Computation and processing of STD data for sound velocity

Computation of sound velocity from digitized STD data for 78 stations covered during oceanographic cruises of INS *Darshak* was carried out on DCM-Micro System 1101 and the data were transferred on to the punch cards and several sets of listings were produced.

(8) ROSCOP (Report of observations / samples collected by oceanographic programmes)

As our contribution to the International Oceanographic Data Exchange (IODE) of the Intergovernmental Oceanographic Commission, the inventory of the cruises of RV *Gaveshani* on ROSCOP forms were completed.

(9) INODC Newsletter

This year it was decided to issue an INODC Newsletter which would contain the observations/samples collected under oceanographic programme (ROSCOP) and cruise tracks of RV *Gaveshani* covered during the year. The first yearly Newsletter was completed and issued.

(10) INODC Catalogue

The work related to preparation of INODC catalogue for physical and chemical data is under progress while the catalogues for biologicaldata have been completed.

(11) Onboard data processing

The staff of the Data Centre participated in several cruises of RV *Gaveshani* and developed programmes for conversion of coordinates from UTM to Shoran, geographical to UTM and vice-versa and for applying tidal correction to the measured echo-sounding depth for on-the-spot processing of data.

2.8

interdisciplinary task forces

2.8.1 *Protection of marine environment and monitoring of pollutants (Project* No.101)

1. Marine environmental monitoring along the Goa coast
2. Marine environmental monitoring along the Bombay coast
3. Marine environmental monitoring in the waters off Cochin

2.8.2 *Oceanography of the waters around Lakshadweep (Project No.*102)

2.8.1 Protection of marine environment and monitoring of pollutants

During the year environmental studies were carried out at three different Centres of the Institute, namely, Goa, Bombay and Cochin. The details are as follows:

1. Marine environmental monitoring along the Goa coast

Periodical monitoring of water quality in the Velsao Bay was carried out with a view to keep a watch on the effect of the effluents discharged from the Zuari Agro-Chemicals Ltd., through the submarine pipeline.

As a part of oil pollution studies, tests were conducted for four indigenously manufactured chemical dispersants to examine their suitability for removal of spilled, oil and their effects on marine biota. Results indicated that their efficiencies in the removal of oil vary between 85% and 99% of the spilled oil. Toxicity tests using the green mussel, *Mytilus viridis,* the mole crab, *Emerita holthuisi* and the prawn, *Macrobrachium idella* indicated that the dispersant having maximum efficiency is least toxic while the least efficient one was the most toxic. The other two dispersants also showed toxic effects.

Two brands of indigenously manufactured polyurethene foams were also tested for their capacity in removing spilled oil. One of them removed 99.94% of its own weight of oil while the capacity of the other was 72%. Repeated use of both the foams decreased their efficiency.

Monitoring of dissolved petroleum hydrocarbons in the upper 10 m of the Arabain Sea was initiated. It was observed that their ambient concentrations in the Arabian Sea are higher than the other oceanic areas probably because 58% of the world's transport of petroleum and Its products are taken from the Gulf countries across the Arabian Sea to Far East, Japan and western countries.

Examination of Petroleum hydrocarbons in sediments indicated that their peaks were at wavelengths different from those of pure hydrocarbon. This maybe because of degradation of oil in sediments.

Data on the concentration of oil in water were used as part of the Indian programme for MAPMOPP of IGOSS.

A project for monthly monitoring of 40 parameters at 9 stations in the rivers Zuari and Mandovi and at 3 stations along the coastal stratch between Baga and Colva has been initiated from October 1977.

Two cruises with the objectives to study 'Health of the Arabian Sea' and 'Health of the Bay of Bengal' were conducted during March and September-October respectively. Samples of water, organisms and sediments have been collected and analysed for petroleum hydrocarbons, chlorinated pesticides and some toxic and non-toxic heavy metals and metalloids, *e.g.* Hg, Pb, Fe, Cu, Zn, Ni, Co, Mn and As. Chlorinated pesticides in water could not be estimated due to practical difficulties. However, several zooplankton samples, collected by surface hauls in the Arabian Sea, indicated values varying from 0.05 to 3.21 ppm (wet weight) expressed as *t*-DDT. These concentrations were somewhat higher than the accepted limits and will have to be carefully watched.

The integrated consumption of pesticides in India from 1970-1976 is about 2,40,000 tonnes. it is normally assumed that about 25% of this reaches the sea-DDT has been banned in many countries of the world but not in India. High concentration of pesticides in the sea might be the cause of their high concentration in zooplankton samples taken from the Arabain Sea. Mercury concentrations in water at the surface layer of the Arabian Sea ranged from 13 to 123 mg/litre. It recorded an increase upto about 500 m depth beyond which it tended to decrease. Concentrations of Cu, Co, Fe and Zn in water, particulate matter and zooplankton were also determined.

2. Marine environmental monitoring along the Bombay coast

The effect of pollutants on certain organisms was studied in the area which is known to be polluted by domestic and industrial waste.

Plankton biomass and bacterial population in polluted and non-polluted waters of Bombay were also studied. This study will form a baseline data (background) for the estimation of pollution and its effect on living resources.

3. Marine environmental monitoring in the waters of Cochin

(i) *Pollution in backwaters :* Monitoring studies were carried out during the year in the northern part of Cochin backwaters with special reference to the effluent discharge from the chain of industrial establishments located on the banks of the Periyar river and which join the northern limb of the estuary. Four observations were covered in the stretch with monthly sampling at Kalamassery, Eloor, Elamakkara and Barmouth. The first station which is located upstream of the Industrial Complex served as the control station. This station and the one at Eloor had fresh water regime throughout the year while the last two stations were subjected to seasonal variations in salinity and associated brackish water characteristics of the estuary.

The environmental parameters showed a seasonal cycle. An increase in the pollutant load was noticed during the premonsoon. The COD values at the industrial

complex area (Eloor) varied considerably in different seasons. A more or less similar variation in COD was noticed at the other two estuarine stations. The control station up Eloor also showed little variation in COD. At all the stations, except Eloor, suspended solids were high during the monsoon. During the pre-monsoon an accumulation of dark coloured sediments with **a** strong sulphide smell was noticed in this area though this material was washed away during the monsoon. Oil patches and foam were common in this area and could be seen floating along a stretch of several kilometres down stream. Floating dead fishes were also occasionally noticed. The stretch of backwaters of about 2-3 km down stream from the Eloor observation station was found to be devoid of bottom fauna. It is inferred that the cumulative effect of the variety of effluents from the different types of factories emptying in the Eloor stretch of the backwaters have rendered the area totally devoid of aquatic life.

Major biochemical components of four species of molluscs, *viz., Meretrix sp.* and *Vellorita cyprinoides* form the estuarine stations and *Lamelliden marginalis* and *Batissa* sp. from the control station were estimated. These were found to contain normal amounts of proteins and lipids. Seasonal variations in these components were also quite normal. Analysis of trace elements in sediments, water and shell fish is in progress.

Pollution monitoring studies have been extended to the other major backwater systems of the Kerala coast.

(ii) *Beach pollution :* As part of the environmental monitoring programme a study of pollution of beaches of Kerala with faecal matter was undertaken. Beaches at Cherai and Fort Cochin were investigated and faecal pollution was maximum at Cherai practically throughout the year. Counts of the 'indicator bacteria' like *E. coli* and *Streptococcus faecalis* occuring in the beach sand and seawater were also made.

Beach pollution studies were extended during the year to the entire Kerala coast with observation stations at Vizinjam, Kovalam, Shankumugham, Quilon, Neendakara and Alleppey beaches south of Cochin and Calicut, West Hill, Kapad, Mopla Bay and Payyambalam (Cannanore) beaches north of Cochin. Monthly samples of sand and water from three transects along each beach were collected and the 'indicator bacteria' occurring in these samples were recorded. Other environmental parameters such as temperature, pH, dissolved oxygen, salinity, H_2S, organic carbon etc. are also being studied. From this study it will be possible to assess the extent of beach pollution along the entire Kerala coast.

(iii) *Oil pollution :* Collection of samples from Trivandrum, Cochin and Calicut beaches of Kerala were undertaken according to the procedure adopted under IGOSS programme. During May, July, August and November tar deposits were observed on Cherai beach, but the quantity was low this year.

2.8.2 Oceanography of the waters around Lakshadweep

Major contribution to the biomass *of* sandy beaches at Kavaratti, Agatti and Suheli beaches is from the bivalve *Mesodesma glabratum.* Other animals

which contribute to the biomass are polychaetes, *viz., Glycera* sp., *Scoloplos* sp., *Sipunculids* and an unidentified burrowing holothurian. A similar pattern of distribution occurs at all the three islands. *M. glabratum* is recruited to the beach at Kavaratti just prior to south-west monsoon.

The destructive star fish *Acanthaster* sp. was seen in the sea surrounding Bangaram Island and at several atolls large patches of destroyed corals were seen. This year for the first time *Acanthaster sp.* has been reported from Lakshadweep Sea.

Another study undertaken during the year was to investigate the zonation in molluscan species at Kavaratti Atoll. For this purpose four major biomorphological zones have been selected. These are: (1) sandy beach, (2) lagoon floor, (3) intertidal rocky shore and (4) inner reef platform. Species diversity of molluscs has been found to be greatest in the intertidal rocky shore. About 45 molluscan species were found in the intertidal rocky shore, 28 in the inner reef platform and 19 in the lagoon floor.

2.9

sponsored projects

2.9. 1 *Studies on the beach stability and nearshore environment at Sinquerim (Goa)*

2.9.2 *Oceanographic studies off Mangalore coast*

2.9.3 *Hydrographic survey off Karwar*

2.9.4 *Temperature and current measurements in the Bombay High area*

2.9.5 *Waste water disposal and submarine outfall studies in marine environment around Bombay*

2.9.6 *Environmental studies in relation to beach erosion at Thumba*

2.9.7 *Survey of submarine pipeline route from Bombay High to Bombay (Phase II)*

2.9.8 *Shallow seismic survey of the south Bombay High*

2.9.9 *Survey of submarine pipeline route from Bombay High to Bombay (Phase III)*

2.9.10 *Soil sampling and testing including study on stability of pipeline from Bombay to Bombay High*

2.9.11 *Survey of submarine pipeline route from Bombay Floating Light, Karanja and Butcher Islands to Trombay*

2.9.12 *Side scan sonar survey for ZAC's effluent pipeline in the Cola Bay, Goa*

2.9.13 *Oceanographic studies for Alkali and Chemicals Corporation of India at Ennore, Madras.*

2.9.14 *Oceanographic survey for effluent disposal and submarine pipeline route for the Travancore Titanium Products Ltd., Trivandrum*

2.9.15 *Pollution control master plan for Kolak and Damanganga river basins (Phase I and II)*

2.9.16 *Hydrographic and pollution survey of the, river Par*

2.9.17 *Seaweed resources of the Maharashtra*

2.9.18 *Pharmacologically active components from marine sediments*

2..9.19 *Sorting of zooplanktons amples*

2.9.20 *Consultancy services*

2.9-1 Studies on beach stability and nearshore environment at Sinquerim (Goa)

This project was undertaken for M/s India Resort Hotels Ltd., Bombay in connection with the construction of a beach resort hotel near Sinquerim. The final report was submitted to the sponsoring agency.

2.9.2 Oceanographic studies off Mangalore coast

This project, sponsored by the Mangalore Chemicals and Fertilizers Ltd., was completed and a report recommending a suitable point for the discharge of treated effluents from the Mangalore Chemicals and Fertilizers Factory was submitted to the sponsors.

2.9.3 Hydrographic Survey off Karwar

The project sponsored by Ballarpur Industries Ltd. was undertaken to locate a suitable point for the release of treated effluents from the caustic soda factory. The report recommending the discharge point was submitted to the sponsoring agency.

2.9.4 Temperature and current measurements in the Bombay High area

The project was sponsored by the ONGC with a view to determine bottom and surface temperature and currents along the route from Bombay High to Bombay and also at other drilling sites. Crude oil from this region is believed to freeze at temperatures below 19°C and the studies were undertaken to ascertain whether at any location the temperature reaches at such a critical point. Observations have indicated that temperature during November tends to reach almost 20.5°C but is still higher than the critical level.

2.9.5 Waste water disposal and submarine outfall studies in marine environment around Bombay

The project sponsored by Metcalf & Eddy and Environmental Engineering Consultants (consultants to the Bombay Municipal Corporation) has been completed and a detailed report has been finalised. Extensive hydrographic, bathymetric and water quality studies were carried out for a period of 18 months to study the pollution load of receiving waters and to determine the criteria for the treatment and mode of disposal of collected sewage of Bombay City. The findings indicate that there is a need for proper treatment of combined industrial effluent and domestic sewage, and the disposal of the treated effluents should be at a point 3 km away from the Bombay coast so as to achieve maximum dilution and dispersion.

2.9.6 Environmental studies in relation to beach erosion at Thumba

At the request of the Thumba Equatorial Rocket Launching Station (TERLS) of the Vikram Sarabhai Space Centre, Trivandrum, a detailed study on the coastal environmental conditions was carried out with special reference to beach erosion at Thumba. The final report was prepared highlighting (i) seasonal observations of the coastal environment causing changes in the beach profile, (ii) analysis of the data with a view to identify the dominant factors causing beach erosion at Tumba and (iii) design of suitable measures to protect the coastal installations. The suggested measures are being implemented.

2.9.7 Survey of submarine pipeline route from Bombay High to Bombay (Phase II)

In continuation of the work initiated last year, additional surveys along the submarine pipeline route from Bombay High to Bombay Floating Light (BFL) were carried out using R.V. *Gaveshani.* The surveys included echosounding (830 line km), side scan

sonar (670 line km) and shallow seismic (400 line km) followed by bottom sampling. Surface sediment samples were collected from selected sites and bulk samples of fluorescent tracer were released in the area to determine the possible movement of the sediments. Shorain was used for position fixing.

The proposed pipeline route from Bombay Floating Light up to a depth of 57-65 mlies in an area of even topography and gentle gradients (1:7000 to 1:000) with a clay cover and laying the pipeline in this area may not be a problem. The area west of the prominent NNW-SS ridge may offer some problems because of the comparatively steep gradients (1:4500 to 1:200 and locally 1:200 to 1:20), uneven topography, sand waves and sandy strata and patchy clay distribution.

2.9.8 Shallow seismic survey of the south Bombay High

A survey of the South Bombay High of the Platform-A was carried out during January-February, 1977 using R.V. *Gaveshani*. About 1029 line km of echosounding and shallow seismic surveys were carried out on E.W. lines. Shoran was used for position fixing. Bathymetric and shallow seismic data were required by the ONGC for designing the production platforms in the area.

The area is charcterised by uneven and rugged topography and topographic variations of the order of 2-5 m are common while occasional rises and falls of about 10 m are also recorded. The topographic features have generally a NNE-SSW trend. Subbottom profiles indicate a penetration of the order of 35-40 m. The seabed in the northern part of the area has a clay cover (5-10 m) which becomes thinner towards the west and towards the south. These sediments are underlain by sand which has two prominent reflectors between 10-20 m and 25-30 m. This probably indicate lithified sands or limestones.

2.9.9 Survey of submarine pipeline route from Bombay High to Bombay (Phase III)

The survey of final route from Bombay High to Bombay was completed and a suitable route was proposed from Bassein to Hazira and Tarapur at the request of the ONGC. The study includes bathymetry, coring, snapper sampling, side scan sonar and shallow seismic survey.

2.9.10 Soil sampling and testing including study on stability of pipeline from Bombay to Bombay High

Geotechnical data obtained from the seabed samples collected by R.V. *Gaveshani* were analysed and the stability and settlement characteristics of the proposed oil and gas pipeline to be laid from Bombay High to Bombay were evaluated. The final report was submitted to ONGC.

2.9.11 Survey of submarine pipeline route from Bombay Floating Light to Karanja and Butcher Islands to Trombay.

A survey of submarine pipeline routes from Bombay Floating Light to Karanja and Butcher Island to Trombay was carried out on board FV *Kalindi* during November-December, 1976. The surveys included about 260 line km of echosounding, side scan sonar and shallow seismics (boomer) surveys on different lines (about 250 m apart) followed by bottom sampling. Positions were fixed using sextant angles of shore objects.

Along the route from Butcher Island to Trombay the maximum depth is 4 m and the gradients vary from 1:750 - l:400 in the channel to 1:50 in the nearshore regions. Near the Butcher Island the seabed is uneven due to rock outcrops, but the other parts of the routes show an even topography. Acoustically transparent clays (3-4 m) are found over the uneven bed rock at the shore-end and the thickness of the clays increase to 9 m in the channel.

Between Butcher Island and Karanja Island the depth varies from about 6 m at the Butcher Island end (1:70 to 1:50) to 13 m in the shipping channel (1:750 - l:250) and gradually decreases to about 3 m near Karanja Island (1:3000 - 1:1000). The topography is smooth in the channel but uneven near Butcher Island and from the shipping channel towards Karanja Island. The sediments are about 16 m thick in the vicinity of the channel but their thickness decreases towards Butcher Island. Extensive rock outcrops occur beyond the channel towards Karanja Island. The sediments in the region are thin and occur in patches.

From Bombay Floating Light to Karanja Island, the depths vary from about 2 m in the nearshore area (1:3000 to 1:5000) to 6-10 m over the Thal Shoal (1:750 - l:600) and locally (1:125 to 1:50) and about 12 m in the vicinity of Bombay Floating Light (1:3000 to 1:5500). The area shows a smooth topography except at the nearshore area and the Thal Shoal which show an uneven topography due to rock outcrops. The thickness of the sediments decreases from 7 m near the shore to about 2-3 m over the scarps and then increases gradually midway towards Thal Shoal and abruptly to 7 m over scarps. The sediments then decrease in thickness till the Thal Shoal, where rock outcrops become predominent. Beyond the Thal Shoal the sediment thickness increases from 3 to 5 m (near the Thal Shoal) to about 12 m at offshore end of the lines surveyed.

2.9.12 Side scan sonar survey for ZACs effluent pipeline in the Cola Bay, Goa

The surveys revealed that about 600 m pipeline near the shore end is exposed (has come out of the seabed). Beyond this the pipeline is covered with sediments till the discharge point. Surveys carried out in October-December 1976 showed that about 200 m of pipeline at the discharge end was exposed. Of this, about 120 m was spanned but after repairs in April 1977 only about 120 m remained out of the seabed but it was no longer spanned. The final report was submitted according to the terms of reference.

2.9.13 Oceanographic studies for Alkali and Chemicals Corporation of India at Ennore, Madras

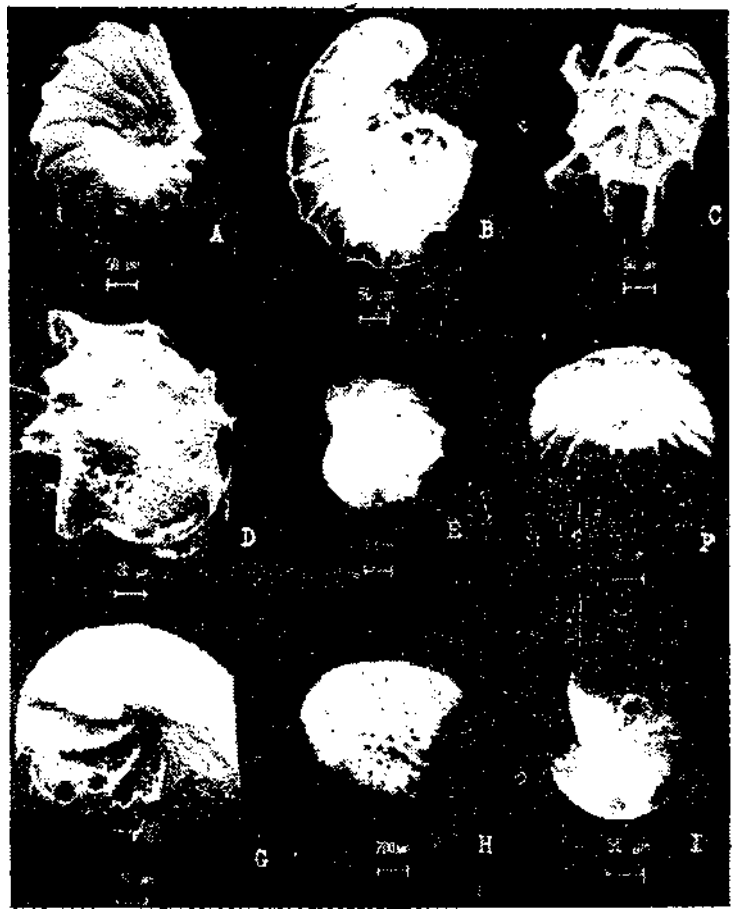
Water quality and hydrographic parameters were studied in the Bay of Bengal near Madras Port off Ennore with a view to determining the background levels of existing water quality and to suggest a suitable mode of disposal of effluents from a chemical plant to be set up at Ennore by the above mentioned firm. The quality and quantity of effluents were considered before proposing the mode of disposal through a submarine pipeline at a safe point located in the sea at a distance of one kilometre fro m the coast.

2.9.14 Oceanographic survey for effluent disposal and submarine pipeline route for the Travancore Titanium Products Ltd., Trivandrum

At the request of M/s Travancore Titanium Products Ltd., the sponsors of this project, an oceanographic survey was carried out in the area between the coastline and

50 m contour line off Trivandrum to suggest a suitable point for the safe discharge of factory effluent. A variety of data on the physical, chemical and biological aspects were collected from the area. Observations were made on the beach profile, bathymetry of the area, littoral current, tides, temperature of the effluent and nearshore water, salinity and coastal currents using current meters and plastic drifters. Coastal samples were also collected at the breaker zone where the effluent mixes with sea water. Besides this, the surface and bottom samples were collected for the estimation of total solids, salinity, pH, acidity, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and the total ionic content.

Biological samplings were conducted at monthly intervals on the beach fauna, benthos and plankton from four sectors from and around the discharge point. Investi-



Corrosive effect on the surface of the calcium carbonate foraminiferal tests by the acid waste discharges from T.T.P.

gations were also made to see the effect of effluents on foraminifera. A detailed survey has shown the occurrence of 85 species of foraminifera belonging to 44 genera and 26 families. Due to the discharge of acid wastes along the coast, surface of tests (shells) of foraminifera were found corroded at the outfall.

The interim report on the study, incorporating recommendations, was submitted to sponsors.

2.9.15 Pollution control master plan for Kolak and Damanganga river basins (Phase I&II)

This project was sponsored by the Cential Board for Prevention and Control of Water Pollution, New Delhi. As desired by the sponsors, a detailed survey was undertaken in the rivers Kolak and Damanganga which receive effluent from a large industrial estate setup by the Gujarat Industrial Development Corporation at Vapi. According to the findings of the survey, the estuarine part of the river Kolak is severely affected by the effluents. The oxygen levels were observed below the minimum permissible limits at several locations in the estuary.

Both the rivers appear to be severely polluted and for this recommendations towards proper treatment of the industrial effluent has been included in the report submitted to the sponsoring agency.

2.9.16 Hydrographic and pollution survey of the river Par

M/s Atul Products Limited, Valsad, release about 22,000 kilolitres of effluents into the estuarine region of the river Par. This project was undertaken at their request to evaluate the existing state of receiving waters and the extent of treatment required for the effluent so that it can be discharged into the river. The surveys were conducted during pre-monsoon period when the environmental conditions in the river were in their most severe form. In the report submitted to the sponsors it has been suggested to take steps for immediate neutralisation of the acid content and aeration to increase the dissolved oxygen content of the industrial effluents before its discharge into the Par estuary.

2.9.17 Seaweed resources of Maharashtra

This sponsored project was undertaken at the request of Science and Technology Cell of the Government of Maharashtra. The work on the assessment of seaweed resources has started and it is being continued.

2.9.18 Pharmacologically active components from marine sediments

This project was sponsored by Hoescht Pharmaceuticals Ltd., Bombay and the work which was initiated in June 1977 is in progress.

2.9.19 Sorting of zooplankton samples

The Institute has agreed to do sorting of zooplankton samples received from CSIRO Australia. The NIO Regional Centre, Cochin has already processed several batches of zooplankton samples (10 samples in each batch).

2.9.20 Consultancy services

1. *Development of a Dolphinarium and marine land complex at Visakhapatnam, Andhra Pradesh:* This project sponsored by the Forest Department, Andhra Pradesh, was completed and a feasibility report was submitted to the sponsoring agency.

2· *Development of a marine park in Pirotan and Deda islands in the Gulf of Kutch:* The project sponsored by the World Wild Life Fund was undertaken to suggest the development of marine parks in the Gulf of Kutch. Field observations were completed and the data are being processed and analysed.

3. *Control of beach erosion in Diu:* A preliminary investigation was conducted along the eroding coasts of Diu at the request of the Government of Goa, Daman and Diu and a proposal was submitted detailing the various studies required to suggest suitable remedial measures for protecting the coast.

4· *Control of beach erosion in Tamil Nadu:* At the request of the Government of Tamil Nadu, coastal erosion problems in North Madras area were studied and a suitable proposal was submitted indicating the scope and objectives of the study to be undertaken for suggesting appropriate remedial measures.

5· *Marine pollution control:* Consultancy services on marine pollution were extended to industrial and Government agencies. Free services were given to Universities and Government agencies on special requests for the analysis of water and the analysis of metals in water, effluents and marine fauna and flora.

2.10

international projects

1. *United Nations Environment Programme (UNEP)*
2. *Integrated Global Ocean Stations System (IGOSS)*

1. United Nations Environment Programme (UNEP)

Work was continued on the first phase of the project, entitled, "Marine Environmental Monitoring and Marine Living Resources Assessment Programme for the Indian Ocean Region" on a contract from United Nations Environment Programme (UNEP).

Follow up action to the report on the Survey of institutional Capabilities was initiated and all concerned institutions were approached for the preparation of a Directory of Marine and Environmental Research Centres in the Indian Ocean Region. Information from 78 Institutions of 14 countries, namely, Bangladesh, Brunei, Burma, India, Indonesia, Malagassy Republic, Malaysia. Mauritius, Pakistan, Philippines, Seychelles, Singapore, Sri Lanka and Thailand has been received. Moreover, attempts are being made to get information about the institutions in Viet Nam and Democratic Kampuchea (Cambodia) through the UNEP Regional Office in Bangkok.

The Directory is under preparation.

2. Integrated Global Ocean Station System (IGOSS)

Work on the Indian participation in Marine Pollution (Petroleum) Monitoring Pilot Project (MAPMOPP) of IGOSS was continued.

Observations were carried out systematically from R.V. *Gaveshani*, during all its cruises in the Ababian Sea and Bay of Bengal, for oil slicks and other floating pollutants. Besides, water samples were collected from the surbace and from 10 m depth for the analysis of dissolved petroleum hydrocarbon. A neuston net was also towed every day for 15 minutes while the ship steamed at 1 knot. The samples were, examined for tar particles and other floating material.

The report is under preparation and will be submitted to the IOC Working Committee for IGOSS and NODCs of USA, Japan and India.

3

administrative set-up

3.1. Cruise Planning and Programme Priorities Committee for R V. Gaveshani

1. Dr. A. Ramachandran Secretary, Dept. of Science and Technology and DGSIR, New Delhi.	Chairman
2. Dr. C.R.V. Raman Project Director, Monex Indian Meteorological Dept., Lodhi Road, New Delhi.	Representing IMD
3. Dr. K. V. Sundararaman Naval Physical & Oceanographic Laboratory Naval Base, Cochin.	Representing NPOL
4. Cdr. V. S. Saptharishi Naval Hydrographic Office, Dehra Dun.	Representing NHO
5. Cdr. Narindra Singh Director (O), Dept. of Science & Technology New Mehrauli Road, New Delhi.	Member representing DST
6. Cdr. V. Ravindranath Coast Guard Cell, Ministry of Defence. New Delhi.1.	Special Invitee representing Coast Guard
7. Mr. K. N. Johry Head, ISC, CSIR, New Delhi.	Special Invitee representing CSIR
8. Cdr. M. M. Kaul Manager, Delhi Branch Shipping Corporation of India Ltd., Chanderlok Building, First Floor 36, Janpath, New Delhi.	Representing SCI
9. Dr. R. P. Rao Oil & Natural Gas Commission, Dehra Dun.	Representing ONGC
10. Dr. R. N. Sinha Institute of Petroleum Exploration Dehra Dun.	Representing IPE, Dehra Dun
11. Dr. K. L. Kaila Project Co-ordinator, DSS Project NGRI, Hyderabad.	Special Invitee representing NGRI

12. Dr. K. Venkoba Rao Director, GSI, Calcutta.	Member representing GSI
13. Mr. P. C. Shrivastava GSI OME & M G Division, Calcutta.	Representing GSI
14. Dr. A. Daniel Deputy Director, Marine Biological Station Zoological Survey of India 69, Santhome High Road, Madras.	Special Invitee representing ZSI
15. Mr. I. C. Jain Law Officer, Legal & Treaties Division Ministry of External Affairs, New Delhi	Representing MEA
16. Commodore I. K. Puri, Adviser, NIO/CSIR, New Delhi.	Member representing NIO
17. Dr. S. Z. Qasim Director, NIO, Goa	Member Convenor

Professor D. Lal, Physical Research Laboratory, Ahmedabad and Dr. A.K. Ganguly, BARC, Bombay, regretted their inability to attend the meeting.

3.2 Executive Committee

1. Dr. S. Z. Qasim
   Director
   National Institute of
   Oceanography
   Dona Paula (Goa).
2. Shri K. R. Ramnath
   Chairman & Managing Director
   Hindustan Shipyard
   Visakhapatnam (A. P).
3. Dr. A. K. Ganguly
   Director (Chemical Group)
   Bhabha Atomic Research Centre
   Trombay, Bombay.
4. Shri V.L.N. Sastry
   Chief Geophysicist
   Oil & Natural Gas Commission
   12th Floor, Express Tower
   Nariman Point, Bombay.
5. Dr. J. S. Sastry
   Scientist 'E'
   National Institute of
   Oceanography
   Dona Paula (Goa).
6. Dr. P. E. Sankaranarayanan
   Head, Instrumentation Division
   National Institute of
   Oceanography
   Dona Paula (Goa).
7. Shri T. C. S. Rao
   Scientist-in-charge
   Regional Centre of NIO
   Andhra University Campus
   Waltair (A.P.).
8. Administrative Officer
   National Institute of
   Oceanography
   Dona Paula (Goa).
9. Finance & Accounts Officer
   National Institute of
   Oceanography
   Dona Paula (Goa).

Invitee to the Executive Committee Meeting

Director General, SIR or his nominee and Chairman, CSIR Coordination Council of Physical and Earth Sciences.

3.3 Scientific Advisory Committee

1. Dr.S.Z.Qasim
   Director
   National institute of Oceanography
   Dona Paula (Goa).
2. Director
   Industries & Mines, Government of Goa, Daman & Diu, Panaji (Goa).
3. Shri R. L. Chowgule
   Director
   M/s Chowgule & Co.
   Vasco-da-Gama (Goa)·
4. Dr. G. S. Sharma
   Professor of Physical Oceanography
   Cochin.
5. Shri S. D. Soman
   Head, Health Physics Division
   Bhabha Atomic Research Centre
   Trombay, Bombay.
6. Dr. K. Venkoba Rao
   Head, Marine Geology Group
   Geological Survey of India
   Calcutta.

3 4 Budget

The Budget of the Institute for the year 1976-77 was as follows:

	Budge	(Rs.	in	Actual lakhs)	
			Non-Plan	Plan	Total
1.	Recurring	41.039	61.518		102.557
2.	Capital	1.631		66.315	67.946
	Total	42.670	127.833		170.503

3.5 Scientific and Technical Staff

Director

Dr. S. Z. Qasim

A. Divisions at the Headquarters

1. Physical Oceanography Division

Head of the Division

Dr. V. V. R. Varadachari
(Deputy Director)

Scientists

Dr. J. S. Sastry
Shri L. V. Gangadhara Rao
Shri C. S. Murty
Dr R. Mahadevan
Shri P. K. Das
Shri M. J. Varkey
Dr. P. G. Kurup
Shri C. K. Gopinathan

Senior Scientific Assistants

Shri K. K. Varma
Shri P. S. Joseph (on deputation to Japan)
Shri V. Ramcsh Babu
Shri V. Kesava Das
Shri A. F. Anto
Shri Albert D. Gouveia

Junior Scientific Assistants

Shri P. V. Sathe
Shri D. V. Rama Raju
Shri Y. K. Somayajulu

2. Chemical Oceanography Division

Scientist-Incharge

Shri C. V. Gangadhara Reddy

Scientists

Shri S. P. Anand
Dr. R. Sen Gupta
Shri S. Y. S. Singbal

Senior Scientific. Assistants

Shri S. N. D'Souza
Miss Solimabi
Shri S. P. Fondekar
Shri S. B. Kamat
Shri M. D. George
Dr. T. K. Jana

Junior Scientific Assistants

Shri N. B.Bhosle
Miss S. S. Naik
Shri S. W. A. Naqvi
Shri M.D. Rajagopal
Shri .R. S. Topgi

Junior Technical Assistants

Miss C. F. Moraes
Mrs. B. Das

3. Geological Oceanography Division

Head of the Division

Shri H. N. Siddiquie

Scientists

Dr. M. G. Anantha Padmanabha Setty
Shri P. S. N. Murty
Shri R. R. Nair
Shri Ch. Madhusudana Rao
Shri D. Gopala Rao
Shri M · Veerayya
Shri G. Victor Rajamanickam

Senior Scientific Assistants

Shri B. G. Wagle
Shri R.M. Kidwai
Shri M. V. Sankaranarayana Guptha
Shri F. Almeida
Shri N. H. Hashimi
Shri A.N. Nath
Shri G. C. Bhattacharya
Shri A. L. Paropkari
Shri L.V. Subbaraju
Shri K. H. Vora
Shri A.R.Gujar
Shri K. S. V. R. Krishna Rao
Shri M. Karisiddaiah

Senior Technical Assistants

Shri K. L. Kotnala
Shri M.C. Pathak

Junior Technical Assistant

Shri S. K. Nanyasi

Junior Mechanical Assistant

Shri R.S. Bongade

4. Biological Oceanography Division

Scientist-Incharge

Dr. M. .J. George

Scientists

Dr.K. Radhakrishna
Dr. A. H. Parulekar
Dr. A. G. Untawale
Shri V.P. Devassy
Shri S. C. Goswami
Dr. (Miss) Aditi Pant
Dr. (Mrs) Sumitra-Vijayaraghavan
Shri K.J.Peter
Shri P. M.A. Bhattathiri
Dr. (Mrs) Vijayalakshmi R. Nair

Senior Scientific Assistant

Shri S. Ayyappan Nair

Junior Scientific Assistants

Shri C. T. Achuthankutty
Shri S. N. Harkantra
Mrs. L. Krishnakumari
Shri Z. A. Ansari
Shri M. V. Mohideen Wafar
Shri S. R. Sreekumaran Nair

5. Ocean Engineering Division

Head of the Division

Dr. B. U Nayak

Scientists

Shri N. M. Anand
Shri A. K. Jain

Senior Scientific Assistants

Shri C. L. Waghray
Shri K. K. M. Rafique
Shri B.A. Ramesh

6. Instrumentation Division

Head of the Division

Dr. P. E. Sankaranarayanan

Scientists

Shri T. K. Sivadas
Dr. B. E. D'Sa
Shri M.R. Nayak

Senior Scientific Assistants

Shri C. Rameshu
Shri S. G. Diwan
Shri M. Ramesh

Senior Technical Assistant

Shri S. Ranganathan

Junior Scientific Assistant

Mrs. Vani B. Peshwe

Junior Technical Assistants

Shri Md. Wahidullah (Drawing)
Shri V. M. Date (Photography)
Shri E. Dias (Electronics)
Shri S. Chellam (Electroplating)

Junior Mechanical Assistant

Shri T. B. Suryakant

7. Planning and Data Division

Scientist-Incharge

Dr. V. S. Bhatt

Scientist

Shri R. M. S. Bhargava

Senior Scientific Assistants

Shri M. K. Antony
(on deputation to Japan)
Shri J. S. Sarupria
Shri Avinash Chandra

Junior Scientific Assistants

Shri S. G. Dalal
Shri S.R. Bhat

Proof Reader

Shri S. P. Sharma

8. Library

Senior Scientific Assistant

Miss M. Joshi

B. *Regional Centre of NIO, Cochin*

Scientist-Incharge

Dr. T.S. S. Rao

Scientists

Dr. M. Krishnankutty
Shri V. S. Rama Raju
Dr. R. V. Unnithan
Shri. V. N. Sankaranarayanan
Shri H. Krishnan Iyer
Shri P. Udaya Varma Thirupad
Dr. P. Sivadas
Shri U. K. Gopalan
Shri P. Gopala Menon
Shri B. M. Panikkar
Dr. M. Saraswathy
Shri P. N. Arvindakshan
Shr. T. Balachandran
Shri V. T. Paulinose
Smt. C. B. Lalithambika Devi
Shri K. Kameswara Rao

Senior Scientific Assistants

Shri P. S. Gore
Shri T. C. Gopalakrishnan
Dr. V. Santhakumari
Shri K. K. C. Nair (on deputation)
Shri G. Narayana Swamy

Junior Scientific Assistants

Smt. P. P. Meenakshi Kunjamma
Smt. Rosamma Stephen
Smt. U. P. Saramma
Shri P. Haridas
Shri T. Balasubramanian

Junior Technical Assistants

Shri P. Venugopal
Shri Abraham Pylee
Shri B. Narayanan
Smt. K..Sarala Devi
Shri O. Raveendran

C. Regional Centre of NIO, Bombay

Scienlist-Incharge

Dr. B. N. Desai

Scientists

Shri S. A. H. Abidi
Dr. M. D. Zingde
Shri V. Josanto (upto 14.11.77, presently on deputation to CMFRI, Cochin)

Senior Scientific Assistants

Dr. R. Kashinathan
Dr. K. Govindan
Shri M.M. Sabnis

Junior Scientific Assistant

Shri R. V. Sharma

D. *Regional Centre of NIO, Waltair*

Scientist-Incharge

Shri T.C. S. Rao

Scientist

Shri D. Panakala Rao

Senior Scientific Assistants

Shri .P. Chandra Mohan
Shri K. Subrahmanyam

Junior Scientific Assistants

Shri T. V. Narasimha Rao
Shri X. Terry Machado

E. R.V. Gaveshani

Scientist-Incharge

Dr. A. B. Wagh (Executive Officer)

4

library

During the year under report, more than 450 books and about 300 technical reports were added to the library. The library received about 300 journals either by subscription or in exchange to our journal '*Mahasagar*'· The microfilm collection is also growing steadily.

The inter-library loan facility was extensively used by the research scientists. About 20 publications were loaned to other establishments during the year.

The library continued to issue the current awareness services "Aquatitles" and "New Arrivals". In addition to the Institute staff, about fifty outside visiting parties also made use of the library.

The library received a gift of books and journals worth £1000 and the BLLD coupons worth £200 from the British Council.

5

awards, honours and membership of various committees

1. *Dr. S. Z.Qasim* acted as
   - Chairman, Indian National Scientific Committee for Oceanic Research.
   - Chairman, Working Committee on Training, Education and Mutual Assistance (TEMA) of IOC/UNESCO.
   - Member, High Level Review Committee for Central Water and Power Research Station, Pune.
   - Member, High Level Committee for Central Soil and Materials Research Station, New Delhi.
   - Member, Board of Governors, I.I.T., Bombay.
   - Member, Indian National Commission for Cooperation with UNESCO.
   - Member, National Committee for Environmental Planning and Coordination.
   - Member, Technical Education Advisory Council for the Union Territory of Goa, Daman and Diu.

2. *Dr. V. V. R. Varadachari* was nominated as member of the Indian National Committee for International Union of Geology and Geophysics (I.U.G.G.).

3. *Dr. J. S. Sastry* was nominated as a member to the ISI-Thermometers, Sub-Committee, CDC-33:2.

4. *Dr. B. N. Desai* continued to work as :
   - Member, ISI-Water Sectional Committee, CDC-26
   - Member, ISI-Water and Effluents Sub-Committee, CDC-26:3.
   - Member, Environmental Protection Advisory Committee, a Joint Committee set up by the ISI and the National Commission on Environment.
   - Member, High Power Science and Technology Advisory Committee, Government of Maharashtra.
   - Member, Board of Study in Zoology, Jodhpur University.
   - Member, Advisory Board to Maharashtra State Fisheries.

5. *Dr. P. E. Sankaranarayanan* has been awarded the Ph.D. degree for his thesis, entitled, "Studies in phase shifting and phase measuring techniques and network with applications in Instrumentation" in October 1977 by the Bombay University, Bombay.

6. *Dr. B.U. Nayak* became a member of the National Society of Fluid Mechanics, and Fluid Power, Bombay.

7. *Dr. M. G. Anantha Padmanabha Setty* was elected as member of Sigma XI, the Scientific Research Society of North America by the International Chapter of the Society.

8. *Dr. R. Sen Gupta* was nominated as a member of the Executive Committee of Goa State Safety Council.

9. *Dr. V. S. Bhatt* acted as:
   - Member, FAO/IOC Panel of Experts for Aquatic Sciences and Fisheries Information System (ASFIS) since 1975.
   - National Coordinator for International Oceanographic Data Exchange to deal with the matters connected with the IOC on this subject, since 1975.
   - Member, IOC Working Group on Marine Environmental Data and Information (MEDI) since 1976.
   - Member, IODE/WC ad hoc Group on Marine Information Management since 1976.
   - Member, Steering Group for International Oceanographic Data Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC)-UNESCO.
   - Invited Member of Joint Working Group on Scientific and Technical Information of the Indo-US Subcommission on Science and Technology.

10. *Shri L.V.G. Rao* was nominated as alternate member of the ISI-Thermometers Sub-Committee, CDC-33:2.

11. *Dr. R. V. Unnithan* was awarded the degree of Doctor of Science (D.Sc) of the Cochin University in April 1977 on his published contributions.

12. *Dr. A.H. Parulekar* acted as:
   - Member, Sub-group on Fisheries (Research, Development and Training), Indian Council of Agricultural Research (ICAR) and Konkan Agricultural University.
   - Member, Syllabus and Curriculum Committee on Aquatic Biology and Limnology, Shivaji University.
   - Member, Editorial Board of Vishwakosha (Marathi Encyclopaedia), Government of Maharashtra.

13. *Shri U. K. Gopalan* was elected as
   - Executive Member of the Marine Biological Association of India.
   - Executive Member of Association of Fisheries Technologists, India.
   - Executive Member of Kerala Sastra Sahithya Parishath.

14. *Shri S.A.H. Abidi* was nominated as a member of the Committee for preparing the syllabus for the course of study leading to the degree of B.Sc. (Marine Sciences) under the three years integrated degree pattern of Bombay University.

15. *Shri M. Madhu Pratap* was awarded the degree of Doctor of Philosophy (Ph.D.) by the Cochin University in May 1977 for the thesis, entitled, "Study on the ecology of zooplankton of Cochin Backwaters (a tropical estuary)".

6

deputations

1. *Dr. S. Z. Qasim* was deputed to Kiel (West Germany) to attend a meeting on matters related to Training, Education and Mutual Assistance (TEMA) of IOC/UNESCO on 21st and 22nd February, 1977.

— was deputed to New York to chair 2nd Session of the Working Committee for Training, Education and Mutual Assistance (TEMA II) of IOC/UNESCO from 17 to 23 July, 1977.

2 Dr. J. S. Sastry was deputed to attend the 3rd Planning Meeting for the Monsoon Experiment as a representative of SCOR Working Group 47 held at New Delhi during February-March, 1977.

3. *Dr. B. N. Desai* was deputed to USA for a period of 3 weeks to participate in the discussion of the project "Pollution Control of the Bombay" as a member of the Indian delegation along with a team from Bombay Municipal Corporation from 25th September to 19th October, 1977.

4. *Dr. V.S. Bhatt* was deputed to attend the meeting of a Stecring Group for International Oceanographic Data Exchange (IODE) held at Paris from 14 to 18 February, 1977.

- was deputed to attend the second session of Experts on Marine Environmental Data Information Referral System (MEDI) held at Geneva from 10 to 14 October, 1977.

5. *Shri V. S. Rama Raju* was deputed to the Instytut Budownictwa Wodengo. Gdansk, Poland, during May-June 1977 under the Exchange Programme of Scientists between IBW, PAN and CSIR.

6. *Shri T. C. S. Rao* was deputed to USA under Indo-USA Scientists' Exchange Programme for a period of 6 months.

7. *Shri R. M. S. Bhargara* was deputed to France under Scientists' Exchange Programme between CSIR-CNRS from 15 Sept to 2 Nov, 1977.

8. *Shri N. M. Anand* was sent on deputation to Technical University of Trondheim, Norway under a bilateral technical assistance programme between the Government of India and Norway for training in the field of coastal engineering and wave mechanics at the Department of Port and Ocean Engineering.

9. *Smt. C. B. Lalithambika Devi* worked in the South West Fisheries Centre, La Jolla, California in USA on UNESCO study grant from June to October, 1977. During this period she also underwent MAR MAP Training Course on Fish Eggs and Larvae and also visited the Scripps institution of Oceanography, California Academy of Sciences and San Diego Museum Natural History.

10. *Shri K. K. Chandrasekharan Nair* was deputed to Biological Laboratoty Helgoland, West Germany, for experimental studies in handling zooplankton collections under the German Academic Exchange Fellowship.

7

meetings, exhibitions, seminars and symposia

1. *Dr. J.S. Sastry* and *Shri L. V. G. Rao* participated in the symposium on 'Monsoon Dynamics' organized jointly by IUTAM and IUGG at the Indian Institute of Technology, New Delhi from 5-9 December, 1977.

2. Dr. B.N. Desai attended the symposium on Natural and Human Resources and their Utilization, organized by the School of Biological Sciences, Bhopal University from 28-29th October, 1977 at Bhopal.

3. *Shri T. C. S. Rao* attended the seminar on 'Consultancy and Equipment Manufacture for Water Pollution Control', on 8th January, 1977 at A.P. Sathe Board for Prevention and Control of Water Pollution, Hyderabad.

Prof. Per Bruun inaugurating the Seminar on Coastal Engineering held at the Institute. Sitting (L. to R.) are Dr. S. Z. Qasim and Dr. B. U. Nayak.

He also attended the meeting on "Programme of Research Work of the Orissa Coast" held on 30th July, 1977 at Office of the Directorate of Fisheries, Cuttack, Orissa.

4. Shri T. C. S. Rao and other scientific staff of Regional Centre of NIO, Waltair attended the symposium on "Management of Coastal Marine Resources" on 17th November, 1977 at Geology Department, Andhra University, Waltair.

5. Dr. V. S. Bhatt attended the Indo-US Seminar on Scientific and Technical Information held on 18-22 July, 1977 at Bangalore, Sponsored by the D.R.T.C. the theme of the seminar was 'Information Science Education-User Education'.

6. A national seminar on Coastal Engineering was organized on 24-25th March, 1977 at the Institute and it was inaugurated by Prof. Per Bruun, Chairman, Port and Ocean Engineering Department, Technical University of Trondheim, Norway. About 70 technical papers were presented by various organisations in the country like Central Water and Power Research Station, Pune, Vikram Sarabhai Space Centre, Trivandrum, Port Trusts of Madras, Bombay and Mormugao, Engineers India Limited, New Delhi, Indian Institute of Technology, Madras and Andhra University, Waltair.

8

colloquia and special lectures

Speaker	Subject	Date
1. Dr. Anand Prakash	Certain aspects of marine planktonic production	6.1.77
*2. Dr. (Miss) Ann Stilling	Some aspects of marine pollution	18.1.77
†3. Dr. David Cronin	Deep sea minerals with particular reference to Indian Ocean	31.1.77
4. Dr. P.E. Sankar. narayana Shri S· G. Diwan Shri Prabhu Desai & Shri M. R. Naik (Group discussion)	Instrument development in NIO	3.2.77
5 Prof. D. J. Crisp	The biology of barnacles	
	(i) Feeding, respiration and growth	5.2.77
	(ii) Reproductive stratagems	15.2.77
6 Dr. D. S. Cronan	Marine metallogenic deposition	
	(i) Marine mineral deposits with particular reference to the Indian Ocean	14.2.77
	(ii) Environmental differentiation of marine manganese nodules	26.2.77
	(iii) Metaliferrous sediments of the ocean	28.2.77
	(iv) Exploration and exploitation of marine mineral deposits	1.3.77
7 Prof. Albert G. Hahn	Geomagnetics, random samples, their processing and consequences	2.3.77
8 Shri Nitin Gupte	An outline of the transcendental meditation	13.4.77
9 Dr. T. Eldholm	The evolution of the Norwegian Sea and its continental margin	11.5.77

	Speaker	Subject	Date
10	Dr. R. Sen Gupta Shri V. N. Verlencar Miss Solimabi Shri R.S.Topgi and Shri S. P. Fondekar (Group discussion)	Oil Pollution studies	16.5.77
11	Shri S.P.Anand	Some aspects of modified solar still	4-6-77
12	Prof. G.M.Philip	Modelling of polluted estuaries	17.6.77
13	Dr. J. N. Nanda	Analysis of echosounder	21.7.77
14	Dr.Venkataratnam Kolla	Mineralogy and sedimentation in Indian Ocean	8.8.77
15	Scientific staff of NIO	Review of on-going R & D projects	19.8.77
16	Shri R.A. Haine	Ship-borne wave recorder	15.9.77
17	Prof. P. Holmes	Research needs of offshore engineering	23.9.77
18	Dr. K. S. Yajnik	Effect of moderate Rossby number on boundary layer characteristics	28.9.77
19	Prof. V. Herout	Some aspects of natural product chemistry	17.10.77
20	Dr. George Grice	Pollution experiments in controlled ecosystem	12.11.77
21	Shri Ravi Challu	Application of micro-computers in scientific research	15.11.77
22	Dr. T. Carstens	The climate and natural resources of Norway's coastal and shelf waters with special emphasis on coastal pollution	19.11.77
23	Dr. R. Flather	Storm surge prediction using numerical models	15.12.77
24	Prof. B. P. Dash	Significance of the island systems of west coast of Africa	23.12.77

* Lectures delivered at Regional Centre of NIO, Waltair.
t Lectures delivered at Regional Centre of NIO, Cochin.

9

radio talks

Speaker	Date	Subject
Dr. S.Z.Qasim Dr.V.S.Bhatt	2.4.1977	Potential ocean wealth for *"Ratna Bhandar Mahasagar"* (Interview in Hindi)
Dr. M. J. George	30.6.1977	Prawn culture
Dr. S. Z. Qasim	15.9.1977	Our beaches and pollution
Dr. B. N. Desai	19.12.1977	Food from sea
Shri Ayyappan Nair	22.12.1977	Sea farming
Dr. S. Z. Qasim	26. 12.1977	Shrimp farming

10

publications

10.1 Publications of the Institute

1.. Annual Report, 1976·

2. Quarterly bulletin of the Institute—*Mahasagar,* Vol. 9, Nos 1 to 4.

3. Indian National Directory of Marine Scientists (INDMS).

4.. Collected Reprints, Vol.3 of 1972.

5. Cruise Reports of R.V. *Gaveshani* (Cruise XIV-XXVII).

10.2 Papers published by the staff

Achuthankutty, C.T., M.J.George and S.C.Goswami, 1977. Larval ingression of penaeid prawns in the estuaries of Goa. *Proc. Symp. Warm Water Zoopl. Spl. Publ. UNESCO / NIO,* 412-424.

Anand, S. P., 1977. A note on field trials of new prototype solar still. *Mahasagar—Bull-natn. Inst. Oceanogr.,* 10(1& 2) : 75-78.

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Ansari, Z.A., S.N. Harkantra, S.A. Nair and A. H. Parulekar, 1977. Benthos of the Bay of Bengal : A preliminary account. *Mahasagar—Bull. natn. Inst. Oceanogr.,* 10 (1 & 2) : 55-60.

Ansari, Z.A., A.H. Parulekar, S.N. Harkantra and Ayyappan Nair, 1977. Shallow water macrobenthos along the central west coast of India. *Mahasagar—Bull. natn. Inst. Oceanogr.,* 10 (3&4) : 123-127.

Ansell, A.D. and A.H. Parulekar, 1977. On the rate of growth of *Nuclulana minuta* (Miller) (Bivalvia: Nuculanidae). *J. Mollusc. Res., U.K., 2* (1) : 27-38.

Anto, A.F., 1977. Observational studies on land sea breeze phenomena around the Island of Sylt. *Meteorol. Rdsch.* 30: 118-122.

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Bhargava, R.M.S., P.M.A. Bhattathiri and V.P. Devassy, 1977. Relative contribution of nannoplankton to the primary production of two estuaries of Goa. *Mahasagar-Bull. natn. Inst. Oceanogr.,* 10 (1 & 2) : 61-66.

Bhattathiri, P.M.A. and V.P. Devassy, 1977. Diel variations in phytoplankton pigments and primary production of Bombay. *Indian J. mar. Sci.,* 6 (1); 96-99.

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Bhosle, N.B., 1977. Intraspecific variation in the soluble nuclear eye lens proteins of the mullet, *Mugil cephalus* (L). *Mahasagar-Bull. natn. Inst. Oceanogr.*, 10(1 & 2): 29-34.

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Das, Hari Pada, 1977. The fecundity of grey mullet *Mugil cephalus* along the Goa coast. *Mahasagar—Bull· natn. Inst. Oceanogr.*, 10 (1&2): 79-82.

Das, Hari Pada, 1977. Length-weight relationship and relative condition of grey mullet, *Mugil cephalus* (L). *Mahasagar-Bull. natn. Inst. Oceanogr.*, 10 (3&4): 145-149.

De Sousa, S.N. 1977. Monitoring of some environmental parameters at the Zuari river, Goa. *Indian J. mar. Sci.*, 6(2): 114-117.

Dhargalkar, V.K.. T.W. Kureishi and M.V. Bhandare. 1977. Deposition of tar balls (oil residue) on beaches along the west coast of India. *Mahasagar—Bull. natn. Inst. Oceanogr.*, 10(3&4): 105-108.

D'Sa, E. and P.E. Sankaranarayanan, 1977. Constant amplitude triangular wave generation with Op. Amps. *Electronic Engineering*, 19.

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Gore, P.S. and R.V. Unnithan, 1977. Thiobacilli from Cochin Backwaters and their oxidative and corrosive activity. *Indian J. mar. Sci.*, 6(2): 170-172.

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21. National report on physical oceanography and marine geophysics for progress in geophysics.

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