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ABSTRACTS OF PAPERS

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COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

NEW DELHI

INTRODUCTION

A three-day Symposium on "INDIAN OCEAN" is being organized jointly by the Indian National Committee on Oceanic Research (CSIR) and the National Institute of Sciences of India from 2nd through 4th March, 1967.

The principal objective of the symposium is to bring together all the scientific workers in different disciplines of Oceanography from different Institutions in India and also a small number of scientists from abroad who have actively participated in the International Indian Ocean Expedition, to a common forum to discuss the results obtained during the expedition and to develop new aspects of investigations in the Indian Ocean. Besides the data collected during the IIOE, the Symposium will also discuss some of the earlier work carried out in the Indian Ocean with a view to providing newer interpretations to these earlier findings based on recent concepts and theories in Oceanography. It is hoped that the papers and the discussions will indicate the gaps in our knowledge and the outstanding problems which have emerged from the past few years' work.

The Symposium is being organised under the following sections:

1. Physical and Chemical Oceanography, including Geochemistry and Radio-chemistry.
2. Geology and Geophysics.
3. Marine Biology including Productivity.
4. Fisheries.
5. Maritime Meteorology.

The Symposium is being held at the auditorium of the National Institute of Sciences of India, Bahadurshah Zafar Marg, New Delhi-1.

Abstracts of contributions for the Symposium are given in the following pages. Arrangements are being made for publishing the papers presented in Symposium in a special Symposium Number of the National Institute of Sciences.

ABSTRACTS OF PAPERS

1 *Sec. II* THE ORIGIN OF THE INDIAN OCEAN

F.A. AHMAD

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Two diagonally opposite views are held about the present distribution of continents and oceans; one that the continents, with minor changes, have always been where they are and the other that they were formerly jumbled together in a single super-continent that has broken up and the constituent blocks dispersed. The Indian ocean, in the latter case, came into being at the time of this break up of the super-continent, Gondwanaland. The paper examines the various reconstructions of Gondwanaland in the light of geological, palaeontological, palaeomagnetic, and palaeoclimatologic evidence. It is concluded that the earliest break came in the Triassic in the S.E. Africa—Tasmania—South Victoria-land region. It was followed by a break between India—Australia from Africa in the Cretaceous and the former soon after started rotating in the anti-clockwise sense. Soon after this Australia broke away from India.

The fact that mountain ranges are continuous from Assam to Turkey suggests that India has not drifted *independently* of Africa from 3000 miles, since the Jurassic, as has been suggested on palaeomagnetic data, for such a linear translation of the Indian landmass

would have resulted in a distinct break in the mountain ranges. This also suggests that in any reconstruction of Gondwanaland, India must fit beside Africa.

The hypotheses of global expansion and crustal sliding are also reviewed and it appears that both have been operative and can be distinguished.

2 *Sec. III* AN ACCOUNT OF THE STOMATOPOD LARVAE IN THE INDIAN OCEAN AND ADJOINING AREAS

K. H. ALIKUNHI

Central Institute of Fisheries Education, Bombay.

Descriptive accounts of collections of stomatopod larvae have been considered 'unprofitable' because specific identification of larvae, so markedly differing from their adults, was impossible. However, recent work in India have shown that pelagic larvae could successfully be reared in the laboratory to the post larval and adult stages. With correct identification and specific definition of larval characters, study of larval collections becomes purposeful.

54 collections accumulated at the Zoological Survey of India since 1908, from the Arabian sea, Bay of Bengal including Andaman Sea and Burma coast, and Pacific ocean have been studied in detail, throwing light on the pattern of distribution of different species. New and

undescribed larvae have been described and attempts made to correlate them with adult species.

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Sec. IV

A NATIONAL CO-OPERATIVE PROGRAMME FOR MARK-RECOVERY STUDIES ON COMMERCIALY IMPORTANT MARINE FISHES OF INDIA

K. H. ALIKUNHI & P. C. GEORGE

Central Institute of Fisheries Education, Bombay

Mark-recovery studies constitute one of the most dependable tools for obtaining direct information on population structure, movements of stocks and growth and age of any given species of fish. Such studies are all the more important in the case of migratory species of commercial value.

Sardines (*Sardinella* spp.) and mackerels (*Rastrelliger kanagurta*) together constitute about 30% of India's annual marine fish landings. These species are migratory in habit, seasonal in occurrence and extremely fluctuating in abundance. The fishery is largely concentrated along the south-western sector of the coast and nothing is now known about their stocks during the off-season. In the context of our national plans for increasing fish production there is urgent need for information on age and composition of stocks and their migration patterns as rational basis for organising exploitation programmes. A well-planned, large-scale tagging programme will provide such information.

The tagging of Indian mackerel (*R. kanagurta*) and sardine (*Sardinella gibbosa*) carried out off Marmgao, in Goa, in December 1966, has clearly demonstrated that with proper handling these delicate marine species could be successfully tagged and released. Subsequent trials at Bombay have further indicated that pomfrets, sciaenids and several other

demersal fish and crustaceans could also be successfully tagged.

The relative merits of different types of tags that could be considered for large scale tagging have been discussed. A workable programme of large scale tagging of sardines and mackerels from different centres with specific objectives, has been outlined. The feasibility of adopting similar programmes on other important species is also indicated in the paper.

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Sec. I

DISTRIBUTION OF TEMPERATURE AND OXYGEN IN THE ARABIAN SEA AND BAY OF BENGAL DURING THE MONSOON SEASON

S.P. ANAND*, C. B. MURTY*, R. JAYARAMAN,† AND B. M. AGGARWAL*.

Based on the data collected by *INS KISTNA* from the Arabian Sea and the Bay of Bengal during the monsoon seasons of 1963 and 1964, charts showing the horizontal distribution of temperature and oxygen at six levels, upto a depth of 200 m have been prepared.

In the surface layers upto 20 m depth, a tongue of warm water off the west coast of India appeared to be spreading from the Gulf of Cambay towards the south almost parallel to the coast. In the Bay of Bengal the temperatures slightly decreased away from the coast. Temperatures less than 26°C were observed around the south western coast south of 9°N.

At depths 50 m and more, the low temperature water off the southwestern coast has spread northwards along the coast and further offshore. In the Bay of Bengal, a cell of low temperature in the Northern Central part and another of high temperature in the southwestern part have formed.

The pattern of isopleths of oxygen, both in the Arabian Sea and the Bay of Bengal was

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generally similar to that of the temperature. The concentration in and the thickness of the oxygen rich layer were greater in the Arabian Sea than in the Bay of Bengal.

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Sec. III

A PRELIMINARY REPORT ON THE GEOGRAPHICAL DISTRIBUTION OF THE SPECIES OF CARINARIIDAE AND PTEROTRACHEIDAE (HETEROPODA, MOLLUSCA) FROM THE IOE

P. N. ARAVINDAKSHAN

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This is a description of the distribution in the Indian Ocean of species belonging to two families of Heteropoda, the Carinariidae and the Pterotracheidae. The observations are based on plankton collected by *Argo*, *Anton Bruun*, *Pioneer*, and *Vityaz* during IOE. The samples obtained by these vessels provide broad coverage of the Indian Ocean, including the Arabian Sea and Bay of Bengal, and southward to 40°S.

Pterotracheids outnumber the Carinariids in abundance. *Pterotrachea scutata*, *Cardiropoda richardi*, and the species of the genus *Carinaria* deserve special mention because of their low density in the Indian Ocean. Most abundant and widely distributed are *Firoloidea desmaresti* and *Pterotrachea hippocampus*. *Pterosoma planum* and *Cardiropoda placenta* appear to be more restricted to the tropical zone. The identification of the specimens is mainly based upon Tesch.

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Sec. V

DRY EQUATORIAL BELT OVER THE OCEANS

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For long, it has been thought that the dol-

drums are the equatorial oceanic regions of nearly calm surface winds with upward vertical motion and consequently with plenty of cloudiness and rain. In the General Circulation picture, the region of doldrums was visualised as the common limb of vertical upward motion of the two Hadley type cells in the two tropics of the two hemispheres.

There were a few observations in the past to suggest that this picture of the equatorial doldrums with plenty of cloudiness and rain was perhaps not prevailing in the real atmosphere and that this region of doldrums was probably split up into two zones, one on each side of the Equator and separated by a zone very close to the Equator in which descending air motion and dry weather conditions appeared to prevail. Recently, satellite cloud pictures have firmly established that in the mid-oceanic regions, Equator is a region of very little cloudiness. This observational fact needs a theoretical explanation.

In this paper, a theoretical explanation is offered as to why the Equator should be a region of very little cloudiness. A revised picture of the General Circulation pattern near the Equator is provided.

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Sec. II

GEOLOGIC SIGNIFICANCE OF THE REPORTED RADIOMETRIC AND HEAT FLOW DATA PERTAINING TO PARTS OF THE ARABIAN SEA AND BAY OF BENGAL

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An analysis of the reported data indicates that the Deccan Trap basalts and the basalts dredged from the floor of the southern Indian Ocean are comparable in age (about 60 m.y.) and composition (predominantly tholeiitic).

This suggests that the extensive volcanic activity in the lower tertiary times affected both continental and oceanic areas in and around India. The Maldivo-Laccadive Ridge, though presently aseismic, might have been active during the early tertiary period. Despite the scatter of values, the crestal zones of the Ridge tend to have a higher heat flow (about 1.8 ucal/cm²/sec) than the sides (about 1.5 ucal/cm²/sec). The extremely high heat flow in the Andaman Basin (about 5 ucal/cm²/sec) seems to be a consequence of the thinness of the sediment veneer and volcanism.

SOME NEW DATA ON DEEP-SEA SEDIMENTATION IN THE INDIAN OCEAN

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At the Second International Oceanographic Congress the authors exhibited the maps of bottom sediments of the Indian Ocean and the maps of CaCO₃ and SiO₂ amorph, distribution compiled on a scale of 1 : 15 000 000 using the materials of the Soviet marine expeditions on board the research vessels "Ob" and "Vityaz". After the Congress the scientists of the Institute of Oceanology, the USSR Academy of Sciences, have continued their studies of chemical and mineralogical composition of the deep-sea sediments aimed at elucidating the processes of their formation and preparing the lithological maps for the Geological Atlas of the International Indian Ocean Expedition.

The distribution of organic carbon, iron and manganese in recent bottom sediments has been thoroughly examined (several hundred analyses). High C_{org.} concentrations (over 1% and in some places to 4-5%) surround the ocean by an almost uninterrupted semicircle,

being confined mainly to the clay and low-carbonate sediments in the lower part of the shelf, the continental slope and the continental rise. Such distribution may be related to high plankton productivity of the coastal waters. C_{org.} content of the sediments decreases seaward, but in the whole of the northern portion of the Indian Ocean (southward to 15-20° S) it is higher than that in the same latitudes of the Central Pacific due to higher biological productivity of the Indian waters.

High concentrations of Fe (>5%) and Mn (>0.5%) are found: 1) in terrigenous clay sediments in the western part of the Bay of Bengal which are, on the whole, deposits carried out by the Ganges and enriched by these elements in the surface layer during the diagenesis processes (Fe_{max} 6.7%, Mn_{max} 1.78%); 2) in volcanogenic sediments in the vicinity of Java and some other volcanic islands (Fe_{max} 6.8%, Mn_{max} 0.8); 3) in red clay deposited at the bottoms of deep basins (Fe_{max} = 7.6%, Mn_{max} = 1.34%); 4) in non-carbonate sediments of the rift valley in the Mid-ocean ridge (Fe_{max} = 7.83%, Mn_{max} = 0.49%). Radiolarian, diatom and especially foraminiferal oozes are relatively low in iron and manganese. The iron-manganese nodules widely-distributed in the central parts of the ocean, in the areas with rugged bottom topography, in red clays, radiolarian and foraminiferal oozes contain (according to the analysis of data from 29 stations) 4.5—22.07% of Fe and 9.5—29% of Mn. The Mn/Fe ratio in nodules ranges from 4.5 to 6.52.

Ultrabasic rock outcrops (serpentinites, peridotites, dunites, etc.) have been found by the "Vityaz" expeditions in the rift zone of the Indian mid-ocean ridges. The disintegration products of these rocks form a special type of detrital sediments in the rift valley. The mineralogical composition of these sediments is characterized by the predominance of the serpentine-chlorite minerals, olivine, pyroxens (enstatite, diopside), amphiboles, ore minerals

(magnetite, chromite, chromopicitote). An essential role in the formation of the rift valley sediments belongs to the underwater slumps and turbidity currents.

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Sec. II

RECENT FORAMINIFERA FROM VISAKHAPATNAM BEACH SANDS, INDIA.

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Ten samples of beach sands from Visakhapatnam were examined for a study of foraminiferal fauna. A total of twenty species of Foraminifera are described and illustrated. The assemblage includes several characteristic species of Indo-Pacific Zoogeographical realm.

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Sec. I

TRACE ELEMENT GEOCHEMISTRY

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The distribution of trace elements in sea water is a function of large number of processes like the input from the continents, accretion from the interplanetary space, and biological, physical and chemical processes occurring within the ocean. Depending upon the geochemical nature of element, one or two of these processes play important role in its distribution. Thus a combined study of several trace elements present in ocean water makes it possible to obtain valuable information on a variety of geochemical and geophysical processes.

Experimental techniques for determining the concentrations and for enriching a few of these elements are discussed. Theoretical models are discussed in relation to experimentally observed distribution of certain key elements and their isotopes. For example, the disequilibrium of uranium and thorium isotopes in sea water is used for evaluating their rates of input by river inflow and residence times in the ocean. The distribution of thorium isotopes in the upper layers of the ocean permits a study of the mean size of particulate matter responsible for its gravitational settling following chemical absorption. The role of biological processes in transport is evaluated for certain biologically active elements, e.g., lead and silicon.

Some recent oceanographic data on trace element concentrations have implications to the accretion of extraterrestrial matter; these data are discussed and ideas are developed for obtaining an entry into certain astrophysical problems.

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Sec. III

VERTICAL DISTRIBUTION OF INTER-TIDAL ORGANISMS ON SANDY AND MUDDY SHORES

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Vertical distribution of species has been studied on three sandy and muddy shores of Bombay. It is observed that, on the basis of their vertical distribution, the organisms on the shore can be divided into three groups, according to the following basic pattern.

GROUP I : In general, the members of this group live between Mean High

Water and Mean Tidal Level 13
(M.T.L.).

GROUP II : Members of this group have their maximum densities below M.T.L.; and most of the species have their lower limits below Mean Low Water of Springs.

GROUP III : The forms constituting this group are essentially sublittoral forms which have extended upwards in the intertidal region to varying heights below Mean Low Water of Neaps.

The variations in the vertical limits in different localities are discussed. The basic pattern is compared with the universal system of intertidal zonation for rocky shores and with other schemes of classification for sandy and muddy shores.

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Sec. I

THE ESTUARY OF THE HOOGLY

S. K. BHATTACHARYA
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The paper mentions the changes in the course of the Ganga during the last several centuries and the development of the estuary of the Hooghly which is the sea-way to the Port of Calcutta. The presence of salient oceanographic characteristics have been discussed together with the nature of transport of sediment from upland and at the sea face of the estuary. A few measurements confirm some of the conclusions. The paper concludes by examining the salinity intrusion in the estuary and a brief comparison with other estuaries has been made.

Sec. IV

LARVAL AND JUVENILE STAGES OF THE FLYING FISH *EXOCOETUS VOLITANS* LINN. AND *HIRUNDICHCHTHYS COROMANDELENSIS* (HORNELL) FROM THE BAY OF BENGAL

K. BALASUBRAHMANYAM, K.S.P. BHUSHANA
RAO AND R.C. SUBBARAJU,

*Marine Biological Station
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The paper reports observations on the larval and juvenile stages of *Exocoetus volitans* and *Hirundichthys coromandelensis* collected in the Bay of Bengal during the 15th and 16th cruises of INS *KISTNA* in June, 1964. Larvae and juveniles of the former were present in collections made from 25 stations out of a total of 60 stations investigated. 1238 specimens of larval and juvenile stages were collected, of which 1172 were less than 10mm in body length. The post larvae were abundant along 82°-83° and 84° and 85° parallels between latitudes 10°02' and 9°. A few juveniles were collected from different stations but they were never concentrated in any station. It is possible that spawning of *Exocoetus volitans* took place during April-May east of Ceylon and the prevailing surface currents in the Bay of Bengal during May-June might have resulted in the distribution observed during the 15th and 16th cruises of INS *Kistna* in June, 1964. Previous observations on the eggs and larvae of *Exocoetus volitans* in the Bay of Bengal were chiefly by Kovalevskaja, Parin and Gorbunova. The former reported the occurrence of eggs and larvae, and the latter described in detail the embryonic development of artificially fertilized eggs of *E. volitans*—collected by the *Vityaz* at station 5247 (Lat. 5° Long. 79°) on 29th September, 1962. It might be that spawning of *E. volitans* takes place during different periods around the coasts of Ceylon.

33 larvae and juveniles of *Hirundichthys coromandelensis* ranging from 4.0mm to 75mm were present in collections made from 0 stations out 60 stations investigated in the Bay of Bengal. The larvae and juveniles were never concentrated in any particular station although *Hirundichthys coromandelensis* appeared in large shoals along the Coromandel coast during May-June in most years for spawning. Parin reported the occurrence of *H. coromandelensis* from the western Indian Ocean, which he collected using electric light. The larvae and juveniles of *H. coromandelensis* resemble very much those of *H. oxycephalus* reported by Imai

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Sec. II

DISTRIBUTION OF BENTHIC FORAMINIFERA IN SEDIMENTS FROM CONTINENTAL SHELF OF BAY OF BENGAL

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Measured quantities of sediments collected during XVII and XVIII Crusies of INS *KISTNA* from 27 stations on the continental shelf to the eastern coast of Indian peninsula were washed for recovering and studying the faunal content. Present paper mainly deals with the distribution pattern of benthic foraminifers in the surface sediments. No foraminifers were recorded from some of these stations.

About 60 species have so far been identified. Their distribution, though mainly restricted to certain depth range, is found to be dependant on the nature of the sediment also. Deltaic sediments contain few foraminifers. Certain forms show latitude preferences. Arenaceous forms are common in sandy beds of shallow depths and also in canyons.

Factors affecting flourishing of foraminifers must have changed in this part of the ocean during geologically quite recent times as several stations show abundant foraminifers at some

depth below the sediment surface whereas the uppermost factions contain few.

Two new species of *Bolivina* and *Triloculina* are described.

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Sec. III

SOME QUANTITATIVE STUDIES ON ZOOPLANKTON OF THE GODAVARI ESTUARY

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Quantitative studies on the zooplankton of the Godavari estuary, which is the second largest in India, were carried on for about five years. The data presented is only for about nine months in a year as the river is flooded during the other 3 months, when there is practically fresh water conditions in the estuary.

In spite of the highly fluctuating conditions of temperature and salinity a regular seasonal succession of zooplanktonic organisms was observed. The zooplankton showed a bimodal pattern of abundance with a primary peak in November-December and another in May-June, with an intervening phytoplankton peak in March-April. The copepods, decapod larvae, and medusae were the major components of the zooplankton almost throughout the period. The composition of plankton more or less followed the same patterns as in the inshore waters adjoining the estuary. There was, however, a time lag in the occurrence of peak periods in the different stations in the estuary from the mouth towards the head end.

A study of the tidal cycles showed that there was more concentration of organisms during high tide than during the low tide. A diurnal rhythm was also observed in the abundance of the organisms. The night abundance of copepods and veligers was many times higher than during the day.

Of the 110 species identified, 17 were medusae, 4 cladocerans, 60 copepods, 12 mysids and the remaining 17 belonged to other groups. All the groups showed fluctuations in their density and the peak numbers were found during seasons of stable hydrographical conditions. In general the zooplankton was found to be rich in bulk in the middle reaches (Stations IV and V) as compared to the head of the estuary and mouth. This may be due to the greater turbulence at the mouth and large admixture of fresh water at the head of the estuary whereas more stable conditions are present at Stations IV and V in the middle reaches. The plankton was also found to be richer both in volume and numbers in the Bhairavapalem branch as compared with the Kothapalem. This is perhaps due to the widely open mouth of the former with free access to the sea.

The copepod fauna in the estuary are of three distinct categories depending on the degree of their salinity tolerance. Of the sixty species identified only fifteen were euryhaline, present throughout the year, in considerable numbers. Thirty two species were present during restricted period depending on the salinity and temperature conditions while the remaining thirteen species were casual migrants. The majority of the species reported are also present in the coastal waters in the adjoining sea and their seasonal distribution was also the same as those in the inshore waters.

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Sec. II

MINERAL POSSIBILITIES ON THE CONTINENTAL SHELF OF INDIA—AN APPRAISAL OF THE EXISTING DATA

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and

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The exploration and exploitation of mineral resources on the continental shelf has attracted

increasing attention in the last few years. A similar concerted effort in this direction in India is also called for.

The geology of the continental shelf is largely a continuation of the geology of the adjacent land areas but in the shelf region, as elsewhere, in oceanic areas, the geology is largely obscured by a cover of sediments. Thus the deposits which are likely to be of immediate interest from the point of view of the ease of exploration and exploitation are the surficial deposits.

Our existing knowledge about the continental shelf of the country is meagre except for a portion of the eastern continental shelf of the peninsula. Available data about its topography, sediments and their geochemistry even though meagre, permit an evaluation of the mineral potentialities and the delineation of favourable areas for further detailed work.

Apart from the well known monazite and ilmenite beach sands of the west coast, occurrences of phosphatic concretions (off North Andamans) barium concretions (off the west coast) and calc or shell deposits have also been reported.

In view of the present shortage of phosphate based fertilizers in the country, the search for these on ocean floor assumes added importance. The reported occurrence of phosphatic concretions off the coast of northern Andaman needs re-examination. Occurrence of upwelling, mass mortality and exposed bedrock on the shelf of the west coast of India is of considerable significance in this search for phosphate as conditions similar to these have been reported in known offshore phosphatic environments.

Occurrence of calcarous deposits (coralline/foramineferal sands and shell deposits) have been reported from the bottom sampling station in the Andaman-Nicobar and Saurashtra, Kerala and Laccadive areas. Some of these are possibly of cement grade and could support a cement industry in the Western coastal region with a view to exploiting the large export market in west Asia.

The recent efforts made in this direction in drawing a comprehensive exploration programme in the Geological Survey of India are briefly discussed. The programme for exploration drawn up by the Geological Survey of India envisages traversing the entire shelf region of India with tracks spaced 30 km apart and station intervals of 5/10 km. The preliminary survey covering 26526 km 5303/2651 stations is likely to be completed in about 11 months or roughly two working seasons.

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Sec. II

FORAMINIFERA OFF MANGALORE COAST, SOUTH INDIA

B. P. CHATTERJEE AND M. N. GURURAJA

Geological Survey of India, Calcutta.

The paper records the results of certain studies carried out of the foraminifera found off the Mangalore Coast, South India. The samples available for study were collected using the Petersen Grab from eight stations along a traverse upto a distance of nearly $5\frac{1}{2}$ miles from the coast with corresponding depths of four to ten fathoms. The samples were first boiled in Sodium hexa-meta-phosphate, washed and then screened. Equal quantities of washed material were examined and the contained microfauna were actually counted on a grid tray.

The faunal assemblage consists mainly of foraminifera, ostracoda, minute shells of pelecypods and gastropods and echinoid spines. The foraminifera comprise over 90% of the assemblage having 11 genera of which three forms namely, *Cibicides*, *Nonion* and *Rotalia* are most abundant. *Cibicides* and *Nonion* occur in large numbers in all the samples but reach the peak at a distance of 2.91 miles with the corresponding depth of 6.25 fathoms. *Globobigerina* is the only planktonic foraminifera

recorded which occurs in the sediments from 2.47 miles and beyond.

The number of individuals of the important foraminiferal genera has been plotted against the depth and distance off the shore.

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Sec. III

SIPHONOPHORES COLLECTED DURING THE 35TH. CRUISE OF THE R. V. VITYAZ IN THE EASTERN PART OF THE INDIAN OCEAN

R. DANIEL AND A. DANIEL,

Zoological Survey of India, Calcutta.

The distribution pattern of sixty species of Siphonophores collected during the 35th. Cruise of the R.V. VITYAZ in the eastern part of the Indian Ocean is presented. The greater concentration of species appears to be around the Equator extending between 5°N and 10°S.

Marrus antarcticus Totton 1954, considered to be a deep or mid-water form associated with the Antarctic zone and with waters that have recently left the zone, was encountered at Lat. 9°57'S and Long. 91°32'E at 125-150 metres depth.

A new genus and species of Physonectae, *Frillagalma vityazi* Daniel 1966, has been recorded and published.

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Sec. III

PRELIMINARY STUDIES ON THE ZOOLOGICAL CONSTITUENTS OF THE SONIC SCATTERING LAYER AT SEVEN STATIONS ESTABLISHED IN THE EASTERN PART OF THE INDIAN OCEAN BY R. V. VITYAZ.

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Zoological Survey of India, Calcutta.

The zoological constituents collected by the Isaacs Kidd trawl of the sonic scattering layer

at seven stations was found to mainly consist of siphonophores (40%), pelagic tunicates (25%), euphausiids (20%), fishes (10%), shrimps (3%), medusae (1%), with squids, copepods, mysids, heteropods, pteropods making up the remaining portion.

A detailed study on siphonophores and pelagic tunicates was conducted, and these were found to have the following composition:—The siphonophores being represented by 21 species belonging to 4 families; the pelagic tunicates, by 9 species belonging to 2 families.

The depth of the layer and its relation to total depth, temperature and salinity are presented.

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Sec. V

A STUDY ON THE MOVEMENT OF MAY CYCLONIC STORMS IN THE BAY OF BENGAL.

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An examination of tracks of May storms in the Bay of Bengal brings out three different regions according to the direction of motion of the tropical storms viz. (1) regions from which storms move in some westerly direction (2) region from which storms lack in any westward components in their motion and lastly the region where any type of movement is equally probable.

Rai Sircar (1958) and Koteswaram (1961) have given the detailed climatology of these storms. Desai and Rao (1955) and Pishoroty and Desai (1956) have discussed the causes of various direction of movement of tropical storm in the Bay of Bengal.

In the present study to understand the synoptic features responsible for different types of movement of May tropical storm in the Bay of Bengal, we have taken two typical contrasting cases one of May 1962 where the storm moved in a westerly direction and other of May 1963

which lacked any westward component in its movement.

Climatological aspects of May storm vis-a-vis mean upper air flow pattern have also been examined.

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Sec. V

AIR MASSES OVER THE ARABIAN SEA DURING THE SOUTHWEST MONSOON SEASON

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Data for the IIOE period 1963-64 over the north Indian Ocean and the Arabian Sea presented in the papers of Colon (1964) and Pisharoty, Rangarajan and Srivastava, Ramage, Miller and Keshavamurthy and Bunker (1965), have been discussed with a view to ascertain the nature of air masses over the Arabian Sea when the monsoon was vigorous or active or weak or there were break conditions as judged from rainfall over the west coast of the Peninsula. Characteristic air mass stratification over the Arabian Sea with moist deflected trades in the lower levels and drier unstable air from Arabia and neighbourhood in the upper levels is very favourable for active to vigorous monsoon on the west coast, the larger the strength of the deflected trades and their normal component to the Western Ghats the greater the amount of rainfall. The monsoon is only active when the deflected trades in the lower levels are strong but in the upper levels there is air from West Africa side which has given precipitation over the Ethiopian highlands and has lapse near moist adiabatic. If there is in all the levels (a) continental air, there would be break conditions with little rain and (b) if moist air from west Africa side, there would be only light rain.

A diagram is presented to show the probable distribution of air masses over the Arabian

Sea at different levels for active or strong monsoon conditions over the west coast of the peninsula.

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Sec. III

A COMPARISON OF THE MARINE AND ESTUARINE BENTHIC FAUNA OF THE NEARSHORE REGIONS OF THE ARABIAN SEA.

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The distribution and abundance of the benthic fauna of the Arabian sea were studied in the nearshore region at a depth of 10 fathoms, about 10 miles off Cochin. The results showed that the macrofauna was more abundant than the meiofauna. The foraminiferans and the nematodes formed the dominant groups of the meiofauna. The larger foraminiferans such as *Rotalia beccarii* occurred in fair numbers in the macrofauna as well. The macrofauna was mostly represented by gastropods, bivalves and a few small bottom-dwelling fishes. A comparison of the benthic fauna of this area with that of the backwater revealed that although the main groups of the fauna were the same in both the areas, the species composition was different.

The benthic biomass in the nearshore area was higher than those regions of the backwater which had similar substrata. The values obtained were 6.37 gm/m² in the nearshore region as compared to 2.44 gm/m² and 3.36 gm/m² in the estuarine region. However, the benthic biomass at the mouth of the backwater as has been reported earlier was considerably higher than that of the nearshore region.

In the backwater the variations in the salinity and the nature of substrata were thought to be the main factors controlling the distribution and abundance of the benthic fauna; but in the nearshore region, since salinity is less variable, it seems that the nature

of the substratum is the primary factor governing the abundance of the bottom fauna. The substratum in the nearshore region was predominantly clayey-silty and this may account for the absence of larger macrofauna.

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Sec. IV

IDENTIFICATION OF FISH POPULATIONS WITH PARTICULAR REFERENCE TO THE PELAGIC FISH STOCKS OF THE INDIAN OCEAN REGION

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The most essential step in any fishery management is the identification of discrete fish populations. This is particularly important for the development of Indian Ocean pelagic fisheries.

The simple signal character analysis of meristic or metric characters which are usually employed do not give complete solutions to the problem, in such instances more sophisticated analysis for studying many characters together using the method of group constellations has been discussed.

The development of blood groups in humans and its recent application to fish groups has been reviewed. The more recent analysis of haemoglobin components using electrophoretic techniques on paper, in agar and starch gel are discussed. The paper describes a new modification of starch gel electrophoresis method currently in use, and the application of this procedure for the study of clupeoid, scombroid and other pelagic fish populations of the Indian Ocean.

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Sec. IV

TUNA RESOURCES OF THE INDIAN OCEAN

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An account of the Tuna Resources of the Indian Ocean is presented and discussed.

The present catch of tuna and tuna like scombroids from Indian ocean is about 175 thousand metric tons. About three fourths of the catch is taken by fishing boats of the countries situated outside Indian Ocean, mainly Japan and Taiwan. The catches of all Indian Ocean countries together are about 54 thousand metric tons. It is obvious that Indian Ocean countries could develop the tuna fisheries to a much larger extent than has so far been possible. A detailed study of the ecology of commercial species and related oceanographic features can help to increase catches of tuna and tuna like scombroids in offshore and nearshore areas.

The fishing areas in the Indian Ocean and the catches of albacore, bigeye and yellowfin tuna during the year 1961-62 have been analysed.

25 Sec. I

VERTICAL DISTRIBUTION OF OXYGEN IN THE BAY OF BENGAL AND ANDAMAN SEA DURING FEBRUARY-MARCH 1963

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AND R. JAYARAMAN

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Based on the observations made by INS *KISTNA* during her VI and VII cruises, an analysis of the vertical distribution of oxygen in the upper 500 meters of the Bay of Bengal and the Andaman Sea during February March 1963 has been made.

The analysis has indicated that in general, the thickness of the upper oxygen rich layer is greater in the Andaman sea than in the Bay of Bengal wherein it decreased towards north. The thickness of the oxygen poor layer in the

Bay of Bengal appeared to be increasing towards north. The concentration in the oxygen poor layer was greater in the Andaman sea than in the Bay of Bengal wherein it decreased towards north.

26 Sec. III

PRELIMINARY STUDY OF THE DISTRIBUTION OF EUPHAUSIACEA FROM IIOE

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2146 samples of zooplankton, 1909 of which were collected according to the standard method prescribed for vessels participating in the International Indian Ocean Expedition, are being processed at the Indian Ocean Biological Centre. The samples are first sorted into component taxa—Copepoda, fish larvae, Chaetognatha, etc. This report deals with the geographical distribution of the Euphausiacea, based upon 1280 standard samples sorted by January 1967. The numerical importance of euphausiids in relation to other taxa is discussed.

Densities of euphausiids averaged for all samples within each 10° increment of longitude show that highest values are found on the western side of the ocean. There is a gradual reduction of density toward the east, but with a secondary peak at 80-90° E, the longitude of the western half of the Bay of Bengal.

Densities considered on a north-south basis show a picture of progressive diminution toward the southern part of the ocean, 45° S. The patterns hold for both seasons considered: April-October and October-April. Observed night-time densities for euphausiids are as much as twice as great as daytime densities. The two sets of values are therefore plotted separately.

Throughout the year, maximum number of euphausiids were found in the western-most

tropical part of the ocean, particularly off Arabia and Somaliland, agreeing with findings for most other taxa. Densities in the Bay of Bengal and in waters south of Java were somewhat higher during the southwest monsoon than during the opposite season.

A discussion of the distribution of separate euphausiid species in an equatorial zone (5°N - 5°S) is based on *Argo* samples from the full breadth of the ocean. Typical Indo-Pacific species are dominant, but surprising numbers of individuals representing faunas from mid-latitudes are mixed in, particularly toward the west and in the zone 0 - 5°S .

27

Sec. IV

STUDIES ON THE MATURITY AND SPAWNING OF SILVER POMFRET, *PAMPUS ARGENTEUS* (EUPHR) IN THE ARABIAN SEA

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The paper presents the results of investigation carried out during 1962-64 to study the maturation and spawning of SILVER POMFRET *Pampus argenteus* (Euphr) in an area between the Gulf of Kutch and Cambay. Observation on the occurrence of various stages of maturity during different months and statistical study of intra-ovarian eggs suggest that the species has a prolonged spawning season extending between February and August, with the probable intensive spawning during April-June. Seasonal variation in the condition factor and the gonadosomatic index corroborate this.

Occurrence of large number of post-larvae and juveniles at depth between 24 and 30 metres off Nawabundar ($20^{\circ}44' \text{N}$; $71^{\circ}05' \text{E}$) and Jafarabad ($20^{\circ}52' \text{N}$; $71^{\circ}22' \text{E}$) indicates that *Pampus argenteus* spawns in the coastal waters along the south and south-eastern part of the Kathiawar Peninsula. A steady improvement in the fishery in this region

from February to May might be the result of the congregation of fish in the spawning ground.

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Sec. III

THE MARINE GASTROTRICHA FROM THE INTERSTITIAL FAUNA OF THE SOUTH-WEST COAST OF INDIA

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NAIR

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No account has hitherto been published on the gastrotrichs of the Indian coasts. This paper reports the occurrence of seven species of marine interstitial gastrotrichs belonging to the order Macrodasyoidea from the South-west coast of India. Full descriptions and suitable illustrations are given emphasising the ecotypical variations noticed in these forms together with the nature of the substratum, and geographical distribution of each species. Of the seven species reported, six namely, *Tetranchyroderma suecica* Boaden, *T. massiliense* Swedmark, *Pseudostomella roscovita* Swedmark, *Macrodasys caudatus* Remane, *Pleurodasys megasoma* Boaden and *Paradasys turbanelloides* Boaden have already been recorded from the European coasts indicating the wide distribution of these interstitial forms. One species *Macrodasys indicus* is described as new to science.

29

Sec. I

RADIOTRACER EXPERIMENT TO STUDY BED MOVEMENT AT SETHUSAMUDRAM CANAL SITE

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A radiotracer technique has been employed for the study of movement of silt on the sea bed to check the suitability of the proposed alignment of the canal for the Sethusamudram Project near Madras. The tracer used was

glass powder incorporating 60 curies of Scandium-46, with particle size to match the sea bed silt. The preparation of the tracer is described. The injection of the silt was effected by remote control and the material deposited on the sea bed.

The movement of the radioactive patch on the sea bed was followed by special underwater detectors. The method of scanning for obtaining the activity contour maps is also described.

The study indicated that the bed movement in the area during the north-east monsoon period was along the alignment proposed for the Sethusamudram canal.

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Sec. III

A PRELIMINARY REPORT ON THE DISTRIBUTION AND ABUNDANCE OF PLANKTONIC OSTRACODS IN THE INDIAN OCEAN

JACOB GEORGE

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This paper deals with the abundance of planktonic Ostracoda, as a whole, based on the data from the I.I.O.E. collections. The average number of ostracods in each 5 Marsden square has been plotted, and change in the size of regional populations is shown between NE and SW Monsoon periods. It is observed that the density of total Ostracods is remarkably high in the northern part of the Arabian Sea during both seasons.

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Sec. IV

EXPLORATORY TRAWLING OFF THE SOUTH WEST COAST OF MYSORE BY M. F. V. TARPON, NOV. '60-MAY '65.

K. M. JOSEPH

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A brief review of the results of the exploratory trawling carried out by the vessel

M.F.V. Tarpon of the Deep Sea Fishing Organization of the Govt. of India in the Offshore waters between the latitudes of 12°N and 14°N and the longitudes of 74°E and 75°E during the period from November, 1960 to May, 1965 is given.

The design and the rigging of the gear and the methods of investigation are briefly described.

The general productivity of the area in terms of fish catch per unit of effort has been worked out for the different years.

The species-wise composition of catch with special reference to prawns has been discussed. Besides seasonal variations in the productivity as well as in species composition have been illustrated.

A comparative study has been made between the productivity of the different fishing centres in the area of survey on the one hand and between other areas along the west and east coasts on the other. The commercial possibilities of trawl fishing in the area have also been discussed in detail.

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Sec. III

FIELD AND LABORATORY INVESTIGATIONS ON SOME MARINE FOULING AND BORING ORGANISMS IN BOMBAY HARBOUR

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The desirability of carrying out field trials of antifouling paints in tropical waters was recognised even before the beginning of the second world war. It has been fully recognised now that owing to high water temperature, fouling growth in tropical waters is considerably severe and that the rate of loss of toxins from the protective films is far too rapid as

compared to temperate waters. Recent records of some new destructive fungi, crustacean borers and copper resistant bryozoans in Indian waters have shown the severity of the fouling and borer problem in this region.

The biological method of assessment of leaching rates and antifouling capabilities of toxic formulations have been now accepted as a useful tool in the hands of those engaged in marine fouling control. Many marine organisms are being increasingly used as test organisms for the accelerated laboratory screening of the candidate toxins.

The present paper describes our observations on the important fouling and boring species incident in Bombay waters and also incorporates notes on some of those reared in the laboratory with a view to using them as the test organisms for the laboratory bio-assay method.

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Sec. II

A REVISION OF THE STRATIGRAPHY OF ANDAMAN & NICOBAR ISLANDS, INDIA.

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Geological Survey of India, Calcutta.

Geological studies in the Andaman and Nicobar Islands commenced as early as 1840 with the examination of certain parts of the Nicobars by Dr. Rink, Geologist on board the Danish ship *Galathea* while on a scientific cruise round the world.

Hochstetter (1858), Ball (1870), Oldham (1885), Tipper (1911), Gee (1926) and others carried out geological investigation from time to time in various parts of the islands.

The Geological Survey of India initiated systematic geological mapping of these islands quite recently. In course of this work it was felt necessary to revise the older nomenclature

of the stratigraphic succession of the Andaman and Nicobar Islands by certain modification of the existing nomenclature, abandoning certain parts of it and introducing a few others. This revised classification has been proposed to take account of all the members, formations and groups, so far known, from these islands. The modifications are in accordance with the terms and recommendations of the Commission on Stratigraphic Nomenclature.

In revision of the Older Sedimentaries and Saddle Hill phase, Port Blair Series and Archipelago Series of previous authors, the rocks are classified into the following Groups viz. Older Sedimentaries, Ophiolite, Mithakharis, Andaman flysch, Archipelago, Rutland etc. The Groups are sub-divided into Formations and Members where necessary.

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Sec. III

PLANS AND FIRST DRAFTS FOR THE ATLAS ON CHEMICAL BIOLOGY OF THE INDIAN OCEAN.

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The atlas on the chemical biology has been achieved by the IOC after having heard the respective committees of experts engaged in the total program of investigations of the Indian Ocean. As further parts the following atlases are under preparation: meteorology, physical oceanography, geology, and geophysics, and zooplankton. Following the conclusions of the IOC-Assembly this part of the total atlas-work should present the following sections:

1. Primary production
2. Chlorophyll *a*
3. Chlorophyll *c*
4. Carotinoids
5. Phytoplankton (biomass by plasma volume)
6. Particulate carbon
7. Total phosphorus

8. Particulate phosphorus
9. Protein
10. Seston
11. Discoloured water

Several parts of the Indian Ocean where an extensive work in this field has been carried out, will be represented in a larger scale (e.g. 1:5,000,000). The emphasis is now put on giving an idea what the entire Indian Ocean looks like, drawn on charts of the scale 1:15,000,000 in an equal area projection. Presently several projections are under discussion, e.g., the Mercator projection for meteorologists, several equal area projections, e.g., one with straight line parallels, one with curved parallels. This last one has the advantage that the area south of 45°S are easily to be compared in area with those near the Equator. This is rather advantageous for all observations of living material, their pre- and post-substances.

The part on Chemical Biology is concerned with ecological problems. Therefore it will be necessary to find out first of all the boundaries of the large-scale-waterbodies. This is not too difficult for the surface area, where mean monthly charts of the main currents have been made available by the Dutch Institute of Meteorology on the basis of an enormous number of observations. These are given in a more or less schematic chart for all months of the year. In contrast to this the temperature does not give so very characteristic areas.

It is necessary to use mean boundaries because the material of these observations is spread over a good number of years, exceeding the period of the IIOE 1959-65. According to the observations made the above mentioned scheme of different charts will be followed.

Unfortunately these observations have been made by different methods. Initially a very careful revision of methods must take place before drawing the final drafts. Presently we are engaged with this task with special

reference to the methods of determination of chlorophylls. In 1965 just after the IIOE had been finished—UNESCO edited a standard procedure for the analysis of chlorophylls. This is surely quite near to the optimum procedure, but it was too late to be applied by all expeditions to the Indian Ocean. So, first of all, we have to look critically on the methods applied and we have to compare especially the different types of photometers. Because of that very narrow peak of chlorophyll *a* in 664 nm an incorrectness in the wave-length as well as a difference in the band-width may cause surprising effects. This may also be valid for the determination of particulate carbon etc.

But in order to give a rough idea about the Indian Ocean, we tried to draft charts with the uncorrected values of chlorophylls, and were confronted with several problems. First of all the number of observations is small—compared with those of the physical oceanographers. And these values are in most cases spread irregularly over the whole year. But we know about the very changing boundaries of the large scale ecological waterbodies. So we must be aware that this first and preliminary draft will not have too much ecological meaning, even if the chart of average chlorophyll values from the surface looks quite reasonable.

Further on we must compare the thickness of the surface layer with the chlorophyll quantity below 1 m². Two charts may demonstrate this.

The next step will be to get an idea about the annual cycle of the chlorophyll concentrations. This is possible for the section of 110°E, where our Australian colleagues did very fine work. It was even possible to draw seasonal sections of the concentration of the particulate carbon in this area.

If we compare the quantities of chlorophyll *a* and particulate carbon in the surface layer we get a rough idea of the utilization of the primary production. Two diagrams of this type may demonstrate this.

SEAWEED DRIFT ON THE INDIAN SEA SHORE

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Although various attempts have been made to estimate the quantity of seaweed washed ashore in certain parts of the sea coast in India, no scientific study of this phenomenon has been made, nor an estimate attempted for the entire coast of the country. Such a study was undertaken as a part of a programme of survey of seaweed resources of the country and the results of such a study are presented here. A preliminary study showed that heavy drafts of seaweeds occur only in certain sections of the Indian coast and are in many places a seasonal phenomenon.

Where sea weed drift occurs throughout the year, there are seasonal fluctuations in amount.

The drift depends on prevailing wind incidence of monsoon, current patterns in the sea and the topography of the seashore. In all places the drift consists of local species only and not those occurring on far off shores.

It is suggested that the data obtained in such a study will be valuable in obtaining an idea of the submerged marine vegetation in the locality with regard to both their biology and locality with regard to both their biology and availability. Freshly cast up sea weeds are as good as harvested weeds so far as their utilisation is concerned as evidenced by a chemical analysis of samples of the drift sea weeds.

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Sec. II

GEOLOGICAL EVOLUTION OF THE INDIAN COAST LINE

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The Peninsula of India acquired its shape during the Jurassic and Cretaceous periods. The swamps and estuaries between the Raj-

mahal Hills and Ramnad which were formed in the Upper Jurassic were the precursors of the marine transgression in the Cretaceous. The Trichinopoly, Bengal and Assam basins were filled by marine sediments during the Tertiary.

The northern part of the western coast may have been formed in the Permian. It connected the Salt Range with the Narmada valley through Rajasthan and Kutch from the Jurassic to the Middle Tertiary. The same coast extended south over western Madagascar as that Island seems to have been attached to the southwest of the Peninsula until the Upper Cretaceous. The separation of India from Madagascar in the Upper Cretaceous led to the intermingling of the Mediterranean and Indo-Pacific faunas. This fracture apparently extended north into the Gulf of Cambay and beyond during the early Eocene.

A marine regression in the Oligocene was followed by a transgression in the Miocene. The coasts were finally faulted down in the Plio-Pleistocene with simultaneous uplift of the southern part of the Peninsula. A further uplift may have taken place during the Pleistocene; evidences for this are found in Kathiawar, Kutch, and in some places along the other coasts. Fluctuations of the coast during the Pleistocene and Recent periods are indicated by submerged or raised beaches, forests, shell banks and other features. Detailed investigations should now be undertaken to study the Pleistocene along the coasts and in the deltas in order to understand the coastal processes.

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Sec. IV

THEORETICAL YIELD STUDIES ON THE LARGE SCALED TONGUE SOLE, *CYNOGLOSSUS MACROLEPIDOTUS* (BLEEKER) FROM THE ARABIAN SEA.

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Theoretical yield values of *C. macrolepidotus* were computed from a simple Beverton and

Holt type model which includes information on growth and mortality rates. The effects of various fishing mortality rates (F) and ages of exploitation (T_p) on yield were considered at three different natural mortality rates, $M=0.4$, 0.5 and 0.6 , since the calculated natural mortality was found to range from 0.4 to 0.575 . The conclusion drawn from the simple model is that when $M=0.4$, fish of 2 years and older may be fished up to F greater than 0.5 ; when $M=0.5$, fish older than 1 year and older may be fished at F less than 1.15 and when $M=0.6$ fish of 1 year and older may be fished up to $F=1.8$. A precise estimate, however, of a T_p required to give the maximum yield for a given F can be determined from the eumetric fishing curve.

The yield of *C. macrolepidotus* has been found to be low in relation to the fishing intensity. This may be because of high natural mortality (M), high rate of deceleration in growth increments (K), and low asymptotic weight (W_∞). The optimum age of exploitation is also low in this fish probably because the growth is largely confined to the first few years and M is high.

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Sec. III

REPRODUCTIVE AND NUTRITIONAL CYCLES IN A FEW INVERTEBRATES FROM THE EAST COAST OF INDIA.

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Systematic study of the gonad and hepatic index of a few invertebrates have shown that on the basis of their breeding behaviour they can be classified into 3 groups: 1) Continuous breeders. e.g., the sea-urchin *Stomopneustes variolaris*; the crab, *Portunus pelagicus*, the prawn, *Penaeus indicus*. 2) Bi-annual breeders e.g., the squids, *Sepia aculeata*; *Sepioteuthis*

arctipinnis the holothurian, *Holothuria scabra*. 3) Annual breeders, e.g. the starfish, *Oreaster hedemanni*.

In many of these forms, there is an inverse relationship between the gonad index and hepatic index.

With an increase in gonad index, there is an increase in lipids, carbohydrates, total nitrogen, non-protein nitrogen and protein. Prior to maturity there is a decrease in nitrogen and protein level. In *Oreaster hedemanni* there is complete depletion of lipids in January, indicating their possible utilization. With the formation of gametes, protein level increases in the gonad indicating its probable synthesis. With onset of maturity, the organic constituents of pyloric caecae in *Oreaster* get reduced, suggesting transfer of material to the gonad. In *Oreaster*, with increase in protein content of the gonad, there is an increase in the RNA. Further, the RNA occurs in greater amount in the ovaries than testes where DNA gives a higher figure.

Various environmental factors may have an influence and these are discussed.

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Sec. III

STUDIES ON THE BENTHOS OF THE SOUTH WEST COAST OF INDIA

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A preliminary survey of the bottom fauna and bottom deposits of the Travancore coast up to the 15 fathom line was carried out during 1943-46. As a continuation of the above work, a detailed investigation of the benthos from 125 stations from Mangalore in the north to Puvur in the south and extending up to a depth of 200 fathoms was conducted during 1958-66 using Petersen grab, Van-Veen grab, Naturalist's dredge and 6 ft beam trawl.

Though the distance of the 100 fathom line from the shore vary at different places, four main zones may be distinguished considering the nature of the bottom—a region of gravel and sand upto 2 or 3 fathoms except at the mud bank and rocky regions (2) a region of soft mud or rock extending upto 10 fathoms (3) a region of fine sand or greenish sand and mud upto 50 or 60 fathoms and (4) a hard bottom with black and white sand mixed with salt and shell fragments and rocks beyond 60 fathoms.

A study of the benthos from the above stations shows that in the region under investigation there is a close relation between the nature of the bottom deposit and the bottom fauna. The benthic biomass varies from 0.5 gm/m² in a gravel and sandy bottom with very small percentage of silt as in the offshore regions, to 500 gm/m² in a fine sand and silty bottom within 15 fathoms. A biomass of 10 kg/m² constituted by *Meretrix sp* and Polychaetes has been observed in the Cochin barmouth (6 fathoms) in a deposit of gravel and clay inspite of the great tidal scour that exists here. Similarly at some stations in the offshore regions, a biomass of 6 kg/m² has been observed at 100-180 fathoms mostly made up by 'ascidian matting'. Some amount of species has been observed in the inshore regions, but beyond 25 fathoms seasonal variations are insignificant.

The meiobenthos is maximum in the mud bank regions where the organic matter reaches as high as 4.5% and the nematodes constituting the dominant group occupy mostly the upper 2-3 cms of the bottom mud. The microbenthos is well represented by ciliates with the maximum in the inshore regions. Animal communities and parallel communities have also been observed within 10 fathoms. Analysis of the macrobenthos shows that the maximum number of species as well as individuals occur within 20 fathoms in a deposit formed of fine sand mixed with a small percentage of silt.

A study of the hydrographical conditions, bottom deposit and benthos of the Cochin harbour area (estuary) has been made at 37 stations. The results show that inspite of the high variations in salinity at the bottom in most of the places the intensity of benthic biomass at the stations outside the shipping channels is high reaching upto 450 gm/m² (macro-fauna 15000 individuals/m²). Higher values of biomass upto 5 kg/m² also have been observed in the estuarine conditions, constituted by beds of *Mytilus*, *Modiolus* and Polychaetes.

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Sec. I

STUDIES OF OCEANIC CIRCULATION IN THE BAY OF BENGAL

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Water motion in the Bay of Bengal and the Andaman Sea has been investigated on several oceanographic cruises conducted by Andhra University, on the first cruise of the R/V *Anton Bruun* in the Spring of 1963, and by other vessels. The Northeast and Southwest Monsoon winds largely control the surface circulation, resulting in clockwise or counter clockwise circulation of the entire Bay as well as large gyral circulations in different areas of the Bay.

During the first part of the *Anton Bruun* cruise the NE monsoon winds prevailed, resulting in peripheral upwelling along the Burmese coast. During the latter part of the cruise upwelling developed along the east Indian Coast.

Other circulations caused by tidal currents result in tidal ranges in the northern part of Bay which are the greatest in the world. Tidal current action across the continental shelf also results in sediment sorting with the coarsest sediment found on the central outer shelf.

Unusually high internal waves, manifested as tidal rips at the sea surface, were recorded.

The horizontal and vertical circulations influence the chemical and physical properties of the water as well as the distribution of organisms. Upwelling, though short lived, also affects organic production in the Bay of Bengal.

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Sec. II

STUDIES ON THE SHELF SEDIMENTS OFF THE MADRAS COAST

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Samples collected from the shelf and slope regions along two sections normal to the coast off Madras and Karaikal and from a few stations in between have been studied for their grain size, Calcium Carbonate content and coarse fraction constituents. Grain size study has shown that the sediments off Madras are mainly sandy in nature and vary from fine to very fine sands in the nearshore and outer shelf regions to medium to coarse sands in the midshelf region. Off Karaikal they vary from coarse sands in the nearshore region to fine sands and silts in the outer shelf and slope regions. The Calcium Carbonate content increases progressively with depth along these two sections and varies from 1.75% to 37% off Madras and from 6% to 54% off Karaikal. Coarse fraction studies have revealed among other things the occurrence of oolites in association with shallow water benthic foraminifera like *Rotalia beccarii*, etc., in sediments beyond 30 fathoms depth, from which it was deduced that these sediments might have been laid down when the sea level was relatively lower than the present-day level and were not covered by the present day deposition of terrigenous sediments.

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Sec. II

HEAVY MINERALS OF SHELF SEDIMENTS BETWEEN VISHAKHAPATNAM AND THE PENNAR DELTA, EASTERN COAST OF INDIA

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The heavy minerals of 36 samples collected from 27 stations off the eastern coast of India between Vishakhapatnam and the Pennar Delta consist of garnet, sillimanite, zircon, monazite, epidote, apatite, hornblende, pyroxene, rutile, tourmaline, opaques (mainly magnetite) and glauconite.

The heavy mineral assemblage indicates that the sediments have mainly been derived from metamorphic and igneous rocks occurring in the catchments of the Godavari, Krishna and the Pennar rivers.

The paper outlines the statistical data on the heavy minerals and significance of variations in their percentage along and across the shore. The variation in the heavy mineral suite appears to be related to the different source areas of the rivers contributing sediments to the area. The distribution of the minerals has also been affected by specific gravity, size, shape, of the minerals and by the current and shelf characteristics.

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Sec. IV

FLYING FISH, *HIRUNDICHTHYS SPECULIGER* (VALENCIENNES). FIRST OCCURRENCE IN THE INDIAN SEAS

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During the 3rd Cruise of the "INS KISTNA" in connection with the International Indian Ocean Expedition, two specimens of the flying fish, *Hirundichthys speculiger* (Val.), 150-250 mm long were collected

at Station No. 21 (Lat. 8° 00' N. Long. 74° 00' E). This occurrence of *H. speculiger* in the Arabian Sea, off Cochin is of special interest because it represents not only a new addition to the Indian marine fauna but a new record for the entire western part of the Indian Ocean. It has so far been known only from the eastern part of the Indian Ocean (Sumatra, Singapore, Java Sea, Straits of Sunda, Ambon and Banda), the West-Pacific, the Central Pacific and the Western and the Eastern Atlantic Oceans. In its circumtropical distribution *H. speculiger* thus leaves a gap only in the West-coast of America.

H. speculiger is a distinct species characterised by the presence of teeth on the palate and a prominent hyaline band on the lower middle part of the pectoral fin. *H. oxycephalus* (Bleeker) and *H. coromandelensis* (Hornell) are the two other members of the genus known from the Indian seas. The distinguishing characteristics and distribution of these three species are discussed in the paper.

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Sec. III

PRELIMINARY STUDIES OF THE DISTRIBUTION OF PLANKTONIC ANTHOZOA (COELENTERATA) IN THE INDIAN OCEAN

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On the basis of the systematic sampling carried out by the International Indian Ocean Expedition from July 1962 to June 1965, a preliminary attempt is made to interpret Indian Ocean zoogeography from the standpoint of the widespread meroplanktonic stages of the class Anthozoa.

This study deals with the distribution of seven groups of anthozoan larvae. The material is from collections made by *Discovery* during June-August 1963 and March-September 1964 in the tropical zone of the western half of the Indian Ocean.

The qualitative and quantitative aspects of distribution are presented in as much detail as the records seem to warrant.

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Sec. I

COASTAL AND NEARSHORE PROBLEMS OF THE SOUTH-WEST COAST OF INDIA

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Kerala State is a relatively narrow strip of land bordering the Arabian Sea in the South-west part of India. The Southerly boundary of the State is about 80 km (50 miles) from Cape Comorin which is the junction of the Arabian Sea, the Bay of Bengal and the Indian Ocean. The north-south coast line is about 560 km in length. Most part of the coastal area is characterised by a barrier strip of land between the Arabian Sea and a chain of back-water areas. There are many river outlets which are closed during the non monsoon period by littoral processes and are open for some length of time during and following the southwest monsoon period.

Heavy mineral deposits ranked as the world's largest and richest occur in the 40 km length of coast and nearshore areas of south Kerala. Laterite outcrops are seen at two regions along the coast—at Varkala in the south and at Tellicherry-Cannanore in the north.

The formation and movement of mud banks is a phenomenon peculiar to the coast of Kerala. Their nature, origin, behaviour the possible causes of formation of mud banks, their movements and effect on the shores are also briefly dealt in the paper.

Coastal erosion has become a severe problems in Kerala. Nearly 300 km of coast is affected by the erosion problem which is severe in many sectors. Erosion of the shore of this and by waves and tide induced currents result in damages and loss of dwelling and agricultural crops. During the past twenty years the

problem has intensified as beach front areas become developed and subject to great damages from the forces of the sea. Construction of marine structures as breakwaters, piers approach channels as part of port and harbour development also has its effect on the shores.

This paper presents the technical data of coast and nearshore of Kerala that are developed to study the erosion problem. These include the investigation of the past history from available records and the investigation of present conditions by means of survey and field observations. The factors pertinent to problem dealt in the paper is the following.

Geomorphology of the beach area.

Shore history.

Shore line and offshore bottom changes.

Volumetric erosion and accretion

Direction, rate and variability of littoral transport.

Characteristics of beach material.

Wind, waves, Tides, and currents pertinent to the littoral zone.

Effect of inlets and river outlets.

Mudbanks and their effects.

Data of the existing marine structures and of other concitive constructions to control erosion are also presented. A preliminary study of these structures and its effect on the adjacent shores is also made.

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Sec. I

UPWELLING ALONG THE EAST COAST OF INDIA

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An examination of the physical characteristics of the shelf waters off Karaikal in the premonsoon period and off Madras and Waltair in the premonsoon and monsoon periods reveals the presence of upwelling along

the east coast of India but with the following differences:

1. Off Madras and Karaikal upwelling seems to be weak. Waters from shallow depths reach the surface nearshore and there is no marked lowering of the surface temperature near the coast.
2. Upwelling is prominent off Waltair during the premonsoon and monsoon periods. Waters from the deeper layers of the shelf appear to reach the surface causing considerable fall of surface temperature near the coast particularly during the latter period.

The probable causes for these differences in upwelling along the coast are indicated.

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Sec. II

DISTRIBUTION OF PHOSPHORUS IN THE MARINE SEDIMENTS OFF THE EAST COAST OF INDIA

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Sediment samples collected from the shelf and slope regions off the east coast of India between 'Swatch of no ground' in the north and Karaikal in the south, have been analysed for their total phosphorus content and its distribution studied. This study has shown that the shelf sediments in the region between Chilka Lake and 'Swatch of no ground' are uniformly rich in their phosphorus content while the sediments in the region between Masulipatam and Pulikkat Lake are uniformly poor with those in the regions between Visakhapatnam and Masulipatam and Pulikkat Lake and Karaikal coming in between. This distribution pattern of phosphorus has been discussed in relation to the phenomenon of upwelling, biological productivity and the influence of river systems.

RADIOCARBON DATE OF AN OOLITIC SAND COLLECTED FROM THE SHELF OFF THE EAST COAST OF INDIA

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A composite sample consisting of oolites and littoral shells collected from the shelf at 70 fathoms depth off the east coast of India, under a 12-inch blanket of Recent Godavari Deltaic sediment, was dated by the C-14 method. Assuming the half-life of radiocarbon to be 5568 ± 30 years, the date obtained for the oolitic sand was 10800 ± 155 years B.P. From this date the following tentative conclusions are drawn:

1. The change in climate off the east coast of India leading to the warming up following the last glaciation was quite abrupt, and took place around 10800 ± 155 years B.P. This view is in conformity with the evidence earlier collected by Broecker *et al.* (1950) for an abrupt change in climate close to 11,000 years ago.

2. The deposition of Recent sediments of the Godavari Delta in the Bay of Bengal was initiated not earlier than 10800 ± 158 years from now.

To substantiate the foregoing conclusions it is suggested that a more systematic dating of oolites along the shelf off the east coast of India be carried out.

CURRENT MEASUREMENTS AT ANGRIA BANK IN THE ARABIAN SEA

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In studies on the distribution of radioactivity in the sea, a knowledge of the sea currents is

an essential pre-requisite since the currents transport radionuclides, both dissolved and particulate. In a programme of work on radioactivity along the West Coast of India, current measurements were carried out at two stations (I: $16^{\circ}34' N$, $72^{\circ}01' E$; II: $16^{\circ}25.6' N$, $72^{\circ}06' E$) in the Angria Bank in the Arabian Sea.

An Ekman-Merz Current Meter was used for measuring the currents over periods of 26 hours covering two tidal cycles. Current speeds at Station I ranged from 0.17 to 0.63 knots at the surface, 0.41 to 0.62 knots at mid-depth and from 0.36 to 0.74 knots at the bottom. The corresponding ranges at Station II were 0.16—0.58, 0.32—0.76 and 0.24—0.75 knots.

An analysis of the data indicated steady currents with an average velocity of 0.23 knots at station I and 0.29 knots at station II. The current directions were west southwest at Station I and west at Station II. This was in accord with the inference on water movements based on salinity-temperature data at the Bank.

CURRENT MEASUREMENTS OFF MORMUGAO

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On a request from Central Water and Power Research Station, Poona and Mormugao Port Trust, Mormugao, a preliminary study of the current pattern was undertaken off Mormugao during January 1967. Currents were measured at three stations ($15^{\circ}23'30'' N$, $73^{\circ}47'18'' E$; $15^{\circ}24'33'' N$, $73^{\circ}46'44'' E$; $15^{\circ}24'40'' N$, $73^{\circ}44'25'' E$), at hourly intervals for 26 hours, using an Ekman Current Meter. Measurements were made at three depths at each of the stations. Simultaneously tidal elevation studies were

also made at hourly intervals for the same period at all the three stations.

This hydrographic study off Mormugao has revealed a number of very interesting possibilities of the physical oceanographic situations at the locations. The tidal elevations ranged from—0.15 m to 2.0 m and currents were comparatively weak not exceeding 0.80 knots. The observed currents were mostly towards northwest, with practically no southerly component. The steady currents were also directed towards northwest and ranged from 0.04 to 0.60 knots in speed. This may be due to the bar effect of the St. George's group of Islands situated southwest of Mormugao.

In view of the special situation obtained in this location, it will be of interest to conduct detailed studies in the area around the year with a view to obtain the hydrological balance and seasonal current patterns.

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Sec. II

SIZE DISTRIBUTION AND CARBONATE CONTENT OF THE SEDIMENTS OF THE WESTERN SHELF OF INDIA

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Sediment samples collected during the 25th cruise of I.N.S. *KISTNA* (Indian Programme of IIOE) were analysed for grain size and carbonate content. The shelf sediments show well defined zonation, except where river-borne sediments tend to mark this zonation, as off Bombay, and the zones have been classified into two categories. (1) The inner-shelf, upto a depth of 20 fms is characterised by high rates of sedimentation and composed of recently deposited silts and clays with low carbonate values ($>20\%$). (2) The outershelf (approximately 20 fms to 70 fm) is a zone of

Relict sediments, having relatively low rates of sedimentation and composed of fine to medium sands. Occasional patches of coarse iron-stained sands and pebbles are also present. The carbonate content in this zone is high (30—80%) being contributed largely by molluscs with minor amounts due to Foraminifera and other organisms. At slope depths (<70 fms.), the outershelf sands grade into foraminiferal sands.

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Sec. IV

FISHERY RESOURCES OF THE INDIAN OCEAN

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The paper gives a critical account of the fishery resources of the Indian Ocean against the background of oceanographic features. The existing resources are principally the clupeoids, scombroids and crustaceans with many smaller fisheries distributed in restricted regions. Although the Indian Ocean fisheries as such includes widely distributed species, their concentration in commercial quantities to form large-scale fisheries is influenced by many factors. Two broad patterns in the resources are obvious, namely the Southern temperate fisheries represented along South African and Western Australian Coasts and the fisheries of rest of the Indian Ocean. In the latter category, we have the fisheries of Arabian Sea region where the neritic—pelagic groups have a high importance and those of Bay of Bengal region with an overall pattern entirely different from the west coast of India. Judged by the physical, chemical and planktonological features, the Gulf of Aden, the Gulf of Oman, South-Western Coast of India, the sea east of Andamans, the areas to the north and south-west of Australia are some of the productive areas.

The sardines, mackerel, tuna, prawns and

lobsters are some of the groups which offer considerable scope for increased production. The shell fisheries are particularly important in the region and the yields from cultural practices for the Coastal species could be increased considerably. The smallness of stocks and the lower density of population call for newer techniques in fishing and better utilization of knowledge concerning oceanographic features, particularly relating to temperature and oxygen. In regard to biological and oceanographical features, the Arabian Sea presents many complex problems, yet it is one of the most highly productive areas of the Indian Ocean. The future of Indian Ocean fisheries is one of moderate optimism, because the indications are that the present yield of 2.5 million tons could be increased to at least 10 million tons in the coming few years and is capable of a ten-fold increase towards the close of the century.

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Sec. III

RADIOACTIVITY AND TRACE ELEMENT LEVELS IN MARINE ORGANISMS FROM THE WEST COAST OF INDIA

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Surface plankton and species of fish and shell-fish from the Arabian Sea were examined for content of radioactivity and trace elements.

In surface plankton, the gross alpha activity varied from 0.4 to 1.0 uuc/g dry weight and the gross beta activity from 7 to 12 uuc/g dry weight.

Gamma spectra of the marine organisms indicated the presence of cesium-137 and potassium-40 in the samples.

The plankton samples were analysed for manganese, zinc, copper and iron by atomic-absorption spectrophotometry.

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Sec. III

A PRELIMINARY REPORT ON THE GENERAL DISTRIBUTION AND SEASONAL VARIATION IN ABUNDANCE OF PELAGIC POLYCHAETES IN THE INDIAN OCEAN

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Pelagic Polychaetes in the IOOE collections are being examined in order to study the general pattern of distribution and seasonal variations in abundance. The change in abundance between southwest and northeast monsoon periods has been illustrated for Tomopterids and for the lumped totals of all other planktonic polychaetes. For the sake of convenience and better understanding, the whole area of the Indian Ocean is divided into six regions and the densities of pelagic polychaetes are compared with one another. It is observed in general that the highest abundances of polychaetes are in the areas recognized as regions of upwelling.

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Sec. IV

LARVAE OF RASTRELLIGER KANAGURTA (CUVIER) FROM THE INDIAN OCEAN

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Rastrelliger kanagurta (Cuvier) is widely distributed in the Indian Ocean and this single species contributes largely to the mackerel fishery of India. But very little is known about its spawning and larval stages. The published records of young specimens are only of a few juvenile stages. No detailed account of its early larval stages and spawning grounds is

available. This paper deals with the description of a few early larval stages of *R. kanagurta* caught from the Indian Ocean during the International Indian Ocean Expedition.

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Sec. IV

PRELIMINARY REPORTS ON THE DENSITY OF FISH EGGS AND LARVAE OF THE INDIAN OCEAN

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The paper deals with an estimate of the total fish eggs and fish larvae calculated for each 5° Marsden square in the Indian Ocean. Charts showing the numerical abundance of fish eggs and larvae for the Southwest Monsoon and Northeast Monsoon and also for day and night periods are represented.

A volumetric estimation of fish larvae in relation to the total bio-mass of zooplankton has been made for purposes of a comparison of the day and night collections made during the two monsoon seasons.

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Sec. V

CROSS-EQUATORIAL AIRFLOW OVER THE INDIAN OCEAN

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Upper wind data of equatorial stations of the Indian Ocean show that the average northward flux of air across the equator, during the northern summer, is small and confined to the lowest one or two kilometres of the atmosphere. The mean flux of air in the equatorial longitudinal belt 80°E to 100°E corresponds to a southerly wind of 6—8 knots and that in the belt 40°E to 60°E to a southerly wind of 2—4

knots. The flux in the belt 60°E to 80°E is relatively negligible. During the northern winter, the fluxes in these three longitudinal belts have practically the same magnitudes as in summer, but are oppositely directed.

The observations of upper-air humidities, made during the northern summer over the equatorial longitudinal belt 40°E to 80°E, indicate that the moisture there is confined to the lowest kilometer, the air aloft being rather very dry. The dryness over this belt can be explained as due to subsidence deducible from considerations of either (a) vorticity advection or (b) trajectory diffluence.

With the observed, though spacially scanty, humidity and wind data over Gan Island, Seychelles and Nairobi, the water-vapour fluxes from the southern hemisphere into the northern have been computed over the longitude belt 40°E to 75°E, for the month of July (1963 and 1964). The flux was found to be nearly half of the corresponding eastward flux across the west coast of India (extended to the equator). As the cross-equatorial flux is transported eastwards mostly south of 10°N, a significant part of the monsoon water vapour flux across peninsular India consists largely of water vapor evaporated from the Arabian Sea itself.

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Sec. V

THE INDIAN OCEAN AND ITS INFLUENCE ON THE METEOROLOGY OF THE ADJOINING LANDS

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The upper-air flow patterns over the Indian Ocean and the adjoining lands, constructed using all available data upto 1963, show the existence of two wind troughs on either side of the equator. The two troughs exist even during the height of the southwest monsoon; the first is the well known trough extending from the Persian gulf to Bengal and north Burma across Baluchistan; the other much less

known trough, just south of the equator, extends from Seychelles to south Borneo. The two troughs persist throughout the year; the northern trough shifts, southwards to about $12^{\circ} 3' \text{N}$, in December, while the southern trough shifts to about 10°S . These wind troughs on either side of the equator exist in the Western Pacific also, but perhaps not in the Atlantic nor over the land areas of Africa and Brazil, where only the summer trough exists.

The global cloud patterns deduced from the TIROS, NIMBUS and ESSA weather satellites exhibit cloud maxima in the neighbourhood of these troughs, the maximum in the summer hemisphere being more marked than the one in the winter hemisphere. The radiation data obtained by the weather satellites also indicate a minimum of outgoing long wave radiation over the two wind trough regions.

The flow patterns over the Indian Ocean determine the regions of low level convergence and moisture flux into the adjoining land areas—the basic parameters for the determination of the rainfall regimes of these land areas. The seasonal changes in the rainfall regimes *vis-a-vis* these flow patterns over the Indian Ocean are discussed. Agriculture, based on seasonal rainfall, is the principal industry in the developing countries bordering the Indian Ocean. Hence the year-to-year fluctuations in the seasonal flow patterns in the upper air are of great consequence to the economy and welfare of the population of these countries.

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Sec. IV

FISHERY AND BIOLOGY OF *PSETTODES ERUMEI* (SCHNEIDER), AN INDIAN OCEAN FLAT FISH

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Fishery

A brief review of the methods of fishing, and the magnitude of fishery of *P. erumei*

has been given. The mode of collection of data has been explained. The growth rate of the fish has been obtained and the rate of catabolism has been found to be high compared to demersal fish of temperate waters. Using the von Bertalanfy equation with reference to the length frequency data, the mean lengths of the fish of successive age classes have been obtained. It was found that only the first three year classes namely O, I, and II were obtained in fishery. It is possible that the higher age-groups occur in deeper waters. On an examination of the indices of abundance it is found that the indices of the I year class are high; compared to those of the II year class. It is seen that the present gear is selective at total length of 150 mm of the fish, lower sizes of *P. erumei* escaping through the gear.

Racial Studies

The technique of analysis of covariance has been used as to study racial variation in *P. erumei*. Samples from six fishing areas have been compared for their meristic and metric characters. It has been found that *P. erumei* on the West coast form a homogenous racial group. There is also overwhelming evidence against a hypothesis that the samples from the West Coast and East Coast (Madras) came from heterogeneous racial stocks. However, a larger sample will be necessary to confirm the above conclusion.

Food and Feeding Habits

The study of food and feeding habits is based on examination of stomach contents of 1582 specimens out of which 532 were juveniles and 1050 were adults. It has been observed that *P. erumei* is carnivorous in its feeding habits. The food consists of teleosts and cephalopods as main groups and crustaceans and bivalves as subsidiary groups. Two phases in the consumption of teleosts were observed in juveniles and adults. The main food items

amongst the teleosts consumed were some species of sciaenids, polynemids and clupeids. The occurrence of other teleosts as food was seen to be rare. In adults the feeding activity showed three different phases, active, moderate and low during the periods November-April, May, June and August—October respectively. The juveniles studied did not show any specific difference as regards the food and feeding habits in comparison with the adults.

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Sec. III

FAUNA OF THE KAKINADA BAY

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The Kakinada bay is situated on the east coast of India and has a total area of about 132 sq. km. It is bounded by the main land on the western side, by marshy mangroves on the southern side and by a sand bar on the eastern side. It opens by a wide mouth into the Bay of Bengal on the north.

The fauna of the Kakinada Bay can be described under two broad divisions, namely those inhabiting the tidal region and those which are at the bottom of the bay not subjected to tidal influence. Each of these can be sub-divided into sub-regions based on the nature of the substratum and the preponderance of a particular animal in each region.

Thus the intertidal region is sub-divided into four regions, based on the nature of the substratum namely (1) Rocky region, (2) Sandy region, (3) Mud flats and (4) Mangroves.

The bottom of the bay is divided into five zones based on the predominance of a particular species of animal in each zone, namely (1) *Anadara* zone, (2) *Placuna* zone, (3) *Paphia* zone, (4) *Tonna* zone and (5) *Turritella* zone.

The fauna of the Kakinada bay is characterised by a predominance of marine element with only a few representatives of estuarine and brackish water forms. Of all the invertebrate groups the molluscs are well represented both in number and in variety. Seasonal changes in populations were observed in different zones. It was also observed that regions with fine sediments rich in organic carbon support a rich population and are the most productive regions in the bay.

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Sec. I

AN ANALYSIS OF SOME WAVE OBSERVATIONS CARRIED OUT ALONG THE EAST COAST DURING AUGUST 1964.

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Wave observations were carried out off the coast of Visakhapatnam from *INS Kistna* in August 1964 during the passage of a relatively heavy depression in the Bay of Bengal. The wave heights are analysed and compared with forecasts made by methods given by Picson, Neuman and James and the agreement is found to be very satisfactory.

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Sec. V

RADON IN MONSOON CURRENT

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Concentrations of radon (3-8 days) and lead-212 (10.6 hours) were measured in sea level air at Bombay. During the pre and post monsoon period, the ratio Pb^{212}/Rn in the

early morning land breeze was 0.1 while that in the afternoon sea breeze was 0.02; intermediate values were observed at noon time. The activity of Pb^{212} in the air during monsoon season was immeasurably small (Pb^{212}/Rn 0.002)—indicating the relative absence of local continental air in the monsoon current.

The concentration of radon in the surface air at Bombay ranged around 40-50 dpm/m³ during the monsoon season while that of its decay products in the rain water was about 15 dpm/ml. There was no measurable activity of Pb^{212} in rain water; the ratio Pb^{212}/Rn must be less than 0.0005 in the air mass from which precipitation occurred.

Concentrations of radon were also measured in surface air over the Arabian Sea and the Indian Ocean. A few degrees south of Equator, i.e. in the region of south east trades, ranged between 2-4 dpm/m³, while those over the Arabian Sea were often ten times as much. Low values characteristic of south east trades were observed upto a few degrees north of equator. The implications of such measurements in terms of interaction between the south east trades and continental air masses during monsoon season are discussed.

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Sec. III

SEASONAL VARIATIONS IN PHYTOPLANKTON IN PORTO NOVO WATERS DURING 1965-66.

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The paper reports observations on seasonal variations in phyto plankton populations at 10-fathom line of Bay of Bengal during 1965 to 1966.

46 species of phytoplankton belonging to 35 genera were observed. Of those 26 species were centric diatoms, 17 species pennate diatoms and 2, blue green algae. *Noctiluca miliaris* was the only dominant group among dino-flagellates.

3 genera of centric diatoms, *Coscinodiscus*, *Rhizosolenia* and *Chaetoceros* were present in every sample of plankton from February 1965 to January 1966. The rest of the species were periodical in their occurrence.

The phytoplankton numbers had a primary peak in March with 63,550 cells per 100 ml and a secondary peak in August with 63,300 cells per 100 ml. The minimum was during April, with 3,800 cells/100 ml.

During March the blue green alga *Trichodesmium erythraeum* constituted 72.4% and during August *Noctiluca miliaris* formed 68.1% of the total phytoplankton.

The variations observed in Porto, Novo waters are compared with what is known for other regions in Indian waters.

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Sec. III

YEASTS IN PORTO NOVO WATERS DURING 1965 to 1966.

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The paper reports observations on the seasonal distribution of yeasts (ascosporogenous and non ascosporogenous) in the near shore waters at 10-fathom line during 1965 to 1966.

15 species belonging to 8 genera of yeasts were isolated and identified from 22 isolates of 33 water samples.

Species like *Rhodotorula pallida* *R. rubra*, *Debaryomyces subglobosus* *N.D. hansenii* were present throughout the period. The remaining species such as *Candida tropicalis*, *C. guilliermondii*, *C. lypolytica*, *Cryptococcus albidus*, *C. luteolus*, *Torulopsis candida*, *T. famata*, *Saccharomyces rosei*, *S. steineri* and *Pichia* sp., were periodical in their occurrence.

Among *Cryptococaceae* (non ascosporogenous) Black yeasts also were isolated.

The seasonal variations observed in Porto Novo waters are compared with what is known for other regions of the world.

UNUSUALLY LARGE NUMBER OF CYCLONIC STORMS IN THE BAY OF BENGAL DURING THE POSTMONSOON SEASON OF 1966

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The postmonsoon season of 1966 experienced an unusually large number of cyclonic storms. In November '66 itself, four cyclonic storms developed in the Bay of Bengal, this being the highest in a month for nearly a century. Factors leading to this unusual cyclonic activity have been studied in this paper in relation to the conditions during year a when cyclonic activity was at its lowest. The deviation from normal position of sub-tropical ridge and equatorial trough during the years of high and low cyclonic activity in relation to the development of cyclonic storms is given. The mean monthly energy changes within the troposphere for the years of high and low cyclonic activity are presented and their possible relationship with cyclonicity is discussed.

BEACH EROSION AT VISAKHAPATNAM

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The coastline along the east coast of India is changing as evidenced from the survey charts and local observations. The beach variations are cyclic at Visakhapatnam with a general cut during March to September and fill in the rest of the year. The cut and fill

in different regions are varying markedly and depends upon the wave convergence and divergence. Both the beach erosion and deposition are severe in the beginning and rate of erosion decreases with time. In the later part of the erosion period, the beach is stable for seasonal wave and erosion takes place only during the approach of steep waves. Certain zones are subjected to erosion only by the waves from the cyclones during north east monsoon. The longshore currents during and after storms of the northeast monsoon season are producing typical beach profiles along the forward and leeward sides of the rocky barriers. The Visakhapatnam beach is getting eroded for the past 3 decades and most of the coastal dunes are destroyed. The off-shore bottom relief and the coastal shelters are responsible for the observed erratic behaviour of erosion and deposition at different zones along the coast.

HYDROGRAPHY OF THE KISTNA ESTUARY

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The hydrography of the Kistna estuary along the east coast of India has been studied in relation to the climatic and oceanographic parameters. The flow of sea waters upstream depends upon the tide and the rate of discharge in the river. The salinity sections in different seasons show considerable dilution in rainy period and high salinities during April when it appears as a negative type of estuary. The velocities of the tidal currents attain upto 200 cm/sec and the diurnal and seasonal variations are related to the tide and river flow. The surface and subsurface temperature

shows dependence on air temperature above it. The bottom topography shows large silting during south-west monsoon season which may be attributed to the sediment from the run-off and from the sea with the tidal currents. Cellular type of vertical circulation is present with in the smaller zones along the axis of the river.

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Sec. V

SEASONAL VARIATION IN HEAT FLUX FROM THE SEA SURFACE OVER THE BAY OF BENGAL

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The seasonal variations in the heat flux from the sea surface to the atmosphere over the Bay of Bengal are studied using the data namely Dry and Wet bulb temperatures, wind speed and sea surface temperature supplied by India Meteorological Department. Sensible and latent heat transfer, evaporation and Bowen's ratio are evaluated using turbulence transfer formulae for each two degree square area of the Bay of Bengal. The evaporation exhibits a double maxima during winter and south-west monsoon period with a minimum in the summer (hot season). The sensible heat transfer is from the sea surface to the atmosphere, which is taken as positive, all over the Bay during the winter season and south-west monsoon retreating period. In the south-west monsoon period also the sensible heat transfer is positive except over South-west part of the Bay. In the summer season the sensible heat transfer is reversed over the central and northern parts of the Bay. The Bowen's ratio is computed all over the Bay. The results are discussed in relation to climatic factors.

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Sec. I

OBSERVATIONS ON THE SCATTERING LAYERS OVER THE CONTINENTAL SHELF OFF KONKAN COAST (INDIA).

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The echograms obtained by "R. V. VARUNA" using asdic during the September, 1963 cruise are analysed. Scattering layers observed over the shelf area, off Ratnagiri, are examined and studied in relation to the thermocline layer present. Comparison of the reflections from the layers in the thermocline region with similar observation in the North Sea has indicated that the layers are not directly due to the physical discontinuity.

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Sec. I

HYDROGRAPHY OF THE KAKINADA BAY

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The one hundred and odd year old Kakinada Bay with a total area of 132 sq. km is situated on the east coast of India. It is a part of the Godavari estuarine system both physiographically and hydrographically. The emergence of an apparently stabilized Godavari sand spit separating the bay partly from the adjoining Bay of Bengal and the gradual extension of the main coast in an eastward direction consequent on the phased construction of groynes from time to time to divert the inflows from the Kakinada Canal, are the two main features which culminated in the formation of the Kakinada Bay.

The hydrographical conditions in the bay are very complex because of (1) the different quantities of fresh water inflow from the head during the south west monsoon and part of the post monsoon months, (2) the sea water entry from north throughout the year from the adjoining Bay of Bengal through a broad mouth (3) entry of brackish water of different salinities from south principally through two channels, Gaderu and Coringa during the north east monsoon and hot weather seasons, (4) the ceaseless and rhythmic action of tides which bring about exchanges of waters of different salinities and temperatures between the Bay of Bengal and the Kakinada Bay on one hand and between Kakinada Bay and the Coringa and Gaderu rivers on the other and (5) the influence of the two coastal currents, which differ markedly in their hydrographical properties, operating on the main coast.

Based on a study of the distribution of salinity and temperature in relation to depth and distance it is clear that intense vertical stratification in salinity and temperature occurs during the active south west monsoon and post monsoon months. During the hot weather season the waters tend to become homogenous vertically and to some extent horizontally.

Based on the orientation of isohalines and isotherms and keeping in view the directions of the two coastal currents and of wind, the pattern of net water movements in the bay seems to clockwise from December to June and counterclockwise from July to November.

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Sec. V

SALINITY MAXIMUM BELOW THE TROPICAL DISCONTINUITY LAYER IN THE ARABIAN SEA AND THE FORMATION OF INDIAN EQUATORIAL WATER MASS

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Below the layer of tropical discontinuity along and off the Malabar Coast a layer of

salinity maximum is generally noticed. This layer occurs between 400 and 500 db surfaces and nearly spreads along the 27-Sigma-T surface. It exhibits certain characteristic variation both seasonal and spatial. The mechanism of its formation and maintenance is related to the formation of the Indian Equatorial water within the Arabian Sea—a hypothesis put forward by the author earlier. The turbulence within this layer is minimum. This study lends further support on the question of the formation of the Indian Equatorial water.

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Sec. III

THE OCCURRENCE OF INTERSTITIAL FAUNA IN MARINE BEACH SANDS

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Very little is known about the interstitial life inhabiting the capillary waters of the tropical marine beaches. This fascinating faunal realm is characterised by the presence of amazingly dense and highly varied microscopic groups of animals. In the present article, the author gives a brief account of the study of the fauna in Indian waters based on the work carried out on the Waltair coast during the years 1960-1963.

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Sec. I

HYDROGRAPHICAL FEATURES OF THE SOUTHERN AND CENTRAL BAY OF BENGAL DURING THE TRANSITION PERIOD BETWEEN WINTER AND SUMMER

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During Feb.-March 1963, *INS KISTNA* has carried out its 6th and 7th oceanographic cruises in the southern and central parts of Bay of Bengal under the Indian Programme of International Indian Ocean Expedition. With the physical oceanographic data collected in

these cruises, the general hydrographical features in the upper 500 metres are studied by preparing the vertical profiles of temperature, salinity and density (σ_t) along the 6 sections chosen for the purpose and discussing the vertical distribution of each parameter in the case of each section. In the upper 50 metres of the Eastern Bay and the Andaman Sea, a low salinity water mass ($S < 33.0\text{‰}$; $\sigma_t < 21.0$), which could be tentatively named as the "Eastern Dilute Water of Indo-Pacific Origin", is encountered. Another water mass, which resembles the "Southern Bay of Bengal Water" with the salinity range 33.0-34.0‰ and σ_t range 21.0-22.0, is identified in the upper 100 metres of the Southern Bay and the western and middle parts of the Central Bay. Throughout the region under study, the Indian Ocean Equatorial Water ($T = 4^\circ - 16^\circ\text{C}$; $S = 34.8 - 35.2\text{‰}$) is encountered as the major subsurface water mass below 100-150m depth. Traces of the high salinity water, which can be related to that of Persian Gulf are found with limited extent in a specific region in the central part of the Bay below 300m depth. Regions of divergence and convergence in the southern boundary of the Bay and a zone of strong convergence in the Central Bay are indicated. In the upper 75 metres, the southwestward spreading of fresh water discharged from the mouths of Irrawaddy River and also a possible northward flow of relatively warm, but more saline and denser water in the Western Bay are inferred.

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Sec. I

VERTICAL DISTRIBUTION OF TEMPERATURE, SALINITY AND DENSITY IN THE UPPER 500 METRES OF THE NORTH EQUATORIAL INDIAN OCEAN DURING THE NORTH-EAST MONSOON PERIOD.

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In the 4th and 5th scientific cruises of *INS KISTNA* under the Indian Programme of

IIOE, five sections were worked out in the North Equatorial Indian Ocean during Jan.-Feb. 1963. Using the physical oceanographic data collected in these cruises, the vertical profiles of temperature, salinity and density (σ_t) for the upper 500 metres are prepared in the case of each section and the vertical distribution of each parameter is discussed. Two water masses—the low salinity water of Bay of Bengal ($S > 34.0\text{‰}$; $\sigma_t > 22.0$) and the high salinity water associated with the typical subsurface salinity maximum of the Equatorial Indian Ocean and the Salinity Maximum E ($S > 35.4\text{‰}$) reported by Rochford, are identified in the upper 150 metres. The former water is found at the surface between 5°N and 8°N in the middle part and north of 5°N in the eastern part of the region under study, while the latter water mass is observed in most of the regions, north as well as south of the equator. The deepening of this high salinity water up to 150-190m depth under the Bay of Bengal water in the northern region of the middle part is note-worthy. At the subsurface levels below 150m, the Indian Ocean Equatorial Water ($T = 4^\circ - 16^\circ\text{C}$; $S = 34.8 - 35.2\text{‰}$) is encountered as a major water mass, while the Persian Gulf High Salinity Water ($S > 35.2\text{‰}$) at an average depth of about 200m and the Red Sea High Salinity Water ($S \geq 35.3\text{‰}$) at depths greater than 450m are traced only in a few specific regions with limited extents. Two regions of divergence—one between 50m level and 150m level within 2° south of the equator at $61^\circ - 63^\circ\text{E}$ and the other in the upper 150 meters off the east coast of Ceylon (along 83°E), are observed. The former is attributed to the presence of Equatorial Under current, probably flowing in an ENEly direction across this region, while the latter is connected to the divergence between the southern boundary of anti-cyclonic circulation of Bay of Bengal and the northern boundary of North Equatorial Current off the east coast of Ceylon.

OCCURRENCE, COMPOSITION AND SIGNIFICANCE OF OOLITES FROM THE CONTINENTAL SHELF SEDIMENTS OFF EAST COAST OF INDIA

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The occurrence of oolites in the outershell sediments off east coast of India is a significant fact, which was first reported by the author briefly in earlier publications. The oolites are found between 40 and 100 fathoms in the outershell and range in size from <1 mm. to about 1 mm. They are best sorted in the 0.5-0.25 mm. or 0.25-0.125 mm size grades. Their shapes vary from ovoid, spherical to irregular and sometimes aggregate in nature. They are creamy white, white, with shades of brown, grey and dark grey in colour. The surface of the oolites is smooth and shining in some cases, while it is rough, pitted and dull in other cases.

The optical examination of the thin sections of oolites revealed their concentric nature of the precipitated material around nuclei of quartz shell fragments, and fecal pellets.

The chemical analysis of +52 fractions of B.S.S. (0.295 mm. size) of oolite-bearing non-clay material indicated that it is principally composed of carbonate of lime with smaller quantities of silica, alumina, iron, magnesium and phosphorus. X-ray analysis of these oolites revealed that they consist primarily of aragonite (85% and more); calcite (about 1%); dolomite (1-2%); and quartz (less than $\frac{1}{2}$ %).

The evidences so far gathered from the microscopic, chemical and X-ray studies of oolites indicate that they are formed by the inorganic precipitation of calcium carbonate, in the form of aragonite, in sea water. It

is concluded that the oolites under study were formed at the time of lowered sea levels probably during Pleistocene glaciation from the evidence of their association with shallow water benthonic foraminifera and coarse clastic sand. The physico-chemical factors responsible for the precipitation of these oolites are discussed in the light of studies carried out on the present-day environments, where oolites are forming now.

AGE OF THE WARKALA (VARKALAI) FORMATIONS AND THE EMERGENCE OF THE PRESENT KERALA COAST, INDIA.

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Warkala formations exposed along the coastal tracts of south Kerala consist of laterites, sandstones, variegated clays and thin beds of lignite. They have been assigned to Upper Tertiary age by earlier workers. During off-shore drilling, these formations were found to continue in the near-shore region beneath recent sands and dark, compact carbonaceous mud with abundant thick-valved molluscan shells. Samples of lignite and the molluscan shells were dated by the Radiocarbon method.

The dates indicate that Warkalas are much younger and correspond approximately to the Third Interglacial age (Upper Pleistocene). Their actual emergence appears to be during the Fourth Glacial age due to the attendant sea-level fluctuations. Thick-valved mollusca, appear to have thrived in place on the mud-flats off-shore, indicate a maximum age of 4,640 years/B.C. which roughly corresponds to the Neolithic stage.

In view of the continuity and extent of these muds further north in the off-shore region and also in the back-waters, it is envisaged that they

represent presumably bay sediments of an earlier cycle which are not in equilibrium with present-day near-shore environment, but are preserved due to their sudden burial beneath recent sands of the coast. Average rate of their sedimentation has been computed from the Radiocarbon dates. Before the formation of the present coast was initiated, this region must have been represented by vast mud-flats or tidal-flats. The present Kerala coast with rich heavy mineral sands on the barrier beaches, is therefore surmised to have been built up on these earlier mud-flats.

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Sec. II

SEDIMENTS OF THE NEAR-SHORE REGION OFF NEENDAKARA-KAYANKULAM COAST AND THE ASHTAMUDI AND VATTA ESTUARIES, KERALA, INDIA.

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Heavy mineral sand deposits occur along the beaches of south Kerala, the richest being on the barrier beach between Neendakara-Kayamkulam in Quilon district. The near-shore region adjacent to this deposit was explored to study nature of bed-material with the aid of Jet Drilling equipment, improvised for the first time. Similar operations were extended in the two estuaries adjoining the barrier beach on landward side. Over 250 samples were studied. The data, along with different sediment parameters are discussed with suitable diagrams.

Anomalous occurrence of compact black mud in the near-shore region and its inland continuation in the estuaries was established. The coarse sediments also are extremely diverse in their third dimension distribution indicating their incompatibility with the present environment. These sediments belonged to an earlier

cycle obviously not in equilibrium with their present near-shore environment, but preserved by their burial beneath the recent sands due to sudden changes in the conditions of deposition.

Also the sediment load brought by the rivers into the estuaries from the hinterland is not in consonance with the bed-material of the estuaries investigated. This is due to rapid flushing out of the river sediments across relatively compacted mud surface of the estuary bed into open sea through the tidal channel at Neendakara. Study of sediment distribution in the near-shore region suggests that the material received from the hinterland through the tidal channel is being drifted northwards by powerful long-shore currents generated by the oblique approach of the south-west monsoon to the coast.

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Sec. II

SOME BATHYMETRIC FEATURES OF BAY OF BENGAL

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The Echograms collected during XV-XXII Cruises of I.N.S. KISTNA of the I.I.O.E. Programme were analysed and the contours were drawn. Some important features of the ocean bottom in the Bay of Bengal are described in this paper.

An Oceanic Rise along 83°E was observed between 11° and 15°N with a Gap at 14°N. The depth of the Gap is nearly 3200 m below the sea surface and the Rise is situated at a depth of 3000m to the south of the gap and 2800 m to the north of the Gap.

A Trench was observed along the East Coast of Ceylon and India. The deepest portion of the Trench (nearly 4400m) from the sea surface was observed at a place to the southeast

of Ceylon. The depth and the width of the Trench gradually decrease as the trench extends towards north.

The Valleys cut by the rivers Mahanadi, Godavari, Krishna etc., were found to extend into the deep sea. All these valleys finally terminate into the Trench. The extension of the Ganges Canyon down the bottom of the Bay of Bengal could be traced upto 9°N.

Another Rise along 90°E was observed extending towards north up to 10°N. The Rise is situated nearly 2900 m below the sea surface. It is considered as the Northern part of the Ninety-Degrees East Ridge.

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Sec. I

DISTRIBUTION OF TOTAL PHOSPHORUS IN THE BAY OF BENGAL

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Data on total phosphorus incorporated in this paper deals with values obtained in the inshore waters of the Bay of Bengal off the coast of Waltair for a period of two years (1961 to 1962) and also from the different regions of the Bay of Bengal obtained during March-April, 1963 on board *Anton Bruun* in the International Indian Ocean Expedition.

Surface average values of total phosphorus exhibit a seasonal variation from high values of 3.4 µg at/l (July 1961) and 3.02 µg at/l (June 1962) to low values of 0.99 µg at/l (April 1961), and 1.66 µg at/l (April 1962) and low values occur also in the October-December period.

Average values in the surface water of the different regions of the Bay of Bengal reveal only a slight variation during March-April 1963 and show a tendency to increase in a south to north direction from the Nicobar sea towards the head of the Bay. The vertical distri-

bution reveals that the total phosphorus content is generally low in surface water and increases with depth upto 500 meters after which the values decrease. Total phosphorus varies almost by a factor of 3 in the vertical distribution.

Total phosphorus values are high preceding the primary phyto-plankton bloom during March-April, but decreases with the increase of standing crop and vice versa. High values of total phosphorus during the summer months (May-July) coincide with low values of inorganic phosphate on this coast.

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Sec. V

VARIATION OF RAINFALL ACROSS EQUATOR

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From ships' reports in the Indian Ocean in the year 1964, the percentage of reports of rainfall in 2 degree latitude belts have been worked out. Appreciable tendency for dry weather is not found near the equator. The variations between 15° on either side of the equator are discussed.

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Sec. I

DISTRIBUTION OF FORAMINIFERA IN THE SHELF SEDIMENTS OFF VISAKHAPATNAM

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Sediment samples from 22 stations located off Visakhapatnam and ranging in depth from 11 fathoms through 104 fathoms were examined for their skeletal materials, especially foraminifera, ostracoda, bryozoans, gastropods and pelecypods. The present paper deals with the distribution of Foraminiferal populations.

The clastic as well as the skeletal material of the sediments larger than 0.66 mm in size

were first washed free of silt and clay size particles and then divided into four size fractions of 0.06—0.125 mm, 0.125—0.25 mm; 0.25—0.5 mm and more than 0.5 mm. Foraminifera are abundant in the fractions of 0.06—0.125 mm size; the coarsest fractions are generally more abundant either in mineral grains or in bivalves and their fragments or in both, while the finer fractions are richer in mineral grains or oolites. In general, in all the four size groups populations are very rich in the shelf at more than 45 fathoms depth. This richness in the outer shelf is attributed to the sparsity of extraneous terrigenous material which would have caused dilution of the biological remains.

In all, 32 species of foraminifera are found to occur in considerable numbers. Their distribution across the shelf is recorded in a tabular form and their distributional pattern are illustrated. The species are also illustrated.

The specimens of certain species are discolored brown and some other are glauconitized. Some shallow water species like the warm miliolids, *Quinqueloculina*, *Rotalia beccarii*, *Elphidium cf. crispum*, *Amphistegnia lessonii*, Alveolinids, etc., which are represented by considerable number of specimens are found in depths to which they are not normally endemic.

It is inferred that the foraminiferal populations of the outer shelf represent a mixture of the shallow water fauna of the past lowered sea stands and of the recent fauna.

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Sec. VI

ICHTHYOLOGICAL STUDIES PERFORMED BY SOVIET PARTICIPANTS OF THE IIOE

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Ichthyological studies in the Indian ocean were conducted by the Institute of oceanology

of the USSR from 1959 to 1964 during cruises of the R.V. "Vityaz". Composition and distribution of the oceanic ichthyofauna, spawning and life history, composition and distribution of the commercial ichthyofauna were the main aspects of studies. About 30 papers have been published.

Oceanic ichthyofauna of the pelagic and the deepsea realms was subjects of studies in the whole as also especially by several groups, e.g. Squaliformes, Beloniformes, deepsea Salmoniformes, Myctophiformes, Lampridiformes, Perciformes. More than 100 species of fish were caught being lured at night by electric light, including oceanic and neritic-pelagic, bathypelagic and purely neritic species.

Deepsea fauna in the Indian ocean seems to be poorer and evidently underinvestigated comparing with that in other oceans. There are nearly no endemic species at all. 13 families of oceanic deepsea fishes (from known 80 of the World ocean) are not known as yet within the Indian ocean; only ca. 280 species are known from the depth of the Indian ocean in comparison with 450 in the Pacific and 700 in the Atlantic. Half of known deepsea fishfauna is represented by Myctophids (60 species), Macrourids (25), Gonostomids (17-18), Alepocephalids (16), Melanostomiatis (13), Oneirodids (11).

Reproduction and life histories of fishes are subject of studies in the whole, from the main theoretical conceptions (periodization, specification, typization, dualistic base of development, ecological-geographical parallelization, stenobiosis) as also especially by several groups, e.g. Clupeidae, Synodontidae, Myctophidae, Beloniformes, Carangidae, Scombroidei, Pleuronectiformes.

Commercial ichthyofauna contains nearly 300 species but only about 150 are taken into account in statistics. It is composed of 3 neritic and, oceanic biogeographical complexes, containing each from 2-5 ecological groups. Concentrations of fish (as those of plankton) are situated mainly along the meeting zones of

the different water masses and currents, as also at the areas of upwellings.

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Sec. I

DISTRIBUTION OF NUTRIENTS IN THE SHELF WATERS OF THE ARABIAN SEA ALONG THE WEST COAST OF INDIA

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and

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The paper presents a descriptive account of the distribution of phosphates, silicates and nitrates in the shelf waters of Arabian Sea along the West Coast of India including a brief mention about the hydrographical features and their relationship with the former during the period September to December 1963. The results indicate marked variations through different periods, in nutrients and other hydrographical features.

Two distinct environmental conditions are apparent in the shelf waters from the nutrients point of view, characterised by nutrient-deficient surface layers in the post-monsoon period and nutrient-rich surface layers in the south-west monsoon period. These conditions are well reflected in the corresponding variations of the hydrographical features. It is also observed, that the concentrations of the nutrients show a general decreasing trend from south to north.

The distribution of the elements are more influenced by a phenomenon similar to upwelling, occurring during the closing phase of the south-west monsoon. The regional differences in the concentrations of the nutrients along the coasts during this period are attributed to the varying intensities of this upwelling like phenomenon. Post-monsoon period is characterised by more vertical stability of the waters and uniform distribution of the pro-

perties. A significant feature of the nutrient components of the nearshore environment (less than 15 miles) is their constancy through different periods; the values are relatively high throughout. Probable factors controlling the vertical and horizontal distribution of nutrients are indicated.

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Sec. I

DISTRIBUTION OF PHOSPHATES AND SILICATES IN THE CENTRAL WESTERN NORTH INDIAN OCEAN, IN RELATION TO SOME HYDROGRAPHICAL FACTORS.

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and

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The paper presents a descriptive account on the distribution of phosphates and silicates of the central region of the Western North Indian Ocean in the upper 200m during the south west monsoon period. The relationship of the nutrients with temperature, salinity, oxygen and also zooplankton is shown.

Vertical distribution of the nutrients indicates low concentrations at the surface layers upto 50 or 75m. This is followed by higher concentration layers down to 200m. Considerable meridional and zonal variations in the concentrations and the thickness of these layers have been noticed. The distributional features of the oceanographic properties indicate the distinctness of the North Equatorial Indian Ocean from the geographically similar regions of the Pacific and Atlantic Oceans. The disposition of the isopleths shows an equatorial upslope of the waters which is associated with the equatorial divergences. However, the ascent appears to be weaker near and along the equator as compared to the equatorial regions of the Pacific and Atlantic. The spreading of the isolines

near and along the equator is probably due to the equatorial undercurrent. Three regions of convergences (1) between Lat. 15°30' and 16°30'N along 68° E, (2) around 8°N and 71°30' E and (3) around 5°N and 75°E have been noticed. The variations in zooplankton volumes seem to be related to the changes in hydrographical features.

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Sec. V

ON THE FORMATION OF DOUBLE EQUATORIAL TROUGHS IN THE ATMOSPHERE OVER THE INDIAN OCEAN REGION

K. R. SAHA,

Mass flow, vorticity, and thermal considerations are applied to discuss the formation of two troughs in the atmosphere near the Equator over the Indian Ocean region.

It is concluded that while one of these troughs is of thermal origin, the other may be of dynamical origin.

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Sec. III

PRELIMINARY REPORT ON THE DISTRIBUTION OF PTEROPODA (THECOSOMATA) FROM THE INTERNATIONAL INDIAN OCEAN EXPEDITION.

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Pteropoda (Thecosomata) from *Anton Bruun* and *Argo* IIOE collections have been identified following Tesch's work on Dana materials. The number of samples examined to date is 398. The areas covered by both ships are the western half of the Indian Ocean, the Bay of Bengal and the equatorial zone. Out of a total of 35 known species of Thecosomata, 22 are so far represented in the samples examined. These include all but the bathypelagic and cold water forms. The distribution of the species, most of which are wide-spread tropical-subtropical forms, is discussed.

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Sec. I

THE NUTRIENTS OF THE NORTH-WESTERN BAY OF BENGAL.

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and

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Studies on the distribution of phosphates, silicates and nitrates in relation to some hydrographical features of the north-western Bay between latitudes 16° and 19°N during the month of January showed marked regional variations. The distribution is found to be related to the prevailing currents. The chief feature of the region investigated is the commencement of coastal upwelling. The ascent of the sub-surface waters is weak and extends only up to 20m below the surface. From the disposition of the isolines it appears that the vertical motions of the waters extend down to 500m. Phosphate maximum is found between 600 to 800m and the nitrate maximum between 300 and 800m. The silicates, on the other hand, continue to increase with depth. The factors influencing the distribution of nutrients over the entire region have been discussed.

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Sec. I

PHOSPHORUS FRACTIONS IN PORTO NOVO WATERS DURING 1965-1966.

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The paper reports observations on the variations in the total phosphorus, inorganic phosphorus and dissolved organic phosphorus in the mouth of the Vellar estuary during the period extending from August 1965 to August 1966, and the conditions prevailing at the mouth are compared with those at the 10-fathom line. In the surface waters, the total phosphate

varied from 1.1 to 4.55 μg . at P/l; the inorganic phosphate from 0.25 to 1.10 μg . at P/l; and the dissolved organic phosphate from 0.60 to 3.45 μg ; at P/l. In the bottom waters the total phosphate varied from 1.2 to 5.12 μg at P/l the inorganic phosphate from 0.22 to 1.10 μg at P/l; and the dissolved organic phosphate from 0.70 to 4.70 μg at P/l.

In surface water all the three phosphate fractions showed minimum value during September and the maximum value during January. In the bottom water the total phosphate and organic phosphate were minimum in September and maximum during January. The inorganic phosphate was minimum during February and maximum during August.

In the surface waters of 10-fathom line, the total phosphate varied from 1.1 to 11.5 μg . at P/l; the inorganic phosphate from traces to 1.0 μg at P/l; and dissolved organic phosphate from 0.70 to 11.5 μg at P/l. In the bottom waters the total phosphate varied from traces to 1.1 μg at P/l; the inorganic phosphate from traces to 1.1 μg at P/l; and the dissolved organic phosphate from 0.70 to 11.8 μg at P/l.

The lowest values for all the three phosphorus fractions at the 10-fathom line were during May for both surface and bottom waters. The highest values for total phosphate and dissolved organic phosphate were observed in March. The highest value for inorganic phosphate for both surface and bottom waters was in June.

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Sec. II

RECENT SEDIMENTATION IN THE INDIAN OCEAN (FIRST RESULTS OF "METEOR" INDIAN OCEAN EXPEDITION)

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The main purpose of the trip with the German Research Vessel "Meteor" was an intensive

exploration of the oceanic areas off the East African coast between Cape Guardafui and Mombasa and off the Indian-Pakistan coast between Cochin and Karachi.

It was intended to get aspects on facial change of the sediments from the shore-line down to the oceanic basin. The origin of these sediments shall also be investigated.

A number of different facies zones can be distinguished running parallel to the coast. Off East Africa five, off the Indian-Pakistan coast seven zones have been found. On the whole the distribution of facies in both areas is quite similar and more or less restricted to certain depths of the ocean bottom. These first results are in agreement with observations in other shell areas, for instance off the Indian East coast.

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Sec. II

STUDIES ON SOME ASPECTS OF THE SEDIMENTS OFF KRISHNA DELTA AND NIZAMPATNAM BAY ALONG THE EAST COAST OF INDIA.

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Samples collected in the 18th cruise of *I.N.S. Kistna* in the areas of the Krishna Delta and Nizampatnam Bay during the IIOE, Programme, have been analysed regarding size, organic matter, calcium carbonate, coarse fraction constituents and clay minerals. The results show that the proportion of clay content in the samples off Krishna River is higher than that of the samples off Nizampatnam Bay the samples are moderately sorted. The organic matter and calcium carbonate content are respectively 0.94% and 8.08% in the former area and 0.85% and 13.10% in the latter. Of the clay minerals Montmorillonite has been found to be the most dominant one. The distri-

bution of the above properties of the sediments has been discussed in relation to the prevailing oceanographic factors.

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Sec. II

SPECIFIC ALKALINITY IN THE NORTHERN INDIAN OCEAN DURING THE SOUTH WEST MONSOON

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Titration alkalinity was measured for a total 500 water samples from the northern Indian Ocean during the south-west monsoon cruises of *I.N.S. KISTNA* in 1963 and the specific alkalinity were calculated from the chlorinity values. Results are represented along two sections in the Indian Ocean, two in the Arabian Sea and three in the Andaman Sea.

Observations were restricted to a depth of 200 metres in the Indian Ocean and to about 500 metres in the Arabian and the Andaman Seas.

In the Indian Ocean the values decreased between 25 and 50 metres where the optimal conditions for the lime secreting organisms seem to exist. The values then increase to about 100 metres and then show a slight decrease to 200 metres. The higher values appear to be in the core of the equatorial under-current, which has been found to exist in the Indian Ocean, as well. In the Arabian Sea the values vary little with depth and slightly higher values are found below 150 metres. These higher values may be due to the high salinity intermediate water in the Arabian Sea whose origin has been traced to the Persian Gulf. The values in the Andaman Sea are comparatively lower at the surface than at the depths slightly below it (between 20 and 40 metres). This may either be due to the 'island effect' or this area being in a zone where precipitation exceeds evaporations, and the observations were taken at the time of almost the highest precipitation. The surface values at the eastern section is in general higher than

those at the western part, which may be due to the effect of the discharges from the River Irawaddy and its tributaries. The values gradually decrease towards the depth which may also be due to the fact that this is an area of intense south-west monsoon upwelling.

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Sec. III

CERTAIN FEATURES OF DIURNAL VARIATIONS OF PHYTOPLANKTON PIGMENTS IN THE ARABIAN SEA OFF COCHIN

N. M. SHAH

University of Kerala

Oceanographic Laboratory, Ernakulam.

Diurnal changes in phytoplankton pigments, temperature, salinity, dissolved oxygen content, inorganic phosphorus and nitrite have been studied. The station depth being 19 metres hydrographic samples were taken from surface, 5, 10 and 15m. Samples for pigments could be taken only from surface and 8m.

Whereas phytoplankton pigments from surface show a peak at noon, the 8m pigments have very little diurnal variation. In the case of temperature, salinity and dissolved oxygen also, while the values have variation in the surface layers, with a minimum in the early morning, at 15m depth they are almost constant. Nutrients do not show any regular pattern of distribution either in space or in time.

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Sec. I

SEASONAL VARIATION OF SOME HYDROGRAPHIC PROPERTIES OF THE SHELF WATERS OFF THE WEST COAST OF INDIA

G. S. SHARMA

*Central Marine Fisheries Research Institute,
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Vertical time sections of temperature, density and dissolved oxygen content of the coastal waters off the west coast of India have been

prepared and the seasonal variation of these parameters are studied.

Marked seasonal variations are noticed in the various features. The trend of isolines of temperature, density and dissolved oxygen content show similar pattern indicating upward movement from depths greater than 75 meters from February or even earlier in certain sections in the south. Upwelling reaches the surface layers by May or June. The isolines run almost parallel to the horizontal axis during late summer and fall seasons. By the end of fall they start moving down indicating sinking. The study reveals clearly that vertical circulation takes place seasonally with upwelling in spring and summer and sinking in winter.

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Sec. I

OSMIUM IN SEA WATER

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and

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Central Salt and Marine Chemicals Research Institute, Bhavnagar.

The paper presents a description of methods of determining and estimating Osmium in Sea water.

The reaction between Ceric sulphate and arsenious acid is a slow reaction. This reaction is catalysed by osmium and Iodine. The interfering non-metal, iodine, has been removed by passing the sea water through the cation exchange resin. The acceleration in the rate of reaction between Ceric sulphate and arsenious acid by the deaerated sea water has been taken as an indirect evidence for the presence of osmium in sea water.

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Sec. II

RECENT SEDIMENTS OF THE BAY OF BENGAL

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Calcutta*

The paper is based on the results of studies

carried out at the Institute of Oceanology, Moscow, on grab samples collected by the U.S.S.R. Research Ships *Vityaz* and *Ob* from the Bay of Bengal.

A large area of the Bay of Bengal is covered by clay. Sand, silt and silty clays are confined to a narrow margin along the coast, except (i) in the Ganges-Brahmaputra delta where silt occupies a wide area and (ii) west of the Andaman Coast where silty clay occupies a very large area extending westwards almost to the central region of the Bay. Regionally foraminifera and unidentifiable calcareous fragments increase towards the central and south eastern parts of the Bay, which explains the CaCO_3 (over 50%) in the sediments of this area; the percentage of terrigenous material and insoluble matter decreases in the same direction.

The light fraction (>2.7) of the acid-treated sediments consists of quartz, feldspar, rock fragments and radiolaria. The heavy minerals consist of feldspar, hornblende, mica, pyroxene, epidote, garnet, opaques, sillimanite, tourmaline, zircon, tremolite-actinolite, etc. The distribution patterns of different minerals in these sediments define a number of terrigenous mineralogical provinces. Illite, kaolinite and montmorillonite are the prominent clay minerals with minor amount of mixed layer minerals and chlorite.

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Sec. II

THE DISTRIBUTION OF PHOSPHATES IN SOME SAMPLES OF THE SHELF SEDIMENTS OF THE WEST COAST OF INDIA

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and

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Calcutta*

In recent years developments in the field

of marine geology have provided interesting information on the occurrence and distribution of phosphates on the continental shelves. Economic exploitation of some of these deposits is foreseen in the near future.

The study of the sediments from the western shelf of India is of particular interest since upwelling has been reported from this area. Earlier studies in this region on the distribution of phosphates in sea water and the underlying sediments have been largely from a biological point of view.

As a part of the programme for exploration for phosphates on the continental shelf of the country 50 samples of bottom sediments collected from different stations on the western shelf have been analysed for their P_2O_5 and CaO content. The distribution of major and some trace elements has been studied in a few selected samples. The results of these analyses are discussed with reference to the configuration of the shelf, the source area of sediments and the distribution of terrigenous matter, shell fragments and plant material (cf. algae). The low value of phosphates in the samples studied suggest that even with higher concentration of phosphate in the overlying water there is practically no enrichment in the sediments.

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Sec. VI

DISTRIBUTION OF FISH EGGS AND LARVAE IN BAY OF BENGAL

N. SOLOMON RAJU AND P. N. GANAPATI,

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A knowledge of the breeding grounds and seasonal distribution of the eggs and larvae of commercially important fishes in the sea is quite essential for the proper exploitation of fishery resources. Few such studies have previously been attempted from the seas around India.

The present study is a preliminary attempt in this direction based on the analysis of plank-

ton samples collected from 754 stations during the oceanographic cruises conducted by The Andhra University during the years 1952-1957 and 13 samples collected in January, 1960 during the 'Kalapani' expedition to the Andamans. Special attention is given to areas opposite Visakhapatnam and Kakinada Bay.

Although a variety of fish eggs of unknown identity were obtained, the distribution of some of the fish eggs and larvae of known identity only has been worked out. The distribution of the eggs and larvae of *Sardinella* sp., *Bregmaceros atripinnis*, *Stolephorus heterolobus*, *Cynoglossus* sp., *Muraena* sp., *Saurida* sp. and *Myctophum* sp., has been studied in detail.

It was generally observed that the eggs and larvae are more common and abundant from December to May, during which period the prevailing hydrographical conditions are very stable. It was also observed that most of the fishes are inshore breeders except a few like the Sardines and *Bregmaceros* which are off-shore spawners.

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Sec. I

WATERMASSES OF THE ARABIAN SEA IN THE UPPER 500 METERS

K. V. SUNDARARAMAM, C.K.B. KURUP &
K. V. SRIRAMAMURTY

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Hydrographic data from several cruises of I.N.S. *KISTNA* in the Arabian Sea between 1962 and 1965 have been used to identify various watermasses in the upper 500 metres. Red sea, Arabian Sea, Persian Gulf and Gulf of Oman Waters are identified on T-S diagrams. Arabian sea water whose source region is identified around $65^\circ E$ and $21^\circ N$, occurs as salinity maximum associated with thermocline throughout the Eastern Arabian sea and spreads southwards upto $8^\circ N$. Arabian sea monsoon

Water characterised by low salinity has been traced in the surface layers all along Malabar coast. Thompson's 'Intermediate Water' is identified around Minicoy island.

Attempts have been made to study seasonal variations of the watermasses in the Arabian sea, during three seasons namely S. W. monsoon, Post monsoon and winter.

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Sec. I

GEOSTROPHIC CURRENTS IN THE EASTERN ARABIAN SEA

K. V. SUNDARARAMAM

AND

K. V. SRIRAMAMURTY

*Indian Naval Physical Laboratory,
Cochin-4.*

Dynamic topographies and geostrophic currents in the upper 500 m of the Eastern Arabian Sea are presented based on the data collected during the monsoon cruises of *I.N.S. KISTNA*. Distribution of zonal currents along some typical sections of the Eastern Arabian Sea is worked out. The Surface currents obtained in the present study agree closely with the Pilot Charts of the Arabian Sea.

In general a south westerly current is prevalent in the Eastern Arabian Sea and is modified by the presence of Laccadive—Maldivian island groups resulting in a circulatory current pattern around these islands.

100

Sec. I

TRANSPARENCY MEASUREMENTS ALONG SOME TYPICAL SECTIONS OFF MALABAR AND CORAMANDAL COASTS

K. V. SUNDARARAMAM & K. V. SRIRAMAMURTY

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Transparency measurements were carried out on board *I.N.S. Kistna* for some of the I.I.O.E.

Cruises, using the transparency meter fabricated in I.N. Physical Laboratory. Analysis has been made for studying the percentage ratio of intensity of light with respect to air reading in a 20m column of water. Vertical distribution of percentage transparency is discussed.

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Sec. I

NATURAL RADIOACTIVITY IN SEA-WEEDS AND SEAWATER CONCENTRATES OF SAURASHTRA COAST

D. P. SURU, S. T. TALREJA, H. V. VAIDYA,
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Data on the natural radioactivity associated with various brown, green and red seaweeds and the seawater concentrates are presented. *Gracilaria milardeti*, *Ulva f.*, *Hypnea mus.*, *Sargassum sw.* and *Cladophora sp* show appreciable beta activities in that order. With 34.5 Be bittern, the Maximum activity recorded is 1-2 $\mu\text{c}/10\text{ ml}$ depending on the months of collection.

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Sec. III

SETTLEMENT STUDIES: A NEW APPROACH

R. THEODORE SRINIVASAGAM,

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Work of earlier investigators is primarily concerned with the substratum offered to larvae for settlement and the preferences of the larvae to settlement sites, besides studies based on the usual physico-chemical parameters. But studies on settlement with reference to the medium

and especially the 'ectocrines' is of recent origin. Larvae of the serpulid *Hydroides norvegica* develop normally in sea water conditioned by their adults and this is also reflected in their settlement; it is greater in water conditioned by adult *Hydroides norvegica* than in natural sea water. That certain of the nitrogenous excretory products of the adult animals probably incur this beneficial effect on the water is suggested by the greater percentage of larvae settling in sea water to which certain amino acids are added. Alanine and leucine in minute amounts appear to be of importance. But confirmatory studies have to be made.

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Sec. I

SOME OBSERVATIONS ON INTERNAL WAVES IN THE BAY OF BENGAL

V. V. R. VARADACHARI AND C. S. MURTY

Physical Oceanography Division of National Institute of Oceanography, Ernakulam.

Vertical sections of temperature and sigma-t at different latitudes in the south-western Bay of Bengal during the south-west monsoon season reveal the probable existence of internal waves of long periods and wave lengths, in the thermocline region. The wave lengths vary from about 150 km to 500 km but the waves of any particular latitude have the same length roughly. The exact nature of these waves could not clearly be established but it is felt that they are probably standing oscillations. Internal waves of short periods were also observed during some of the cruises under the Indian Programme of International Indian Ocean Expedition. These waves were noticed in association with slicks in certain areas of the Bay. Studies show that these are of progressive type.

The effects of these waves on the dynamic computations of currents are discussed.

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Sec. II

ON THE LEVEL OF LEAST MOTION AND THE CIRCULATION IN THE UPPER LAYERS OF THE BAY OF BENGAL

V. V. R. VARADACHARI, C. S. MURTY AND P. K. DAS

Physical Oceanography Division of National Institute of Oceanography, Ernakulam.

The paper presents the circulation pattern in the upper 500 metres of the western Bay of Bengal between 9°N and 16°N during the south-west monsoon period, based on the geopotential anomalies computed from the hydrographic data. The methodology in choosing the reference level is discussed. The circulation is characterised by two anticyclonic cells centred at 11°N 83°E and 19°N 85°E with a strong shear zone between at 11°N 83°E and 16°N 85°E with a strong shear zone between them. The strength of the circulation decreases with depth and becomes feeble below a depth of 400 metres. The level of least motion is situated around 500 metres depth. The probable factors governing the circulation pattern are discussed.

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Sec. I

SOME FEATURES OF THE THERMOCLINE IN THE BAY OF BENGAL

V. V. R. VARADACHARI, C. S. MURTY AND P. UDAYA VARMA THIRUPAD

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The space variations of thermocline depths and the temperature gradients in the upper 100 metres of the thermocline in the western

Bay of Bengal during the south-west monsoon period are presented. The depth of the thermocline and the temperature gradients in general, vary from 20 to 80 metres and 0.5° to 1.4°C per 10 metres respectively. While shallow thermocline areas are associated with weak temperature gradients and the deep ones with strong gradients in the southern half of the region under study, in the northern region no such clear-cut relation exists between the thermocline depth and the temperature gradients. The probable factors responsible for these variations are discussed.

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Sec. II

SUBMARINE CANYONS OFF THE COROMANDAL COAST

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During the 26th Cruise of *I.N.S. KISTNA*, a bathymetric survey was carried out in some detail off the Pondicherry coast. This survey has revealed the existence of three sets of distinctly separate canyons between Cuddalore and Palar River. The morphological features of these canyons are briefly described in this paper on the basis of a few traverses taken across each of these canyons.

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Sec. III

BACTERIA IN THE ECOLOGY OF THE OCEAN, WITH PARTICULAR REFERENCE TO THE INDIAN OCEAN

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Marine bacteriology has not developed as much as the other disciplines among marine

sciences. From the available data however it has become clear that bacteria are intimately concerned in the economy of the ocean. During the last 18 years marine bacteriological investigations have been carried out in India on the East and West coasts by different workers. The studies were at specific locations not far from land and often incidental to fish spoilage investigations. Studies in the Madras, Palk Bay & Gulf of Manar areas included enumeration of heterotrophic bacteria of surface and bottom waters, muds and plankton tow samples, incidence of physiological groups such as denitrifiers, agar and cellulose digesters, etc. Distribution of the heterotrophs appeared to be related to the magnitude of phytoplankton. Bacterial flora of fresh seafood and during storage at refrigeration temperatures was also studied. The studies showed slower rates of spoilage compared with the rates described for fish from temperate waters, indicating that bacteria from tropical environments are more sensitive to the adverse influence of low temperatures. Several bacterial types were isolated from marine sources during the above studies. On the West coast also bacteriological studies included examination of sea water samples and fresh fishflora. Qualitatively the flora of seawater reported from the Malabar coast showed certain differences from the flora encountered in the investigations on the East coast and in the Bombay region of the West coast. Several marine bacterial species isolated from seawater and marine muds off Bombay were shown to produce vitamin B12, antibiotics and bacteriophages.

The overall similarities in the numerical distribution and qualitative nature of the bacteria to those of the marine bacteria in other regions of the world ocean have been brought out in these studies. The above work, mostly qualitative, needs to be followed by sustained long-term investigations both in the laboratory and in situ for obtaining the quantitative data essential for understanding the ecological role of bacteria in the ocean.

TRACE ELEMENTS IN THE SEDIMENTS OF THE CONTINENTAL SHELF OFF CERTAIN PARTS OF EAST COAST OF INDIA

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Copper, nickel and cobalt of the clays of the shelf off apparently two similar regions—Pulicat Lake—River Pennar confluence and Pudimadaka—Vizag shelf have been estimated. Although a complex distribution of the trace elements is revealed, the results suggest the presence of greater proportions of the elements in the sediments off Pudimadaka—Vizag region. Also, the results indicate high content of copper and nickel in the dark green marine clays as compared to the other samples. The distribution of the trace elements in the different samples has been discussed in relation to the other properties of the sediments and the prevailing oceanographic factors.

STUDIES ON THE SEDIMENTS OF THE CONTINENTAL SHELF OFF THE REGIONS PULICAT LAKE—PENNAR RIVER CONFLUENCE AND PUDIMADAKA—VIZAG ALONG THE EAST COAST OF INDIA.

K. VENKATARATHNAM

*N.I.O. Research Fellow At The Geology
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The sediments of the continental shelf off pulicat lake—Pennar river confluence and Pudimadaka—Vizag regions along the east coast, have been analysed for size, constituents of the coarse fraction, organic matter and mineralogy.

The results broadly indicate the tenability of zonal classification of the sediments made by earlier workers in these areas. The size plots (CM Patterns) and the roundness of clastic sands of the sediments from 35 to 45 fathoms depth zone are similar to those obtained for the beach samples and thus substantiate the conclusions of earlier workers regarding the deposition of sediments at 35-45 fathoms depth. The size distribution of the sediments from the Swarnamukhi Canyon point to the absence of any active currents along the canyon bottom and this would probably mean that turbidity currents are not operating at present.

The coarse fraction constituents of a few typical samples have been identified and estimated. The distribution of Foraminifera is consistent with the bathymetry and distance of sampling site from the shore and history of shelf sedimentation. The organic carbon of the marine clays indicates a general progressive increase with depth and its distribution has been shown to depend upon the texture of the sediments and rates of organic production, deposition and preservation in different areas.

The important heavy minerals found in the sediments off Visakhapatnam are, Sillimanite, Garnet, Hornblende, Hypersthene and Epidote. Zircon, Monazite and Staurolite are rarely present. The significance of the distribution of heavy minerals in the sediments has been discussed.

PRIMARY PRODUCTION IN THE ESTUARINE AND INSHORE WATERS AT PORTO NOVO (11°29'N-79°49'E)

Marine Biological Station, Porto Novo.

K. K. VENUGOPALAN

Most of the measurements of organic production in the marine environment, reported so far, have been on the waters of the open sea.

Coastal waters and estuarine waters have received little attention. The present note reports the results of a preliminary study of primary production in estuarine and inshore waters at Porto Novo.

The 'light-dark bottle' methods, as described by Strickland and Parson (1965), was adopted for estimating primary production in estuarine waters. Besides this, data based on ^{14}C technique were collected and estimations made through the help of Dr. Vagn Hansen in February, 1964.

The investigations using light-dark bottle method were carried out during February, March and beginning of April, 1966. Samples of water from surface and from a depth of $1\frac{1}{2}\text{m}$ were collected at five stations (A, B, C, D and E beginning from the mouth and proceeding up the estuary). Samples of water were collected at flood-tide on new moon and full moon days.

In the surface water the gross production varied from 11.77 to 36.99 $\text{mgC}/\text{m}^3/\text{hr}$, and the nett production from 6.72 to 26.22 $\text{mgC}/\text{m}^3/\text{hr}$. In the water from $1\frac{1}{2}\text{m}$ depth, the gross production varied from 21.85 to 58.83 $\text{mgC}/\text{m}^3/\text{hr}$ and the nett production from 18.48 $\text{mgC}/\text{m}^3/\text{hr}$ to 47.07 $\text{mgC}/\text{m}^3/\text{hr}$. The gross production and nett production for both surface water and for water from $1\frac{1}{2}\text{m}$ increased from station A to C, where it was maximum, and then decreased at D and E.

In the surface water the minimum value for gross production as well as nett production was at station E. For lower water the minimum value for both the gross and nett production was at station A. The values for primary production employing ^{14}C technique were very similar to those obtained by the light-dark bottle technique. For the two stations in the sea the values were 11.93 $\text{mgC}/\text{m}^3/\text{hr}$. and 20.17 and for the two stations in the estuary (corresponding to B and C) 35.50 $\text{mgC}/\text{m}^3/\text{hr}$. and 46.99 $\text{mgC}/\text{m}^3/\text{hr}$. The highest value for organic production according to both the techniques was at station C.

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Sec. I

CATION ANALYSIS OF SEA WATER IN THE INDIAN OCEAN : APPLICATION OF ATOMIC-ABSORPTION SPECTROPHOTOMETRIC AND FLUORIMETRIC METHODS

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Atomic-absorption spectrophotometric (AAS) and fluorimetric methods were applied to cation analysis of sea water samples collected during IIOE cruises of *I.N.S. "KISTNA"* and *R.V. "Varuna"*.

In the AAS determination of strontium, interference from other ions was eliminated by the use of ammonium oxalate as the precipitant. Ion-chlorinity ratios for calcium, strontium and potassium are in good agreement with those reported in the literature. Magnesium content of sea water as also the magnesium-chlorinity ratios are, however, significantly higher than those reported for other marine regions.

133 surface samples were examined fluorimetrically for content of uranium. The uranium concentrations ranged from 1.01 to 4.47 $\mu\text{g}/\text{l}$ (average, 2.43 $\mu\text{g}/\text{l}$) with interregional differences being observed between Bay of Bengal and the Arabian Sea. These differences are discussed with reference to hydrological characteristics such as salinity, alkalinity, etc.

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Sec. III

A PRELIMINARY REPORT ON THE BIO-MASS OF CHAETOGNATHS IN THE INDIAN OCEAN COMPARING THE SOUTH-WEST AND NORTH-EAST MONSOON PERIODS

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The data for the present maps have been

inferred from the analysis of 1276 standard samples collected during the International Indian Ocean Expedition (1962-65). Standard samples are those obtained between approximately 200m depth and the surface using the Indian Ocean Standard Net. Samples obtained from shoal water are considered as standard if the depth of haul and depth of water are in close agreement.

At Indian Ocean Biological Centre fractions (3-5 ml) of the samples were sorted and the total number of Chaetognaths in the samples were then computed. The average number of Chaetognaths for all samples from each 5° Marsden square is separately estimated for the SW and NE monsoon periods. For mapping, the contour intervals were chosen so as to reduce the effect of patchiness and at the same time provide five density ranges.

The period mid-April to mid-October (SW monsoon) shows a comparatively higher density of Chaetognaths for all areas except the eastern half of the Arabian Sea. In both the NE and SW monsoon periods the areas of highest density are the western part of the Arabian Sea and waters of the Somalia region.

Average No. of Chaetognaths per 200m³ in 0-200m Stratum.

Area	SW Monsoon	NE Monsoon
Western Arabian Sea (W of 65°E, N of 5°S)	3107	2544
Eastern Arabian Sea (65-80°E, N of 5°S)	1287	1480
Arabian Sea (Above two areas combined)	2369	2166
Bay of Bengal (E of 80°W, N of 5°S)	2502	1859

USE OF SATELLITE CLOUD PICTURES IN THE STUDY OF THE INDIAN SUMMER MONSOON

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AND

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A ground read-out station, for use with the Automatic Picture Transmission (APT) sub-system, on loan from the U.S. National Science Foundation was installed at the IMC at Bombay in December, 1963. It has been picking up daily, pictures of cloud cover from ESSA and NIMBUS 2 satellites during their orbits over the Indian Sub-continent and the equatorial Indian Ocean area since May 18, 1966. A study of these pictures show interesting features of cloud developments associated with the first burst of the southwest monsoon over the Kerala coast of India. These developments are not found to drift westwards from the Bay of Bengal or eastwards from the Somalia coast but are found to take place in the extreme south-eastern parts of the Arabian Sea and the adjoining areas further south and travel northwards. Associated synoptic features are discussed. Salient features of satellite cloud data over the Indian seas and neighbourhood associated respectively with typical strong and weak monsoon conditions are also presented.

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