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GEOLOGICAL EVOLUTION OF THE COAST OF INDIA

India was part of Gondwanaland until the Upper Cretaceous, but the eastern coast began to take shape in the Upper Jurassic when low-lying swamps and estuaries began to develop along the coastal region. The earliest marine formations on this coast are of Neocomian age as evidenced by fossils in the Ganges delta and in the Godavari-Guntur area. It is believed that the Godavari and Mahanadi troughs were formed in the Upper Carboniferous and that these opened out into a shallow sea to the east which spread over Western Australia. A few isolated outcrops of marine strata which exist in Central India contain Lower Permian fossils closely related to those of the Carnarvon Basin of Western Australia.

Marine transgression took place over much of the east coast of India in Albian and Cenomanian, abundant evidences for which exist over the southern part of the Assam Plateau and in Southern Madras. Ceylon was separated from India in the Upper Jurassic or in the early Cretaceous. The present eastern coast has been well defined since the Cretaceous, though a major regression took place in the Mio-Pliocene.

Geological resemblances indicate that Madagascar was contiguous with south-western India on its west. The two must have parted from each other in the Upper Cretaceous but a portion of the coast formed at that time has been faulted down later.

An arm of the Tethys extended over Western Rajasthan from the northwest and perhaps also into the Narmada trough. There are thick Jurassic deposits in Kutch and Western Rajasthan which are similar to those on either side of Mozambique channel. This arm of the Tethys later developed into the Arabian Sea, after India began drifting away from the rest of Gondwanaland. The Deccan Trap eruptions originally covered a part of the Arabian Sea basin but this disappeared when the Bombay-Gujarat coast was faulted down in the Eocene. Marine transgression occurred over a large part of the western Indian costal region in the Eocene and Miocene, with a well marked regression in the Oligocene. The Miocene transgression is also prominent along the southwestern coast. The final shape was given to the west coast of India in the late Pliocene, now marked by the almost straight edge of the continental shelf.

Pleistocene deposits are found along parts of the two coasts–Tirunelveli, Kerala, Gujarat, Bengal and Orissa. They are several hundred metres thick in the Ganges delta. Similar deposits, less thick, occur in the Mahanadi, Godavari and Cauvery deltas. Pleistocene calcareous sandstones have been uplifted to a height of 10 to 20 metres along the Tirunelveli coast. Recent oceanographic work indicates that the sea level along the eastern coast was 60–80 metres below the present one during the glacial maximum. On the western coast, the mud banks of Kerala appear to have been formed during the Pleistocene; the material of these banks may have been derived mainly from the Mio-Pliocene Varkala Sandstone, and partly from the silty sediments brought down by the numerous rivers. Farther north, in Gujarat, Kathiawar Peninsula and Kutch, uplifts took place during the Pleistocene, while the Cambay-Ahmedabad region which was occupied by a shallow sea was silted up and became land. There are no well marked deltas along the western coast (except in the Cambay Gulf) because the sediments brought down by the rivers are distributed on the continental shelf by the strong long-shore currents. It would be necessary to undertake detailed studies of the Pleistocene deposits all along the coasts of India for gaining an idea of the relative movements of land and sea during the last one million years.

The foregoing is the Summary of the lecture delivered by Prof. M. S. Krishnan at the inaugural Session of the Symposium on Coastal and Nearshore Oceanography held in Ernakulam. A few more abstracts of papers which were presented at the symposium are given below.

Radio-Active Tracer Studies at Cochin

C. V. Gole and Z. S. Tarapore
Central Water and Power Research Station, Poona

The approach channel to Cochin Port is approximately 18,000 ft. long and is maintained at–32 ft. LWOST. The dredging of the approach channel is done during the months of January and February by means of a pipeline dredger which dumps the material about 1500 ft. on either side of the channel. The channel is required to be dredged to about El. –39 ft. LWOST allowing for about 7 ft. of siltation over the year. It was feared that the dredged spoil which was dumped very close to the approach channel was finding its way back, thus adding to the total quantum of dredging. Accordingly radio-active tracer studies were conducted durirng the years 1962 and 1963 in order to determine the direction of movement of bed material on either side of the approach channel. Radioactive material was dumped on 3 occasions in May 1962, November 1962 and April 1963. The results of these studies showed that there was a funnelling action, probably due to the large tidal influx into the backwaters behind Cochin gut which causes material dumped in the vicinity of the approach channel both on the north and south sides to be drawn in. However, the direction of travel of material at a point 5 miles south of the approach channel was distinctly to the north. In addition, the injection at a point 3½ miles to the north of the approach channel showed that the direction of travel of bed material was also northwards.

These studies, therefore, reveal that the general direction of bed material in the sea off the Cochin gut is to the north. However, in the vicinity of the approach channel the large tidal influx causes a funnelling action bringing material from both sides into the approach channel.

Survey of Sea Water: Gujarat Coastal Waters—Some ionic relationships

N. N. Sharma and G. N. Dave
Central Salt & Marine Chemicals Research Institute, Bhavnagar

Three important ionic relationships, Viz., (a) salinity–chlorinity, (b) Calcium-chloide and (c) sulphate-chlorinity are described for the coastal waters of Gujarat (divided into about 50 sampling stations). Two of the ratios differ from the generally accepted ratios for sea water, i.e.:

(a) Salinity-Chlorinity ratio is quite on the higher side than the conventional ratios of Dittmar (1884) Jacobson and Kundsen (1940).

(b) Calcium-chloride ratios of Kirk and Moberg (1933).

(c) Sulphate-chlorinity ratio, in general, is in line with the observations of Thompson, Johnston and Wirth (1931).

The above deviation from the generally accepted ratios for sea water are on account of the flow of surface water into the sea. The surface water normally contains, as compared to sea water, a higher percentage of calcium and a very much low percentage of chloride (chlorinity). This is, therefore, responsible for the above differences. The data presented show that the waters around the coast of Gujarat are under the influence of surface water throughout.

Progress of research at the Hydraulics Laboratory of the College of Engineering Trivandrum

K. C. Chacko, Principal, College of Engineering, Trivandrum

The paper describes the facilities available at the Hydraulics Laboratory of the College of Engineering, Trivandrum, for conducting studies in Coastal Engineering.

A review of the completed projects and current projects is presented. They include basic studies on the behaviour of coastal waters and beaches and investigations for coastal structures. A note is also added on the proposed expansion of facilities.

The Characteristic Method in the Analysis of waves on Beaches

Dr. S. Vasudev, Post-Graduate Professor, College of Engineering, Trivandrum.

There exist two main approximate theories to the motion of water with a free surface subject to gravitational forces. One of them results from the assumption of small wave amplitude and the other from assumption of small wave depth. The shallow water theory may be used to formulate a system of quasi-linear hyperbolic equations analogues to similar equations in gas dynamics. The method of characteristics lends inself to easy solution of these equations. The graphical and numerical method of analysis are explained with respect to examples from wave run-up on beaches.

Changes in the Configuration of Visakhapatnam-Waltair Beach

C. H. Madhusudhana Rao and
M. Poornachandra Rao

The paper presents the results of the analysis of the profile data of Visakhapatnam-Waltair beach, which may be divided into three zones based on profile studies. The investigations show that the beach is subject to rhythmic short-term changes, seasonal cycles, changes associated with random cataclysmic events like storms and beach erosion induced by the construction of breakwater. Detailed observations of the profiles of various places showed that while some places experienced cut, other places experienced fill, during the same period. Even during the storms some places experienced fill while other places underwent a cut. Differential erosion was observed along some parts of the beach in the same period. A direct relationship has been found to be present between grain size and slope of the beach and also between size and erosion and deposition. The studies indicate that the Visakhapatnam coast is eroding slowly after the construction of breakwater.

Coastal Erosion at Ratnagiri

C. V. Gole, Z. S. Tarapore and Y. D. Barve
Central Water and Power Research Station, Poona

The problem of erosion of the shoreline of the Ratnagiri Bay was investigated by the Central Water and Power Research Station in 1958, as a result of which certain protective works were recommended for execution. Inability to implement the protective measures resulted in further erosion taking place from year to year threatening valuable land along the foreshore. As an emergency measure the State Government decided to construct a temporary sea wall 1200 ft. long of laterite stone armoured with 6 to 9 inch trap stones. The behaviour of this temporary wall during the monsoon of 1965 is briefly described in this paper.

Use of Modern Technology for Determination of Sediment Along the Coast and Maritime Rivers

S. Muddappa, Mysore Engg. Res. station.

This paper deals with various techniques that have been developed from time to time to trace the movement of sediment in sea and maritime rivers. Different methods such as hydrographic, petrographic and morphologic and use of radioisotopes and luminescent tracers are detailed. The advantages of using tracers are brought out. The manufacture and use of fluorescent are explained in detail. The application of this technique in model studies is touched upon.

INDIAN OCEAN BIOLOGICAL CENTRE, ERNAKULAM

With the addition of 88 samples received from the CSIRO, Australia the total number of existing Zooplankton samples comes to 2,188 by the end of September 1966. The processing of 1,462 samples have been completed so far, thus leaving 726 samples unprocessed.

Among the 79 samples processed during July-September period are 63 samples from R.V. *Varuna* (Indo-Norwegian Project) and 16 from R.V. *Gilchrist* (South Africa). Besides, the re-sorting work of 21 samples more from INS Kistna has also been done.

The research activities initiated at the Centre are also progressing side by side with the processing work. The following are the items of such work taken up by the staff of the Centre.

1. Subsorting of Amphipoda to family.
2. Subsorting of Decapoda to family.
3. Subsorting of larval fishes to order and to a few families.
4. Preliminary study of identification of pelagic Polychaetes.
5. Identification of Heteropoda, exclusive of Atlantidae.
6. Identification of Pteropoda.
7. Preliminary study of literature relating to flat fish larvae.
8. Identification of Euphasiacea.

REPORTS FROM OTHER COUNTRIES

Bathymetric, Magnetic and Gravity Investigations of H.M.S. *OWEN*

Hydrographic Department, Ministry of Defence, London has published early this year the basic data on bathymetric, magnetic and gravity investigations made by H.M.S. *OWEN* during her Indian Ocean Cruises of 1962-63. Data are accompanied by brief analysis of the principal results. The major objectives during the investigation were the following.

1) A detailed study of part of the northern end of Carlsberg Ridge.

2) A study of the crustal structure between the coast of Kenya and the Seychelles.
3) A broad survey of the fault zone S. E. of Socotra which had been postulated to explain an apparent right lateral displacement of the axis of the Carlsberg Ridge (Mathews 1963) This feature was subsequently named the Owen fracture zone.

Similar objectives were followed by other British ships participated in IIOE. A report on the geophysical work carried out by RRS *Discovery* has been published earlier.

The cruise programme of Owen was planned at the Department of Geodesy and Geophysics Cambridge University under the supervision of Dr. M. N. Hill. The ship was engaged in geophysical work in the Indian Ocean during two periods: November-December, 1962 and April-May 1963 covering in all 17500 nautical miles. During the first phase of the cruise commenced from Aden on 1st November, 1962 the ship made two surveys before calling at Bombay on 27th November, 1962. Leaving Bombay on 30th November the ship worked in the Seychelles area and called at Mombassa on 18th December, 1962 making one more survey on the way. The first survey was located on the crest of the Carlsberg Ridge in an area 250 x 38 nautical miles. Peaks in the area reach about 1000 fm. and troughs reach about 2400 fm. Second survey was over the south-western foothills of the Calsberg Ridge near the abyssal plain in an area 30 x 35 miles. The larger ridges here rise to less than 2000 fm. and troughs descend to more than 2500 fm. The third survey was intended to find a strip about hundred miles long, ten miles wide and devoid of seamounts as a suitable site for seismic refraction in a typically oceanic area between Seychelles Bank and the Carlsberg Ridge. The remainder of the ships track in the coast of Kenya was used to reconnoitre the site of seismic refraction profiles between Lamu and Seychelles.

D. H. Mathews, C. S. Mason, J. A. Chaplin and A. K. Wheatley were the scientists on board during this part of the cruise.

The second phase of the cruise began from Mombassa on 8th April 1963 and arrived at Port Victoria on 11th April. Leaving Port Victoria on 16th April the ship called at Karachi on 27th April. During this course a survey area was covered between 19th and 23rd April 1963. On her return from Karachi on 30th April 1963 to Aden the survey area was occupied between 3rd and 13th of May. The cruise was completed at Aden.

The track from Mombassa to Seychelles was arranged to provide a new crossing of the Amirantes Island arc. The main survey work during this part of the season was the investigation of the postulated fault zone South of Socotra. Between 19th and 23rd April the ship made seven transverse crossings of the northern end of Carlsberg Ridge on a course perpendicular to the trend of the Ridge and parallel to the postulated fault while returning from Karachi the survey was continued; the ship made six traverses oriented NW-SE across the fault zone and four more transverse crossings of the north-western end of the Carlsberg Ridge. A small trench having a maximum recorded depth of 3173 fm. C.720 fm. deeper than the adjacent plain was found near 12°35'N; 58°15'E. At the 2500 fm. contour the trench is probably not more than seven miles wide and 20 miles long.

B. C. Browne, C. S. Mason A. K. Wheatley were on board.

Navigation:

Normal astronomical methods were used to determine the ship's position on the oceanic passages. The absolute accuracy of the plotted trace varies and is lowest where the ship was affected by the swift flowing Somali Current. Most of the track is considered reliable to +3 miles. Positions at the time of star sight and the relative accuracy of adjacent sections of the track over periods of about 6 hours are considered to be reliable to about + 1 mile.

Detailed surveys over the Carlsberg Ridge were preceeded by twelve hours of reconnaissance to confirm the suitability of the chosen area. After this beacons were laid and their relative positions were fixed by a taut wire traverse and also measured by radar. Scientist on watch kept record of the times at which contours were crossed on the precision echosounder and magnetometer recorders while the surveyer on watch constructed the tract chart using radar changes and bearings of the anchored beacons. In each of the three areas of detailed survey on one of the beacons was laid a buoy containing a recording proton magnetometer to monitor the daily variation of magnetic field intensity. The results obtained with these instruments were used in reduction of the magnetometer surveys and in a comparision between variation at sea and the land. It may be mentioned here that before leaving Aden a continuously recording proton magnetometer was set up at the R.A.F. Secondary School, Khormaksar to monitor daily change in the total field intensity. These results were signalled and received on board.

Bathymetry

Soundings were taken on a precision echosounder similar to the one evolved at the end of the previous season. This machine uses a hull mounted transducer and a "Mufax" recorder. The profiles have been constructed from Soundings taken at ten minutes intervals plus sounding at peaks and troughs.

Magnetic Measurements

Instruments and methods of graphical reduction of observations was similar to that used during the previous season. Magnetic data for the two detailed surveys was reduced on the computer Edsac II at Cambridge. The machine gave values of magnetic anomaly at one minute intervals after making corrections for heading effect and for daily variation observed at the anchored buoy and substracting a linear regional field gradient.

A determination of magnetic effect of the ship was made in the third survey area round the recording magnetometer buoy moored at 57°W, 1°40'S when the dip angle is 23°S.

Gravity Measurements

The instrumental arrangements used for the gravity measurements were unchanged from the previous season. The accuracy of the measurements reported here is considered to be about ± 10 mgal (1 mgal $= 10^3$ cm/Sec.2). Factors affecting this accuracy are: 1, accuracy of base station values. 2, Gravimeter calibration factor 3, gravimeter drift 4, accuracy of navigation; particularly *Eotvos correction* 5, possible errors due to ships motions cross coupling.

Base Stations

Base stations used were Aden, Bombay, Port Victoria (Seychelles), Mombasa and Karachi. Connection between these harbour stations and the quay beside the ship were made using a worden Master Gravimeter as before. The values are considered accurate to ∓ 0.5 mgal except at Port Victoria where the accuracy may be $\pm$ 1-2 mgal.

Sea Gravimeter and Drift

Although certain changes in the instrument were made between the two cruises no further longline calibrations were made. It was therefore felt that the calibration factor to be used would be average value for the previous year (0.657 mgal/MSD) A table showing the gravimeter drift rate and chart calibration has also been given in the report. Profiles of free air gravity anomalies were plotted exactly as before and presented in the second part of the report.

SCIENTIFIC CRUISES OF *KOYO MARU*, JAPAN.

Koyo Maru—the 1215 ton training ship of Shimonoseki University of Fisheries, Japan participated in the IIOE undertaking scientific cruises in the years 1962-63 and 1963-64. A separate Committee was also established by the University to draw up programme of her participation.

The first cruise began from Shimonoseki in October 1962. On her course calling at Tokyo, Singapore and Colombo the ship arrived at Fremantle on 9th Jan; 1963. Leaving Fremantle after five days, completed the cruise at the home port on 18.2.1963. While returning she called at Singapore and Hongkong. Seven scientists, 39 ships' officers and crew and 72 cadets were on board. This cruise covered about 15,000 nautical miles in 118 days. During the period from November 22 to December 7, several observations were carried out at 14 stations having distances from 34-74 nautical miles along the 94°E line. On the way to Colombo from Station 14 observations were carried out at reference stations locating at O° and 90°E. During the period from December 22 to January 2, of the next year observations were conducted at ten stations having distance ranging 85-96 nautical miles along 94°E line. At the reference station 32°S and 111°50'E, physical, chemical and biological observations were carried out.

The second cruise was undertaken between October 1963 and February 1964. Tokyo, Hongkong Penang, Djakarta, Fremantle and Singapore were the ports of call during the cruise. In the early part from November 23 to December 1, nine stations having distance from 71 to 95 knots along the 94°E line were covered. Five more stations along same direction were worked out during the term between December 15 and 19. Similar observations except current measurement were carried out at 7 stations along the 100°E. At 32°S and 111°50'E, observations on physical, chemical and biological oceanography, meteorology, bacteriology and primary production were carried out.

A total of 15000 nautical miles were covered in 117 days during this cruise. Seven scientists were on board. The following is an outline of the various accomplishments on board.

OUTLINE OF ACCOMPLISHMENTS

Echosounding

During the cruise of the second expedition, echo soundings were carried out continously. Depth recordings were read every ten minutes during the cruise.

The instrument used is "Type HD Deep Sea Echo Sounder", but from the restriction of its efficient powers the reflection of ultrasonic waves from the bottom could not be perceived when the depth was over 6000 meters or the bottom conditions were bad.

And by reason of the shortage of parts, measurements were suspended after Jan. 7, 1964.

Meteorology

Maritime meteorological observations:

During the period of cruise from Tokyo to Shimonoseki except while in port, routine maritime meteorological observations were carried out at 0000 Z, 0600, 1200 Z and 1800 Z every day. The results of the observations were reported to the agencies interested immediately.

Aerological observations:

Pilot balloons were released at about 1200 every day along the observation line, and at the same time radiosondes were also released to measure meteorological elements of the upper layer. And at several points out of the observation line, pilot balloons and radiosondes were released.

Observation of clouds by all-sky camera:

Typical states of clouds observed during the period of this expedition were photographed by an all-sky camera.

Physical Oceanography

Surface observations and water samplings:

During the period of both cruises except while in port, surface water termperature was measured at every first hour and at the same time surface water was sampled to measure its salinity. And during the same period, temperature of surface water was continously recorded.

Bathythermograph observations:

Every three hours during the cruise of the ship, temperature and depth from the surface to about 250 meters depth were recorded by the bathythermograph (BT) and the same observations was carried out at every stations including current measurement stations and exploratory fishing stations.

Surface current observations by GEK:

On the observation lines south of 5°S, surface currents were measured by the GEK (Geomagnetic Electrokinetography) at almost all stations.

Serial observations:

At all stations on the observation lines and reference Stations, temperatures were observed and water samples were collected at the layers with depths as follows:

10, 20, 30, 50, 75, 100, 125, 150 200, 300, 400, 500, 600, 800, 1000, 1200, 1500, 2000, 2500, 3000, 3500, 4000, 4500 and 5000 meters.

Reversing bottles used were the Nansen reversing bottles with two protected reversing thermometers and one unprotected reversing thermometer.

To set the reversing bottles at the standard depths, a wire was prolonged according to the wire angle at observation time.

Current measurements:

On the observation lines from 5°N to 5°S and some other stations, currents at the layers of 10,50,100,200,400 meters and some other depths relative to the reference layer of 800 meters, were measured with two current meters.

Water colour and transparency:

At many stations water colour and transparency were measured respectively, with a Forel-Ule water colour scale and Secchi's transparency disc as far as circumstances permitted.

Drift bottles:

At 20 stations along the cruising course of both years, about 100 dirft bottles were released to collect information on the outline of surface currents.

Chemical Oceanography

Salinity, dissolved oxygen, phosphate (PO_4–P), silicate-silicon (SiO_3–Si) and pH:

At all stations and Reference Stations these elements of water samples collected by serial observations were measured on board in the following methods described in Summary 2. The equipment and methods of "Data of Physical and Chemical Observations in the Indian Ocean from November 1962 to January 1963".

Total phosphorus:

Total phosphorus of water samples collected by serial observations at all stations and Reference Stations were measured at laboratory with an electro-colorimeter (1962-1963) and auto-recording photoelectric filter photometer (1963-1964).

Nitrate-nitrogen:

At 17 stations including Reference Station of 1962-1963, nitrate–nitrogen (NO_3-N) of water samples from depths ranging O-about 100 meters were measured with an auto-recording photoelectric filter photometer.

Planktology and Marine Biology

Eye observations:

During the period of cruise from Tokyo to Shimonoseki except while in port, particular phenomena of sea surface and all objects observed were recorded by watchmen on the bridge in the expedition of 1963-1964.

Standard net samplings:

At Reference Stations and all stations excluding double-sampling stations, vertical haulings were carried out in the depth from about 200 meters to the surface with the Indian Ocean Standard net at about 2000 hrs. ship's time.

Oblique haul of the 160 cm net:

At Reference Stations and all stations excluding double-sampling stations, oblique haulings of a large net with the aperture of 160 cm and with depth recorder were carried out in the evening or at dawn.

Divided samplings by the 80 cm closed net:

In the expedition of 1962-1963, at 3 stations divided haulings were carried out at three layers, depths of which covered from the surface to about 3000 meters depth.

Underway plankton samplings:

At Reference Stations and all stations excluding double-sampling stations mainly in the night, collections by the underway plankton sampler were carried out.

Exploratory samplings by the Isaacs-Kidd midwater trawl net:

At 22 stations in the year of 1962–1963 and 13 stations in the year of 1963-64 including Reference Stations, exploratory samplings were carried out at 1-3 layers with different depths with the modified Isaacs-Kidd midwater trawl net.

Bacteriology

Expedition of 1962-1963.

Samplings:

At 20 stations water samples were taken from 0, 10, 25, 50, 75, 100, 200, 250, 300, 400, 600, 800, 1000, 1200, 1400, 2000, 2500 and 3000 m. depths.

Enumeration of heterotrophs in water:

Viable cells of aerobic heterotrophs in all the water samples were enumerated.

High pressure cultivation of bacteria in water:

At 6 stations, the water samples obtained from 1000, 2000 and 3000 m depths were exa-

-mined for the activities of different physiological types of bacteria under the high hydropressure corresponding to that *in situ*.

Expedition of 1963-1964

Samplings:

At all stations, the water samples were taken from 0, 10, 25, 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, 1000, 1200, 1500, 2000, 2500, 3000, 3500, 4000 and 5000m/. Sediment Sample was obtained from 1450 m deep bottom at a station. Fractions of plankton materials, collected by vertical divided hauls at 5 stations, were also used for bacteriological examinations.

Enumeration of heterotrophs in water:

Viable cells of general aerobic heterotrophs in all the water samples were counted. The population of heterotrophs having relatively simple nutritional requirements was also determined at 3 stations.

Enumeration of nitrifiers in water:

At 3 stations the water samples were examined for the numbers of nitrifying bacteria, i.e. nitrite formers and nitrate formers.

Direct counting of total microbial cells in water:

Total microbial cells in the water samples taken at 4 stations were counted microscopically by a membrane filter technique.

Estimation of bacterial population in plankton materials:

The numbers of aerobic heterotrophs and nitrifying bacteria existing in the plankton materials collected from different water layers were estimated at 5 stations.

Enumeration of bacteria in bottom sediment:

The sediment sample was examined for the numbers of different physiological types of bacteria by using several differential media. The cultivations for counting were made under the high hydropressure corresponding to that *in situ* as well as under normal atmopheric pressure.

Isolation of bacteria and further studies:

Nearly 1400 pure strains of bacteria were isolated from water samples, plankton samples and sediment sample. Detailed studies on the bacteriological characteristics on them are now in progress.

Primary Production

As a part of the IIOE Programme, primary production measurements were carried out. The following items of observation concerning the study of primary production and chlorophyll were practised on board in 1962-1963 and 1963-1964 cruises.

Continuous recording of solar radiation energy:

This measurement was carried out by means of Epley self-recording radiation meter during the whole observation.

Secchi disc reading

Tank experiment:

In 1962-1963 cruise, water samples for determining production were taken from the 6 optical depths, i.e. 100,50,20,10,5 and 1%. In 1963-1964 cruise, water sample was collected not from optical depths, but from the definite depths (0,10,25,50,75,100 and 125 m) which were given beforehand at all the stations. These were dispensed into two transparent and one darkend bottles, and 10/μc $Na_2{}^{14}CO_3$ solution was inoculated into each bottle. These bottles were then placed in an incubator which has a light intensity of 15,000 luxes. These bottles were removed after 4 hours, filtered with Millipore filter. And then Gas-flow countings were made on board. In the first and second cruise, tank method was made at 21 and 15 of all the stations respectively.

Stimulated in situ experiment:

This method consisted of exposing samples, collected from 5 depths except 1% optical depth and inoculated with 10 μc $Na_2^{14}CO_3$ solution, to light intensities comparable to those occurring at the depths from which the samples were taken. This experiment lasted for about half the daylight portion of a day, from midday to sun set. This experiment was made at 13 of all the stations. In the second cruise, this was not carried out.

In situ experiment:

Bottles containing sample water from 6 optical depths in the first cruise and 7 depths (0-125m) in the second cruise were suspended at the depths of sampling respectively. In the first cruise, this experiment was made at 14 and 8 of all the stations in the second cruise.

Chlorophyll measurement:

In the first cruise, six to ten litres of sample water from the 6 optical depths were filtered through Millipore filter HA 47 mm diameter. Having been brought to the laboratory chlorophyll determinations were made on these samples according to the method of Richards and Thompson. Chlorophyll measurements were made at all the stations. In the second cruise, sample water was collected from 9 depths (0, 10, 25, 50, 75, 100, 125, 150 and 200 m). Chlorophyll measurements were made at 13 stations.

Exploratory Tuna Long-line Fishing and Fishery Oceanography

Exploratory tuna long-line fishing:

At line stations in 1962-1963 and twelve stations in 1963-1964 tuna long-line fishings were carried out to explore the potential productivity of tuna resources (see Chart H-1). 120 to about 150 baskets each of which has 5 hooks were used at every stations.

Fisheries oceanography:

At all fishing stations, measurements of surface water temperature, BT observations and serial observations from the surface to about 1000 meters depth were carried out immediately after the throwing of tuna long-lines. Salinity and dissolved oxygen of sample waters were measured on board.

Samplings by the standard plankton net:

In the expedition of 1963-1964, at all fishing stations plankton samplings by the Indian Ocean standard net were carried out after the throwing of tuna long-lines.

Biometrical measurements of fishes caught:

Biometrical items of all fishes caught by tuna long-line fishings were measured on-deck immediately after the lifting of tuna long-lines.

NOTES AND NEWS

Strontium Isotopes in Deep Sea Sediments

Isotope studies have provided significant information about the geologic provenance of deep sea sediments. E. Julius Dasch and his colleagues of the Department of Geology, Yale University had undertaken a study of the strontium Isotope ratio of the core samples raised by Lamont Geological Observatory.

Recent deep sea sediments leached of carbonate have Sr 87: Sr 86 ratios ranging from 0.7044 to 0.7394. Strontium in the detrital sediment has not equilibrated isotopically with sea water strontium. A sample from off the coast of Chile has a ratio of 0.7044 which is near the low values measured from oceanic volcanic rocks. Samples from off the mouth of Congo river has a ratio 0.7394 which may be a near maximum ratio for deep sea sediments. A similar high value has been reported for Lake Superior sediment derived mainly from 2.5 billion year terrain.

Because of the larger proportion of the authigenic minerals and the general lesser age of circum Pacific rock sediments from Pacific basin probably have lower Sr 87: Sr 86 values and a narrow strontium isotope range than Atlantic sediment (*Science*, Vol. 153 No. 3733, July 1966).

Properties of Metals Change in Deep Ocean Environments

The mechanical properties of metals exhibit suprising changes when subjected to the high hydrostatic pressure in the deep Ocean environment. This is of considerable interest in deep ocean engineering. Prof. Alan A. Johnson and his co-workers in their report in *Nature* define a transition temperature at which a sufficiently stressed metal may become completely brittle. Above this temperature the same stress will instead cause steady deformation, the metal being sufficiently ductile to spread the stress so that it is no longer concentrated at the ends of incipient cracks. (*Nature*, Vol. 210 No. 5036, May 1966).

Drifting Organisms in the Precambrian Sea

Drag marks discovered in the upper precambrian Winnal Beds of central Asustralia were interpreted to be made by semi-buoyant flexible objects, presumably algae. This find extends the range of such marks into the precambrian era and supplements the discovery of microflora in the same sedimentary sequence. The discovery was made by Daniel J. Milton of U. S. Geological Survey while mapping the Henbury meteorite crater.

The variety of orientation of intersecting sets as well as the change of direction of individual sets indicate that the objects were moved by random currents or more probably waves. Irregular Oscillation ripple marks on the upper surface of the sandstone bed suggests wave action.

This find extends the range into the precambrian and indicate that before the beginning of paleozoic era life had evolved beyond the microscopic forms into organisms as large as that of the sea weed in modern seas. (*Science*, Vol. 153 No. 3733, 1966)

Artificial Radionuclides in Marine Organisms

Marine organisms modify the distribution of radioisotopes in the oceanic ecosystem by concentration of elements and by their movements and migrations observe C. L. Carey, G. Andrew, and P. William based on their investigation off Oregon, USA. They presented a paper on this in the Second International Oceanographic Congress held in Moscow. Induced radionuclides, e.g. zinc-65, from the cooling waters of the Hanford Washington) reactors and fission products from atmospheric testing have been detected in animals in the northeast Pacific Ocean as far as 490 km off the coast of central Oregon and to depths of 2860 m. Zinc-65, detected in every species analysed, is associated with the surface–laying Columbia River plume and is an active element in biological systems. Geographic seasonal, and bathymetric variations in the concentrations of radionuclides have been found in both the nektonic and benthonic animals off Oregon.

Radiozinc levels in the benthos decreased with distance from the mouth of the Columbia River. At times, similar trends were found in pelagic animals.

Seasonal maxima of Zn^{65} concentration were apparent in the fauna due to the seasonal shifting the position of the Columbia River plume. During the winter, Zn^{65} concentration was fairly uniform in midwater trawl samples from the surface to 1000 m, but during the summer it was much higher in near surface than in deep-water animals. Zinc-65 in the benthos also varied seasonally on the continental shelf due to both shifting plume and reproductive cycles within the animals. Beyond the shelf, Zn^{65} levels were low, and seasonal variations were not apparent,

Before cessation of atmospheric testing, they detected zirconium-95 niobium-95 in the fauna from all depths. Amount of these relatively shortlived radionuclides were much higher than expected in the benthic fauna from the deeper stations (2,800 m).

The position of the fauna in the food chain affects the concentration of radionuclides. Particulate fission isotopes were prominent only in the spectra of the herbivores or detritus and sediment feeders. The carnivorous benthos contained higher amounts of zinc-65 than the sediment-eating forms.

Artifical radioisotopes are difficult to measure in the water and sediment off Central Oregon, although they are readily measurable in the fauna. The organisms, then, are important in determining the distribution and concentration of artifical radionuclides in the marine environment. (Charls. L. Carey et. al. Dept of Oceanography, Oregon State University, Corvallis, US)

Research Vessel Mikhail Lomonosov in Bombay

'Mikhail Lomonosov', the research vessel of the Marine Hydrophysical Institute of the Academy of Sciences of the Ukrainian SSR touched the port of Bombay on July 12, 1966. She is carrying out oceanological research in the Indian Ocean, which is only a part of a big programme chalked out by the Ministry of Fisheries of the USSR.

Since the ship was built in Rostok (G.D.R.) in 1957, this is the 19th cruise in which about 70 scientific workers are carrying out an ocean-research programme under the leadership of a 65-year-old scientist G. Neuimen of Kiev.

Addressing visiting pressmen and scientists on board the ship Neuimen told that this research vessel left Sevastopol at the end of April, crossed the Mediterranean sea, Red sea, Port of Aden, Karachi and Colombo before coming to Bombay on July 12.

Research vessel Mikhail Lomonosov is expected to go to Singapore en route to Vladivostok from where she will go to Tokyo.

The 19th expedition would come to an end in the 4th month from its start.

In past 8 years Mikhail Lomonosov has undertaken 18 different scientific cruises from the North Pole Circle to Atlantic Ocean. This is the first time she is delving deep in the waters of the Indian Ocean.

Recent observations on the Isotope Geochemistry of Calcium in Marine and Biological Materials

James T. Corless in his paper presented in a Symposium during the second International Oceanographic Congress held in Moscow summarises his observations on the neutron activation analysis for the determinations of variations in the abundance and analytical reasons, the experimental work has focused mainly on developing a sensitive and reliable technique for calcium. The work was being done in the Graduate School of Oceanography, University of Rhode Island, USA for about 18 months during which time developmental work on the analytical procedure was completed and as a test for reproducibility a small suite of samples was chosen for repeated analysis. This included sea water, the shell of a local hard clam (*Mercenaria mercenaria*) a composite of ten whole human teeth and a standard (a.r.g. $CaCO_3$) Replicate analysis consistently show variations in the ratio Ca^{48} total Ca among the three natural samples.

These results suggest that further analysis of marine and biological carbonates and phosphates might provide new geochemical information on biological versus non biological mineralisation. Along this they are presently analysing a number of additional samples including recent carbonates from Bahama Banks region and variety of shells, limestones and dolmites in an effort to elucidate both the calcium isotope pattern in the marine evironment and whether as suggested by the above analysis biological mineralization affect Ca^{48}/Total Ca ratio.

Giant gasfield in the North Sea

Five years ago it was only a prediction by Sir Kenneth Hutchison, Deputy Chairman of the Gas Council of U.K. that natural gas would be located in the North Sea. Although some minor success were recorded, the final break through was made possible only when the drilling rigs were taken offshore. Published figures from the new wells indicate that gas fields of Briton might be five times larger than the largest gas field of Holland. Shell/Esso hole of 1200 million cubic feet according to an estimate—is equivalent to more than the total gas supply to the country at the present time.

The economic impact of recent finds of natural gas depend on a number of technological factors concerning distribution and use, says Nigel Calder in his article "Britain's Methane in Perspective" (*New Scientist*, Vol. 30 No. 497, May 1966).

Bedford Institute of Oceanography

The annual report 1965 of the Bedford Institute of Oceanography has been received. Bedford Institute of Oceanography (BIO), now in its fourth year is housed in one campus and in varying degrees, integrates several organizations which previously had operated more or less in isolation from one another. The largest unit is the Atlantic region of the Marine Science Branch, Department of Mines and Technical Surveys of Canada. The second largest unit in the Institute is the Fisheries Research Board of Canada's Dartmouth Laboratory known as the Atlantic Oceanographic group. This laboratory is an independent entity within the Institute with its own Director. The report is jointly presented by these two major unit in two separate parts.

The first part of the report summarises various research programmes in chemical and physical oceanography, air/sea and air/ice/sea interactions, marine geology and geophysics, tides and currents, hydrographic charting, and instrumentation. The second part summarises the programmes of research in Biological Oceanography, and Environmental Oceanography.

Norwegian Government Scholarship

Dr. C Sankarankutty, who has been working at the Biological Oceanography Division of NIO on a Senior Rsearch Fellowship of the National Institute of Sciences of India has been awarded the Norwegian Government Scholarship (1966-67) in marine biology. He left India for Norway in the last week of July. In Norway Dr. Sankarankutty will be working on the decapod larvae and also the life history of *Geryon tridens* Kroyer, a deep sea crab.

EIGHTH GENERAL MEETING OF THE SCOR (Scientific Committee on Oceanic Research) Rome 23-27 May, 1966

The eighth general meeting of the Scientific Committee on Oceanic Research (SCOR) was held at the Consighlio Nazionale delle Ricerche, Rome, on 23-27 May 1966 with the President Captain Luis Capurro in the chair. A business meeting on 23 May was followed by the Symposium on variability in the ocean, during the next three days. On 27 May a visit was made to the zoological station in Naples.

The meeting discussed the following items which were on the agenda and adopted recommendations. Second volume of the proceedings of the SCOR Containing the report on this meeting has been dedicated to Dr. Gunther Bohnecke on the occasion of his Seventieth birthday (on 5 September 1966)

Revision of Constitution

The recommendation of ICSU on the question of most effective working relation between IAPO and SCOR was accepted by the General meeting. The schedule for SCOR to meet at two year intervals in alternate years from IOC Sessions was approved. In the context of the change in interval between the meetings it was agreed to extend the term of office of Vice-President and Secretary to a further period of two years, the limit for continuous service on the executive being six years. These followed by a report of the Secretariate and Budget.

WORKING GROUPS

Establishment of Groups for 1966-67

During the Executive meeting of June 1965 (SCOR *Proceedings*, 1 (1), it was decided that the tenure of SCOR Working Groups would expire at each General Meeting at which time decisions would be made about re-establishing each group, changing its membership or revising its terms of reference. Accordingly the work of each group was discussed and the decisions reported below were taken. Representatives of other sponsoring bodies were present in Rome and Moscow, and agreed to support these decision in presenting them to their organizations.

In order to ensure close liason with national committees in the activities of SCOR working groups it was agreed to make available to national committees lists of WGs and members, to ask for new nominations of national participants, and to instruct WG chairmen to keep national participants fully informed on all activities of the group.

WG. 10 *Oceanographic Tables and Standards* (with ICES, IAPO, and UNESCO). The full report of the October (1965) meeting of this group has been published by UNESCO (Second Report of the Joint Panel on Oceanographic Tables and Standards, UNESCO Technical Papers in Marine Science No. 4, 1964). Tables relating conductivity ratio and salinity have been prepared and will be published by UNESCO. A new definition of salinity, based on conductivity ratio, has been established. Further tables are under consideration, including the following:

A) effect of pressure on conductivity.
B) specific gravity as a function of temperature and salinity.
C) chlorosity as a function of salinity or chlorinity.
D) velocity of sound, as a function of temperature, salinity, and pressure.
E) salinity as a function of refractive index.

It was agreed that the work of this important group should continue. Until now, major emphasis has been on the effect of the concentration of dissolved constitutents. In the future, it will be important also to emphasize the accurate determination of the coefficients of thermal expansion and isothermal compressibility so that the equation of state of sea water can be more completely established. In view of this change of emphasis it was agreed that two physicists concerned with such measurements should be added to the group (or should replace two of the chemists). This change in membership will be worked out in consultation with the Chairman, Prof. Dietrich, and with other sponsoring bodies.

WG. 12 *Abstracts and Bibliography.* It was agreed that the report of this group (SCOR *Proceedings*, 1 (2) Annex IV) had served a very useful purpose in identifying further studies which should be carried out and in describing the present status of the information problem in marine science. It was decided to discontinue the group at this time, and to keep under review the possibility of further activity when it was clear how SCOR could most effectively contribute to a solution. The Secretary was instructed to report this decision to the members, thanking them for their contribution.

A recommendation of WG. 12 has recently been implemented by FAO with the publication in May of the first number of "Current Contents in Marine Science." This will contain the tables of contents of about fifty primary journals covering fisheries biology, oceanography, maritime meteorology and other disciplines in marine science. Further information can be obtained from the FAO Department of Fisheries.

WG. 13 *Zooplankton Sampling Methods* (with ICES and UNESCO). A status report from the Chairman of this group is given in Annex V, together with reports from the various working parties. Comments on these reports should be sent to the Chairman Dr. Fraser. The task set for this group is nearly completed, and it was decided to reduce membership to the chairman, conveners, of the four working parties and Dr. G. Hempel, the final integrated report being completed by this small group. This report would be published by UNESCO together with the reviews prepared upon recommendation of the Sydney meeting of w.p. 3. In order to give this information the widest possible distribution, the chairman, Dr. Fraser, was requested to prepare an appropriate article for publication in *Nature*. It was noted that field trails of recommended equipment will eventually be necessary, and the WG and Executive Committee were requested to consider when and how these trails should be organised.

WG. 14 *General Scientific Framework.* Revision of this document is expected to be completed this summer, and it will be published by UNESCO. A new title is to be chosen by the editors. It was decided to abolish the working group but to ask Professor Revelle, Dr. Deacon, Professor Kort and Dr. Cushing to continue as an a editorial board until the work is completed.

WG. 15 *Photosynthetic Radiant Energy* (with IAPO and UNESCO). A meeting of this group is scheduled to be continued at least until that time.

WG. *General Problems of Standardization and Intercalibration.* In addition to the several SCOR working groups on specific methodological problems. WG 16 has attempted to look at the more general aspects of methodology. This group, made up of some ten specialists, has made some valuable suggestions, but it now appears that a smaller unit with more specific terms of reference might be able to keep this matter under review more effectively. Professor Kort agreed to study the terms of reference of such a group. In the meantime the Executive Committee, in consultation with the secretariats of cooperating organizations, such as UNESCO, FAO and ICES, will arrange for scientific evaluation of such proposals for action in this field as may arise. The present work-group will be disbanded, and its members commended for their help in this difficult problem.

WG. 17 *Photosynthetic Pigments* (with UNESCO). The original task of this group has been completed, and the resulting reports are being published by UNESCO. It was noted that certain aspects of this matter had been left unresolved—the utility of the fluorescene method for chlorphyll, the desirability of measuring carotenoids, the establishment of satisfactory equations for chlorophyll *a*, *b* and *c*, etc. Therefore, while abolishing the working group for the present, it was decided to ask Dr. Humphrey to serve as rapporteur, to keep the matter under review and at the appropriate time, to present recommendations for future action.

WG. 18 *Biological Data (with ACMRR)*. The report of this group (SCOR Proceedings, 1(2), Annex V), played an important part in discussions of the IOC Working group on Data Exchange (Copenhagen, 31 March-2 Apri 1966), and in the revision of biological sections of the Provisional Guide for the Exchange of Oceanographic Data. It is still necessary for various groups of specialists to consider the format for the exchange of biological data. It was agreed to retain this group until the next Executive Meeting, with its work being carried on by correspondence with the initiative of its Chairman, Dr. Hempel. Future activities, terms of reference, and membership would be discussed by ACMRR and a recommendation would be passed to the Executive. The Secretary of SCOR was instructed to obtain from NODC and CODC copies of their proposed formats for the exchange of biological data, for consideration by the group.

WG. 19 *Micropaleontology of Bottom Sediments*. It was agreed that this group should continue, at least until the proposed symposium on marine micropaleontology had been held. The representative of UNESCO stated that some financial support for this symposium might to available in 1967. It was agreed that close cooperation with IUGS in development of the symposium was desirable. Informal meetings of the group were held in Moscow during the Second International Oceanographic Congress, and a report of these discussions together with appropriate portions of the report (unpublished) of the January meeting is attached as Annex VI of the original proceedings.

WG. 20 *Primary Production* (with ICES and UNESCO). This group has not yet met and must be continued at least until it has reported on its terms of reference. An early meeting should be encouraged.

WG. 21 *Continuous Current Velocity Measurements* (With IAPO). Resolution IV-7 of IOC "invites SCOR to consider the establishment of a working group of scientists to evaluate suitable instrumentation for time series measurements." This proposal was discussed several times during the SCOR meeting, the Symposium on Variability, and the Executive Meeting in Moscow. At the last session it was decided to establish such a group to design, and propose means for carrying out, an inter-comparsion at sea of the principal current measuring systems now employed for the continous recording of current velocity on moored stations. These systems include recording meters designed by Richardson, Alekseev, and the Bergen group. The representative of IAPO agreed that cosponsorship by his organization would be appropriate and indicated which of the proposed members would be appropriate IAPO nominees. The Secretary was instructed to invite participation from a list of appropriate scientists suggested durimg the meeting. Subsequently, UNESCO agreed to join in sponsorship of the group.

Several additional working groups were proposed, but their establishment was deferred until additional information is available. These include the following:

Proposed WG on *Nutrient Chemistry* (with ICES and IBP) During the Fifty-third Meeting of the International Council for the Exploration of the Sea (Rome, October 1965), it was decided to establish a group within the frame of the Hydrographical Committee, for intercalibration and standardization of chemical methods in oceanography. The PM section of IBP has recently established a small group to consider nutrient chemical methods in brackish waters. Establishment of a SCOR working group on chemical methods has also been considered by WG 16.

The Chairman of the IBP PM Section, Dr. Ketchum compared the situation in sea water analysis with that in agricultural chemistry and referred to the practice of the American Association of Agricultural Chemists. This organization has a panel of experts who try out all new analytical methods on exchanged samples. As a result of their work, it is possible to publish periodically a handbook of tentative and approved methods. This practice might eventually be useful in marine chemistry.

The need for common action on this problem was recognized and the Secretary was instructed to correspond with officials of ICES, IBP UNESCO and IAPO to obtain more specific information on existing activities, which could form the basis for formulation of the most effective role of SCOR. The matter will be discussed again at the next SCOR Executive Meeting.

Proposed WG on *Marine Pollution* (with ACMRR). Resolution IV-10 of IOC concerns the establishment of an IOC Working Group on Marine Pollution. During the Sixth Meeting of the IOC Bureau and Consultative Council, it was noted that several other international bodies were active in this field, and that the proper role for IOC required careful consideration. A proposal was made that a small panel of experts organized by SCOR and ACMRR might usefully consider such problems prior to meeting of the IOC working group.

During the SCOR meeting it was agreed that such a panel, if given specific terms of reference, would serve a useful purpose. Compilation of the activities of existing international bodies could be most effectively done by the UNESCO and FAO Secretariats. The SCOR-ACMRR working group would, in effect, prepare the terms of reference for the IOC working group by considering scientific problems involved in marine pollution and by identifying the areas in which IOC might make an important contribution. The Secretary was instructed to corresponds with other members of the Executive and with the secretariats of UNESCO|IOC and FAO|ACMRR in order to arrange for establishment of this group.

Proposed WG on *Zooplankton Laboratory Method.* The Consultative Committee of IOBC, during a recent meeting, recommended international consideration of zooplankton laboratory methods. During the SCOR meeting an *ad hoc* group of biologists prepared a proposal for a working group to examine problems of preservation of zooplankton samples, preservation of microplankton and estimation of biomass. This proposal is attached as Annex VII. It was agreed to refer the matter to WG 13 and to other zooplankton experts, and with their advice to discus possible SCOR action at the next Executive Meeting.

The relation with UNESCO and other UN Agencies was another item of discussion. Several resolutions of the Fourth Session of

IOC referred to SCOR and the following called for specific action. Relation with ICSU its constituent bodies and other International Associations were the other major items on the agenda. While considering the International Biological Programme, Dr. Oren, SCOR Representative on SCIBP, reporting on the April meeting of that Committee indicated that major emphasis on the PM section would be given to estuarine and coastal waters. A group has been established to consider nutrient chemical methods in brackish waters. A proposal for establishment of a centre for development of statistical methods for Zoo-and phytoplankton research has been discussed and referred to SCOR for possible support. The Secretary was instructed to request an evaluation of this proposal by working group 13 and by other appropriate experts in preparation for consideration at the next Executive Meeting.

Consideration of Future SCOR Activities:

National Committee from UK had proposed a discussion reviewing SCOR's achievements and its objectives for the future and in particular the ways in which SCOR might generate new ideas in international oceanography. Future programmes of international investigations were discussed at the last Executive meeting in October 1965. In accordance with the proposal of that meeting the Secretary has initiated a study of the desirability of organizing an international exploration of the South Pacific with regard to the review of SCOR's achievements to date it was agreed that these should be made better known to scientists. The review of Scientific aspects of proposed international programmes such as that requested by UNESCO in the case of the South Mediterranean may prove to be a constructive type of activity for SCOR to carry out in future. Other discussions included the Israeli plan to establish a marine research station at Eilat on the Gulf of Aquaba, Red Sea. SCOR has recognized the international value of such a station and affirmed its hope that other countries will support the development of this project and its use as a scientific centre for research in the Red Sea.

An invitation from the Israel Academy of Science and humanities for SCOR to hold its next Executive meeting was accepted and agreed to arrange the meeting during later 1966 or early 1967.

In view of the decision to hold future general meeting at two year intervals it was agreed that the next such meeting would be in May 1968. The location and dates of the meeting should be discussed at the next Executive Meeting.

RESEARCHES ON SCOMBROID FISHES

Summary of the contributions of Dr. Nina N. Gorbunova, published in Trudy of Institute of Oceanology Academy of Sciences, U.S.S.R., No. 62, 1963 and No. 80, 1965.

I THE REPRODUCTION OF SCOMBROID FISHES IN THE INDIAN OCEAN

The study of larvae and juveniles of Scombroid fishes, including tuna, scomber, mackerel and bonito, is indispensable for understanding the biology of this group which is of great importance in the World Ocean's fishery. About 17 species of the commercially valuable Scombroid fishes occur in the Indian Ocean. The biology of this group has been studied inadequately, particularly so in the Indian and Atlantic oceans. Of great importance is our knowledge about the duration of ripening of gonads, as well as about time and conditions of spawning and development at the earlier stages of life.

Over the last ten years, due to the increase in tuna fisheries in the open ocean, much attention was paid to the young tuna fishes. The developmental stages of *Thunnus albacores*, *Katsuwonus pelamis*, *Euthynnus alleteratus*, *E. affinis and Auxis thazard* have been described better than others. These species are most widely distributed and are comparatively more numerous in occurrence. Most of the investigations were conducted by Japanese scientists in the Pacific Ocean. Larvae and juvenile Scombroid fishes from the Indian Ocean were given comparatively less attention, and only in recent years have the Indian Scientists conducted interesting and much needed studies in this field. Data accumulated so far are not only sufficient for descriptive papers to be written but may be also used to draw a number of theoretical and applied conclusions. The comparison of the available data on the time and conditions of spawning of Scombroid fishes in the Atlantic, Indian and Pacific oceans reveals definite geographic regularities connected with the distribution of environments.

Spawning seasons of Scombroid fishes vary in different parts of their area of distribution but the spawning conditions are of the same type everywhere and confined to the warmest period of the year. In the tropical waters the spawning lasts almost the whole year round but the most intensive one is observed in the autumn-winter months. In the subtropical region the spawning period is shorter and lasts only 3-4 summer months. The distribution of Scombroid fishes in the Indian Ocean is limited to the tropical waters. Spawning conditions show little change from season to season and the reproductive season of Scombroid fishes is very long, not less than 9-10 months in the year. The duration of the spawning period depends on the non-simultaneous ripening of gonads of adults from different age groups, the intermittent spawning and the conditions necessary for the reproduction and development of Scombroid fishes during the whole year.

The prolonged spawning is typical of all tuna species. It begins in autumn, in September, and lasts until spring with a short decrease in spawning observed in summer (June, July, August). The period of intensive spawning is noted in November, December and January. Other species inhabiting the coastal waters, as, for instance, *Rastrelliger*, *Scomberomorus*, *Scomber* may have other spawning time determined by somewhat different hydrological regime of the environment.

Thunnus albacores: In the Indian Ocean the larvae of *Th. albacores* were found from January to April and from October to December. The collections made by the research vessel "Kalava" in the Laccadive Sea contain larvae caught in February, March and April. In the open ocean, as the R/V "Vityaz"'s collections show, they were caught from November to March at water temperatures of 27.5–28.5^{0}.

Thunnus obesus: Larvae of big eyed tuna were found in the open parts of the central Indian Ocean in February, March and December ("Vityaz"'s data). In the eastern Indian Ocean, in the vicinity of Indonesia and off the Australian eastern coast, the big-eyed tuna is known to spawn from October to February. This period is confirmed by original data.

Katsuwonus pelamis: Spawning of this species was observed during winter and spring. In the Laccadive Sea larvae were found during winter and spring. In the Bay of Bengal and Andaman Sea larvae were also found in winter. In the central part of the ocean southward from the Equator, larvae of the striped tuna were caught in comparatively large quantities from December to March.

Euthynnus alleteratus: The collections made by the R/V "Vityaz" in the Andaman Sea contained larvae of two species of the genus *Euthynnus*. The first species is little known, while the second one is widely-distributed in the Indian Ocean. Larvae of *Euth. Alleteratus* were caught in October, their length ranging between 3.0 to 16.6 mm.

Euthynnus affinis: Much more information is available on the spawning of *Euthynnus affinis* in the Indian Ocean. Off the eastern coast of Africa it spawns in September-October and in March-April. However, even in winter adult tunas were found having mature gonads. They were essentially less abundant in summer. One may suppose that spawning in the area under consideration lasts from October to April with a decrease in summer. Similar data are available on the spawning periods in the Gulf of Aden and the Bay of Bengal. Our observations show that *Euthynnus affinis* spawns in more coastal waters than large tunas do.

Auxis thazard: Larvae of this species like those of *Euthynnus* are found in coastal waters. There is evidence of their occurrence from October to April. Larvae of *Auxis thazard* are contained in the surface layer and their abundance in some cases is very large—about 500-700 specimens in one sample. Similar results were obtained during sampling made in the Gulf of Aden and off the south-western coasts of Ceylon in October. In the Indian ocean two larval types different in the structure of body are found.

Little is known about spawning of *Scomber* in the Indian Ocean. One may suppose that the reprodutcion takes place in the coastal zone. The spawning conditions of *Scomber* in the Indian Ocean are of interest since all the species of this genus prefer cold waters and are abundant in the waters of the sub-tropical and temperate zones.

Much more widely-distributed in the Indian Ocean are the species of *Rastrelliger* which represent an important object for the Indian commercial fisheries. The study undertaken by the Indian scientists (Sekharan, Vijayaraghavan, Radhakrishnan) resulted in establishing the fact that spawning in the coastal regions begins in April and lasts the whole summer. Spawning conditions of these representatives of Scombroid fishes are somewhat different, they spawn in summer but not in winter.

In addition to *Rastrelliger* 2-3 species of *Scomberomorus* are known to occur in the Indian Ocean coastal waters: *Scomberomorus guttatus* and *Scomberomorus commersoni* which spawn also in the coastal areas. The spawning period, according to Vijayaraghavan's data, is rather long and is observed from July to January. In the vicinity of the Island of Rameswaram the spawning of *Scomberomorus* lasts from April to July (Krishnamoorthi's data). Catches of these fishes show a considerable increase in the above-mentioned period, whereas in winter they fall.

The biology of the reproduction of *Sarda* has been studied still inadequately. Only separate collections of larvae made in December, January and April are available. Like *Scomber*, *Sarda* inhabits colder subtropical waters but we do not know, yet, when the reproduction of this species occurs in the warm Indian waters.

Grammatorcynus bicarinatus: This species also inhabits the coastal waters, the biology of its reproduction has been studied not enough. As observations of the adults show, spawning of this species takes place in the Andaman Sea from January to March, but in the Sulu and Celebes seas, larvae

8.5-17.5 mm long were caught in summer.

Summarizing all the data on the larvae of Scombroid fishes in the Indian Ocean, we should note not only the regions of their occurrence but also certain regularities in the larval distribution of some species. Larvae of *Thunnus albacores, Thunnus obesus, Thunnus alalunga, Katsuwonus pelamis* are found mainly in the open ocean, whereas those of *Auxis thazard, Euthynnus affinis, Rastrelliger*, and *Scomberomorus* prevail in the coastal regions. Spawning of Scombroid fishes is uneven over the ocean area, and the areas of the most intensive spawning are distinguishable. They include, first of all, the eastern part of the Indian Ocean with the Bay of Bengal where, according to the available data, not less than 10 species of this important group of fish spawn. Many larvae of Scombroid fishes are found in the Gulf of Aden for which both the great frequency of occurrence and large catches are typical. For example, a single sample was found to contain 767 larvae of 3 species of *Thunnus*. A great number of tuna larvae is also found in the coastal waters of Ceylon. Ichtyoplankton samples taken from the open ocean contain usually not more than 3-4 larvae. Of great interest is the absence of larvae in the Arabian Sea which is, apparently, due to the peculiarities of its hydrochemical regime. A thorough analysis of all the data would allow the elucidation of this important practical question.

Larval morphology of the most widely distributed species of Scombroid fishes has so far been described rather well, although considerable difficulties turn up in determinations. One of the essential points in the determinations is not only morphological features but also diefferences in the developmental stages of various species. Despite some difficulties that arise, we may consider that the period of describing larvae is over, and now we should turn to elucidating the conditions of reproduction and regularities in the life cycle.

II ECOLOGICAL AND GEOGRAPHICAL PECULIARITIES IN REPRODUCTION OF SCOMBROID FISHES OF THE WORLD OCEANS

As is well known breeding periods and character of spawning in fishes (as in other animals, too) depend on their hereditary nature and are affected by environmental factors. Closely related taxa, pertaining to the same genus or family usually require similar environmental factors for their reproduction. These factors and especially those playing the most important limiting role, are, as a rule, liable to great diurnal or seasonal changes affected by the sitution of the area concerned and on its hydrological regime. Among such factors temperature, light, oxygen content, salinity and current system pattern should be mentioned as most important.

All Scombroid fishes numbering about thirty species spawn in warm waters. The narrow range of appropriate temperatures required for their breeding and their larval development is largely responsible for different terms and duration of spawning in distinct areas. Analysis of the data on the breeding time and spawning conditions of Scombroid fishes in the Atlantic, Indian and Pacific ocean enables us to disclose and outline certain ecological and geographical regularities affected by the change of environmental factors, and especially the temperature, in different climatic zones. The majority of species of this group breed in tropical waters, where annual temperature within the upper fifty meters layer does not decrease below 25°C. Here spawning period lasts from nine to ten months and even more. Breeding season of Scombroid fishes in tropical waters being prolonged to its utmost, nonetheless, the most intensive spawning is observed here from November to April when the occurrence of the larvae is the greatest.

In subtropical and warm temperate zones of both hemispheres (approximately between 25^{0} and 15^{0} northern as southern latitudes) breeding occurs during the warmest spring-summer season, when the limits of the breeding areas gradually expand while the twenty-five degrees isotherm is moving on. No more than five Scombroid species are found to spawn at approximately twenty degrees. Under these conditions breed such species as *Sarda sarda, Scomber scomber* and bluefin tuna (*Thunnus thynnus*) which require the lower temperatures for their reproduction. Among the species just referred to, the blue tuna deserves the greatest attention. Its breeding areas were found in the off-shore waters and in semi-enclosed basins in the Atlantic (Cuban waters, the Gulf of Mexico, and off Florida) and Pacific (off Southern Japanese islands and in Tonking bay in the Northern Hemisphere and in the Great Australian Bight in the Southern Hemisphere). Breeding areas of this species are not known in the Indian Ocean as yet. So far as we know it does not breed in tropical waters at all.

In the regions influenced by cold-water currents breeding of Scombroid fishes is more restricted in time as compared with other areas at the same latitudes. For example, *Thunnus obesus* in the south-eastern Pacific spawns at zero—ten degrees southern latitudes but from January to the middle of March. The variability in duration of the breeding season in different climatic zones (from well-nigh perennial in tropical waters up to 2-3 months in warm—temperate waters) shows a great adaptive "plasticity" in reproductive biology of Scombroid fishes while temperature requirements stay rather rigid. It is evident that more detailed comparative investigations of distinct populations within each species are badly needed. These should include experimental studies on defining thermal parameters required for their development and observations on the differences in intermittant ripening of gonads in the members of distinct populations.

The analysis of other environmental factors, such as salinity, hydrochemical regime and so on, does not reveal such a clear-cut and direct influence on reproduction of Scombroid fishes, as temperature does. However, some irregularities, often inexplicable as yet, may be mentioned. For example. In the Arabian Sea the oxygen content in the uper water layers is adequate and, as it seems, all other environmental factors are favourable for reproduction of Scombroid fishes, and although this region was covered with a dense net of stations, nonetheless no tuna larvae were found here.

Study of reproductive biology of Scombroid fishes is greatly hampered owing to a well-nigh total lack of knowledge concering the larval developmental stages. Furthermore, diagnostic characters of tuna eggs are not worked out. It is to be hoped that in the near future this problem will be solved.

VISITORS

July-Sept. 1966

The following persons visited the Indian Ocean Biological Centre and various Divisions of the National Institute of Oceanography in Ernakulam:

1. Shri Venkitaraman, Lecturer, H.K.R. H. College, Uthmapalayam.
2. Shri D. Swaminathan, Lecturer, St. Joseph's College, Bangalore.
3. Shri Nagaraja, Lecturer, M.F.G. College, Mysore.

4. Shri J. S. Lobo, Lecturer, Govt. College, Tumkur.
5. Dr. Jean Boullion, University of Brussels, Belgium.
6. Dr. B. F. Dada, CIFE, Bombay.
7. Dr. John Steele, Marine Laboratory, Aberdeen.
8. Dr. J. P. Harding, British Museum.
9. Shri M. S. Narayanan, INPL, Cochin.
10. Adm. S. N. Kohli, Dy. Chief of Naval Staff, New Delhi.
11. Com. J. D. Modi, Cochin Naval Base.
12. Dr. W. Liese, University of Hamburg.
13. Shri Zafar Fathehally, Bombay Natural History Society.
14. Dr. Michitaka Uda, University of Fisheries, Tokyo (Delivered two lectures at IOBC).

Those visited the Directorate and Planning and Data Division in New Delhi are the following:

1. Dr. Ilmo Hela, Institute of Marine Research, Finland.
2. Prof. J. Krey, Institute fur Meereskunde, Kiel.
3. Prof. G. P. Wells, University College, London.
4. Prof. Michitaka Uda, University of Fisheries, Tokyo.
5. Dr. A. K. Ganguly, Atomic Energy Estabs., Trombay, Bombay.

PUBLICATIONS RECEIVED

1. Contributions No. 8 1965 (collected reprints) of The Dove Marine Laboratory.
2. India Meteorological Department—Scientific Report No. 1 May 1966. (A note on Meteorological Instruments & Observing Techniques at Aerodromes).
3. Boletin Del Instituto Oceanographico de la Universidad de oriente Vol. IV No. I.
4. Progress in Geophysics Jan-Dec. 1965 (NGRI, India).
5. International Marine Science (UNESCO) Vol. IV Nos. 1|2.
6. Journal of Bombay Natural History Society Vol 62 No. 3 Dec., 1965.
7. Economic Benefits from Oceanographic Research (Publication 1228, 1964—NAS & NRC, Washington.)
8. Atlas of Bathythermograph Data—Indian Ocean (NODC Washington)
9. Bathymetric Magnetic & Gravity Investigations HMS Owen 1962—1963.
10. Lagena Nos. 7 & 8 (Oceanographic Institute, Venezuela).
11. Journal of Marine Biological Association of the U. K. Vol. 46 No. 2 June, 1966.
12. IOC—Information Paper NO. 17, July 1966.
13. Indian Journal of Meteorology & Geophysics Vol. 17 No 3, July 1966.
14. BIC Manuscript Report No. 2. feb.' 66.
15. Fishery Investigation (Ministry of Agriculture, Fisheries & Food, U. K.) Series II Vol. XXIV No. 6. Bulletin de l' Institute Oceanographique (Monaco) Nos. 1333, 1353-1364, 1366-1370, 1372-1375.
16. Collected Reprints Vol. 13 (1965)—NIO, Wormely England.

OBITUARY

Regretfully we record the sad demise of Shri N. R. Adyanthaya a young scientist in the National Institute of Oceanography in a road accident on 6-9-1966 at New Delhi. Shri Adyanthaya was one of the very active scientific workers of the Institute and was closely associated with the work of Indian National Committee on Oceanic Research right from the beginning. He has played an important role in the various stages of the Committee's activities in connection with IIOE and was also associated with IIOE News letter in its initial stages.

In his death NIO and INCOR have lost a very sincere and active scientific worker.

Regd. No. 7427/65

Mud deposit on the Sandy beach of Vypeen (North of Cochin) in December 1965.

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