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SUGGESTION TO AUTHORS OF PAPERS FOR THE RECORDS OF OCEANOGRAPHIC WORKS IN JAPAN

An author wishing to contribute a paper to the RECORDS OF OCEANOGRAPHIC WORKS IN JAPAN should submit in compliance with the following suggestions:

1. Manuscripts will be accepted within the scope of
   Physical Oceanography,   Geological Oceanography,
   Chemical Oceanography,   Biological Oceanography and
   Fisheries.
2. An original and a copy of his manuscript should be type-written double-spaced in 21×29.5 cm paper, within 12 sheets, making 6 printed pages including plates and tables.
3. The manuscript should be addressed to the competent editor and mailed to the official in charge of the Science Council of Japan, Ueno Park, Tokyo, Japan.
4. The author is asked to follow this publication for forms of headings and references, etc.
5. The editors reserve the right to accept the manuscripts and to make minor editorial changes in them, so that all papers may conform to over-all style of this publication.

General Report of the Participation of Japan in the International Indian Ocean Expedition

The National Committee for IIOE,
The Science Council of Japan,
March, 1965

CONTENTS

I. Organization and historical sketch of Japan participation in the I. I. O. E.

The International Indian Ocean Expedition (I. I. O. E.) was discussed at the first meeting of the Special Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU) in September 1958. The proposal was made that there should be an international co-operative attack on the largest unknown, unexplored area on earth, the deep waters and sea of the Indian Ocean. Scientists are keenly interested in the response of density layering and currents to the seasonal reversal of the changing monsoon winds as well as in the high and varying productivity of the ocean as indicated by the frequent catastrophic mass mortalities of fish in the Arabian Sea, and also in the lack of knowledge of the submarine topography, sediments and structure of this vast Ocean. United Nation remarked the importance of the development of fisheries for countries bordering the Indian Ocean to feed their crowded populations suffering from protein deficiencies.

At the occasion of the first International Oceanographic Congress in 1959 at New York a general outline of the Expedition was shown to the participated Japanese oceanographers. In February of 1960 Dr. Robert G. SNIDER, the International Coordinator of I. I. O. E., visited Japan and urged earnestly to the Japanese scientists and governmental officers to collaborate in I. I. O. E. because Japan having higher oceanographic ability among the world developed countries is also the biggest fisheries conducting country in the Indian Ocean and is responsible to its potential resources, suggesting that the maximum benefit from I. I. O. E. might be brought back to the Japanese fishermen.

Soon after the international meetings held by SCOR (participants from Japan Drs. K. HIDAKA, K. SUGAWARA, Y. MIYAKE and M. UDA) at Copenhagen and Helsinki in July 1960 the preliminary plan of Japan Participation in I. I. O. E. was presented to Japanese Government from Subcommittee on I. I. O. E. in the Council of Geodesy and Geophysics, Ministry of Education (Chairman Dr. Koji HIDAKA). Beforehand Japan Participation was initially planned by the member scientists of the National Committee on Oceanic Research (NCOR) established in the Science Council of Japan (Chairman Dr. Yoshio FUJIOKA) and was recommended.

Our initial plan was to participate in I. I. O. E. in the periods of 1962 and 1963 fiscal years by dispatching five research vessels (Ryofu-Maru, Takuyo Umitaka-Maru, Koyo-Maru, and Kagoshima-Maru) for this project and approved among scientists and acting agencies at the end of 1960. However, due to some unsurmountable difficulties of financial budget the modification of the predetermined project was obliged. Finally, the granted participating boats were "Umitaka-Maru" (Tokyo University of Fisheries) and "Koyo-Maru" Shimonoseki College of Fisheries) in 1962/63 and "Umitaka-Maru", "Koyo-Maru", "Kagoshima-Maru" (Kagoshima University, Department of Fisheries) and in the part of Fisheries Oceanography "Oshoro-Maru" (Hokkaido University, Department of Fisheries) in 1963/64. All these Japanese boats are originally in fisheries research and training mission and in this case added the requirement of I. I. O. E. Accordingly some geophysical part was reduced and replaced to fisheries-biological surveys.

NCOR in the Science Council of Japan reorganized in 1960 was directed to plan and coordinate the national support of Japan Participation in the programme of I. I. O. E. from the scientific point of view. NCOR has set up Indian Ocean Expedition Standing Committee and in it the following Working Groups as indicated in Table 1; Bathymetry, Geology, Geography, Geophysics, Physical Oceanography, Productivity, Fishery Oceanography, Biological Oceanography, Chemical Oceanography, Meteorology, Expedition Data and Agencies (Ships) Representative.

The established Working Groups have compiled detailed programs. We also established I. I. O. E. Data Center of Japan in the Office of Marine Division, Japan Meteorological Agency, Otemachi, Chiyoda-ku, Tokyo, Japan (Chief of Data Center in charge, Dr. Kazuhiko TERADA and later Dr. Hidetaka FUCHI) on March 20, 1962, from where I. I. O. E. News Letter (No. 1-5) was published.

During the spring of 1962 it was agreed between SCOR and the new International Oceanographic Commission (IOC) that henceforth the Secretary of IOC would have responsibility for coordination of I. I. O. E. in behalf of Dr. R. G. SNIDER.

The activity of the above Working Groups was promoted by the research fund granted from Ministry of Education for the Cooperative Studies of Indian Ocean (representative scientist: Dr. FUJIOKA, and the member scientists shown in Table 1) essentially. The grants were 1.5 million Yen for each year of 1961, 1962, 1963 and 0.7 million Yen for the fiscal year of 1964.

Several times in a year meetings were held to discuss its detail, to arrange the surveys and to promote the researches in each field.

The determination of the terms of observation for each boat and the special scientists on board were recommended and fixed.

Standardization and intercalibration of techniques and instruments were carefully made with studies of international and national cooperation. At the occasion of the tenth Pacific Science Congress at Honolulu in 1961 standardization and intercalibration for the methods of primary productivity measurement and chemical determination of dissolved oxygen and phosphate were promoted on board of Vityaz (USSR), Diamanthina (Australia) and others successfully (Japanese participants; Drs. Y. SAIJO, and Y. SUGIURA). The

Table I-1. Lists of the Members of the Organized Working Groups and Survey Items.

WG. Members of WG (* Chairman) (including collaborators) § Survey Items

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1. Bathymetry: Hiroshi NIINO*1) (Geology & Geography)
Geology: Takao SAKAMOTO2)
Geography: Chuji TSUBOI*2) (Geophysics), Ryutaro TAKAHASHI2)
Geophysics: Takeo WATANABE2), Hikaru WATANABE3), Yushiro TSUKAMOTO*4) (Bathymetry)
Bathymetry: Masashi YASUI5), Bunkichi IMAYOSHI4), Yukiyasu SASAKI1), Kazuo TAGUCHI6), Shiro MINAMI7)
Geology, Geography: Noriyuki NASU2), Michihei HOSHINO4), Ryuichi TSUCHI, Kei OSHIDE8), Nobuhiro HATAE9), Takayasu UCHIO2), Torao YOSHIKAWA2), Hiroshi TODANI9), Shozo HAYASAKA10)
Geophysics: Seiya UEDA2), Masashi YASUI5), Shinkichi UTASHIRO4), Keijiro OZAWA1), Hiroshi SUZUKI1), Yoshibumi TOMODA2), Tsuneji RIKITAKE2), Jiro SEGAWA2)

§ Underway Precise Continuous Recording of Echo Sounding
§ Bottom Sampling, Piston Corer Sampling, Dredging
§ Proton Magnetometer Continuous Recording
§ Gravity on the Sea Heat Flow at the Sea Bottom Measurement

---

2. Physical Oceanography: Yoshio FUJIOKA1), Koji HIDAKA2)
Meteorology: Michitaka UDA*1) (Physical Oceanography), Kazuhiko TERADA5), Tadao TAKAHASHI6), Shoichiro HAYAMI12), Hidetaka FUCHI*5) (Meteorology)
Physical Oceanography: Jotaro MASUZAWA5), Hideo AKAMATSU5), Daitaro SHOJI4), Shozo YOSHIDA4), Makoto ISHINO1), Keizi NASU13), Masashi YASUI5), Tadayoshi SASAKI1), Yasukazu SAITO1), Masaaki CHAEN6), Takero SATO7), Eiichi INUI7), Toshiyuki HIRANO14), Kozo YOSHIDA2), Hideaki KUNISHI12), Takuichi MATSUZAKI4), Jiro FUKUOKA5), Tsugio SHIMANO4)
Meteorology: Hideaki FUCHI5), Yuichiro KUGA5), Tugio MATUMOTO5), Yasuaki TURUOKA5)

§ Thermograph Recording, Surface Oobservation, BT Observation, Serial Observation, Color of the Sea & Transparency of Sea Water, Equatorial Current Measurement (by Ekman-Merz Two Current-meter method), Drift Bottle Experiment
§ Surface Meteorological Observation, Aerological Observation (Radio Sonde, Pilot Baloon), Air-Sea Heat Exchange.

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3. Chemical Oceanography: Ken SUGAWARA15), Yasuo MIYAKE* (Chemical O.)16), Yoshio SUGIURA17), Yukio SUGIMURA9), Tsugio SHIMANO4), Yoshimi MORITA1), Kanama SAITO18), Keiichiro SHAZUKI6), Rinnosuke FUKAI14), Satoru KANAMORI15), Hiroyuki KITAMURA5), Katsumi YAMAMOTO5), Shiro OKABE21)

§ Measurements of Cl, O_2, pH, P, ΣP, Si, NO_3, CO_2, Sr^{90}, Cs^{137}, C^{14}, H^3, Ra, Th, Rare earth, Organic Substances, Radioactivity of Sea Water.

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4. Biological Oceanography
(Plankton and Primary Production) Hiroaki AIKAWA14), Yoshio HIYAMA2), Takeharu KUMAGORI1), Susumu KURITA14), Yoshiyuki MATSUE2), Den-

Table I-1. Continued.

saburo MIYADI[12], Shigeru MOTODA* (Plankton)[20], Ken SUGAWARA* (Primary Production)[15], Ryuzo MARUMO[5], Hiroshi NAGAYA[4], Jiro SENOO[1], Toshiro SAISHO[6], Takuro CHIBA[7], Nobuo TAGA[2], Minoru SAKAI[20], Yutaka YOSHIDA[7], Teruyoshi KAWAMURA[20], Tatsuro MASUDA[1], Ichitaro SAKAMOTO[22], Takeshi TAGUCHI[1], Koji NOZAWA[6], Kaoru TAKESUE[7], Yatsuka SAIJO[15], Shunmei ICHIMURA[16]

§ Eye Observation, ^{14}C Primary Production Measurement, Chlorophyll Measurement, Bacteriological Observations, Indian Ocean Standard Net Hauls, Other Plankton Net Hauls, High Speed Plankton Sampling, Midwater Trawling

5. Fishery Oceanography: Hiroaki AIKAWA[19], Tasuku HANAOKA[19], Yoshiyuki MATSUE[2], Shigeru MOTODA[20], Michitaka UDA* (Fishery Oceanography)[1], Jiro SENOO[1], Yukiyasu SASAKI[1], Keijiro OZAWA[1], Takuo CHIBA[7], Yutaka YOSHIDA[7], Shiro MINAMI[7], Takero SATO[7], Goro SAKURAI[7], Tadao TAKAHASHI[6], Masaaki CHAEN[6], Soichi UEDA[6], Takeharu FUJII[20], Tsuneyoshi SUZUKI[20], Motoichi UENO[20]

§ Tuna Longline Fishing, Otter Trawling, Serial Observation at Fishing Localities, Current Measurement (GEK, Drift of Longline), Echo Traces, Eye Observation (Birds, Fish, Whales etc.), Biological Studies of Caught Fishes, Tagging Experiment.

6. I. I. O. E. National Data Center: Yoshio FUJIOKA[11], Hidetaka FUCHI*[5] succeeding to Kazuhiko TERADA*[5], Koji HIDAKA[2], Hiroshi NIINO[1], Shigeru MOTODA[20], Ken SUGAWARA[15], Tadao TAKAHASHI[7], Yushiro TSUKAMOTO[4], Michitaka UDA[1], Jotaro MASUZAWA[5], Masao HANZAWA[5], Shozo YOSHIDA[4], Yasukazu SAITO[1], Takero SATO[7]

§ Data Center Business (Japan Meteorological Agency), Publication of I. I. O. E. NEWS LETTER, Report to WODC, Distribution of base maps.

7. Representatives of Agencies (Vessels)

Kazuhiko TERADA (Meteorological Agency), Takuichi MATSUZAKI (Hydrographic Office), Hajime MATSUI (Shimonoseki University of Fisheries, Koyo Maru), Takeharu KUMAGORI (Tokyo University of Fisheries, Umitaka Maru), Tadao TAKAHASHI (Kagoshima University, Kagoshima Maru)

Remarks:

1) Tokyo University of Fisheries
2) University of Tokyo
3) Ochanomizu Woman University
4) Japan Hydrographic Office
5) Japan Meteorological Agency
6) Kagoshima University, Faculty of Fisheries
7) Shimonoseki University of Fisheries
8) Hokkaido Gakugei University, Hakodate
9) Tokyo Municipal University
10) Tohoku University
11) Saitama University
12) University of Kyoto
13) Japanese Whales Research Institute
14) Tokai Regional Fisheries Research Laboratory
15) Nagoya University
15) Tokyo University of Education
17) Meteorological Research Institute
18) Odaru Commercial University
19) Japan Fisheries Ageny
20) Hokkaido University, Faculty of Fisheries
21) Fukuoka Gakugei University
22) Mie Prefectural University

Second Meeting was held at Sydney in 1962.

Training for each discipline of sampling, observation and analysis was conducted on board of research vessels (Umitaka-Maru,, Ryofu-Maru, and Takuyo).

Newly developed instruments and gears designed for I. I. O. E. were tested and improved some of them. For example, University of Tokyo Surface Ship Gravity Meter, Precise Deep Sea Echo Sounder, Two protected and two unprotected reversing thermometer attached Nansen Water Bottle, $_{14}$C Productivity measuring appratus, Indian Ocean Standard Net etc. may be referred.

In fact, since 1873 less than two dosen research vessels have carried out oceanographic investigations there and several Japanese fishery research or training boats since 1930 conducted also similar surveys. However, before I. I. O. E. modern advanced techniques and gears were used few in limited areas and time.

I. I. O. E. is noteworthy in its exact oceanographic surveys ever made and raised the accuracy of oceanographic investigation epochmakingly.

In January, 1964 Dr. Michitaka UDA was appointed for the I. I. O. E. National Coordinator of Japan and attended to the First I. I. O. E. International Coordinating Meeting at Paris (Jan., 1964 and June, 1965).

Acknowledgement

We are indebted to the members of the editiorial board of this report as indicated in the following:

Editor in chief: Dr. M. UDA (with the assistance of Dr. M. ISHINO, Mr. K. HASUNUMA and Mr. K. TANAKA)

Editor: Drs. H. NIINO and R. TSUCHI (Bathymetry, Geology and Geophysics)
Drs. H. FUCHI and M. HANZAWA (Meteorology)
Drs. M. UDA, T. SATO and M. ISHINO (Physical Oceanography)
Drs. Y. MIYAKA and Y. SUGIURA (Chemical Oceanography)
Drs. K. SUGAWARA and Y. SAIJO (Primary Production)
Drs. S. MOTODA and J. SENO (Marine Biology)
Dr. J. SENO, Captain K. OZAWA (Eye Observation)
Drs. M. UDA and J. SENO, Captains S. UEDA, K. OZAWA, T. FUJII and G. SAKURAI (Fisheries Oceanography)

II. Activities of the Japanese I. I. O. E. working group for preparation

1. Bathymetry

(1) Precise Depth Recorder (PDR) to be manufactured.

(2) Continuous depth record, record reading within 2 sea-miles.

(3) Ship position by star fix 3 times a day on before sun-rise, at noon, after sun-set.

(4) Track Chart should be conserved and be sent afterward to the Japanese Hydrographic Office.

(5) Similarly for echogram as in (4).

(6) Correction table for submarine acoustic velocity to be used refering to H. D. 282 made by Hydrographic Office.

2. Geology

(1) Bottom sampling at every Special Observing Station and at Gereral Observing Station within her capability.

(2) Piston Core Sampling at every Special Observing Station (need reserved corer). Gravity Core Sampler....at the same St. (according to circumstance).

Small size bottom sampler as they are available.

Dredge....For particular topographic sea bottom. (reserves needed).

(3) Standardization of report format. (For field survey and laboratory)

(4) Sample Processing Committee.

(5) Preservation of records and samples.

(6) Botton Sampling at Special localities such as guyot found.

3. Geophysics

(1) Earth magnetism measurement by Proton Magnetometer.

(2) Heat flow measurement at sea bottom by Geothermometer.

(3) Gravity measurement by Tokyo Univ. Surface Ship Gravimeter.

(4) Observation of natural earthquakes.

4. Physical oceanography

(1) Observing layer depth....

Om., 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 800, 1000, 1200, 1500, 2000, 2500, 3000 m or more.

(2) Serial observation as standard: for each level one Nansen bottle attached with one unprotected (at least) and two protected reversing thermometers.

For the observation deeper than 150 m. depth unprotected rev. therm. needed.

(3) Salinometer (standardized) to be used.

(4) Current measurement by two (Ekman-Merz type) currentmeter method.
Observed layer depths....10, 20, 50, 75, 100, 150, 200, 300, 400 m. and reference level, 800 m. depth (assumed no motion layer).

(5) Current measurement by GEK at the latitudes higher than 15°.

(6) Drift bottle release experiment....each boat.

(7) BT observation at every 30 or 60 seamiles and on regular observing stations. (Interval of 3 hours or more).

5. Meteorology and aerology

(1) Surface observations. All ships. Four times a day. (00, 06, 12, 18 Z).

(2) Aerological observations. (Koyo Maru).
  a) Radio-sonde observation....once a day (12Z).
  b) Pilot balloon observation....once a day (12Z).

(3) Observations on air-sea interaction problems. (Kagoshima Maru).
4 levels at each station (total 30 stations).

(4) Meteorological information. Obtained data were sent to coastal radio stations (Singapore or Penang, Colombo, Djakarta, Sydney or Perth, Rangoon).

6. Biology

(1) Deep divided vertical haul with a small closing net (moutharea 0.5 m^2, 0.1 mm aperture) for microplankton at 13 stations by Koyo Maru and 17 sts. by Kagoshima Maru in 5 divided layere upper than 2000 or 3000 m. depth.

(2) 0-200 m. vertical haul with Indian Ocean Standard Net for medium-sized zooplankton at 27 sts. (10 sts. of these on the fishing ground) by Umitaka Maru, at 22 sts. (twice at same st.)

(3) Oblique haul with 160 cm net for macroplankton, fish larvae, and small nekton at 27 sts. (10 sts. of these on the fishing ground) by Umitaka Maru, at 13 sts. by Koyo Maru and at 22 sts. by Kagoshima Maru. 0-800 m oblique trawling by Isaacs-Kidd Midwater Trawl at 9 sts. by Koyo Maru.

(4) High speed sampling at 27 sts. by Umitaka Maru, at 27 sts. by Koyo Maru ahd at 40 sts. by Kagoshima Maru.

(5) Sample water for meaurement of primary production is taken from 7 layers, 0, 10, 25, 50, 75, 100 and 125 m layers.
In situ method is used at 12 sts. by Koyo Maru and 8 sts. by Kagoshima Maru. Simulated *in stiu* method is used at 12 sts.

Tank method is used at 12 sts. by Koyo Maru and at 46 sts. by Kagoshima Maru and sts. undecided for Umitaka Maru. Water sampling for Chlorophyll determination.

7. Chemical oceanography

(1) Results of the intercalibration test, international and domestic were discussed by ROCHFORD (1963) and by Sugiura. Results of check on the variation of standard solutions were refered to the second observation. From that experience the followings were recognized: A 100 mm. long cell should be altered to a drum type one. Plastic dispensers are recommendable and ampouled standard solutions as well.

(2) The following points were confirmed on the analytical procedure to be employed in the next observations.

a) Dissolved oxygen: Ampouled KIO_3 (1/50N) is to be used as a standard.

b) Phosphate: Ampouled standard solutions as shown below are to be prepared; 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 μg-at/l for making a calibration curve.
The calibration curve is to be checked at every station with four kind of ampouled standard solutions i. e. 0.0, 0.5, 1.0, and 2.0 μg-at/l.

c) Total P: Collected waters are to be analyzed after brought in laboratory on land.

d) Silicate: Chromate solution is to be used as a standard.

e) Nitrate: Reduction is to be carried out following the method of Mullin and Riley and coloration is accomplished with the G. R. Griese—Romijn reagent.

f) Nitrite: The G. R. reagent is to be used as color developing agent.

g) pH: An electric pH meter with a pair of glass electrode is to be used and checked with two kind of buffer solutions i. e. pH 7.0 and 9.0.
Preparation of ampouled standard solutions of nutrients and buffer solutions was supervised by Yoshio SUGIURA.

8. Fishery aspect of oceanography

The Working Group was set up in July, 1963.

(1) The area of survey by means of tuna longline and otter trawl in the cruise of I.I.O.E. (Oct. 1962—Mar. 1963, Oct. 1963—March 1964) is shown in Figs. III 1~3.

Participating four boats are Umitaka Maru, Koyo Maru, Kagoshima Maru and Oshoro Maru.

(2) Experimental fishing survey by means of tuna longline.
Number of basket to be used: 100-200 (hooks for one basket, 5-6).
Hook depths planned....60-150 meters.
Beginning of line thrown in (03.00-06.00 SAT).
Beginning of line haul (08.30-15.00 SAT).

(3) Experimental fishing survey by means of otter trawl.
On the continental shelf along the north and northwestern coasts of Australian continent.

(4) Serial observation at each fishing ground.
Hydrographic cast down to 1000 m. or more, daily once or over.
(In the case of trawling ground down to the sea bottom.)

(5) Current measurement by means of GEK and driftage of longline.

(6) Plankton sampling.
(Vertical haul....the same way as Biological Group).

(7) Biological sampling by means of large sized larval net.
(In the same way as Biological Group. Operation within the range of capability for each boat).

(8) Benthos sampling and bottom sampling in the case of experimental trawling.

(9) Catch and biological studies of caught fishes (stomach content, biometric studies etc.)

(10) Investigation of migration and distribution of shark and killer-whale as predators of tunas (by means of eye observation and harvesting).

(11) Investigation of larvae and juveniles for tunas. (By means of net cellection and stomach content studies. In cooperation to Nankai Regional Fisheries Research Lab.)

(12) Tagging experiment for tunas (mainly for fish by trolling for each boat as possible as they can. In cooperation to Nankai Regional Fisheries Research Laboratory).

(13) Flock of birds etc., in relation to fishing grounds (eye observation).

(14) Echo traces including DSL by means of supersonic fish finder.

(15) Format of Report (formats used by Umitaka Maru A, B, C, refered).

III. General report of the officially declared I. I. O. E. participation

UMITAKA-MARU (Tokyo University of Fisheries, Ministry of Education, Tokyo) (1453 gross tons, 73.4 m length, Diesel 2100 HP)

(1) Itinerary of Cruise (1962-63) (Refer to Station map, Fig. III-1)

Port of Call	*Arrival*	*Departure*	*Remarks*
Tokyo		Oct. 29, 1962	Total milage: 14930 miles 106 days, inclusive of experimental fishing
Bangkok	Nov. 13		
Singapore	Nov. 22 (3°S, 78°E... Dec. 10)	Nov. 19	
Colombo	Dec. 20 (5°S, 78°E... Dec. 29) (25°S, 78°E... Jan. 6 1963)	Nov. 27	
Singapore	Jan. 21	Jan. 26	
Tokyo	Feb. 11		

Captain Keijiro OZAWA and officers 13. crew 26, cadets 42.

Scientists

Prof. Hiroshi NIINO (Head) (Marine geology and geography)

Biology: Prof. Shigeru MOTODA, Kenjiro KONNO.

Geology: H. NIINO, Kei OSHITE.

Bathymetry: Keijiro OZAWA, Tsutomu ISOUCHI.

Physical oceanogr.: Yasukazu SAITO, Makoto ISHINO.

Chemical oceanogr.: Yoshimi MORITA, Satoru KANAMORI.

Productivity: Yatsuka SAIJO.

Eye obs.: Kanoo MATSUIKE.

(2) Scientific work

Hydrographic cast: Down to 3000 m. depth or more. 20 sts.

Surface water temp.: Continuous recording.

BT observation: On each St. and on each mid-st. (39 sts.).

Current measurement: a) GEK observations at 10 sts. b) Two current meter method. In the equatorial region and at special points. (10 sts.).

Transparency & color of the sea: Frequent observations.

Drift bottle experiment: 200 bottles released, 100 bottles for each St.

Chemical observations: Salinity. O_2, nutrient salts etc.

Productivity: Chlorophyll method and C^{14} method. (In situ & tank expt.)

Plankton sampling: IOS-net, Juday-type & Hart-type closing nets.

Special biological survey: Large square net of Umitaka type, and a simple high speed sampler, Model V.

Experimental fishing: Tuna long line catch was examined.

Bathymetry: Continuous recording by echo sounder.

Geology: Sampling with piston corers and dredges.

Underwater radiance: Measurements of sky and underwater radiance, DSL, and solar radiation.

(3) Scientific findings

a) The tentatively named "Umitaka Sea Mount" is located southwest of Andaman Island. That rises from the sea bed of 4000 m. depth. Some surface deposits were obtained by dredging.

b) The tentatively named "Cocos Sea Mount" is located some 80 miles southwest of Cocos Island, and rises from the flat 4000 m. sea bed upto the 700 m. depth. Some bottom specimens were obtained with dredge.

UMITAKA-MARU (Tokyo University of Fiseeries, Ministry of Education, Tokyo) (1453 gross tons, 73.4 m. length, Diesel 2100 HP)

(1) Itinerary of Cruise (Cruise 1963-64) (Fig. III—1).

Port of Call	*Arrival*	*Departure*	*Remarks*
Tokyo		Oct. 30, 1963	
Darwin	Nov. 15	Nov. 18	Along 120°E, 5 sts.
Broom	Nov. 28	Nov. 30	Tuna long-line 5 sts.
Geraldtown	Dec. 13	Dec. 17	Along 112°E, 7 sts.
Fremantle	Dec. 27	Jan. 2, 1964	Coring, dredging & one hydr. st.
Penang	Jan. 27	Jan. 31	Along 105°E and 100°E, 13 sts.; coring, trawling.
Tokyo	Feb. 17		

Captain Keijiro OZAWA & officers 13, crew 26, cadets 42.

Scientists (10)

Prof. Jiro SENOO (Head) (biologist)

Physical oceanogr.: Tsugio SHIMANO, Keiji NASU.

Chemical oceanogr.: Shiro OKABE, Katsumi YAMAMOTO.

Biology: Jiro SENOO, Tatsuyoshi MASUDA.

Geology: Ryuichi TSUCHI.

Bathymetry: Keijiro OZAWA, Tsutomu ISOUCHI.

Productivity: Ichiro SAKAMOTO.

Geophysics: Yoshibumi TOMODA, Jiro SEGAWA.

Fisnery Oceanogrphy: Jiro SENOO, Keijiro OZAWA, Kiyoshi INOUE, Tatsuyoshi MASUDA.

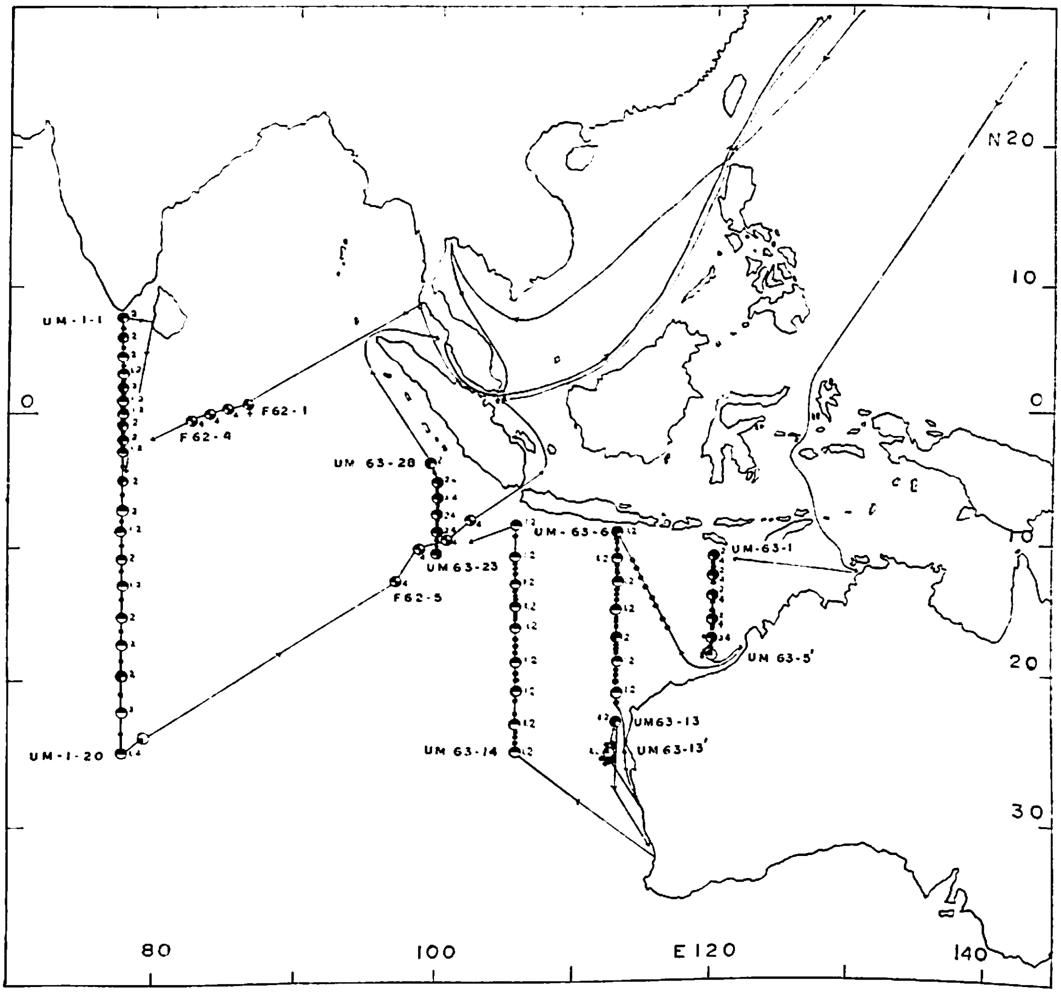


Fig. III-1. Track chart of UMITAKA-MARU cruises in the winter of 1962-63 & 1963-64.

SUGGESTED CODE FOR IIOE TRACK CHART

STATION

◇	SCOR-IIOE Reference Station	
○	Position Station	
•	BT and/or Surface Station	
--•--	Area of Extensive Studies	
▨	Works undertaken at Station (to be superimposed on position station/reference station).	
◐	Physical and Chemical Observations (Do, Cm, Ph, Ch)	
◔	Biological Observations (Ps, Ab)	
	1. Primary production in situ expt.	◔
	2. Indian Ocean Standard net haul	
	3. Mid water trawl	◔
◒	Experimental Fisheries (Fr)	
	4. Longline fishing	
	5. Trawling	
◑	Geology and Geophysics (Gg, Mt)	

TRACK

———	With underway observations
-------	Without underway observations

(2) Scientific work

Hydrographic cast: At 27 stations.

Current measurements: a) Current observed with GEK and Ekman-Merz Current meter. b) 100-200 drift-bottles released at each St. except Nos. 5, 6, 13 & 28.

Chemical analysis: pH, O_2, phophate. nitrate and silicate.

Biology: a) IOS-net vertical haul (200-0 m. 28 Sts. b) Larva net & UMITAKA's large square net hauls for macroplankton at 29 sts.

Productivity: a) $_{14}C$ *in situ* and tank experiments. b) Underwater illumination by chemical method and photo-cell. Continuous recording of solar radiation with Robitzsch's actinometer.

Bathymetry: Continuous recording.

Marine-geophysics: Continuous recording of earth's magnetism with towed proton magnetometer and gravity with shipborne Gravimeter on whole course.

Geology: a) Core sampling with piston corer; at 7 sts. b) Dredging at 23 sts.

Meteorology: Three hourly synoptic observations.

Experimental fishing: a) Tuna long-line fishing at 10 sts. b) Trawling at 2 localities; 14 casts.

Eye observation: Current-rips, birds, fishes etc.

(3) Remarkable findings

A new sea-mount was discovered on January 7, 1964 in the vicinity of 22°12′S and 104°40′E. shallowest depth of 1923 m. The diameter covering the area of less than 2000 m. is about 13 SM. The sea mount was tentatively named "Zenith Sea Mount".

KOYO-MARU (Shimonoseki University of Fisheries, Ministry of Agriculture, Shimonoseki) (1215 gross tons, 72.2 m. length, Diesel 1800 HP)

(1) Itinerary of Cruise (1962-63) (Refer to Station map, Fig. III-2(a)).

Port of Call	*Arrival*	*Departure*	*Remarks*
Tokyo		Nov. 6, 1962	Total milage: 17067 SM, 118 days, inclusive of experimental fishing
Singapore	Nov. 16	Nov. 20	
Colombo	Dec. 13	Dec. 18	
Fremantle	Jan. 9, 1963	Jan. 14	
Singapore	Jan. 29	Feb. 2	
Hongkong	Feb. 8	Feb. 12	
Shimonoseki	Feb. 18		

Captain Goro SAKURAI and officers , crew , cadets .

Scientists

Prof. Takuo CHIBA (Head) (biologist)

Meteorology: Yasuaki TURUOKA, T. SATO.
Physical oceanogr.: Takero SATO.
Chemical oceanogr.: Keiichiro SHAZUKI, K. TAKESUE.
Bathymetry: Takeo TANIGUCHI.
Biology: Takeo CHIBA, Takeo TANIGUCHI.
Productivity: Kaoru TAKESUE.
Bacteria: Michinori NAKANO.

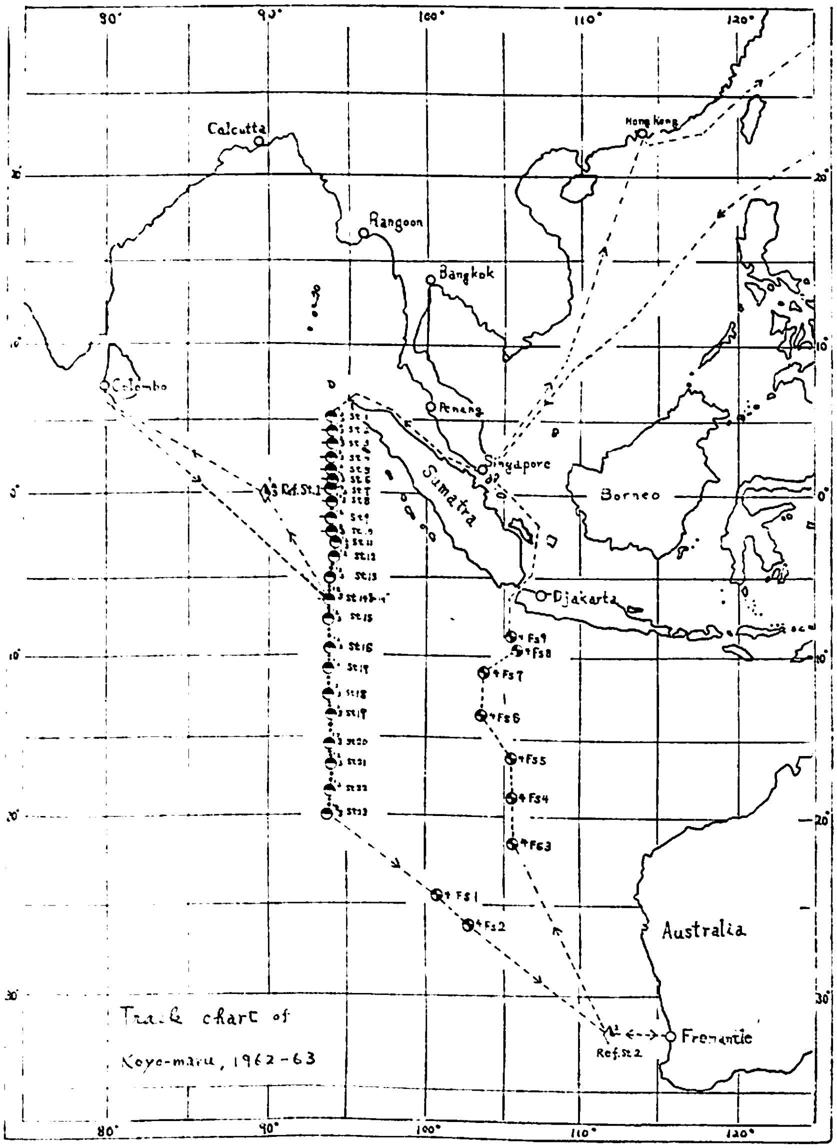


Fig. III-2(a). Track chart of KOYO-MARU cruise in the winter of 1962-63.

(2) Scientific work

Hydrographic cast: Serial observations down to 3000 m. depth or more. 5°-20°S, along 94°E line; 23 sts. Two ref. St. (0°, 96°E), (32°S, 111°50′E) and St. 14′ were occupied repeatedly. Fishery Sts.: 9 sts. down to 1000 m. obs.

Current measurement: a) By means of 2 Ekman currentmeter at 15 sts. (10, 50, 100, 150, 200, 400 m. layers and 800 m. layer as reference level. b) By GEK at stations south of 6°30′S.

BT observations: At each St. and in-between St. (69 sts.).

Surface sampling & temp. obs.: With two hour intervals underway.

Meteorological obs.: a) Surface obs.; 4 times a day (0, 6, 12, 18Z). b) Aerological obs.; Once a day (12Z) Radiosonde 33, 21280 m. mean alt. 27261 m. max. Pilot-baloon 28, 2485 m. mean, 8800 m. max.

Chemistry: Cl, O_2, pH, P, Si, ΣP and NO_3.

Productivitity: At 26 sts., 113 cm Standard net sampling at 20 h. 1 hour surface haul with 160 cm. net at 26 sts. Divided sampling from 1000 m. layer with 80 cm. net, at 25 sts. Mid-water trawl at 19 sts. Sampling of water for marine bacteria at 18 sts.

Experimental tuna long-line fishing: 9 sts.

KOYO-MARU (Shimonoseki University of Fisheries, Ministry of Agriculture, Shimonoseki) (1215 gross tons, 72 m. length, Diesel 1800 HP)

(1) Itinerary of Cruise (1963-64) (See Station map, Fig. III-2(b).

Port of Call	*Arrival*	*Departure*	*Remarks*
Shimonoseki		Oct. 25, 1963	
Hongkong	Nov. 12	Nov. 15	St. 1- , tuna longline F 1-6
Penang	Dec. 5	Dec. 8	St. 9- ,
Djakarta	Dec. 25	Dec. 29	St. 14-19, tuna longline F 7-12
Fremantle	Jan. 14, 1964	Jan. 18	
Singapore	Feb. 2	Feb. 7	St. 20, Rf. 1 (32°S, 111°50′E)
Shimonoseki	Feb. 18		

Obs. 94°E line (8°-10°S)......13 sts.
100°E line (12°30′S-21°30′S)......7 sts. Fisheries 12 sts.

Captain Goro SAKURAI & officers 13, crew 26, cadets 65.

Scientists

Prof. Yutaka YOSHIDA (Head) (biologist)
Bathymetry: Satoru TAWARA.
Meteorology: Tugio MATUMOTO, S. SANO, H. HIGASHI, A. FUJIISHI.
Physical oceanogr.: Takeo SATO, E. INUI. S. OMURA, S. HIGASA.
Chemical oceanogr.: Shoji TAGAWA, T. WADA.
Biology: Yutaka YOSHIDA, Goro SAKURAI (Fisheries); S. KATAOKA, H.

IMANISHI, Y. HATA (bacteria); T. NAKAGAWA, Kaoru TAKESUE, A. SUENOBU (productivity).

(3) Scientific work

Hydrographic cast: Down to 5000 m.

BT observations: At the Sts. and in between Sts.; 70 sts.

Surface sampling & temp.: One hour interval underway.

Current measurements: a) 2 Ekman currentmeters method; 10, 50, 100,

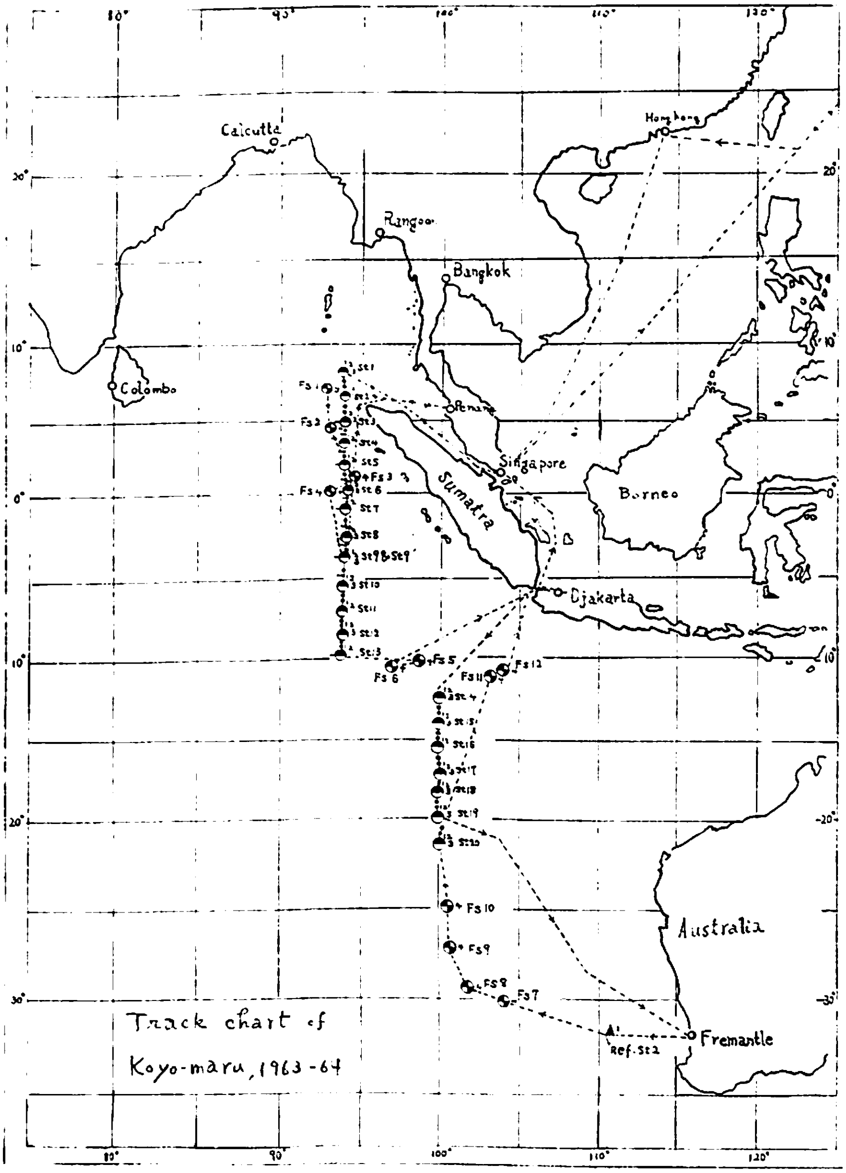


Fig. III-2(b). Track chart of KOYO-MARU cruise in winter of 1963-64.

150, 200, 400 and 600 m. layers with 800 m. layer as reference; 12 stations. b) GEK at stations south of 5°S.

Chemical analysis: Cl, O_2, pH, Si, total-P. NO_3 at stations of productivity study.

Biology: a) IOS-net (night-haul) at 21 sts. b) Divided hauling from 3000 m., with 80 cm. net, at 11 sts. (5 layers). c) Mid-water trawling at 13 sts. d) oblique haul with 160 cm. ring net at 22 sts. e) High speed sampling at 21 sts.

Productivity: a) Photo-synthesis and chlorophyll measurement at 24 sts. b) $_{14}C$ enriched measurements at sts. Continuous recording of solar radiation at all sts.

Bacteriology: a) Sampling of water at all sts. b) Bottom sampling at 3 sts.

Bathymetry: Continuous recording.

Meteorology: a) Surface observation; 6 hourly. b) Aerological observation; daily 12Z. Radiosonde (30, 20201 m. alt. mean to max. 27230 m.) Pilot balloon (30, 4744 m. alt. mean to max. 11710 m.)

Experimental fishing: Tuna longline with hydrogra. cast down to 1000m., IOS-net haul at 12 sts.

KAGOSHIMA-MARU (Faculty of Fisheries, Kagoshima University, Ministry of Education, Kagoshima) 1038 gross tons, 60.5 m. length, Diesel 1700 HP 13 set)

(1) Itinerary of Cruise (1963-64) (See Station map Fig. III-3)

Port of Call	*Arrival*	*Departure*	*Remarks*
Kagoshima		Nov. 8, 1963	86°E; 78°E, north of 6°S
Penang	Nov. 18	Nov. 23	78°E; south of 6°S
Colombo	Dec. 19	Dec. 24	Tuna long line fishing
Penang	Jan. 31, 1964	Feb. 3	Total 14070 SM: 100 days
Kagoshima	Feb. 15		(obs. 36 days)

Captain Soichi UEDA. officers and cadets.

Scientists

Physical oceanogr.: Masaaki CHAEN, Kenya MIKUZU.

Eye observation: Takehiko IMAI.

Bathymetry: Kiyohisa UESHIBA, K. TAGUCHI, M. UENO.

Geology: Shozo HAYASAKA, N. HATAE.

Chemistry: Kaname SAITO, S. YAMASHITA, A. KANAZAWA.

Plankton: Toshiro SAISHO, H. ISHIDA.

Productivity: Takuro ENDO, K. NOZAWA, K. TAMAI.

Fisheries: Soichi UEDA, T. KARIMATA, T. IMAI, T. NOZAWA.

Ichthyology (Larvae): Takehiko IMAI.

(2) Scientific work

Hydrographic cast: To the depth of 4000 m. at 33 sts. 6 sts. were occupied twice.

BT observations: 77 sts in total.

Current measurements: 2 current-meter methods and GEK (south

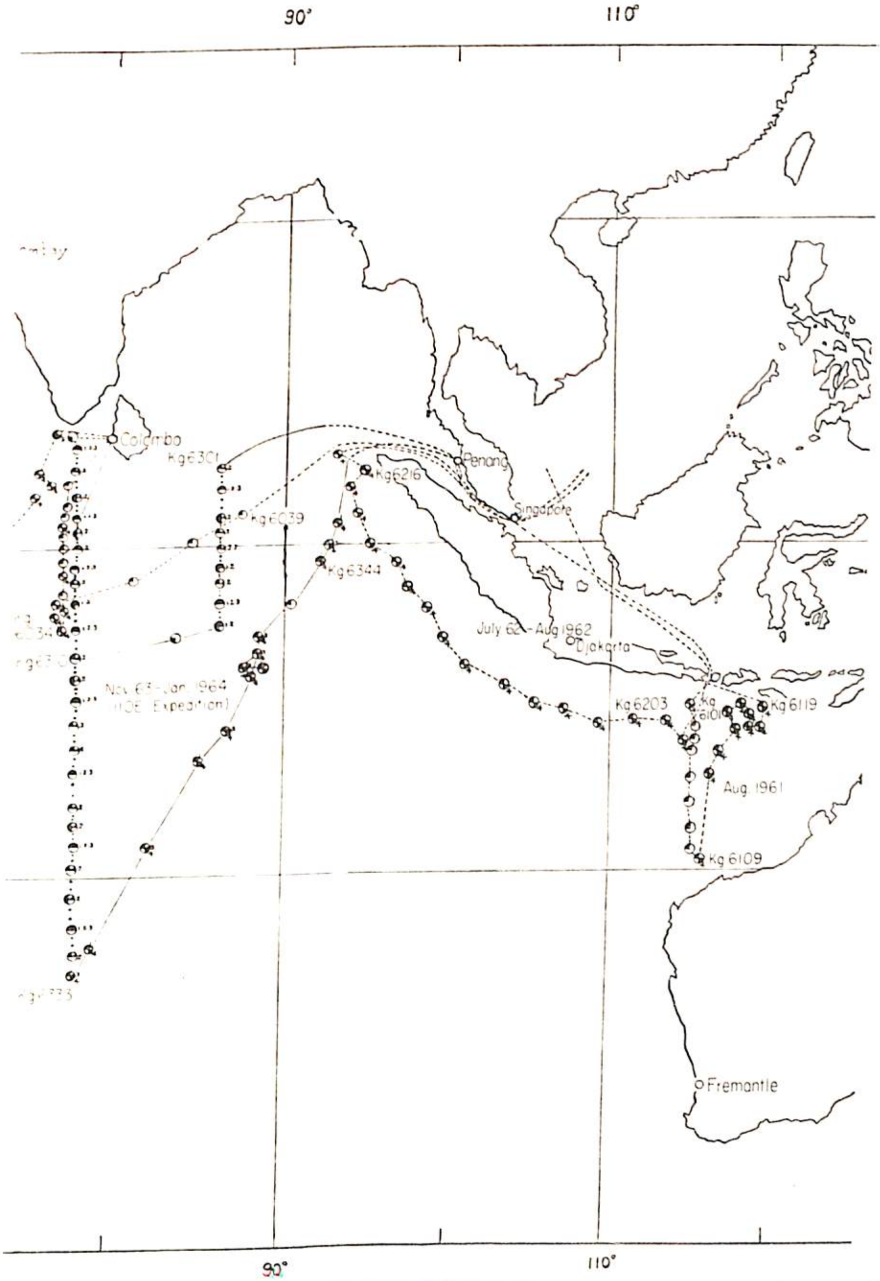


Fig. III-3. Track chart of KAGOSHIMA-MARA cruise in the winters of 1960-61 & 1963-64 and in the summers of 1961 & 1962.

of 8°S)

Chemical analysis: Dissolved oxygen, phosphate, silicate, nitrate, pH, zinc, cadmium & nicotinic acid.

Biology: a) IOS net; 200-0 m., vertical haul at all sts. b) Juday net; divided vertical haul at 11 sts. (200-0, 500-200, 1000-500, & 2000-1000 m.). c) Larva-net; Surface horizontal haul at 11 sts. d) Mid-water trawl net; all sts. e) High speed sampler; at all sts.

Productivity: a) $_{14}$C technique; tank experiment at all sts. *in situ* experiments at 13 sts. b) Chlorophyll measurement; at 11 sts. Continuous recording of solar radiation; at all sts.

Bathymetry: Continuous recording.

Geology: a) Core sampling with piston corer; at 11 sts. b) Dredging twice off the Cape Comorin.

Meteorology: a) Surface obs.; every two hours with water temp. continuous recording. b) Air-sea interaction; wind obs. at 1, 2, 4, 8, 10 m. above the sea level; humidity at 0.5, 1, 2, 4, 8, 10 m. above sea level; sea salt nuclei at 1, 2, 4, 8 m. above the sea level.

Experiment fishing: Tuna long-line fishing at 12 sts.

Eye observation: Birds, animals and other phenomena.

OSHORO-MARU (1181 gross tons, 66.7 m. length, Diesel 2000 HP) (Faculty of Fisheries, Hokkaido University, Ministry of Education, Hakodate)

(1) Itinerary of Cruise (1963-64) (See Station map, Fig. 4)

Port of Call	*Arrival*	*Departure*	*Remarks*
Hakodate		Nov. 11, 1963	Total milage: 12252 SM. 88 days.
Bangkok	Nov. 29	Dec. 4	
Singapore	Dec. 7	Dec. 10	Occupied 31 sts. Tuna long-line fishing, trawling.
Port Darwin	Jan. 9, 1964	Jan. 13	
Hakodate	Feb. 6		

Captain Takeji FUJII & officers 11, crew 27, cadets 22.

Scientists (Faculty members) 7.

Prof. Dr. Sigeru MOTODA (plankton), Dr. Teruyoshi KAWAMURA (primary productivity), Mr. Motokazu UENO (tuna fishing and trawling), Dr. Tuneyoshi SUZUKI & Mr. Isamu WADA (DSL & underwater illumination), Mr. Tuneo NISHIYAMA (fish biology), Mr. Keisuke OSAWA (plankton).

Two UNESCO fellows from the United Arab Republic, Mr. Ibrahim Abdel Fattah Mahmoud Soliman and Mr. Hamed Mamed Mohamed Saleh, joined the cruise from Bangkok to Hakodate.

(2) Scientific work

Hydrographic cast: a) Down to 1500 m.; at 14 sts. b) To the bottom on trawling ground; at 7 sts.

Biology: a) IOS-net hauls (200-0 m.); at 14 sts. b) Horizontal hauls in 5-7 layers between 0 to 3000 m.; at 7 sts. c) Larva net surface haul with high speed plankton sampler (at night); at 14 sts. e) Microplankton sampling from several depths; at 12 sts. f) DSL observations and plankton net haul; at 16 sts.

Productivity: a) *In situ* experiments; at 6 sts. b) Tank experiments; at 19 sts. c) Chlorophyll-a measurements; at 12 sts. d) Underwater light intensity measurements; at 21 sts.

Experimental fishing: a) Tuna long-line cast: at 13 sts. b) Trawling; at 17 sts (20 trawlings).

IV. Other surveys made by Japanese boats before I. I. O. E.

OSHORO MARU (Faculty of Fisheries, Hokkaido University, Ministry of Education, Hakodate)
(1181 gross tons, 66.7m. length, 2000 HP diesel)

(1) Itinerary of Cruise (1962-63)

Nov. 17 left Hakodate; Dec. 11, started oceanographic observations in the Indian Ocean; Dec. 14, started experimental trawl fishery in the waters northwest coast of Australia; Dec. 23-28, Fremantle; Dec. 13 1962.Jan. 18, 1963, experimental tuna long-line fishing in the eastern Indian Ocean,; Jan. 19, finished oceanographic observation; Jan. 21-26, Singapore; Feb. 12, returned to Hakodate. Total milage: 13, 914 SM., and total cruising hours; 1482.

From Dec. 1962 to 19 Jan., 1963, total observed sts. 51. (Water temperature, salinity etc. by serial obs.) 17 levels down to 1500m hydrographic coast Captain Takeharu FUJII, oceanographer in charge Kiyotaka OTANI The Data Report was published in the Data Record of Oceanographic Observations and Exploratory fishing No. 8 (March 1964) (The Faculty of Fisheries, Hokkaido University).

(2) Main scientific findings

a) In the eastern Indian Ocean (between Sunda Islands and northern coast of Australia), pod of squid of about 20 cm were observed coming to the light of night oceanographic observation. However, number decreases towards west.

b) In the northwest coast of Australia, while trawl fishing was underway, eastward current having a velocity of lese than 1 knot was perceived.

c) Off the north side of the said waters, namely in the area 13-14°S, west-north-westward flow having a velocity of 1 knot was perceived.

d) In the period of tuna long-line operation, the Equatorial Front was located near 12-13°S. Frequent squalls were observed in the said region (northern and southern sides) it was fine weather. Activity of the frontal zone seemed to be considerably vivid.

KAGOSHIMA MARU (Kagoshima University, Faculty of Fisheries, Ministry of Education, Kagoshima)
1038 gross tons, 60.5m. lemgth, diesel 1700HP)

Itinerary of three cruises in the Indian Ocean during 1960-62. KAGOSHIMA MARU engaged in the oceanographic surveys and experimental tuna long-line fishing of the Indian Ocean three times since 1960. In 1960, zonal line along about 5°N latitude was observed in the western Indian

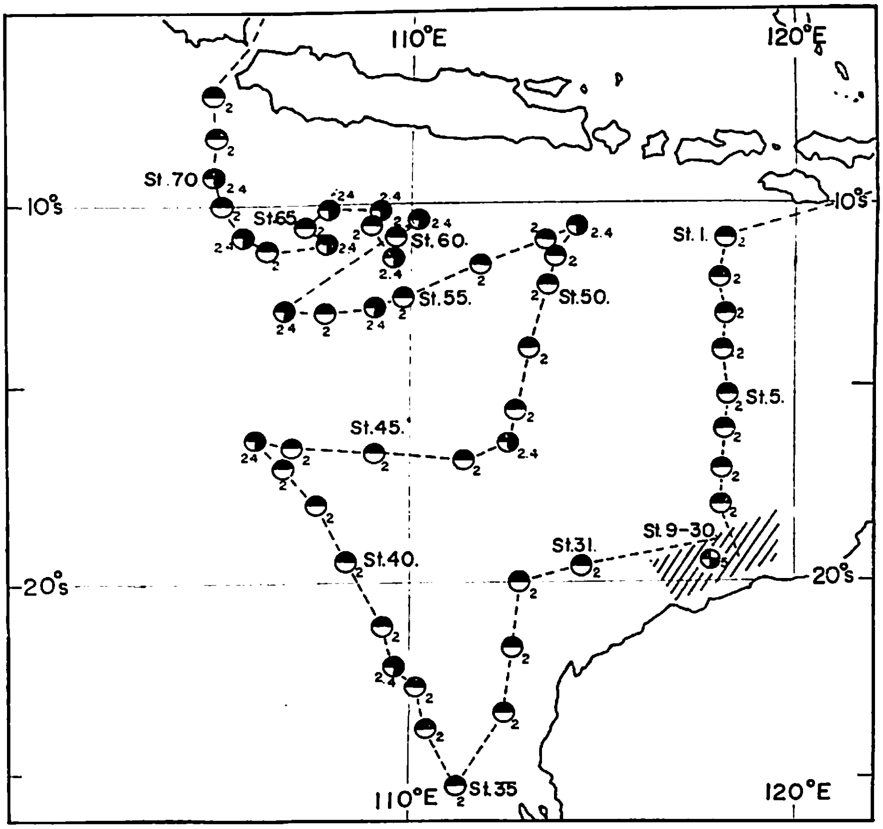


Fig. IV-1(a). Track Chart of cruise Oshoro Maru in the winter of 1962-63.

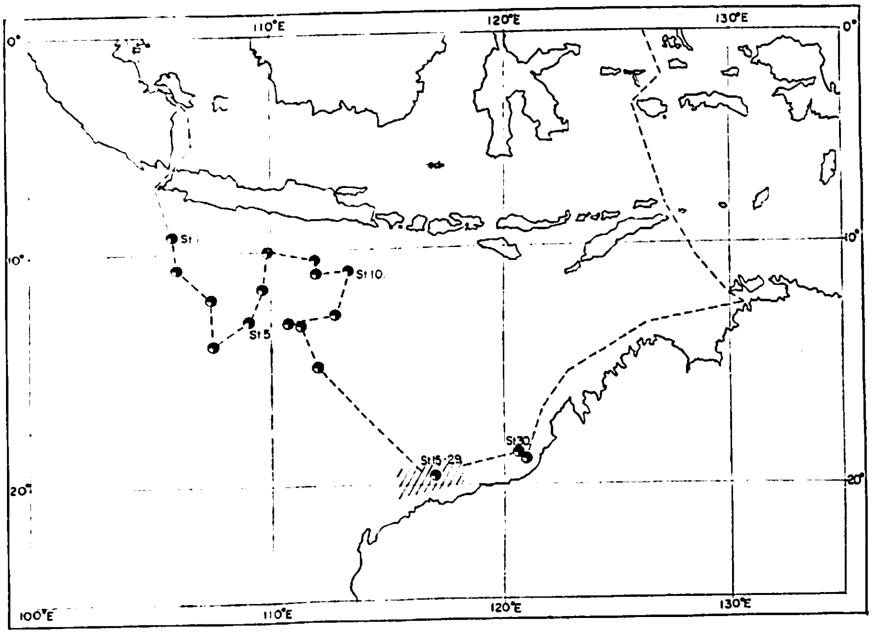


Fig. IV-1(b). Track Chart of Oshoro Maru Cruse in the winter of 1963-64.

Ocean with the extension in the Red Sea. Southward observational line from Cape Comorin was also occupied. In 1961, southwestern waters along Sumatra and Java was occupied. And in 1962, southward observational line from Bali Island was occupied.

UMITAKA MARU (Tokyo University of Fisheries, Ministry of Education, Tokyo)
(1453 gross tons, 73.4m length, diesel 2100HP)

Itinerary of Cruise (1960/61)...Presurvey of IIOE.

From November 1960 to January 1961 in the Eastern Indian Ocean, Arafura Sea and Banda Sea, 59 Stations......Serial observation made down to 3890m. Water temperature, salinity, dissolved oxygen, PH, phosphate and silicate etc.

Captain; Keijiro OZAWA

Scientists in charge;

Makoto ISHINO, Takeshi TAGUCHI, Ryogo UEHARA.

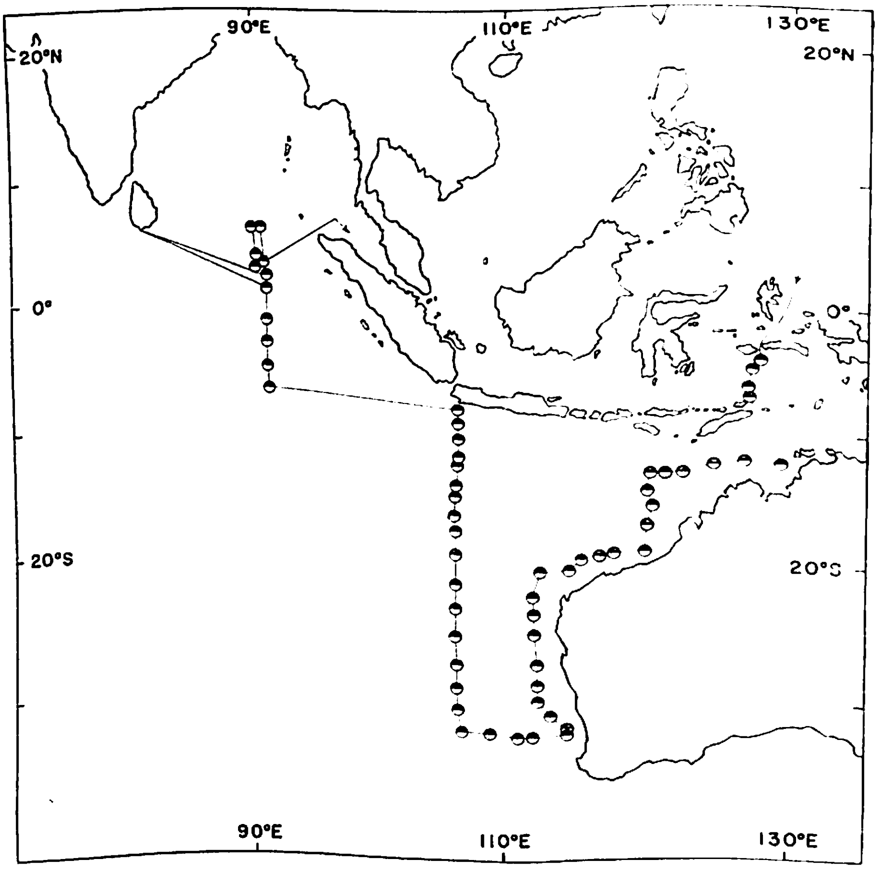


Fig. IV-2. Track chart of UMITAKA MARU cruise in winter of 1960~'61.

V-1. Bathymetry and Geophysics

The Working Group for Bathymetry and Geophysics

1) Bathymetry (Figs. V-1-1 ~ V-1-4)

Several charts are synthetized by the Hydrographic Office of Japan. The data were obtained by Umitakamaru, Koyomaru and Kagoshimamaru during the year of 1962-1964 jointed with the International Indian Ocean Expedition.

2) Geophysics (Figs. V-1-5 ~ V-1-7)

The results of survey on geomagnetism and gravity by Umitakamaru at the East Indian Ocean in the winter of 1963-1964 are shown in some figures. The Surface Ship Gravity Meter "T. S. S. G-γ" is used for the measurement of gravity force at sea, and as for the magnetic force the Proton Magnetometer is used. Both instruments are newly constructed and revised so as to be able to measure quite automatically. Throughout the expedition the observations were performed almost continuously, and the number of measured values amounts to 5000 in gravity and 2000 in geomagnetism, respectively.

(Yoshibumi TOMODA)

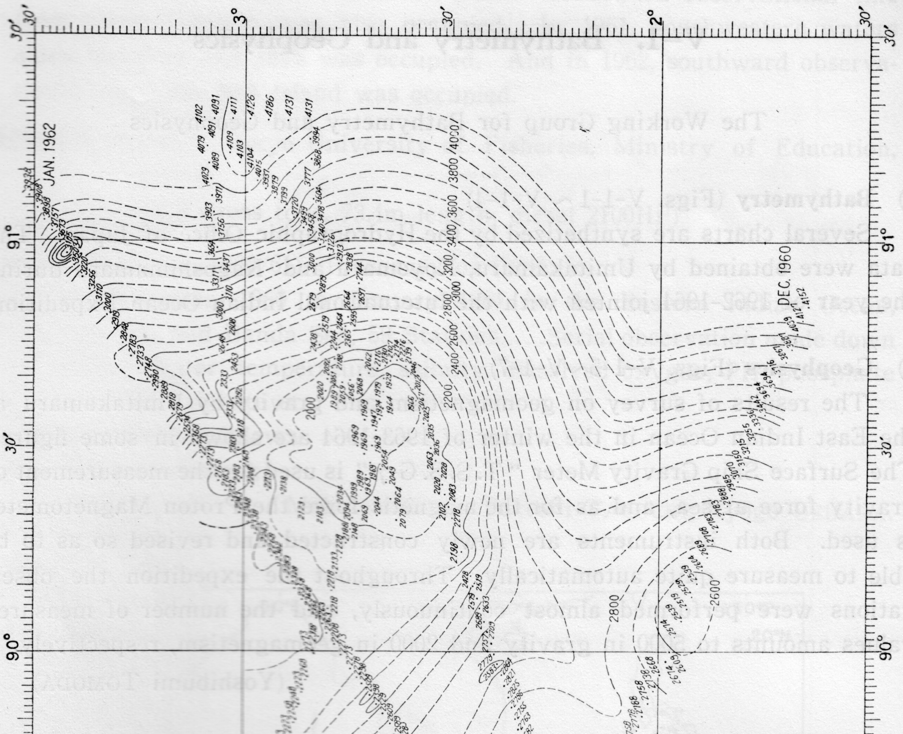
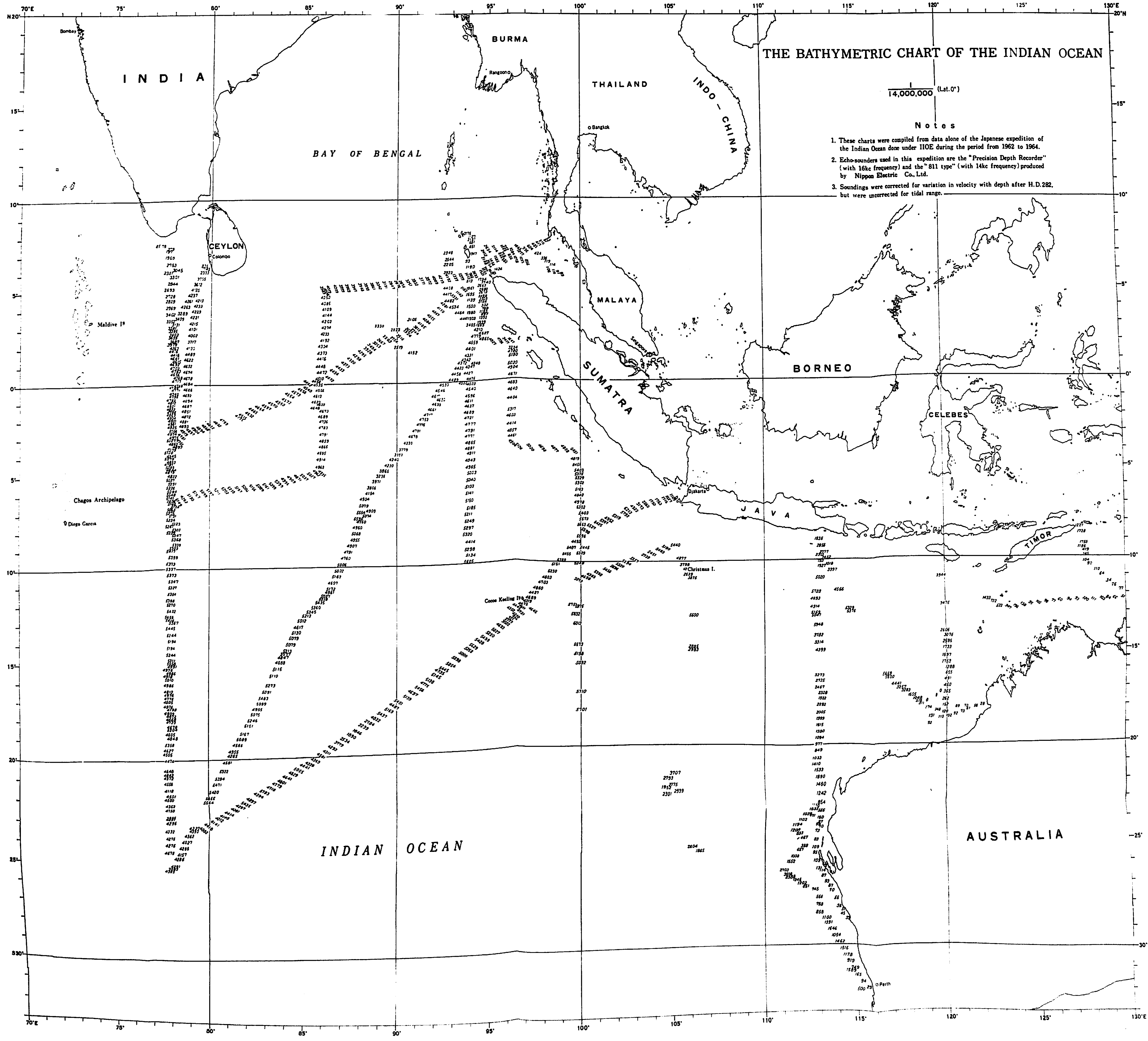


Fig. V-1-1. The bathymetric chart of the Indian Ocean



THE BATHYMETRIC CHART OF THE INDIAN OCEAN

$\frac{1}{14,000,000}$ (Lat.0°)

Notes

1. These charts were compiled from data alone of the Japanese expedition of the Indian Ocean done under IIOE during the period from 1962 to 1964.
2. Echo-sounders used in this expedition are the "Precision Depth Recorder" (with 16kc frequency) and the "811 type" (with 14kc frequency) produced by Nippon Electric Co., Ltd.
3. Soundings were corrected for variation in velocity with depth after H.D.282, but were uncorrected for tidal range.

Fig. V-1-2 The bathymetric chart of the Indian Ocean.

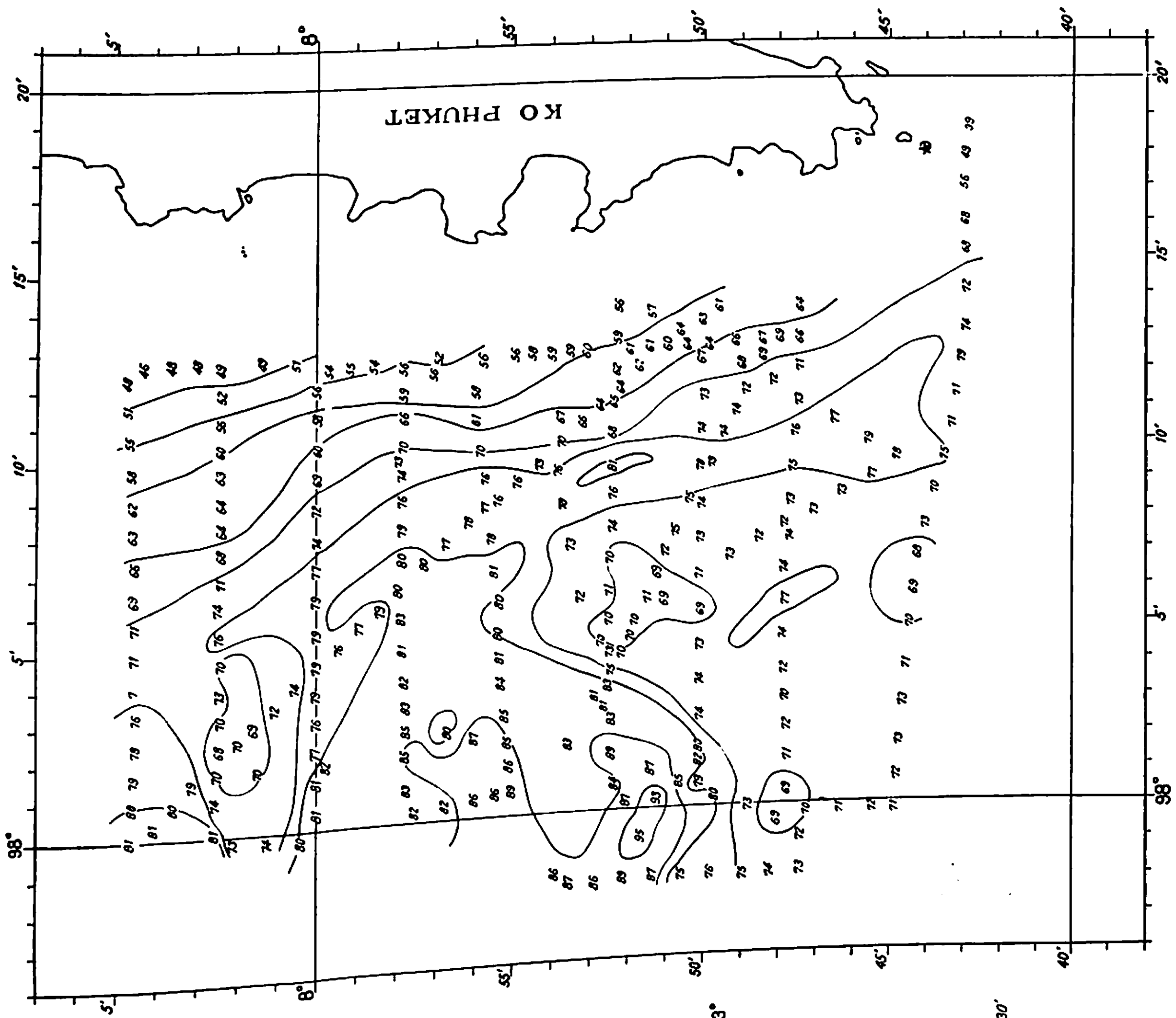


Fig. V-1-4. The bathymetric chart of the Indian Ocean.

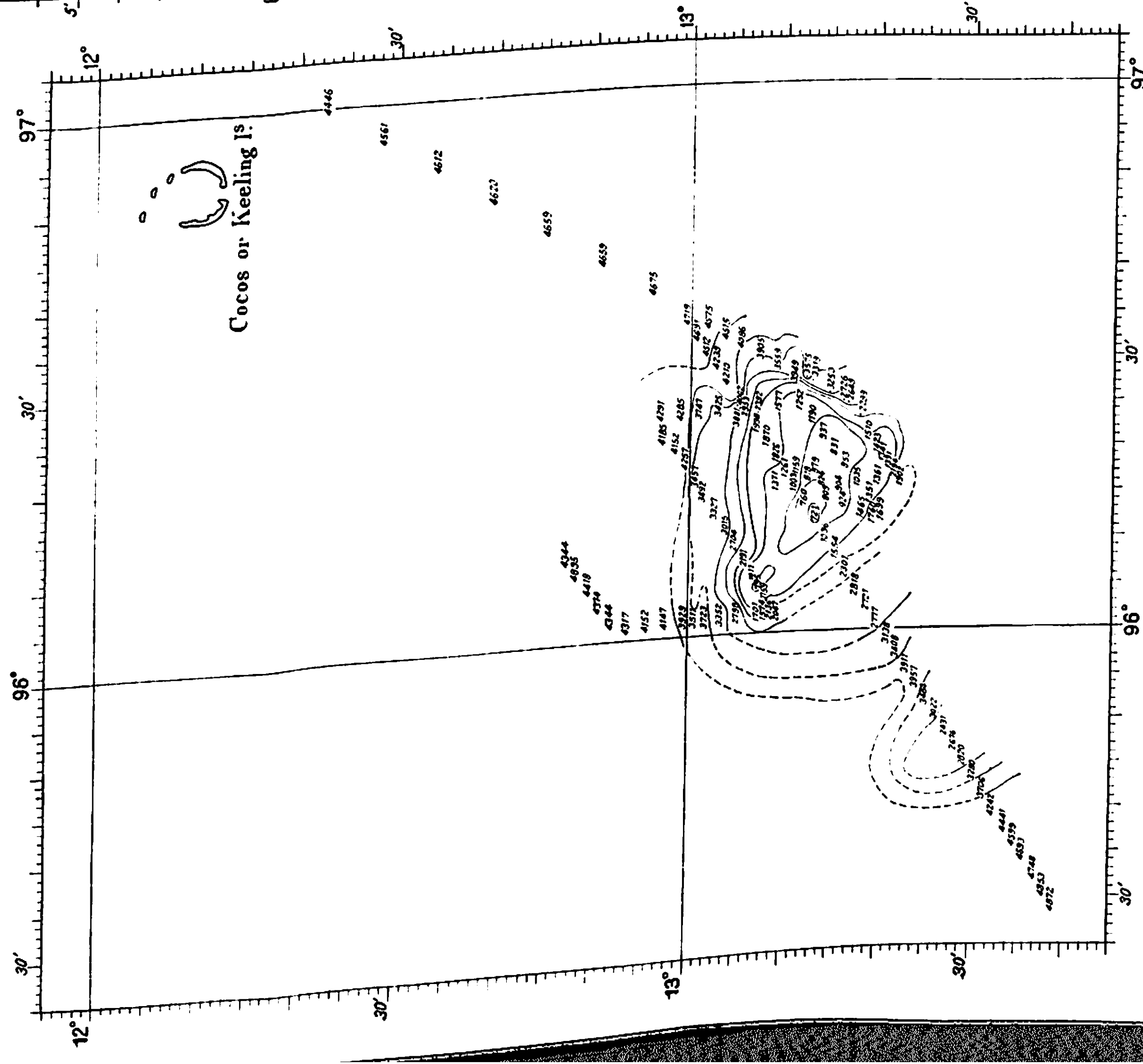


Fig. V-1-3. The bathymetric chart of the Indian Ocean.

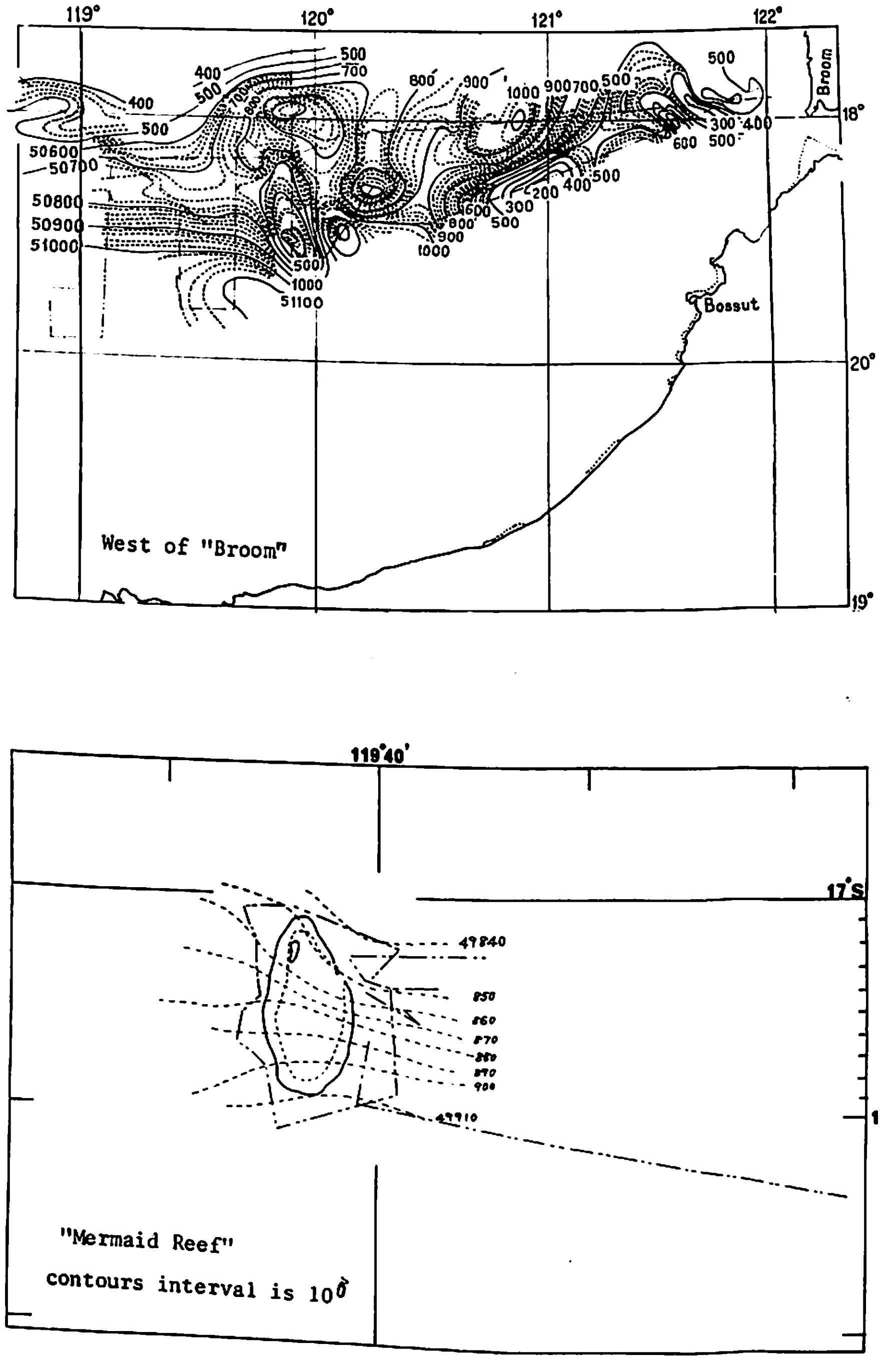


Fig. V-1-5. Geomagnetism in east part of the Indian Ocean.

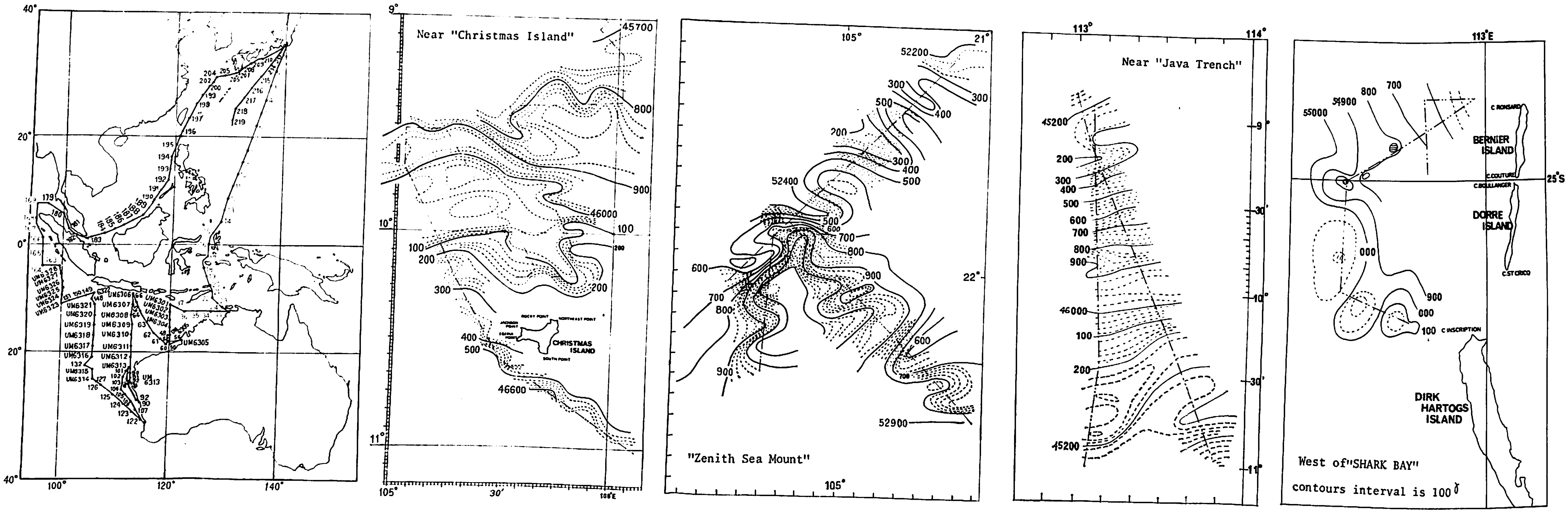


Fig. V-1-6. Geomagnetism at east part of the Indian Ocean.

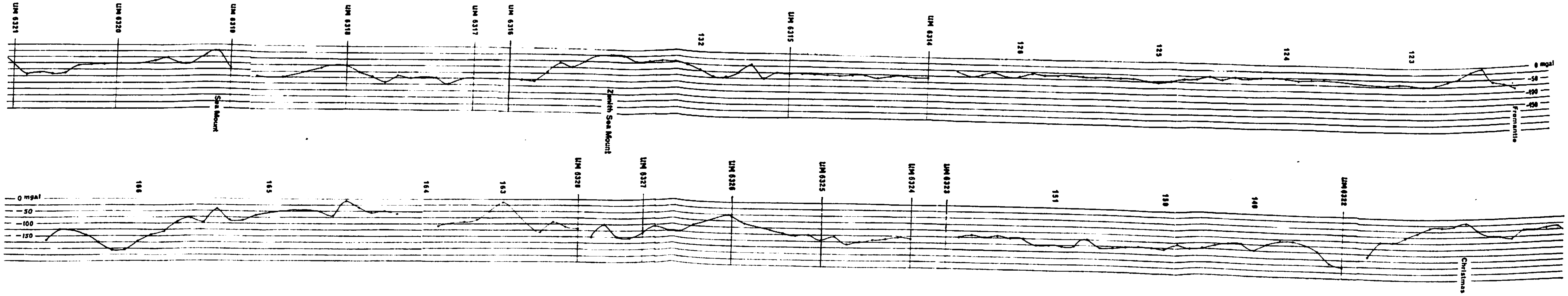


Fig. V-1-7. Free-air gravity anomaly in east part of the Indian Ocean.

V-2. Marine Geology

The working Group for Marine Geology

The first surves on marine geology at east part of the Indian Ocean were done in the winter of 1962-1963, along the track of Umitakamaru, Tokyo University of Fisheries.

The second survey were also done at east part of the Indian Ocean in the winter of 1963-1964 along the track of two ships; Umitakamaru and Kagoshimaru of the Department of Fisheries, Kagoshima Umiversity.

The studies of obtained data are going on now and the results of their outline are as follows. Tracks of those ships are put a mark on the part of the bathymetric chart of the Indian Ocean reported from Japan.

Scientific staff for geological survey:

Umitakamaru, 1962-1963.........
 Dr. Hirosei NIINO, Tokyo University of Fisheries.
 Dr. Kei OSHITE, Hokkaido Gakugei University.
Umitakamaru, 1963-1964
 Dr. Ryuichi TSUCHI, Geological Institute, Shizuoka University.
Kagoshimamaru, 1963-1964.........
 Dr. Shozo HAYASAKA, Institute of Geology and Paleontology, Tohoku University.

Geologic Survey by the Umitakamaru International Indian Ocean Expedition in the winter of 1962-1963 (by Hiroshi NIINO and Kei OSHITE)

The following items which are selected from the items of marine geological survey decided by the Marine Geology Committee of the International Indian Ocean Survey Headquarters, asked by the Indian Ocean Ad Hoc Committee of Japan to be carried out by the Umitakamaru, and approved by the Tokyo University of Fisheries;

1) Core-sampling of the sea-bottom sediments by the piston-core-sampler and gravity-core-sampler.
2) Mud-sampling by dredges on the newly discovered submarine rising areas.

Progresses:

1) Mud-sampling by the piston-core-sampler; locality, instruments-Table v-2-1.
2) Mud-sampling by the dredges; locality, instruments-Table v-2-2.

Collected samples:

1) Collected samples by the piston-core-sampler;

The localities of sampled cores, UMI-2, -5, -8 and -9 are scattered between Lat. 1°56'S and 5°56.2'N, covering an area close to the Indian Peninsula and the Maldive Islands. All the localities are more than 4,000m in depth with an exception of locality UMI-2 of level at 2,000m. Tee collected samples are all blue clay with the reddish brown top, i.e. the sea bottom surface. Under the microscype, rounded quartz grain, ferromagnesian minerals, volcanic glass, vegetable fibres, planktonic foraminifera and radiolaria are seen and they suggest the terrestrial influence.

Another group of the localities of samples includes localities UMI-12, -18 and -21, covering deep sea area between lat. 7°04.1'S and 21°53.7'S. All the collected samples are of red clay. Under the microscope, they are formed of the genuine oceanic sediments of volcanic glass, cosmic dusts, planktonic foraminifera, radiolaria, etc. In the upper layer of the sample from St. UMI-18, there are found number of the manganese nodules with weak radioactivity of grade of 20 counts. The manganese nodules are often by found in the pelagic sediments, especially in the marginal part of a large scaled rising area in the sea bottom.

2) Collected samples by the dredges; (Fig. V-1-2)

Continental shelf sediments of the Indian Peninsula:

At St. UMI-1, sampling was done through O-type dredge (designer: K. OSHITE) and N-type dredge (designer H. NIINO). The former dredge collected at two localities of St. UMI-1A and 1B samples of coarse-grained sand and *Dentalium*. The latter collected at St. UMI-1C and 1D sandstone fragments, pebbles, reef coral fragments, deep sea coral, single coral, calcareous sponge, snells, crustacea, brittle-star, gastropoda, pelecypoda and small fishes. Those localities are betwen 115m and 183m in depth, lying on the slope of the marginal part of the continental shelf. The area could be considered for the benthos fishery.

Umitaka-guyot (tentative name): (Fig. V-1-3)

This is a guyot composed of two peaks which rise from the sea bottom of around 4000m upto the depth of around 2000m in southwest of the Andaman Islands. Through dredging by St. Umitaka-guyot D-1, and guyot D-1, and burnt coal fragment from D-2. The latter sample has worm nest on its surface which suggests that the sample was exposed on the surface of the sea bottom. Locality D-1 is on the western peak and D-2 on the eastern one. Both of these samples, however, are from surface sediments so that the basement geology of the Umitaka-guyot is not yet known.

Cocos-guyot (tentative name)

This guyot rises from the flat sea bottom more than 4000m deep upto the depth of about 700m around the point 80 nautical miles southwest of the Cocos Islands.

The samples from St. Cocos-guyot D-A through N-type dredge contain abundant rock fragments, gravels, remains of pelagic corals, etc. and a few creatures. From St. Cocos-guyot C-B, abundant rock fragments, remains of pelagic corals and sponges, a few creatures.

The limestone, which is considered as from basement rocks, shows a corroded surface, a manganese-covered one in part, and surface with trace of attached living life. The most abundand life remains is *Collarium konojoi* Kishinouye var. which has skelton changed in color and surface stained with manganese in many cases. Living sample of the species is also collected. Samples of single corals and sponges are mainly remains.

Living creatures are pelecypods, brachiopods, single corals, brittle stars, etc. They are few in number and poor in quantity. Foraminifera are abundant, and sandy and mainly planktonic.

The basement rocks contain fossils, and it will be possible to determine the geologic age of the basement rocks on the top of the Cocos-guyot. Under the microscope, *Lepidocyclina* and *Miogypsina* were observed in the thin slide of the basement limestone. Those kinds of fossil foraminiferas are an indicator of Miocene sediments.

The specific names of foraminifera from limestone dredged at Cocos-guyot

Loc. I.

Lepidocyclina (*Nephrolepidina*) *radiata* (Martin)
L. (*N.*) aff. *omphalus* Tan
L. (*N.*) aff. *shndaica* Yabe and Hanzawa
L. subgen. and sp. indet.
Cyclolypeus eidae Tan
Operculina sp.

(Lowermost Burdigalian)

Loc. II.

Lepidocyclina (*Eulepidina*) *formosa* Schlumberger
L. (*Nephrolepidina*) sp.
Cycloclypeus sp.
Heterostegina sp.

(Aquitanian)

The list of specific names of foraminifera in the sand from Cocos-guyot

Loc. II. :

Globorotalia cultrata (d'Orbigny)	23.1%
G. tumida (Brady)	6.3
G. truncatulinoides (d'Orbigny)	0.8
G. crassaformis (Galloway and Wissler)	1.3
G. scitula (Brady)	0.4
Globoquadrina dutertrei (d'Orbigny)	3.8
Gq. ? *hexgona* (Natland)	0.4
Gq. ? *conglomerata* (Schwager)	3.4
Globigerina bulloides d'Orbigny	0.4
G. aff. *falconensis* Blow	0.4
G. of. *calida* Parker	1.3
Globigerinella siphonifera (d'Orbigny)	0.8
Globigerinoides conglobatus (Brady)	9.2
G-oides sacculifer (Brady)	34.1
G-oides ruger (d'Orbigny) (pyramidalis type)	5.0

G-oides cf. *obliqua* BOLLI	0.4
G-oides *tenellus* PARKER	0.8
Orbulina universa D'ORBIGNY	0.8
Pulleniatina obliquiloculata (PARKER and JONES)	2.5
Sphaeroidinella dehiscens (PARKER and JONES)	3.8
Globigerinita glutinata (EGGER)	0.4
Globigerina ? sp.	0.4
Bethonic species	
Rupertia stabilis WALLICH	few
Molluscs dredged from Cocos-guyot Loc. I.:	
Samacar pacifica NOMURA andZIMBO	2 specimens
Halicardia (s.s.) cf. *gouldi* DALL,BARTSCH and REHDER	1
Puncturella dorcas KIRA and HABE	1
Siliquaria (*Agathirses*) *anguinus* (LINNÉ)	5
Molluscs dredged from Cocos-guyot Loc. II.:	
Athleta sp.	1 specimen
Corals from Cocos-guyot Loc. II.:	
Madrepora ocellata LINNÉ	Abundant
Solenosimila sp.	
Desmophyllum sp.	

Many siliceous sponge, bryozoa and hydrozoa remains were found from Loc. I and II.

Gravels are sandy pebbles and pumiceous one. They may present some parts of the guyot.

The present survey was only on two points on the top of the guyot and it is necessary to have deeper dredging for study on the origin and the geologic age of the guyot in near future.

Geologic Survey by the Umitakamaru International Indian Ocean Expedition in the winter of 1963-1964 (by Ryuichi TSUCHI)

Through Oct., 1963, the research and training ship of Tokyo University of Fisheaies, Umitakamaru, carried out oceanographic works in the Eastern Indian Ocean as on her 24th training cruise in compliance with the programm of international research of the Indian. The projects on marine geology were sampling of sea-bootom sediments by means of 1) piston core-sampler and 2) dredge. The operations are sammarized in Tables V-2-3 and V-2-4.

Seven core-samples were obtained from various stations by means of the piston corer (400cm in total length, 75mm in diameter). Top sediments of these cores were all composed of calcareous and/or siliceous ooze with the exception of one from the slope of the Bali Trench, which consists of pumice- and scoria-bearing greenish gray mud. Further investigation on these cores are now in progress.

A discovery of a seamount which is located in lat. 22°12'S, long. 104°40'E is one of the important results of our survey. Its peak, forming a gentle elevation, attains 1923 meters deep. The mountain was tentatively named

"Zenith". The area may belong to the northwest extention of the West Australian Ridge. Judging from observation of bottom sediments collected by core-sampler and beam-trawl, the summit area of the seamount seems to be covered with thick *Globigerina*-Radiolarian ooze.

Bottom sediments were also obtained from 21 stations by means of the NIINO-type dredge. Dredgings were carried out mainly on continental shelves off Western Australia. especially, on the Rowly Shelf in the offing of Broome, northwestern Austrrlia and also on the Dirk Hartog Shelf in the offing of Shauk Bay, western Australia, both at about 100 meters deep.

On the Rowly Shelf, surface sediments were mostly organogenic calcareous sands consisting of foraminiferal tests, molluscan shells, bryozoan skeletal fragments and well-sorted calcareous spheroids. Besides those, finegrained angular quartz were found. Several attempts for collecting of bedrocks were failed because of their hardness.

On the Dirk Hartog Shelf, organogenic calcareous sands are found, too. They are composed of remains of foraminifera, molluscs, bryozoans and calcareous rollers derived probably from bryozoan skeletal fragments. A part of the basement rocks of the shelf is composed of calcarenite which may be comparable with the Pleistocene Coastal Limestone being exposed extensively on the coastal area of Western Australia.

Molluscan shell-assemblages from the above-mentioned two areas have close resemblance to each other in the generic combination, though common species scarcely be found. Both thanatocoenose are represented by *Oblimopa-Glycymeris-Neotrigonia-Venericardia* assemblages which suggest typical communities of open shelf.

Bottom sediments dredged from continental slope off Western Australia were mostly *Globigerina* ooze, where macro organic remains could scarcely be found.

Geologic Survey by the Kagoshimamaru International Indian Ocean Expedition in the winter of 1963-1964.

Shozo HAYASAKA

1) The projects on marine geology assigned to the Kagoshimamaru were; sampling of the marine sediments by use of the (a) piston or gravity core sampler and (b) dredge.

Among these, dredge operations were done only twice, once at each of the two stations adjacent to each other, because the dredge was lost. Sediment core sampling was carried out by the piston core sampler at 11 stations, and at seven of them more than 2 m long core samples were obtained. The details of the operations are summarized in Tables V-2-5 and V-2-6.

2) The instruments used for sampling of the bottom sediments are: (a) T.S.-Piston Core Sampler (the larger type, 5,668 m in total length), (b) T.S.-Dredge (medium sized). For the operation of these instruments, ca 10,000 m long wire (8 mm-18 mm) winded on a drum run by a Trawl Winch was used. During piston core sampling, a self Balancing Meter (Kyowa Dengyo, SLW-210 PA type) was used as a tension meter to indicate the exact moment of reaching the bottom. This meter was effective to conferm the arrival and the abnormal play of the instrument.

3) The core samples were transformed to the Institute of Geology and Paleontology, Tohoku University for study. To elucidate the geological history of the Indian Ocean during the rather latest geological ages, detailed studies on them, such as mechanical and chemical analysis, and analysis on the assemblages of Foraminifera, Diatom and Coccolithophoridae are planned to be undertaken. Since these laboratory studies on the mentioned projects have just started, only a preliminary report is given here.

4) Three of seven core samples contain Foraminifera ; i. e. the cores from the stations Ka-9′, Ka-18 and Ka-15. Among them, the *Globigerina* ooze from the station Ka-18 was analysed to understand the constitution and historical changes of planktonic foraminiferal assemblages.

Thirty-two species belonging to 11 genera of planktonic Foraminifera were discriminated from the core of St. Ka-18. Through the studies on their frequency and distribution from top to bottom of the core sample, the following two points were made clear.

(a) Throughout the core, the predominant species are *Globorotalia menardii, Globoquadrina dutertrei, Globigerinoides ruber, G. acculifer, Pulleniatina obliquiloculata* and *Globigerinita glutinata,* and the stbordinate ones are *Globigerina bulloides, Globigerinella siphonifera, Globoquadrina conglomerata, G. hexagona* and *Globigerina trilocularis.* All are Recent species which inhabit warm waters and seem to belong to the "warm water fauna" of BRADSHAW (1959) and to the "tropical fauna" of BALYAEFF (1963, 1964).

(b) Judging from the distribution pattern of these warm water species in the core sample, three periods of towering of sea-water temperature are recognized. Namely, the typical warm water species *Pulleniatina obliquiloculata, Globorotalia menardii, Sphaeroidinella dehiscens* and *Globoquadrina conglomerata* show a marked decrease in number of individuals at the horizons 20, 100 and 180 cm downward from the top respectively.

Notes: UMI—Umitaka Maru position.
(IC)—Tentative number of coreing station.

Table V-2-1. Piston Core Sampling Stations Umitaka Maru, in the winter winter of 1962-1963. (H. Niino and K. Oshite)

Station	Date	Starting				Bottoming							Finishing				Instrument used		Corrected core			Remarks
		time	lat.	long.	depth	time	lat.	long.	depth	length of wire	dip	mean dip	time	lat.	long.	depth	main	sub	main	sub	material	
(IC-1)	1962 Nov. 30	0915					8°02.4′N	98°12.4′E	50m	54m			0939				B	A	36cm	20cm	muddy	West of Phuket
(IC-2)	Nov. 30	1400					7°56.0′N	98°02.2′E	86m	90m			1431				A	A	98cm	—	muddy	- do -
UMI. 9(IC-3)	Dec. 11	0810	1°59.7′S	77°59.7′E	4863m	1171	1°56.0′S	78°01.6′E	4863m	5100m	10°	16°	1428	1°54.2′S	78°03.0′E	4862m	A	B	337cm	51cm	blue mud	
UMI. 8(IC-4)	Dec. 12	0955	1°00.5′S	77°59.1′E	4751m	1259	0°58.1′S	78°01.5′E	4756m	4959m	10°	16°	1550	0°55.8′S	78°01.6′E	4745m	B	B	389cm	64cm	blue mud	
UMI. 5(IC-5)	Dec. 15	0810	1°56.2′N	77°56.6′E	4341m	1053	1°58.2′N	77°55.8′E	4308m	4552m	7°	18°	1325	1°58.0′N	77°54.7′E	4320m	A	B	384cm	—	blue mud	
UMI. 2(IC-6)	Dec. 18	1056	5°56.7′N	77°53.0′E	2622m	1248	5°56.2′N	77°50.7′E	2523m	2930m	10°	30°	1436	5°55.5′N	77°47.7′E	2468m	B	B	138cm	26cm	blue mud	
UMI. 12(IC-7)	Dec. 30	0730	7°02.7′S	78°03.8′E	4981m	1050	7°04.1′S	78°03.5′E	5114m	5494m	10°	20°	1348	7°06.2′S	78°04.8′E	5089m	A	B	360cm	—	red clay	Deepest point
UMI. 18(IC-8)	1963 Jan. 5	1017	19°54.1′S	78°01.0′E	4682m	1319	19°52.9′S	77°56.0′E	4374m	4913m	8°	24°	1602	19°52.8′S	77°52.4′E	4518m	A	B	308cm	30cm	red clay	Southernmost point
UMI. 21(IC-9)	Jan. 8	0920	23°54.6′S	79°20.7′E	4341m	1201	23°53.7′S	79°18.2′E	4114m	4433m	10°	20°	1441	23°54.9′S	79°19.3′E	4248m	B	B	—	25cm	red clay	

Table V-2-2. Dredge Sampling Stations Umitaka Maru, in the winter of 1962-1963. (H. Niino and K. Oshite)

Station	Date	Starting			Length of wire	Finishing time	Collected samples					Remarks
		time	lat.	long.	depth			color	sediments	mineral	life (remain)	life (living)	
I- 1	1962 Nov. 29	1809	7°53.9′N	98°03.2′E	81m	130m	1819	yellowish gray	muddy sand	—	pelecypoda, foraminifera	pelecypoda, foraminifera	Continental shelf off Phuket
I- 2	Nov. 29	1827	7°52.3′N	98°04.0′E	75m	130m	1234	reddish gray	shell-bearing coarse sand	—	fossil shell, sand-pipe	foraminifera	„ „ „
I- 3	Nov. 29	1850	7°51.8′N	98°05.3′E	71m	130m	1854	dark gray	very coarse sand	—	pelecypoda	pelecypoda, brittle star	„ „ „
I- 4	Nov. 29	1951	7°50.3′N	98°08.5′E	76m	140m	2000	yellowish gray	mud-bearing coarse sand	—	pelecypoda	—	„ „ „
I- 5	Nov. 29	2014	7°49.2′N	98°10.8′E	74m	130m	2026	yellowish gray	mud-bearing fine sand	large rounded coal cinder	—	—	„ „ „
I- 6	Nov. 29	2042	7°48.0′N	98°12.8′E	69m	120m	2047	yellowish gray	mud-bearing fine sand and caarse sand	large rounded coal cinder	—	—	„ „ „
I- 7	Nov. 30	1114	7°57.1′N	98°12.2′E	56m	80m	1123	dark gray	mud-bearing coarse sand	tin ore grain	pelecypoda	brittle star	„ „ „
I- 8	Nov. 30	1146	7°58.0′N	98°09.8′E	73m	120m	1154	yellowish gray	mud-bearing fine sand	—	pelecypoda, gastropoda	brittle star	„ „ „
I- 9	Nov. 30	1233	8°00.0′N	98°04.8′E	78m	130m	1242	dark gray	coarse sand	—	—	—	„ „ „
I-10	Nov. 30	1308	8°01.9′N	98°02.1′E	71m	140m	1323	whitish gray	coarse sand	—	—	—	„ „ „
I-11	Nov. 30	1613	7°47.8′N	97°59.4′E	70m	120m	1623	whitish gray	(Foraminifera) sand	—	benthos, foraminifera	benthos, foraminifera	„ „ „
I-12	Nov. 30	1628	7°47.4′N	97°59.0′E	72m	140m	1639	whitish gray	(Foraminifera) sand	—	benthos, foraminifera	benthos, foraminifera	„ „ „
I-13-I	Dec. 3	1407	2°48.0′N	90°38.5′E	2004m	3000m	1819	whitish gray	*Globigerina* ooze	—	foraminifera	—	finishing station; 2°43.5′N 90°41.0′E, 2063m on Umitaka-guyot
I-13-II	Dec. 3	1843	2°42.5′N	90°41.0′E	2060m	3000m	2239	whitish gray	*Globigerina* ooze	—	foraminifera	—	„ ; 2°38.0′N 90°43.5′E, 2174m on Umitaka-guyot
I-14	Dec. 4	0746	2°28.5′N	89°22.0′E	2486m	3300m	1203	—	coarse sand	coal cinder	—	—	„ ; 2°26.0′N 89°25.0′E, 2313m on Umitaka-guyot
I-15-I	Dec. 19	0945	7°27.1′N	77°50.0′E	183m	280m	1008	dark gray	coarse sand	—	—	Dentalium	Continental shelf off Ceylon
I-15-II	Dec. 19	1009	7°26.8′N	77°49.7′E	175m	360m	1038	dark gray	coarse sand	—	—	—	„ „ „
I-15-III	Dec. 19	1107	7°29.9′N	77°43.6′E	115m	200m	1118	light yellowish green	coarse sand	sandstone gravel	coral, gastoropoda, pelecypoda	coral, gastropda, crabs, pelecypoda, hermit crabs, starfish, fish	„ „ „
I-15-IV	Dec. 19	1126	7°29.9′N	77°43.6′E	115m	200m	1142	light yellowish green	coarse sand	—	coral, gastoropoda, pelecypoda		„ „ „
I-16-I	1963 Jan. 14	0815	13°14.3′S	96°18.0′E	810m	1200m	0941	—	—	limestone fragment	coral, gastoropoda, pelecypoda	sponge, coral, crabs, gastropoda, pelecypoda, hermit crabs, brachiopoda, brittle star	On Cocos-guyot
I-16-II	Jan. 14	0943	13°14.4′S	96°17.1′E	890m	1300m	1055	—	—	pumice	coral, gastoropoda, pelecypoda		On Cocos-guyot

Table V-2-3. Piston Core Sampling Stations Umitaka Maru, in the winter of 1963-1964. (R. Tsuchi)

Station	Date	Starting				Bottoming						Finishing				Collected core			Remarks
		time	lat.	long.	depth	time	lat.	long.	depth	length of wire	dip	time	lat.	long.	depth	main	Sub	material	
IC-10	1963 Nov. 13	1745	9°48.5′S	127°33.8′E	467m	1806	9°48.8′S	127°31.5′E	410m	430m	1°	1830	9°49.2′S	127°30.8′E	414m	33cm	—	light greenish gray *Globigerina*-Pteropod ooze	Timor Sea
IC-11	Dec. 5	1000	9°04.3′S	113°02.1′E	1896m	1117	9°04.0′S	113°02.2′E	1917m	1990m	10°	1212	9°03.3′S	113°02.5′E	1938m	68cm	—	greenish gray sandy mud	Off East Java
IC-12	Dec. 9	1050	16°55.6′S	113°00.5′E	2390m	1237	16°55.8′S	113°01.4′E	2266m	2480m	6°	1358	16°55.2′S	113°03.4′E	—	62cm	—	light brown *Globigerina* ooze	Off NW Australia
IC-13	Dec. 24	1324	26°47.1′S	111°23.6′E	2553m	1500	26°46.0′S	111°24.7′E	2522m	2750m	18°	1641	26°44.6′S	111°26.1′E	2381m	46.5cm	—	light brown top green bottom *Globigerina* ooze	W of Shark Bay
IC-14	1964 Jan. 7	1212	22°25.0′S	104°39.5′E	2301m	1339	22°22.3′S	104°39.4′E	2234m	2500m	30°	1502	22°21.7′S	104°39.2′E	2198m	92.5cm	—	light brown *Globigerina*-Radiolarian ooze	" Zenith " seamount
IC-15	Jan. 14	1350	10°12.4′S	105°35.9′E	3798m	1830	10°11.3′S	105°35.1′E	3876m	4045m	2°	2110	10°10.5′S	105°34.6′E	3954m	39cm	—	brown top gray bottom *Globigerina*-Diatom-Radiolarian ooze	Near Christmas Is.
IC-16	Jan. 22	1415	3°54.7′S	99°15.0′E	4698m	1725	3°54.0′S	99°13.7′E	4704m	5100m	2-3°	2030	3°52.1′S	99°11.1′E	4777m	113cm	—	dark brown top dark gray bottom Diatom-Radiolarian ooze	Off Sumatra, the deepest point

Table V-2-4. Dredge Sampling Stations Umitaka Maru, in the winter of 1963-1964. (R. Tsuchi)

Station	Date	Starting				Length of wire	Finishing time	Collected samples				Remarks
		time	lat.	long.	depth			sediments	mineral	life (remain)	life (living)	
I-17	1963 Nov. 13	1627	9°47.0′S	127°33.0′E	623m	900m	1657	light greenish brown *Globigerina*-Pteropod ooze		molluscan shells		Timor Sea
I-18	Nov. 26	0900	17°07.5′S	119°40.0′E	287m	450m	0925	reef fragment only				Mermaid Rf., off Western Australia
I-19	Nov. 26	0948	17°07.0′S	119°39.8′E	267m	450m	1015	light greenish brown organogenic calcarcous sand	fine grained angular quartz	molluscan shells		” ” ”
I-20	Nov. 26	1045	17°06.0′S	119°41.3′E	387m	500m	1100	—	—	—	—	” ” ”
I-21	Nov. 26	1518	17°03.6′S	119°44.6′E	425m	650m	1540	light greenish brown *Globigerina* ooze		molluscan shells		” ” ”
I-22	Nov. 27	1400	18°15.4′S	120°16.6′E	99m	150m	1408	—		molluscan shells	sponge, single corals	Off Broome, Western Australia
I-23	Nov. 27	1442	18°18.3′S	120°14.0′E	106m	170m	1449	light greenish brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	single corals, mollusca	” ” ”
I-24	Nov. 27	1655	18°22.8′S	120°12.3′E	104m	170m	1700	light greenish brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	single corals, mollusca	” ” ”
I-25	Nov. 27	1716	18°23.5′S	120°12.3′E	89m	150m	1723	light greenish brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	single corals, mollusca	” ” ”
I-26	Nov. 27	1742	18°24.3′S	120°12.4′E	88m	150m	1750	light greenish brown organogenic calcareous sand	fine grained angular quartz	molluscan shells bryozoans, single corals, echinoids	single corals	” ” ”
I-27	Dec. 21	1305	24°57.5′S	112°31.1′E	119m	200m	1320	brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	mollusca	Off Shark Bay, Western Australia
I-28	Dec. 21	1346	24°56.0′S	112°34.8′E	111m	200m	1402	brown organogenic calcareous sand	fine grained angular quartz	molluscan shells		” ” ” ”
I-29	Dec. 21	1425	24°54.8′S	112°37.0′E	104m	200m	1442	brown organogenic calcareous sand	fine grained angular quartz	molluscan shells		” ” ” ”
I-30	Dec. 21	1503	24°53.8′S	112°38.8′E	101m	200m	1518	brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	mollusca	” ” ” ”
I-31	Dec. 21	1543	24°52.2′S	112°40.6′E	97m	200m	1551	reddish brown organogenic calcareous coarse sand	fine grained angular quartz	bryozoans, molluscan shells		” ” ” ”
I-32	Dec. 21	1624	24°51.5′S	112°42.7′E	90m	200m	1635	brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	sponge abundant	” ” ” ”
I-33	Dec. 21	1659	24°50.0′S	112°44.6′E	87m	190m	1708	brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	sponge abundant	” ” ” ”
I-34	Dec. 21	1730	24°48.3′S	112°47.6′E	79m	190m	1740	reddish brown organogenic calcareous fine sand	fine grained angular quartz	molluscan shells	mollusca, sponge abundant	” ” ” ”
I-35	Dec. 21	1803	24°47.7′S	112°49.0′E	79m	190m	1810	reddish brown organogenic calcareous coarse sand	fine grained angular quartz	molluscan shells		” ” ” ”
I-36	Dec. 22	1722	22°54.9′S	112°47.8′E	1084m	1800m	1835	brown *Globigerina* ooze		molluscan shells		” ” ” ”
I-37	Dec. 23	1358	24°36.8′S	111°56.1′E	762m	1200m	1500	light brown *Globigerina* ooze		molluscan shells		” ” ” ”
I-38	Dec. 25	1245	28°43.4′S	113°18.4′E	1104m	1500m	1346	light brown *Globigerina*-Pteropod ooze		molluscan shells		Off Abrolhos Is., Western Australia
I-39	Dec. 25	1620	28°44.4′S	113°34.8′E	248m	400m	1628	greenish brown organogenic calcareous fine sand	fine grained angular quartz	molluscan shells		” ” ” ”
I-40	Dec. 25	1643	28°44.1′S	113°35.4′E	169m	260m	1651	brown organogenic calcareous sand	fine grained angular quartz	molluscan shells	mollusca	” ” ” ”

Table V-2-5. Piston Core Sampling Station Kagoshima Maru, in the winter of 1963-1964. (S. Hayasaka)

Station	Date	Starting				Bottoming						Finishing				Collected core			Remarks
		time	lat.	long.	depth	time	lat.	long.	depth	length of wire	dip	time	lat.	long.	depth	main	sub	materials	
Ka- 3	1963 Nov. 28	1425	2°02.5′N	86°01.7′E	4344m	1510	2°02.4′N	86°02.4′E	4347m	4480m	14°	1714	2°02.8′N	76°13.7′E	4347m	—	15cm	grayish brown mud containing foraminifera	
Ka- 6	Dec. 1	1429	1°05.8′S	86°02.2′E	4640m	1538	1°06.9′S	86°02.5′E	4643m	4950m	15°	1725	1°07.4′S	86°03.2′E	4643m	10cm	—	light brown mud partly limonitized	
Ka- 9	Dec. 4	1713	4°57.0′S	85°56.1′E	4847m	1810	4°56.1′S	85°55.3′E	4882m	5270m	23°	2035	4°56.2′S	85°52.3′E	4837m	—	—	—	
Ka- 9′	Dec. 5	1139	5°14.3′S	83°30.0′E	4945m	1252	5°27.9′S	83°37.7′E	4938m	5240m	—	1515	5°30.2′S	83°39.5′E	4970m	260.5	little	gray mud	
Ka-18	Dec. 15	1521	3°29.7′N	77°50.4′E	3367m	1602	3°29.7′N	77°49.6′E	3454m	3685m	2.5°	1720	3°27.8′S	77°50.8′E	3453m	205.5	—	light grayish brown mud, *Globigerina* ooze	shallowest point
Ka-15	Dec. 12	1648	0°02.8′N	78°02.4′E	4700m	1744	0°00.5′N	78°08.8′E	4843m	4998m	10°	1947	0°00.4′S	78°07.0′E	4739m	319cm	—	greenish gray mud containing foraminifera	
Ka-12	Dec. 9	1436	3°21.0′S	78°05.0′E	4868m	1600	3°19.6′S	78°06.5′E	4890m	5034m	6°	1830	3°20.5′S	78°07.0′E	4883m	249cm	12cm	reddish brown clay, almost no foraminifera	
Ka-21	Dec. 28	1525	8°04.1′S	77°47.1′E	5373m	1721	7°58.2′S	77°46.8′E	5389m	5641m	7°	1938	7°57.3′S	77°45.3′E	5394m	336.5	—	reddish brown clay, no foraminiferal test	
Ka-24	Dec. 31	1343	12°31.6′S	77°56.5′E	5442m	1456	12°31.9′S	77°55.3′E	5433m	5747m	10°	1816	12°33.1′S	77°56.0′E	5455m	341cm	—	reddish brown clay, no foraminiferal test	deepest point
Ka-27	1964 Jan. 4	1533	16°52.0′S	77°50.6′E	4795m	1623	16°52.0′S	77°50.4′E	4771m	5107m	4°	1938	16°54.5′S	77°52.3′E	4812m	little	—	reddish brown clay, almost no foraminifera	
Ka-30	Jan. 7	1525	21°33.5′S	77°54.8′E	4474m	1621	21°30.9′S	77°55.0′E	4587m	4871m	8°	1833	21°30.3′S	77°58.4′E	4568m	303cm	little	chocolate clay, no foraminiferal test	

Table V-2-6. Dredge Sampling Stations Kagoshima Maru, in the winter of 1963-1964. (S. Hayasaka)

Station	Date	Starting				Finishing				Length of wire
		time	lat.	long.	depth	time	lat.	long.	depth	
1	1963 Dec. 8	0705	7°37.8′N	77°36.3′E	71m	0725	7°32.2′N	77°33.6′E	75m	120m
2	Dec. 8	0755	7°37.2′N	77°32.4′E	77m	0810	7°36.8′N	77°30.9′E	77m	175m
3	Dec. 8	0935	7°41.8′N	77°19.3′E	75m	Dredge was lost.				170m

V-3. Meteorology

V-3-1. Meteorological Observations of the I. I. O. E.

Yasuaki TURUOKA and Tugio MATUMOTO

(1) *Introduction*

Meteorological observations of the IIOE were carried out both for the disciplines of surface and aerological meteorology. In case of surface observations, on board of each vessel, the routine observations were carried out 4 times a day, namely, 00, 06, 12 and 18 G. M. T. Such obtained data were sent to the coastal radio staions along the coast of the Indian Ocean immediately after the observations, and aerological observations on board of the Koyo-maru were carried out usually once a day, 12 G. M. T., as far as possible.

(2) *Diurnal variation of pressure and sea surface temperature*

(a) *Pressure*

As to the diurnal variation of pressure of the Indian Ocean, maximum appears 2 times a day, 09 and 21 hours Local Time, and also minimum appears two times a day, 15 and 03 hours Local Times.

Its diurnal range amounts 4.0 mb in the equatorial zone (0°N, 94°E). As the ship moves towards higher latitudes, its range decreases. In the southern waters (20°S, 94°E), it reaches to about 2.0 mb.

(b) *Sea surface Temperatures*

Surface temperatures in two years show the following features. In the tropical area, they scarcely reach 30°C usually having a maximum of daily temperature at 14 hour Local Time. And after 2-3 hours its temperature decreases almost stationary.

Daily range of temperature is rather small and its value is about 3°C in tropical area (4°N, 94°E), but in the I. T. C. and in squall area daily range is so small and low temperatures than neighbouring waters usually predominate.

(3) *Clouds*

On the whole, the total amount of cloud were 9-10, almost in every case between 5°N to 10°S. Especially in the tropical zone, in the upper atmosphere, high humidity is conserved. For that reason, development of clouds from low to high levels are seen.

Because of convective instability condition which prevails up to high altitude, development of nimbocumulus are seen.

Along the 10°S latitude and also in the southern area cloud amount decreases and in the southern hemisphere, in the subtropical anticyclone off western Australia, there is an indication of surpass in cumulus and stratocumulus.

(4) *Precipitation*

The total amount of rainfall of 114 mm concentrates within a belt of 10 N to 10°S sea area, from November 1962 to January 1963, but on the same periods of the next year total amount indicated 90 mm between 3°N to 4°S.

Total amount of precipitation in 1962 exceeded that of 1963. Its rainfall were almost dropping from nimbocumulus and large part of it occur in the I. T. C. As a result, activity of I. T. C. in 1962 exceeded a little than that of 1963.

(5) *Distribution of surface wind*

According to the analysis of observations for the data of 1962, in the 5°N and northern waters in late November, monsoon season started because of the outbreak of the Siberian Anticyclone. Wind direction indicates NE or E and its speed amounts 4-10 knots.

In the area from 4°N to 2°N, there exists equatorial calm or weak wind-speed zone having instable wind directions.

In the area from 1°N to the Equator in early December, there is a zone called Intertropical Convergence Zone (I. T. C.), where excellent westerlies prevail, having a speed of 20 knots or more.

In the southern zone beyond the equator, there are also westerlies of 10-20 knots.

Specially in the areas of 0°45′S, 1°30′S and 3°00′S there obseved gusts with maximum instanteneous wind speed of 40 knots or more, along with passing of squalls.

In the southern side, namely, in the area between 8°S to 9°S, in the middle of December, there exist wind shift line both in northern and southern boundaries.

Further to the south, beyond 20°S, wind speeds usually amount to 20 knots or more. Accordingly, heights of swell became 2-3 meters or over.

According to our observations in 1963, on the northward more than 5°N in late November, monsoon blew with NE or E-ly.

But their winds were weak as compared with those of 1962. In the area from 5°N to 2°S, in late November and early December, ITC was formed and the wind direction was unstable and the wind speed was weak. Gusts were observed frequently in ITC or around their southern limit, but there were no observations of gusts in 1963 because the activity of ITC was weakened in that year.

In the area from 2°S to 10°S, in middle December, there observed SE-ly trade wind, but its velocity was weak.

Beyond 10°S, in late December, in the southern hemisphere there is a belt of subtropical anticyclones. Predominant wind direction was SE and the velocity was 15-30 knots.

(6) *Aerological Observations*

Aerological observations (Radio-sonde and pilot-balloon) along the 94°E or 100°E line in two years were carried out. Observation lines and stations are shown in Figs. V-3-1 and V-3-2, respectively.

Inflating and launching of balloon were done at upper deck on ship. Observations in rainy day were most difficult. Isopleth of these observations are shown in Figs. V-3-3 and V-3-4, respectively.

Tropopause heights near the Equator were almost 16,000-17,000 meters and its temperatures were almost −85°C. Especially in the upper air of I. T. C. there was a tendency that tropopause becomes higher and its tempera-

Fig. V-3-1 Aerological observation line and staions from Nov., 1962 to Jan., 1963.

○ Radiosonde and Pilot △ Radiosonde only

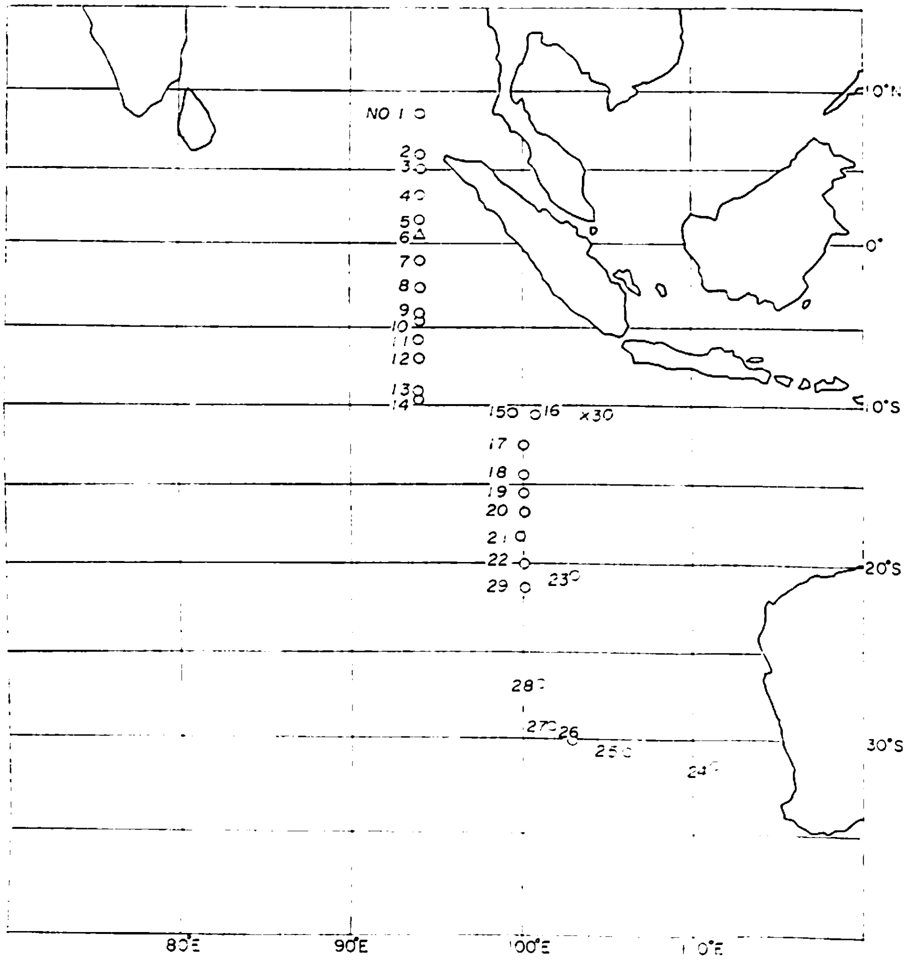


Fig. V-3-2. Aerological observation line and stations from Nov., 1963 to Jan., 1964.

○ Radiosonde and Pilot △ Radiosonde only × Pilot only

tures are lower compared with the neighbouring areas. Adjacent to Equator and I. T. C., high humid air is kept to upper altitudes and there exists convective instability up to 14,000 meters according to the analysis of adiabatic charts. According to vertical distribution of humidity, there were high humid layer to upper air. In accordance with rainfall area in the waters between 1°N-Equator, and 6°S-8°S in 1962 ; and 2°N-1°N in 1963. These facts may show up the locations of the I. T. C.

In the belt of 13°S-15°S and more southward waters, there were subtropical anticyclones accompanying subsidence and divergence on a large scale.

In consquence, there appeared isothermal layer or inversion layer in 1,000 to 2,000 meters in height. Along the 20°S and more southward, there exists a clear inversion of 5°-8°C. In the lower parts of inversion layer, there were

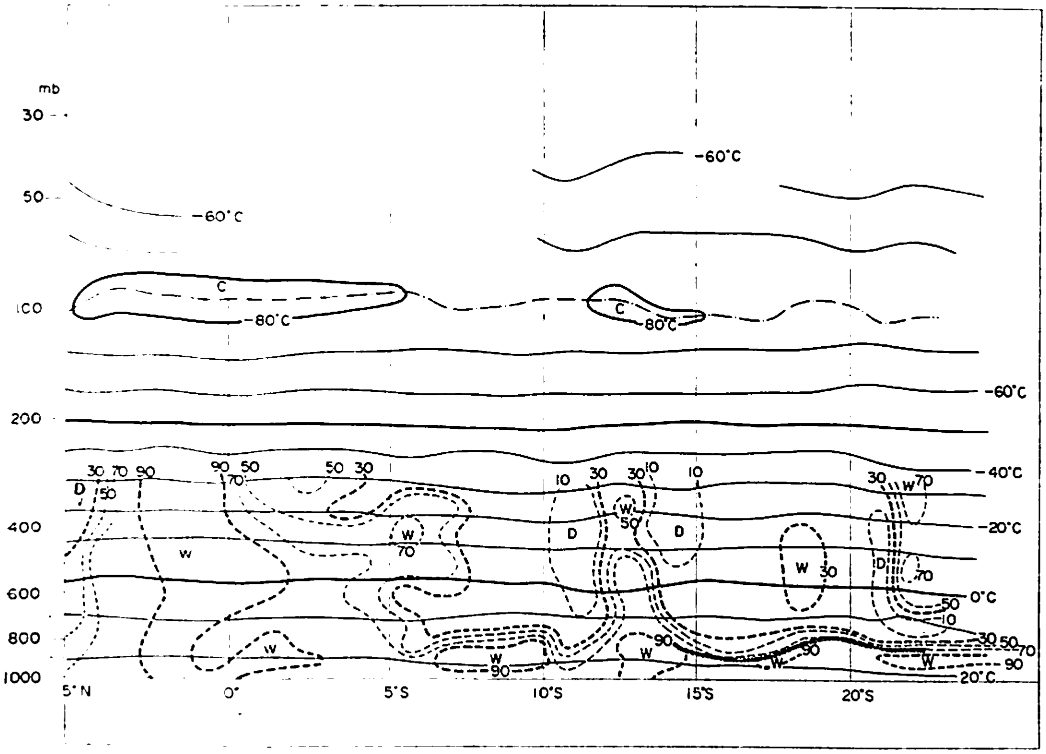


Fig. V-3-3. Vertical cross section from 5°N to 20°S along 94°E in 1962.

Solid line ———: Temperature in °C   Parallel line ▨: Inversion layer

Broken line - - - - -: Humidity in %   Dotted line —·—·: Tropopause

C: Cold   W: Wet   D: Dry

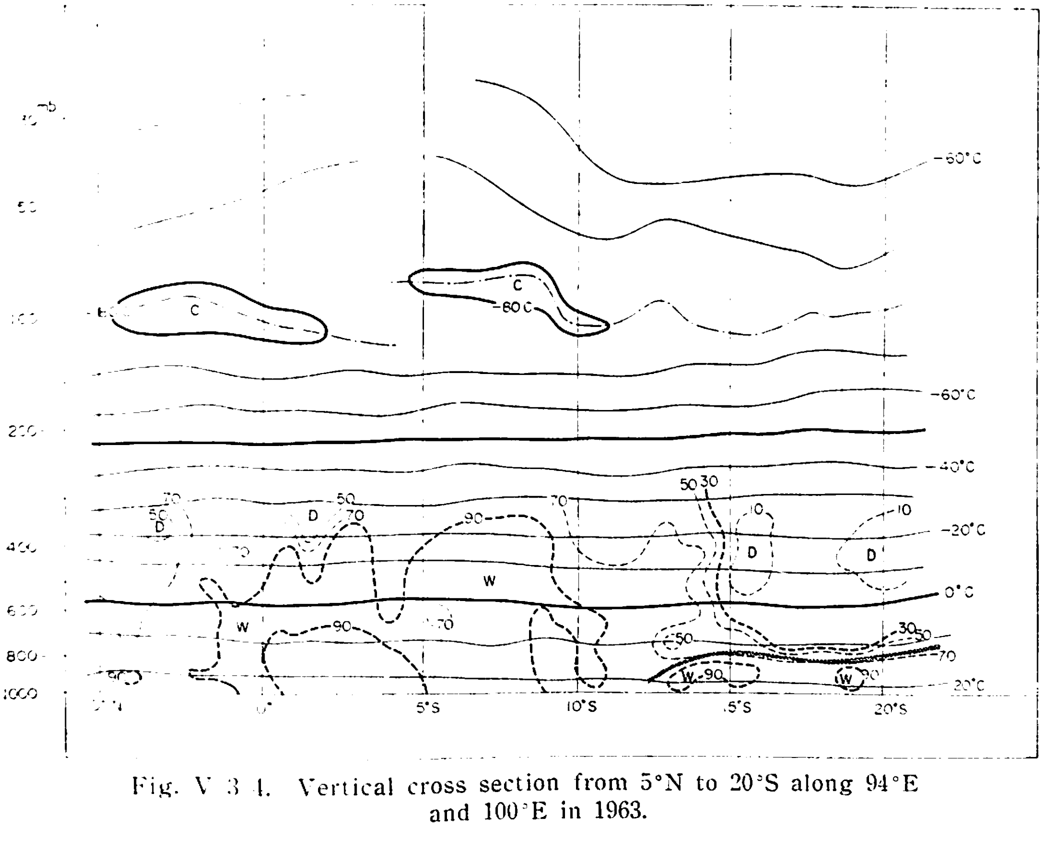


Fig. V-3-4. Vertical cross section from 5°N to 20°S along 94°E and 100°E in 1963.

south-east winds and a prevalence of high humidity and existed an absolute instability as a result of super-adiabatic change.

On the other hand, in the upper parts of them, wind became north-east and we encountered both high temperature and dry air for decrease of 10-20 percent at 3,000-4,000 meter heights.

In the lower parts of inversion layer, there exist stratocumulus and cumulus.

(7) *Intertropical Convergence Zone* (*I. T. C.*)

Migrating positions of I. T. C. based on the analysis of synoptic weather charts and observational results were shown in Fig. V-3-5.

According to this analysis the I. T. C. existed northern side of Equator in early December, but in accordance with the change of seasonal phenomenon by the elevation angle of sun, its position shifted towards the direction of southern hemisphere crossing the Equator after the middle of December. The positions of I. T. C. in the southern hemisphere were more clearly distinguished in 1962 than those in 1963.

Some features of I. T. C. are as follows:—

a) There were wind shift line, but sometimes wind direction changed

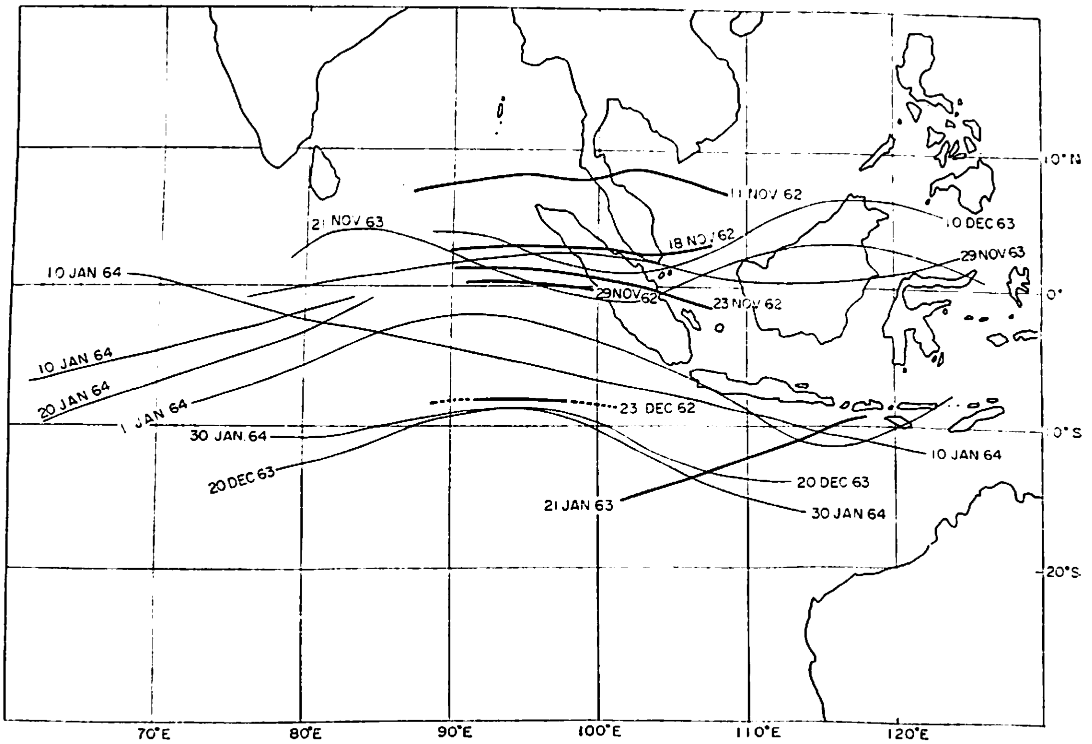


Fig. V-3-5. Movement of ITC Positions.

——— Nov. 1962～Jan. 1963 ——— Nov. 1963～Jan. 1964 not sharply both in northern and southern limits.

b) Owing to the convective instability in the upper air, in the I. T. C., development of nimbocumulus and heavy squall or thunderstorm were observed.

c) Within the area of I. T. C., squall were observed in every place. Sequence of each squall is characterised by sudden commencement, rapid development and the succeeding disappearance.

d) Stage of squall were limited to small scale. Sometimes whole sky was covered for a long time. In a large scale squall, rainfall continued for all day.

e) Temperature falls rapidly with the commencement of squall and lower temperatures prevail over the neighbourhood waters.

(8) *Comparison of meterological observation results of 1962 and 1963*

Observation results taken on board of the Koyo-maru in these two years are tabulated. Since the expedition areas of these two years are not identical, this table does not show up literal comparison of 1962 and 1963, but it could be possible to learn general tendency from the comparison of these two years.

Table. V-3-1. Meteorological observation results.

Observation periods Elements	1962	1963
Number of observations	54	57
Number of clear days	0	3
Number of partly cloudy days	25	26
Number of cloudy days	29	28
Number of rainy days	32	25
Total amount of precipitation (mm)	189. 0	148. 7
Total amount of precipitation per day (mm)	3. 5	2. 6

In consequence, in 1963 fine weather days exceed those of 1962, but, on the contrary, cloudy and rainy days exceed 1962 than 1963.

Acknowledgments

The authors would like to express their gratitude to Dr. H. Futi, Marine Division, Japan Meteorological Agency, and to Dr. M. HANZAWA, the same agency, for their consistent interest and guidance in making this report. We would like to acknowledge the aid of officers and crew members of the Koyo-maru, Japanese IIOE participating ship.

V-3-2. Air-sea interaction

Tadao TAKAHASHI

Wind speed, temperature, and humidity are measured at six levels within the layer to 10 m height above the sea surface during the serial observations of physical oceanography at 28 Kagoshima-maru stations (Fig. V-3-6), when the port side is kept on the windward side. Instruments at the upper three are mounted on the oblique side of an triangular mast setted specially on the port side ; and at the lower three levels they are mounted on the arms stretching from the mast on a bouy floating ca 60 m windward apart from the port side, keeping its upper surface as nearly same level as the sea suaface. For wind speed measurement, cup anemometers of Robinson type are used ; and for temperature and humidity, sets of dry and wet bulb of resistance thermometers are used. All recorders are fixed in the laboratory of the vessel. Observed data are in analysis and the results will be discussed afterward.

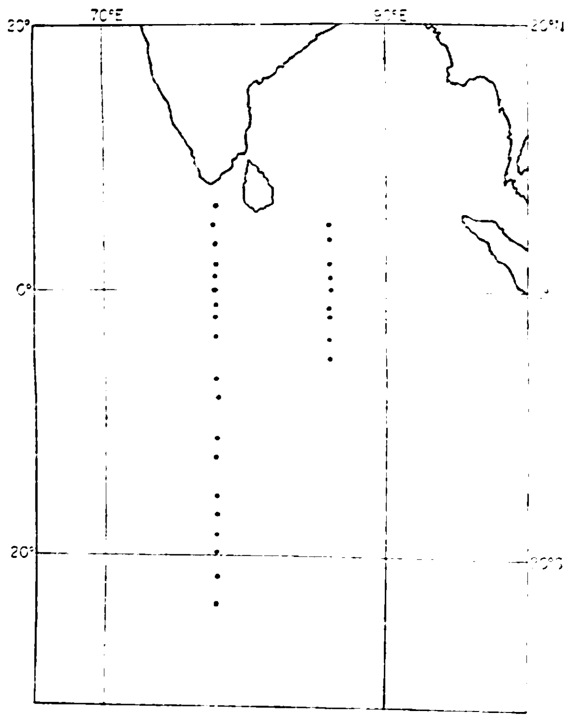


Fig. V-3-6. Map showing the observing points

V-4. Physical oceanography

The Working Group for Physical Oceanography

The following is the outline of the results of I. I. O. E. by four boats, Umitaka Maru (M. ISHINO, Y. SAITO, T. SHIMANO, K. NASU etc.), Koyo Maru (T. SATO etc.), Kagoshima Maru (M. CHAEN & others), and Oshoro Maru (F. FUJII, K. OTANI etc.)

1. *Horizontal Distribution* (M. UDA)

Distribution maps of water temperature, salinity and dissolved oxygen etc. at the levels of 0, 50, 100, and 200 m. depths basing on the observed data by Umitaka Maru., Koyo Maru, Kagoshima Maru and Oshoro Maru in the winters of 1962/63 and 1963/64 were prepared respectively in which the characteristic features were investigated. Data obtained by U. S. surveying boat *Antoon Bruun* was also utilized in the above maps.

(i) Horizontal distribution of water temperature

a) Surface water temperature

1962/63 Water temperature in the region north to 15°S is above 27°C and falls down from 27°C to 21°C in the zone from 15°S to 30°S. In the region of 5°N-10°S it shows higher temperature than 28°-29°C, and warmest near equator (0°-2°N). (Fig. V-4-1)

1963/64 Water temperature in the area north to 18°S is 29.0-29.5°C, wherein it shows a zone of higher water temperature than 28°C. In the zone of 20°S-33°S water temperature falls down suddenly from 26°C to 20°C and in the area south to 20°S it shows the value lower than 25°C. (Fig. V-4-2)

b) Water temperature at the depth of 50 m. depth

1962/63 Coming to the area south to 20°S water temperature becomes suddenly low. A zone warmer than 27°C lies in the zone of 10°N-15°S. We can recognize a northward flow off the west coast of Australia i. e. the West Australian Current. (Fig. V-4-3)

1963/64 Water temperature indicates almost 27°C-28°C around the equatorial zone of 10°N-15°S. We find an upwelled cold water area within 300 sea-miles south off Java Island (20°-25°C).

In contrast to cooler water northwest to Sumatra and near to Andaman-Nicobar Islands (25°-26°C), the warmest temperature zone appears near at 13°S higher than 28°C). (Fig. V-4-4)

c) Water temperature at the level of 100 m. depth

1962/63 A warmer zone higher than 28°C west off Sumatra is presumably

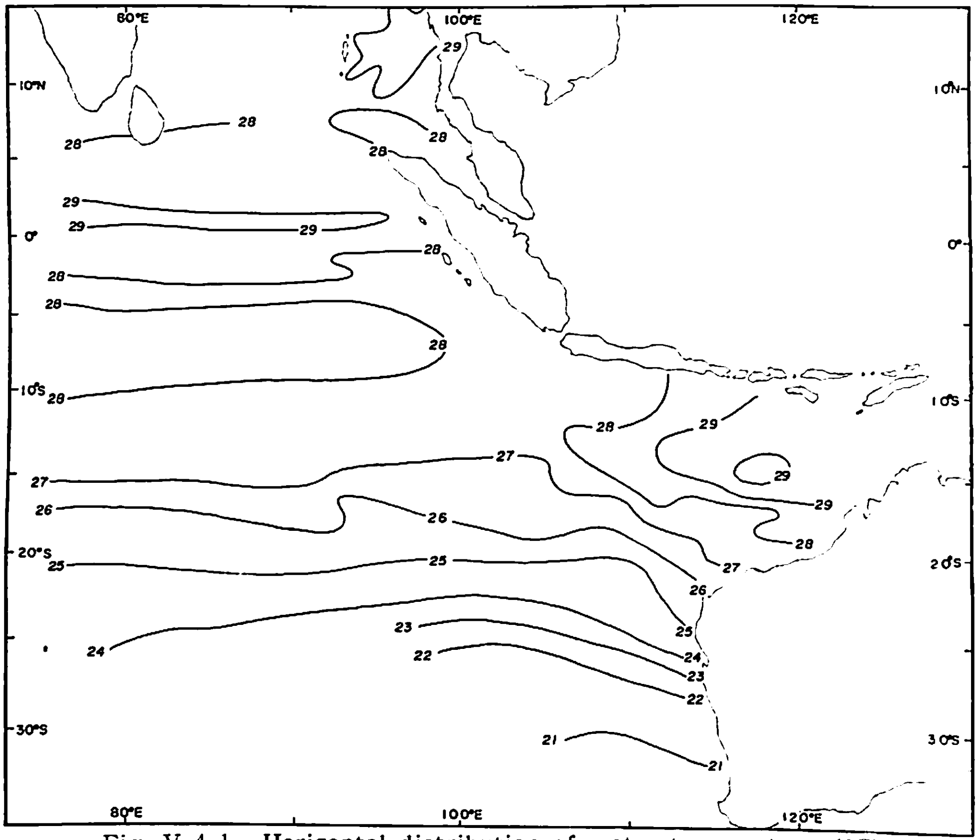


Fig. V-4-1. Horizontal distribution of water temperature (°C) at the surface in the winter of 1962/63.

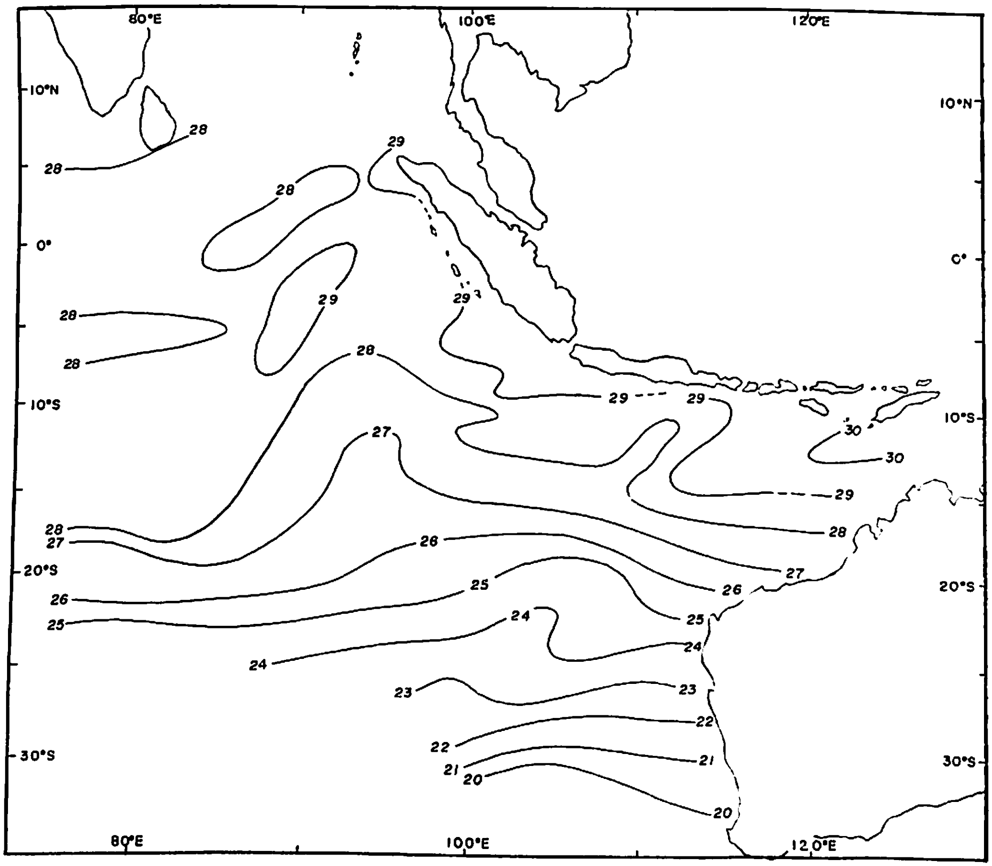


Fig. V-4-2. Horizontal distribution of water temperature (C°) at the surface in the winter of 1963/'64.

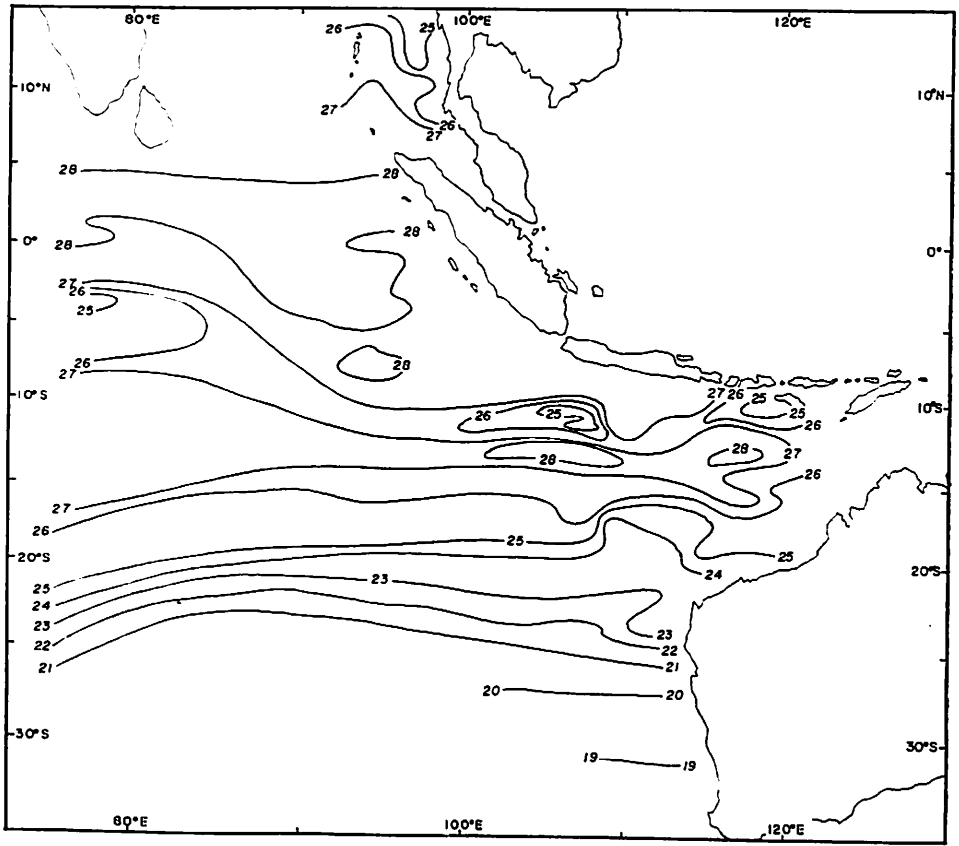


Fig. V-4-3. Horizontal distribution of water temperature (°C) at the depth of 50 m in the winter of 1962/'63.

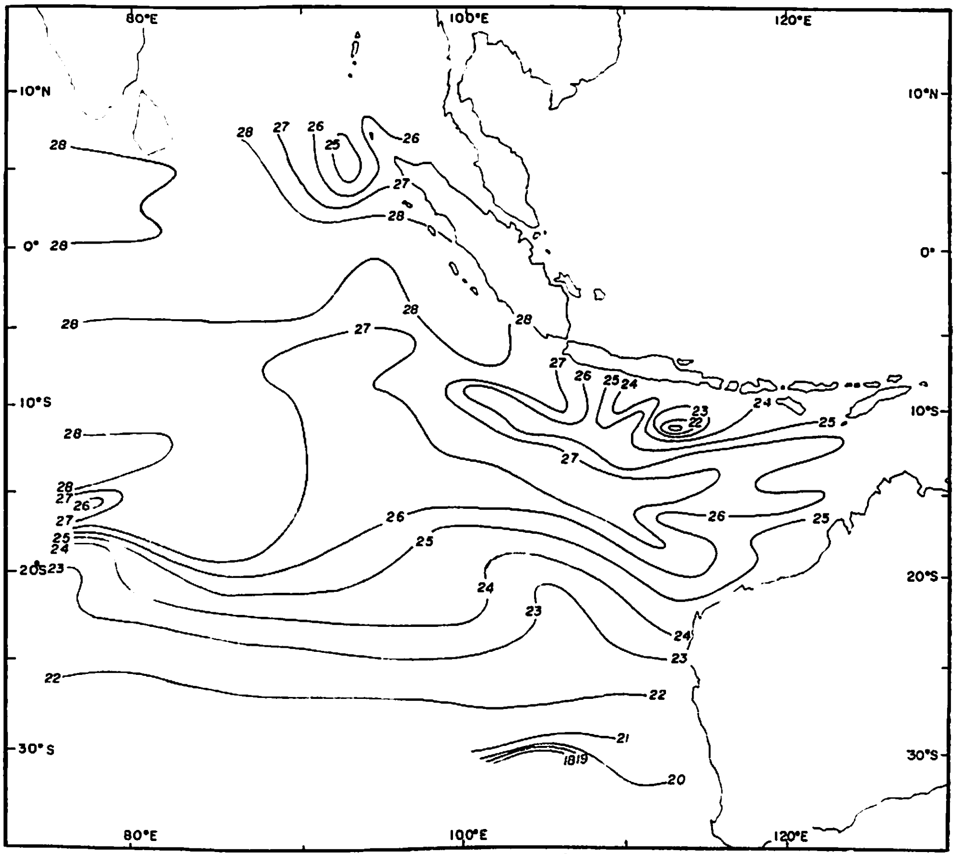


Fig. V-4-4. Horizontel distribution of water temperature (°C) at the depth of 50 m in the winter of 1963/'64.

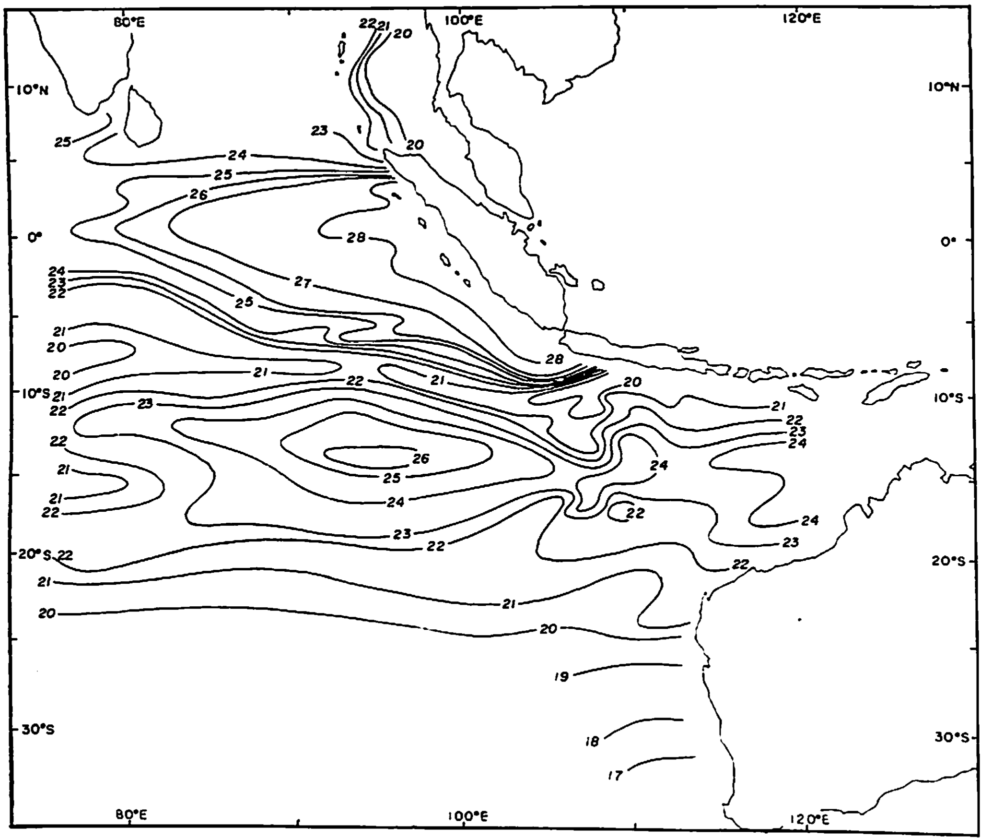


Fig. V-4-5. Horizontal distribution of water temperature at the depth of 100 m in the winter of 1962/'63.

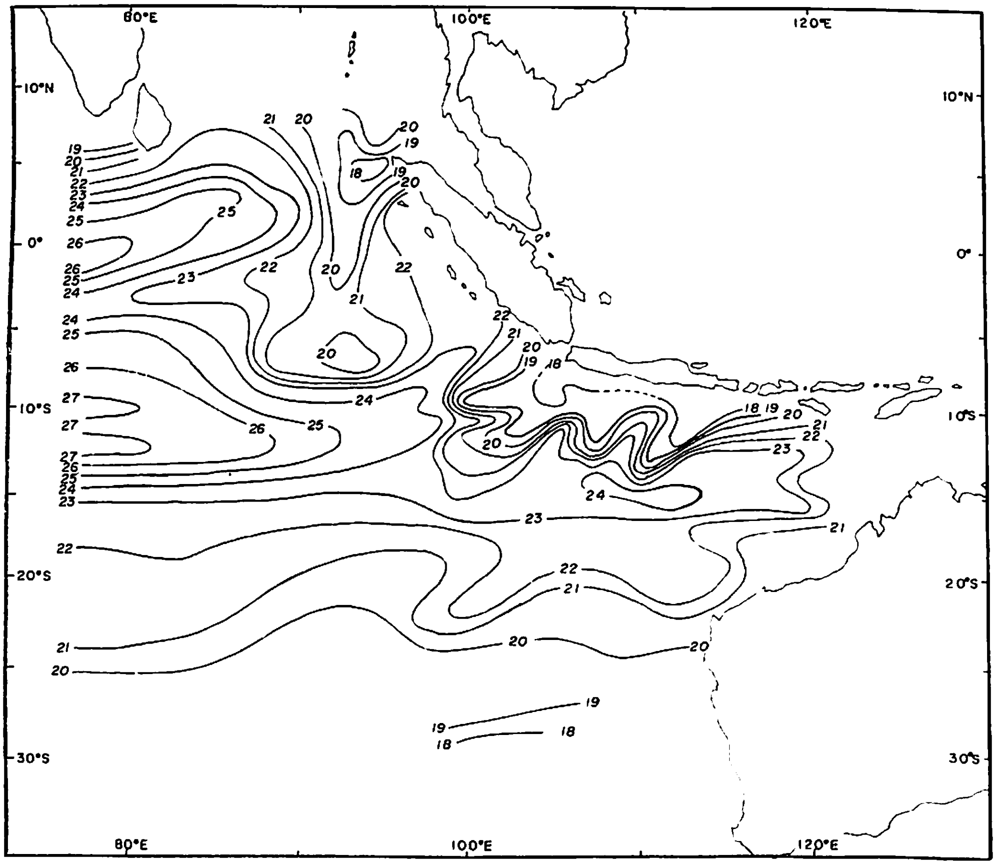


Fig. V-4-6. Horizontal distribution of water temperature (°C) at the depth of 100 m in the winter of 1963/'64.

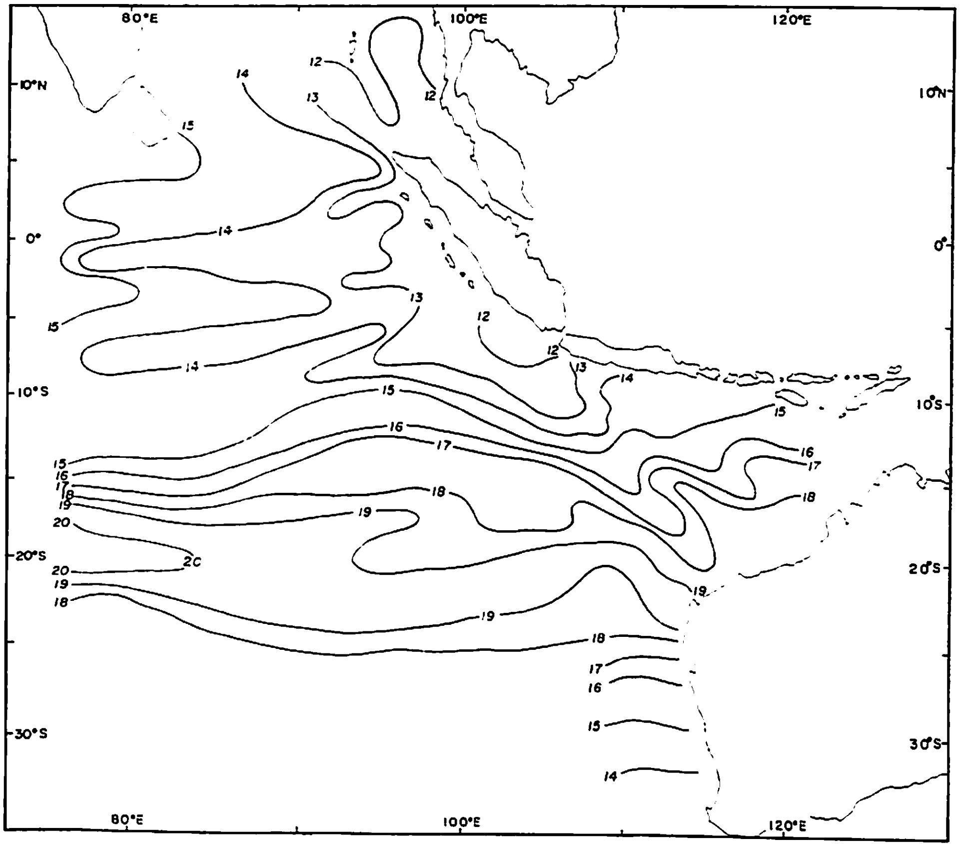


Fig. V-4-7. Horizontal distribution of water temperature (°C) at the depth of 200 m in the winter of 1962/'63.

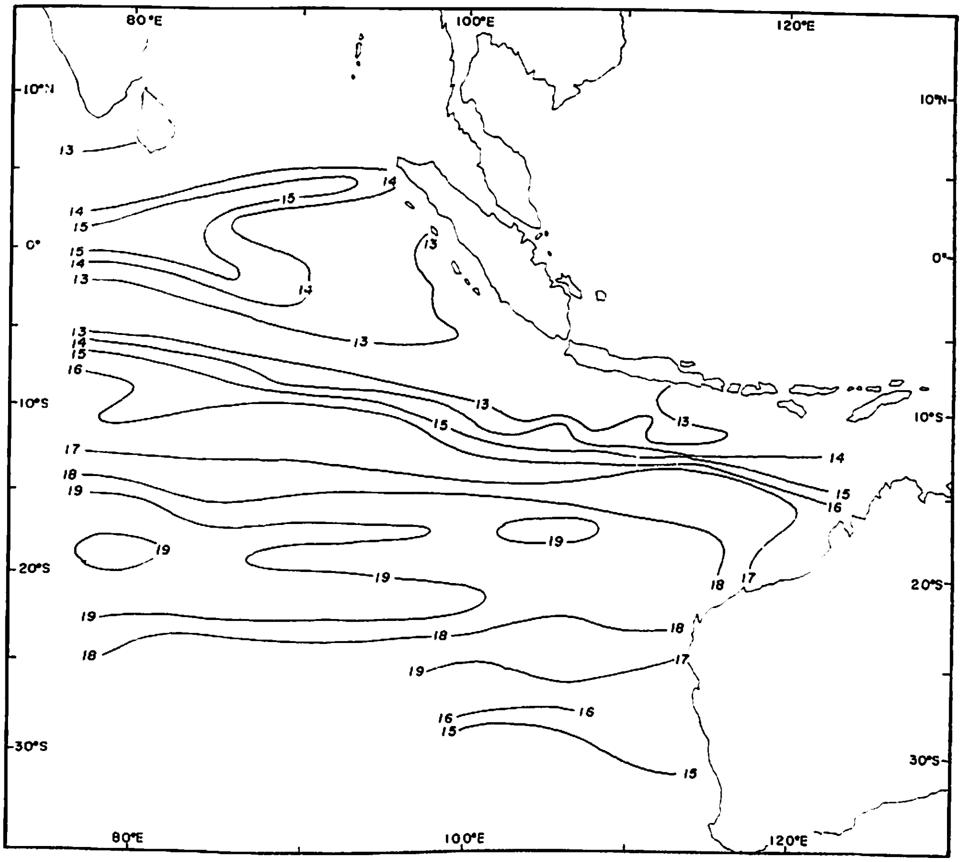


Fig. V-4-8. Horizontal distribution of water temperature (°C) at the depth of 200 m in the winter of 1963/'64.

sinking zone. Since the region around 15°S (10°-20°S) is comparatively warmer above 24°C, a narrow stretched belt of cold water from and west between 10°-16°S intercepted by the above two warmer water zone.

Especially it is remarkable that the existence of presumably upwelled cold water below 20°C south off Java Island is found. Also cold water north to Sumatra near Andaman Island is noticed. Further, an intruding cold water from south to north along the meridional line of 110°E longitude off the west coast of Australia is noted. (Fig. V-4-5)

1963/64 A cold water below 20°C exists south off Java and such upwelled cold region locates northerly compared to the previous year, showing temperature less than 18°C. Southward intrusion of cold water from the region north to Sumatra is shown. Between 3°-5°S wee see a cold water belt intercepted by two warm waters lying at 2°N-2°S and 5°-10°S. (Fig. V-4-6)

d) Water temperature at the level of 200 m. depth

1962/63 A cold belt of water temperature less than 13°C in the Andaman Sea, a cold belt of temperature of 13°-14°C along Sunda Islands, and the highest water temperature zone south to India or Ceylon around 5°S are seen.

In the zone of 0°-13°S a cold belt lies. A warm belt of temperature higher than 15°C is seen around the latitudal axis of 25°S. (Fig. V-4-7)

1963/64 A warm water belt higher than 15°C exists near at equator south to Ceylon and another warm belt of temperature higher than 15°C is found in the zone of 7°-30°S of which the maximum temperature zone (higher than 19°C) lies between 15°-25°S. Intermediate between the two above warm water belts a cold water belt lower than 13°C appears in the zone of 5°-10°S. As we approach nearer to Sumatra and Java Islands we can see a conspicuous cold water due to the effect of upwelling. (Fig. V-4-8)

(ii) Horizontal distribution of salinity

a) Surface salinity

1962/63 A saline water having salinity higher than 35‰ around equator intrudes from west to east and indicates its maximum salinity of about 35.4‰. Between the above saline water mass and another saline water mass having salinity higher than 35‰ in the area south to about 17°S we can see a belt of relatively fresh water having salinity below 34.0‰ which intrudes from east to west around the latitudal axis of about 10°S.

Waters adjacent to Sunda Islands and in Gulf of Bengal indicate a remarkable low salinity below 34.0‰ within the region of 100 sea-miles from the coasts, corresponding to the influence of asiatic coastal waters. (Fig. V-4-9).

1963/64 Water of low salinity extended strongly westward off Sumatra is probably due to the driving effect of monsoon. The distribution pattern in this winter period of 1963/64 differs greatly from that of the previous year. We see a highly saline water of 35.0-35.3‰ in the zone of 0°-5°S to the south of Ceylon and India and also another saline water of salinity higher than 35.0‰ in the region south to the latitude of 20°S, showing it's maximum salinity 36.0‰ in the zone of 30°-35°S. Line of demarkation indicating rapid change of salinity appears in the zone of 5°-10°S. (Fig. V-4-10)

b) Salinity at the level of 50 m. depth

1962/63 We can recognize a highly saline water in the equatorial zone (5°N-5°S) of salinity higher than 35.2‰ which corresponds to the water flowing eastward in Equatorial Counter Current having its origin in the Western Indian Ocean or the Arabian Sea.

A water belt of lowest salinity along 10°S-12°S extends from east to west which is considered to be transported by South Equatorial Current. West Australian Current flowing northward and having saline water of salinity higher than 35‰ forms (bluefin and albacore) tuna fishing grounds near its boundary zone. (Fig. V-4-11)

1963/64 Again we see salinity maximum of 35.4‰ near along 3°N. and another southern salinity maximum of 35.5-35.9‰ (South Indian Ocean Central Water) to the south of 23°S. Between those northern and southern saline waters we see a relatively low salinity water of less than 34.5‰. Particularly different from that of the previous year in this period a low salinity water extends westward off Sumatra. It is considered that in general the whole current system in this period compared to the previous year shifted to north. The abnormal climatic and oceanic conditions in the winter of 1963 might be occurred in global scale. (Fig. V-4-12)

c) Salinity at the level of 100 m. depth

1962/63 In the Gulf of Bengal west to Andaman, Nicobar Islands and Malay Peninsula generally it shows low salinity water. Between the maximum salinity zones locating at 5°N-7°S (Salinity higher than 35.2‰) and at 25°S-33°S (higher than 35.8‰) we find the minimum salinity zone lying in 10°-13°S which continues to the region south to Sunda Strait and Java Island.

In the central upwelling area of 105°E-115°E, north to 15°S a great clockwise whirl of cold and relatively low salinity water is formed which indicates the different oceanographic structure to the eastern zonal one. (Fig. V-4-13)

1963/64 Two maximum salinity zones exist near at equator (water having salinity higher than 35.2‰ and flowing from west to east) and water at 22°S-30°S (saline South Indian Ocean Central Water of salinity 35.5-35.8‰). Between them a water zone of low salinity having 34.2-34.6‰ extends from west to east around the latitude of 10°S, presumably due to upwelling of Antarctic Intermediate Water. (Fig. V-4-14)

d) Salinity at the level of 200 m. depth

1962/63 Between the saline South Indian Ocean Central Water (having salinity higher than 35.8‰ in the zone of 22°S-30°S) and the saline water mass of North Indian Ocean near equator having salinity of about 35.1‰, a

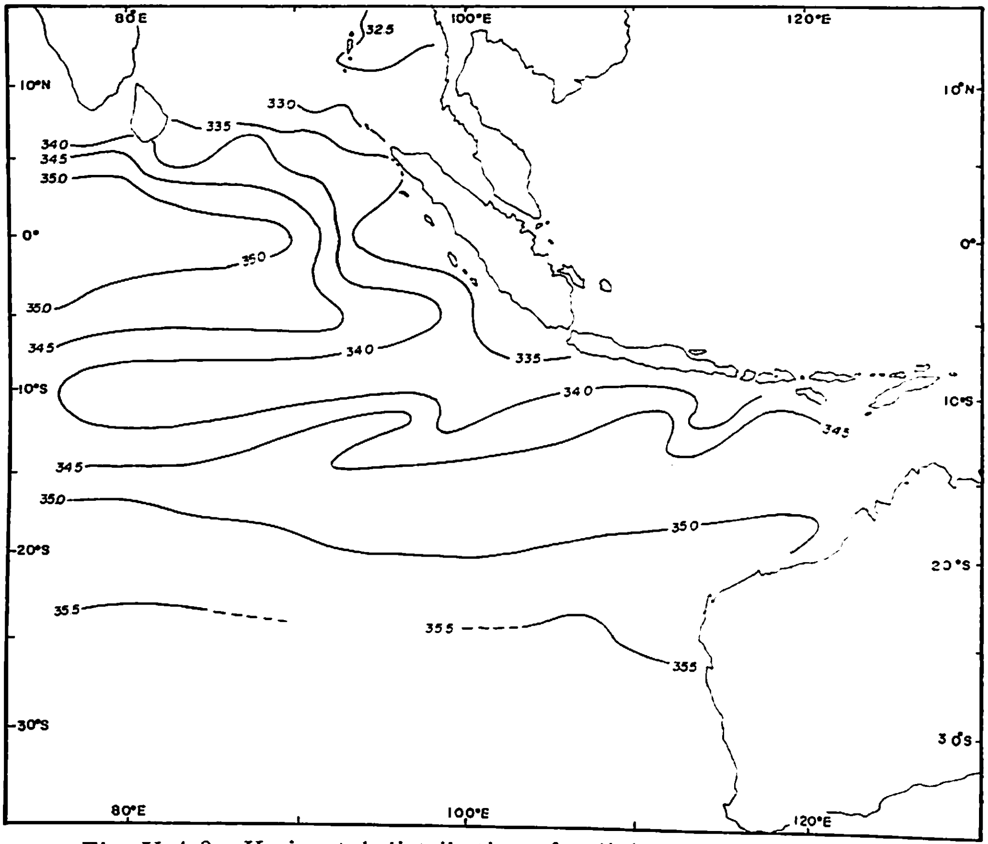


Fig. V-4-9. Horizontal distribution of salinity (‰) at the surface in the winter of 1962/'63.

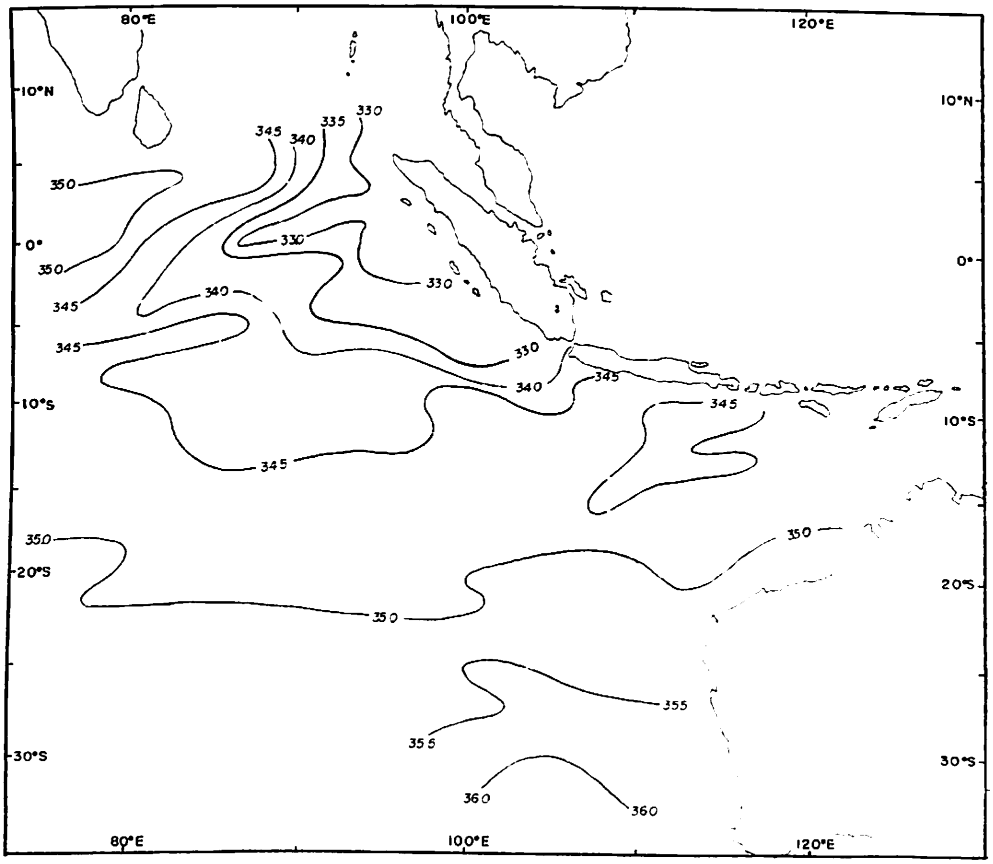


Fig. V-4-10. Horizontal distribution of salinity (‰) at the surface in the winter of 1963/'64.

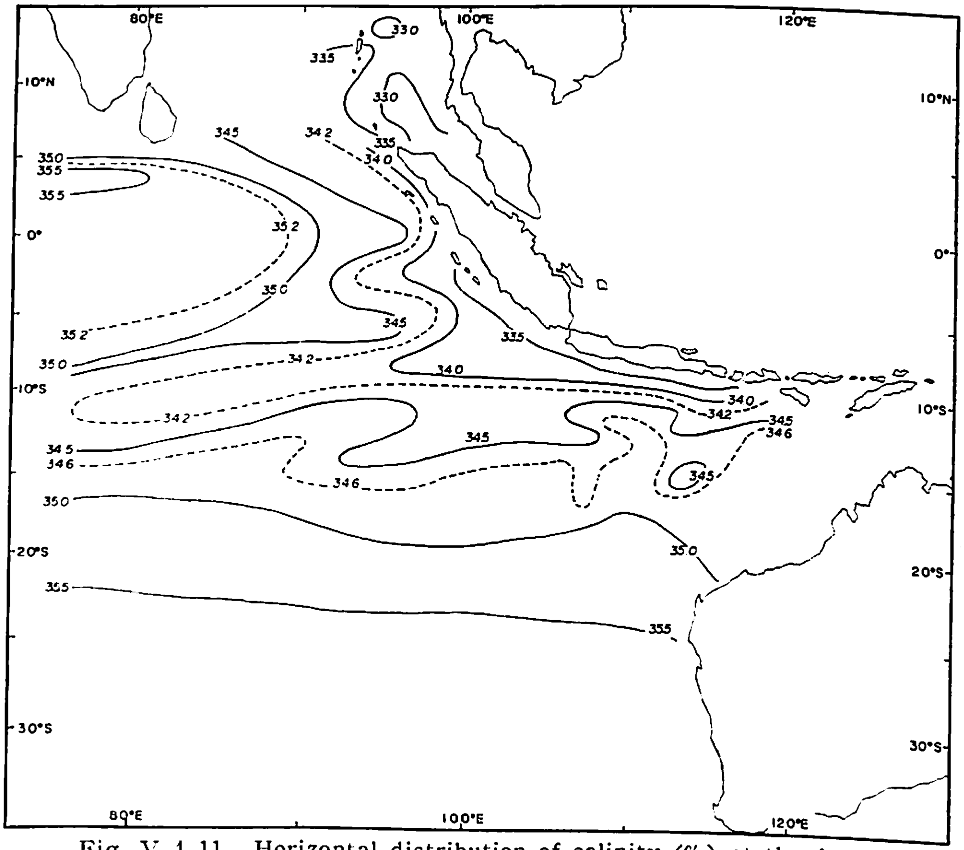


Fig. V-4-11. Horizontal distribution of salinity (‰) at the depth of 50 m in the winter of 1962/'63.

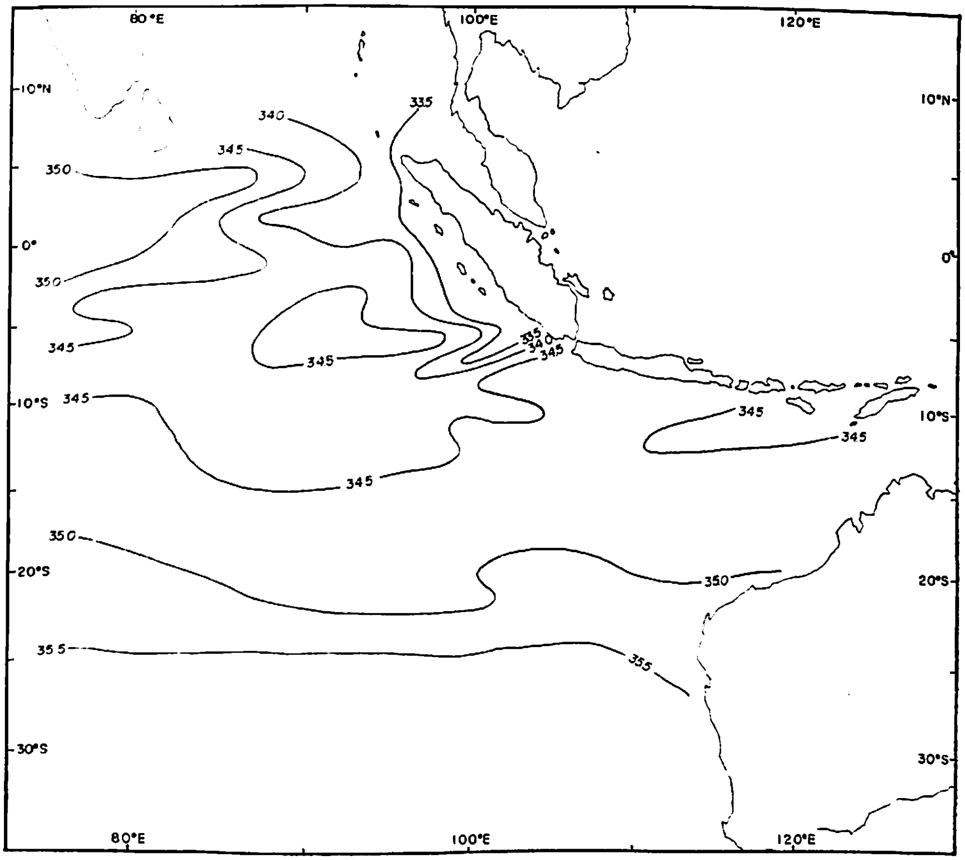


Fig. V-4-12. Horizontal distribution of salinity (‰) at the depth of 50 m in the winter of 1963/'64.

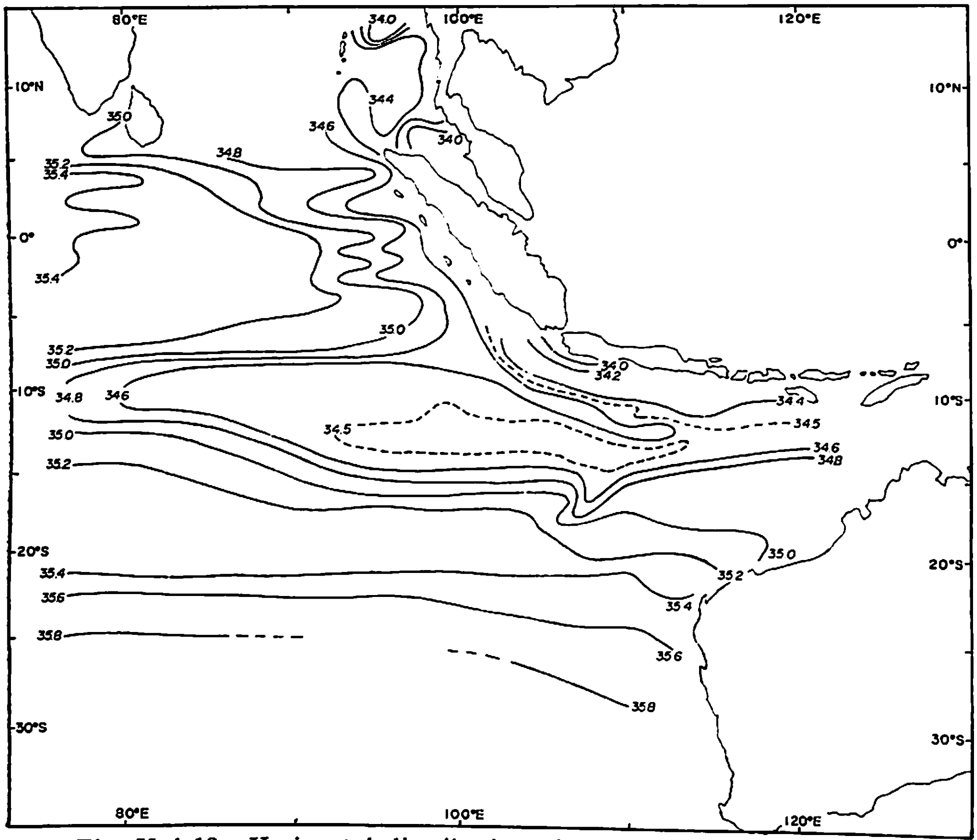


Fig. V-4-13. Horizontal distribution of salinity (‰) at the depth of 100 m in the winter of 1962/'63.

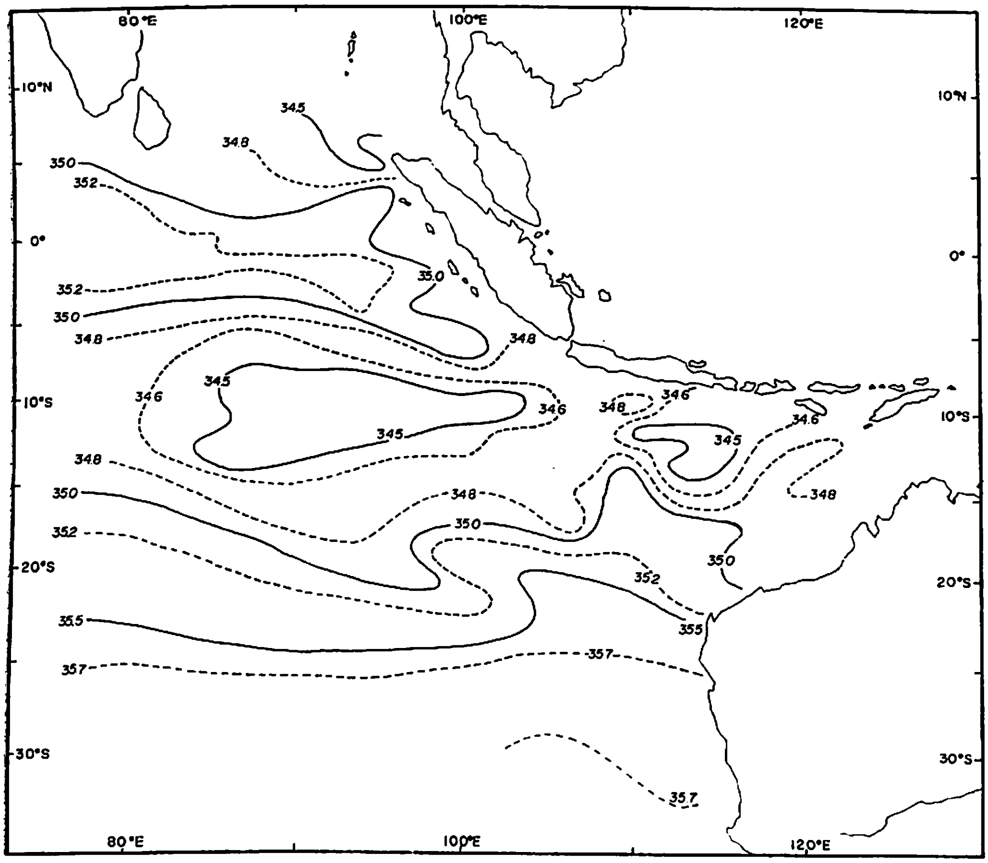


Fig. V-4-14. Horizontal distribution of salinity (‰) at the depth of 100 m in the winter of 1963/'64.

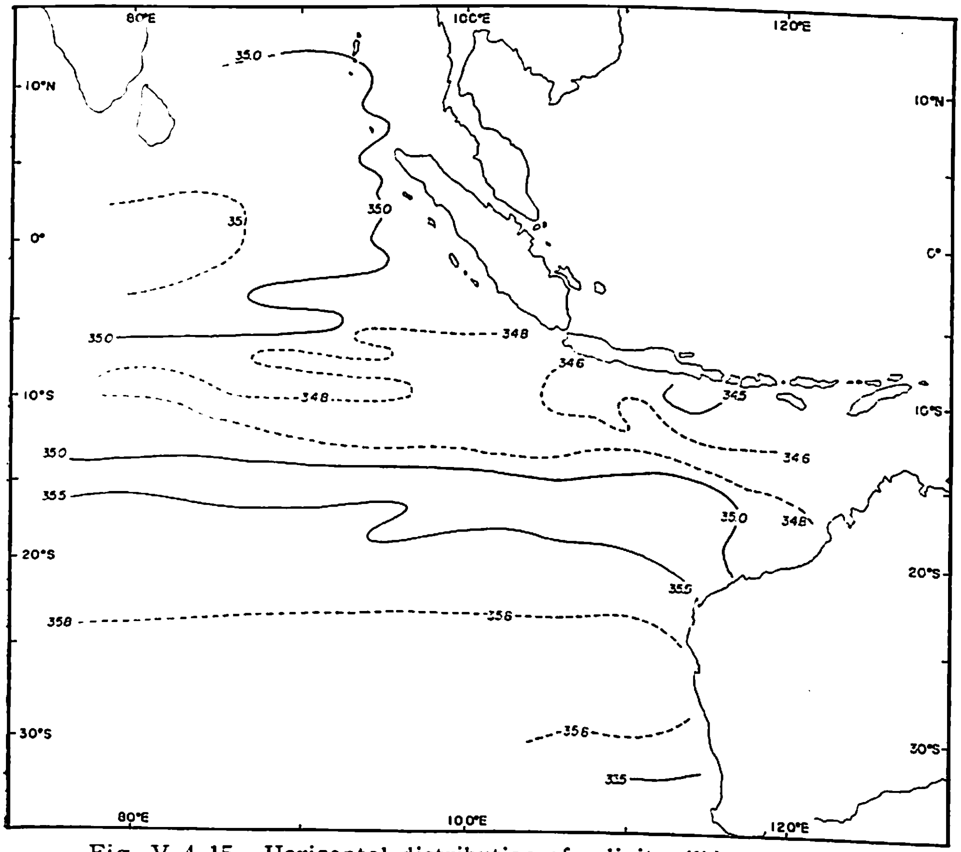


Fig. V-4-15. Horizontal distribution of salinity (‰) at the depth of 200 m in the winter of 1962/'63.

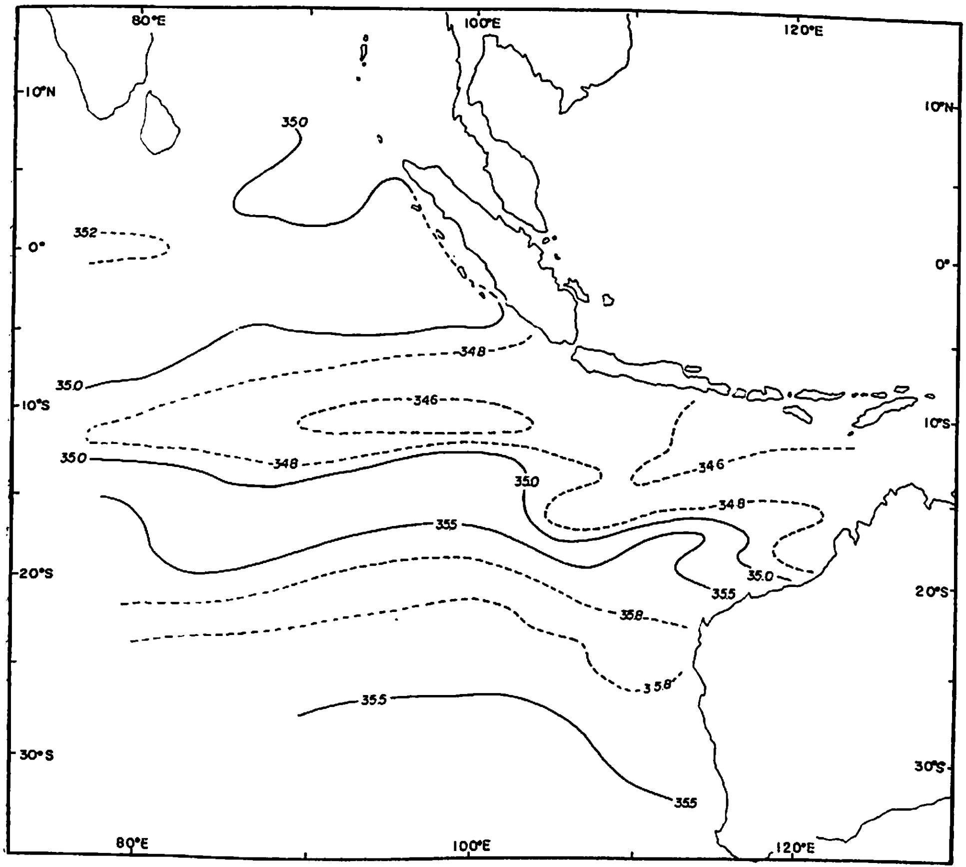


Fig. V-4-16. Horizontal distridution of salinity (‰) at the depth of 200 m in the winter of 1963/'64.

belt of water of relatively low salinity below 34.8‰ is distributed around the latitudal axis of 10°S adjacent to Sunda Islands. (Fig. V-4-15)

1963/64 A water belt extending from east to west having lower salinity (34.5-34.8‰) between the latitudes of 5°S and 15°S seems roughly to be transported by South Equatorial Current.

A belt of highly saline water (35.0-35.25‰) lying nearly along equator intrudes in the Eastern Indian Ocean from the Arabian Sea on the west side which corresponds to the location of the Equatorical Counter Current area.

Going to further south, we can see a highly saline water in the zone of 20°-25°S, having salinity higher than 35.8‰ corresponding to the South Indian Ocean Central Water.

In the area south to Java between the longitudes of 110° and 120°E, we can recognize the northward-flowing West Australian Current. We find a remarkable discontinuity of temperature and salinity at about 15°S between the longitudes of 100°E and 120°E, showing conspicuous oceanic fronts and eddies which might explain favourable fishing grounds of tunas. (Fig. V-4-16

2. *Sectional Distribution*

We have picked out some characteristic features of hydrography in the Eastern Indian Ocean, basing on the sectional distribution maps of water temperature, salinity, dissolved oxygen and nutrient salts at the meridional sections indicated in Figs. V-4-1, 2 and 3.

A. UMITAKA MARU

1962/63 Winter 78°E Section (Makoto ISHINO)

Water temperature (Fig. V-4-17)

In the surface layer north to 10°S water temperature shows the value higher than 28°C. Going to south to the latitude 28°S it continues to fall down. In the region nearly north to 13°S we find a remarkably developed thermocline between the layers of 50-100 m. depth (about 26°C) and of 150-200 m. depth (about 16°C).

Water temperature at the level of 500 m. depth shows about 10°C in the northern part and about 12°C in the southern part of the ocean. It becomes almost homogeneous 6°C at the level of 1000 m. depth and about 2°C at the level of 2500 m. depth respectively.

Salinity (Fig. V-4-18)

In contrast to the upper waters above the 100 m. depth in the areas around 7°N and 7°S-16°S indicating lower salinity of about 34.6‰, waters in the zone of 6°N-6°S at the depth of 200 m. and in the region south to 17°S above the 400 m. depth are highly saline (higher than 35.2‰). We can recognize waters of lower salinity influenced by the northern Asiatic Coastal Water, and that of low salinity continued to the area near 10°S in the northeastern part of Indian Ocean, Equatorial Water effected by the saline water of the

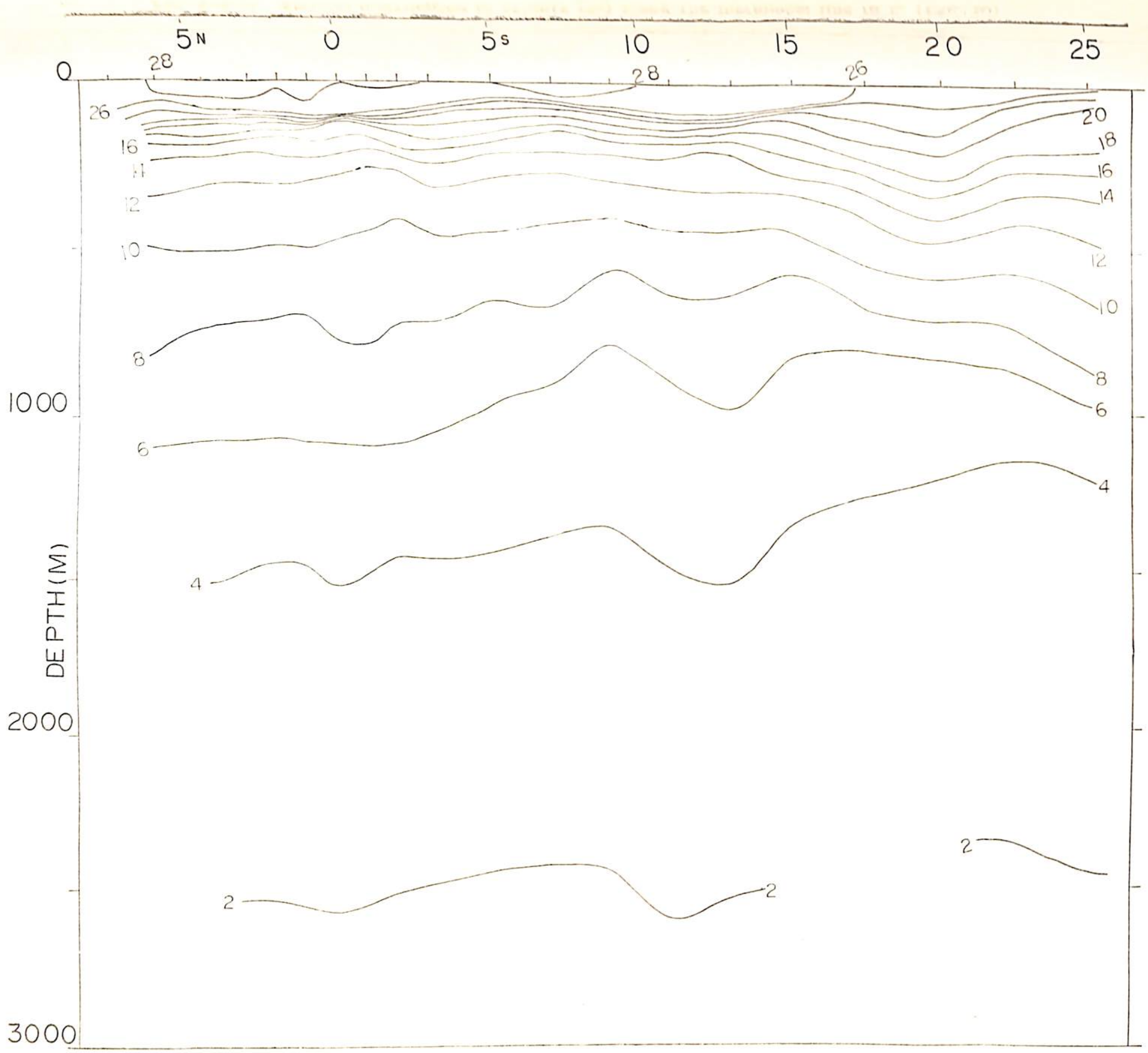


Fig. V-4-17. Vertical distribution of water temperature (°C) along the meridional line 78°E. (1962/'63)

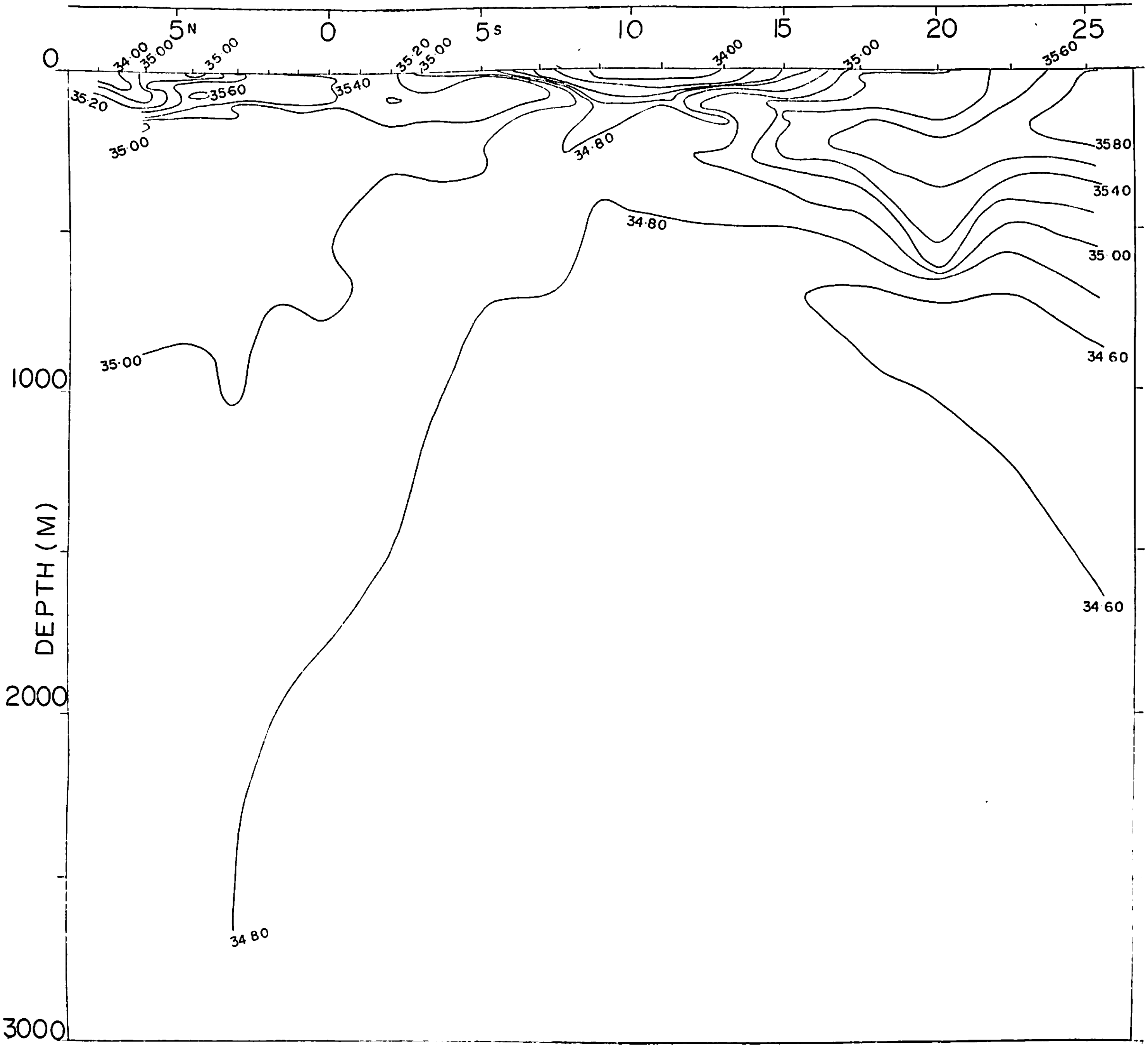


Fig. V-4-18. Vertical distribution of salinity (‰) along the meridional line 78°E. (1962/'63)

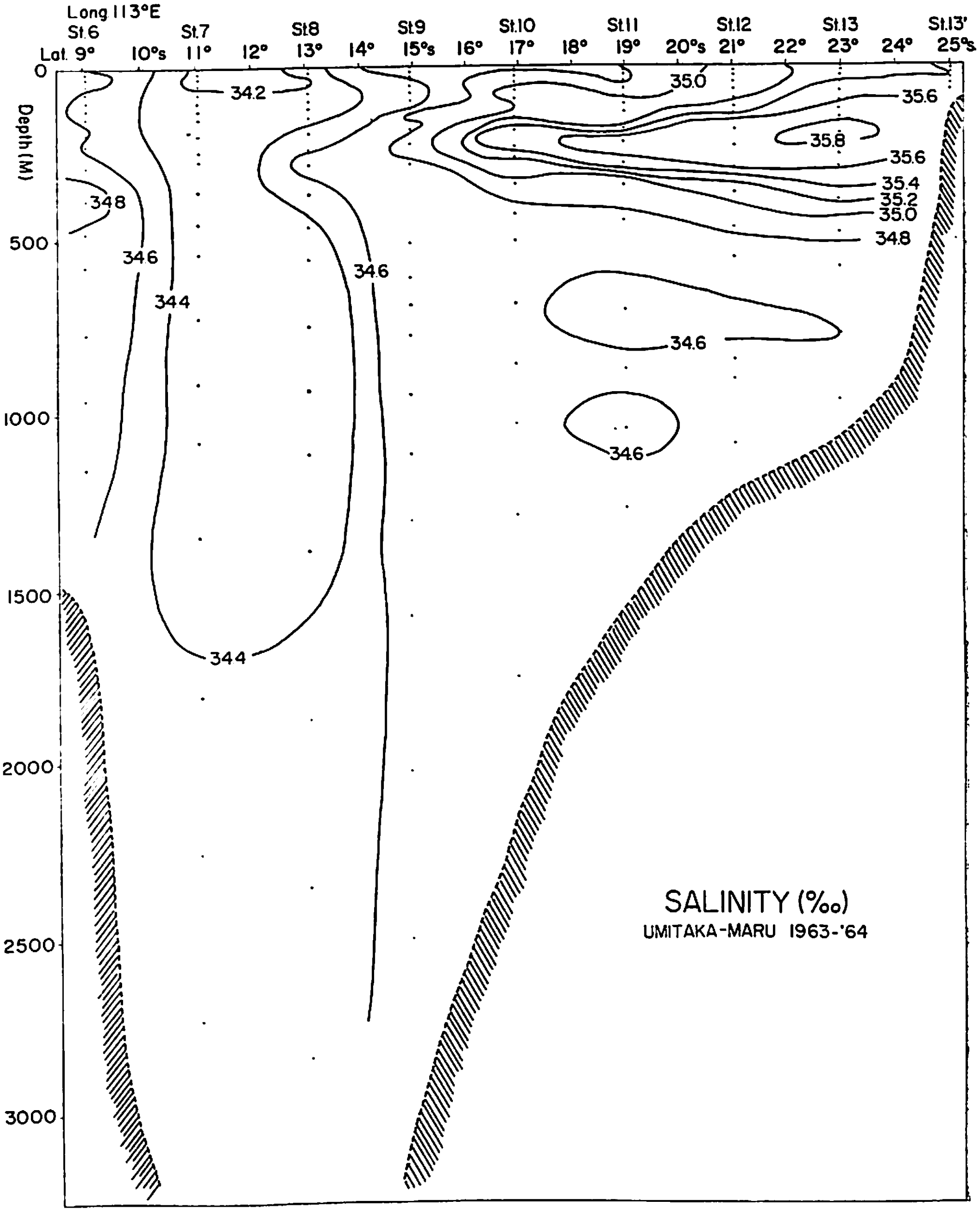


Fig. V-4-19. Vertical distribution of water temperature (°C) along the meridional line 113°E.

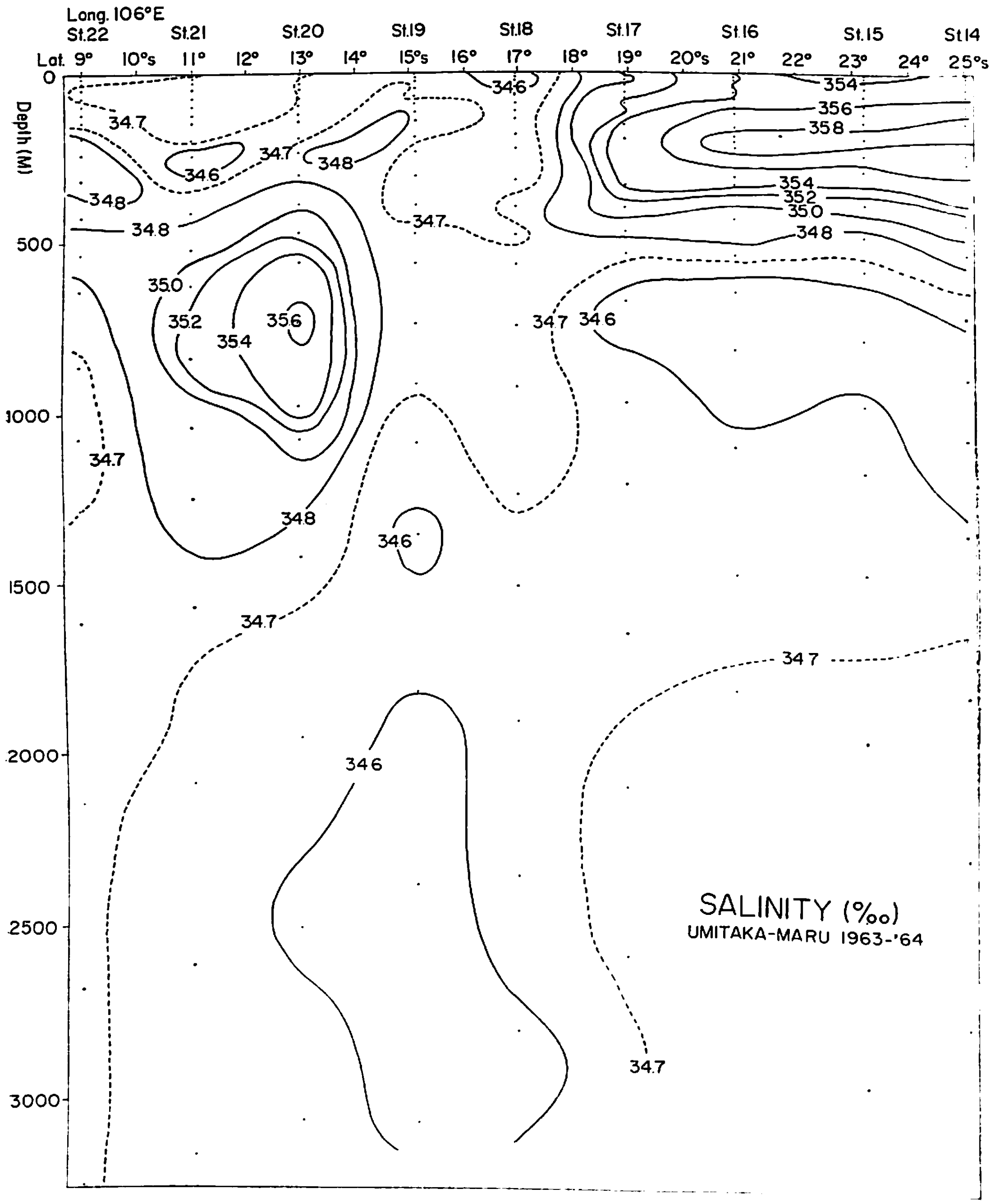


Fig. V-4-20. Vertical distribution of salinity (‰) along the meridonal line 113°E.

Red Sea origin intruding from northwest direction and waters in the southern part influenced by the Central Water of South Indian Ocean (having salinity higher than even 35.8‰).

Near the surface layer between 6°S-7°S and 16°S-18°S horizontal gradient of salinity is remarkable. In the region south to 16°S at about 1000 m. depth we can notice Antarctic Intermediate Water having salinity less than 34.6‰ clearly. Approaching to about 16°S the core level of it rises to shallowest at about 700 m. depth level, and beyond that zone the core level increases again. We can follow the pattern of minimum salinity corresponding to the Antarctic Intermediate Wayer to the latitude of 5°S. Temperature inversion at the level of 200 m. depth on 13°S indicates the peculiarly of oceanic front between the cooler, relatively fresh water and the warmer, saline water.

1963/64 Winter (Keizi NASU and Tsugio SHIMANO)

Section at 120°E (Fig. V-4-21)

Thermocline lies nearly at the level of 100 m. depth. In the region south to 17°S a saline water of salinity higher than 35‰ intrudes to north alike to a wedge in the layer of 200-300 m. depths which shows a conspicuous front against to the water of low salinity below 34.6‰ lying in the region north to the boundary between the mixing water zone near the Equatorial Counter Current and the region of the South Equatorial Current.

105°E Section (Fig. V-4-22)

In the region south to 20°S we see saline water having salinity higher than 35‰ from south, while another system of saline water exists at about 800 m. depth level near 15°S.

B. KAGOSHIMA MARU (Tadao TAKAHASHI & Masaaki CHAEN)

1963/64 Winter 86°E Section (5°N-5°S)

The thickness of transitional layer for the temperature range of 25°C-15°C is about 100 m. or more. Salinity shows the lowest value near at Equator in the surface layer. The intrusion of tongue-like saline water of highest salinity (35.2‰) from north to south at about the level of 300 m. depth which comes deeper near 2°S.

Vertical distribution of dissolved oxygen in the surface layer having its maximum higher than 4 cc/l increases again toward bottom gradually in the layers deeper than the level at 1500 m. depth.

The second maximum of dissolved oxygen is found at about 300 m. depth in the region south to equator, and the second minimum (less than 1 cc/l) is found at about 700 m. depth in the region north to 1°N.

78°E Section (7°N-25°S)

The thickness of the layer of water temperature 20°-15°C is about 100 m. near equator and increases gradually toward south to about 200 m. in the region south to 15°S. The depths of isothermal line 10°C and that of 5°C are the shallowest at the latitudes of 3°S and 20°S respectively.

Salinity maxima are found at the tongue-like portion of water intruding from north to south and at the part of saline water in the south having salinity higher than 35.8‰, extended toward north at about 200 m. depth.

O_2-Minimum (less than 1 cc/l) sinks down toward south from the level of 500 m. depth at 7°N to the level of 1500 m. depth at 25°S.

O_2-Maximum (more than 5 cc/l) is found at the level of 600 m. depth south to 17°N.

25°S, 78°E-1°N, 94°E Section

The layer thickness of the isothermal lines 25°-15°C is about 200 m. near at equator and increases from 8°S toward south. The isothermal line of 5°C descends obliquely toward north from 10°S.

The water of low salinity 34‰ is found at the north of 5°S. A highly saline water in the surface layer extends from north to south, while another saline water intrudes from south to nearly 15°S. Dissolved oxygen in the lower layer shows a far higher value in the southern part of the ocean than that in the northern part.

C. KOYO MARU

1962/63 Section (94°E, 5°N-20°S)

Water Temperature

The sea-region north to 9°30′S in the upper zone above the 50-100 m. depths is warm showing the temperature higher than 28°C in contrast to the colder area south to 10°S. Remarkable thermocline is found in the layer of about 100-150 m. depths in the northern region including 9°30′S-15°S at a rate of about 10°C drop for 50 m. descent. In the sea-region south to 11°S we see the double thermoclihe, indicating the lower inclined thermocline in addition to the upper thermocline above mentioned. Coming down to 20°S the thermocline descends to the depth of 300-400 m. The pattern of water temperature above the depth of 150 m. shows High in North and Low in South, and that in the layer of 150-50 m. depth High in the South and Low in the North, respectively. Also taking account of High in north, Low in south, we see three layers as a whole in the zone deeper than the level of 600 m. depth.

1963/64 (94°E, 8°N-10°S and 100°E, 12°27′S-21°34′S) Section

Water Temperature The upper thermocline lying at the depths of 50-100 m. around the 75 m. depth level as its axis showing uprupt temperature drop from 28°C to 14°C. In this case we have not noticed the peculiar pattern of temperature structure corresponding to the Equatorial Undercurrent. In the region south to 7°S the lower thermocline developes at the depths of 50-250 m. Corresponding to its we find the distribution of water temperature in the zone deeper than 600 m. down to the depth of 1500 m., showing the pattern of High in north, Low in south and homothermal temperature 1.5°-

1.1°C in the deepest zone of 3000-4500 m. depths.

Distribution of Dissolved Oxygen 1962/63 94°E Section

The first maximum of dissolved oxygen is found in the layer above the the 100-150 m. depth level and the second maximum of O_2 is located at the depth of 400-600 m. in the latitudes of 9.5°S-20°S, of which level ascends to shallower toward north. We can see the developed oxycline in the layer of 100-150 m. depth near equator (5°N-2°S) showing an uprupt decrease of dissolved oxygen from the value higher than 4 cc/1 to the value less than 2 cc/1.

The Oxygen-Minimum layer descends from the 200-500 m. depth (the value of O_2 less than 1.5 cc/1) north to 5°N through the 750 m. depth (O_2 less than 1.5 cc/1) in the latitudes of 4°N-3°S, to the 1000-1200 m. depth (O_2 less than 2.5-3 cc/1) in the latitudes of 9°S-20°S). The O_2-Maximum layer indicating 3.5-4 cc/1 in the layer deeper than 2000-2400 m. depth in the latitudes of 7°S-10°S is due to the effect of the Antarctic (originated) Bottom Water of rich dissolved oxygen.

1963/64 Section of (94°E-100°E)

Oxycline appears at 50-100 m. depth in the region north to 6°S, showing the rapid drop of the value of dissolved oxygen from higher than 4 cc/1 in the layer above the 30 m. depth to that less than 2 cc/1 in the layer deeper than 100 m. depth.

O_2-Minimum. It descends from the level of 150-600 m. depth in the latitudes of 8°N-3°N to the level of 800-1000 m. depth in the latitudes of 800-1000 m. depth. Or in other word, as we go to south further, the more increases the value of oxygen and the level of core O_2-Minimum becomes deeper.

O_2-Maximum. In the region south to 8.5°S we find the first maximum in the surface layer above 75 m. depth, the second maximum in the layer of 400-500 m. depth, and the third maximum in the layer deeper than the 2500 m. depth.

3. *Topography of the Discontinuity Surface in the Indian Ocean*

Topography of the discontinuity surface (top of thermocline) in the tropical and subtropical regions in the Eastern Indian Ocean in northern winter is drawn tentatively, shown by depth contours in meters, using temperature data of 20 Umitaka-maru stations, 24 Koyo-maru stations, and 49 Oshoro-maru stations in winter of 1962-1963 (Fig. V-4-23); and another one, using those of 46 Kagoshima-maru stations, 22 Koyo-maru stations, and 20 Oshoro-maru stations in winter of 1963-1964 (Fig. V-4-24). Corresponding current directions assumed on the basis of dynamical consideration are drawn also in these maps. Observation stations are shown by dots. The following facts may be recognized through the inspection of these maps.

The North Equatorial Current is rather variable even in winter and it is

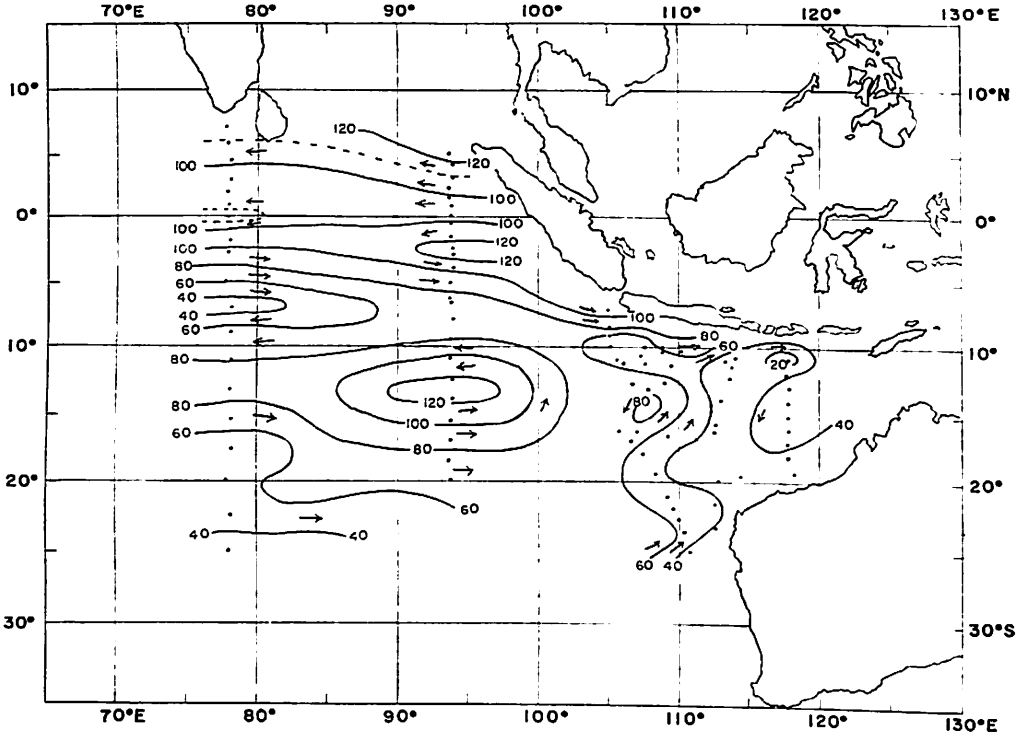


Fig. V-4-21. Topography of the discontinuity surface in the tropical and subtropical regions in the Eastern Indian Ocean in winter of 1962-1963, shown by depth contours in meters. Dots indicate the observation stations. (T. TAKAHASHI, Kagoshima U.)

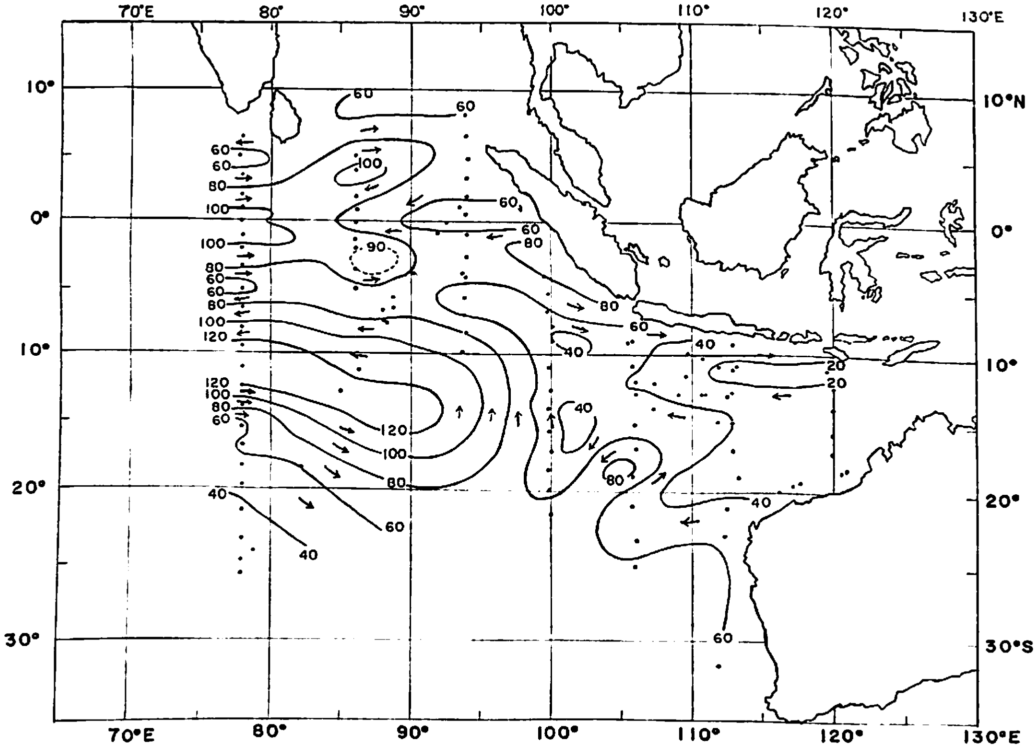


Fig. V-4-22. Topography of the discontinuity surface in the tropical and subtropical regions in the Eastern Indian Ocean in winter of 1963-1964, shown by depth contours in meters. Dots indicate the observation stations. (T. TAKAHASHI, Kagoshima U.)

difficult to determine its boundaries. Though the westward current is found to the north of ca 2°S in Fig. V-4-21, the eastward current exists in the same area in Fig. V-4-22, except for a narrow zone including the equator. It should be noticed that in Fig. V-4-22 not divergence but convergence seems to occur along the equator. The Equatorial Countercurrent exists in a zone between ca 2°S and ca 7°S in Fig. V-4-21, but it is hard to define the Equatorial Countercurrent in Fig. V-4-22. A cum sole vortex exists around 13°S, 95°E in Fig. V-4-21 and its northern part continues to the South Equatorial Current in a zone between ca 7°S and ca 13°S. Fig. V-4-22 the South Equatorial Current deviates more or less to the north around 80°E. Currents in a region to the east of 100°E are rather complicated, where small vortices are found in both Figs. However, a current flows to the east along south off Java in both Figs. It seems to be able to expect upwelling processes off the northern part of Sumatra. (Tadao TAKAHASHI)

4. *Distribution of the Thickness of Mixed Layer* (Fig. V-4-23)

1963/64 The thickness of the warm water mixed layer is deeper than

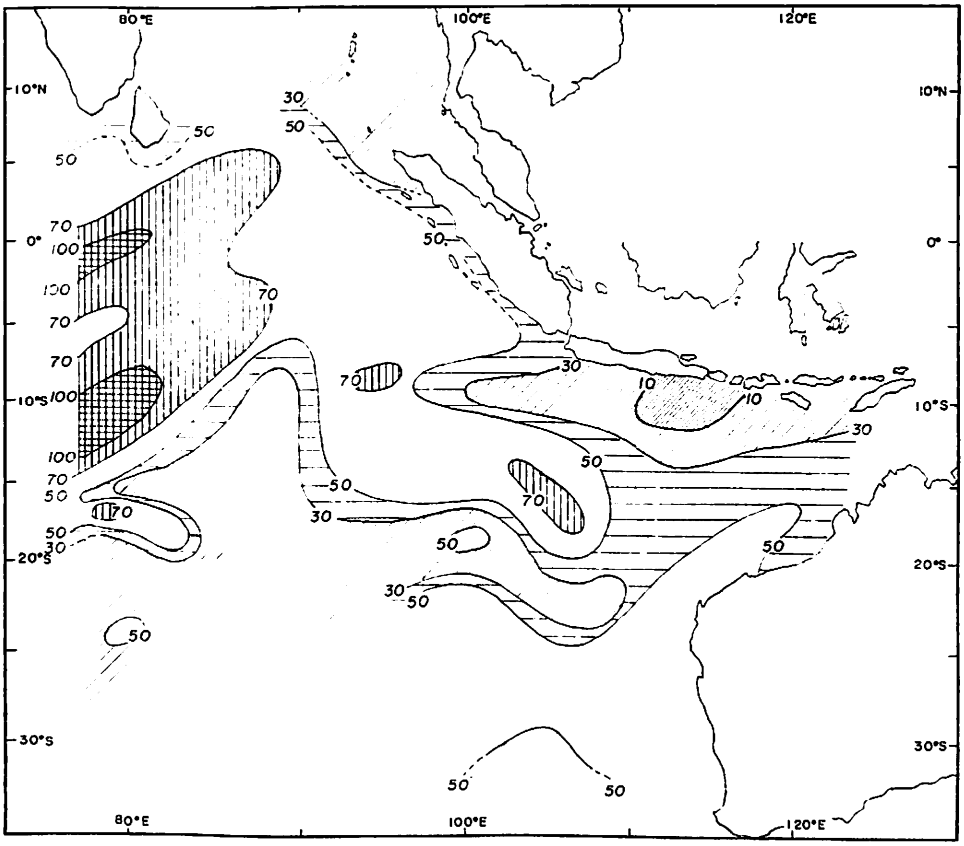


Fig. V-4-23. Thickness of the upper mixed water in meter.

70 m. in the sea-region south to India and reaches to the depth of 120 m. However, in the region extending from 15°S to 25°S around the axis of 20°S it shows thinner thickness of about 30-50 m. In the region south of Java Island it becomes very thin, indicating the depth of 10-30 m. from sea surface. In the region north to Sumatra the mixed layer is also shallow in depth from sea surface showing about 30 m. thickness. (M. Uda)

5. *Distribution of Salinity-Minimum Layer* (Fig. V-4-24)

The value of S-Min. as the core of the Intermediate Water of Subantarctic origin indicates lower salinity in the south and increases to the higher salinity due to the mixing in accompany with the northward movement of that water. It shows about 34.4‰ off Fremantle (Western Australia), 34.5‰ in the west-offiing of Broome, 34.6-34.7‰ in the west-offiing of Java, and attains to 34.8‰ in the west-offiing of Sumatra. The depth of Core water S-Min. is shallowest in the latitudes of 15°S-20°S, indicating the depth less than 700-800 m. and is presumed to be due to upwelling. The core depth is deeper than 1000 m. in the regions north to 10°S and in the region south to 25°S. (M. UDA)

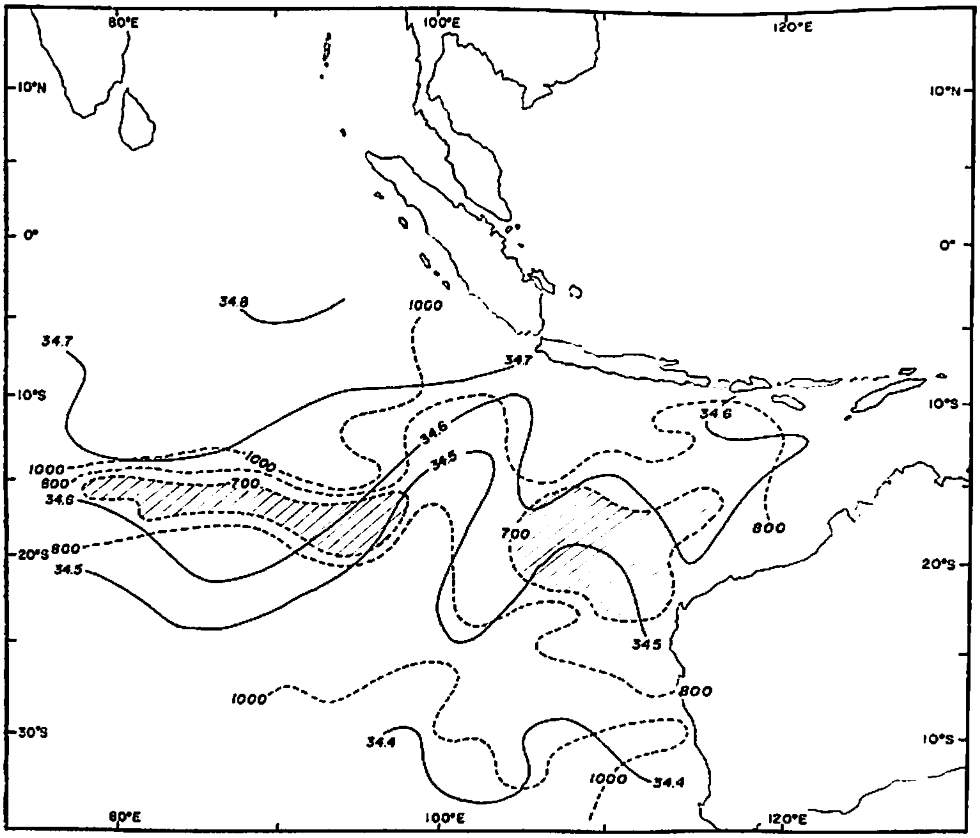


Fig. V-4-24. S-minimum (‰) & its depth (m).

6. *Distribution of Salinity-Maximum Layer* (Fig. V-4-25)

1963/64 Two belts of high salinity water (S higher than 35.2‰) are seen in the areas at the latitudes of 5°N-5°S and south to 15°S. Between them a belt of lower salinity water (less than 35.0‰) lies at the latitudes of 5°S-15°S around 14°S, and particularly it shows its lowest salinity (34.6-34.8‰ or less) occupying in the shallow upper layer above the 100 m. depth in the southern waters adjacent to Java Island which suggests us the existence of upwelling of Subantarctic Intermediate Water having lower salinity in this region. (M. UDA)

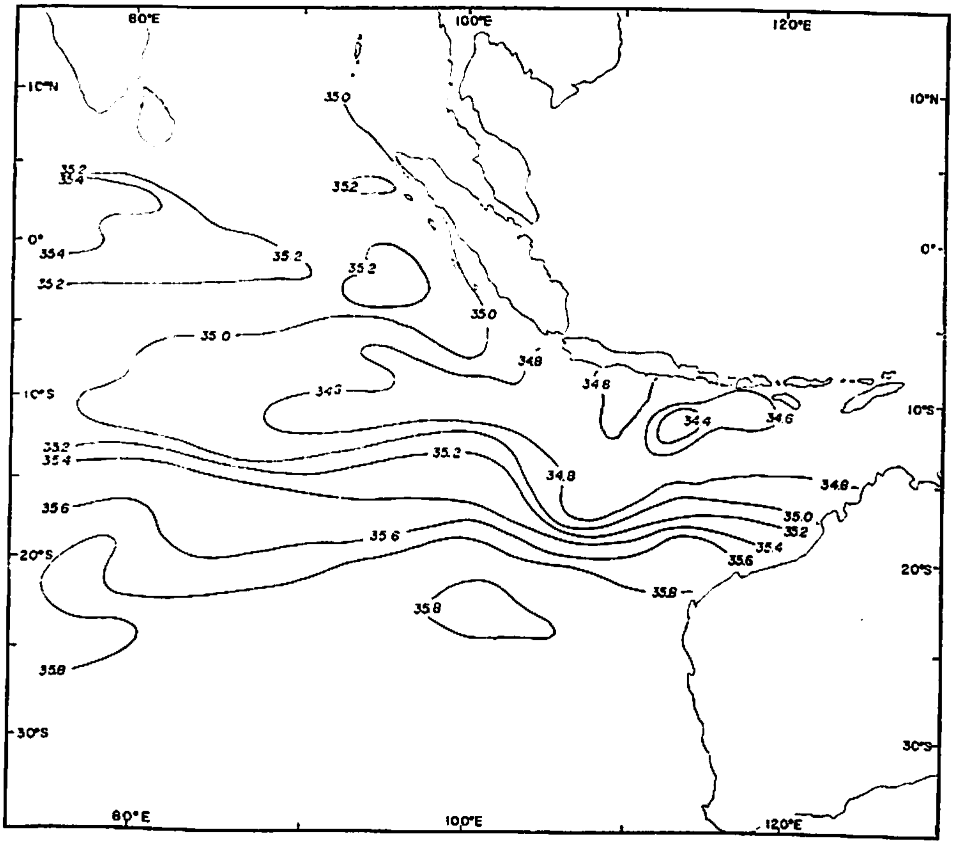


Fig. V-4-25. Horizontal distribution of salinity (‰) at the depth observed "Smax"

7. *Equatorial Circulation*

As the results of current measurement by two Ekman-Merz current-meters method in the equatorial region (1962/63 Umitaka Maru Survey) we found westerly flow around 2°N in the surface layer, and easterly flow south to the above region.

There seems to exist an uniform westerly flow around the layer of 150 m. depth, particularly considerable flows of speed having about 30 cm/sec around

Table V-4-1. Current measured by two current meters method in the Eastern Indian Ocean (Umitaka-maru).

St. No.	UM I-4	UM I-5	UM I-6	UM I-7	UM I-8	UM I-9	UM I-10	UM I-13	UM I-16	UM I-20
Date	16~17, Dec., 1962	15, Dec., 1962	14~15, Dec., 1962	13, Dec., 1962	12~13, Dec., 1962	11~12, Dec., 1962	10~11, Dec., 1962	31, Dec., 1962	3, Jan., 1963	7, Jan., 1963
Wind	NNE 2	NE 2	S 2	SE 2	SW 2	SSW 3	SSW 3	NW 4	SE 4	NE 5
	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s
10 m	25.5 (8°)	58.9 (344°)	17.2 (333°)	47.7 (34°)	11.9 (17°)	46.8 (18°)	29.3 (73°)	45.1 (333°)	22.8 (355°)	45.3 (315°)
20 m	44.2 (34°)	50.8 (0°)	22.5 (319°)	27.7 (53°)	11.8 (308°)	25.3 (27°)	34.0 (106°)	47.1 (323°)	11.5 (27°)	56.2 (222°)
50 m	44.2 (29°)	36.7 (47°)	2.2 (301°)	22.7 (195°)	25.0 (205°)	21.2 (180°)	60.9 (146°)	32.5 (310°)	12.0 (37°)	24.4 (274°)
100 m	13.4 (154°)	205 (221°)	67.7 (349°)	32.5 (313°)	15.5 (298°)	21.0 (213°)	14.5 (239°)	34.5 (4°)	11.6 (35°)	38.0 (211°)
150 m	41.5 (197°)	12.0 (322°)	27.7 (11°)	36.0 (251°)	20.9 (281°)	54.0 (285°)	28.9 (317°)	34.5 (15°)	23.2 (22°)	30.0 (240°)
200 m	18.0 (151°)	15.5 (224°)	15.0 (111°)	24.0 (216°)	62.1 (209°)	17.6 (315°)	25.1 (308°)	18.7 (319°)	3.1 (252°)	44.9 (292°)
400 m	333 (221°)	17.3 (236°)	13.2 (203°)	17.0 (226°)	20.1 (165°)	7.9 (63°)	18.9 (357°)	8.7 (280°)	10.8 (24°)	24.8 (222°)
Remarks										

Table V-4-2. Current measured by two current meters method in the Eastern Indian Ocean (Umitaka-maru).

St. No.	7	8	9	11	12	13	14	15	18
Date	6, Dec., 1963	7, Dec., 1963	8, Dec., 1963	10, Dec., 1963	11, Dec., 1963	22, Dec., 1963	5, Jan., 1964	6, Jan., 1964	10, Jan., 1964
Wind	SSE 3	S 4	S 3	SW 4	SW 4	S 4	S 2	S 4	S 4
	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s
10 m	33.0 (99°)	23.9 (225°)	38.1 (280°)	39.5 (224°)	39.0 (238°)	38.0 (227°)	8.7 (211°)	47.7 (177°)	42.2 (215°)
20 m	34.0 (97°)	27.1 (240°)	18.4 (256°)	45.9 (216°)	36.3 (215°)	33.5 (227°)	5.0 (274°)	52.8 (176°)	34.0 (199°)
50 m	53.2 (75°)	20.2 (180°)	11.5 (189°)	12.4 (221°)	39.0 (217°)	—	11.0 (306°)	40.4 (174°)	25.7 (205°)
75 m	—	—	20.7 (203°)	—	26.2 (231°)	14.7 (172°)	11.0 (158°)	33.0 (181°)	27.5 (201°)
100 m	50.9 (80°)	20.7 (175°)	24.3 (163°)	36.7 (192°)	27.5 (211°)	17.0 (201°)	13.8 (175°)	20.2 (173°)	38.1 (193°)
150 m	—	21.6 (164°)	21.1 (225°)	34.9 (184°)	44.1 (201°)	13.8 (156°)	10.6 (219°)	20.7 (158°)	—
200 m	38.5 (85°)	27.5 (202°)	4.6 (187°)	22.9 (169°)	26.2 (214°)	9.2 (287°)	17.0 (215°)	19.3 (195°)	21.1 (195°)
300 m	39.9 (84°)	16.5 (180°)	6.9 (276°)	28.9 (183°)	20.7 (252°)	—	20.7 (220°)	14.7 (198°)	19.7 (192°)
400 m	—	9.6 (273°)	9.6 (214°)	23.9 (199°)	13.3 (223°)	7.8 (247°)	17.9 (216°)	11.5 (204°)	20.7 (199°)
Remarks									

Table V-4-2. Continued.

St. No.	19	20	21	22	24	25	26	27
Date	11, Jan., 1964	12, Jan., 1964	13, Jan., 1964	15, Jan., 1964	18, Jan., 1964	19, Jan., 1964	20, Jan., 1964	21, Jan., 1964
Wind	S 4	SW 2	S 2	SSE 2	ESE 2	E 4	E 2	WNW 2
	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s	cm/s
10 m	16.5 (240°)	11.0 (235°)	15.1 (241°)	33.5 (151°)	10.1 (129°)	59.2 (127°)	6.0 (9°)	17.4 (78°)
20 m	20.7 (185°)	15.6 (203°)	21.1 (228°)	34.4 (162°)	—	—	—	—
50 m	21.1 (185°)	11.9 (210°)	34.4 (221°)	47.3 (173°)	22.0 (93°)	59.7 (99°)	15.1 (346°)	46.8 (265°)
75 m	18.4 (164°)	19.3 (197°)	23.9 (199°)	55.1 (155°)	—	—	—	—
100 m	11.0 (237°)	24.3 (223°)	20.7 (288°)	36.7 (175°)	27.1 (107°)	25.7 (136°)	15.6 (236°)	40.4 (287°)
150 m	9.2 (80°)	—	—	55.1 (151°)	—	—	—	—
200 m	22.9 (259°)	18.4 (177°)	8.3 (41°)	39.0 (151°)	18.4 (134°)	19.3 (21°)	28.0 (283°)	20.7 (233°)
300 m	14.7 (192°)	21.1 (189°)	11.9 (44°)	25.2 (186°)	—	—	—	—
400 m	10.6 (197°)	17.4 (155°)	6.4 (137°)	21.1 (159°)	—	—	—	—
Remarks								

equator and 50 cm/sec around 2°S respectively. In the layer at the depth of 400 m. current is feeble generally. (Table V-4-1) (Makoto ISHINO)

In June-September 1962 and in February-May 1963 Dr. Mizuki TSUCHIYA on board of US Research vessel ARGO measured Equatorial Undercurrent in the Indian Ocean. During March and April a very clear easterly Undercurrent (E-W component 30-80 cm/sec) is found at a depth of 80-120 m. about in the longitudes of 61°E-92°E, showing higher velocity in the east than west and deeper level in the east than that in the west. Thermal structure at the cross section corresponding to thus Undercurrent reveals "Thermocline Spreading" in vertical direction clearly. It is considered that although in the Northeast Monsoon period (end period) Equatorial Undercurrent exists actually in the eastern part of Indian Ocean, however, it is not so conspicuous in comparison to those of Pacific Ocean and Atlantic Ocean, and appears to fluctuate more violently. Dr. Kozo YOSHIDA (1963) studied the relationship between wind and Equatorial Undercurrent in the Indian Ocean.

Results of direct current measurement by two Ekman current-meter method (Tsugio SHIMANO and Keiji NASU) were compiled in Table V-4-2.

8. *Investigation of Currents by Means of Drift-Bottle Experiment.*

Results by drift-bottle experiments on Umitaka Maru and Koyo Maru were compiled in maps (Fig. V-4-26 and Fig. V-4-27).

The rate of recovery of drift-bottles by the experiment in 1962/63 was about 3.6% (numbers of bottles recovered/numbers of bottles released 143/4000) and that by the experiment in 1963/64 was about 1.6% (76/4000). The results of driftage are shown in Figs. V-4-26, 27. Inspecting these charts we can find the following roughly:

(i) Bottles thrown on the line of 78°E, north to about 2°N drifted mostly westward to Maldive Islands. The average speed estimated is about 0.7-0.8 knot.

(ii) Bottles thrown on the line 78°E, at the stations between 1°N and 5°S drifted to eastward direction.

(iii) Bottles thrown at the stations between 8°S and 26°S except those south off Java Islands have shown westward flow and were found mostly along the east coast of Africa. The drift speed in average estimated is about 0.3 knot.

(iv) Bottles thrown at the northern stations near the Sunda Islands were found at localities in the Bay of Bengal and those thrown at the southern stations off Sunda Islands drifted eastward at the coasts of Sunda Islands.

9. *Water Mass Analysis by TS-Diagram.*

(See Fig. V-4-28, 29). Water mass analysis made by representative thermohaline curves has produced a map of the distribution of water masses A, B, C, D, E, F characteristic to the eastern Indian Ocean and their boundaries.

A ....South Indian Ocean Central Water Mass (highly saline).
B ....Arafura Sea (origin) water mass (lower salinity higher temperature).
C ....Arabian Sea (origin) water mass (highly saline), near and south to equa-

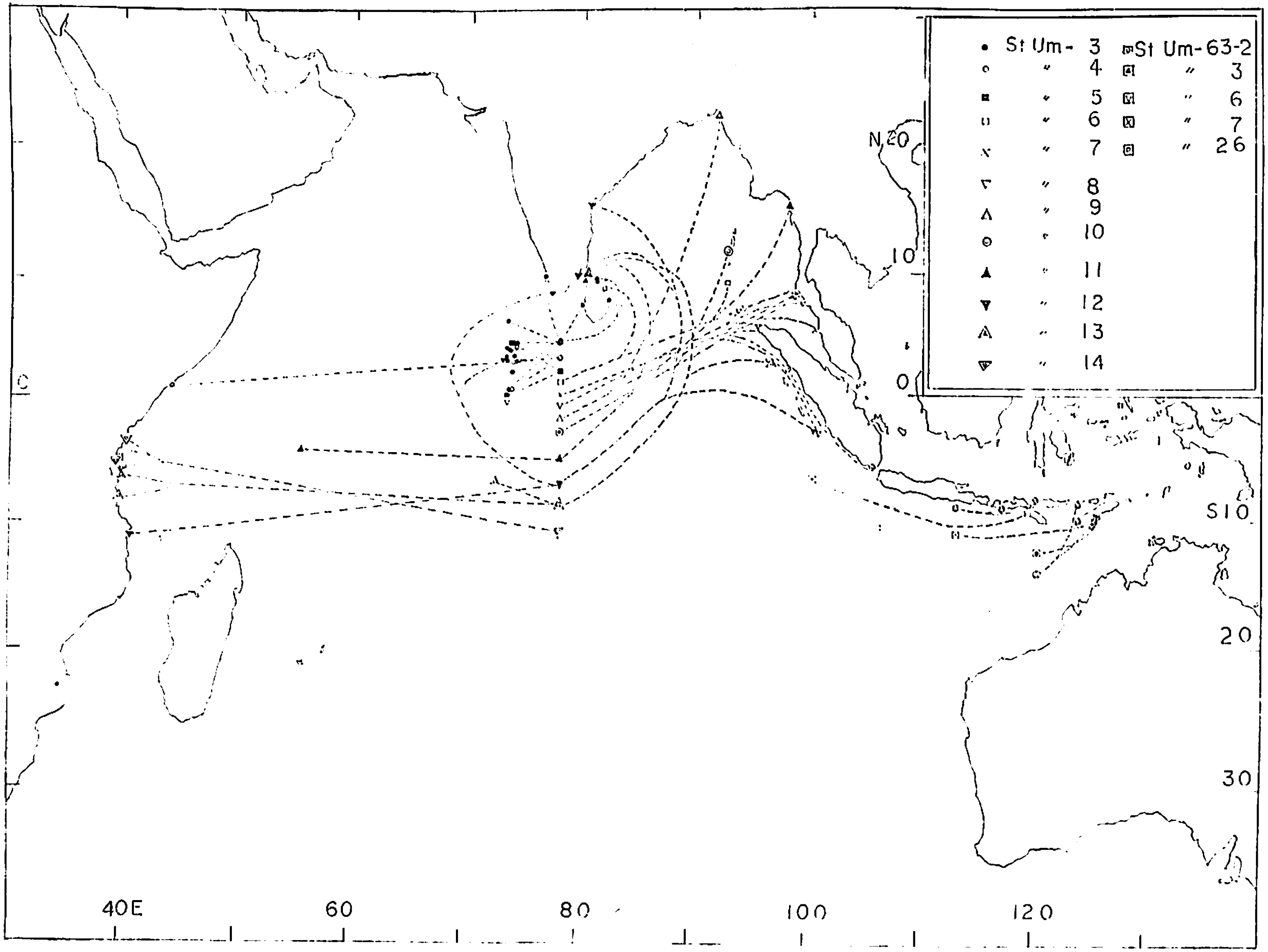


Fig. V-4-26. Map indicating records of drift botles. (Umitaka Maru)

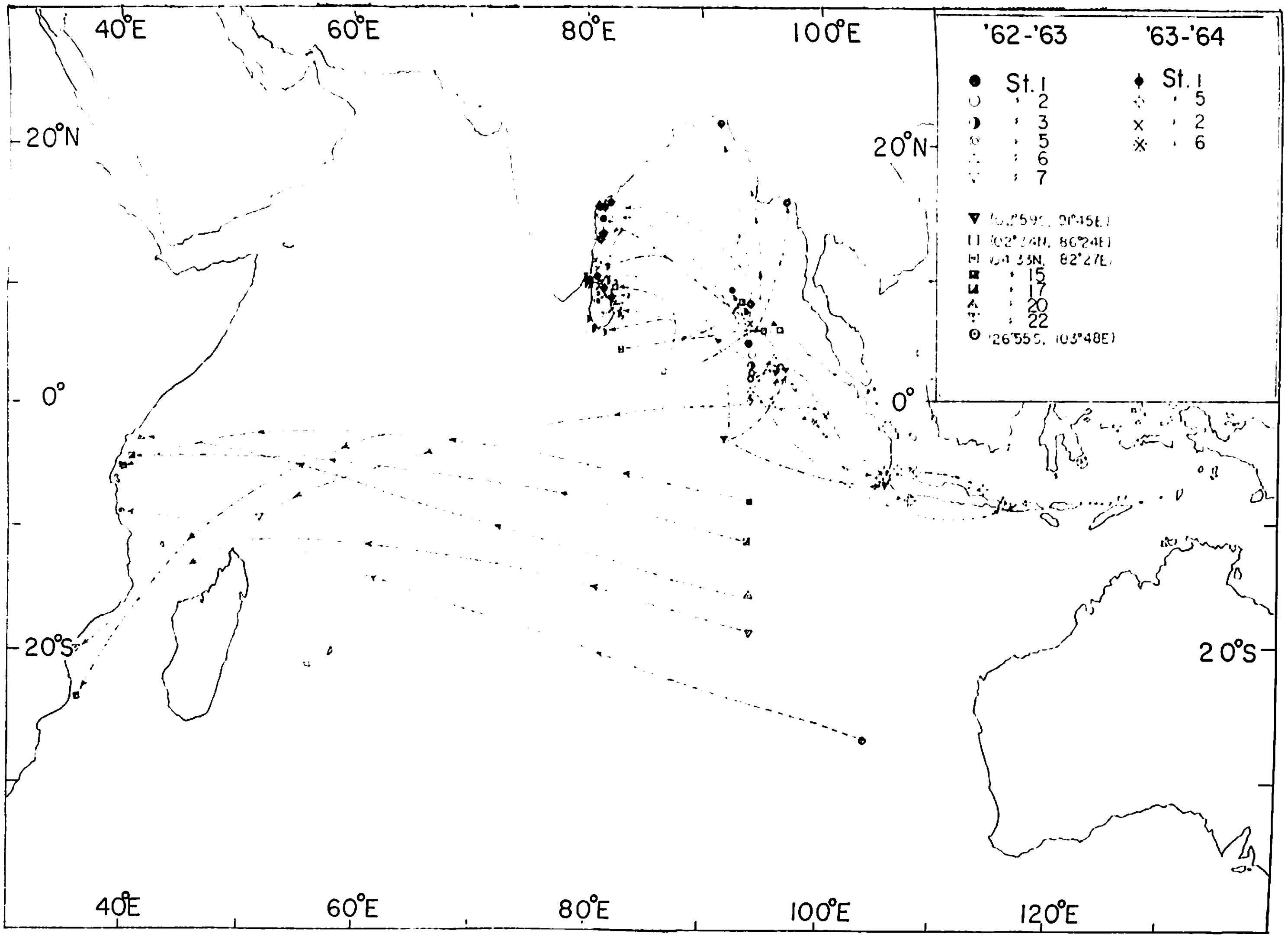


Fig. V-4-27. I. I. O. E. Records of drift cards. (Koyo-Maru)

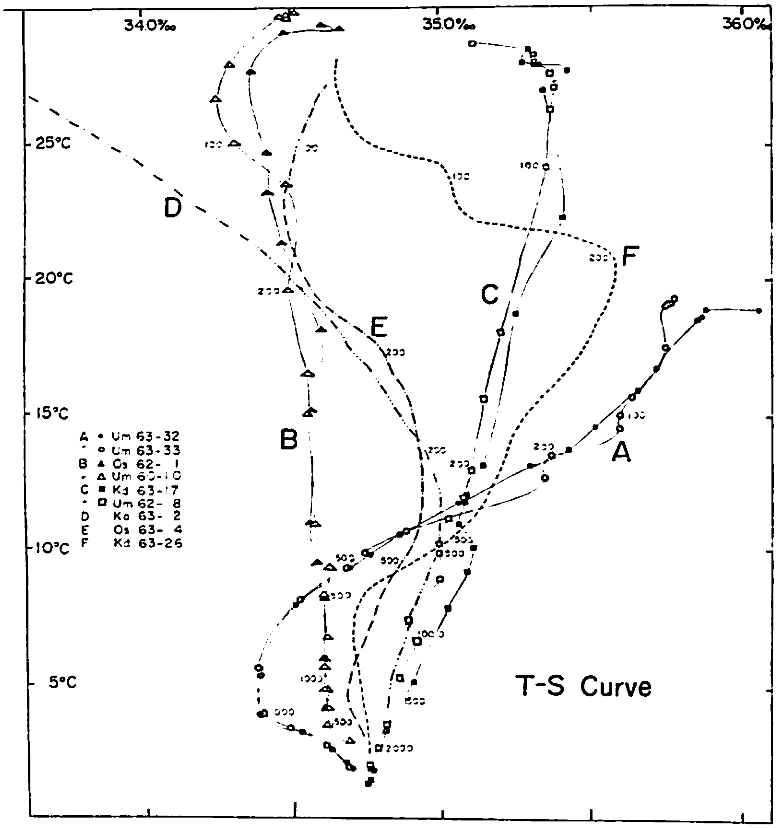


Fig. V-4-28. TS-curves of representative watermasses.

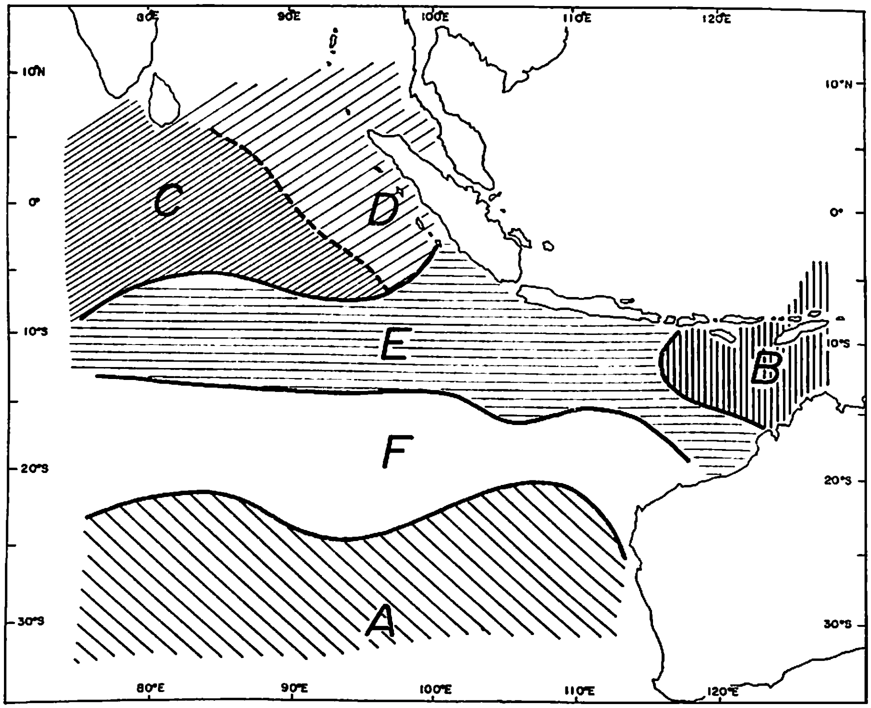


Fig. V-4-29. Distribution of Water masses.

tor flowing toward east, contrary to the north of equator flowing toward west.

D ....North Indian Ocean and Bengal Bay (origin) water mass (lower salinity), extending from Bengal Bay to the north or west of Sumatra.

E ....Mixed water mass upwelled to the south of Sunda Island.

F ....Mixed water mass flowing to the west, which belongs to the South Equatorial Current.

Results compiled in Fig. V-4-30 31, basing on the data in 1962/63 and 1963/64 indicate 4 fundamental water mass, A, B, C, D and the mixed intermediate water mass E, F. Among them E-water corresponding to upwelling is particularly important for tuna fisheries.

Notes: This article was written by Dr. M. UDA based on the reports submitted by

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V—5. Chemical Oceanography

The Working Group for Chemical Oceanography

Introduction

The working group for chemical oceanography was established in April, 1961 within the National Committee for SCOR in JSC.

The members of the working group are listed in the page 4.

The committee dealt with the standard methods of observation, standardization of instruments and reagent and so forth. As a conclusion, the following recommendations and plans for chemical observations were adopted.

1. Items of determinations were decided as follows: chlorinity, dissolved oxygen, inorganic and total phosphorus, nitrate, silicate, pH and some of minor chemical elements; "Manuals for Oceanographic Observations" edited by Japan Meteorological Agency (1955) should be referred except for the total phosphorus and nitrate; for nitrate determination Mülline-Riley method should be employed; as to the total phosphorus, the manual should be given later; all but the total phosphorus should be determined aboard a ship.
2. It was decided that the standard solution for oxygen, phosphate, silicate and nitrate be prepared and distributed to each party under the supervision of the committee (see below).
3. It was recommended that in order to improve the accuracy of the analyses, new instruments were to be introduced (see below).
4. It was recommended that the reversing bottles of Nansen type of 2 liter volume were to be used. The inner wall of the bottle should have teflon lining.
5. It was decided that the standard buffer solutions for pH determination should be prepared at one of the institutions to which members of the committee belong, then being distributed to each party.
6. It was recommended to equip with a deep-freezer on each ship for storage of samples.
7. It was recognized that at least three members be needed for chemical works aboard each ship.
8. It was recommended that simultaneous inter-calibration of methods be made at an appropriate time using an appropriate ship.

Preparation of standard solutions for analyses

Dissolved oxygen: 0.1 N KIO_3 solution was prepared, which was diluted ten times just before use.

Phosphate: Solution of dihydrogen potassium phosphate respectively with the concentration of 0.25μg at/m*l*, 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0μg at/*l*1).

Silicate: Potassium chromate solution was used whose concentration was equivalent respectively to 2.5μg at/m*l*, 0, 10, 20, 30, 40, 50, 60, 80, 100 and 120μg at/*l*.

Nitrate: Solutions of potassium nitrate of 10μg at/m*l*, 0, 5, 10, 20, 40, 60, 80μg at/*l*.

These solutions were prepared by Tokyo Kagaku Sangyo Co. under the direction of the committee. As shown above, the series of diluted solution was to be used directly for photometric standards and concentrated solutions are for reservation. Solutions were kept in 50 m*l* ampoules made of hard glass. The concentration of each solution was checked throughout the IIOE observation and no appreciable change was found to occur.

Newly employed instruments

The self-recording type photometer, which is equipped with a photo-cell and color filters. This type of photometer was developed first by Japan Hydrographic Office. With some modification and improvement, several photometers of the same type were manufactured and distributed to each ship. At first, there was a source of error or fluctuation due to the vibration of liquid in the cell (10 cm long), but this was removed by filling the liquid up to the top in a closed cell. Also, an open cylindrical tube of 4 cm diameter was proved to be useful for photometry without arising fluctuation in recording due to ship motion.

It was confirmed that by employing this type of photometer, we could avoid any errors caused by ship motion regardless the size of ships which improved great deal the accuracy of analysis2).

In determining dissolved oxygen, the ordinary buret with a stopcock was replaced by the piston buret manufactured by Metrohm AG Herisau Co., Switzerland. This type of buret is of 20 m*l* volume with graduation marks down to 0.02 m*l*. The reading of the liquid volume can be done by the use of a micrometer. This buret helped greatly in increasing the efficiency as well as the accuracy of titration in a narrow laboratory in a moving ship.

Up to now, Wassermann type of pipet with a rubber bulb was generally used for the addition of reagent solutions, but this was replaced by the syringe type pipet. The latter was made of methacrylate resin and properly designed for a laboratory work aboard a ship. The content of the pipet can be adjusted down to 2 m*l* by changing the movable length of the piston stem. This type of pipet is convenient especially in the works at night, because the reading of the volume is not necessary.

The Nansen type of reversing bottles of 2*l* volume were newly manufactured and used. The inside wall of metallic bottles were coated with teflon to avoid the consumption of the dissolved oxygen at the interface of metal and water.

Intercalibration tests

The international calibration tests for chemical analyses were done twice respectively in September 1961 at Honolulu and in July to August 1962 off Freemantle, Australia. One of the committee members (Y. SUGIURA) participated in both calibration tests. Participants were from Australia, India, Japan, Pakistan, UK, USA and USSR in the first meeting and Australia. Japan, USA and USSR in the second meeting the latter of which was held aboard the Russian research vessel " Vitiaz " for seven days. The main items of calibration were phosphate and dissolved oxygen determinations in both cases.

National calibration tests for phosphate and oxygen were done in September 1962 at the Sagami Bay of Honshu for three days. Chemical oceanographers from the seven institutions concerned participated in this intercalibration test meeting. The results of these intercalibration tests showed that the standard deviation in phosphate determination was about ±0.05μg at/l on an average

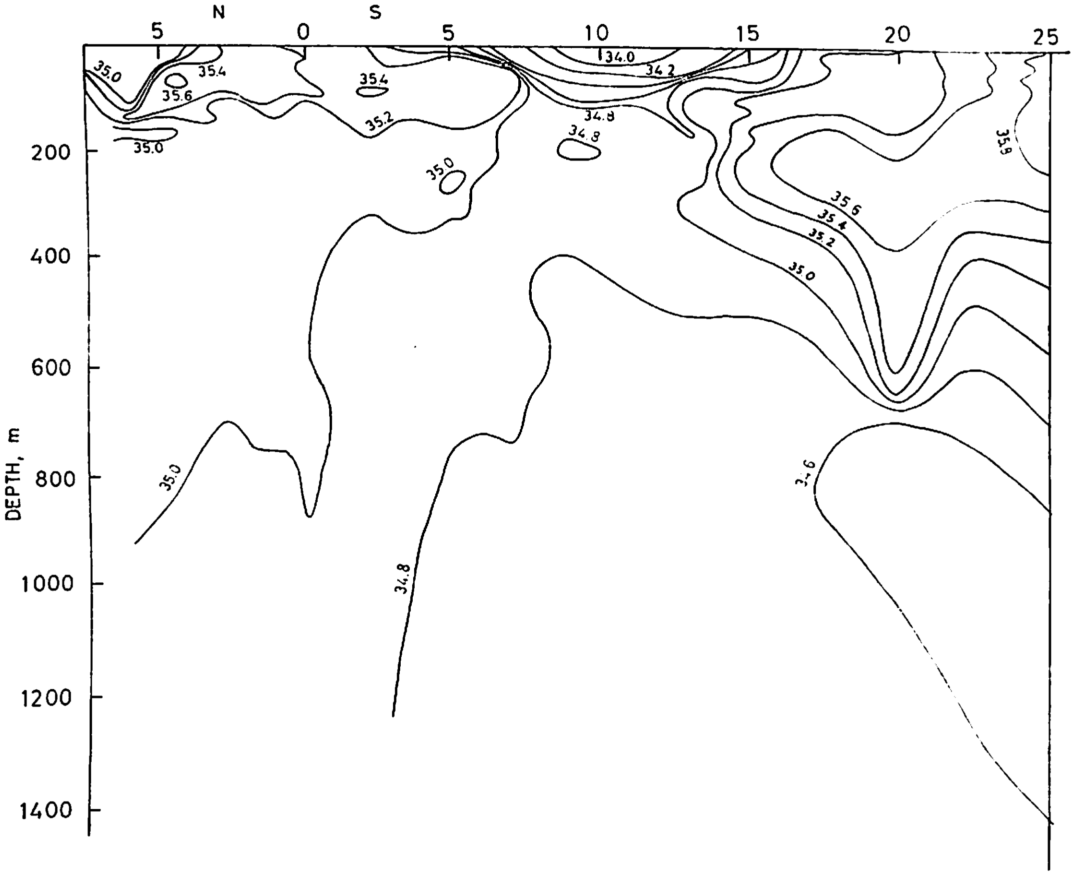

Fig. V-5-1. Distribution of salinity (‰) along the meridional line 78°E.

in the concentration range up to 4μg at/l where the deviation was a little lower for the low phosphate concentration (<0.5μg at/l) and a little higher (±0.1μg at/l) for the high phosphate concentration (3μg at/l). The standard deviation for oxygen determination was less than ±0.05 ml/l for the concentration range of 0.5-5 ml/l.

Methods of analyses

Dissolved oxygen	Winkler method
Phosphate, inorganic	Denigés-Atkins method
Silicate	Silico-molybdate method
Nitrate	Müllin-Riley method
pH	Glass electrode method

Results of observation and considerations

It was recognized that in the distribution of chemical constituents along meridional line there is a common trend regardless the difference in meridian.

Fig. V-5-1 shows the vertical distribution of salinity along the meridional line 78°E. With respect to the salinity of water below 700 m depth which has

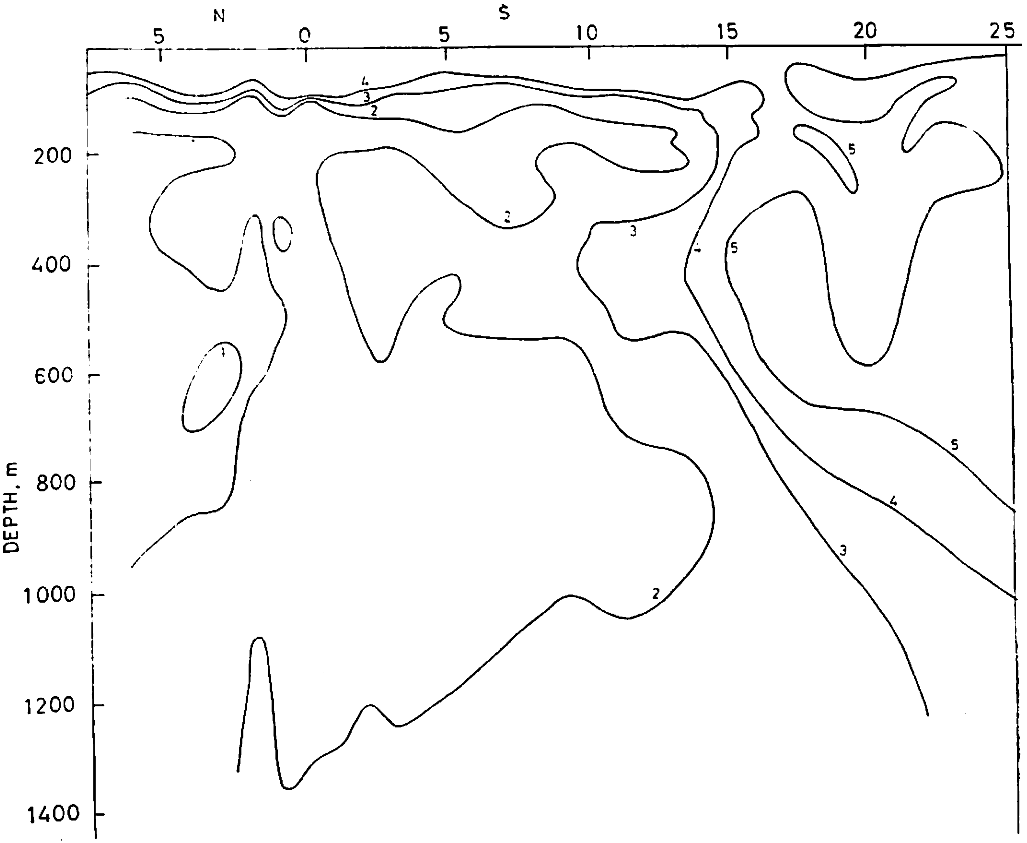

Fig. V-5-2. Distribution of dissolved oxygen (ml/l) along the meridional line 78°E.

σ_t larger than 27.0 in density *in situ*, it is higher in the north and lower towards the south. On the contrary, in the layer shallower than 700 m, the salinity is high in both north and south and shows the minimum around 10°S, in the middle of the meridional line. In Fig. V-5-2 the vertical profile of dissolved oxygen along the same meridional line is shown. Two minima of dissolved oxygen content are observed respectively at about 200 m and 1000 m. The depth of the second oxygen minimum increases from 600 m to 1300 m from north towards south. Between two minima of oxygen, the maximum layer of oxygen enters from the south.

Fig. V-5-3 shows the oxygen versus σ_t. From this figure, one can see that the shallower oxygen minimum appears at the layer with σ_t range of 25.0 to 26.5 and the deeper one at the layer σ_t, 27.0 to 27.6. When we see the increase of depth or increase of σ_t of the oxygen minimum towards the south where the occurrence of the oxygen maximum layer is remarkable, or the splitting of oxygen minimum layers into two above and below the oxygen maximum layer, it may be said that the oxygen minimum layers are strongly

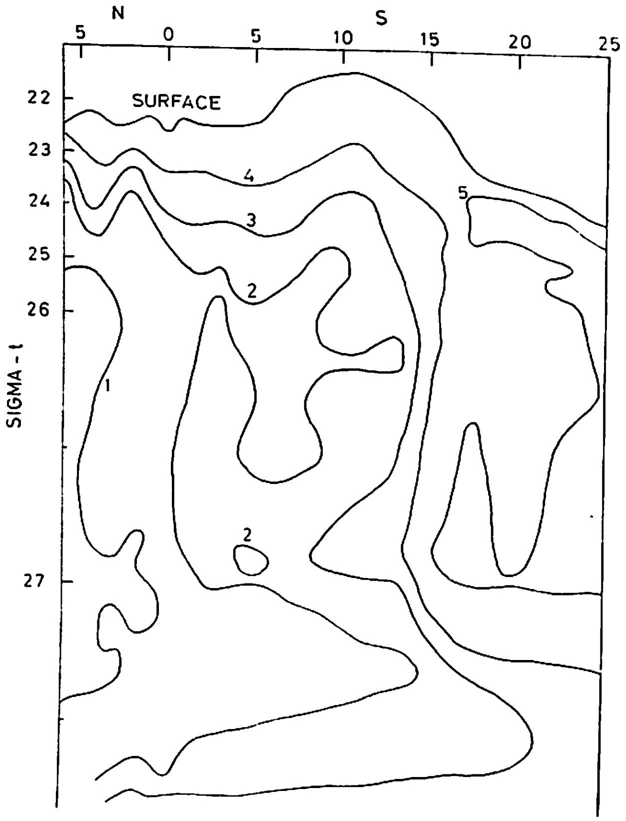

Fig. V-5-3. Distribution of dissolved oxygen (ml/l) against σ_t along the meridional line 78°E.

affected by the oxygen maximum layer. In other words, if there is no oxygen maximum layer of which central core is in the south, there will be no splitting of oxygen minimum layers and the range of σ_t value at the oxygen minimum layer will be narrower.

A similar distribution to the oxygen maxima and minima in the Indian Ocean is also observed in the Southern Pacific[3] and Southern Atlantic[4] waters as well. Probably, these peculiar stratifications of the oxygen may be caused by the same kind of mechanism.

Fig. V-5-4 shows the distribution of the so-called AOU (apparent oxygen utilization) that is the difference between the saturated and observed amounts of oxygen. The distribution resembles that of oxygen in the relative sense. It is to be noted that there is a steep inclination on the north-south direction at about 15°S. As will be stated below, there is a remarkable correlation between the amounts of oxygen and nutrient matter, therefore, it may be reasonable to say that there is also a corresponding, characteristic distribution in nutrient matter in this area of the ocean. It may be said that there is a boundary at about 15°S on both sides of which the property of the ocean

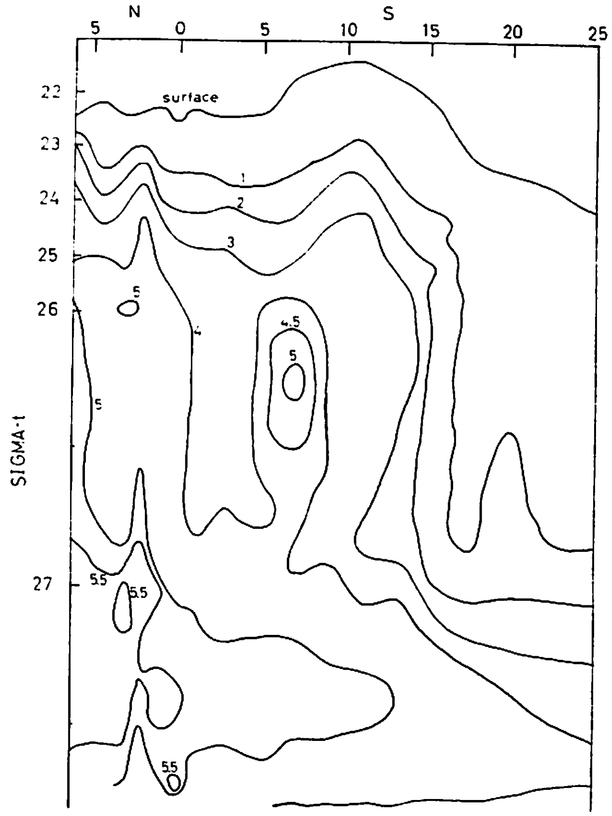

Fig. V-5-4. Distribution of AOU (m*l*/*l*) against σ_t along the meridional line 78°E.

differs considerably. Until now, it has been expected that the phosphate content in the Indian Ocean water is low (thus, we prepared a 10-cm long cell for photometric phosphate determination). This is true so far as for southern waters beyond 15°S are concerned, in which AOU is less than 1.0 ml/l down to the 700 m depth. This value is considerably lower than those in other oceans, from which the smaller concentration of phosphate is anticipated. The observation proved this true.

Fig. V-5-4 shows that the maximum of AOU splits into two layers which corresponds to the double layers of the oxygen minima shown in Fig. V-5-3. AOU decreases simply from the north to the south below the layer at which σ_t is 26.8. By comparing this tendency with Fig. V-5-1, it may be concluded that water with higher salinity and with σ_t of 27.0 to 27.2 has also higher AOU. According to ROCHFORD[5], the salinity maximum appears at the layer with σ_t 27.0 to 27.2. On surveying the distribution of the salinity on the isopycnal layer with σ_t 27.0 to 27.2, one can find the highest salinity near the mouth of the Red Sea. This suggests that the salinity maximum with σ_t

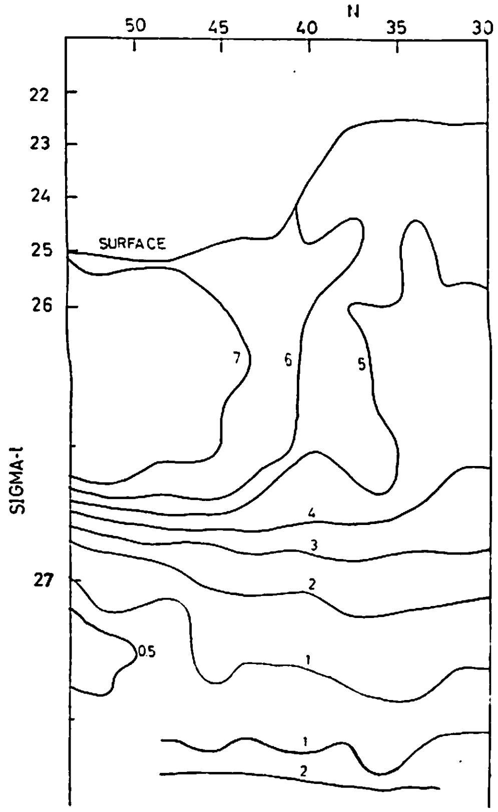

Fig. V-5-5. Distribution of dissolved oxygen (ml/l) against σ_t along the meridional line 165°E in the North Pacific.

27.0 to 27.2 is derived from the saline water in the Red Sea. As a matter of course, the presence of water with higher AOU is also expected near the Red Sea.

With respect to waters with σ_t 25 to 26, there are two different layers of water with high salinity respectively with a higher and a lower AOU. Water with high salinity and high AOU is located in the north while water with high salinity and low AOU is in the south. In the middle of the two, there is water with intermediate salinity and AOU values. According to ROCHFORD[6], high salinity water in the north is affected by saline water from Arabian Sea. Therefore, with the same reason above, the presence of water with high AOU may be expected near the Arabian Sea.

In summarizing the distribution of oxygen and salinity in the Indian Ocean, the maximum of salinity occurs at the layer with σ_t of about 27.2 above which (at about 26.85) there is a stretch of the oxygen maximum from south towards north. Consequently, the oxygen minimum splits into two layers. The central core of the oxygen minimum may exist in the north beyond 6°N. In this con-

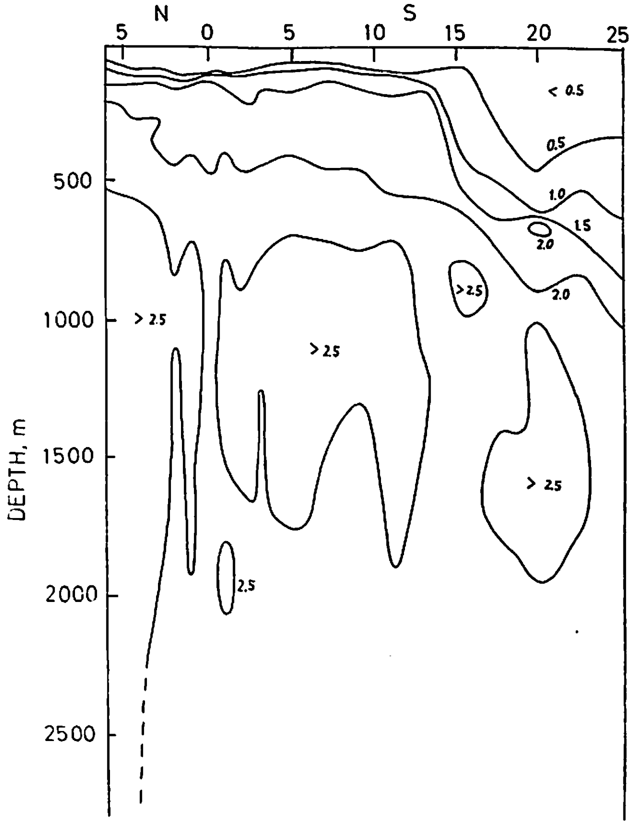

Fig. V-5-6. Distribution of phosphate concentration (μg at/l) along the meridional line 78°E.

nection, the observation aboard the R. V. Anton Bruun (May 22 to July 2, 1963) showed that the central core of the oxygen minimum was present north beyond 10°N. The separation of the central cores of the oxygen minimum and maximum respectively in the north and the south together with the splitting of the oxygen minimum into two layers are not observed in the North Pacific. As a comparison the vertical oxygen distribution along the latitudinal line 30°-54°N in the Pacific is given in Fig. V-5-5. As can be seen in Fig. V-5-5, central cores of both oxygen minimum and maximum coexist in the north and the oxygen minimum layer is single.

Figs. V-5-6 and 7 show the vertical profile of phosphate-phosphorus along the same meridional line as above. The distribution resembles those of oxygen and AOU which suggests the close correlation between them.

Fig. V-5-8 shows the relation between AOU and phosphate content. In this figure, waters with σ_t 27.0 to 27.4 are classified into six groups according to the chlorinity as follows: Cl 19.0-19.1, 19.1-19.2, 19.2-19.3, 19.3-19.4, 19.4-19.5 and >19.5‰ and the relation between AOU and phosphate is shown for each group of water. As shown in the figure, it seems that dots in the figure scatter around among six groups that makes difficult to identify dots belonging to each group. However, there is a distinct deviation between two groups, i.e. the first group consisting of Cl 19.0-19.1‰ and 19.1-19.2‰ and the other group with higher chlorinity. Dots which belong to each group are orienting close to each different line whose inclination ($\Delta O_2/\Delta P$) is 272 in the atomic ratio. The inclination is the same as that in the North Pacific[7].

The extrapolated value of concentration which is the intersection between the line representing $\Delta P/\Delta O_2$ and the ordinate is called " reserved phosphate concentration " or shortly RPC. This is the same as that which REDFIELD *et al* called previously " preformed phosphate "[8]. But, as there is some ambiguity in the term of " preformed ", the present authors prefer the name " reserved " to " preformed ". While RPC of water with the chlorinity 19.0-19.2‰ is 0.8-1.2μg at/*l*, it is a little lower (0.6-1.0μg at/*l*) for water with higher chlorinity (19.2-19.5‰). This indicates that RPC is higher in water with lower salinity.

As is already clearly seen in Fig. V-5-4, in water with σ_t 27.0-27.4, both AOU and salinity increased as going towards north. From the result of Fig. V-5-7, it is found that water in the south with lower AOU and higher oxygen content has higher RPC which decreases towards the north. It is to be noted that the RPC in water with high oxygen content and low phosphate is higher than that in water of low oxygen and high phosphate found in the north.

In the North Pacific, there is an area in the north beyond 45°N where the highest RPC is found[9]. Water in this area has σ_t 26.5 and it does not go to the deep as 300 m as in the Indian Ocean.

Fig. V-5-9 shows the distribution of RPC. Here again, making 15°S as a

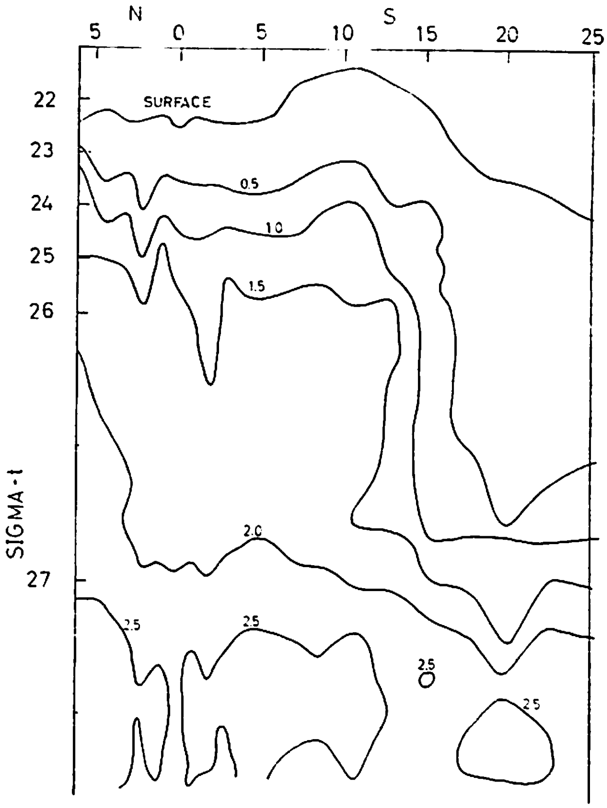

Fig. V-5-7. Distribution of phosphate concentration (μg at/l) against σ_t along the meridional line 78°E.

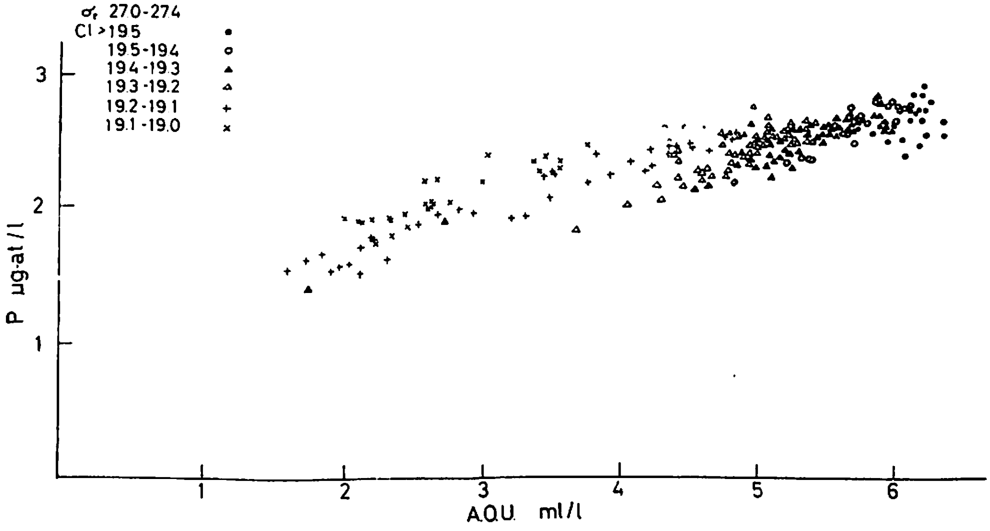

Fig. V-5-8. Relation between AOU and phosphate concentration.

boundary, the different features in the north and the south can be seen.

In comparing Fig. V-5-1 showing salinity distribution with Fig. V-5-9, it is seen that RPC is higher in water with σ_t 26.0 when salinity is low and RPC increases and salinity decreases south in water with σ_t 27.5.

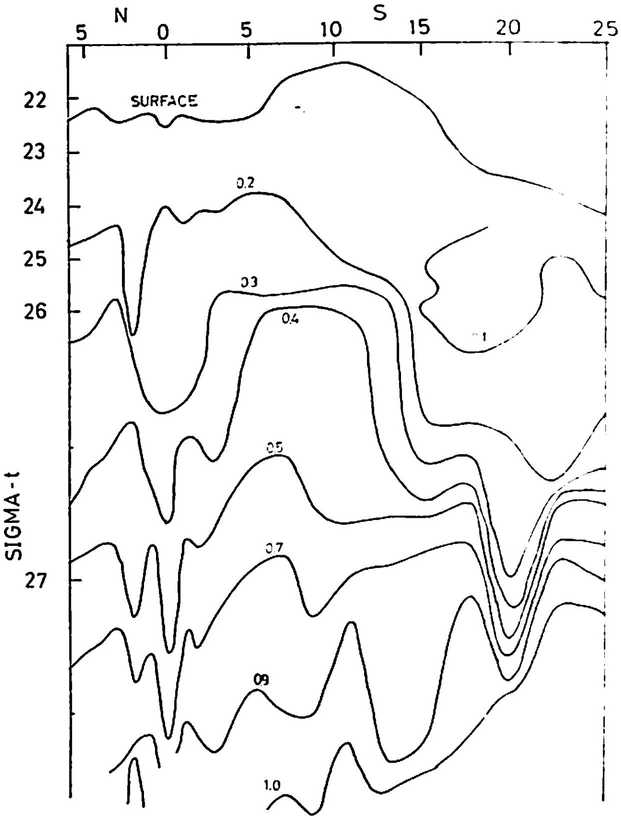

Fig. V-5-9. Distribution of reserved phosphate concentration (RPC, μg at/l) along the meridional line 78°E.

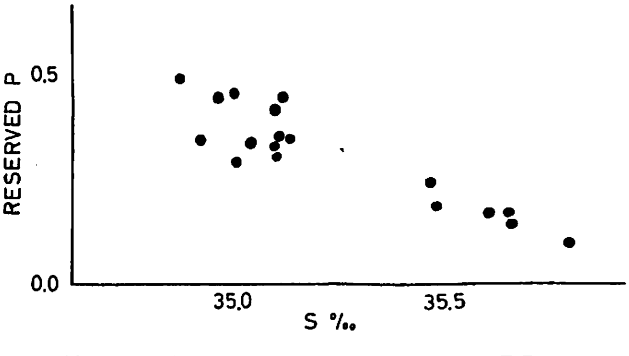

Fig. V-5-10. Relation between salinity and RPC (μg at/l).

In Fig. V-5-10 is shown as an example the relation between RPC and salinity for water with σ_t 26.3-26.5. The figure illustrates that in water with high salinity RPC is low. Characteristics in the RPC distribution are as follows: RPC is higher than 0.8μg at/l and salinity is 34.7-34.8‰ in water with σ_t 27.7 and higher which is located at the depth beyond 1500 m. In water at the salinity minimum layer which extends from the south, the salinity is lower than 34.6‰, σ_t is lower than 27.45 and RPC is higher than 1.0μg at/l. Around at 10°S there is a water mass with the salinity lower than 34.8‰ and lower RPC. beyond 15°S South, there is a water with salinity higher than 35.5‰ and RPC of lower than 0.2μg at/l.

Fig. V-5-11 shows the relation between AOU and silicate content using observed data obtained aboard R. V. Umitaka-Maru and R. V. Anton Bruun. The relation is examined according to the previous classification for chlorinity of water with σ_t 26.7-27.0. An approximately linear relation can be seen, for example, for water with Cl 19.4-19.5‰ but it shifts gradually to the right when the chlorinity increases. The same tendency is seen in both observations, except some difference in the values of silicate concentration against the same value of AOU.

The inclination of the linear part for water with AOU 3-5 ml/l is about

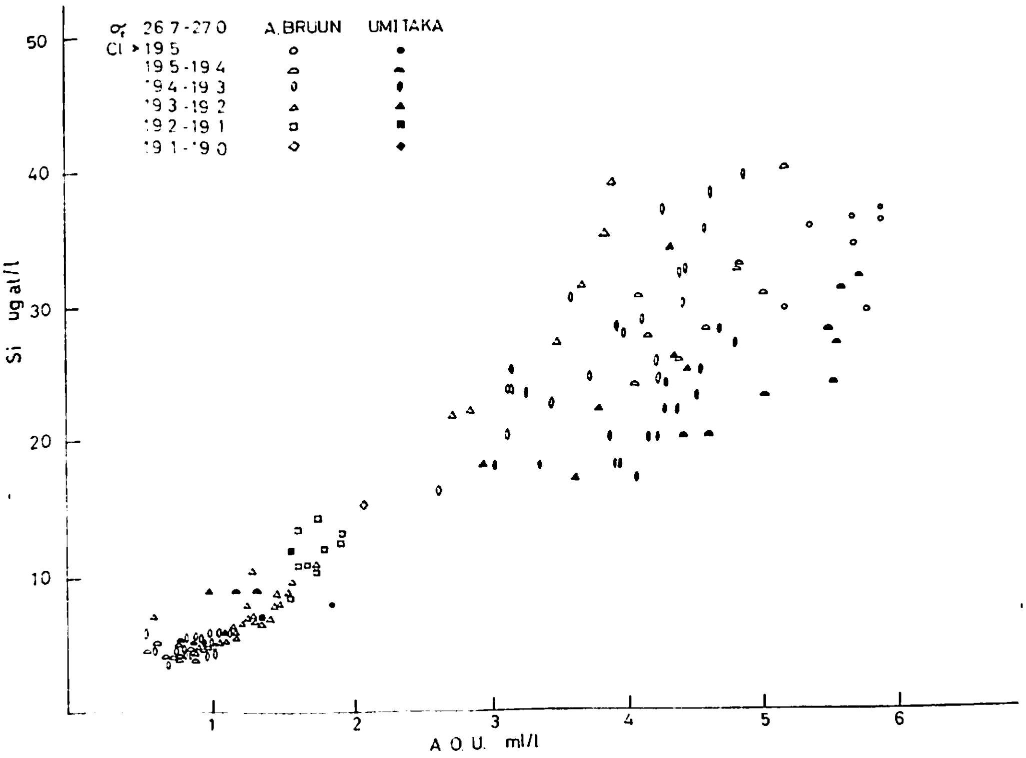

Fig. V-5-11. Relation between AOU and silicate concentration.

the same in water in the North Pacific (σ_t 26.7-27.0 which is shown in Fig. V-5-12[10)]. But it seems that the inclination is less steeper than the above in water with the same value of σ_t but smaller AOU. While dots for water of AOU less than 2 m*l*/*l* represent that at 400-800 m depth, those for AOU 3-5 m*l*/*l* represent water at 400-500 m level. That is to say, in this case even when water with the same σ_t is chosen, the value of AOU is smaller and the inclination is less steeper. In the North Pacific, as going deeper, both values of σ_t and inclination increases simply, however, in the Indian Ocean, depth and inclination sometimes differ against the same σ_t value. From those two examples, one can say that the inclination is controlled by the value of AOU rather more than by the depth or σ_t value.

The inclination of the line representing water with low AOU is smaller than that representing water with larger AOU. This is commonly illustrated in both examples above.

Assuming that the relation is linear, we extrapolate it to AOU=0, when we will obtain negative value of "reserved silicate concentration". This is quite different from the case of phosphate. To make RSC positive, the inclination must be smaller with the decrease of AOU. In conclusion, it may be considered that the regeneration of silicate depends on the degree of decom-

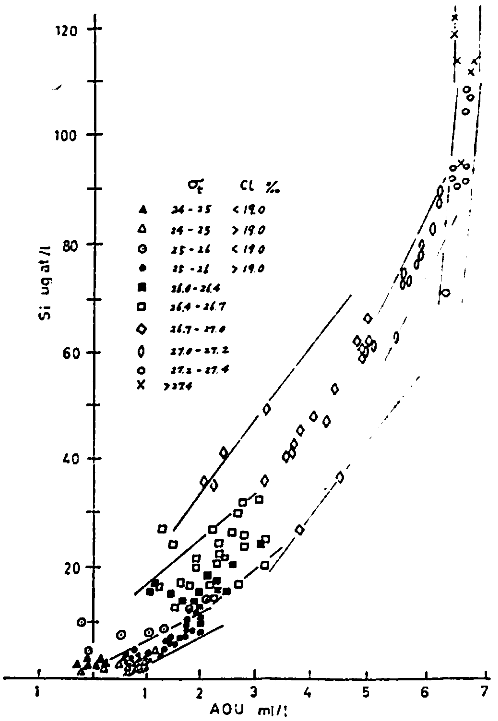

Fig. V-5-12. Relation between AOU and silicate concentration in the North Pacific.

position of organic matter which is represented by AOU. In other words, as the decomposition of planktonic material proceeds, the dissolution of silicate may be accelerated.

Figs. V-5-13 and 14 show the relation between AOU and nitrate concentration in waters respectively with 26.7-27.0 and 27.0-27.4. As in other cases, waters are classified according to the salinity. The relation between nitrate and AOU is less clear than that of phosphate and AOU. This may partly be due to the lower accuracy in determining nitrate than phosphate. However, it can be seen that nitrate content is higher in lower salinity water. The inclination $\Delta O_2/\Delta NO_3$ is something between 272/16 to 272/30 in water with chlorinity 19.0-19.1‰. As $\Delta O_2/\Delta P$ is 272/1, this value corresponds to $\Delta NO_3/\Delta P$ of 16-30, which is comparable to the averaged value of 16 in plankton given by FLEMING[11].

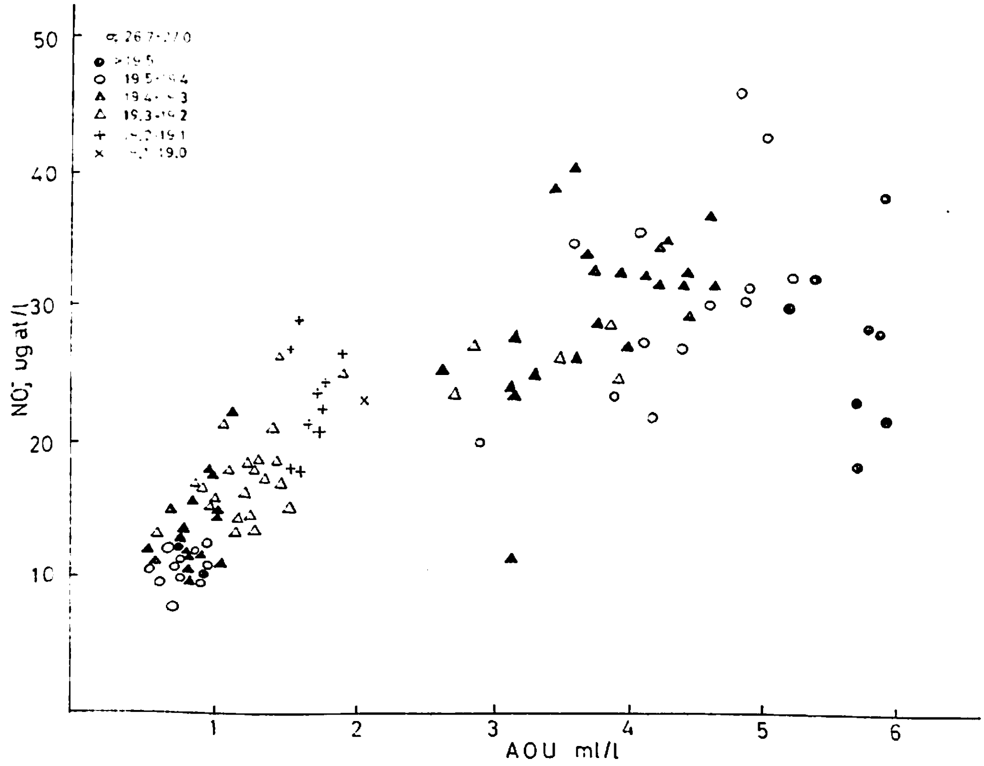

Fig. V-5-13. Relation between AOU and nitrate concentration.

Some of minor constituents in sea water in the Indian Ocean were also analyzed. Among them, the analytical results of molybdenum and vanadium will be described below. Molybdenum content in 30 water samples collected from the Indian Ocean during the 1962-63 cruise of Umitaka-Maru was determined. The values from 20 stations, UI-1 to UI-20, range from 0.115μg

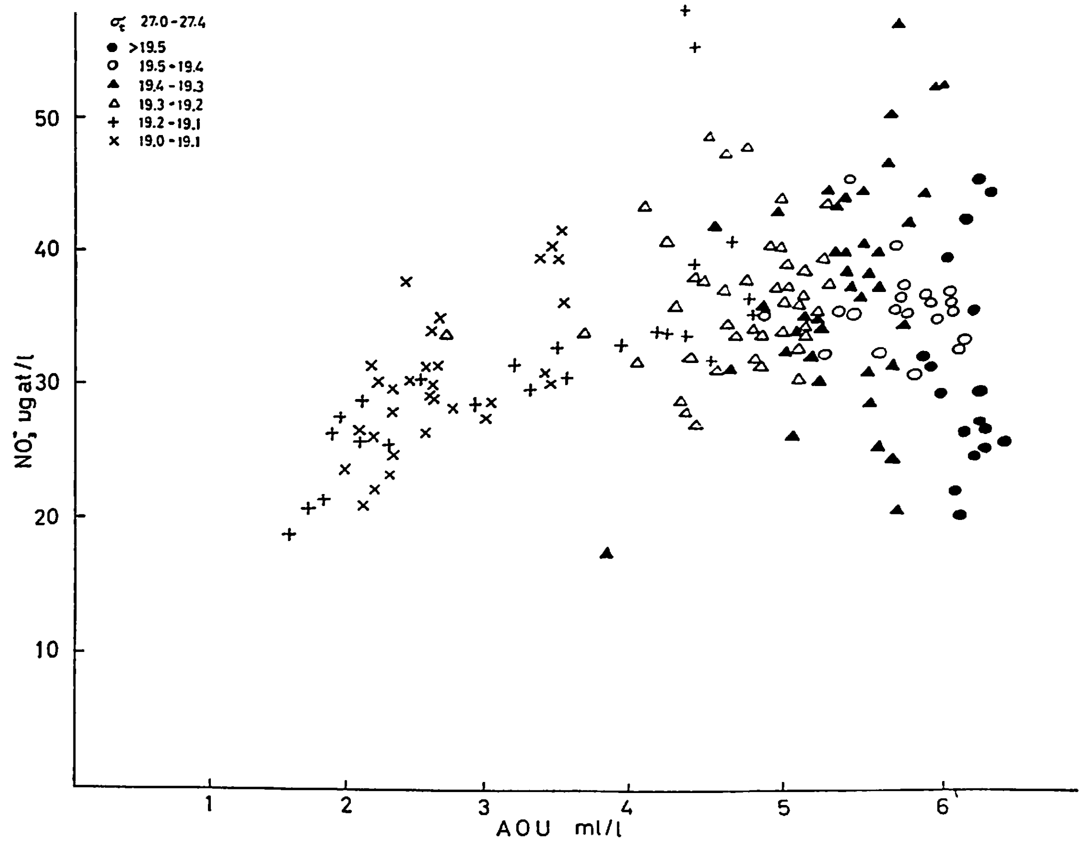

Fig. V-5-14. Relation between AOU and nitrate concentration.

at/kg to 0.123μg at/kg with an average 0.12μg at/kg. The result confirms the previous conclusion[12,13] that the Indian Ocean is highest in the molybdenum content among the oceans so far explored. Vanadium content in the Indian Ocean ranges from 0.033μg at/kg to 0.045μg at/kg with an average 0.039μg at/kg. The values are generally higher than the previous data in the same ocean, which were uniformly 0.033 μg at/kg for 9 different stations. Then, the total average for the Indian Ocean including old and new values becomes 0.035μg at/kg, which is slightly lower than the world average, 0.037μg at/kg.

Note: This article was written by Y. MIYAKE and Y. SUGIURA based on the reports submitted by;

S. KANAMORI	Nagoya University
A. KANAZAWA	Kagoshima University
Y. MORITA	Tokyo University of Fisheries
S. OKABE	Fukuoka Gakugei University
K. SHATSUKI	Shimonoseki University of Fisheries
T. SHIMANO	Japan Hydrographic Office
K. SUGAWARA	Research Institute of Natural Resources

S. Tagawa Shimonoseki University of Fisheries
K. Yamamoto Maizuru Marine Observatory.

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V–6. Primary production

Working Group for Primary Production

The determination of primary production by means of ^{14}C and plant pigment was carried out by many Japanese research ships including Oshoro-Maru, Hokkaido Univerity, during their 1962-1964 cruises of the International Indian Ocean Expedition.

The majors results are as follows.

1) As previously expected, the primary production was found to be very low in the eastern region of the Indian Ocean with values near those in the Kuroshio region.

2) High values were observed in the sea region southeast of Java Island as found in the Oyashio region.

3) Covering the whole explored area, at levels ranging from 50 to 125 m, which constituted the upper part of the thermocline, the enrichment of chlorophyll substances was found, which had already lost the photosynthetic activity.

Methods used.

The general procedure of the determinations of photosynthesis and plant pigment was as follows, which partly differed from one ship to another.

Water sampling.

Samples were collected at each station at 9-11 a. m. from depths, 0, 10, 25, 75, 100, 125, 150 and 200 m., by using a nonmetallic Van Dorn type sampler of a 12 1 capacity.

A newly made vinyl chloride sampler proved to be toxic to phytoplankton and lower its photosynthetic activity. After the sampler has been immersed in sea water for a sufficient time, the sampler became completely free from the toxity.

Measurement of photosynthesis.

"Tank method" was applied at all the stations for measuring photosynthesis, while "in situ method" was used at stations, where the situation favored at each level from the surface down to 100 or 125 m. During the 1962-1963 cruises, a set of two bottles, one light and one dark, was placed at each level, while during the 1963-1964 cruises a set of three bottles, two light bottles and one dark bottle, was used to increase accuracy. The reagent bottles were of Tyston brand with a capacity of 250 ml. Ampouled 10 μc/ml $Na_2{}^{14}CO_3$ solutions were supplied by Daiichi Kagakuyakuhin Co., the activity of which was kindly calibrated by Mr. H. Jitts, C. S. I. R. O., Australia.

Tank method.

Immediately after the sample water was collected, it was divided into a certain number of bottles. After the addition of the ^{14}C solution, they were illuminated for four hours in an incubating tank with a temperature regulated to that of the surrounding surface water. The illumination was made from the bottom of the vinyl chloride transparent tank by six 30 W fluorescent lamps having a reflector. The total exposure was approximately 12,000 lux. Then the water was filtered through a Millipore HA type filter of diameter 24 mm. The residue was washed with 0.001 N HCI in 3% NaCl solution and 3% NaCl solution, then placed in a dessicator to dryness. Radioactivity was measured for the dry sample by using 2π gasflow counter, partly aboard ship and partly in a land laboratory after it was transported to Japan.

The photosynthetic rate was calculated by subtracting the count of the dark bottle from that of the light bottle where the total CO_2 was assumed to be 90 mg/l.

In situ method

Sets of test bottles were kept hanged from a bouy down to different depths from noon to sunset. Excepting this, the bottles were processed the same as in tank method.

Unusually high values were often met for the dark bottle, which rarely occurs in the ocean of temperate zone. A rapid growth of bacteria on the inner wall of the bottle proved to be responsible for these high values. A previous treatment of careful washing and heat sterilization of the bottle was shown to be quite effective for avoiding the high values.

Measurement of plant pigment.

A sample of 6 to 8 litres was filtered through a Millipore HA type filter. After having been steamed for 30 seconds and dried in a dessicator, the filter was transported to Japan being kept frozen in the dark. Then it was dissolved in 92% acetone and subjected to sonification (10 KC) for 5 to 10 minutes. After 24 hours storage in a refrigerator, the solution was put to centrifugation for 10 minutes at more than 10,000 G.. The optical density of the solution was determined at wave-lengths 750, 665, 645, 630, 510 and 480 mμ by using a spectrophotometer of Hitachi or Shimazu. The error of determination caused by turbidity was eliminated by subtracting the 750 mμ value from the values for other wavelengths.

Results and discussions.

1. Photosynthetic rate.

Except the sea region southeast of Java Island, where upwellings were observed, the photosynthetic rate was generally low. Thus the rate for the surface water was relatively high with values ranging 0.2 to 0.4 mgC/m³/hr in the region west of 100°E and north of 5°S, while it dropped down to 0.1 mg C/m³/hr in the south. As for the region east of 100°E, the area north of 10°S is characterized by high values greater than 0.4 mg C/m³/hr and the area south of 10°S is by low values 0.1 to 0.3 mg C/m³/hr. Vertically the photosynthetic rate increasing from the surface reaches a maximum. Along 78°E this maximum was found at the layer 25 m deep in the north, and tended to go down deeper to the depths 50-75 m towards south. It is remarkable that these maximum photosynthetic layers from tank method lie deeper than the corresponding layers as revealed from in situ method. The same relation is also clear along 106°E and 113°E but not so clear along other latitudinal lines.

Two series of data of observation repeated successively during 1962 1963 and 1963-1964 along 78°E show that the data for 1962-1963 were higher than those for 1963-1964. Along same latitudinal line, the equatorial region was characterized by a high photosynthetic rate with values ranging 0.6 to 1.0 mg C/m³/hr in 1962-1963 cruise.

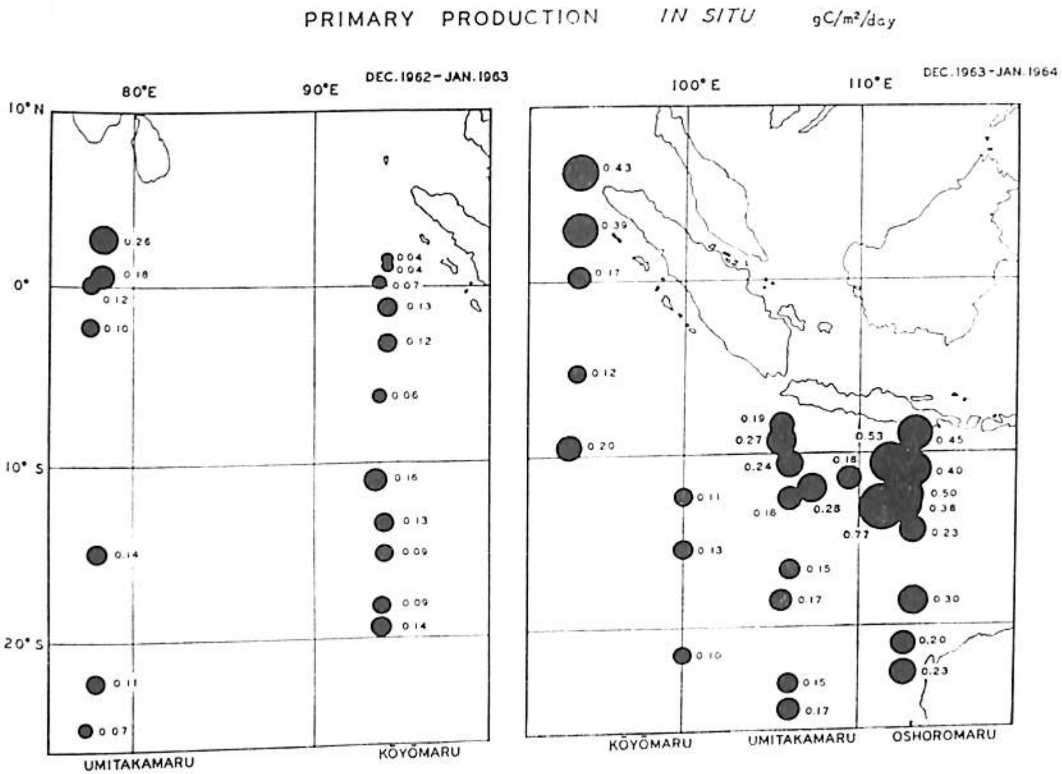
2. Primary production, the photosynthetic rate as calculated from in situ data.

The diurnal primary production was calculated by doubling the half-day in situ observation datum. For the whole explored region, the value ranged 0.1 to 0.2 g C/m²/day except high values ranging 0.3 to 0.7 g C/m²/day from the southeast sea area of Java.

3. Amount of plant pigment.

The amount of chlorophyll-a was generally low excepting near shore waters. As for the surface water, it was around 0.1 mg/m³ in the north area of the west region of 100°E, and below 0.05 mg/m³ in its south area., while the east region of 100°E showed generally 0.05 mg/m³.

Deeper layers showed hardly values exceeding 0.2 to 0.3 mg/m³. It is worth noting that the chlorophyll-a maximum was found in layers of 50 to 150 m deep forming the bottom of the euphotic zone. These layers lying at a depth 50 to 75 m in the area near equator lay at depths of 100 to 125 m in the south. It is also remarkable that these layers correspond to the upper limit of thermocline, and that the greater portion of the chlorophyll found there had already lost the photosynthetic activity as shown from the comparison of the data with those from the photosynthetic rate measurement.



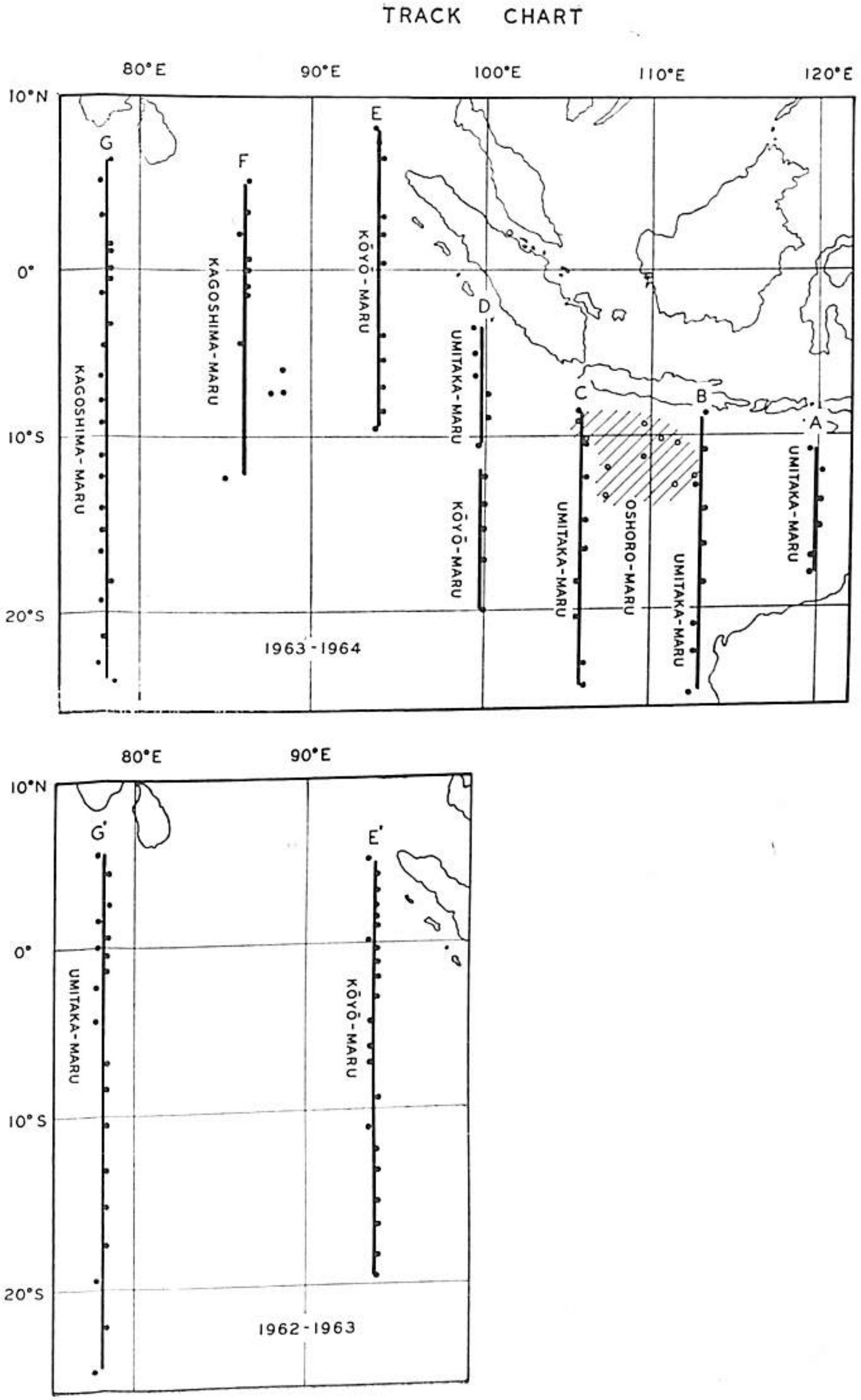


Fig. V-6-1. Tack charts and primary production.

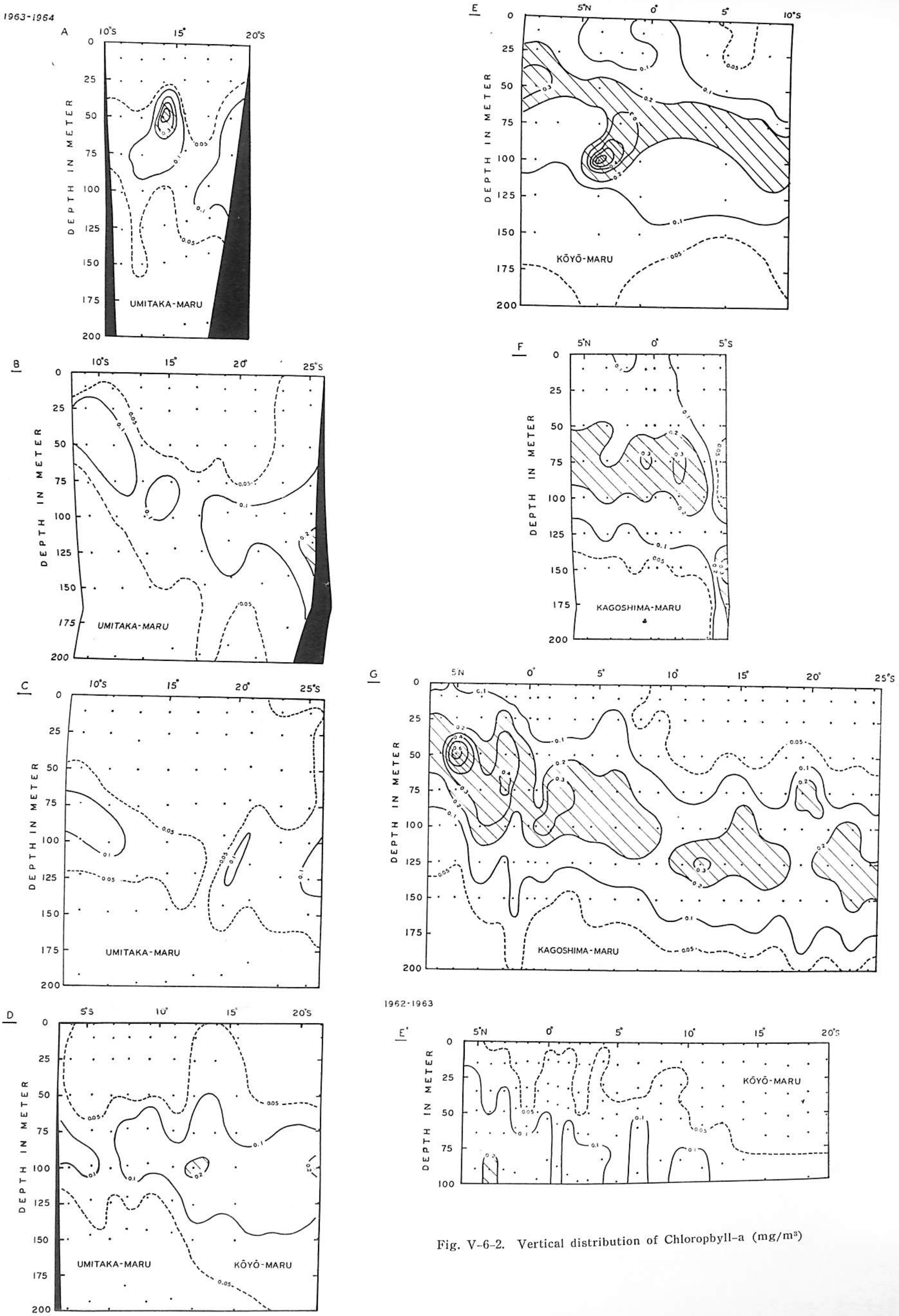


Fig. V-6-2. Vertical distribution of Chloropbyll-a (mg/m³)

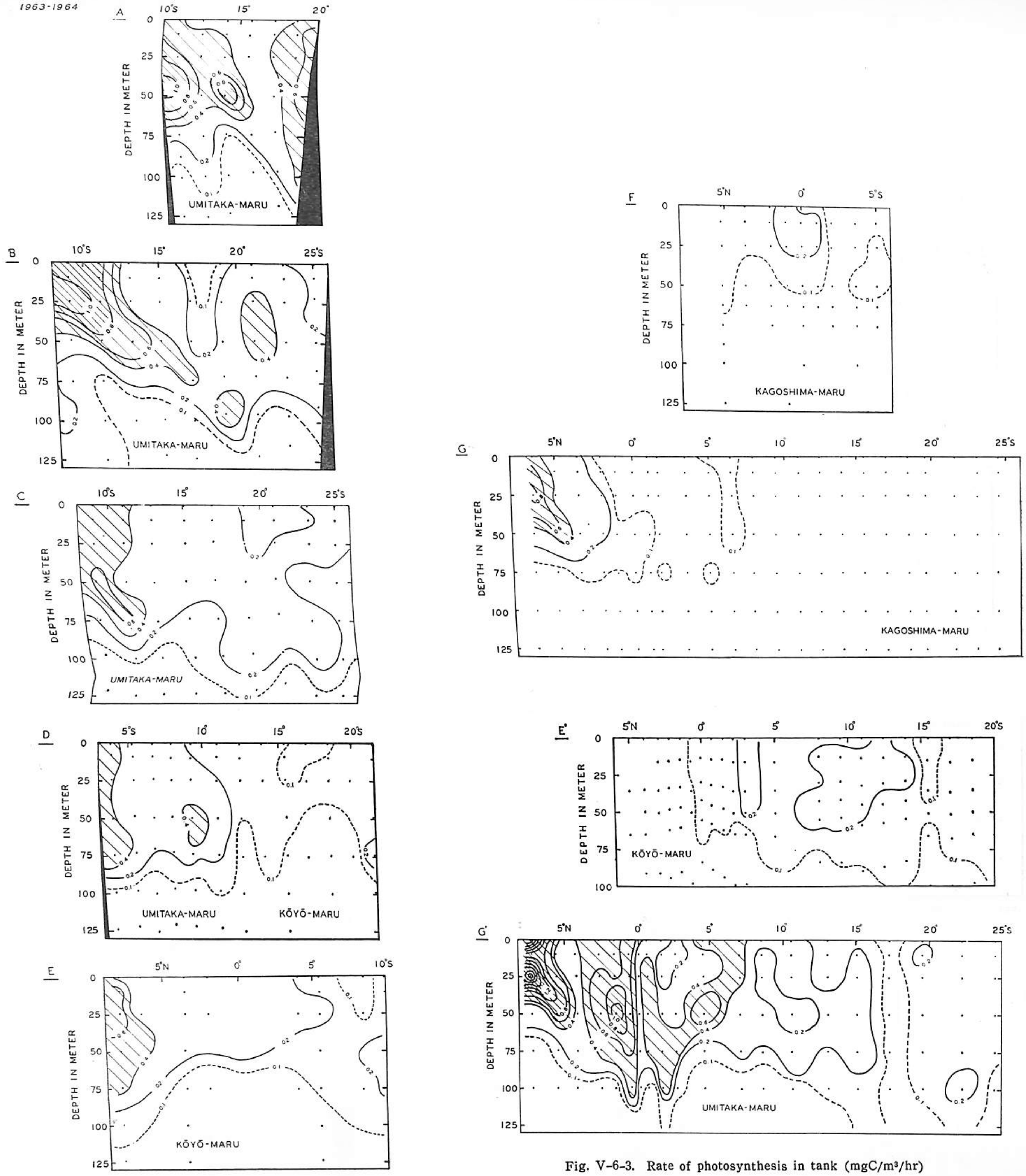


Fig. V-6-3. Rate of photosynthesis in tank (mgC/m³/hr)

Note: The present article was written by K. SUGAWARA and Y. SAIJO by using the reports submitted by the following experts.

Ship Cruise
Yatsuka SAIJO, Umitaka-Maru, the first cruise (1962-1963).
Ichitaro SAKAMOTO, „ , the second cruise (1963-1964).
Kaoru TAKESUE, Koyo-Maru, the first cruise.
Kaoru TAKESUE & „ , the second cruise.
Akihiro SUENOBU,
Takuro ENDO, Kagoshima-Maru, the 1963-1964 cruise.
Teruyoshi KAWAMURA, Oshoro-Maru, the 1963-1964 cruise.

Reiji NOZAWA was in charge of treating samples after they were transported to Japan.

V–7 Marine Biology

Working Group for Marine Biology

The Japanese program of the IIOE has been conducted by the training ships of the fisheries colleges in addition to their regular schedule of training cruises. The limitation of time available for the research work and the multiplicity of the research program forced us to undertake each observation by compromise. All participating ships were obliged to do primary production *in situ* experiment and zooplankton standard hauls as a minimum requirement of the biological observations, but it was strongly recommended that they also make as many more extensive and detailed biological samplings as possible according to their interests. At nearly all hydrographic stations zooplankton samplings with the Indian Ocean standard net were made, and the samples were sent to the Indian Ocean Biological Centre which was established at Ernakulam, South India, through the assistance of UNESCO, primarily for the purpose of gathering and sorting the zooplankton samples taken by the standard method on all ships participating in the IIOE. Samples taken by methods other than the standard hauls were kept at the institutions which have made samplings. The priority of processing those samples would be held by the respective institutions, but it is requested that the institutions holding the samples provide those which are not needed by specialists in their own institutions to the specialists in any organization. Since the studies on the biological specimens are beginning, this report concerning the collections of plankton and fish, and bacteriological observations deals with mainly the methods and gear used, location and date of samplings, names of the ships and institutions which have made samplings, place where the samples are stored, and so on. Report on the work of primary production and chlorophyll will be prepared by other sub-group of W/G in Biology. (S. Motoda)

1. *Microplankton samples gathered by settling method.* (Table V-7-1)

The purpose of the sampling was to estimate quantitatively the distribution of microplankton at various depths in the euphotic zone. At all stations where the primary production *in situ* or tank experiments were made, two litres of water were sampled at the same time and from the same depth, as in the sampling of water for chlorophyll determination. The depths of sampling were usually 0, 10, 25, 50, 75, 100, 125 and 200 metres. Although the amount of water sampled might have been insufficient for collecting the microplankton in a tropical ocean, shortage of capacity of the sampler and storing bottles, space of stores, etc. did not allow us to sample larger amounts of water. The sample water was stored with formalin and brought back to

Table V-7-1. Sampling of microplankton by settling from two litres of water.

No.	Ship	Institution	IIOE cruise No.	Date	Number of stations occupied	Meximum depth of sampling (m)	Number of depths of sampling	Number of samples collected	Place where samples are stored
1	Um	TUF	1	Dec. 10, 1962 —Jan. 7, 1963	20	200	9	180	TUF
2	Ka	FFKU	2	Nov. 26, 1963 —Jan. 8, 1964	21	200	9	180	FFKU
3	Ko	SUF	2	Nov. 16, 1963 —Jan. 30, 1964	22	200	9	180	SUF
4	Um	TUF	2	Nov. 2, 1963 —Feb. 12, 1964	65	200	9	180	TUF
5	Os	FFHU	2	Dec. 13-25, 1963	12	200	9	180	FFHU

Table V-7-2. Sampling of microplankton by vertical hauls with fine-mesh net.
(0.095mm mesh, 80cm Juday net)

No.	Ship	Institution	IIOE cruise No.	Date	Number of stations occupied	Maximum depth of haul (m)	Number of samples collected	Place where samples are stored
6	Um	TUF	1	Dec. 10, 1962 —Dec. 16, 1963	4	1500	10	TUF
7	Ko	SUF	1	Nov. 23, 1962 —Jan. 15, 1963	24	3000	68	SUF
8	Ka	FFKU	2	Nov. 26, 1963 —Jan. 9, 1964	11	2000	38	FFKU
9	Ko	SUF	2	Nov. 23, 1963 —Jan. 8, 1964	11	3000	49	SUF

land; then the materials contained in the sample water were concentrated by settling and centrifugal methods. The studies on μ-flagellates in the tropical ocean are thought to be very interesting, but the preservation of those organisms in the stored samples was impossible. (S. MOTODA

2. *Plankton samples callected by vertical hauls with 80 cm Juday type closing net (0.095 mm mesh).* (Table V-7-2)

This work was planned to obtain small planktonic organisms by hauling a comparatively fine-mesh net through great depth. The filtering cloth used for the net was the bolting silk, XX 13, 129 meshes per inch, approximately 0.095 mm X 0.095 mm mesn openings. It was desirable to enlarge the mouth of the net as much as possible because the plankton in the deep water was supposed to scarce, but it could not be enlarged to the extent that the sinking velocity of the net would be impaired. A Juday type net consisting of a cylindrical canvas portion in the anterior and a filtering cone in the posterior was employed (MOTODA, 1962. *Inform. Bull. Planktol. Japan*, No. 8, p. 30). The dimension of the net was 80 cm in diameter at the mouth ring, 125 cm in length of canvas cylinder, 80 cm in diameter at trunk ring at the connection between the canvas cylinder and the filtering cone, 3200 cm in length of filtering portion tapered from 80 cm to 10 cm in diameter at the cod end. While the net was hauled vertically from the great depth, e. g., 3000 m, for a certain distance, a messenger weight was slid down along the wire cable to meet the release mechanism on the net so that the net was closed on time at desired depth. The hauls could not be stopped on the way, otherwise some of the materials which had been collected in the net would spurt out or escape from the net (NISHIZAWA and ANRAKU, 1956. *Bull. Fac. Fish., Hokkaido Univ.* Vol. 6, p. 298). When the messenger weight released a mechanism (similar principle to that of Discovery type) (MOTODA, 1963. *Inform. Bull. Planktol. Japan*, No. 9, p. 37), the bridles of the net were released from the wire cable, and the net became suspended by a line connected with the trunk ring, resulting in the closing of the net. Probably as much material did not spurt out from the mouth of net at the moment of the closing of the net, as is usual in the ordinary throttling net (cf. BARNES, 1949. *Jour. Mar. Biol. Ass.*, Vol. 28, p. 429). However, the amount of samples collected with this deep closing net was usually very small. A flow-meter was mounted at the center of the mouth ring, but almost all samplings failed to obatin quantitatively accurate samples. Notwithstanding the fact the release mechanism was very simple in construction, it frequently did not work properly, mainly due to poor manufacturing. The work was really time-consuming and samplings failed many times. (S. MOTODA)

3. *Plankton samples collected by vertical or horizontal hauls with 25 cm Hart type closing net (0.095 mm mesh)* (Table V-7-3)

As a supplemental work to the 80 cm Juday closing net, a small Hart type closing net made of bolting silk of the same mesh as the Juday net was hauled on some occasions. The dimension of the net was 25 cm in diameter at the mouth ring, 40 cm in length of truncated canvas cone, 30 cm in diameter at the trunk ring, and 100 cm in length of filtering cone tapered from 30 cm to 4 cm in diameter at the cod end. The performance of the net was quite satisfactory, but the small size of the net always yielded very few materials. During the latter part of cruise 1962-63 of the "Umitaka Maru" several numbers of this type of the net were hauled horizontally by attaching them to the inside of the 160 cm ring net (cf. 7). (S. MOTODA)

4. *Standard plankton samples collected by 0-200 m vertical hauls with IOSN (0.33 mm mesh)* (Tables V-7-4, V-7-5)

At the meeting of zooplankton workers assembled in India in August 1962, prior to the beginning of the IIOE, the value of standardization of zooplankton sampling in the IIOE was discussed. According to the agreement obtained at this meeting it was recommended that all ships participating in the IIOE should make samplings of zooplankton by 0-200 metre vertical hauls (at a speed of 1 m/sec) at about 8.00 p. m. using an Indian Ocean standard net. The standard net designed by CURRIE was 113 cm in mouth diameter, 70 cm in length of cyindrical coarse netting, 30 cm wide band of sail cloth, 100 cm in length of cylindrical filtering portion, 300 cm in length of filtering portion tapered from 113 cm in diameter at the cod. The filtering cloth should be of approximately 0.33 mm X 0.33 mm mesh openings, *i. e.*, Müllergaze Nr. 3 (corresponding to Japanese bolting silk GG 54) (CURRIE, 1962. *Nat. Inst. Oceanogr. Intern. Rep.*, B 1 ; MOTODA, 1962. *Inform. Bull. Planktol. Japan*, No. 8, p. 26; TRANTER 1963. SCOR-UNESCO Zooplankton Intercalibration Test. IIOE. Cronulla).

The purpose of the standard sampling was to obtain comparable data on zooplankton biomass as well as to obtain complete samples for biogeographical studies of zooplankton species in the upper waters of the Indian Ocean covering as wide an area and a many seasons as possible. To meet the convenience of every ship the standard method could not be too complicated; the method had to be selected which could be operated even on the most poorly equipped vessel participating in the IIOE. However, the standard net selected was fairly large and cumbersome, and the handling in vertical hauls was quite laborius. Some workers preferred to use a smaller and more convenient type like the Clarke-Bumpus sampler, but there was as strong feeling that a small net would not benefit us in collecting the sparsely distributed plankton in the tropical ocean. The coarse netting in the upper portion was

Table V-7-3. Sampling of microplankton by vertical or horizontal hauls with small fine-mesh net. (0.095 mm mesh, 25 cm Hart net)

No.	Ship	Insti-tution	IIOE cruise No.	Date	Number of stations occupied	Method of haul	Maximum depth of haul (m)	Number of depth of haul	Number of samples collected	Place where samples are stored
10	Um	TUF	1	Dec. 6, 1962 —Jan. 16, 1963	7	Vertical	2850	14	25	13 TUF 12 Dr. Durairatnam
11	Um	TUF	1	Dec. 29, 1962 —Jan. 7, 1963	5	Horizontal	642	9	9	TUF
12	Os	FFHU	1	Dec. 13, 1962 —Jan. 4, 1963	2	Vertical	3830	9	3	FFHU

Table V-7-4. Sampling of zooplankton by standard method with IOSN (0.33 mm mesh, 113 cm in mouth diameter) (0-200 m vertical haul).

No.	Ship	Institution	IIOE cruise No.	Date	Number of stations occupied	Number of samples collected	Place where samples are stored (with number of samples)	Number of samples sent to IOBC
13	Um	TUF	1	Dec. 19, 1962 —Jan. 7, 1963	20	40	TUF(20)	20
14	Ko	SUF	1	Nov. 23, 1962 —Jan. 15, 1963	26	51	SUF(25)	26
15	Os	FFHU	1	Dec. 12, 1962 —Jan. 19, 1963	51	84	FFHU(36)	48
16	Ka	FFKU	2	Nov. 26, 1963 —Jan. 9, 1964	32	64	FFKU(32)	32
17	Ko	SUF	2	Nov. 23, 1963 —Jan. 25, 1964	21	42	SUF(21)	21
18	Um	TUF	2	Nov. 21, 1963 —Jan. 22, 1964	28	56	TUF(28)	28
19	Os	FFHU	2	Dec. 13, 1963 —Dec. 26, 1964	14	26	FFHU(13)	13

Table V-7-5. Calculated zooplankton biomass (mean values in 2° Lat. X 2° Long. grid area) based on the materials of standard hauls with IOSN. (*Inform. Bull. Planktol. Japan*, No. 11, pp. 26-29, Tables 5, 6)

Latitude	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³	Number of stations	Mean displacement cc/1000m³
08°N～06°N	2	74.5																		
06°N～04°N	1	38.0			3	16.9														
04°N～02°N	1	46.0			2	21.4														
02°N～00°	3	101.1	1	51.9	3	42.1														
00° ～02°S	2	72.9			2	33.7														
02°S～04°S	1	65.7			3	31.0														
04°S～06°S	1	101.5			1	24.1														
06°S～08°S	1	78.9			2	63.1	2	19.9												
08°S～10°S	1	24.9			1	34.0	2	33.2			1	47.3								
10°S～12°S	1	21.7			1	20.8	1	31.0	4	42.5	3	29.3	2	19.9	3	55.8			2	36.3
12°S～14°S	1	38.4			2	22.4			2	48.8	2	33.1			2	51.3			2	17.7
14°S～16°S	1	49.8			1	18.4									1	52.8			2	23.3
16°S～18°S	1	28.1			1	13.8			4	37.5	1	40.3	1	40.2	1	36.6			2	35.0
18°S～20°S	1	8.5			2	16.0					1	58.2			1	62.9	1	60.6		
20°S～22°S											2	57.4			1	80.5				
22°S～24°S	1	24.4											2	45.7	1	133.0				
24°S～26°S	1	16.5																		
31°S～33°S															2	26.0				
Longitude	77°E～ 79°E		90°E～ 92°E		93°E～ 95°E		104°E～ 106°E		106°E～ 108°E		108°E～ 110°E		110°E～ 112°E		112°E～ 114°E		114°E～ 116°E		117°E～ 119°E	

designed to make possible fast sinking of the net. Oblique hauls might have been better than the vertical hauls to collect sufficient number of animals as well as to eliminate errors of abundance of animals due to the patchiness in their distribution. However, many ships working in the IIOE did not facilitate such work and frequently the ships had to work more than two items at the same time by stopping the motion. The net was lowered by attaching a 40 kg sinker to the depth of 200 metres which was estimated by the angle of wire cable on deck and the length of wire cable to be run out. This estimation was made when the wire cable was run out to the depth of 170 metres or so, and special attention was given to haul the net immediately after it had reached to the desired depth, otherwise the net would sample the plankton horizontally at the depth of 200 metres due to the drift of the ship. The haul could not be stopped until the net was raised above the sea surface, otherwise some of materials inside the net would be lost (NISHIZAWA and ANRAKU, *loc. cit.*). The sea was rarely calm at open ocean, and virtually vertical plankton hauls at sea were rather like oblique hauls. Japanese ships did not maneuver to keep the wire cable suspended vertically during the operation, and so usually the wire cable which had been run out drifted away from the ship during the plankton vertical hauls as much as or more than a 30 degree angle of wire. A flow-meter was mounted at the center of the mouth ring of the net to register the amount of the water filtered by the net. However, the action of the flow-meter was frequently unreliable, and it was impossible to calculate the amount of water filtered by the net in each individual sampling by the flow-meter reading. Estimation of the amount of water filtered by the net, therefore, was made without using readings of the flow-meter at individual samplings, but using a formula obtained by averaging all data. The formula gives the relation between the angle of wire cable (which corresponds to the length of wire cable paid out so as the net reaches the estimated depth of 200 metres) and the distance of the path of the net (corresponds to the volume of water filtered) (MOTODA *et al.* 1963. *Inform. Bull. Planktol. Japan*, No. 10, p. 22; MOTODA and OSAWA, 1964. *Ibid.* No. 11, p. 11). Where y is length (m) of wire cable extended long enough for the net to reach 200 metre depth, and x is volume of water (m^3) filtered by the net, the formula:

$$y=0.482x+130$$

was obtained. In nearly all cases duplicate hauls were made. Since the variation of samples in replicate hauls is generally considerbly large, the mean values of duplicate samples would be more reliable to express the biomass of the samples at each station. Based on the above-method of calculation, the mean biomass in each grid area of two degees of latitude and longitude is shown in Table 5 (MOTODA, *et al.* 1963, *loc. cit.*: MOTODA and OSAWA, 1964, *loc. cit.*). The hydrographic and chemical data of the cruises concerned are not yet available, so that the relationship between the distribution of the zooplankton biomass and hydrographic structures will be discussed later. (S. MOTODA)

5. *Plankton samples collected with 0.33 mesh net other than standard net.* (Teble V-7-6)

On the " Oshoro Maru " in the 1962-63 cruise a Norpac standard net (MOTODA, 1957, *Inform. Bull. Planktol. Japan.* No. 4, p. 13), 45 cm X 180 cm, conical, made of bolting silk, GG 54, 0.33 mm mesh apertures, was converted to the Juday type closing net by attaching a canvas cylinder above the top of the net. This net was hauled from great depth dividing the water column into several zones. On the 1963-64 cruise of the same ship, seven 60 cm horizontal closing nets (modified from the horizontal square net in MOTODA, 1963, *Bull. Fac. Fish. Hokkaido Univ.* Vol. 14, p. 155), made of bolting silk, GG 54, were hauled horizontally by attaching them to a single wire cable. After the nets were damaged five 45 cm open ring nets were hauled in the same way. (S. MOTODA)

6. *Plankton samples collected by horizontal hauls with 130 cm larva net (various mesh sizes)* (Table V-7-7)

A larva net having 130 cm mouth ring which has been normally used on the ships of Japan Fisheries Agency and its regional laboratories was towed in the Indian Ocean on the cruises of the " Umitaka Maru " (1962-63) and the " Oshoro Maru " (1963-64). Tows were made through the surface layer at a low speed at night, by hanging the net from the boom protruded from the bulwark on the foredeck. The samples thus obtained were not contaminated by the subsurface samples because of no disturbance of water due to the motion of the propeller of the ship as occurring in the tows from the stern. The samples contained a number of heteropods, pteropods, cephalopod larvae, fish larvae, and so on, which were rarely found in the samples taken by the tows from the stern. (Y. YOSHIDA)

7. *Plankton samples collected by horizontal or oblique hauls with 160 cm ring net (2.0 mm mesh)* (Table. V-7-8)

The net was designed to be hauled horizontally or obliquely through certain depths. Sampls taken by horizontal or oblique hauls with several number of the nets attached to a single wire cable could be available for observations of vertical distribution of macroplankton in the upper waters, desirably through 0-200 metre depth. Because of the uniformity of mesh size from the top to the cod end, the quantitative estimation of samples could be made by registering the amount of water filered by the net by means of a flowmeter. Closing mechanism on the net was not available, but the contamination

Table V-7-6. Sampling of medium-sized zooplankton with 0.33 mm mesh net other than IOSN.

No.	Ship	Institution	IIOE cruise no.	Date	Number of stations occupied	Net used	Method of haul	Maximum depth of haul (m)	Number of depth of haul	Duration of haul (min)	Number of samples collected	Place where samples are stored
20	Os	FFHU	1	Jan. 13-17, 1963	5	45 cm Juday type	Vertical	3960	6		5	FFHU
21	Os	FFHU	2	Dec. 14-17, 1963	2	50 cm closing net	Horizontal	2580	7	60	14	FFHU FFNU (Amphipoda)
22	Os	FFHU	2	Dec. 19-24, 1963	3	45 cm open net	Horizontal	2880	7	120	15	FFHU FFNU (Amphipoda)

Table V-7-7. Sampling of Macroplankton with 130 cm larva net (various mesh sizes).

No.	Ship	Institution	IIOE cruise no.	Date	Number of stations occupied	Method of haul	Depth of haul (m)	Duration of haul (min)	Number of samples collected	Place where samples are stored
23	Um	TUF	1	Jan. 8-10, 1963	13	Horizontal	Surface	30	13	TUF
24	Os	FFHU	2	Dec. 13, 1963 Dec. 26, 1963	14	Horizontal	Surface	15	14	FFHU

Table V-7-8. Sampling of macroplankton by horizontal or oblique haul with 160 cm horizontal net (2 mm mesh).

No.	Ship	Institution	IIOE cruise no.	Date	Number of stations occupied	Method of haul	Number of depths at which nets were hauled simulaneously	Maximum depth of haul (m)	Duration of haul (min)	Speed of haul (knots)	Number of samples collected	Place where samples are stored
25	Um	TUF	1	Nov. 30, 1962 —Jan. 7, 1963	9	Horizontal	3	350	30	2-4	24	TUF
26	Ko	SUF	1	Nov. 23, 1962 —Jan. 7, 1963	25	Oblique	1	0-433	60	2-3	24	SUF
27	Ka	FFKU	2	Nov. 26, 1963 —Jan. 26, 1964	42	Horizontal	1	Surface	30 or 60	2-4	29	FFKU
28	Ko	SUF	2	Nov. 23, 1963 —Jan. 25, 1964	21	Oblique	1	0-380	60	2-3	22	SUF

Table V-7-9. Sampling of plankton by high-speed tow with simple samplers (without depressor).

No.	Ship	Institution	IIOE cruise no.	Date	Number of stations occupied	Type of sampler used	Mouth opening of sampler (cm in diam.)	Length of warp run out (m, subsurface)	Speed of tow (knots)	Duration of tow (min)	Number of samples collected	Place where samples are stored
29	Um	TUF	1	Nov. 1, 1962 —Feb. 8, 1963	45	Small type	2	30	12-13	60	45	FFHU
30	Os	FFHU	1	Dec. 1, 1962 —Feb. 2, 1963	29	Model VI	4	50	12	30 or 60	29	FFHU
31	Os	FFHU	1	Dec. 12, 1962 —Feb. 2. 1963	39	Model V	7	50	12	60	39	FFHU
32	Ko	SUF	1	Nov. 22, 1962 —Jan. 17, 1963	31	Model V	7	200	12-13	60-120	31	SUF
33	Ka	FFKU	2	Nov. 26, 1963 —Jan. 8, 1964	31	Model V	7	50	12	120	31	FFKU
34	Ko	SUF	2	Nov. 23, 1963 —Jan. 26, 1964	21	Model V	7	150	12-13	120	23	SUF
35	Os	FFHU	2	Dec. 13, 1963 —Dec. 26, 1963	14	Large type	15	50	12	40	14	FFHU

of materials from other layers than the desired layer was supposed to be comparatively small in such a long duration of haul compared with the depth of sampling. A lot of zooplankton samples were obtained by this net haul. A number of small sized fish, mostly young forms, were collected on the cruise of the "Umitaka Maru" in 1962-63. The samples taken by the "Kagoshima Maru" in 1963-64 were divided into two halves, and one half was placed for the counting of radioactivity. (Y. YOSHIDA

8. *Plankton samples collected by high-speed tow with simple sampler.* (Table. V-7-9)

On the "Umitaka Maru" cruise in 1962-63 a small type of simple sampler was towed every night throughout all the courses. The sampler was 4.5 cm in diameter and 30 cm long with a mouth opening 2 cm in diameter, at the head piece. The net inside was made of bolting silk, GG 54, 0.33 mm apertures. The purpose of sampling was to collect the small copepods such as Corycaeidae. Other high-speed samplings were planned for the purpose of collecting rather agile plankton animals. The ships were not trained to haul a heavily resistant tool at high speed by which the tool was depressed into the depth by very strong force of a depressor, so that the surface tows with simple samplers without having a depressor were always carried out at night. The sampler towed by the "Koyo Maru" was a Simple Underway Catcher Model V (MOTODA, 1959, *Mem. Fac. Fish. Hokkaido Univ.* Vol. 8, p. 73; MOTODA, 1961, *Inform. Bull. Planktol. Japan*, No. 7, p. 11) of which the outer case was 15 cm in diameter and 100 cm in length, with a mouth opening of 7 cm in diameter at the front of the head piece. A conical coarse mesh net and a small flowmeter were installed inside the case. On the "Oshoro Maru" two samplers, Model V and VI, were towed on the 1962-63 cruise, and a large sampler, Model VII, was towed on the 1963-64 cruise. In the large sampler, Model VII, the outer case was 30 cm in diameter and 200 cm in length, tapered at both ends. The mouth opening of the case was 15 cm in diameter. The conical net installed was 28 cm in diameter at the mouth ring and about 90 cm long, made of Pylene cloth with 0.93 mm X 0.93 mm mesh openings. In both Models V and VII, leptocephalids, myctophids and other similarly sized animals were often collected. (Y. YOSHIDA)

9. *Micronekton (fast-swimming macroplankton) samples collected by the tows of Isaacs-Kidd mid-water trawl or other similar gear* (Table. V-7-10)

The Isaacs-Kidd mid-water trawl (ISAACS and KIDD, 1953, *SIO, Reference* 53-3, *Oceanogr. Equip. Rep.* No. 1; Aron, 1962, *Rapp. Proc.-Verb.* Vol. 153, p. 29) was towed on the "Koyo Maru" on 1962-63 cruise at 25 stations and on 1963-64 cruise at 20 stations. Suitable stern gallows were not installed and the operation was dangerous for untrained cadets. On the "Umitaka Maru"

Table V-7-10. Sampling of macroplankton by the tows of Isaacs-Kidd mid-water trawl or other similar gear.

No.	Ship	Institution	IIOE cruise no.	Date	Number of stations occupied	Type of gear used	Weight of sinker attached (kg)	Method of haul	Maximum depth of haul (m)	Duration of tow (min)	Speed of tow (knots)	Number of samples collected	Place where samples are stored
36	Um	TUF	1	Dec. 11, 1962 —Jan. 7, 1963	2	UmN	60	Horizontal	70	60	2-4	2	TUF
37	Ko	SUF	1	Nov. 23, 1962 —Jan. 1, 1963	19	IKT		Oblique	800	60 120	2-3	25	SUF
38	Ka	FFKU	2	Nov. 27, 1963 —Jan. 26, 1964	18	KaN	60	Oblique	1000	60	2-4	18	FFKU
39	Ko	SUF	2	Nov. 23, 1964 —Jan. 25, 1964	16	IKT		Oblique	770	60	4-7	17	SUF
40	Um	TUF	2	Nov. 20, 1963 —Jan. 22, 1964	28	UmN		Horizontal	400	30	2-4	89	TUF

a large square net, 270 cm X 270 cm at the mouth frame, 10 metre long net made of 15 mm, 10 mm, 5 mm, and 0.3 mm mesh nets, was towed at a low speed using 12 mm diameter warp, attaching a sinker, 60 kg. On the cruise 1963-64 the gear was located to the depth at which the sonic scallering layer existed. On the "Kagoshima Maru" a large net, 140 cm X 400 cm at mouth frame, 14 metre long net, made of 15 mm, 10 mm, 5 mm and 2 mm mesh nets, was towed. (Y. YOSHIDA)

10. Biological specimens collected by dredging, and beam- and otter trawlings. (Tables. V-7-11-13)

Samplings of invertebrates and bottom fishes were made at the same time of collection of geological materials by dredging with Niino type dredge (65 cm × 36 cm at the month) on the "Umitaka Maru" on the 1962-63 and 1963-64 cruises and on the "Kagoshima Maru" on the 1963-64 cruise. On the "Unitaka Maru" 1962-63 cruise, four dredgings in Thai Bay showed that there was an accumulation of dead shells, most of them being small sized shells, suggesting that the conditions on the sea bottom would become nearly anerobic sometime in a year. Many living shells, polychaetes, and other invertebrates were collected by dredging at some comparatively offshore stations off Phuket Island. The sediment bottom on the summit of Umitaka Sea Mount elevating from about 4000 metre deep surronding sea bottom to the depth less than 2000 metres, was composed of foraminifera ooze, and no larger invertebrates were collected. Samples obtained by dredging on the Cocos Sea Mount were solitary corals, white corals (*Collarium konojoi*), siliceous sponges bivalves, polychaetes, brittle stars, and so forth. On the "Umitaka Maru" 1963-64 cruise, specimens of small bottom fishes, sponges, corals and molluscan shells were obtained by dredging in Timor Sea and off the north-western coasts of Australia. The samples obtained by dredging off Cape Comorin on the "Kagoshima Maru" 1963-64 cruise, were composed of dead bivalves, living echinoderms, brachyuran crabs, gastropods, madreporaian corals, actiniarians and hydroids.

A beam trawl net (460 cm X 82 cm at the mouth) was towed on the sea bottom on the cruise of the "Umitaka Maru." A number of animals including one species of sea slug (Nudibranchia), two species of decapod, cephalopods and five species of macruran shrimps were obtained on the ground off the north west coast of Australia, and prawns, fishes, sea cucumbers, sea pens, jellyfish, and so on, were obtained on the Zenith Sea Mount (provisionally named by Capt. OZAWA).

Otter trawl net of commercial size was hauled for the purpose of training of cadets in fishing operations as well as of obtaining samples for biological and fisheries researches. The "Oshoro Maru" carried out 13 trawlings on the 1962-63 cruise and 20 trawlings on the 1963-64 cruise on the shallow

Table V-7-11. Sampling of bottom animals by dredging.

No.	Ship	Institution	IIOE cruise no.	Date	Area of dredging	Depth of sea bottom (m)	Number of stations occupied	Place where samples are stored
41	Um	TUF	1	Nov. 13, 1962	Thai Bay, ca 11°19′N, 102°10′E		4	TUF
42	Um	TUF	1	Nov. 29-Dec. 1, 1962	Off Phuket Is. 7°45′N~7°58′N, 98°00′E~98°09′E		12	TUF
43	Um	TUF	1	Dec. 3-4, 1962	On Umitaka Sea Mount 2°48′N~2°27′N, 90°57′E~89°26′E	2174-2313	6	TUF
44	Um	TUF	1	Dec. 18, 1962	South of Cape Comorin 7°31′S, 77°41′E	Ca 80	2	TUF
45	Um	TUF	1	Jan. 14, 1963	On Cocos Sea Mount 13°14′S, 96°17′E ~96°18′E	796-890	2	TUF
46	Um	TUF	2	Nov. 13, 1963	Timor Sea 9°47′S, 127°33′E	623	1	TUF
47	Um	TUF	2	Nov. 26, 1963	Mermaid Reef 17°04′S~17°08′S, 119°40′E~119°45′E	267-425	4	TUF
48	Um	TUF	2	Nov. 27, 1963	Off Broome 18°15′S~18°24′S, 120°12′E~120°17′E	88-106	6	TUF
49	Um	TUF	2	Dec. 21-23, 1963	Shark Bay 22°55′S~24°58′S 111°56′E~112°49′E	70-1084	11	TUF
50	Um	TUF	2	Dec. 25, 1963	Off Abrolhos Is. 28°43′S~28°44′S 113°8′E~113°35′E	169-1104	3	TUF
51	Ka	FFKU	2	Dec. 18, 1963	South of Cape Comorin 7°32′S~7°38′S, 77°31′E~77°36′E	71-77	3	FFKU

Table V-7-12. Sampling of bottom animals by beam trawling.

No.	Ship	Institution	IIOE cruise no.	Date	Area of trawling	Depth of sea bottom (m)	Place where specimens are stored
52	Um	TUF	1	Nov. 29-Dec. 1, 1962	Off Phuket 7°45′N~7°58′N, 98°07′E~98°09′E		TUF
53	Um	TUF	2	Nov. 26, 1963	Near Mermaid Reef 17°07′S~17°05′S 119°49′E~119°50′E		TUF
54	Um	TUF	2	Jan. 7, 1964	On Zenith Sea Mount 20°02′S~22°04′S, 104°38′E~104°40′E	1962-2029	TUF

Table V-7-13. Sampilng of bottom animals by otter trawling.

No.	Ship	Institution	IIOE cruise No.	Date	Area of trawling	Depth of sea bottom (m)	Number of stations occupied	Place where specimens are stored
55	Os	FFHU	1	Dec. 14-19, 1962	Off N-W coast of Australia 19°15′S~19°21′S, 116°31′E~119°06′E	40-115	13	FFHU
56	Os	FFHU	2	Dec. 18, 1963, —Jan. 6, 1964	Off N-W coast of Australia 18°28′S~20°11′S, 116°20′E~121°01′E	45-100	20	FFHU
57	Um	TUF	2	Dec. 1-2, 1963	Off Broome 18°10′S~18°41′S, 118°18′E~119°55′E		6	TUF
58	Um	TUF	2	Dec. 18-20, 1963	Shark Bay 24°59′S~25°23′S, 112°33′E~112°47′E		8	TUF

Table V 7 14. Sampling of fish specimens by tuna longlining.

No.	Ship	Institution	IIOE cruise no.	Date	Area of fishing	Number of stations occupied	Place where samples are stored
59	Um	TUF	1	Dec. 5-8, 1962	0°35′N~ 1°23′S, 86°38′E~ 82°32′E	4	TUF
60	Um	TUF	1	Jan. 13-17, 1963	12°39′S~ 7°23′S, 97°10′E~102°26′E	4	TUF
61	Ko	SUF	1	Jan. 4-5, 1963	24°37′S~26°12′S, 100°50′E~102°51′E	2	SUF
62	Ko	SUF	1	Jan. 18-25, 1963	8°53′S~21°29′S, 103°44′E~105°47′E	7	SUF
63	Os	FFHU	1	Dec. 31, '62-Jan. 18, '63	9°10′S~22°08′S, 104°50′E~113°54′E	13	FFHU
64	Ka	FFKU	2	Jan. 1-26, 1964	1°00′N~25°36′S, 78°00′E~ 93°45′E	12	FFKU
65	Ko	SUF	2	Dec. 10-22, 1963	7°12′N~10°23′S, 92°42′E~100°57′E	6	SUF
66	Ko	SUF	2	Jan. 21-29, 1964	10°47′S~30°04′S, 100°13′E~103°56′E	6	SUF
67	Um	TUF	2	Nov. 21-25, 1963	11°09′S~17°13′S, 119°48′E~102°11′E	5	TUF
68	Um	TUF	2	Jan. 17-21, 1964	5°18′S~11°04′S, 99°43′E~100°17′E	5	TUF
69	Os	FFHU	2	Dec. 13-26, 1963	9°12′S~14°58′S, 105°50′E~112°48′E	13	FFHU

grounds off the north-west coast of Australia. The " Umitaka Maru " carried out 14 trawlings off Broome and in Shark Bay on the 1963-64 cruise. The samples collected by the " Umitaka Maru " including sea stars, sea urchins, brittle stars, crinoids, brachurans, anomurans, macrurans. octopods, squids and cattle fish, gastropods, polychaetes, octocorals, madreporarians, sponges, and so on, were preserved. Of the specimens collected by trawling on the " Oshoro Maru " on 1962-63 cruise, 142 species of fishes were identified, and the specimens of each species were preserved. On the 1963-64 cruise 20 specimens of fishes which included species which had not been collected on the previous cruise were preserved and brought back to the university. (J. SENO)

11. Fish specimens collected with tuna longline (Table V-7-14)

Exploratory as well as training operations of tuna longline were carried out on all the Japanese ships participating in the IIOE in both years, 1962-63 and 1963-64 (Table 14). In addition to the commercially important tunafish, any kind of fishes hooked were preserved as zoological specimens. (J. SENO)

12. Further studies on the samples collected

Plankton samples collected by settling method or net haul and other animal specimens collected by dredging, trawling or longlining, have been stored in the institutions which have made samplings. These samples are being arranged for the further studies by specialists. There is no systematic program for the distribution of the samples to specialists under which participating institutions are obliged to treat their samples. However, it is strongly recommended that samples should not be held in the store without any program of processing, and that if they are not needed by the respective institutions, they would be provided to specialists in any organization in the county, and if necessary to specialists in foreign countries. Necessary information on the qualified specialists in each group of plants and animals can be available from NCOR or other pertinent societies of botany, zoology, ichthyology, biogeography, plankton and others existing in Japan. It is recommended that specialists who desire to examine the materials listed in this report, would contact NCOR or directive institutions. Such proposals from specialists would greatly encourage the institutions holding the materials.

The following samples are in process of examination by the specialist:

Microplankton samples (No. 1, in Table V-7-1) were offered to Dr. Y. KAWARADA and Mr. A. SANO, Oceanographical Section, Japan Meteological Agency, for the studies of diatoms and dinoflagellates. Then the samples will be passed to Dr. K. NAKASEKO, Osaka University, for the studies of Radiolaria, and to Dr. S. HONJO, Faculty of Science, Hokkaido University, for the studies of Coccolithophora. Microplanktons samples (No. 2 in Table V-7-1) were sent to Ocean Research Institute, University of Tokyo, for the studies of diatoms and dinoflagellates. Microplankton samples (No. 4 in Table V-7-1) are being processed by Dr. I. SAKAMOTO, Prefectural University of Mie. Microplankton samples (No. 5 in Table V-7-1) are being processed by Dr. T. KAWAMURA, Faculty of Fisheries, Hokkaido University, (diatoms and dinoflagellates), and then will be passed to Dr. K. NAKASEKO, Osaka University, (Radiolaria) and Dr. S. HONJO, Hokkaido University, (Coccolithophora).

Specimens of amphipods collected by the "Oshoro-Maru" on the 1963-64 cruise (No. 19 in Table V-7-4, No. 24 in Table V-7-7) were offered to Dr. H. IRIE, Faculty of Fisheries, Nagasaki University. Copepods and pelagic molluscs in the samples (No. 13, 18 in Table V-7-4, No. 23 in Table V-7-7, No. 25 in Table V-7-7) are being studied by Mr. J. SENO and his colleagues at Tokyo University of Fisheries. Zooplankton samples collected by holizontal hauls with 160 cm net (No. 26, 28 in Table V-7-8) containing such copepods as *Megacalanus, Euchirella, Chirundina, Pareuchaeta, Gaetanus, Scottocalanus, Gausia, Arietellus, Scaphocalanus*, etc., are being studied by Drs. T. CHIBA and A. TSURUTA, Shimonoseki University of Fisheries. Leptocephalids of Apodes in those samples are being studied by Dr. I. MATSUI and Dr. T. TAKI of the same institution. Fish specimens taken by the haul with a large Kagoshima Net (No. 38 in Table V-7-10) were sorted and examined by Dr. S. IMAI and his colleagues at the Faculty of Fisheries, Kagoshima University. A part of those samples were sent to Dr. T. IMAI, Faculty of Agriculture, Tohoku University.

Molluscan shells contained in the bottom samples (Nos. 46-50 in Table V-7-11) are studied by Dr. R. TSUCHI, Faculty of Literature and Science, Shizuoka University. One hundred and forty-two species of bottom fish were listed from the samples taken by otter trawling (No. 55 in Table V-7-13) on the "Oshoro-Maru" 1962-63 cruise, by Dr. S. OKADA, Mr. K. KOBAYASHI and Mr. T. OMI, Faculty of Fisheries, Hokkaido University. Photographic pictures of specimens of the species listed were published in *Data Record of Oceanographic Observations and Exploratory Fishing, Fac. Fish., Hokkaido Univ.* No. 8, 1964). Specimens taken on the cruise in the following year (No. 56 in Table V-7-13) are being studied by Dr. S. OKADA and his colleagues. Fish specimens caught by longlining are studied by ichthyologists in the respective institutions. Specimens taken by the "Koyo-Maru" (Nos. 61, 62, 65, 66 in Table V-7-14) are studied by Dr. I. MATSUI and his colleagues. Specimens taken by the "Umitaka-Maru" (Nos. 59, 60, 67, 68 in Table V-7-14) are studied by Mr. J. SENO and Dr. T. MASUDA. They listed 12 species from the samples taken in 1963-64 cruise (Nos. 67, 68 in Table V-7-14). Specimens taken by the "Kagoshima-Maru" (No. 64 in Table V-7-14) are studied by Dr. S. IMAI and his colleagues. Specimens taken by the "Oshoro-Maru" (Nos. 63, 69 in Table V-7-14) have been studied by Dr. S. OKADA, Mr. K.

KOBAYASHI, Mr. T. OMI and their colleagues. Twenty-nine species of fish were identified and photographed from the samples taken by longlining on the "Oshoro-Maru" 1962-63 cruise. The photographic pictures were published in *Data Record Oceanogr. Explor. Fish., Fac. Fish., Hokkaido Univ.* No. 8, 1964. Specimens collected during the tuna longlining on the 1963-64 cruise are being studied by Dr. S. OKADA and his colleagues. (S. MOTODA)

13. Bacteriological observations

Sampling and examination of marine bacteria were conducted by Mr. M. NAKANO on the "Koyo-Maru" in 1962-63, and by me (Y. HATA) on the same ship in 1963-64.

Water samples were taken with J-Z bacteriological sampler (ZOBELL, 1941, *J. Mar. Res.*, Vol. 4, pp. 173-188) from 0, 10, 25, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 800, 1000, 1200, 1500, 2000, 2500 and 3000 metres at twenty stations located at 05°03′N to 32°00′S and 90°30′E to 111°50′E on the cruise in 1962-63. Viable cells of aerobic heterotrophs in the water samples were counted by agar pour plate method and membrane filter method (JANNASCH and JONES, 1959. *Limnol. Oceanogr.*, Vol. 4, pp. 128-139) at 20° to 25°C using a modified formula of ZOBELL's medium 2216E (OPPENHEIMER and ZOBELL, 1952. *J. Mar. Res.*, Vol. 11, pp. 10-18): poly-peptone 5 gr, yeast extract 1 gr, ferric phosphate-soluble 0.1 gr, agar 10 gr, sea water 1000 ml, pH 7.5. Aerobic heterotrophs were widely found in all samples from the surface to 3000 metres depths. Their population varied over a wide range from less than 1 to 10^4 cells per ml of water.

Studies on aerobic heterotrophs, starch hydrolysers and nitrifiers which could grow under high hydropressure in the deep water were also made for the water samples taken from 1000, 2000 and 3000 metres at several stations. The samples were examined by minimum dilution method using a high pressure cultivation apparatus (ZOBELL and MORITA, 1959. *Galathea Rep.*, 1, pp. 139-154). By this method the presence of those bacteria in the above-mentioned depths was demonstrated.

On the cruise in 1963-64 water samples were collected with a modified J-Z bacteriological sampler from 0, 10, 25, 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, 1000, 1200, 1500, 2000, 2500, 3000, 3500, 4000 and 5000 metres depths at eleven stations located at 08°05′N to 31°57′S and 93°54′E to 111°40′E. Bottom sediment was also taken for the bacteriological examination by the use of a gravity core from 1450 metres deep bottom at a station, 04°59′N, 94°01′E. Fractions of plankton samples collected by vertical divided hauls at five stations located at 08°05′N to 20°00′S and 93°58′E to 100°00′E were used for bacteriological studies.

Aerobic heterotrophs in the water samples were observed by membrane filter method at 22° to 25°C using a modified formula of medium 2216E as on the previous cruise. Fifty ml of the water samples were passed through a sterile membrane filter (50 mm, type Co. 5). Population of viable aerobic heterotrophs ranged from less than 1 to 1000 cells per 50 ml. Abundance of viable cells generally tended to decrease with increasing depth.

For enumerating total microbial cells in sea water direct microscopic counts with membrane filter method (KRISS, 1955. *Vestnik Akad. Nauk USSR*, Vol. 1, pp. 30-40) were made. Thirty ml of the water samples were passed through a membrane filter (10 mm, No. 3) and then the cells retained on the filter were stained with 1% erythrosine in 5% phenol. Although it was considerably difficult to distinguish microbial cells from detritus, approximately 10^4 to 10^6 cells to microbes per 30 ml of water were present in the samples tested.

In order to estimate the number of nitrifying bacteria in sea water, the water was examined by minimum dilution method at 22° to 25°C according to KIMATA's technique (KIMATA *et al*, 1916. *Bull. Jap. Soc. Sci. Fish.*, Vol. 27, pp. 593-597). Both nitrite formers and nitrate formers were detected in a very few number, 0 to 10 cells per 100 ml.

Plankton materials collected from different depths were resuspended in sterile sea water to give a volume of 250 ml. Aerobic heterotrophs and nitrifiers in the suspensions were enumerated at 22° to 25°C by means of agar pour plate method and minimum dilution method, respectively. The abundance of heterotrophs existing in the plankton suspensions was 10^4 to 10^8 cells per ml, generally decreasing in number with increasing depth. Nitrifiers in the plankton suspensions were considerably abundant compared with those in sea water samples mentioned before.

For determining the number of different physiological types of bacteria in the bottom sediment, minimum dilution counts were made using several different media. One series of media inoculated with dilution series of the sediment sample was incubated at 22° to 25°C under normal atmospheric pressure for 2 weeks or more. Another series was kept in a high pressure cultivation apparatus under 145 atm hydropressure which corresponded to *in situ* hydropressure, at 3° to 5°C for 2 months or more. In the normal pressure cultivation, few thousands cells of general aerobes and ammonofiers, several hundreds cells of starch hydrolysers and acid formers from glucose, several tens cells of gas formers from glucose and agar decomposers, and several cells of nitrate reducers, nitrite formers from ammonia and sulfate reducers, per gram wet weight were found in the topmost 5 cm stratum of the sediment. In the high pressure cultivation, on the other hand, only a few viable cells of those bacteria were detected.

Detailed observations on the bacteriological characteristics of one thousand and several hundreds pure strains of bacteria which were isolated from water samples, plankton samples and sediment sample are in progress by me (Y. HATA) at the Shimonoseki University of Fisheries. (Y. HATA)

15. Papers on biology based on the materials taken during the IIOE of Japan.

Motoda, S., K. Konno, A. Kawamura and K. Osawa, 1963. Proposed method of estimation of quantity of water filtered by vertical net haul, and its application on illustrating distribution of zooplankton biomass in the eastern Indian Ocean. *Inform. Bull. Planktol. Japan*, No. 10, pp. 22-28.

Durairatnam, M. 1964. Vertical distribution of phytoplankton in an area near Cocos-Keeling Islands. *Ibid.* No. 11, pp. 1-6.

Motoda, S. and K. Osawa, 1964. Filtration ratio, variance of samples and estimated distance of haul in vertical hauls with Indian Ocean standard net. *Ibid.* No. 11, pp. 11-24.

Saijo, Y. 1964. Size distribution of photosynthesizing phytoplankton in the Indian Ocean. *Jour. Oceanogr. Soc. Japan*, 19 (4), 187-189.

Abbreviations in Tables

FFHU: Faculty of Fisheries, Hokkaido University, Hakodate.
FFKU: Faculty of Fisheries, Kagoshima University, Kagoshima.
FFNU: Faculty of Fisheries, Nagasaki University, Nagasaki.
IKT: Isaacs-Kidd mid-water trawl
IOBC: Indian Ocean Biological Centre, Ernakulam, South India.
IOSN: Indian Ocean standard net.
Ka: "Kagoshima Maru" of FFKU.
KaN: Kagoshima net, 140 cm × 400 cm in mouth frame.
Ko: "Koyo Maru" of SUF.
Os: "Oshoro Maru" of FFHU.
SUF: Shimonoseki University of Fisheries, Shimonoseki.
TUF: Tokyo University of Fisheries, Tokyo.
Um: "Umitaka Maru" of TUF.
UmN: Umitaka net, 270 cm × 270 cm in mouth frame.

V–8. Eye Observation

Working group for eye observation

During the periods from November 1962 to February 1963 and from November 1963 to February 1964, four Japanese ships Umitaka-Maru, Koyo-Maru, Kagoshima-Maru and Oshoro-Maru, participated in the International Indian Ocean Expedition. Umitaka-Maru, Koyo-Maru and Oshoro-Maru cruised in the Indian Ocean in both periods, Kagoshima-Maru in the latter. They carried out sight observations throughout the cruises, while underway or stopping for survey.

The objects which were recorded on the log sheets were sea birds, land birds, sea snakes, flying fish, sharks, dolphins, skipjack schools, smaller or larger whales, *Vella*, cuttle-bone, sea weeds, insects and floating materials from the land.

One birds, both land and sea birds, Umitaka-Maru observed the species and the number at the time when they appeared. Fortunately, the ship's tracks generally covered the eastern Indian Ocean depending on the two cruises during the above-mentioned periods (summer season in the Southern Hemispere), and also the data obtained by Koyo-Maru and Kagoshima-Maru.

Brief descriptions given on the distributions of principal species of sea birds in respect to number ; that is, Sooty tern, Boobies, Shearwaters. Tropic-birds snd Frigate birds, and also on that of land birds, skipjack schools, flying fish and insects.

The figures are shown by quantitative patterns, a total of the number appearing per day, for the objects respectively. The wind arrows are indicated solely in the figure showing the occurrence of land birds and insects. The isotherms which are represented by the solid line and the equatorial convergences by the dotted line are entered on the each sheet.

1. Occurrence of land birds and insects.

Fig. V-8-1 shows occurrences of land birds and insects at sea and wind system. Dragon flies appeared sometimes in the areas north of a parallel of 2°S, between Sumatra and Cocos Islands and off Northwest Cape, Western Australia.

Most dragon flies seemed to be *Pentala flavescens*.

Appearance or collections of land birds are as follows:

Sacred kingfisher *Halcyon sanctus*	Nov. 14, '63	15′ WNW of Channel Rock, Darwin.
Nankeen kestrel *Falcho cencroides*	Nov. 30, '63	12′ west of Ganthaeume Pt., Broome.

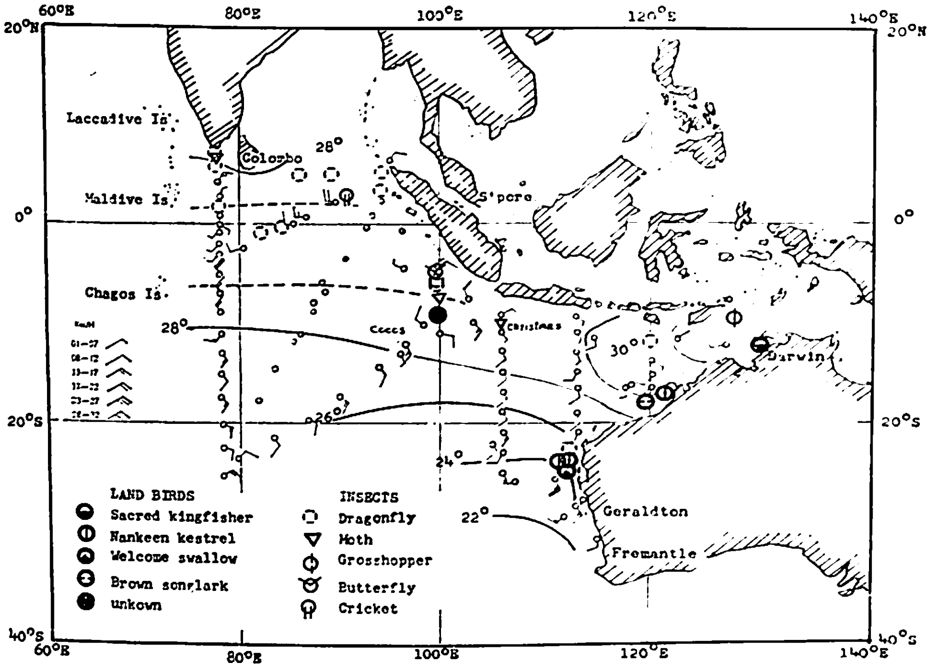


Fig. V-8-1. Showing occurrences of land birds and insects with wind map.

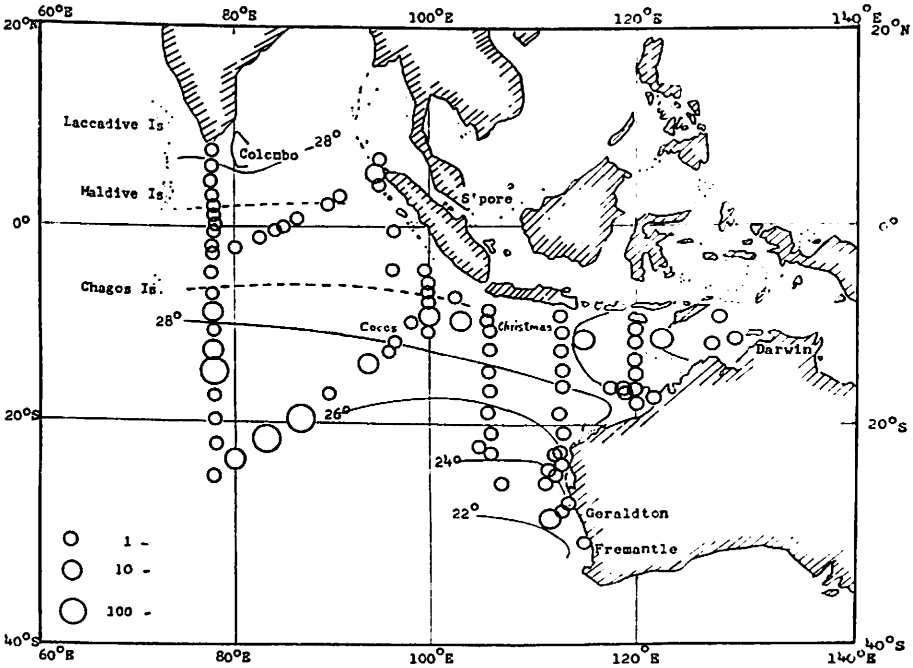


Fig. V-8-2. Distribution of flying fish with quantitative patterns.

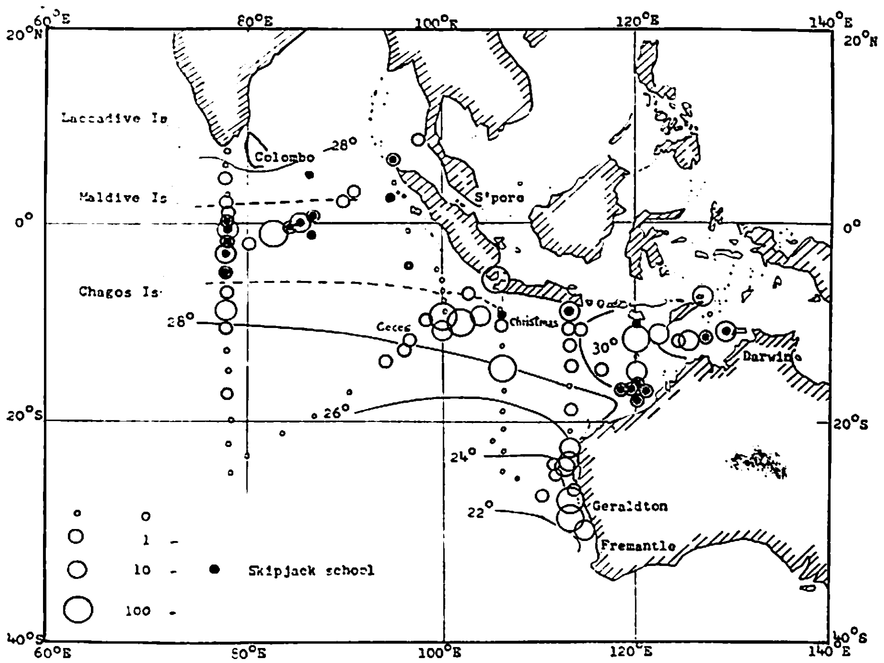


Fig. V-8-3. Distributions of *Sterna fuscata* with quantitative patterns and occurrence of skipjack schools.

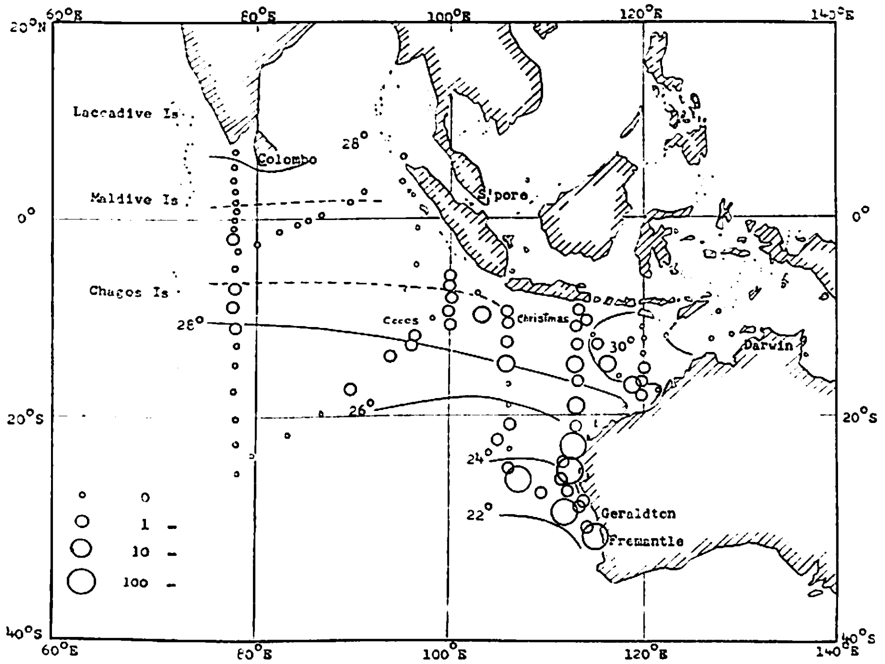


Fig. V-8-4. Distribution of Shearwater, (*Puffinus* spp.) with quantitative patterns.

„	Dec. 19, '63	25°03'S, 112°40'E
„	Dec. 20, '63	25°07'S, 112°35'E
Brown songlark *Cinclorampus cururalis*	Dec. 1, '63	18°16'S, 119°46'E
Welcome swallow *Hirundo meoxena*	Dec. 20, '63	25°07'S, 119°46'E

The above species was identified according to Dr. D. L. Surventy, CSIRO, Australia.

2. Distribution of flying fish.

Generally, the flying fish was found in the southern portion as shown in Fig. V-8-2. The composition of large, medium and small sized flying fishes was as follows 10%, 25%, 65% respectively, which depended upon the data obtained throughout the cruise of Umitakr-Maru during the period November 1963 to February 1694.

3. Distributions of Sooty tern (*Sterna fuscata*) and skipjack schools.

Fig. V-8-3 shows the distribution of Sooty tern (*Sterna fuscata*) and skipjack school.

Sterna fuscata was the abundant species and appeared in mass grouping at sea, particularly on the equatorial counter-current zone, around Cocos and Christmas Island, on small islets south of Timor, and around the Abrolhos Group off Geraldton, Western Australia. This species appeared commonly above skipjack schools, and was usually in association with Frigate birds, which appeared circling high above them.

4. Distribution of Shearwater, (*Puffinus* spp.)

The distribution of Shearwater, (*Puffinus* spp.) is shown in Fig. V-8-4.

Wedge-tailed shearwaters, (*Puffinus pacificus*) ranged widely in the southern waters of the equatorial convergence as far as 18°S and off the western coast of Australia. However, in the southern portion of the west coast *Puffinus assimili* and perhaps *P. carneipes* came in this category.

The eastern extremity of the range seemed to be between the eastern end of Java and Dampier Land, Australia.

5. Distributions of Tropic-birds, (*Paethon* spp.) and Frigate birds, (*Fragata* spp.).

Fig. V-8-5 shows the distributions of Tropic-birds, (*Phaethon* spp.) and Frigate birds, (*Fragata* spp.). *Phethon* species appeared widely. The southern limit generally coincided with isotherm of 28°C except off the western coast of Australia, but the number was few (twenty per day maximum).

Fragata species, *Fragata ariel* ranged mainly off Australian coast, *Fragata minor* elsewhere and *Fragata andrewsi* around Christmas Island.

Depending on Fig. V-8-5, there are two distributional areas, the western

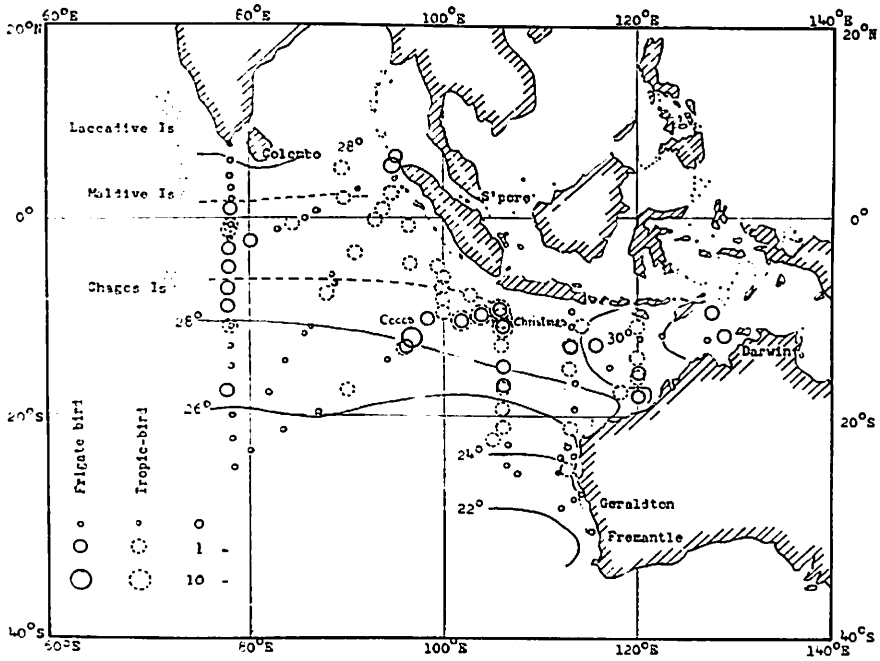


Fig. V-8-5. Distributions of Tropic-birds, (*Phaethon* spp.) and Frigate birds (*Fragata* spp.).

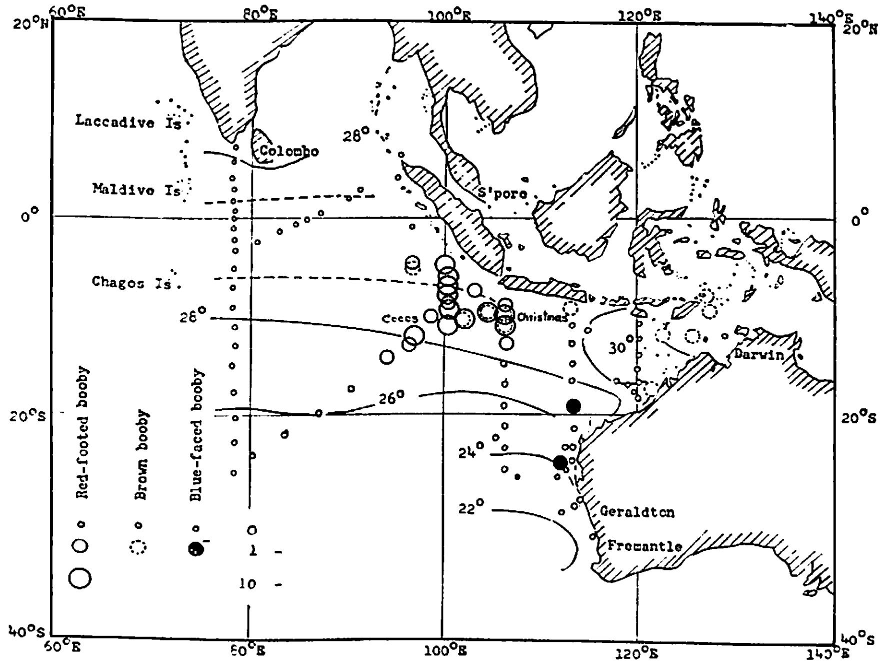


Fig. V-5-6. Distributions of Boobies, (*Sula sula*, *S. dectylatra* and *S. leucogastar*).

area entering Laccadive, Maldive, Chagos and Rodriguez Island, the other is an area surrounded with the Soenda Islands on the northern coast Australia on the south and Cocos and Christmas Islands on the west.

6. Distribution of Boobies, (*Sula* spp.).

Boobies, Red-footed booby, (*Sula sula*), Blue-faced booby, (*Sula dactylatra*) and Brown booby, (*Sula leucogaster*) were in this category.

The distributions is shown in Fig. V-8-6.

The former two species mainly appeared around Cocos and Christmas Islands and also between these islands and the Soenda Islands. *Sula sula* exceeded *Sula leucogastar* in number. *Sula dactylatra* appeared off the north-west coast of Western Australia.

7. Occurrences of other species of sea birds.

Gull-billed tern, (*Gelochelidon nilotica*) ranged inshore the west coast of Ceylon and the north-west coast of Australia. Indian black-headed gull, (*Larus brunnicephalus*) inshore along the west coast of Thailand and also Ceylon. Silver gull, (*Larus novaehollandiae*) on the Australian coastral waters.

Numerous Arctic skua, (*Stercorariidae parasiticus*) appeared off Fremantle when cruising between December 27, 1963 and January 3, 1964.

Two Yellow-nosed albatrosses, (*Diomedea chlororhynchos*) were seen in 31°29′S, 115°02′E on December 26, 1963.

White-faced storm-petrels, (*Pelagodroma marina*) appeared off the western coast of Austria, but were few in number. (Keijiro OZAWA).

Notes: This report was written by Captain K. OZAWA & Dr. J. SENO. (Tokyo University of Fisheries)—Using the data submitted by Umitaka-Maru, Koyo-Maru, Kagoshima-Maru, and Oshoro-Maru.

V–9. Fishery oceanography

Working Group for Fishery Oceanography

A. Report on Tunas Long-line Fishing, Fishing rate, and Distribution of Tunas

Since 1962, tunas fishing research with long-line has been done by Koyo Maru, Umitaka Maru, OshoroMaru and Kagoshima Maru in the southern summer season (November-January) in the Indian Ocean, as a part of I. I. O. E. Research Program. Through this research some informations were obtained as follows:

1. Fishing rate of tunas

Distributions of fishing rate (%) which is number of hooked tunas per 100 hooks, is shown in Fig. V-9-1. It may be laid down as general that the points showing percentage of good catch are distributed in the western part (area H, I, J, K, L, M in Fig. V-9-2. and that above all it was more than 4%

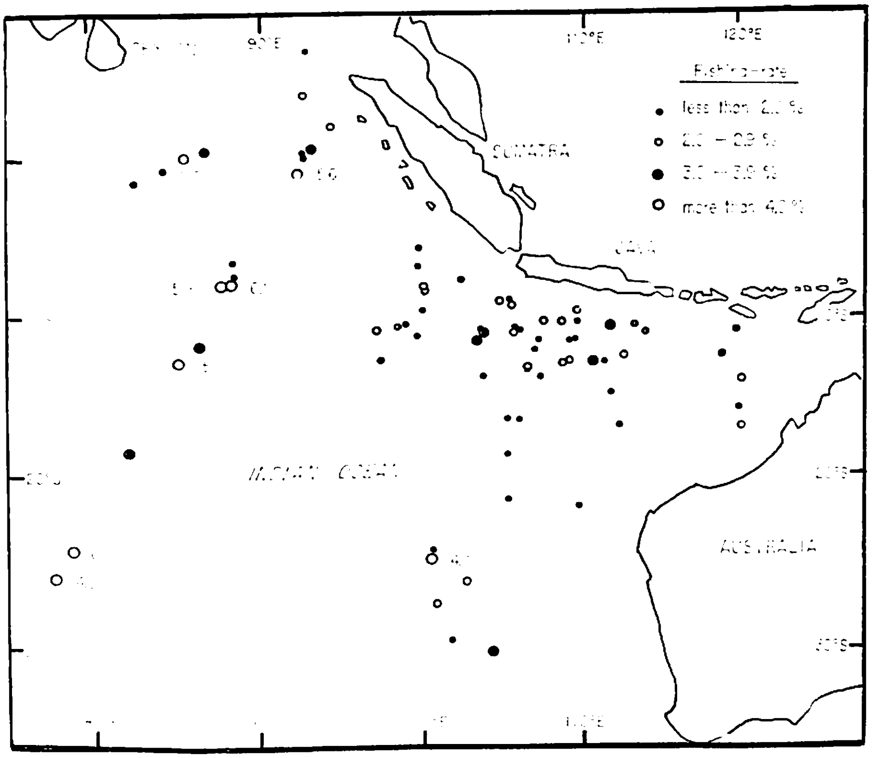


Fig. V-9-1. Map showing tunas-fishing position. Figure on map indicated fishing rate, which is number of tunas per 100 hooks.

at south to the equator in these areas.

Comparing to that in the western part, lot of points showing poor fishing rate were seen in the eastern part (area, A, B, C, D) and it was less than 2.9% at most points except only four points in the sea adjacent to Java Island.

2. Distribution of tunas

Summarizing the result of fish caught (Table V-9-1), the tunas were more abundant than the marlin in any area. Yellow-fin tuna was mainly distributed in the zone between the equator and the line of latitude 10°S and was much caught at localities in the western part of the above zone.

Southern Australian bluefin-tuna was abundantly caught in the eastern sea of Australia and some of them appeared at the oceanic front off Java Island and southwest side of Sumatra Island along longitudal line of 100°E.

Big-eyed tuna was distributed in the zone betweeen the line of lat. 5°S and the line of 10°S and was more caught in the western part of the zone.

Albacore was distributed in the zone between the line of lat. 10°S and lat. 30°S increased its abundance in the westward or southward direction.

Marlins were widely distributed in the ocean but their numbers were very few. The catch of sail-fish and striped marlin was comparatively good among them.

Short-nosed spear fish was very few and was merely caught in the area

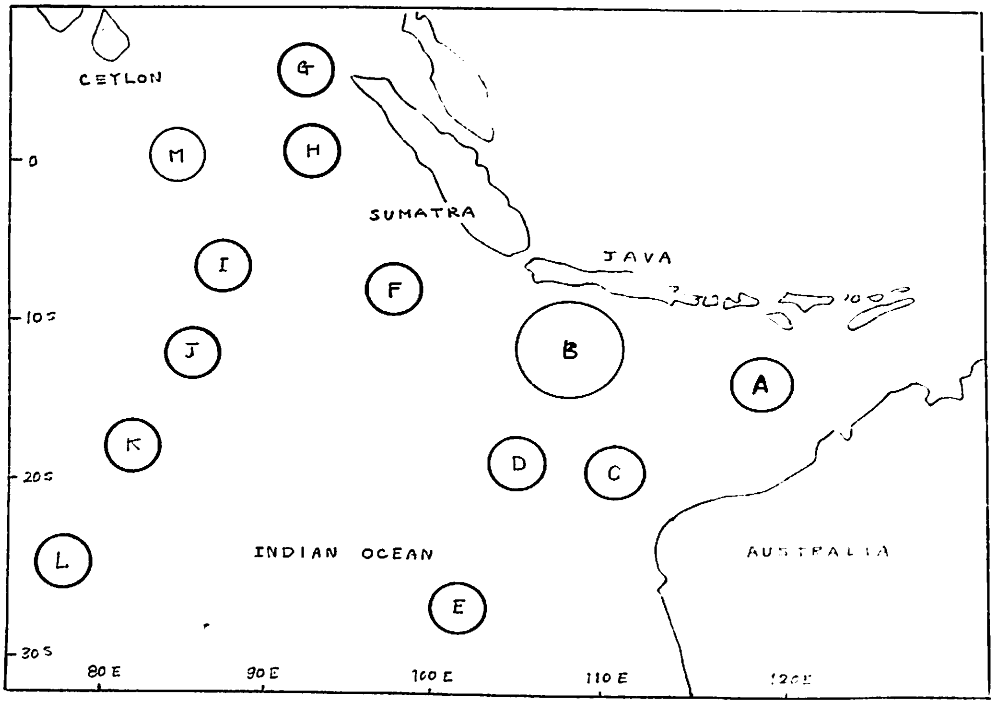


Fig. V-9-2. Area map, divided tunas-fishing position into area.

Table V-9-1. Number of tunas caught in the area and rate of its appearance into the area.

Area	Yellow-fin tuna		Big-eyed tuna		Southern Australian Blue-fin tuna		Albacore		Striped marlin		Sword fish		Mazara		White marlin		Sail fish	
A	22	44%	3	6%		%	3	6%	6	12%		%	1	2%	11	22%	4	8%
B	119	47	69	27	13	5	13	5	8	3	8	3	5	2	7	3	12	5
C	9	60	1	7			5	33										
D	1	2	4	11	3	8	22	58	3	8			1	2	2	5	2	5
E			13	11	54	45	48	40	3	3							2	1
F	26	28	22	24	12	13	11	12	2	2	1	1	3	3	2	2	13	14
G	2	9	14	6	2	9			1	4	4	17						
H	75	72	12	11					10	10	1	1	2	2			4	4
I	50	42	46	39			8	6	2	2	1	1	3	2			9	8
J	14	19	12	16			42	56	1	1	1	1	3	4			2	3
K	1	3					25	81					4	13			1	3
L	19	23	1	1			58	69	2	2							4	5
M	57	86	3	4					3	4			1	2			2	3

Note; These inlude number of tunas, snapped by shark and failed in picking it up.

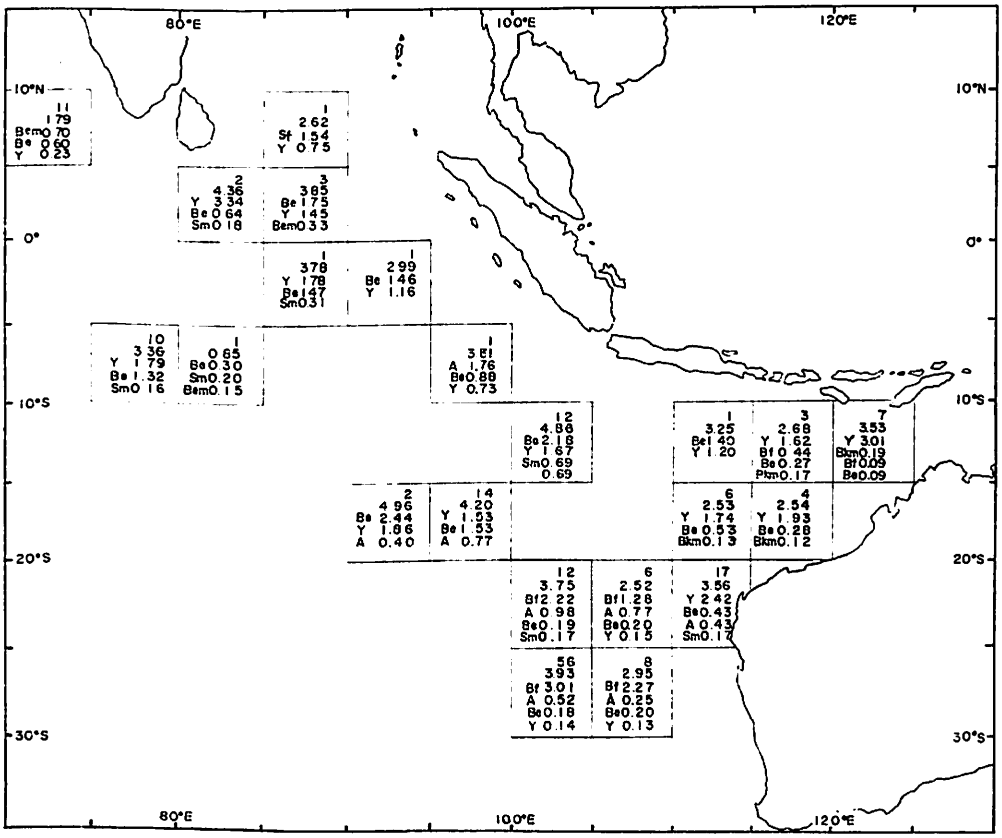


Fig. V-9-3. Tuna longline fishing statistics by Japanese tuna fishing boats in Dec. 1962 in each Number of 5° square. Number of fishing effort and hooked rate per 100 hooks.

A: Albacore, Y: Yellowfin, Be: Bigeyed, Bf: Bluefin, Bem: Blue marlin Bkm: Black marlin, Sm: Striped marlin, Sf: Sword fish marlin.

K and L. (S. UEDA)

3. *Commercial Fishing Grounds of Tunas in the Eastern Indian Ocean*

The distribution of fishing rate for each species of tunas caught by the Japanese commercial tunas long-line fishing boats in the Eastern Indian Ocean during the periods of northern winter (December, January of 1962/63 and 1964/64 is compiled in the grids of 5° longitude and latitude and plotted in charts. (Fig. V-9-3~V-9-6) Basing on these charts in comparison of figures, we can notice favourable tuna fishing grounds at the boundary zone of water masses (oceanic fronts) especially the northern fishing grounds near the coast concentrated on the boundary between the water masses E, D and C or B, and also the southern offshore fishing grounds concentrated on the boundary between the water masses of F and A.

The most interesting result is the fact that the higher productivity of tunas fishing grounds occurs around the upwelling zone located in the region south to Java Island lying in the eastern part of the water mass E.

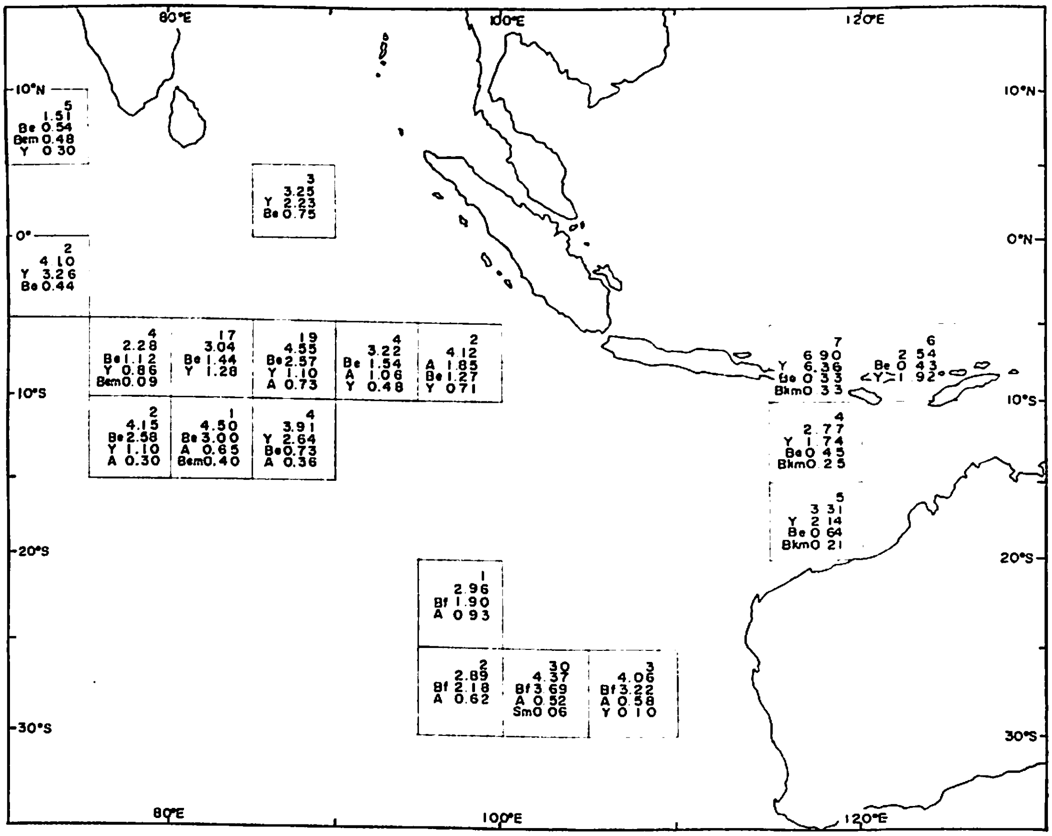


Fig. V-9-4. Tuna long line fishing statistics by Japanese tuna fishing boats in Jan., 1963. Number of fishing effort and hooked rate per 100 boats in each 5° square.

Also favourable yellowfin and bigeyed tunas fishing are found in the region of 5°N-20°S and poor in the area south to 20°S (water mass A). Favourable fishing ground of albacore tuna is found in the region south to 15°S. Fabourable bluefin tuna fishing grounds distribute in the region east to 100°E and especially conspicuous in the area extending from 15°S to 30°S. (M. UDA)

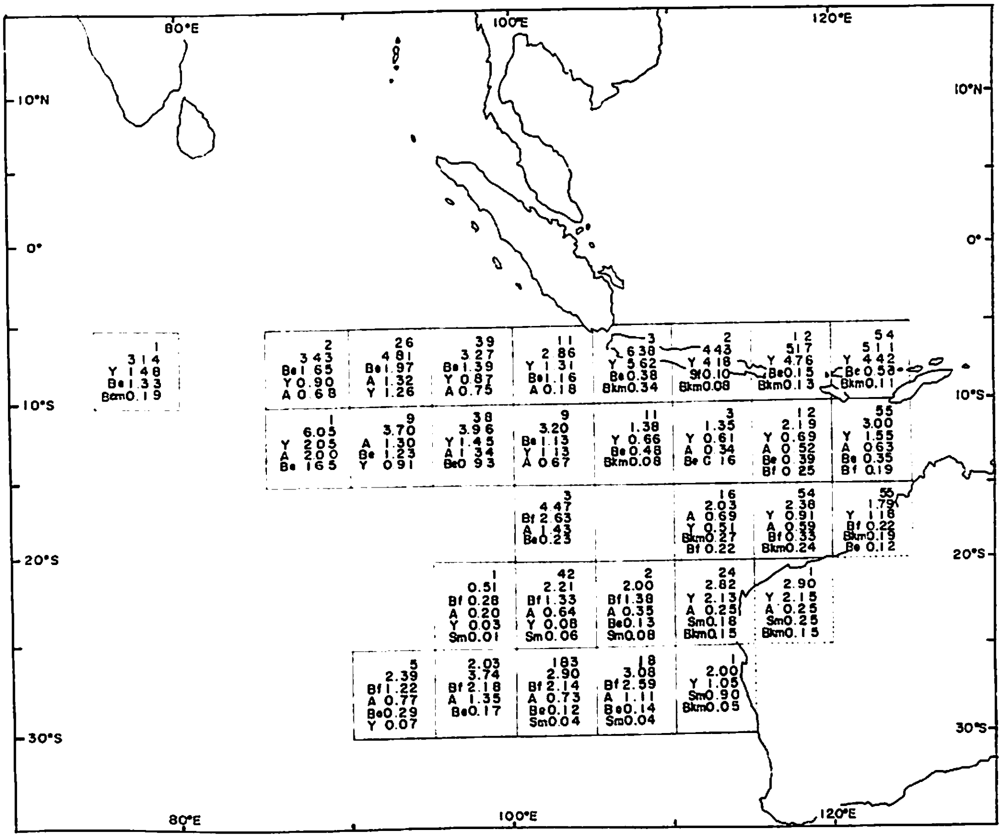


Fig. V-9-5. Tuna long-line fishing statistics by Japanese tuna fishing boats in Dec., 1963. Number of fishing effort and hooked rate per 100 boats in each 5° square.

B. Summary on experimental trawling off the coast of Western Australia

During the period 1962-1963 and 1963-64, experimental trawling, a total of 49 hauls, was carried out off the coast of Western Australia by Japanese ships participating in the International Indian Ocean Expedition.

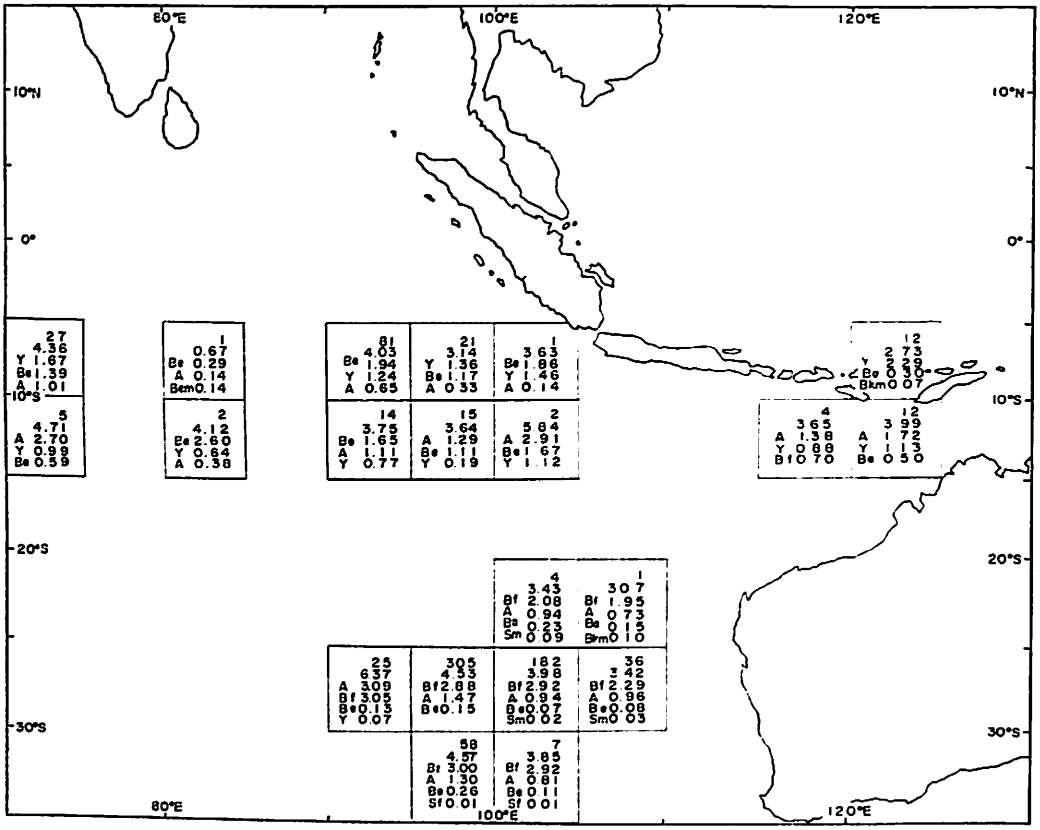


Fig. V-9-6. Tuna long-line fishing statistics by Japanese tuna fishing boat in Jan., 1964. Number of fishing effort and hooked rate per 100 boats in each 5. square.

Place	Date	Ship	Number of haul
Off N. W. coast	Dec. 14-19, 1962	Oshoro Maru	15
″	Dec. 1-2, 1963	Umitaka Maru	6
Off Shark Bay	Dec. 18-20, 1963	″	8
Off N. W. coast	Dec. 28, 1963—Jan. 6, 1964	Oshoro Maru	20

Basing on the data obtained by the above operations, general descriptions in respect to the fishing grounds and the catches off the northwest coast of Australia and off Shark Bay, are noted.

1. *On the ground off the northwest coast of Western Australia*

Fig. V-9-7 shows the bathymetric sketch and trawling stations on it.

This sea area belongs to the underwater terrace of Rolley Shelf (FAIRBRIDGE 1952, 1953, 1955). The exposed rocky cliff of the terrace showing in Fig. V-9-7 by the dotted line, running almost ENE-WSW, was observed, generally coinciding with the 100-meters contour and its height was measured

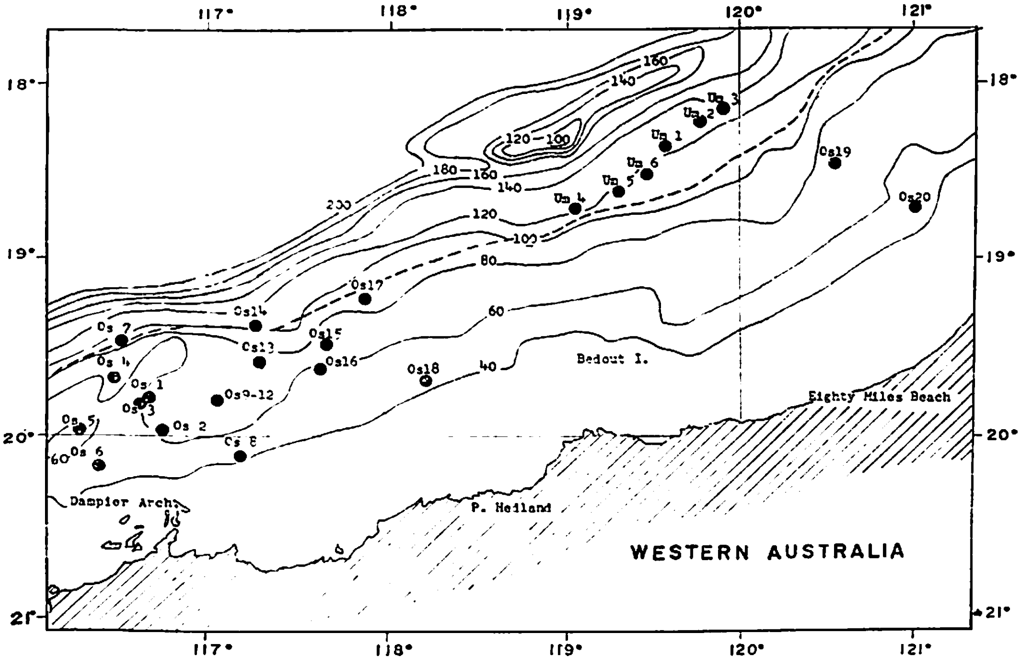


Fig. V-9-7. I. I. O. E. Trawl fishing ground with isobaths (meter) and Obs. Sts. (Umitaka maru, Oshoro maru).

2-10 meters. There is a hill-shaped swell centering at 18°22′S, 119°E, the shallowest depth charted 49 meters, extending appoximately 72 miles in 160-meters contour, which extends ENE-WSW. The nature of the bottom between the swell and the previously mentioned cliff is light greenish-brown sand or silty sand which are composed of mainly remains of calcareous organisms.

On the terrace between the cliff and shore, contours run parallel to the shore line except Dampier Rise off the same name archipelago. The nature of sand shell covers throughout this area except off Dampier Archipelago where boulders appear in the area of St. Os 1, 2 and 3, and also around a rock lying at 18°26′S, 120°08′E, which depth is 70 meters at the top. Sponge was found in large amounts on the north side area along the rocky cliff on the terrace, St. Os 7 and 14, Um 5 and 6, and a lesser degree towards the shore, however, a large quantity of sponge was in the net in the coastal waters, St. Os 6, 7, 8 and 20.

Based on the data of oceanographical surveys which were carried out by Oshoro Maru mainly around Dampier Rise in December 1963, high temperature and high salinity water appeared, which extended northwestward, St. Os 8-1-4, while on the east side of this water there was an intrusion of comparaively low temperature and low salinity water coming southward.

The fishes caught and catch rates per hour trawling in relation to the depth, are shown in Table V-9-2.

Table V-9-2. Summary of catch weight (kg) of principal species per an hour trawling in relation to depth.

Depth (m)	-60	-80	-100	120	-140
Station	Os 6, 8, 18, 20	Os 1, 2, 3, 4, 5, 9, 10, 11, 12, 13, 15, 16, 19	Os 17	Os 7*, 14 Um 5, 6	Um 1, 2, 3, 4
Bottom temp. °C	24.5-27.1	24.0-25.5	24.9	23.3 23.8	—
Species:	average range	average range		average range	average range
Lathrinus sp.	84 0-335	94 27-155	84	14 0 18	0
Iutjanus sebae	14 0- 38	16 8- 26	44	12 0 77	4 0- 15
Lutjanus vaigiensis	23 0- 84	41 0-160	100	19 0- 91	6 0- 16
Lutjanus vitta	4 0- 12	22 5- 48	50	5 0- 21	0
Lutjanus gribbus	27 0- 77	12 0- 48	37	9 0 39	0
Nemipterus peronii	32 0-109	40 3- 95	13	0	3 0- 10
Argyrops spp.	3 0- 10	12 0- 17	47	4 0- 18	0
Pristipomoides argyrogrammius	0	6 0- 15	62	8 0- 78	2 0- 15
Gymnocranius griseus	0	0	0	0	9 0- 37
Glaucosoma hebraicum	0	5 0- 19	17	4 0- 17	0
Priacanthus sp.	0	0	0	4 1- 5	5 1- 13
Caranx sp.	14 0- 50	20 0- 97	49	15 0- 81	12 2- 34
Trichiurus lepturus	0	0	0	0	4 3- 5
Saurida undospquanis	0	23 0- 50	0	5 0- 20	3 1- 11

* Os 7 Trawled depth 90 m to 24 m.

In conclusion, *Lathrinus ornatus* was the most abundant species in catch, comparatively larger catches of *Latjanus janthinuropteus*, *Scolopsis temporalis* and *Argyrops spinifer* were recorded at the grounds on the east side of the warm water, St. Os 7 and 9. On the contrary, the catches of *Nemipterus peronii*, *Lutjanus vitta* and *Lutijanus sebae* seemed to be inhabitants in deep waters. *Caranx* sp. ranges widely.

The catches of *Argyrops spinifer*, *Lutjanus janthinuropterus*, *Epinephelus* sp., *Caranx malabaricus* and *Scolopsis temporalis* seemed less at night than that in the daytime.

2. *On the ground off Shark Bay*

Fig. V-9-8 shows the bathymetric sketch with contours of 5-meters intervals and trawling tracke. This area is belonging to the Dirk Hartogs Shelf (FAIRBRIDGE, 1952, 1953, 1955).

There are three exposed rocks which are represented in letter "R" on the map, particularly, rocky portion 25 miles west of Bernier Island is clearly recorded on the echogram which depth is 78 meters at the top. These rocks seem to build this comparatively wide terrace. The intervals of depth contours both off Geographic Channel and Dirk Hartogs Island are dense, forming steep slopes to seaward.

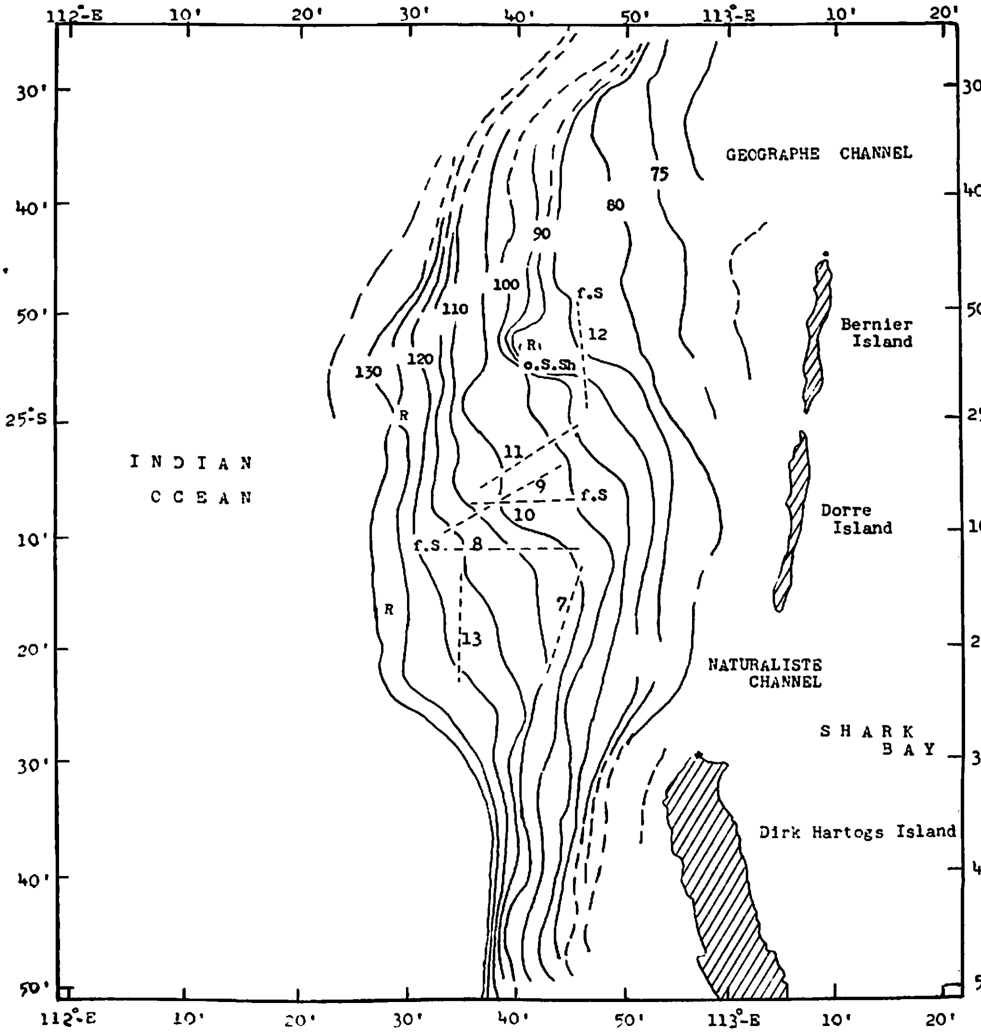


Fig. V-9-8. Showing the bathymetry off Shark Bay, depth conturs 5-meters intervals, trawling tracks shown by the dotted line.

The nature of the bottom is generally medium or fine sand composed of elastic calcareous materials of organic nature, coarse or very coarse sandy bottom was observed around the above mentioned rock. The mud content did not exceed 5 percent at any one locality.

The water, shallower than 50 meters deep, showed warmer than 23°C and salinity ranged between 35.2-35.3‰, but the deeper water to the bottom was 23-21°C and 35.3-35.3‰. The water on the shelf and naturally more southerly waters were virtually characterized by the sub-antarctic water.

The fishes caught and these catch rates per an hour trawling, are tabulated in Table V-9-3.

Table V-9-3. Summary on catch weight (kg) of principal species per an hour trawling.

Station	Um 7	8	9	10	11	12	13
Depth (m)	107-100	101-112	112-100	95-105	105-90	83	117-100
Species:							
Lutjanus sebae	0	0	1	2	3	0	0
Chrysoprys sp.	0	6	28	5	8	6	0
Gymnocranius griseus	0	0	0	0	7	19	0
Glaucosoma hebraicum	0	1	6	8	0	0	0
Caranx sp.	0	82	60	24	10	0	60
Tranchurus sp.	0	54	0	0	0	0	0
Sphyroena jello	0	0	3	0	3	0	13
Genyagnus sp.	3	0	0	0	0	3	0
Saurida undos	0	6	13	20	20	0	0

According to this table, comparatively abundant fishes, *Chrysophrys* sp., *Caranx* sp., *Glaucosoma hebricum* and *Saurida undos* were caught in this area southward of the 78 meters rock, however, a large quantity of sponge was also in the net.

References

MASUDA K. et al. (1964). Survery of Trawl Grounds of the North-West Coast of Australia with Special Reference to Hydrographidal Conditions on the Grounds. Bulletin of the Faculty of Fish., Hokkaido Univ., Vol. 15, No. 2, pp. 77-88.

Notes: This Report (V-9) was written by captains S. UEDA (Kagoshima Maru), K. OZAWA (Umitaka Maru) and Dr. M. UDA basing on the data submitted by the four boats, and others.

VI. Summary Note

1. Four Japanese surveying boats Umitaka-Maru, Koyo-Maru, Kagoshima-Maru and Oshoro-Maru participating in IIOE in the two northern winters of 1962/63 and 1963/64 in the Eastern Indian Ocean have completed the scheduled programme successfully. The data collected by hydrographic cast was sent already to WDC's through the national IIOE Data Center of Japan (Japanese Meterological Agency). Reprints to be published as Collected Reprints by UNESCO shall be sent in succession afterwards.

In the course of the arrangement and operation of these surveys accuracy of observations was raised greatly, especially through international standardization and intercalibration in each discipline.

2. Biological data and samples were sent and are to be sent to IIOE Biological Center in India by Dr. Shigera MOTODA and others. Meteorological data were sent to the International Meteorological Center of IIOE at Bombay in India through the Meteorological Agency of Japan (Drs. T. TERADA and H. FUCHI).

3. *Results of Bathymetry, Marine Geophysics and Marine Geology*

The measurement of gravity and magnetic force in the Indian Ocean was made for the first time as a geophysical survey by Japanese cruise. Newly constructed instruments, the Surface Ship Gravity Meter and the Proton Magnetometer, were used.

A discovery of seamounts, "Umitaka", "Cocos" and "Zenith" is one of important results of bathymetrical and geologic survey. From the top of the Cocos guyot, basement rocks containing some time-index fossils were collected.

As a result of the geologic survey, 26 core-samples and also many bottom sediments were obtained from various stations in the east Indian Ocean by means of piston-core-sampler and dredge. By analyzing those core fluctuations of seawater temperature during the latest geologic ages are being elucidated.

4. *Results of Meteorological Observations of the IIOE*

Extensive meteorological program was carried out on board of the Japanese IIOE participating ships during the winters (northern hemisphere) of 1962 and 1963.

Synoptic and statistical considerations are given for the details of the various weather conditions and comparison of the meteorological states in these two years is also presented.

Concerning air-sea interaction wind speed, temperature, and humidity are measured at six levels within the layer to a 10 m. height above the sea surface during the serial observations in the sea at 28 Kagoshima-Maru stations.

5. *Results of Physical Oceanography*

Synoptic maps representing the distributions of water temperature, salinity and other oceanographic elements on horizontal levels (0, 50, 100 and 200 m. depths) and in vertical sections from north to south were made and studied.

Further, maps of salinity-minimum, salinity-maximum, dissolved oxygen-minimum and its maximum, thickness of mixed layer, and thermocline topography etc. were drawn and inspected.

Water mass analysis by representative thermohaline curves has produced a map of the distribution of watermasses A, B, C, D, E, F characteristic to the eastern Indian Ocean and their boundaries.

A....South Indian Ocean Central Water mass (highly saline).
B....Arafura Sea origin water mass (lower saline, higher temp.).
C....Arabian Sea origin water mass (highly saline), near and south to equator flowing toward east, contrary to the north of equator flowing toward west.
D....North Indian Ocean and Bengal Bay origin water mass (lower salinity), extending from Bengal Bay to the north or west of Sumatra.
E....Mixed water mass upwelled to the south of Sunda Islands.
F....Mixed water mass flowing to the west, which belongs to the South Equatorial Current.
(Refer to Figs. V-4-28, 29.)

Current measurement by Ekman-Merz two current-meters method was carried out across and near equator, with the estimation of surface drift by current-bottle experiment, and surface current measurement by GEK. Tables V-4-1, 2 and Figs. V-4-26, 27). Computation of geostrophic flow are going on to the study of the Indian Ocean circulation.

With the contrast to the current structure, the water masses in the Indian Ocean were investigated closely.

Further, the study of the variation of currents and water masses in response to the changing monsoon is an important problem by comparison of the oceanographic maps and weather maps or climatic maps obtained. Effect of deep current (Antarctic Bottom Current and Subantarctic Intermediate Current) on the upper water masses in the Indian Ocean is notable, especially in the upwelling region south to Sunda Islands. Influence of the highly saline water extension flowing from Red Sea, Arabian Sea Gulf of Persia upon the water masses in the Eastern Indian Ocean is also remarked.

Optical property in the Eastern Indian Ocean is to be studied by the observed submarine light intensity and transparency of sea water.

Throughout the whole surveys one can find a remarkable zone of discontinuity in the meridional sections near the latitudes around 15°S in the Eastern Indian Ocean. Further one can notice a considerable variation of distribution patterns of water temperature, salinity etc. between the winters in 1962/63 and 1963/64, showing the northern shift of current-systems and upwelling area of cold water in the south offing of Sunda Islands, and also southward expansion of low salinity water in the surface layer west to Sumatra in the periods.

Since 1960 the above Japanese fisheries training boats have engaged in the experimental fishing (trawling and tuna longline fishing) along the oceanographic survey, we are now able to study the relationship between the fluctuations of fisheries and oceanic conditions. We can enhance the actual state of upwelling, convergence and eddies more closely and clearly from our synoptic maps.

6. *Results of Chemical Oceanography*

The working group for chemical oceanography adopted several recommendations and plans concerning items of observations, methods, standard solutions, instruments to be employed, equipments, number of chemists required per ship and intercalibration of methods.

Main results of observations are as follows: Salinity of water below 700 m depth was higher in the north and lower in the south. In the layer shallower than 700 m, the salinity was high in both north and south showing the minimum at around 10°S. Two minima of dissolved oxygen content were resulted by intrusion of oxygen rich water from the south. There was a boundary at about 15°S on both sides of which the property of the oceanic waters, such as AOU and concentration of phosphate differed considerably. The central core of the oxygen minimum was present in the north beyond 10°N and that of the oxygen maximum in the south beyond 20°S. It was observed in waters with σ_t 26.0, 26.3-26.5 and 27.0-27.4 that reserved phosphate concentration was higher in the water with lower salinity. The remarkable point in the silicate-AOU diagram was that even if σ_t was equal the inclination of the straight line was less steeper for waters with the smaller AOU. In the nitrate—AOU diagram a definite correlation could not be recognized probably due to poor precision of the analytical method.

The molybdenum content in sea water of the Indian Ocean was 0.12μg at/kg in average, which was highest ever studied. The vanadium content was 0.039μg at/kg in averge.

7. *Results of Primary Production*

The major results are as follows:

a) As previously expected, the primary production was found to be very low in the eastern region of the Indian Ocean with values near those in the Kuroshio region.

b) High values were observed in the sea region southeast of Java Island as found in the Oyashio region.

c) Covering the whole explored area, at levels ranging from 50 to 125 m., which constituted the upper part of thermocline, the enrichment of chlorophyll substances was found, which had already lost the photosynthetic activity.

8. *Results of Marine Biology*

a) A series of zooplankton samples collected by the standard method was sent to the Indian Ocean Biological Center, South India. Another series by the same method and the other samples taken by other various methods are stored at the institutions operating their ships in IIOE. They are being arranged for the studies by each specialists.

b) Concerning bacteriological observations conducted by the Koyo Maru in 1962/63 and 1963/64 down to the depth of 3000 m. and 5000 m., aesobic heterotrophs were found widely in the whole water column, varying it population counts over a wide range from less than 1 to 10^4 cells/ml.

Bottom sediment was also sampled for the bacteriological examination by the use of gravity corer.

In order to estimate the number of nitrifying bacteria in the sea, the water was examined by minimum dilution method. Nitrifiers in the plankton suspensions were considerably abundant compared with those in sea water samples.

9. *Results of Eye Observation*

The four Japanese boats participating in IIOE carried out continuous observations during the cruises in the winters of 1962/63 and 1963/64, and recorded sea birds, land birds, sea snakes, flying fish, sharks, dolphins, skipjack schools, smaller or larger whales, Vellela, cuttle-bone, sea weeds, insects and floating materials on log sheets. Particularly Umitaka Maru contributed for the distribution of sea birds in relation to fishing grounds.

Figs. showing occurrences of land birds and insects with wind map, distributions of flying fish, *Sterna fuscata* and occurrence of skipjack schools, Tropic birds (*Phaethon* sp.), Shear Waters, Frigate birds and Boobies were indicated with quantitative patterns.

10. *Results of Fishery Oceanography*

a) Since 1962 tunas experiment fishing research with long-line has been carried out by the Japanese IIOE participating boats in the southern summer seasons in the Eastern Indian. Results are compiled in the two maps including a map of tunas fishing position with specified amount of fishing rate or hooked-rate at each station (number of tunas caught per 100 hooks), and an area map represented by the divided tunas fishing positions into different areas. Table showing number of tunas for each species caught in the area and rate of appearance into the area is compiled.

With reference to the above, maps showing the distribution of tunas fishing rate for each species respectively caught by Japanese commercial tuna boats in the periods (Dec., Jan.) of 1962/63 and 1963/64 are compiled and studied in comparison to the oceanographic maps obtained. As a consequence the most favourable fishing grounds are located in the waters south to Java corresponding to the marginal areas of upwelling zone. Favourable grounds of yellowfin-tuna and big-eyed tuna (5°N-20°S), albacore-tuna (south to 15°S), and bluefin-tuna (east to 100°E, 15°S-30°S) are found.

b) During the periods of 1962/63 and 1963/64, experiment trawling (a total of hauls) were carried out off the coast of Northwest Australia including Shark Bay by Oshoro-Maru and Umitaka-Maru participating in IIOE. The fishing grounds with bathymetric sketch and the catches (seabreams etc.) are noted by Figs. and Tables with catch rate per hour trawling in relation to the depth.