THE KUROSHIO III

PROCEEDINGS OF

THE THIRD CSK SYMPOSIUM

BANGKOK, THAILAND

1973

INTRODUCTION

The Proceedings of the 3rd CSK Symposium is the result of the close scientific study which has been carried out cooperatively by marine scientists from various countries around the Pacific. This is the third of its kind of the efforts to reveal the mysteries of the counter part current of the well known Gulf Stream of the Atlantic.

Thailand was chosen as a venue for the Ninth Session of the International Co–ordinate Group for the Co–operative Study of Kuroshio and Adjacent Regions on May 30–June 1, 1973. The Session was held at the UNESCO Regional Office for Education in Asia, Darakarn Building, Bangkok. Prior to this meeting the Third CSK Symposium was held on May 26–29, 1973 at the same place.

The Symposium was divided into three Sessions which deal with the following subjects;

Session 1 : Physics, Chemistry and Geology

Session 2 : Biology and Biochemistry

Session 3 : Fisheries

Ten papers were presented in Session 1, seven papers in Session 2 and five papers in Session 3, making a total of 22 papers.

In the publication of this Proceedings the National Research Council of Thailand accepted the responsibility of setting up an editorial board. It is very much appreciated that the UNESCO has made the publication possible by contributing to its cost.

Special gratitude goes to Dr. O. Mamayev, Assistant Secretary of IOC and Dr. I.A. Ronquillo for their helpful assistance; to Dr. Ken Sugawara for his valuable advice; and to Mrs. Sakuntala Bhodhiprasart for her invaluable and devote service in organizing and handling the work of the secretariat.

UNESCO/Intergovernmental Oceanographic Commission

THIRD CSK SYMPOSIUM

(Cooperative Study of the Kuroshio and Adjacent Regions)

Conference Room, UNESCO Regional Office Bangkok

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LIST OF PARTICIPANTS AND OBSERVERS

THIRD CSK SYMPOSIUM

BANGKOK, 26-29 MAY 1973

Paticipants

Country	Name, Title, Address
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Assistant Professor, Department of Marine Science

Chulalongkorn University

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Upper air and Marine Meteorology Section

Department of Meteorology

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UNESCO/INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

THIRD CSK SYMPOSIUM

(Cooperative Study of the Kuroshio and Adjacent Regions)

UNESCO Regional Office BANGKOK

PROVISIONAL TIME TABLE

Saturday, May 26, 1973

08.30–09.00 hours	Registration.
09.00–09.30 hours	Programme for the opening session.
10.30–12.00 hours	Small short session, selected Chairman & Discussion Leader & Rapporteur for each session
Afternoon	Free

Sunday, May 27, 1973 Field Trip to Rayong Province

Monday, May 28, 1973

09.00–10.30 hours	SESSION I: PHYSICS, CHEMISTRY AND GEOLOGY. General Results of Oceanographic Observation in 1970, 1971 in the Gulf of Thailand

Tavorn Pongsapipatt

Gullaya Sapsomwong

....

Marine Sediments in the Nhatrang Area

Nguyen–Ngoc–THACH

....

Tidal Prediction by a Computer

Thanom Charoenlaph

Krisda Kiangsiri

....

10.30–10.45 hours	Coffee break
10.45–12.00 hours	SESSION II : BIOLOGY AND BIOCHEMISTRY

Phytoplankton in the Sea Area of the Southeastern Asia

Ryuzo Marumo

....

Seasonal Variation of some Planktonic Organisms in the Bay of Nhatrang

Nguyen–Thuong–Dao

....

Zooplankton Distribution off Mindoro Island and Balayan Bay, Luzon Island, Philippines-South China Sea

Jose A. Ordonez

Rizalina M. Legasto

Nicanor R. Metrillo Jr.

....

14.00–15.30 hours — The Distribution of Planktonic Hyperiids (Crustacea, Amphipoda) in the South China Sea and the Relationship to the Distribution in the Gulf of Thailand

Suraphol Sudara

....

Phytoplankton and Circulation North of New Guinea in Summer 1971

Bruno Wauthy

....

Dominance of Coccolithophorids in the Phytoplankton of the Western Equatorial Pacific Waters in June–July 1971

Roger Desrosieres

....

The Estimation of Phytoplankton Production in the Gulf of Thailand from Chlorophyll Content or Oxygen Determination and Light Data

Ampan Lursinsap
Manop Charoenruay

....

15.30–15.45 hours — Coffee break

15.45–17.00 hours — SESSION III: FISHERIES

A Preliminary Report on a Bottom Trawl Survey of the North Shelf of the South China Sea March 1972 to March 1973

R.M. Chilvers

....

Study on the Biology of *Psenopsis anomala* (Temminck and Schelgel) with a Note on its Fisheries in Hong Kong

R.T. Chung

....

Tuesday, May 29, 1973

09 . 00–10 . 30 hours — CONTINUATION OF SESSION III

The Reproduction, Growth, and Survival of *Upeneus moluccensis* (Bleeker) in Relation to the Commercial Fishery in Hong Kong

C.K.C. Lee

....

An Analysis of the Gut Contents of the Indo-Pacific Mackerel Lavae

Sunee Suvapepun

....

Additional Paper to the Identification of *Nemipterus* spp. in Thailand

Thosaporn Wongratana

....

10 . 30–10 . 45 hours	Coffee break
10 . 45–12 . 00 hours	CONTINUATION OF SESSION I
	Intermediate Waters North of New Guinea
	H. Rotschi, C. Colin, C. Henin, C. Oudot
	....
	Upper Waters North of New Guinea in 1971
	C. Colin, J.R. Donguy, C. Henin, C. Oudot, B. Wauthy
	....
	Equatorial Currents System North of New Guinea
	C. Colin, C. Henin, F. Jarrige, P. Rual
	....
14 . 00–15 . 30 hours	Water Masses and Currents in the South China Sea and their Seasonal Changes
	Michitaka Uda Toru Nakao
	....
	Thermohaline Diversity of the Japan Sea
	O.I. Mamayev
	....

Cyclonic Cold Eddies along the Edge of the Kuroshio Current in Relation to the Genesis and Passage of Cyclones

Michitaka Uda

Akira Kishi

....

15 . 45–17 . 00 hours SESSION IV CONCLUSION

Final Discussion and Recommendation

....

THE OPENING CEREMONY

of

The 9th Session of the International Co-ordination Group for the Co-operative Study of the Kuroshio and Adjacent Region (CSK) and the 3rd CSK Symposium

Saturday 26 May 1973

at

Darakarn Building (UNESCO's Office)

Sukumvit Road

Bangkok

Schedule

8.30 a.m.	–	Registration
9.00 a.m.	–	Participants and honorable Guests assemble in the Conference Room
9.25 a.m.	–	H.E. The Prime Minister, Chairman arrives at the Darakarn Building
	–	Dr. Pradisth Cheosakul, Secretary-General of the National Research Council escorts the Chairman to the Conference Room
9.30 a.m.	–	Report by Dr. Pradisth Cheosakul
9.35 a.m.	–	Address by Dr. J.M. Harrison, Assistant Director General for Science of UNESCO
9.40 a.m.	–	Keynote Address by H.E. the Prime Minister, Chairman of the Ceremony

M.C. – Mrs. Sakuntala Bhodhiprasart
Deputy Secretary–General for Natural Science of the National Research Council

Item 1. Opening Ceremony

The Session was opened by Dr. Pradisth Cheosakul, Secretary–General of the National Research Council and Chairman of the National Marine Science Committee. After a short welcoming address, Dr. Cheosakul invited Dr. Kiyoo Wadati, International Co–ordinator for CSK, to take the Chair.

Dr. Mamayev (UNESCO/IOC) highlighted the most important matters that have occured in the life of the CSK and stressed the necessity for consideration by the Session of future CSK activities. He also stated that another recent problem is that of marine pollution and this too must be studied closely to see what action could be taken in this problem area.

The Chairman proposed that Mr. Chilvers (U.K.) and Capt. Tavorn Pongsapipatt (Thailand) act as Rapporteur and Vice–rapporteur respectively. This proposal was seconded by Dr. Loi (Vietnam) and carried unanimously.

In view of the change in representation at the Session compared with the preceding Symposium, new delegates were requested to registered their attendance and a complete list of participants is attached to this Summary Report.

Item 2. Adoption of the Agenda

Following lengthy discussion and suggestion from the floor, the provisional agenda, with the inclusion of a new item 4 and consequent re–numbering, was adopted.

Item 3. Progress Report of CSK Activities since the Eighth Session.

(a) Reports of ICG/CSK Officers.

The following report, were delivered to the Session. It should be noted that there is no report from the Co-ordinator of the South China Sea Survey.

1. Report of the International Co-ordinator

2. Report of the Assistant International Co-ordinator.

3. Report of the Director of the Kuroshio Data Centre.

In the absence of the Director, the report was delivered by Dr. Ken Sugawara.

Following the report, Dr. Sugawara (Japan) distributed a summary of the replies to the questionnaire on marine pollution in member countries received to date for consideration under Agenda Item 6. There were complaints that the questionnaire had either not been received at all or received only indirectly. Dr. Sugawara apologised on behalf of UNESCO for this unfortunate event.

4. Report of the Director of the Regional Marine Biological Centre.

In the absence of the Director, this report was delivered by Dr. Stayaert (UNESCO) who hâd brought copies of the report from Singapore.

These reports were accepted without demur by the Session but later, considerable discussion arose concerning the Regional Marine Biological Centre (RMBC) and the examination of the sorted samples by specialists and Junior planktologists. In the absence of the RMBC Director, Dr. Vagn Hansen, Secretary for the Advisory Panel for Marine Biological Centres sponsored by UNESCO, clarified the situation by pointing out that processed, and at a later stage, the identified samples are kept as a permanent reference collection at the RMBC now housed at the University of Singapore, to which the collection from the previous National Museum of Singapore has been transferred. The plankton samples will be kept as a regional reference collection under the responsibility of the Government of Singapore.

Selection of taxonomists: A list of senior taxonomists from the CSK member states will be drawn up by a panel organised by the ICG and forwarded through the RMBC director to the UNESCO Advisory Panel for final selection. Priority will be given to taxonomists from the region but in cases of conflict involving the preparation of international monographs priority will be given to the latter taxonomists irrespective of nationality, Senior taxonomists should be encouraged to study material with a team of Junior taxonomists (at postgraduate or doctorate level) as part of a training programme, either in their own countries or in Singapore. Funds will be made available for the latter purpose.

(b) Reports of National Co-ordinators.

In view of the length of some of the orally delivered reports, only summaries, where applicable, are presented as follows:

1. JAPAN
2. KOREA
3. PHILIPPINES
4. THAILAND
5. UNITED KINGDOM (HONG KONG)
6. UNION OF SOVIET SOCIALIST REPUBLIC
7. VIETNAM

Following the presentation of the National Co-ordinators report the Chairman invited country observers and the representatives of the regional and international organizations to make their reports. A written report from ORSTOM (France) was shown.

Dr. Sahrhage (FAO) made a brief statement to the effect that is seemed to be preferable to report on specific aspects of collaboration between CSK and FAO/IPFC programmes under the appropriate agenda items. He then described the FAO/UNDP South China Sea Fisheries Development and Co-ordinating Programme, which is presently in Phase 1, the planning stage of one year duration. The Programme is concerned with fisheries development, acquiring a better knowledge of the resources by survey and evaluation of the stocks and their potential; and technical matters e.g. harbour development, vessel and improvement gear fish processing. From the results of Phase I, an action plan will be developed for Phase II which is expected to be implemented in early 1974 and may be of 4-5 years duration. Marine pollution studies may also form part of the Programme.

Dr. Arporna Sribibadh (SEAFDEC) commented verbally on the work undertaken by his organisation which is an implementing body operating research on fisheries and oceanography from Singapore in the South China Sea and conducting fisheries training in Thailand. It is intended to expand the geographical area of operations and to utilise more types of gear SEAFDEC has every intention of continuing to co-operate with IPFC and CSK since many of its members are also members of these other bodies.

REPORT

by

Dr. Pradisth Cheosakul

Secretary-General, National Research Council

in

the opening ceremony of

the 9th Session of the International Co-ordination Group for

the Co-operative Study of the Kuroshio and Adjacent Region (CSK) and

the 3rd CSK Symposium

Your Excellency, the Prime Minister :

It is a great honour to and display of great trust in Thailand that the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization has requested Thailand to host the CSK Symposium again. As the Secretary-General of the National Research Council and the Chairman of the National Marine Science Committee which is directly involved in this matter, I would like to report to you the background of the International Co-ordination Group for the Co-operative Study of the Kuroshio and Adjacent Region (CSK) and Thailand's role in it.

The Regional Meeting of the experts in Marine Science of Asia and Southeast Asia held by UNESCO in Manila on March 5-8, 1962 proposed that the CSK project be carried out cooperatively under the sponsorship of the Intergovernmental

Oceanographic Commission established by UNESCO in Paris. Later on the 2nd Intergovernmental Oceanographic Commission Meeting held in Paris on September 20-28, 1962 supported this proposal. Finally the 3rd Intergovernmental Oceanographic Committee held in Paris on June 10-19, 1964 adopted a resolution to sponsor the CSK project and set up an International Co-ordination Group composed of National Co-ordinators and Assistant National Coordinators from eleven member countries, namely, Republic of China, Indonesia, Japan, Korea, the Philippines, Singapore, Thailand, the United Kingdom (Hong Kong), the United States, the USSR and Republic of Vietnam.

Since its inception the CSK project has brought for the numerous achievements, e.g., oceanographic research conducted simultaneously at various fixed points in the sea, whereas in fisheries studies were made on some species of marine animals selected on the basis of their relative importance for fisheries in general and the degree of abundance in which they were caught in at least two countries.

In the original stage the CSK project concentrated its attention on the Kuroshio region. Later it was considered that the adjacent region of the Kuroshio especially the South China Sea including the Gulf of Thailand and the Sunda Continental Shelf which are important areas for oceanographic and fisheries research, is of significant relevance to the project. Since a study of these areas will not yield comprehensive results if it is not carried out jointly, Thailand has decided to join the CSK project for the Survey of the South China and received much benefits from it. Countries participating in the South China Sea study cooperate with one another in exchanging data, training personnel, and classifying planktons through the support of the Biological Centre for Classifying Plankton in Singapore and the Kuroshio Data Centre in Japan. Scientists of member countries are, therefore, provided with facilities for the survey of various areas in the South China Sea and at the same time receive data from the surveys of other countries for the use of their study and research, thus increasing the store of knowledge in oceanography and fisheries which is of future economic value.

Thailand was the venue for the 4th CSK symposium in 1967 which turned out to be a tremendous success. The Intergovernmental Oceanographic Commission again requested Thailand to host the 9th Session of the International Co-ordination Group for the Co-operative Study of the Kuroshio and Adjacent Region and the 3rd CSK Symposium. Today a number of honoured representatives and distinguished marine scientists from this region and related agencies are present to discuss the administration of this project in the Session of International Co-ordination Group. They will discuss their problems and findings regarding the research on the Kuroshio and Adjacent Region in this Symposium as well.

KEYNOTE ADDRESS

of

H.E. Field Marshal Thanom Kittikachorn, the Prime Minister

in

the opening ceremony of

the 9th Session of the International Co-ordination Group for

the Co-operative Study of the Kuroshio and Adjacent Region (CSK) and

the 3rd CSK Symposium

Honoured Guests :

In the name of the Thai government, I feel very honoured and delighted that Thailand has been requested to host the 9th Session of the International Co-ordination Group for the Co-operative Study of the Kuroshio and Adjacent Region, and the 3rd Symposium on the study and research under the Kuroshio project, in which delegates of over 11 countries are participating.

According to the report of the Chairman of the National Marine Committee on the background of CSK and the statement of the Assistant Director-General for Science of UNESCO, it is evident that the CSK project results from strong efforts of scientists in various fields of marine science to solve various problems cooperatively in order to reveal the mysteries of the Pacific currents which equal in importance to the Gulf Stream in the Atlantic. The information received from the research work of these scientists will give much benefits not only to scientific community but also to the economies of various countries in this region.

Activities in marine science need knowledge and competence in many fields of science such as physics, biology, chemistry, meteorology, etc. There are many deficiencies in these fields, especially the lack of data, which require the use of expensive ships as well as equipments and which prevents simultaneous surveys at various points. However, in spite of all these difficulties, you are able to make good progress in your work.

In the midst of the present world crises, one thing that avoids political fights and conflicts is perhaps the close and peaceful co-operation among scientists such as yourselves who sacrifice their time and effort to study nature by co-operative projects and exchange of data.

I am confident that the support of the parent organizations, i.e., the Intergovernmental Oceanographic Commission and the UNESCO, as well as the capable management of the related personnel especially Dr. Kiyoo Wadati, the International Co-ordinator and Dr. Pradisth Cheosakul, the Chairman of the National Marine Science Committee of Thailand, will certainly guide the 9th Session of the International Co-ordination Group for the Co-operative Study of the Kuroshio and Adjacent Region to its objectives. I also hope that the jointly held 3rd CSK Symposium will bring to light many significant research findings.

On behalf of the Thai Government I express our sincere wish that your meetings are fruitful. I also would like to welcome all of you in your visit to Thailand and hope that you enjoy your stay. At this auspicious moment, I declare the meetings open.

Third Symposium on the Results of the

Co-operative Study of the Kuroshio and Adjacent Regions

SUMMARY REPORT

UNESCO Regional Office, Bangkok

26-29 May, 1973

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1. OPENING SESSION

1.1 The Third CSK Symposium was held at the UNESCO Regional Office for Education in Asia, Bangkok, Thailand from 26-29 May, 1973, under the sponsorship of the National Marine Science Committee of the National Research Council of Thailand.

1.2 Dr. Pradisth Cheosakul, Secretary-General of the National Research Council of Thailandand Chief of Thai delegation, gave a report on the background of the International Coordination Group for the CSK.

1.3 Dr. J.M. Harrison, Assistant Director General for Science of UNESCO and Prof. Kiyoo Wadati, International Coordinator of CSK addressed the assembly, stressing on the importance of oceanography.

1.4 The participants were welcomed in a keynote address by His Excellency, Field Marshal Thanom Kittikachorn, the Prime Minister of Thailand.

1.5 Dr. I.A. Ronquillo (Philippines) was Convenor for the Symposium. Dr. Pradisth Cheosakul (Thailand) was elected Chairman and Dr. C.K.C. Lee (U.K. - Hong Kong) was elected Rapporteur.

1.6 Discussion leaders and rapporteurs were appointed for the three Sessions of the Symposium :

Session I	Dr. A. Rogotsky (U.S.S.R.)	Discussion leader
	Dr. Manuwadi Hungspreuge (Thailand)	Rapporteur
Session II	Dr. Twesukdi Piyakarnchana (Thailand)	Discussion leader
	Dr. Tran-Ngoc-Loi (Vietnam)	Rapporteur
Session III	Dr. R.M. Chilvers (U.K. - Hong Kong)	Discussion leader
	Dr. Surapol Sudara (Thailand)	Rapporteur

2. Special lecture on Scientific Approach to Marine Pollution by Prof. K. Sugawara (Japan).

2.1 Prof. Sugawara (Japan) discussed on the various scientific approaches which should be considered in studying the problems of marine pollution. He also pointed out the need to standardise existing techniques and develop new methods for determining pollutants, and the cooperation of regional experts on the national level is required, as stated in the Report of the First Session of the International Coordination Group for GIPME (Global Investigation of Pollution in Marine Environment) April 2-6, 1973. On a global scale, IGOSS (Integrated Global Ocean Station System) has a marine pollution monitoring program, and IOC/GIPME has a program to clarify the sources and rates of input of pollutants into the sea. Prof. Sugawara finally pointed out that the CSK policy towards the subject of marine pollution should be considered in the light of the above factors.

2.2 Dr. Pradisth Cheosakul (Thailand) expressed his concern over the relatively large number of methods which are being used for the analysis of metals in fish. Dr. Sugawara (Japan) explained that efficient and standardised methods are yet to be found.

2.3 Dr. D. Sahrhage (FAO) drew attention to the FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing held in Rome, December, 1970 the results of which are available in book form. He also pointed out that various international agencies have Working Parties on marine pollution, and that of regional interest is the IPFC Working Party on Aquaculture and Environment.

3. The three Sessions of the Symposium deal with the following subjects:

Session I : Physics, Chemistry and Geology

Session II : Biology and Biochemistry

Session III : Fisheries.

4. SESSION I.

4.1 Ten papers were presented in the fields of Physics, Chemistry and Geology. The geographical area covered in these papers ranges from the Gulf of Thailand to the Japan Sea, Western Pacific, and waters north of New Guinea. Of particular interest are Paper Numbers 105, 106 and 107 which reveal the very complex oceanographic situation in the Western Pacific. As research vessels of many nationalities visit this region, the desirability of carrying out experiments on the inter-calibration of instruments and methods of measurement among vessels working in the same or adjacent waters becomes evident, so that scientists in one area may use the results of those from another area with more confidence.

4.2 A comparison of the results of Paper Numbers 108 and 111 seems to show that they are contradictory. It was however pointed out that the discrepancy in the direction of flow of currents in and out of the Japan Sea may be due to the fact that the time at which measurements were made are different in the two Papers.

4.3 Paper Number 102 on marine sediments was interesting in that coral banks contribute to the calcareous components of the sediments. The successful use of Shannon's index in temperature-salinity analysis as presented in Paper Number 109 also provides an additional quantitative parameter which may be used in the analysis of ocean water masses.

5. SESSION II

5.1 Seven papers were presented in this Session, of which five are on phytoplanktons and two are on zooplanktons.

5.2 The complexity of tropical phytoplankton communities and the difficulties encountered by investigators are emphasized in Paper Number 201. In the Indo-Pacific region, chlorophyll content was found to be greatest in the Sulu and Celebes Seas. The importance of *Trichodesmium* sp. in the tropical ecosystem lies not only in its abundance but also in its possible effects on the exchange of gases between the atmosphere and the water through its ability to fix nitrogen.

5.3 The diversity of phytoplankton species is demonstrated in the large number of species of Cocolithophorids reported in Paper Number 206 for water north of New Guinea.

5.4 The efficiency of the sampling gear is an important consideration in the study of the distribution of plankton. This point was raised during discussions on the results of Paper Number 202 & 203.

5.5 In the results of Paper Number 204, certain amphipods species have a comparatively wide distribution, and Dr. Ronquillo (Philippines) suggested that these species may be used as indicators for water masses.

5.6 Paper Number 207 presented interesting results on the primary productivity of waters of the Gulf of Thailand. The complexity of the environment, however, indicates that in the future more advanced techniques are required (e.g. use of Carbon–14) so that the quality of the results is comparable to that obtained in other parts of the Pacific.

5.7 In conclusion, it was felt that the relatively small number of papers on zooplanktons may be due to the fact that the specimens from the Singapore Sorting Centre have not been distributed to experts and local marine biologists for further investigations.

6. SESSION III

6.1 Five papers were presented on the subject of fisheries. The main point that emerges from a consideration of the subject matter of the limited number of papers delivered under this heading is their variety. All papers, however, are interlocked. Paper number 305 on the identification of *Nemipterus* is an excellent example of the prime problem facing workers in any fisheries field, namely, that of identifying in the first instance, the particular species in which he may be interested. Without such studies, workers in other fields would be severely handicapped. This problem has long been recognised and received recent action in the form of the FAO–DANIDA Workshop on Fish Taxonomy held in Phuket, Thailand from 6 November – 8 December 1972 which prompted the present work. The report from the Workshop has already been published. It is suggested that the Symposium should recommend that the ICG congratulate FAO and DANIDA on the success of the Workshop and that FAO be asked to expedite the publication of the 280 species identification sheets.

6.2 Miss Sunee Suvapepun's work (Paper Number 304) on the food of the larval stages of *Rastrelliger neglectus* has great practical applications and although the presence of an item in the gut does not necessarily mean that it will undergo digestion to serve as a source of food, the finding that the larvae undergo a change in diet from zoo-to phytoplankton should greatly assist future culture work conducted in Thailand or elsewhere. It could well be that a similar feeding pattern exists for closely related groups and studies of this nature should be encouraged.

6.3 The paper by Dr. Lee (Paper number 303) and Mr. Chung (Paper Number 302) on various aspects of the biology of individual fish species also have practical applications as they greatly assist in the understanding of the factors controlling the distribution, abundance and rate of exploitation which individual species from tropical or subtropical areas might be expected to support. Both papers stress the importance of the collection of commercial catch and effort statistics and it is suggested that the symposium should recommend to ICG that this matter should receive the priority attention of the governments of the different countries participating in the CSK programme.

6.4 Paper Number 301 presented only the preliminary results of a different approach from studies on individual species and adopts a gross biomass approach to fish abundance. It is suggested that this type of investigation gives a better understanding of the states of exploited or unexploited stocks. Certain anomalies with respect to the depth distributions reported were pointed out, but the generalisation made was intended to apply only to the north shelf of the South China Sea and supported Shindo's contention that this area is in danger of overexploitation. It is suggested that this paper should be studied in relation to those presented at the SEAFDEC Seminar which preceeded the Third CSK Symposium.

7. FINAL DISCUSSIONS

7.1 After some discussions, Dr. Arporna (SEAFDEC) drew attention to the fact that the Summary Report of the SEAFDEC Seminar (May 21–25, 1973, Bangkok) contains 8 recommendations of which 3 are related to the 4 points raised by Mr. Chilvers (U.K. – Hong Kong) in his report of Session III. Dr. Arporna pointed out that this is a good opportunity for SEAFDEC to be considered in ICG discussions so as to enable the efficient coordination of research effort.

Dr. Pradisth agreed that since similar recommendations came up independently from CSK and SEAFDEC, these recommendations will be in a position to reinforce one another.

7.2 Dr. Rual (France–New Caledonia) pointed out the desirability of holding joint Symposia when two organisations, such as CSK and SEAFDEC, are dealing with similar subjects. Dr. Pradisth (Thailand), while agreeing with the view of Dr. Rual, pointed out the difficulties exemplified by his past experiences. Prof. Sugawara (Japan) stressed that different organisations are established on different traditions and methods of functioning, and this in turn leads to different approaches in the advancement of oceanography.

7.3 Dr. Mamayev (IOC) pointed out the need to decide if the Symposium papers are to be published. After some discussions on the publication of the papers presented at the 2nd CSK Symposium, he informed Dr. Pradisth that UNESCO has a provision budgetted at about US $ 4000 for the said purpose. Dr. Mamayev also suggested that a recommendation be made to the IOC to contribute to the publication costs.

8. RECOMMENDATIONS

After some further discussion, the Symposium made the following recommendations for consideration at the 9th ICG/CSK Session.

Recommendation 1 : Improvement of observations to study the Kuroshio inter-annual variability

Since one of the main problems of international study of the Kuroshio is the investigation of inter-annual variability, it is clear that the period of observations of nine years, starting from 1965, is not sufficient for the purpose of drawing quantitative conclusions. The Symposium recommends the continuation of standard observations and direct current measurements, the frequency of which should not be less than twice a year (once during each main reason of the year). It is also highly desirable to achieve complete synchronization of the surveys.

Recommendation 2 : Current measurements in the South China Sea

Due to the general lack of direct current measurements in the South China Sea, the Symposium recommends that all efforts be made to obtain them.

Recommendation 3 : The Analysis of bottom sediments and the study of bottom topography

Noting that there were but a few works on the analysis of bottom sediments and the study of bottom topography in the CSK area, the Symposium recommends that survey ships should include the programs of collection of bottom sediments and studies on bottom topography by echo sounders in their activities.

Recommendation 4 : Marine Pollution

The Symposium recommends that ICG should explore the possibility of establishing a tropical centre for the study of marine pollution.

Recommendation 5 : Phytoplankton Research

The Symposium recommends that further research in qualitative and quantitative variability of phytoplankton be carried out and also include the most useful biochemical methods such as C^{14} technique and fluorescence method, be encouraged among scientists in the region.

Recommondation 6 : Zooplankton Research

Noting the relatively small amount of work presently undertaken on zooplankton and realizing the urgent need to improve the knowledge on fish eggs and larvae which may provide additional information on the abundance and distribution of fishery resources in the CSK area, the Symposium recommends that more work on zooplankton, particularly the early life stages of fish, be conducted by member countries. Such studies would be a most useful supplement to the fisheries resources surveys and assessments to be undertaken under the framework of the FAO/UNDP South China Sea Fisheries Development and Coordinating Programme and studies carried out by SEAFDEC. It is noted that substantial material of zooplankton, including fish eggs and larvae, is available at the Regional Marine Biological Centre in Singapore, and the Symposium urges the final evaluation of these samples and publication of the results. Special attention should be given to annual variablity.

Recommendation 7 : Larval Feeding

The Symposium recommends that studies similar to those on *Rastralliger neglectus* (Paper Number 304) be encouraged in the region.

Recommendation 8 : Fish Taxonomy

The Symposium appreciates results of the Technical Seminar on Fish Taxonomy in South East Asia (November-December 1972, Phuket, Thailand) and request FAO to expedite the publication of Identification Sheets for 280 species prepared during that Seminar so that they may be used for the improvement in the collection of fisheries statistics and for other purposes.

Recommendation 9 : Fisheries Statistics

The Symposium recommends that the collection of catch and effort statistics by member countries should receive the priority attention of their governments.

Recommendation 10 : Fishery Resources

The Symposium noted that the Southeast Asian Fisheries Development Center (SEAFDEC) held a Technical Seminar on South China Sea Fisheries Resources in Bangkok from 21 to 25 May 1973. It welcomed the recommendations made by the SEAFDEC Seminar which are reproduced in Annex and endorses them fully.

The Symposium noting the importance of the results presented in paper Number 301 on the trawl catch rates in the Northern part of the South China Sea, recommends that this paper should be studied in relation to those presented at the SEAFDEC Seminar.

Recommendation 11 : Shipboard Training

The Symposium recommends that the ICG explore the possibility of making arrangements with member countries for the shipboard training of young scientists, wherever possible.

Recommendation 12 : Publication of Symposium Papers

The Symposium recommends that Symposium papers be published in a form similar to that of the two previous CSK Symposia, and that the IOC be approached to contribute to the cost of publication through the assistance of UNESCO Regular Program for IOC and the IOC Fund-in-Trust.

9. CLOSING OF THE SYMPOSIUM

9.1 Dr. Loi (Vietnam) on behalf of all the participants moved a vote of thanks to the Government of Thailand for hosting the 3rd CSK Symposium and to Dr. Pradisth Cheosakul and all his staff for their efforts in making this Symposium possible.

9.2 Prof. Ronquillo thanked the Chairman, the participants and the Secretariat of the National Research Council of Thailand for the kind cooperation he had received during the Symposium.

9.3 There being no other business, the meeting adjourned at 17.00 hours on 29th May 1973.

Local Secretariat : Mrs. Sakuntala Bhodhiprasart
Deputy Secretary General for Natural Sciences
National Research Council

Mrs. Boonthom Dhamcharee
Acting, Special Grade Scientific Officer
National Research Council

Miss. Praparsi Thanasukarn
Chief, Research Compilation and Co-ordination
Division
National Research Council.

SESSION I

Physics, Chemistry and Geology

1.1 GENERAL RESULTS OF OCEANOGRAPHIC OBSERVATION IN 1970, 1971

in

THE GULF OF THAILAND

by

CAPTAIN T. PONGSAPIPATT R.T.N. AND MISS GULLAYA SAPSOMWONG

Abstract

The results of the cruises of early August 1970 and 1971 were discussed. It was found that sea water properties in mid-SW monsoon were affected to a large extent by discharges of river water into the Gulf of Thailand. Temperature and salinity showed distinct tongue of water intruding from South China Sea along the western gulf and out flow of less saline and cooler along the eastern gulf.

OBSERVATIONS OF 1970

1. Temperature

The observed distribution of temperature between August 5, and September 10, 1970 at surface, in vertical section and in three dimensional composite sections are shown in figures which will be discussed in the following.

a. HORIZONTAL TEMPERATURE DISTRIBUTION

Surface and subsurface contours of temperature are shown in Fig. 1 to Fig. 6.

1) At surface – The maximum temperature of 30.14°C occurs from about latitude 8°30'N. to latitude 10°30'N. in the western part of the Gulf of Thailand. There is a decrease of temperature Northward and Southward from this area in Fig. 1. A minimum temperature

of 28.18^{o}C occurs in the eastern part of the Gulf, and then increase northward and southward.

2) <u>At 10 meter</u> – The distribution of temperature at this level is shown in Fig. 2. The highest temperature is 29.6^{o}C and, similar to the surface, it occurs from about latitude 8^{o}30$'$N. to latitude 10^{o}30$'$N., between Surathani and Nakornsrithamarat. The temperature decreases northward and southward from this area. Low temperature is found off the east coast.

3) <u>At 20 meter</u> – The high temperature distribution is similar to 10 meter level. Low temperature of 26.3^{o}C is found near Kalantan with temperature gradient increasing northward and southward. The relatively cool water with temperature less than 28.2^{o}C is found from latitude 4^{o}40$'$N to latitude 9^{o}30$'$N along the east and west coast.

4) <u>At 30 meter</u> Temperature distribution at 30 meter is shown in Fig. 4. The highest temperature of 29.0^{o}C occurs at about latitude 10^{o}40$'$N. in the middle region of the Gulf, and low temperature water occurs at latitude 6^{o}20$'$N. The temperature gradually increases northward and southward from this cool area. The isotherm of 28.2^{o}C is found along the west and east coast.

5) <u>At 40 meter</u> – The high temperature distribution at this level is similar to 30 meter level (see Fig. 5), but low temperature water is at latitude 3^{o}N off the west coast.

6) <u>At 50 meter</u> – The temperature distribution of this level is shown in Fig. 6. The high temperature of 29.0^{o}C is found at latitude

$11^{o}N$. in the middle region of the Gulf, and the coldest water with temperature of $25.27^{o}C$ is found at latitude $8^{o}40'N$.

b. VERTICAL TEMPERATURE DISTRIBUTION

The distribution of temperature in vertical section in the year 1970 is shown in Fig. 7 and 8. There are 9 sections in NE – SW cross-section and 4 sections in longitudinal section.

1) Low surface temperature is near both sides of the upper part of the Gulf of Thailand (see profile 7.1) from then a gradient of temperature is found with increasing temperature to the middle of the Gulf. In the middle region of the Gulf appears a uniform temperature from surface to bottom (see profiles 7.1, 7.2) because of a well mixing. Low temperature water occurs along the east coast from surface to about 20 meter depth. (see profiles 7.2, 7.3, 7.4, 7.5, 7.6 and Fig. 1)

2) In the western part of the Gulf, it appears that the temperature decreases with depth and a stratification of isotherms is apparent (see profiles 7.2, 7.3, 7.4, 7.5 and 7.6). Maximum vertical temperature gradient is found in the western part and some regions in the middle of the Gulf. Thermocline layer rises toward the surface as it approaches the west coast. But a well mixed water is found in the eastern part of the Gulf of Thailand (see profiles 7.1, 7.2, 7.3).

3) Thermocline layer at both sides of profile 7.5 is between depths of 30 and 45 meter, but at the western part, it is deeper than the eastern part. In profiles 7.4 and 7.5 below thermocline layer is underlain by cold water.

4) In profile 7.9, surface temperature off the west coast is lower than the east coast. Thermocline properties is found along this profile between depths of 30 to 70 meter, and the isotherms move upwards the surface, going from east to west.

2. Salinity

The observed distribution of salinity between August 5, and September 10, 1970 over the surface, in vertical section and in three dimensional sections are shown in figures that follow.

a. HORIZONTAL SALINITY DISTRIBUTION

Surface and subsurface isoline of salinity are shown in Fig. 9 to Fig.14.

1) At surface – The highest salinity occurs near the west coast in the upper part of the Gulf of Thailand, and decreases eastward until reaching minimum. At the lower part of the Gulf near the west coast, salinity is less than 32.4 per mille and then gradually increases eastward and southward (see Fig. 9).

2) At 10 meter – High salinity water occurs near the west coast off the area of Nakorn Srithamarat, Surat Thani and Chumphon, and decrease eastward to be less than 31.00 per mille in the vicinity of Poulo Panjang, (see Fig.10). But in the lower part of the Gulf, high salinity occurs near the east coast.

3) At 20 meter – Fig.11 shows that the low salinity is in the middle region of the Gulf and in the area of Poulo Panjang on the eastern side. In the western side and in the lower part of the eastern area high salinity is found.

4) At 30 meter – High salinity above 33.00 per mille occurs at both sides and decreases gradually to the middle region of the Gulf, (see Fig.12). The highest salinity of 33.75 per mille on this level is found south of latitude 7°N. in the western area.

5) At 40 meter – In the upper part of the Gulf, high salinity occurs at both sides and decreases while proceeding to the middle region of the Gulf (see Fig.13).

6) At 50 meter – This deepest level is shown in Fig.14, the salinity distribution in the upper part of the Gulf is similar to 40 meter level (see Fig.13).

VERTICAL SALINITY DISTRIBUTION

1) The distribution of salinity in the year 1970 shows that, the highest salinity occurs at the western side near the coast of Prachuap Khirikhan, (see profiles 15.1, 15.2 and Fig. 9), and then decreases eastward. The lowest salinity of 30.80 per mille is found near Poulo Panjang. This less saline water extends from surface to the depth of 20 meter, but below this layer the salinity increase abruptly to about 33.00 per mille. The salinity gradient do not occur in the middle region of the Gulf in profile 15.2, because of the existence of well mixed water.

2) Off the west coast, high saline water is found along the coast (see profile 15.4). But the high saline water isoline in the lower part of the gulf dip deeper than the water off the coast of Prachuap Khirikhan and dip deeper as they go farther east, (see Fig. 16). The salinity at both sides in profiles 15.5, 15.6, between latitude

$6^\circ 30'$N. and latitude 9°N. are 32.0 per mille and 32.5 per mille. Vertical salinity gradient is found along the west coast and in the deep layer of the middle region with salinity in excess of 33.5 per mille. At the deepest level profiles 15.4, 15.5 show that water in this area is underlain by a high saline water.

3) South of latitude $6^\circ 40'$N., (see profile 15.7) the salinity off both sides of the Gulf are 32.5 and 33.0 per mille, and this profile shows a well mixed water.

4) In the lower part of the Gulf (see profiles 15.8 and 15.9), high salinity water is found in the deep region and extends from west to east (see Fig. 16). Surface salinity is between 32.5–33.0 per mille.

OBSERVATIONS OF 1971

1. Temperature

a. HORIZONTAL TEMPERATURE DISTRIBUTION

Surface and subsurface isotherm for 1971 between July 20 and August 17, are shown in Fig. 17 to 22.

1) At surface – Sea water with temperature below 27.6°C is found in the upper part of the Gulf, in the area of Chumphon. The temperature decreases southward from this area. The highest temperature of 29.6°C occurs off the coast of Pattani and Narathiwat. Average surface temperature in this year is lower than the previous year (see Fig. 17).

2) At 10 meter – The temperature distribution at this level is similar to that at surface (Fig. 18).

3) At 20 meter – The lowest temperature of 26.82°C is found at the lower part of the Gulf, it reaches the highest temperature as it approaches the coast of Pattani. The other low temperature water is near the upper part of the Gulf of Thailand (Fig. 19).

4) At 30 meter – There are three areas of low temperature in this level (Fig. 20). These are off the coast of Kalantan, Cape Camau and north of Prachuap Khirikhan. The lowest temperature of 25.77°C is at latitude 6°30′N off the coast of Kalantan, and the highest temperature of 28.92°C is found in the middle region of the Gulf.

5) At 40 meter – The lowest temperature occurs off the coast of Kalantan and increases northward (see Fig. 21).

6) At 50 meter – There are two areas of cold and warm water in this deepest level (Fig. 22). The colder area is at the lower part of the Gulf.

๖. VERTICAL TEMPERATURE DISTRIBUTION

The temperature distribution in 1971 is similar to the year 1970 in the upper part of the Gulf (see Profile 23.1) the temperature maintains between 27.5°–27.8°C from surface to bottom. Low surface temperature is found off the coast of Chumphon (see Profile 23.1). The vertical temperature gradient occur at the lower part of the Gulf off the west coast (see Profiles 23.2, 23.3, 23.4, 23.5, 23.6 and Fig. 24) where thermocline layer is between 12 to 33 meter depth and 35 to 45 meter from west to east respectively. Thermocline rises upward when approaching the coast. But at the eastern part, the water is well mixed from surface to bottom, (see Profiles 23.2, 23.3, 23.4 and 23.5).

2. Salinity

a. HORIZONTAL SALINITY DISTRIBUTION

Surface and subsurface isolines of salinity are shown in Fig. 25 to Fig. 30.

1) At surface – The highest salinity is found in the upper Gulf especially near the coast of Chumphon and Prachuap Khirikhan to Songkla and Nakorn Srithammarat. The lowest salinity of 30.70 per mille occurs near Cape Camau, (see Fig. 25) and another high salinity area is to the south of latitude 7°N.

2) At 10 meter – The salinity distribution at this level is the same as at surface (see Fig. 26).

3) At 20 meter – Along the west coast the salinity is above 33.0 per mille and gradually decreases as it approaches the east coast. The low salinity water is at the middle region of the upper part of the Gulf (see Fig. 27).

4) At 30 and 50 meter – The distribution of salinity is similar to depth of 20 meter.

b. VERTICAL SALINITY DISTRIBUTION

The vertical salinity distribution for 1971 is similar to the year 1970. The highest surface salinity occur in the upper part of the gulf on western side (see Profiles 31.1, 31.2) and the high salinity is found off the west coast of Chumphon, Prachuap Khirikhan and from Songkla to Nakorn Srithammarat. The salinity is also increases with depth (see Profiles 31.3, 31.4, 31.5). This high saline water in deeper levels extend farther south than the year 1970. The low salinity occurs near

Cape Camau from surface to 20 meter depth. Below this lesser saline water is the higher saline water (see Profiles 31.5 and 31.6). The steep vertical salinity gradient is found at the western side but in the eastern side the gradient is weak showing a well mixed water (see Profiles 32.2, 33.4). At the deepest level of the Gulf it is underlain by water of salinity above 33.5 per mille.

SUMMARY OF FEATURES OF INTEREST

1. The high salinity water occurs along the west coast. It is believed that this high saline water comes from the South China Sea extending and climbing up the slope of the west coast, which is indicated by high salinity and increasing of temperature as they climb up near the surface. This water mass move upward the slope as it approaches the upper part of the Gulf of Thailand (see Fig. 1, 8, 9, 16, 17, 24, 25, 32, Profiles 7.1, 15.1, 23.1 and 31.1).

2. The low salinity and temperature is found off the east coast to the area of Cape Camau. Because the excessive precipitation on this side in the south west monsoon period and the accumulation of freshwater runoff from Cambodia. This less saline and cooler water extends from the surface to about 20 meter depth, (see Fig. 1, 2, 8, 10, 16, 17, 18, 24, 25, 26, and 32). Below that layer, the salinity increases abruptly, which is the properties of the water from South China Sea.

3. Low surface temperature in the upper part of the gulf near Prachuap Khirikhan corresponds to high salinity which is an indication of upwelling as illustrated in Fig. 1, 9, 17, 25, Profiles 7.1, 15.1, 23.1 and 31.1.

4. A well mixed water occurs near the east coast and in the middle region of the gulf, (see Profiles 7.1, 7.2, 15.1, 15.2, 23.1, 23.2, 31.1, 31.2, Fig. 8, 16,

24, 32). But near the west coast and the lower part of the gulf a steep vertical gradient of temperature is shown. Thermocline layer slopes down from west to east with warmer layer water above.

References

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Hydrographic Department, Royal Thai Navy, 1971; Oceanographical observations in the Gulf of Thailand (Area IV), H.T.M.S. CHANTHARA, CRUISE 1/71.

Robinson, M.K., 1963; "Physical Oceanography of the Gulf of Thailand", Section II of "Ecology of the Gulf of Thailand and the South China Sea" (Report of the NAGA Expedition, 1959–1961), SIO Ref. 63–6, 34 50.

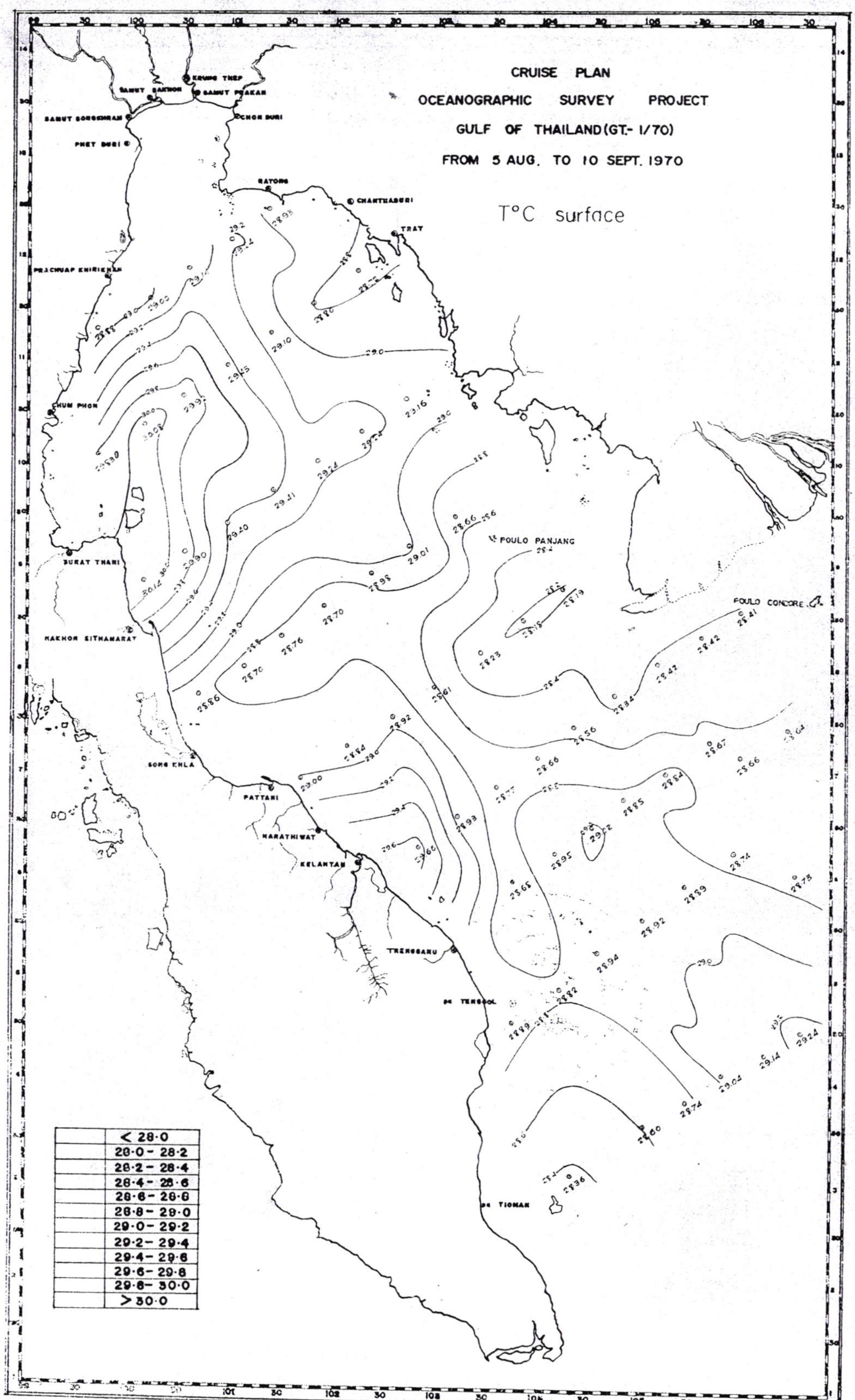

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
T°C surface
POULO PANJANG
POULO CONDORE
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TIOMAN
CHUM PHON
SURAT THANI
NAKHON SITHAMARAT
PRACHUAP KHIRIKHAN
PHET BURI
SAMUT SONGKHRAM
SAMUT SAKHON
SAMUT PRAKAN
KRUNG THEP
CHON BURI
RAYONG
CHANTHABURI
TRAT
< 28.0
28.0 - 28.2
28.2 - 28.4
28.4 - 28.6
28.6 - 28.8
28.8 - 29.0
29.0 - 29.2
29.2 - 29.4
29.4 - 29.6
29.6 - 29.8
29.8 - 30.0
> 30.0

Fig. 1

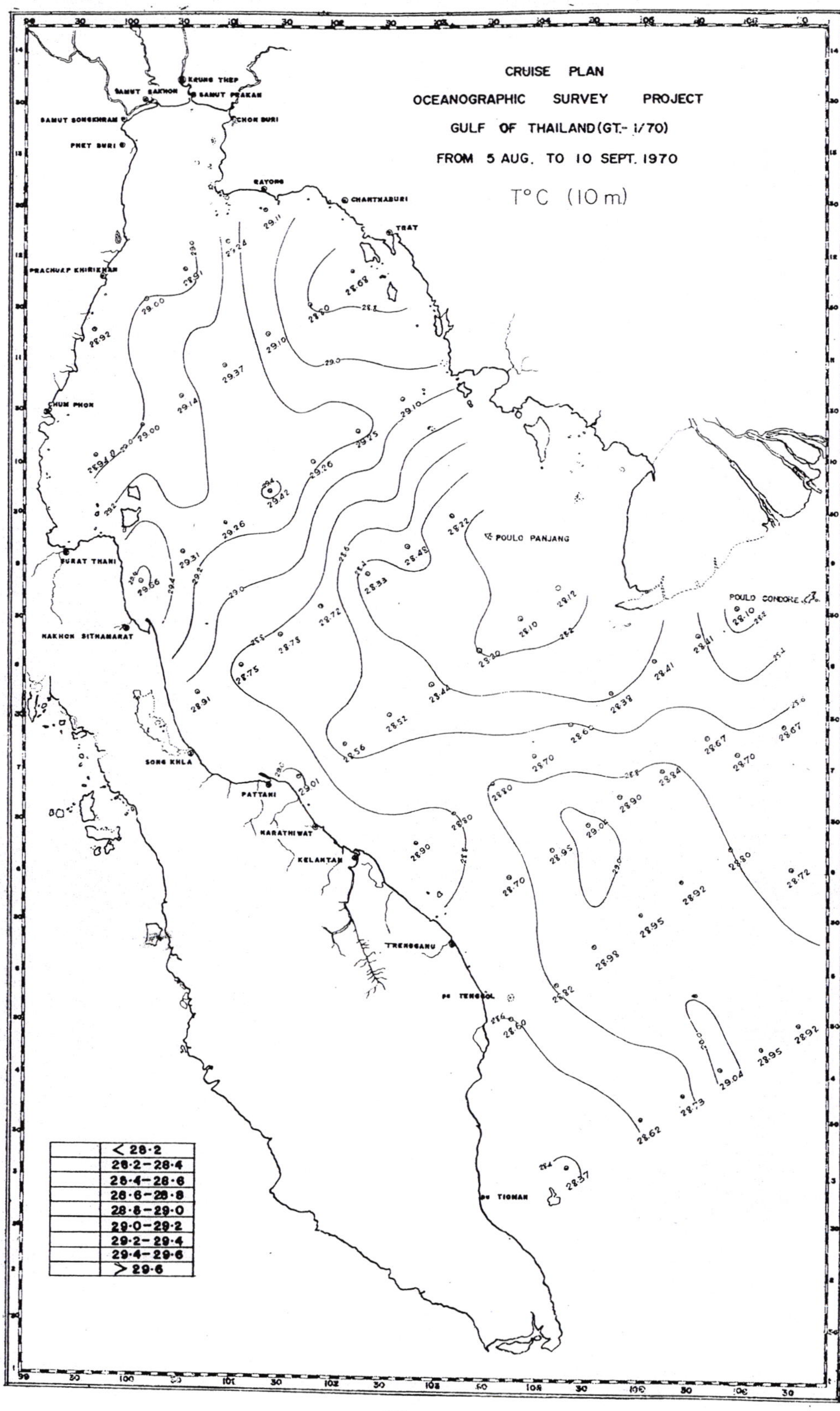

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
T°C (10 m)
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
SURAT THANI
NAKHON SITHAMARAT
POULO PANJANG
POULO CONDORE
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
< 28.2
28.2 – 28.4
28.4 – 28.6
28.6 – 28.8
28.8 – 29.0
29.0 – 29.2
29.2 – 29.4
29.4 – 29.6
> 29.6

Fig. 2

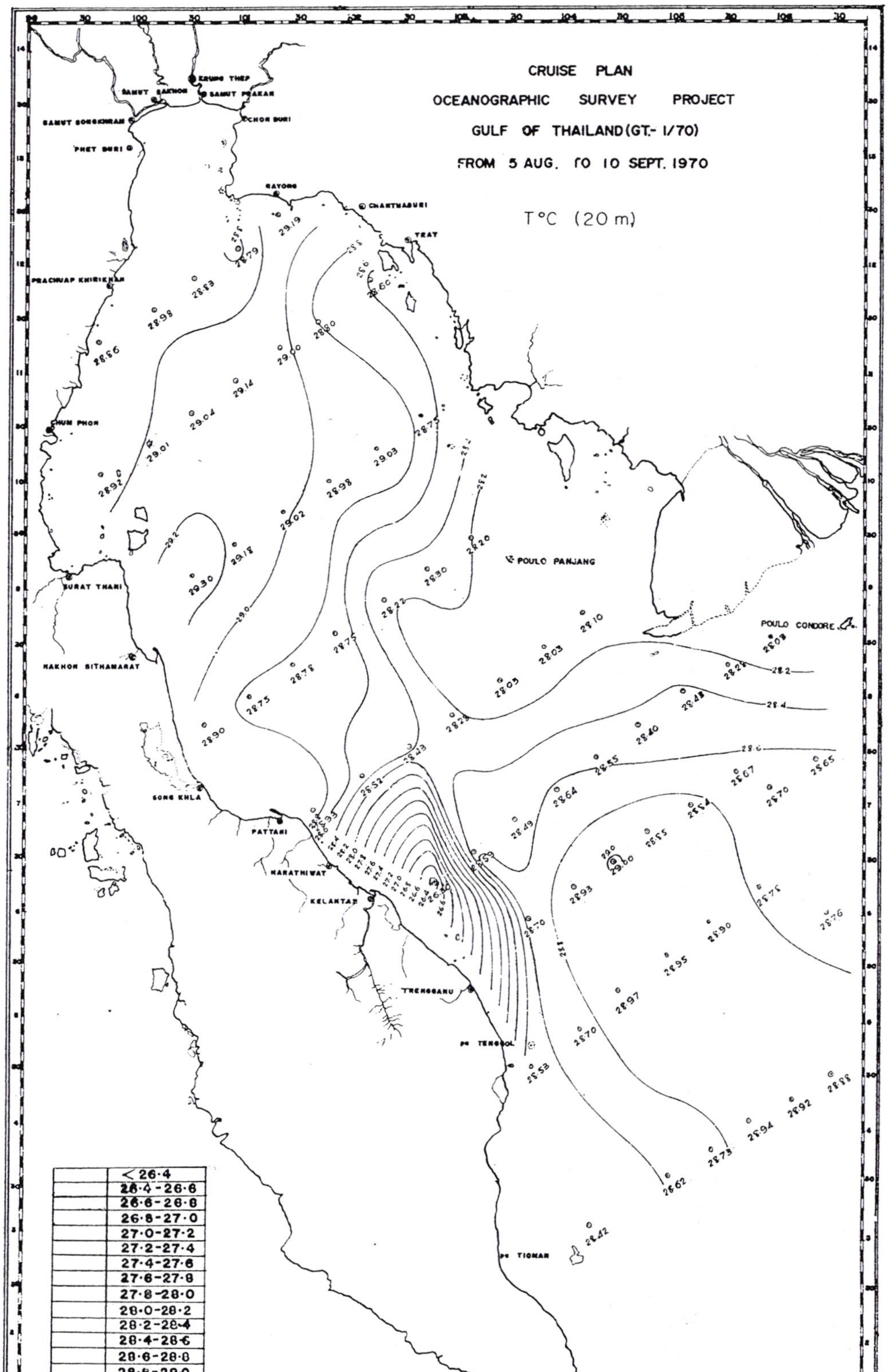

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
T°C (20 m)
POULO PANJANG
POULO CONDORE
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
SURAT THANI
CHUM PHON
PRACHUAP KHIRIKHAN
RAYONG
CHANTHABURI
TRAT
< 26·4
26·4 - 26·6
26·6 - 26·8
26·8 - 27·0
27·0 - 27·2
27·2 - 27·4
27·4 - 27·6
27·6 - 27·8
27·8 - 28·0
28·0 - 28·2
28·2 - 28·4
28·4 - 28·6
28·6 - 28·8
28·8 - 29·0
29·0 - 29·2
> 29·2

Fig. 3

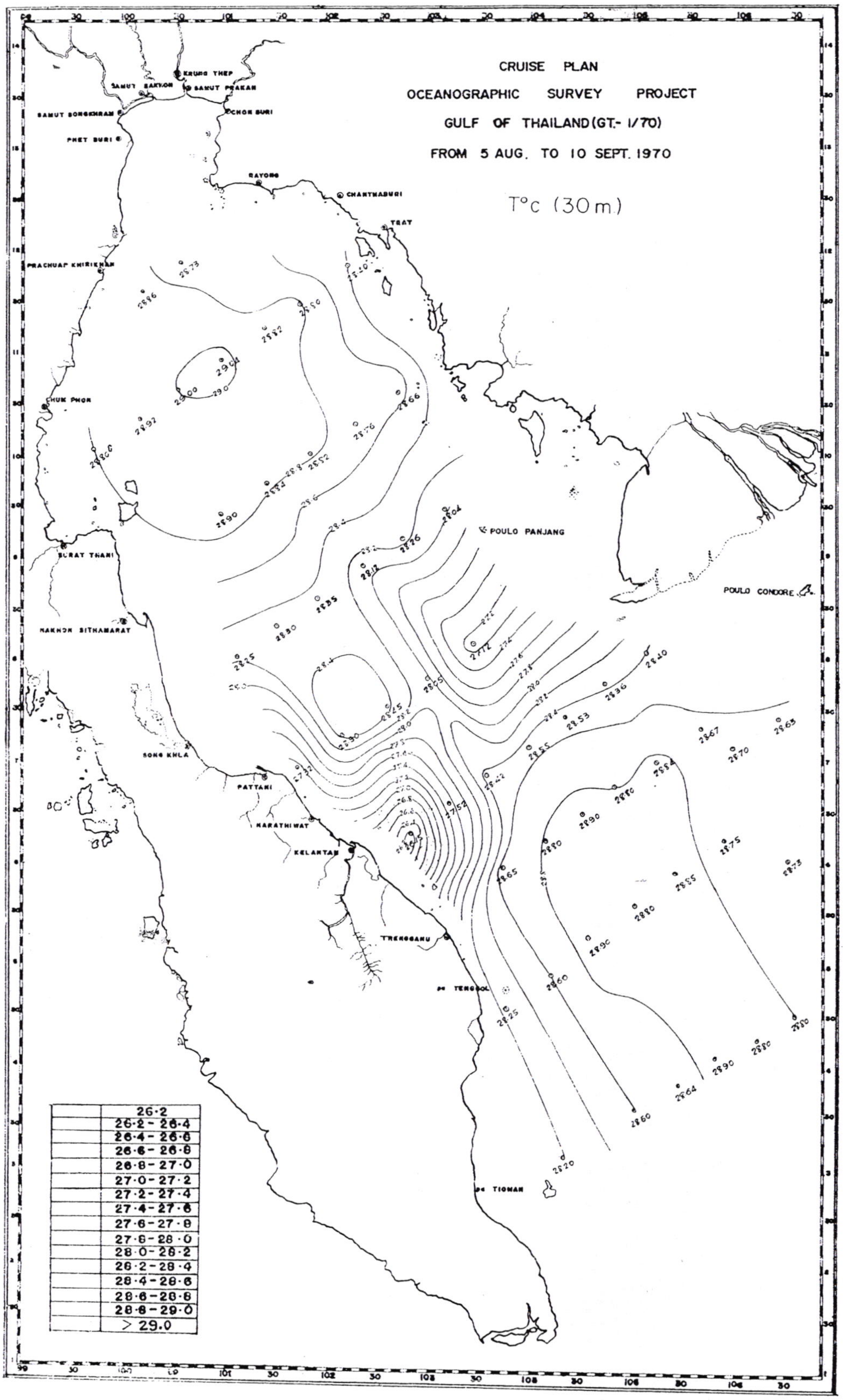

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
T°c (30 m)
26·2
26·2 - 26·4
26·4 - 26·6
26·6 - 26·8
26·8 - 27·0
27·0 - 27·2
27·2 - 27·4
27·4 - 27·6
27·6 - 27·8
27·8 - 28·0
28·0 - 28·2
28·2 - 28·4
28·4 - 28·6
28·6 - 28·8
28·8 - 29·0
> 29.0

Fig. 4

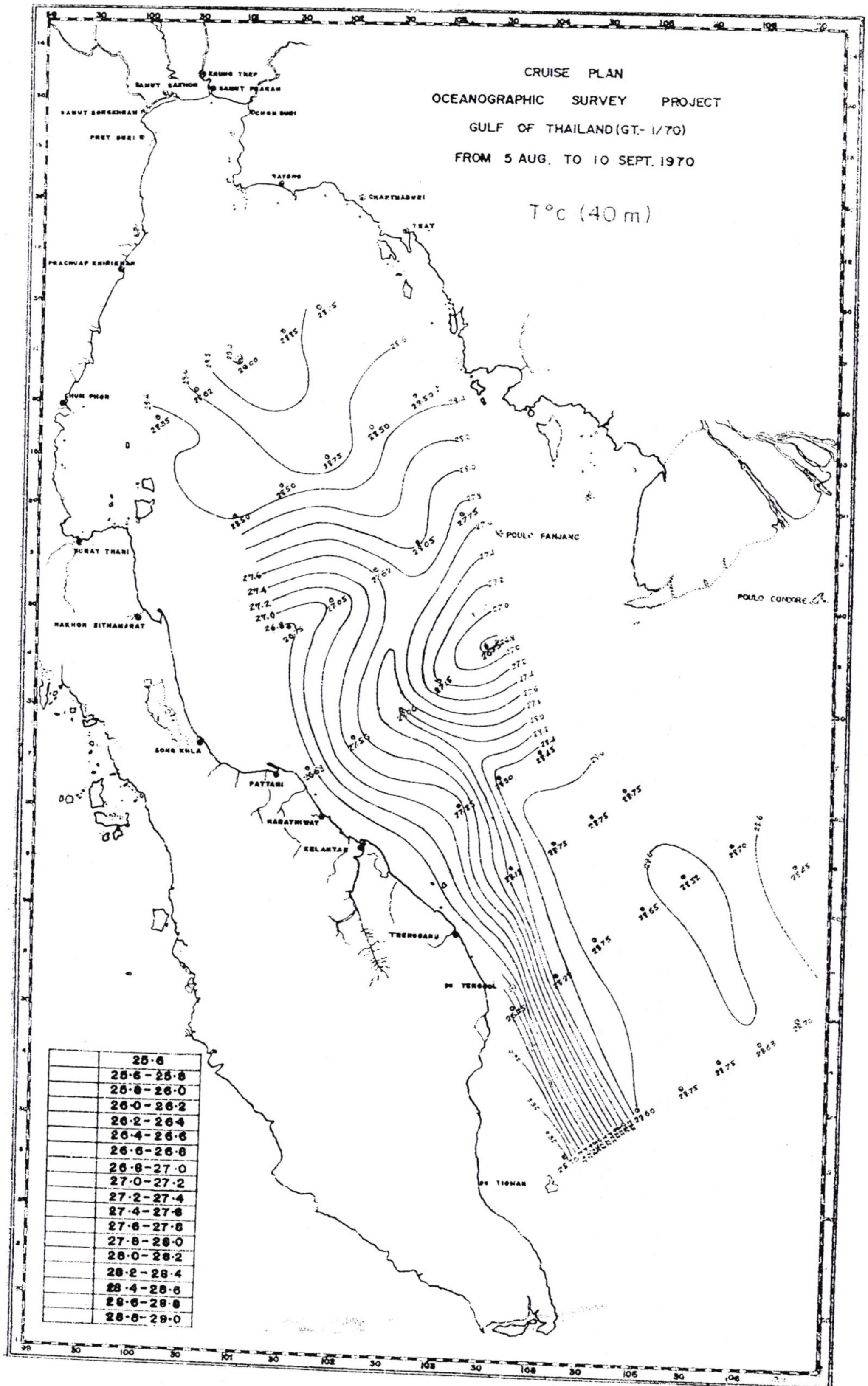

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
T°c (40 m)
POULO PANJANG
POULO CONDORE
SONG KHLA
PATTANI
KELANTAN
TRENGGANU
SURAT THANI
CHUM PHON
NAKHON SITHAMMARAT
25·6
25·6 - 25·8
25·8 - 26·0
26·0 - 26·2
26·2 - 26·4
26·4 - 26·6
26·6 - 26·8
26·8 - 27·0
27·0 - 27·2
27·2 - 27·4
27·4 - 27·6
27·6 - 27·8
27·8 - 28·0
28·0 - 28·2
28·2 - 28·4
28·4 - 28·6
28·6 - 28·8
28·8 - 29·0

Fig. 5

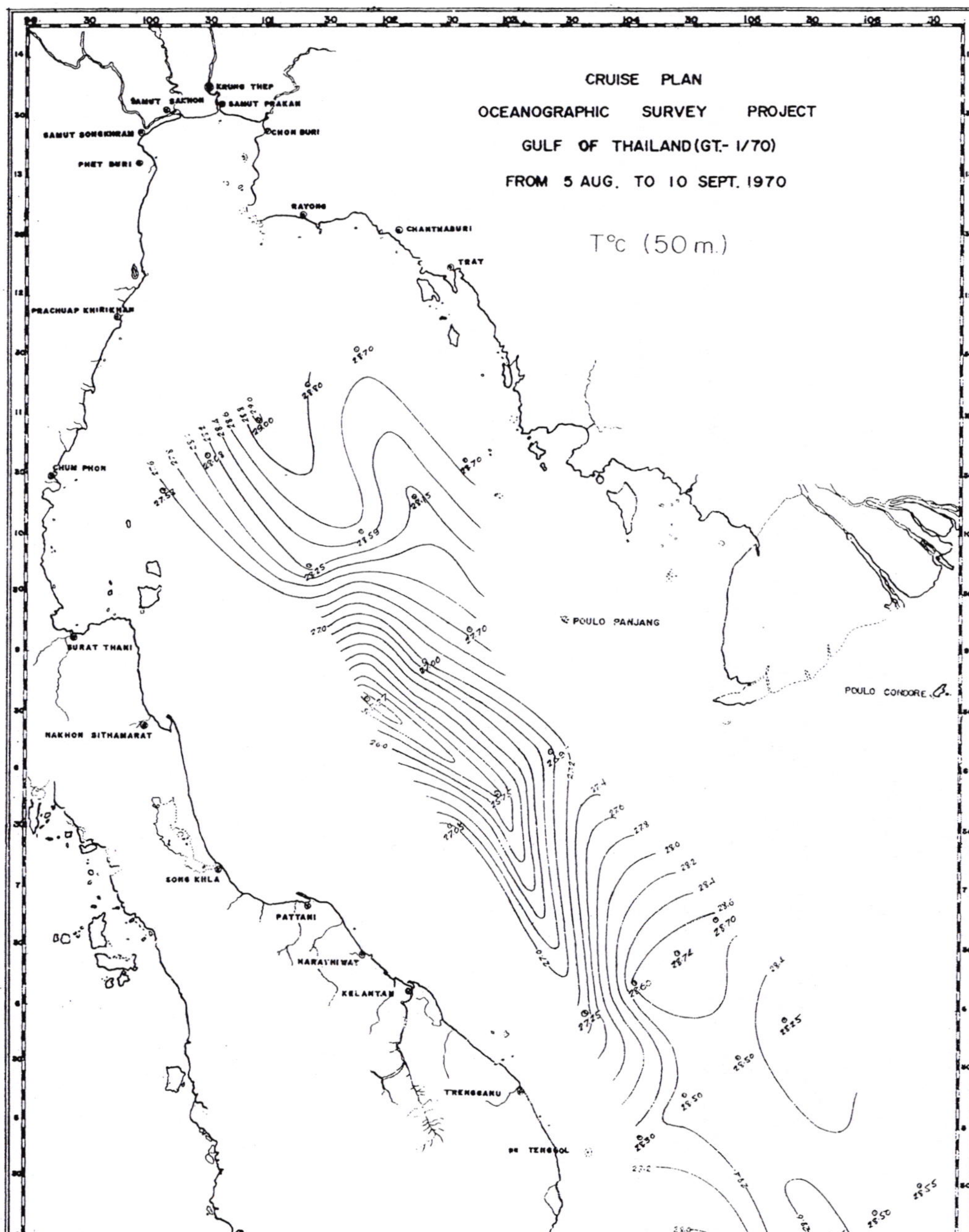

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
T°c (50 m.)
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
POULO PANJANG
POULO CONDORE
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
< 25·4
25·4 - 25·6
25·6 - 25·8
25·8 - 26·0
26·0 - 26·2
26·2 - 26·4
26·4 - 26·6
26·6 - 26·8
26·8 - 27·0
27·0 - 27·2
27·2 - 27·4
27·4 - 27·6
27·6 - 27·8
27·8 - 28·0
28·0 - 28·2
28·2 - 28·4
28·4 - 28·6
28·6 - 28·8
28·8 - 29·0

Fig. 6

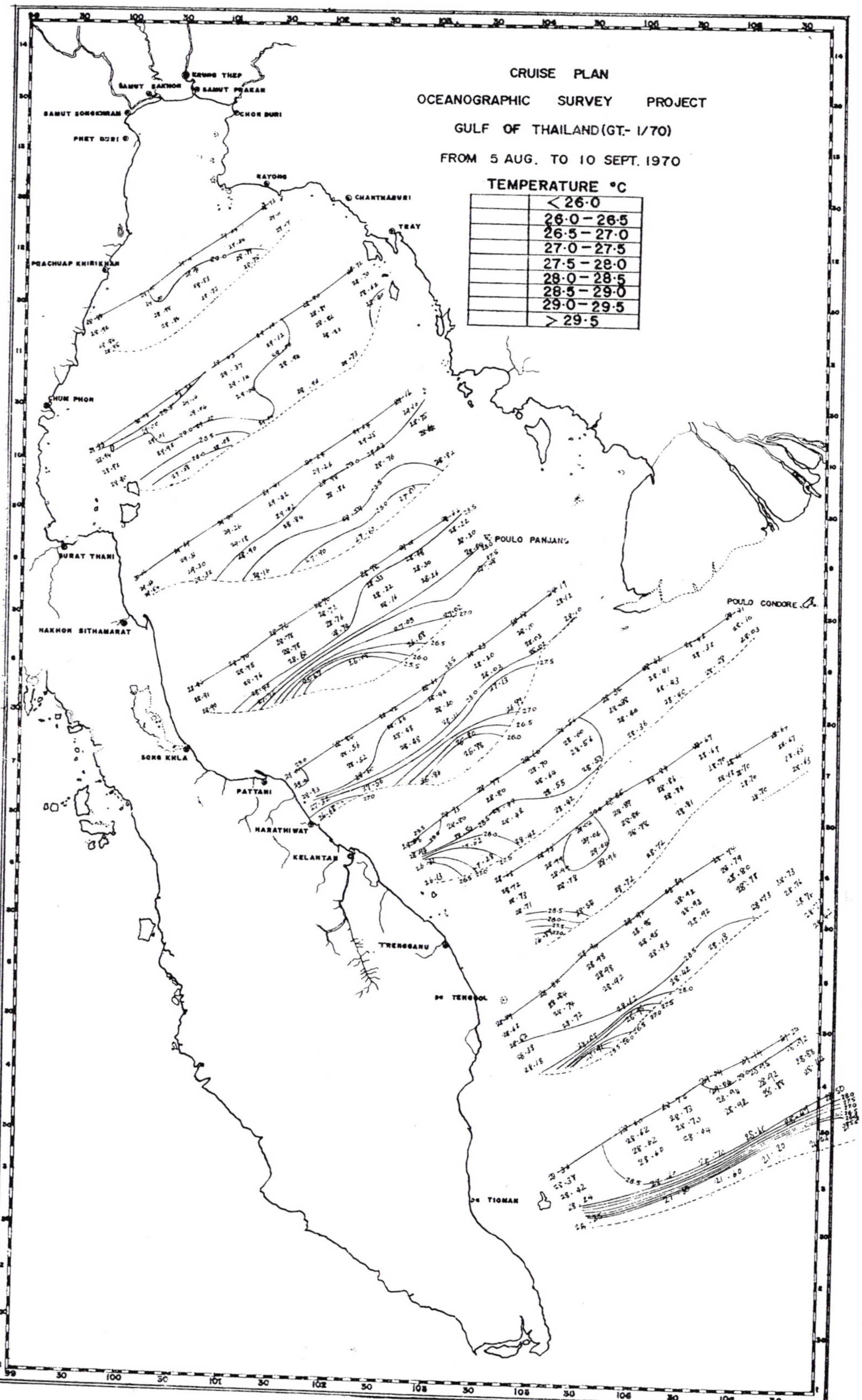


Fig.7
Profile 7.1–7.9

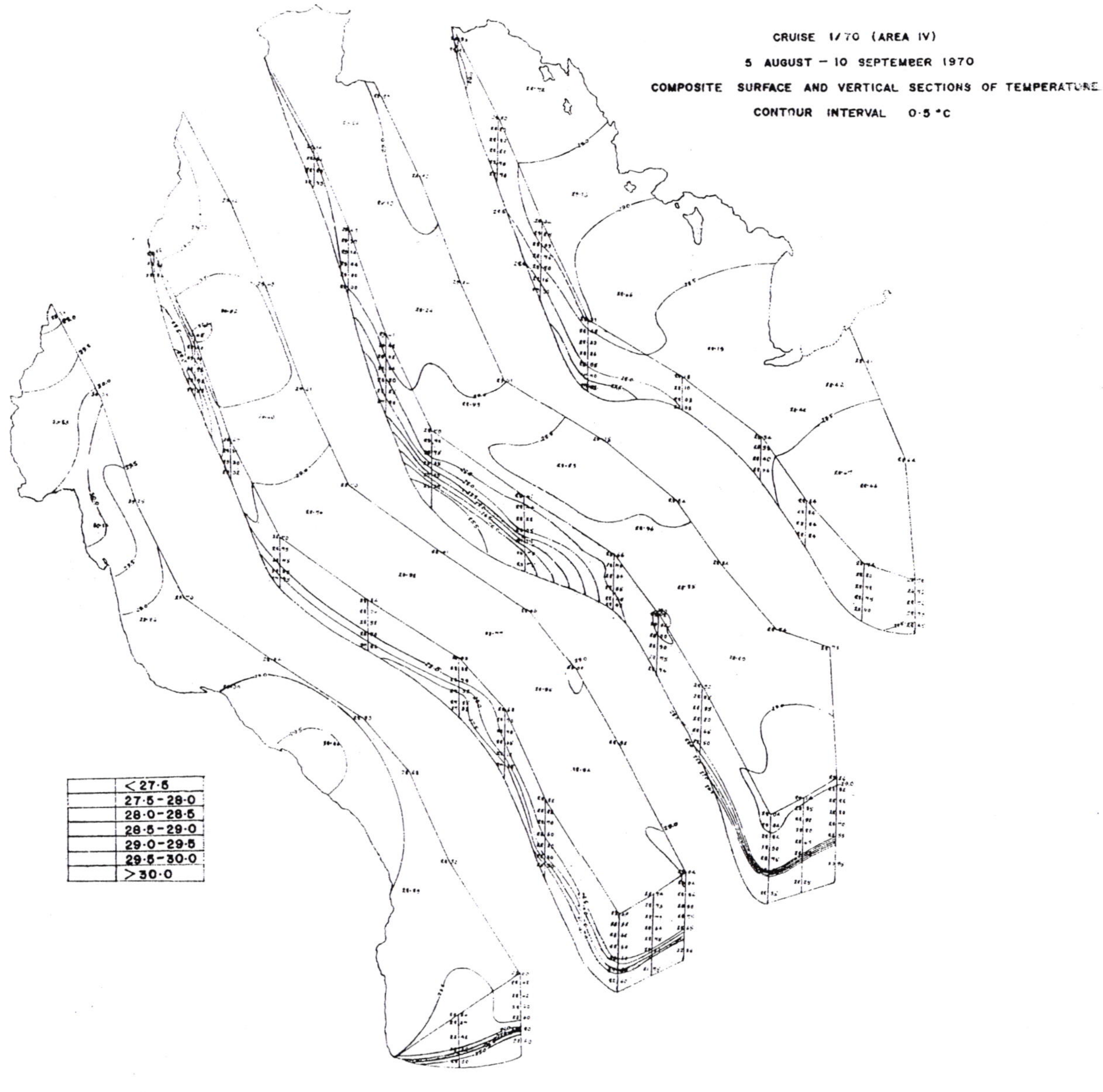


Fig. 8
Profile 8.1-8.4

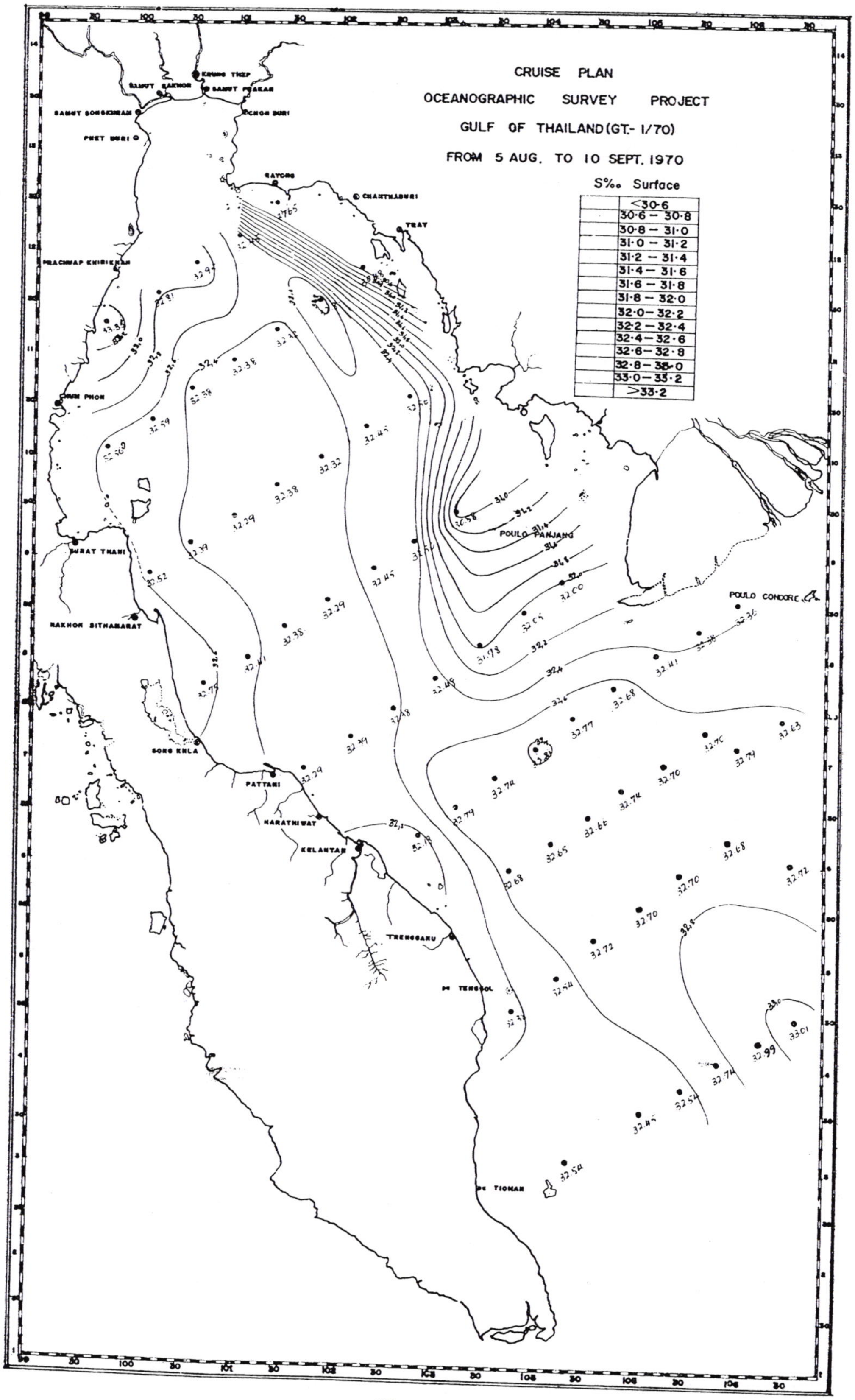

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
S‰ Surface
<30·6
30·6 – 30·8
30·8 – 31·0
31·0 – 31·2
31·2 – 31·4
31·4 – 31·6
31·6 – 31·8
31·8 – 32·0
32·0 – 32·2
32·2 – 32·4
32·4 – 32·6
32·6 – 32·8
32·8 – 33·0
33·0 – 33·2
>33·2
POULO PANJANG
POULO CONDORE
SURAT THANI
SONG KHLA
PATTANI
KELANTAN
TRENGGANU
TIOMAN

Fig. 9

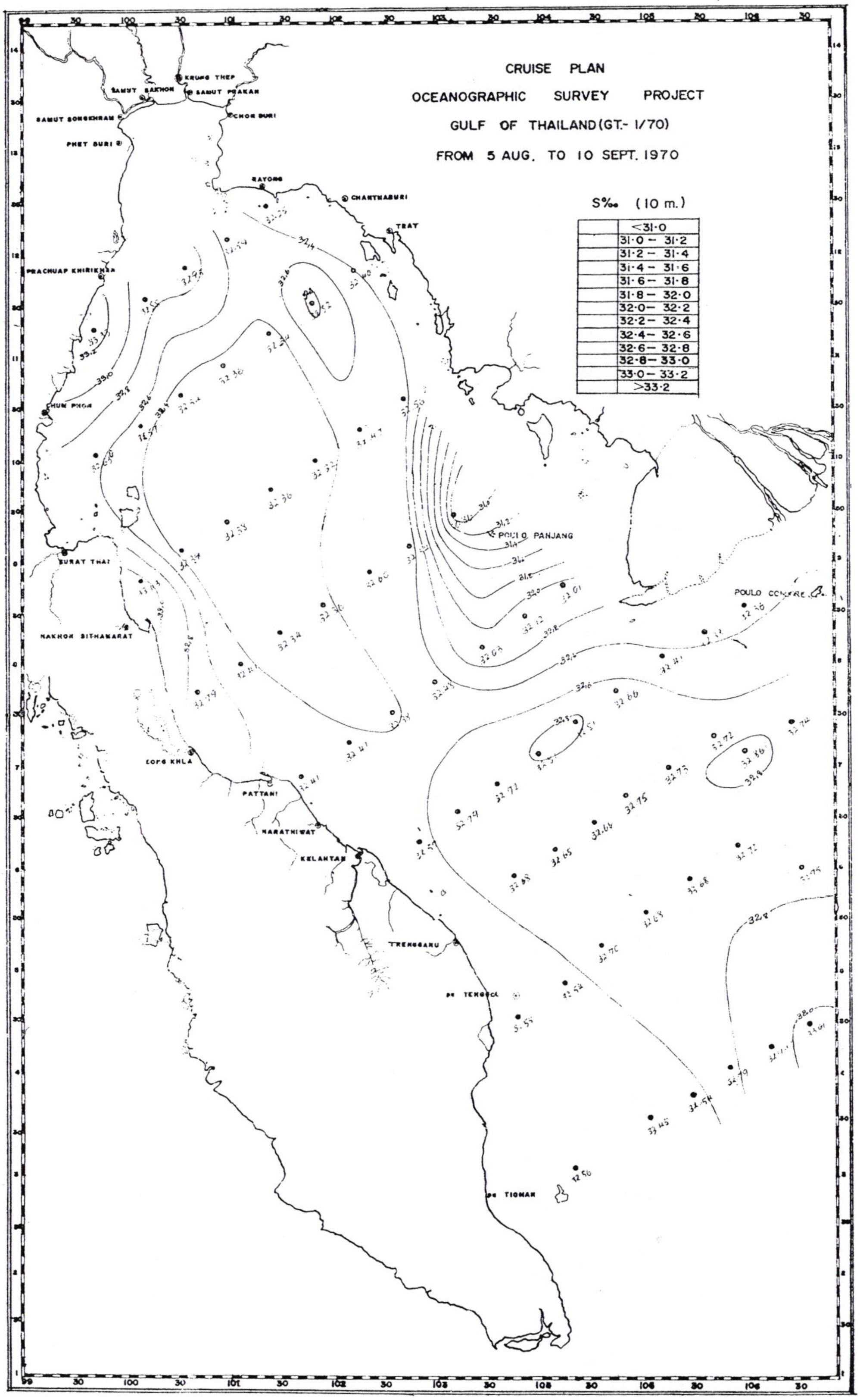

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
S‰ (10 m.)
<31·0
31·0 – 31·2
31·2 – 31·4
31·4 – 31·6
31·6 – 31·8
31·8 – 32·0
32·0 – 32·2
32·2 – 32·4
32·4 – 32·6
32·6 – 32·8
32·8 – 33·0
33·0 – 33·2
>33·2
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
SURAT THAI
NAKHON SITHAMARAT
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TIOMAN
POULO PANJANG
POULO CONDORE

Fig. 10

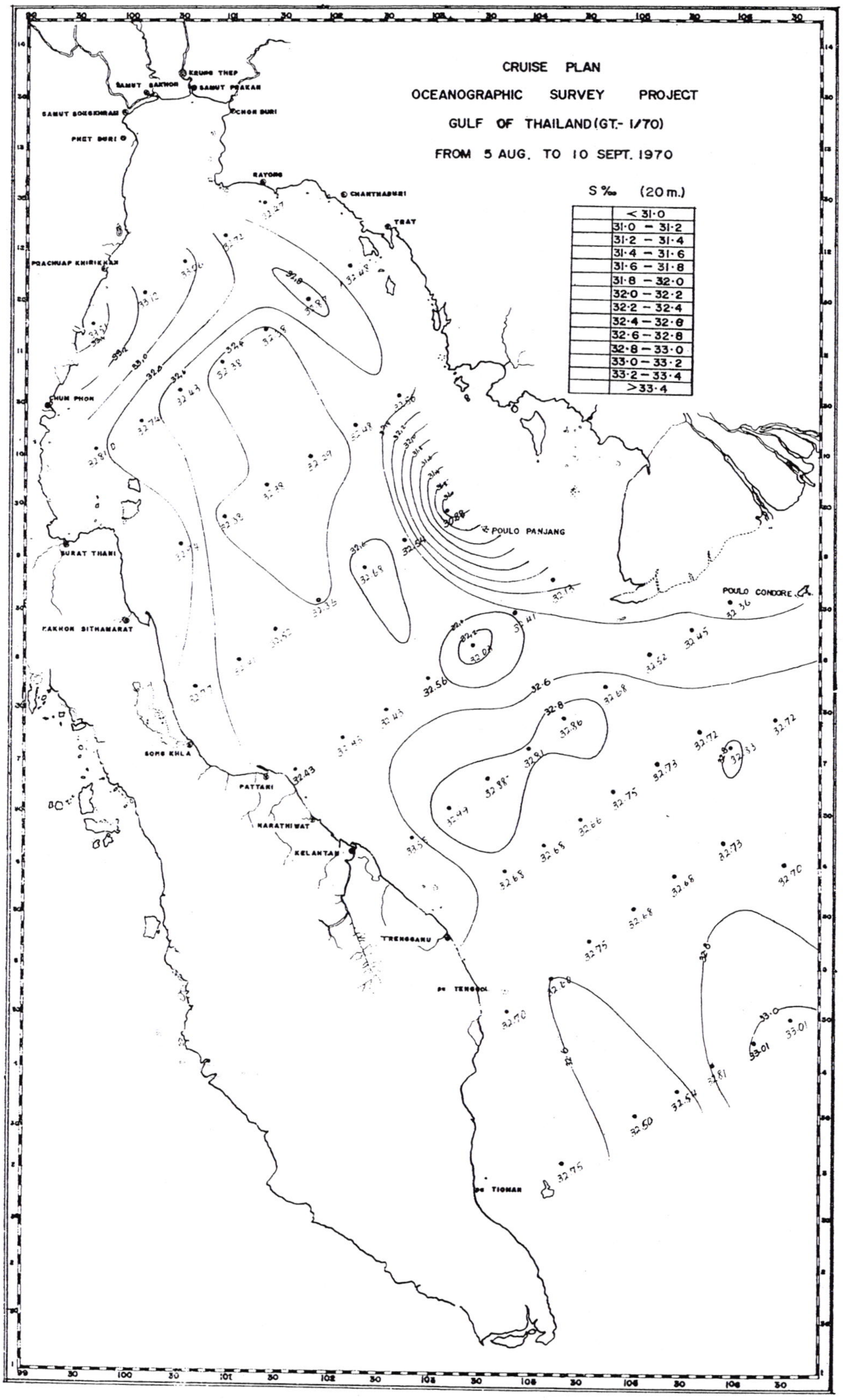

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
S ‰ (20 m.)
< 31·0
31·0 – 31·2
31·2 – 31·4
31·4 – 31·6
31·6 – 31·8
31·8 – 32·0
32·0 – 32·2
32·2 – 32·4
32·4 – 32·6
32·6 – 32·8
32·8 – 33·0
33·0 – 33·2
33·2 – 33·4
> 33·4
POULO PANJANG
POULO CONDORE
SURAT THANI
SONG KHLA
KELANTAN
TRENGGANU
TIOMAN

Fig. 11

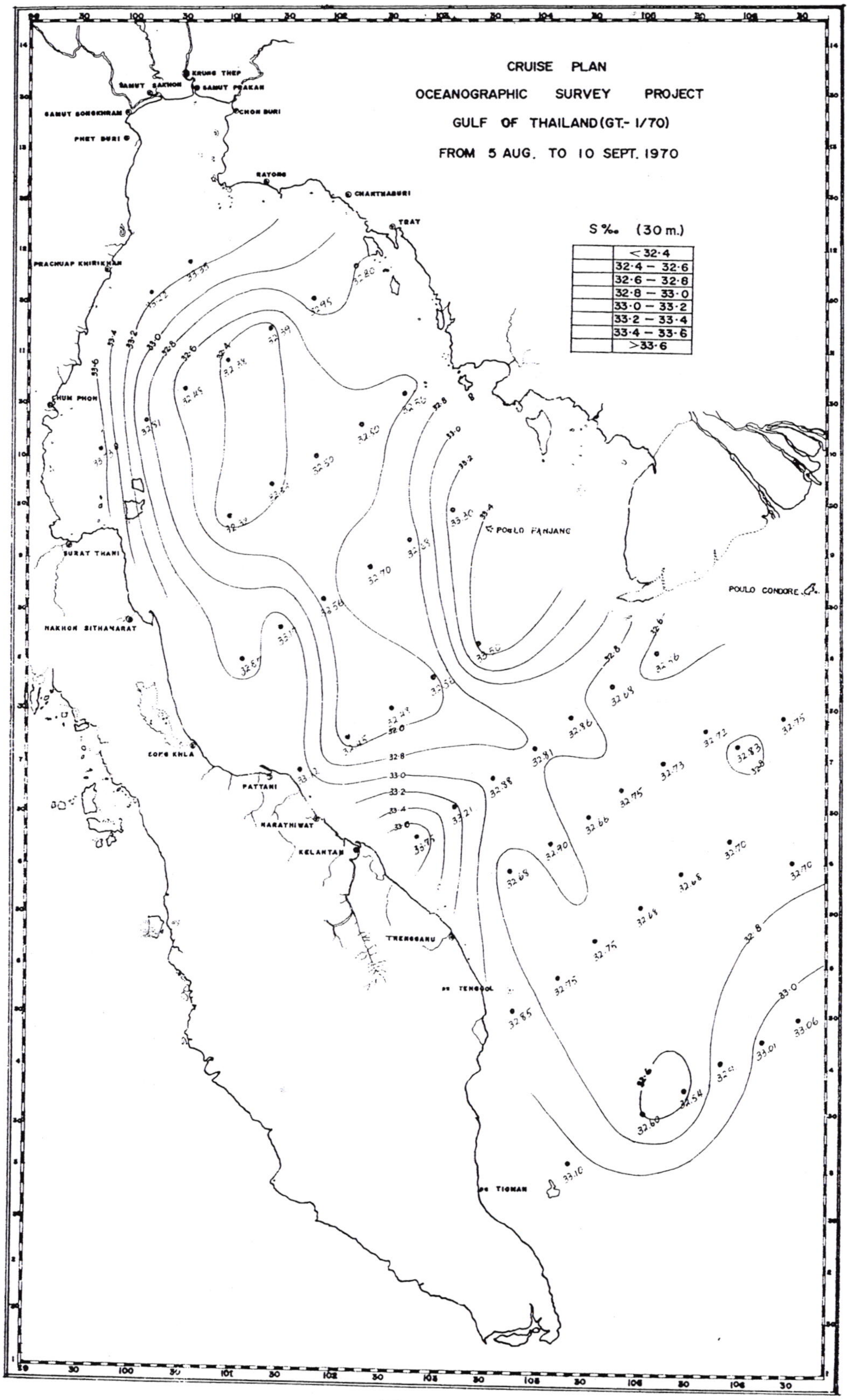
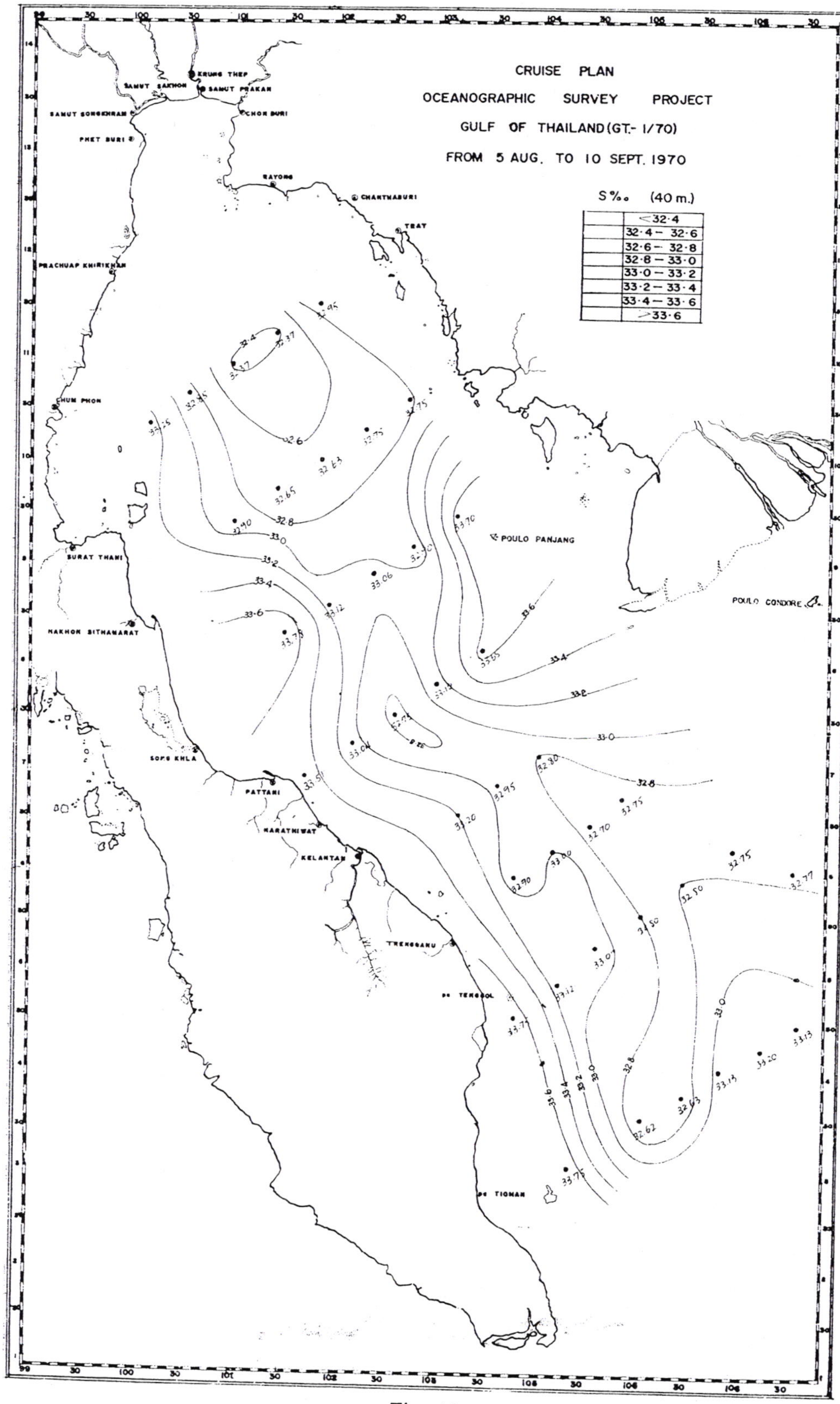

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
S ‰ (30 m.)
<32·4
32·4 – 32·6
32·6 – 32·8
32·8 – 33·0
33·0 – 33·2
33·2 – 33·4
33·4 – 33·6
>33·6
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
CHON BURI
SAMUT SONGKHRAM
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
SURAT THANI
NAKHON SITHAMARAT
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
POULO PANJANG
POULO CONDORE

Fig. 12



CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
S‰ (40 m.)
<32·4
32·4 – 32·6
32·6 – 32·8
32·8 – 33·0
33·0 – 33·2
33·2 – 33·4
33·4 – 33·6
>33·6
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
POULO PANJANG
POULO CONDORE

Fig. 13

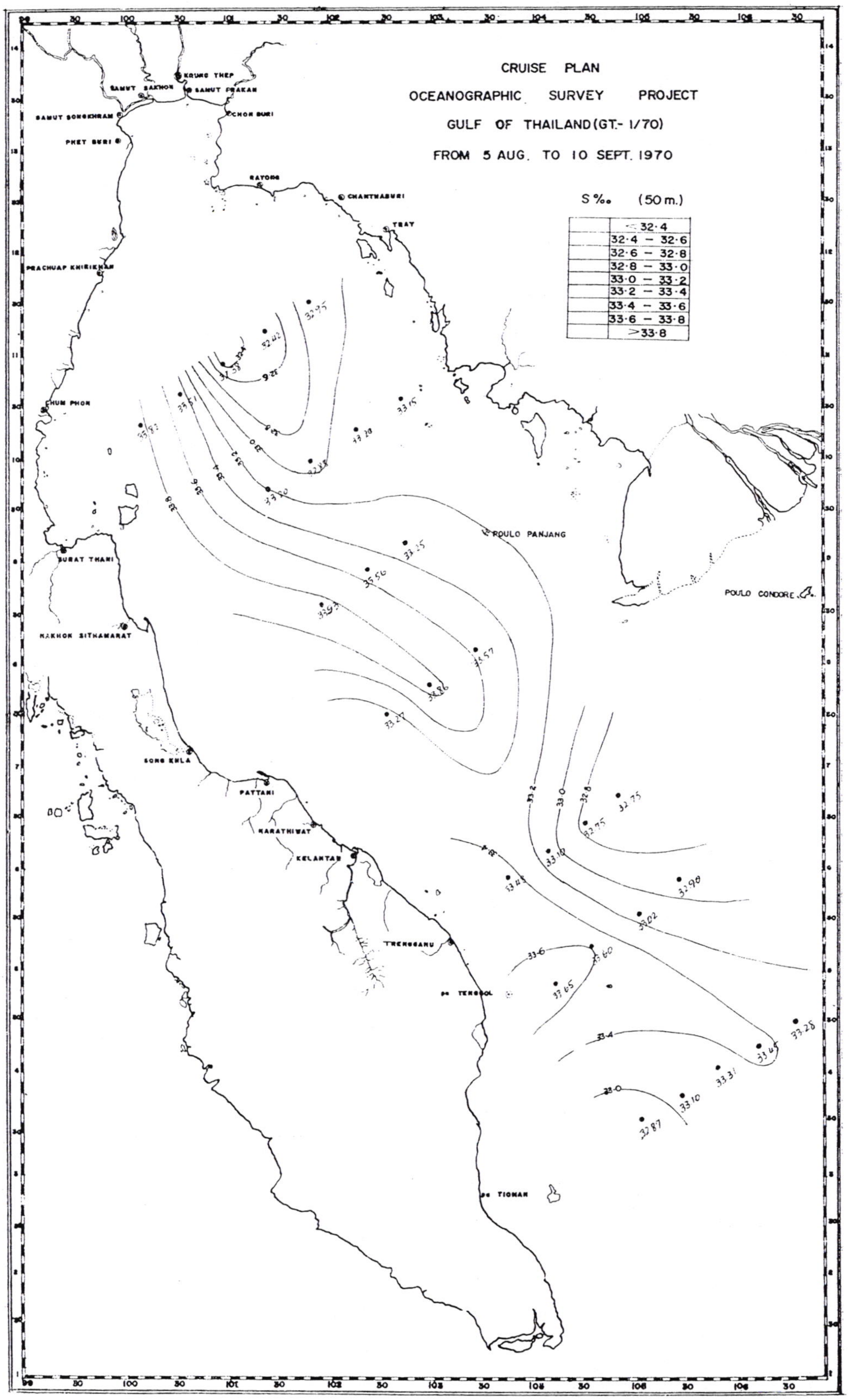

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND (GT.- 1/70)
FROM 5 AUG. TO 10 SEPT. 1970
S‰ (50 m.)
< 32·4
32·4 – 32·6
32·6 – 32·8
32·8 – 33·0
33·0 – 33·2
33·2 – 33·4
33·4 – 33·6
33·6 – 33·8
>33·8
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
POULO PANJANG
SURAT THANI
NAKHON SITHAMARAT
POULO CONDORE
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN

Fig. 14

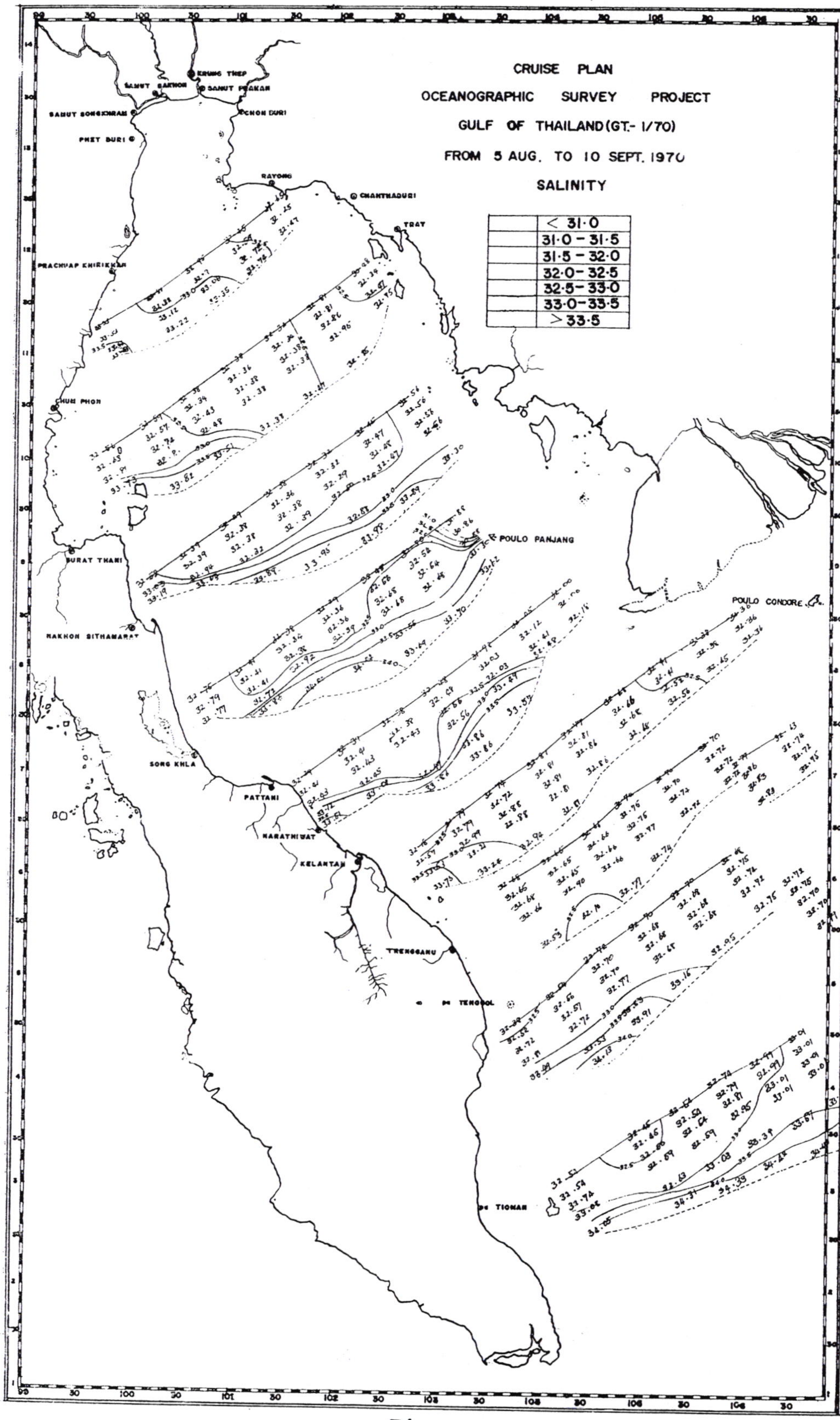


Fig. 15
Profile 15.1-15.9

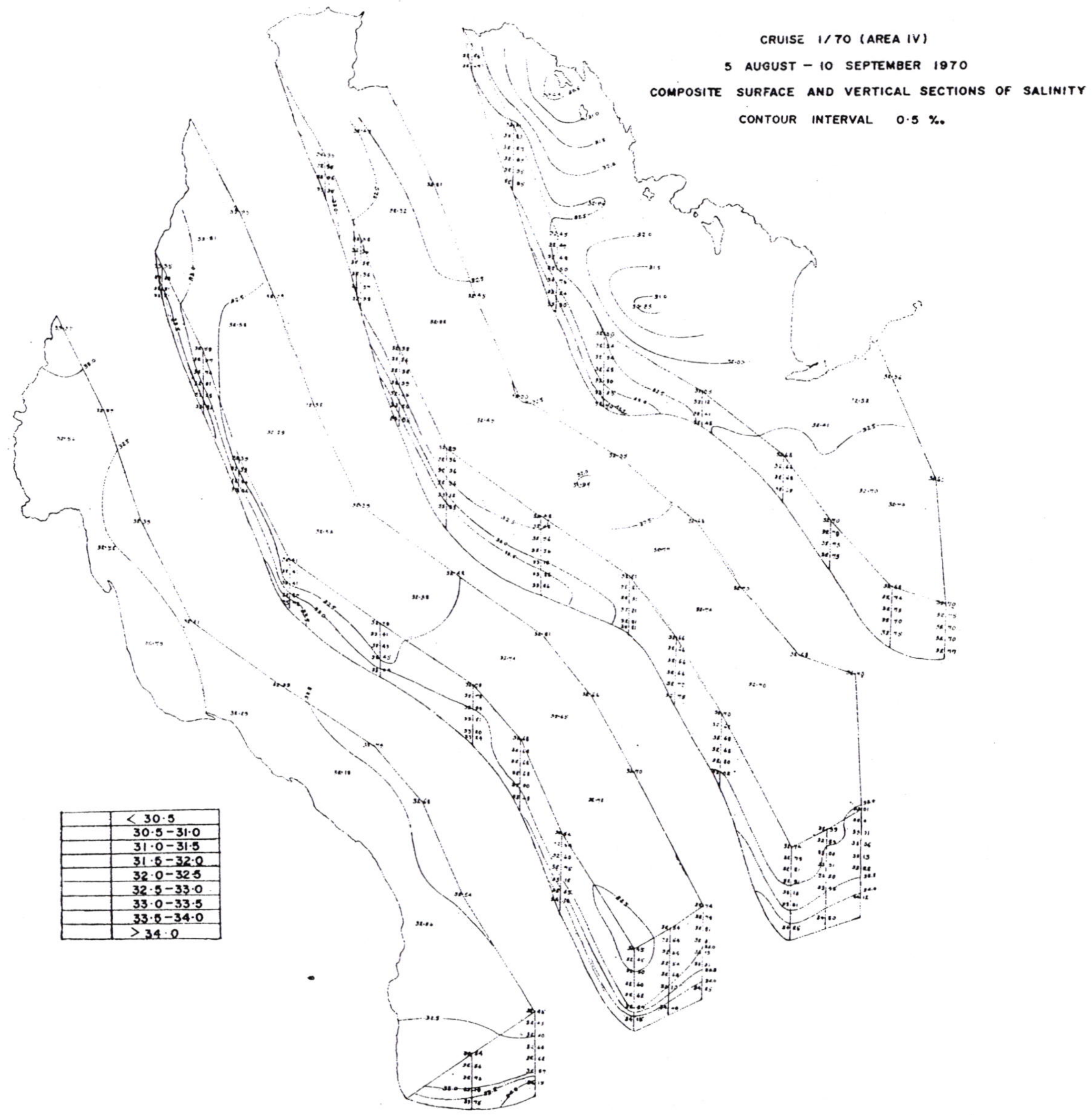
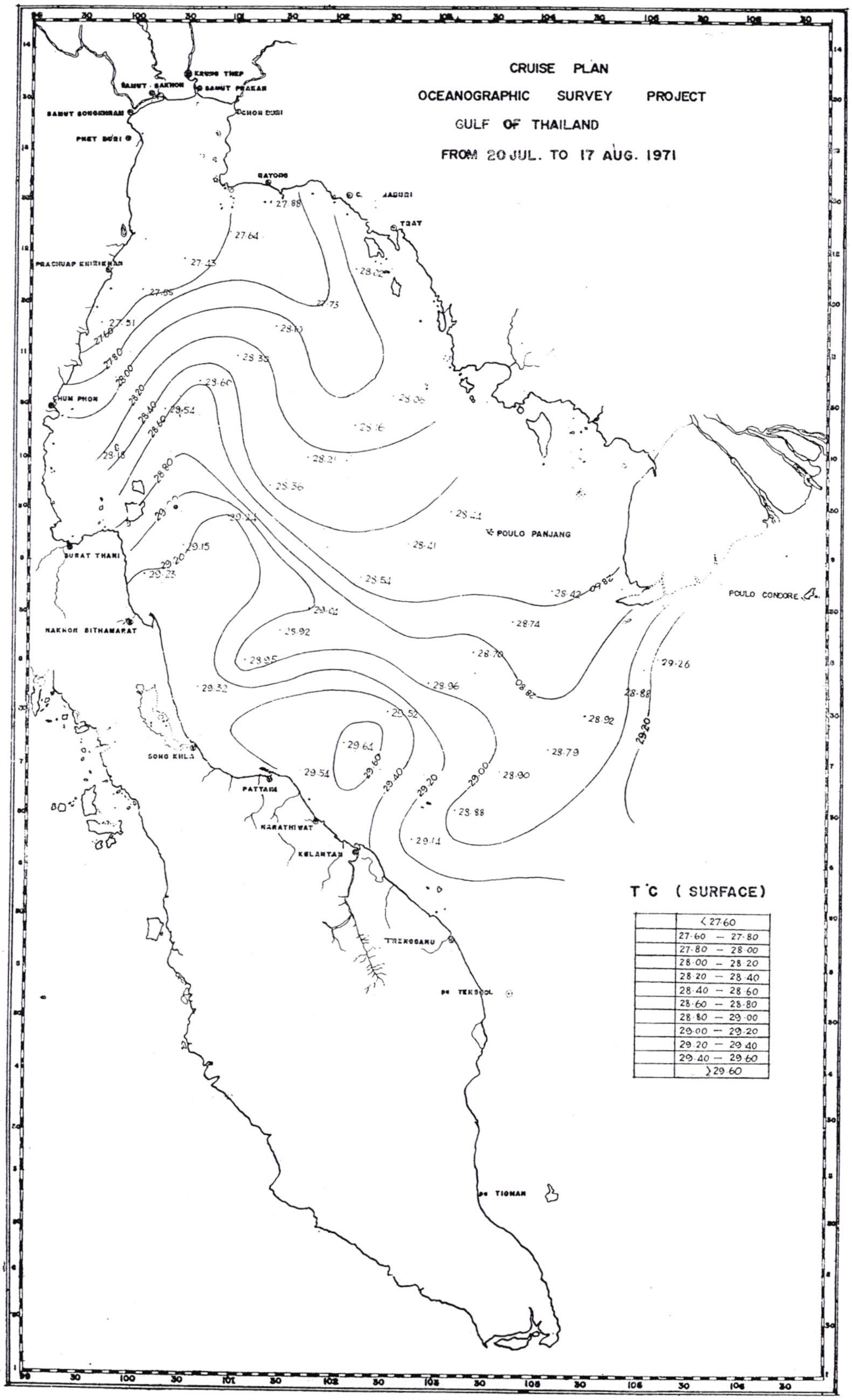


Fig. 16

Profile 16.1 – 16.4



CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
FROM 20 JUL. TO 17 AUG. 1971
POULO PANJANG
POULO CONDORE
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TIOMAN
T °C (SURFACE)
< 27.60
27.60 — 27.80
27.80 — 28.00
28.00 — 28.20
28.20 — 28.40
28.40 — 28.60
28.60 — 28.80
28.80 — 29.00
29.00 — 29.20
29.20 — 29.40
29.40 — 29.60
> 29.60

Fig. 17

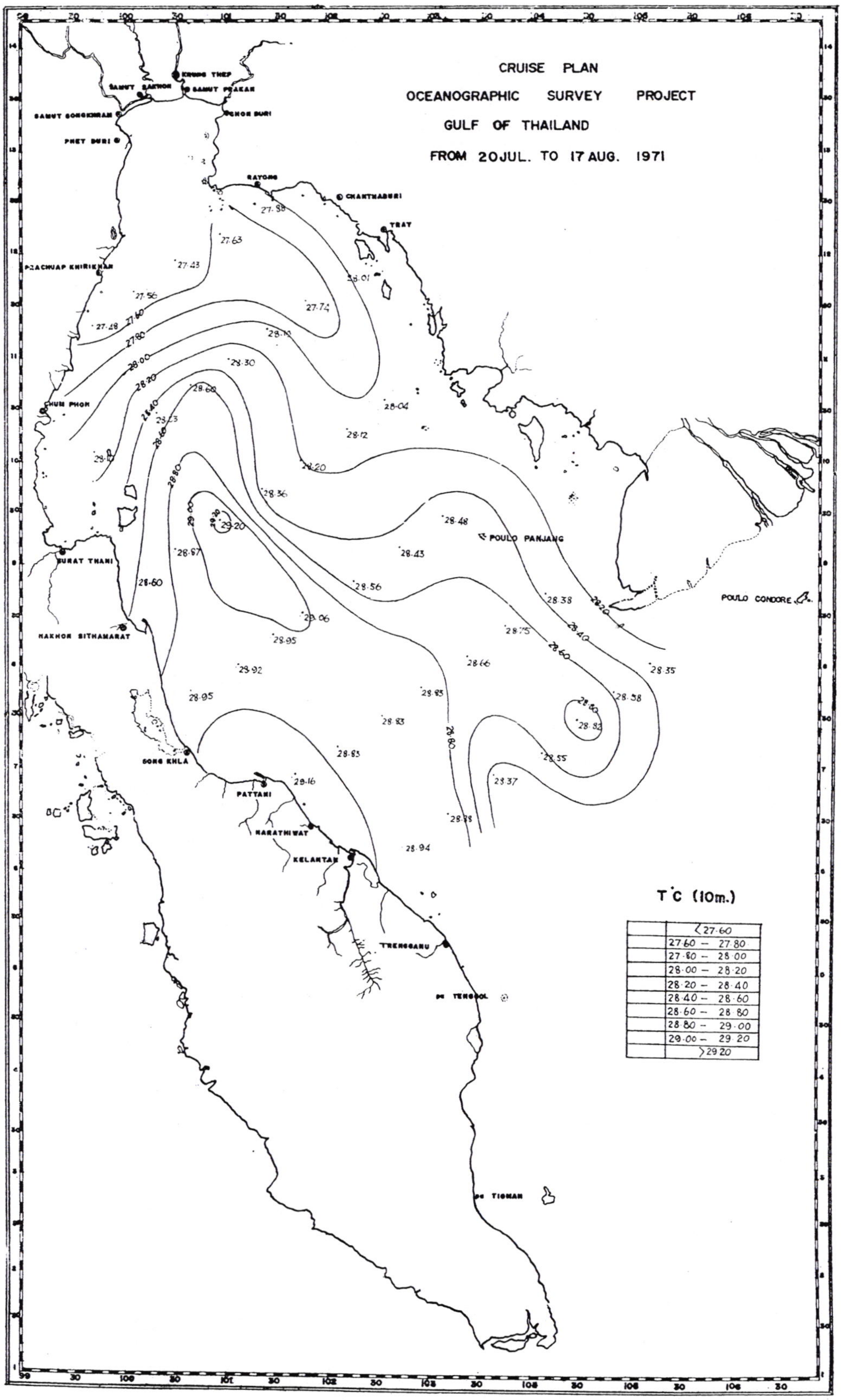

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
FROM 20 JUL. TO 17 AUG. 1971
T°C (10m.)
<27.60
27.60 – 27.80
27.80 – 28.00
28.00 – 28.20
28.20 – 28.40
28.40 – 28.60
28.60 – 28.80
28.80 – 29.00
29.00 – 29.20
>29.20
POULO PANJANG
POULO CONDORE
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TIOMAN

Fig. 18

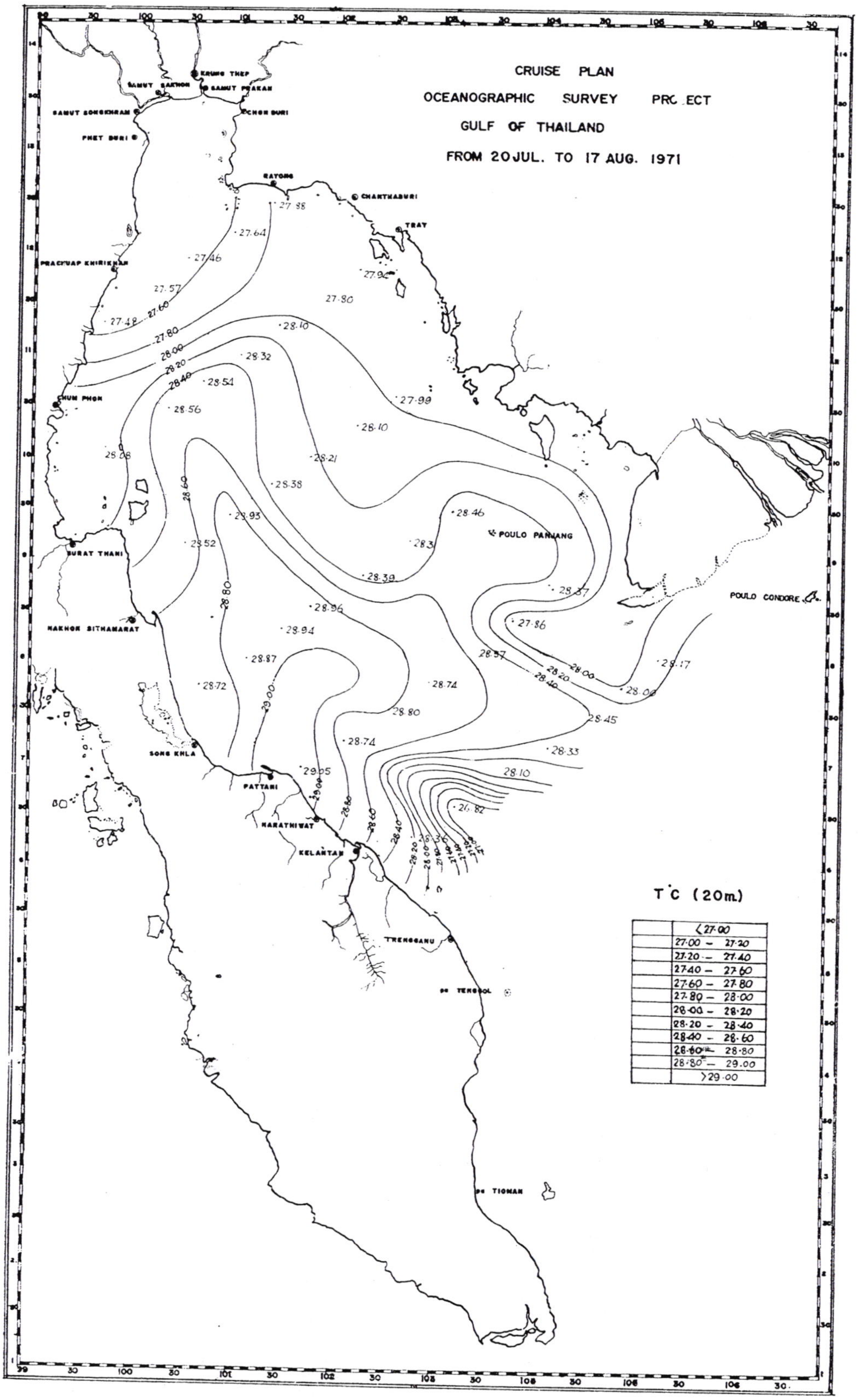

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
FROM 20 JUL. TO 17 AUG. 1971
T °C (20m.)
<27.00
27.00 – 27.20
27.20 – 27.40
27.40 – 27.60
27.60 – 27.80
27.80 – 28.00
28.00 – 28.20
28.20 – 28.40
28.40 – 28.60
28.60 – 28.80
28.80 – 29.00
>29.00
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
SURAT THANI
NAKHON SITHAMARAT
POULO PANJANG
POULO CONDORE
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN

Fig. 19

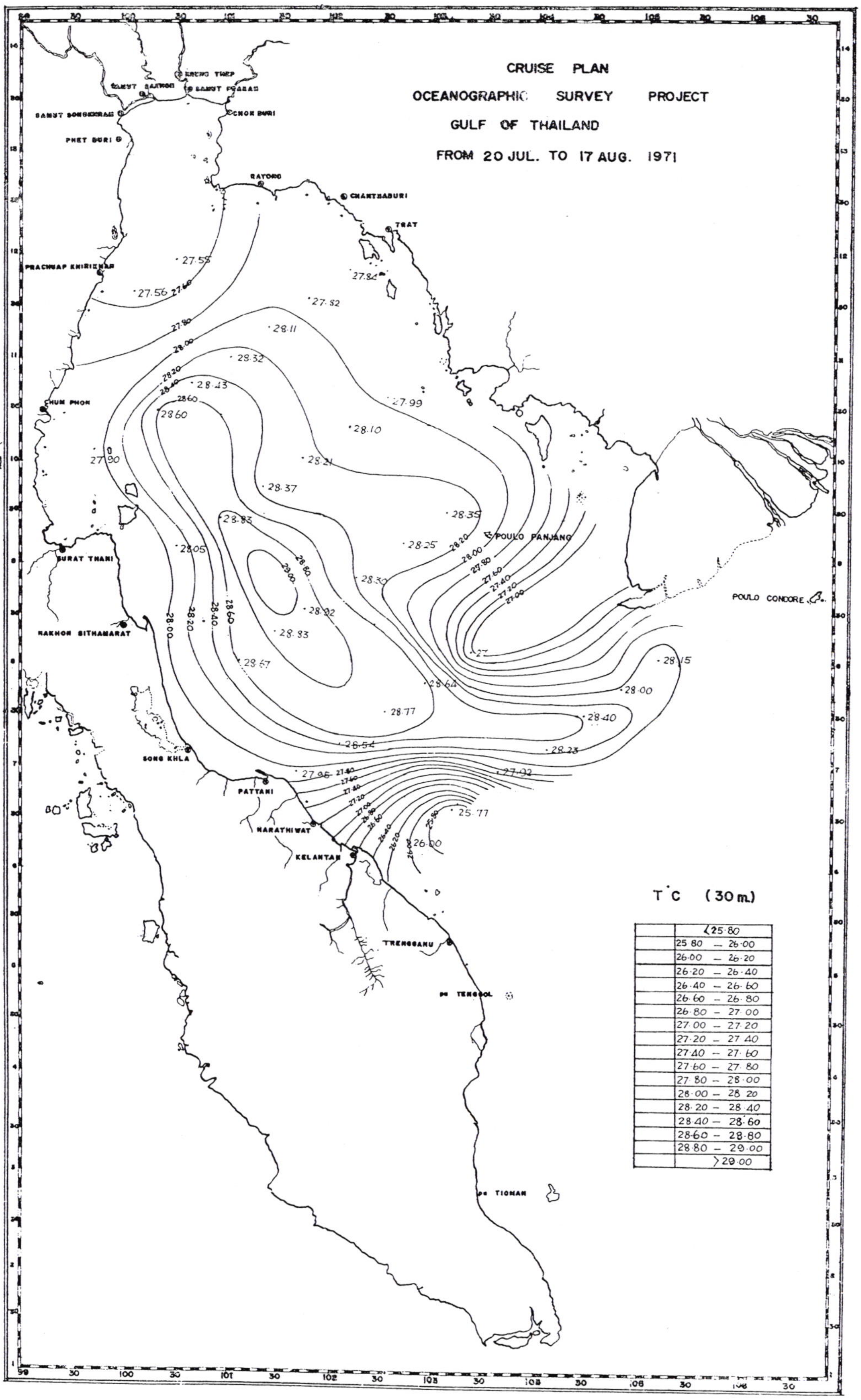
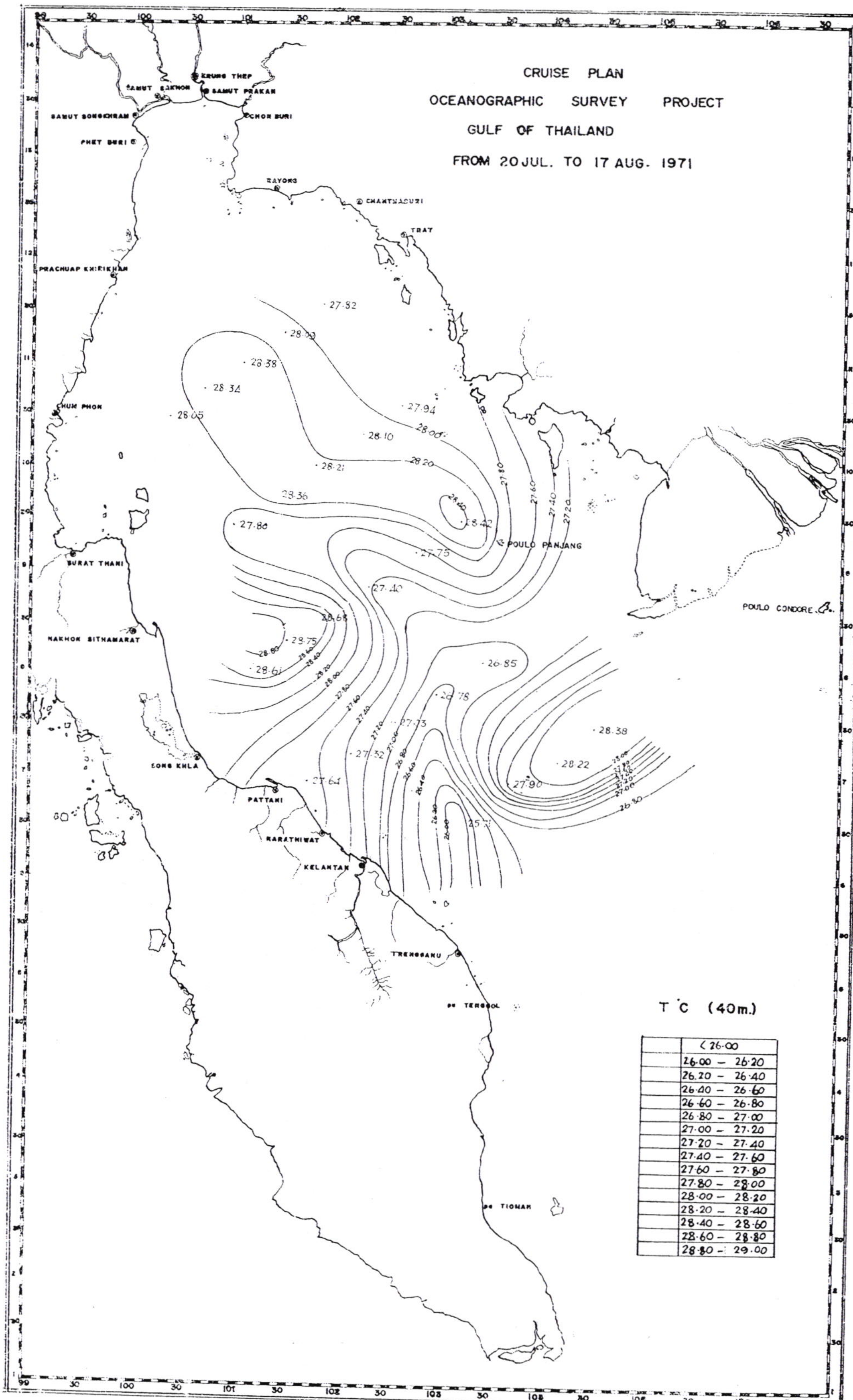

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
FROM 20 JUL. TO 17 AUG. 1971
T°C (30 m)
<25.80
25.80 – 26.00
26.00 – 26.20
26.20 – 26.40
26.40 – 26.60
26.60 – 26.80
26.80 – 27.00
27.00 – 27.20
27.20 – 27.40
27.40 – 27.60
27.60 – 27.80
27.80 – 28.00
28.00 – 28.20
28.20 – 28.40
28.40 – 28.60
28.60 – 28.80
28.80 – 29.00
>29.00
SURAT THANI
SONG KHLA
PATTANI
KELANTAN
TRENGGANU
POULO PANJANG
POULO CONDORE
TIOMAN

Fig. 20



< 26.00
26.00 – 26.20
26.20 – 26.40
26.40 – 26.60
26.60 – 26.80
26.80 – 27.00
27.00 – 27.20
27.20 – 27.40
27.40 – 27.60
27.60 – 27.80
27.80 – 28.00
28.00 – 28.20
28.20 – 28.40
28.40 – 28.60
28.60 – 28.80
28.80 – 29.00

Fig. 21

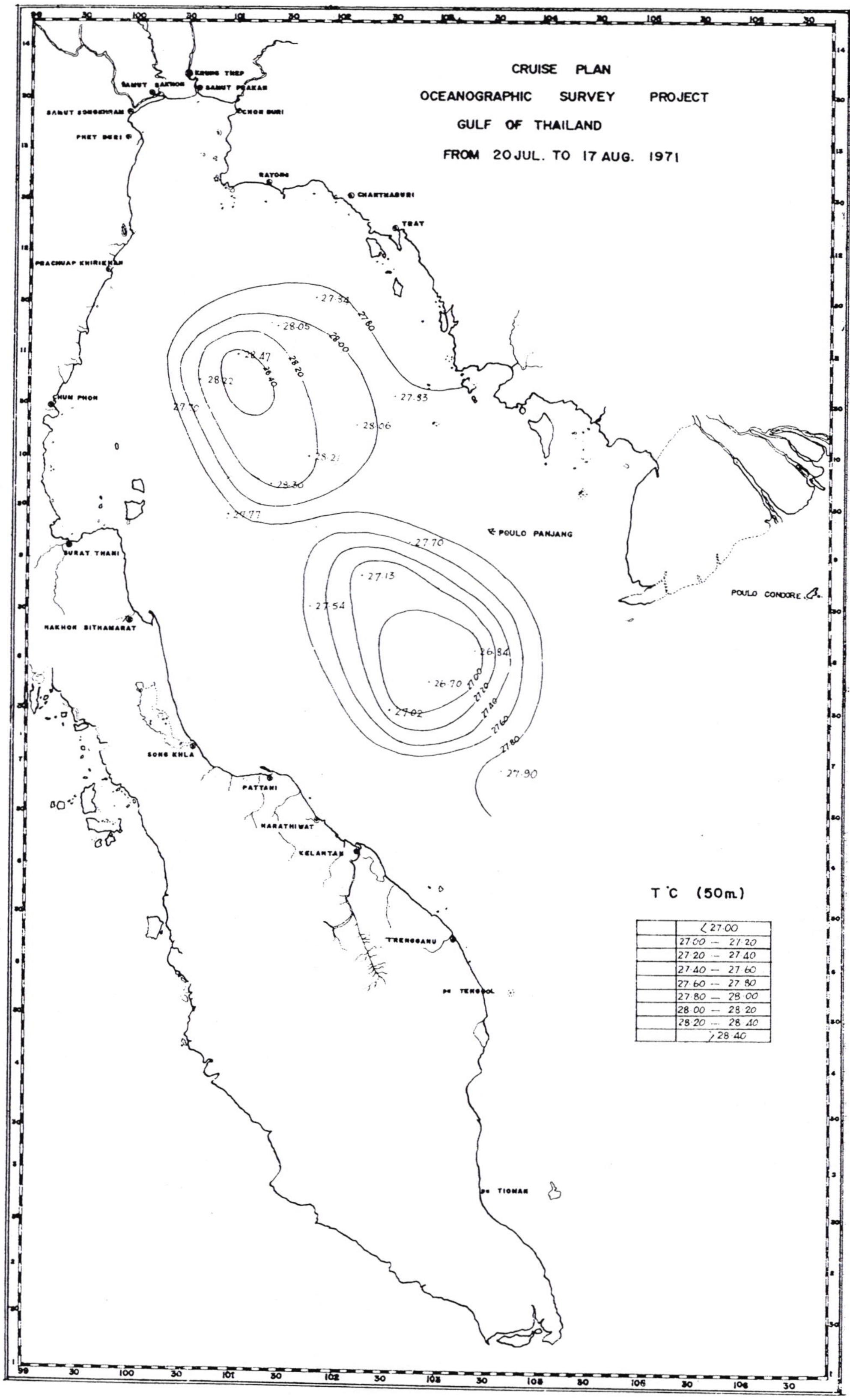

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
FROM 20 JUL. TO 17 AUG. 1971
T °C (50m.)
< 27.00
27.00 — 27.20
27.20 — 27.40
27.40 — 27.60
27.60 — 27.80
27.80 — 28.00
28.00 — 28.20
28.20 — 28.40
> 28.40
POULO PANJANG
POULO CONDORE

Fig. 22

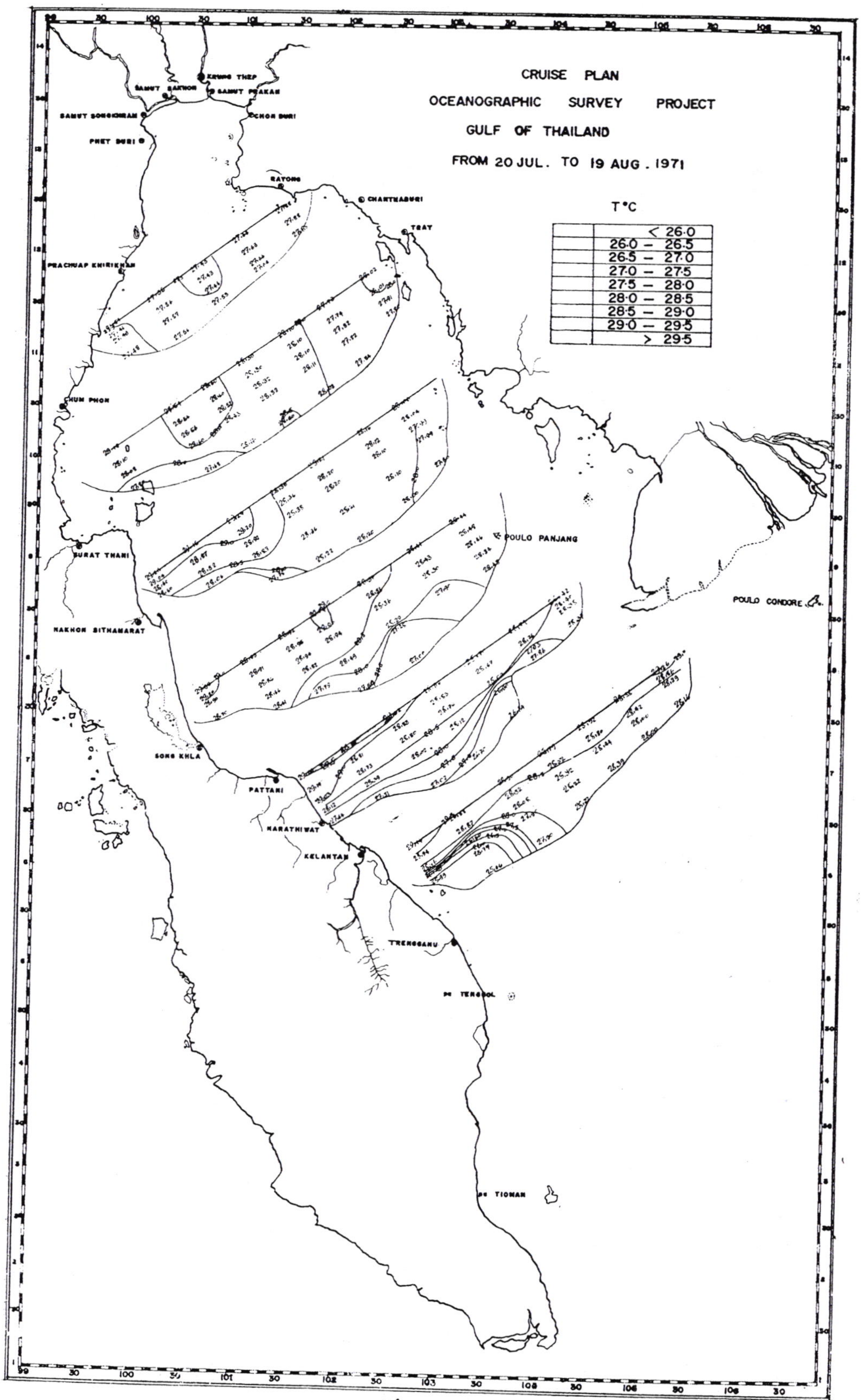


Fig. 23
Profile 23.1-23.6

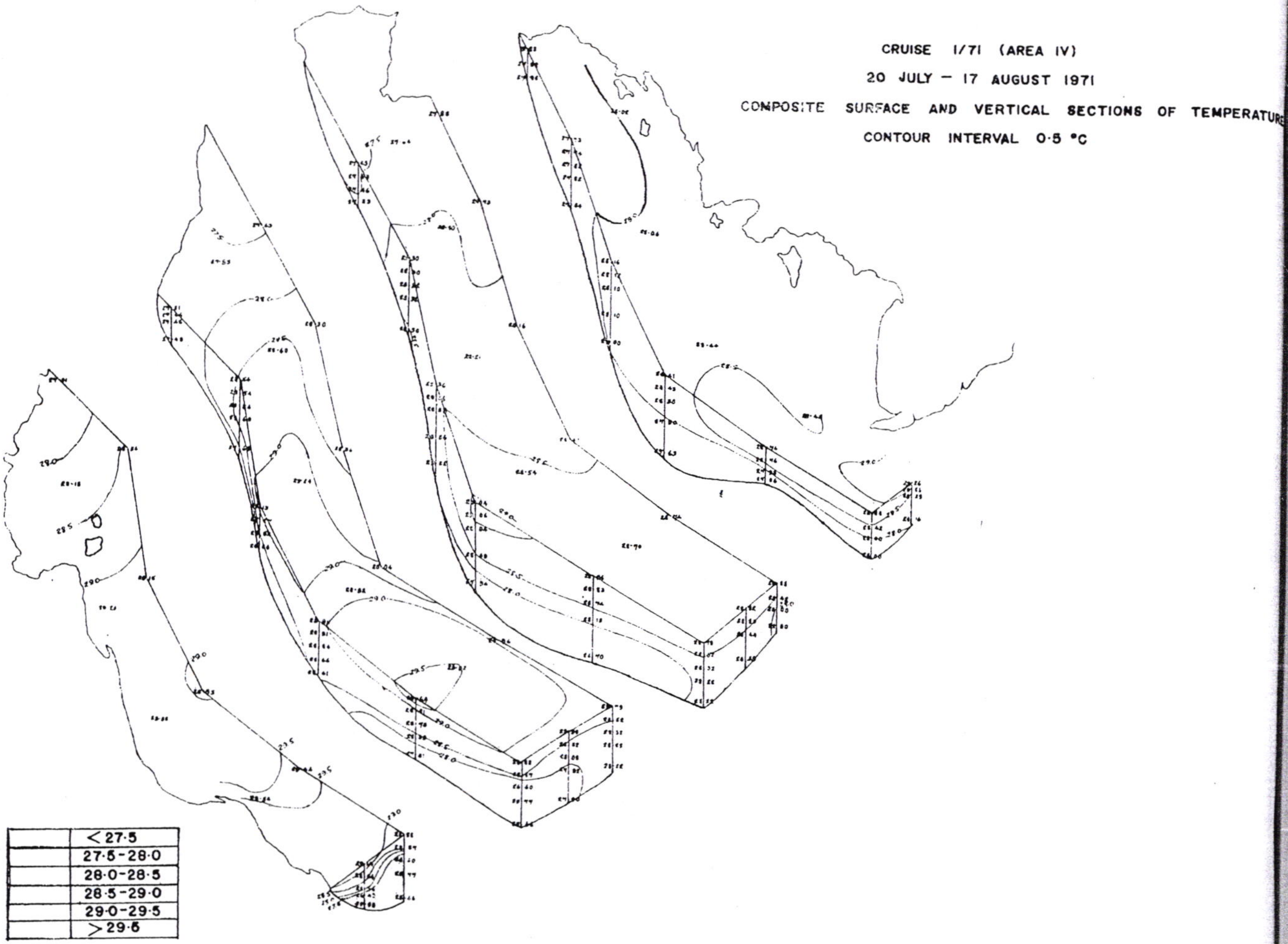


Fig. 24
Profile 24.1-24.4

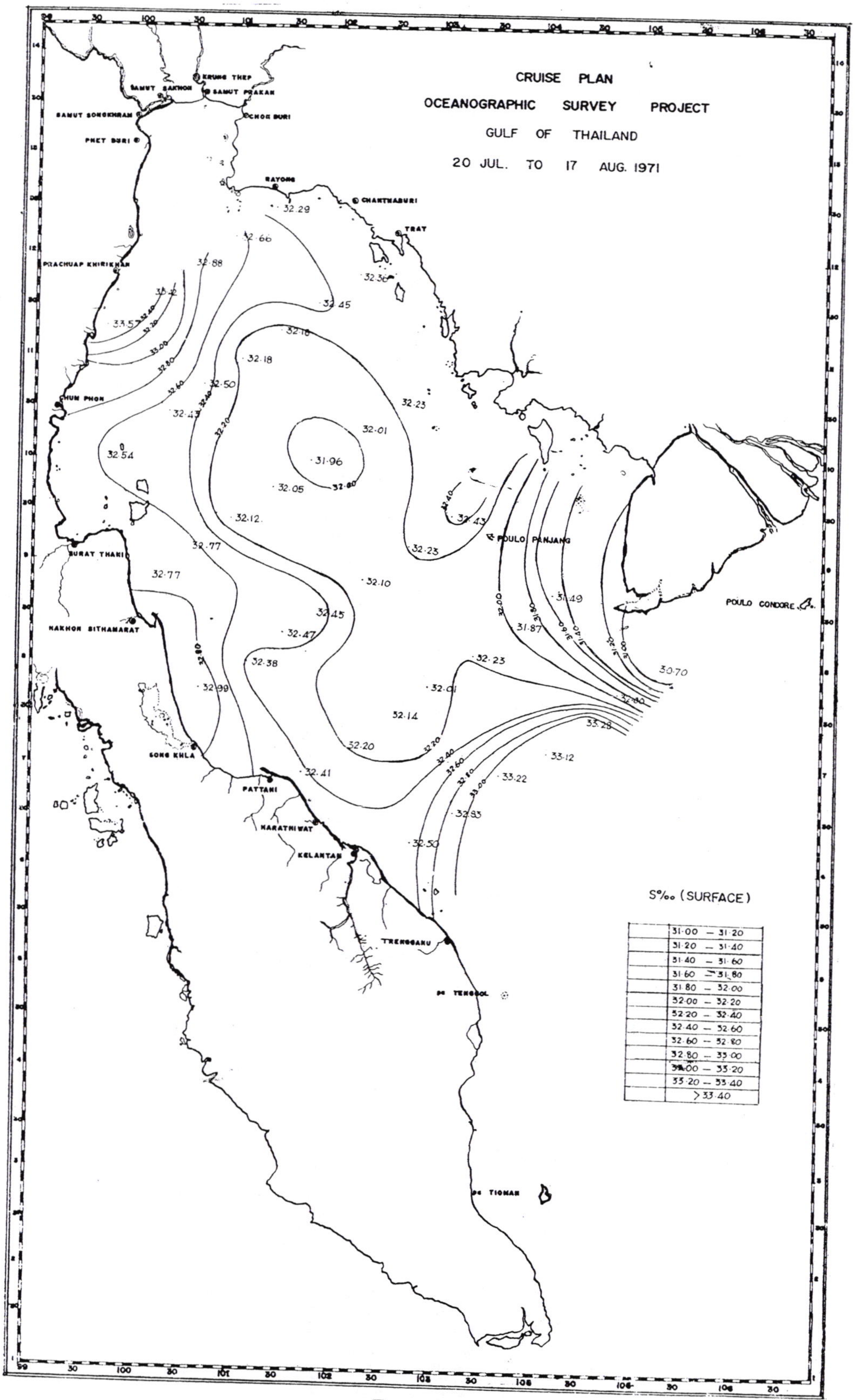

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
20 JUL. TO 17 AUG. 1971
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
POULO PANJANG
POULO CONDORE
S‰ (SURFACE)
31·00 – 31·20
31·20 – 31·40
31·40 – 31·60
31·60 – 31·80
31·80 – 32·00
32·00 – 32·20
32·20 – 32·40
32·40 – 32·60
32·60 – 32·80
32·80 – 33·00
33·00 – 33·20
33·20 – 33·40
>33·40

Fig. 25

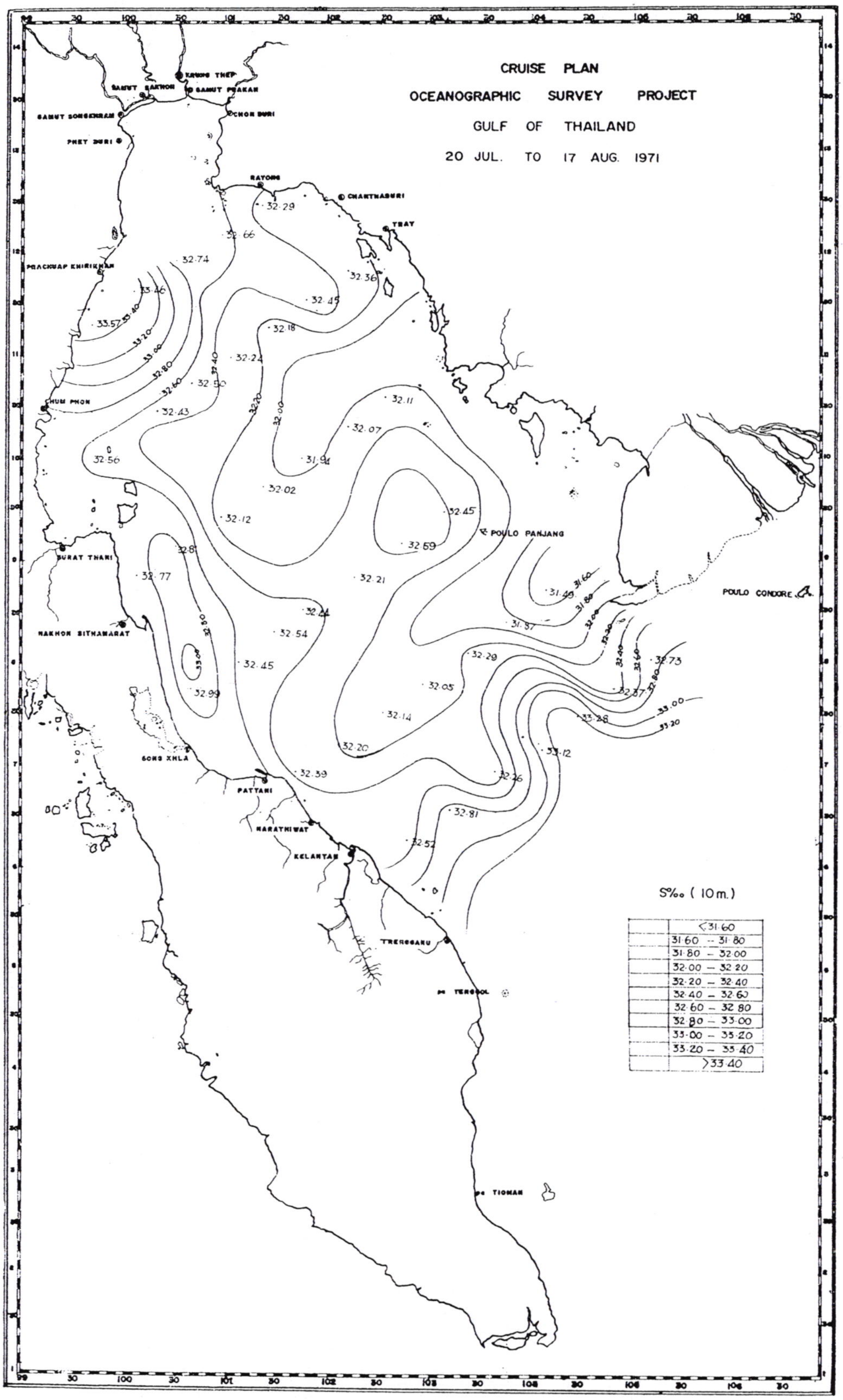

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
20 JUL. TO 17 AUG. 1971
RAYONG
CHANTHABURI
TRAT
CHUMPHON
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TIOMAN
POULO PANJANG
POULO CONDORE
S‰ (10 m.)
<31.60
31.60 – 31.80
31.80 – 32.00
32.00 – 32.20
32.20 – 32.40
32.40 – 32.60
32.60 – 32.80
32.80 – 33.00
33.00 – 33.20
33.20 – 33.40
>33.40

Fig. 26

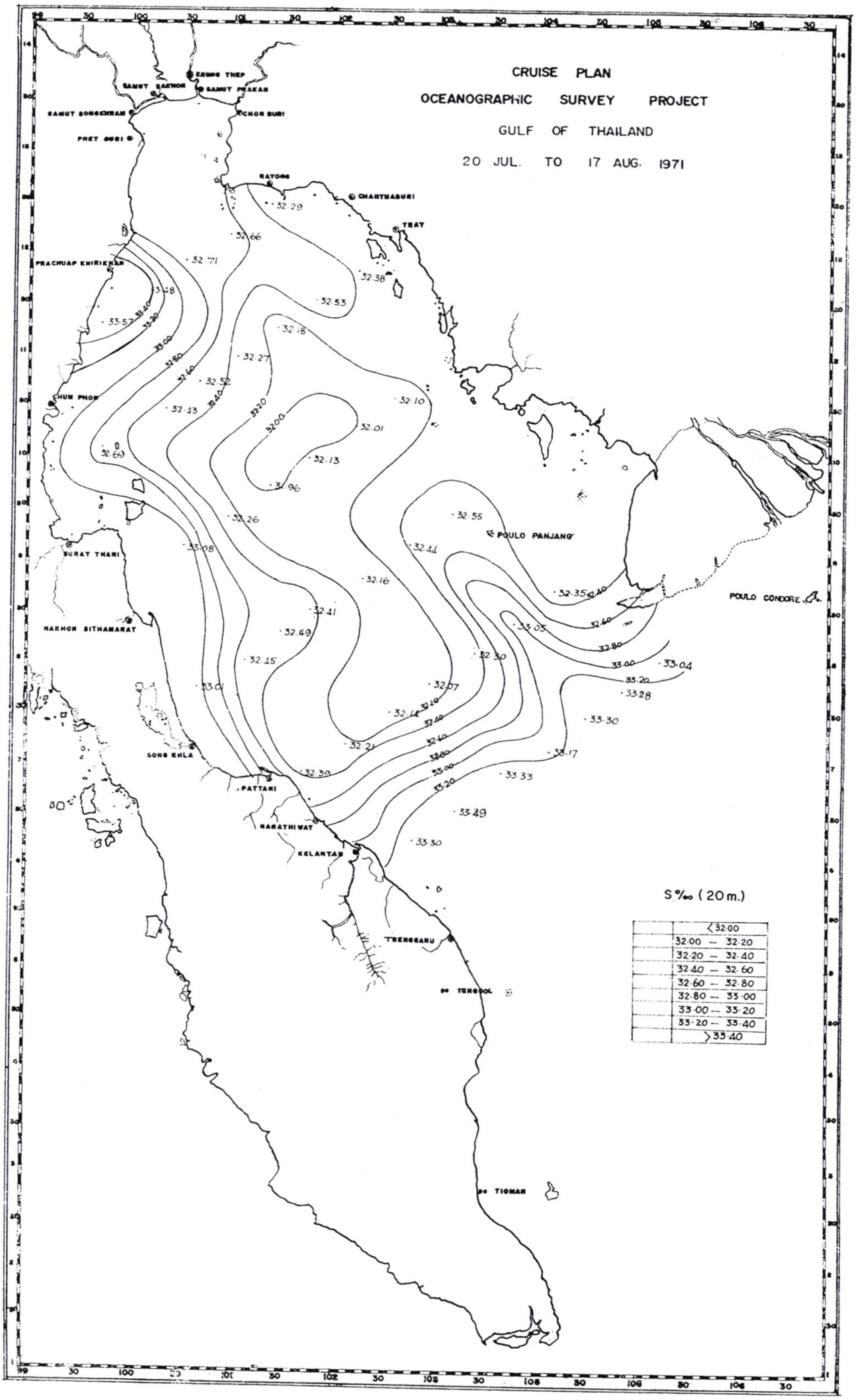

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
20 JUL. TO 17 AUG. 1971
KRUNG THEP
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
POULO PANJANG
POULO CONDORE
S‰ (20 m.)
<32.00
32.00 – 32.20
32.20 – 32.40
32.40 – 32.60
32.60 – 32.80
32.80 – 33.00
33.00 – 33.20
33.20 – 33.40
>33.40

Fig. 27

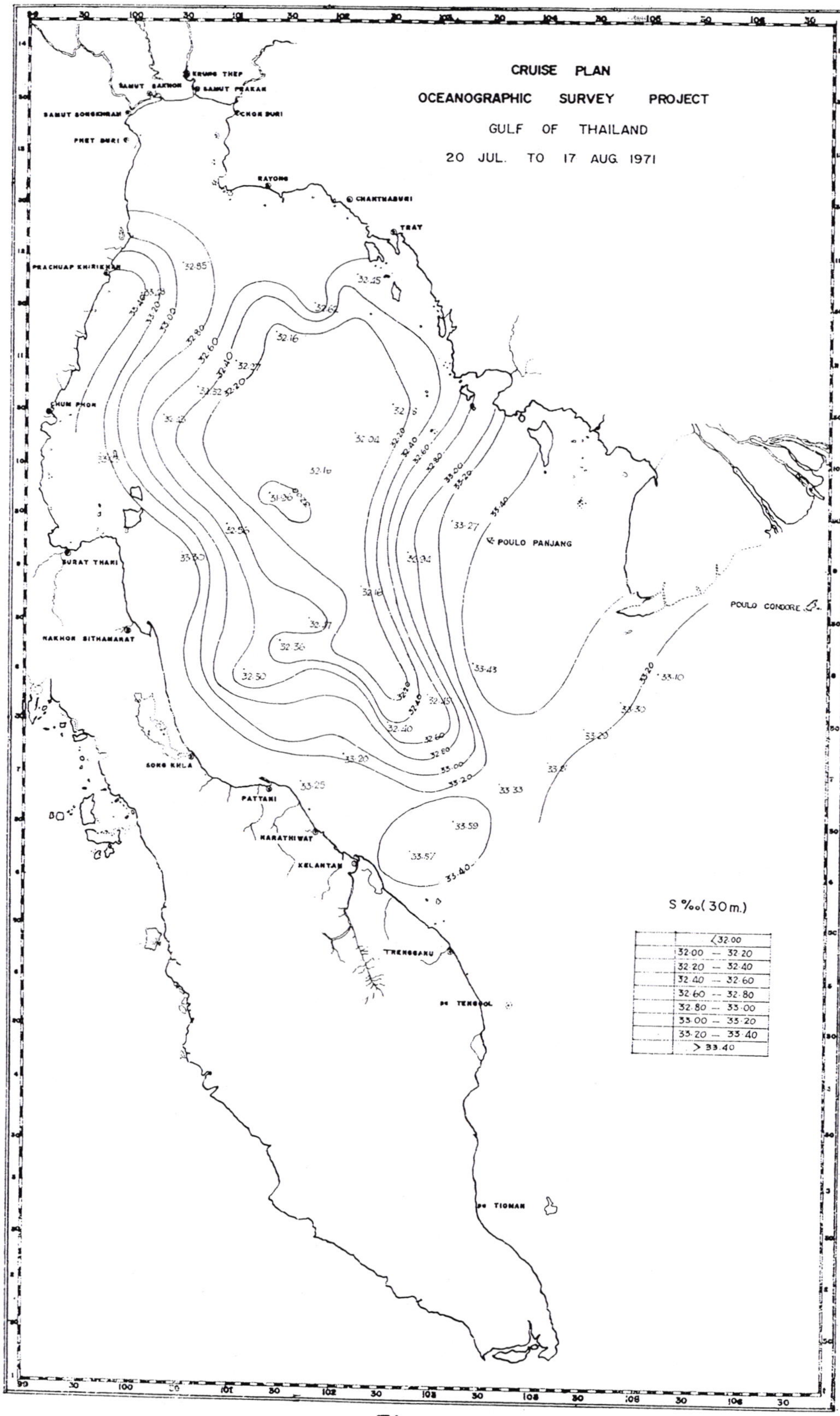

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
20 JUL. TO 17 AUG. 1971
S ‰ (30 m.)
< 32.00
32.00 -- 32.20
32.20 -- 32.40
32.40 -- 32.60
32.60 -- 32.80
32.80 -- 33.00
33.00 -- 33.20
33.20 -- 33.40
> 33.40
SAMUT SAKHON
SAMUT PRAKAN
SAMUT SONGKHRAM
CHON BURI
PHET BURI
RAYONG
CHANTHABURI
TRAT
PRACHUAP KHIRIKHAN
CHUM PHON
SURAT THANI
NAKHON SITHAMARAT
SONG KHLA
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
TENGGOL
TIOMAN
POULO PANJANG
POULO CONDORE

Fig. 28

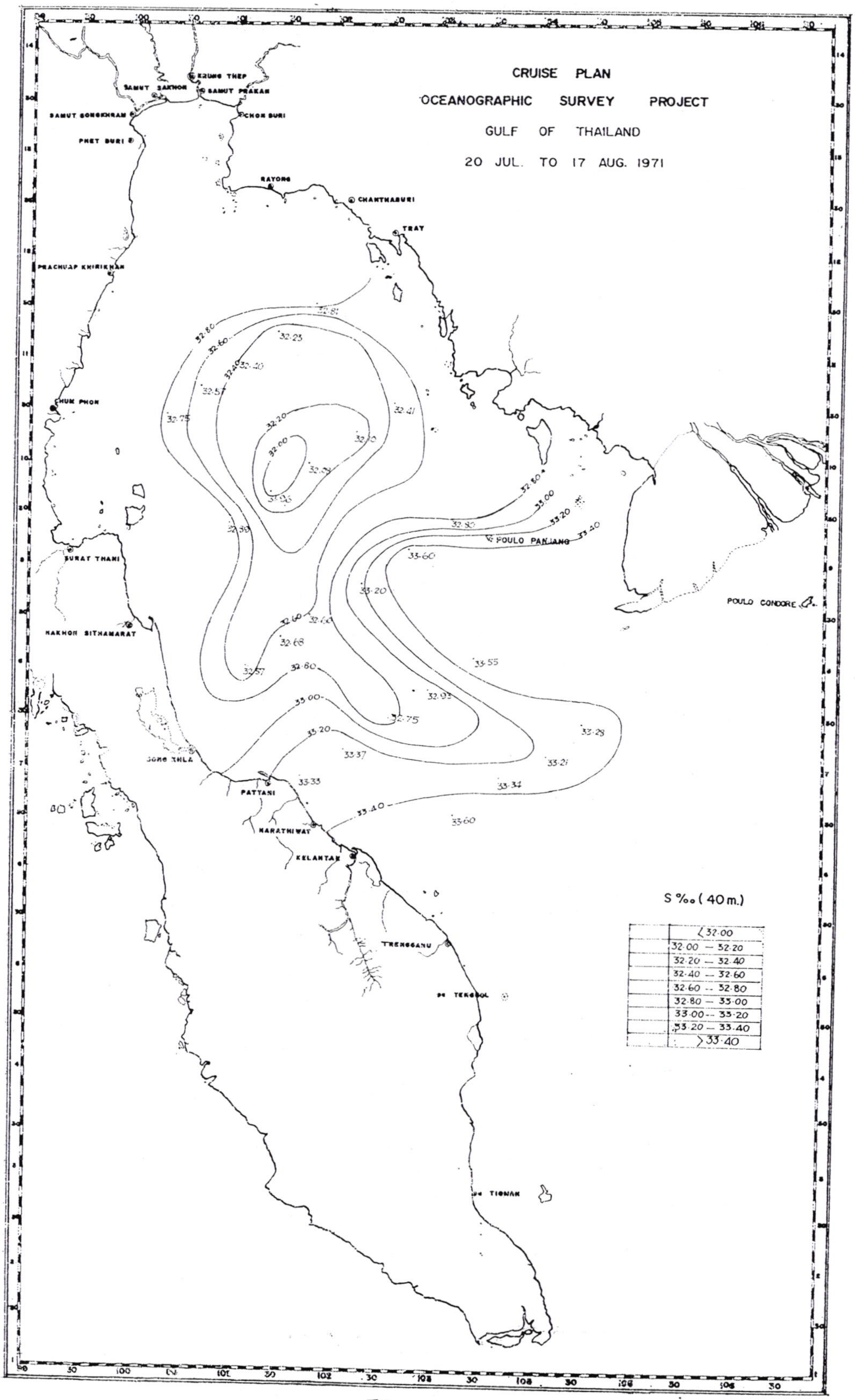

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
20 JUL. TO 17 AUG. 1971
S ‰ (40 m.)
< 32.00
32.00 — 32.20
32.20 — 32.40
32.40 — 32.60
32.60 — 32.80
32.80 — 33.00
33.00 — 33.20
33.20 — 33.40
> 33.40
POULO PANJANG
POULO CONDORE
SURAT THANI
CHUM PHON
PATTANI
NARATHIWAT
KELANTAN
TRENGGANU
CHANTHABURI
TRAT
RAYONG

Fig. 29

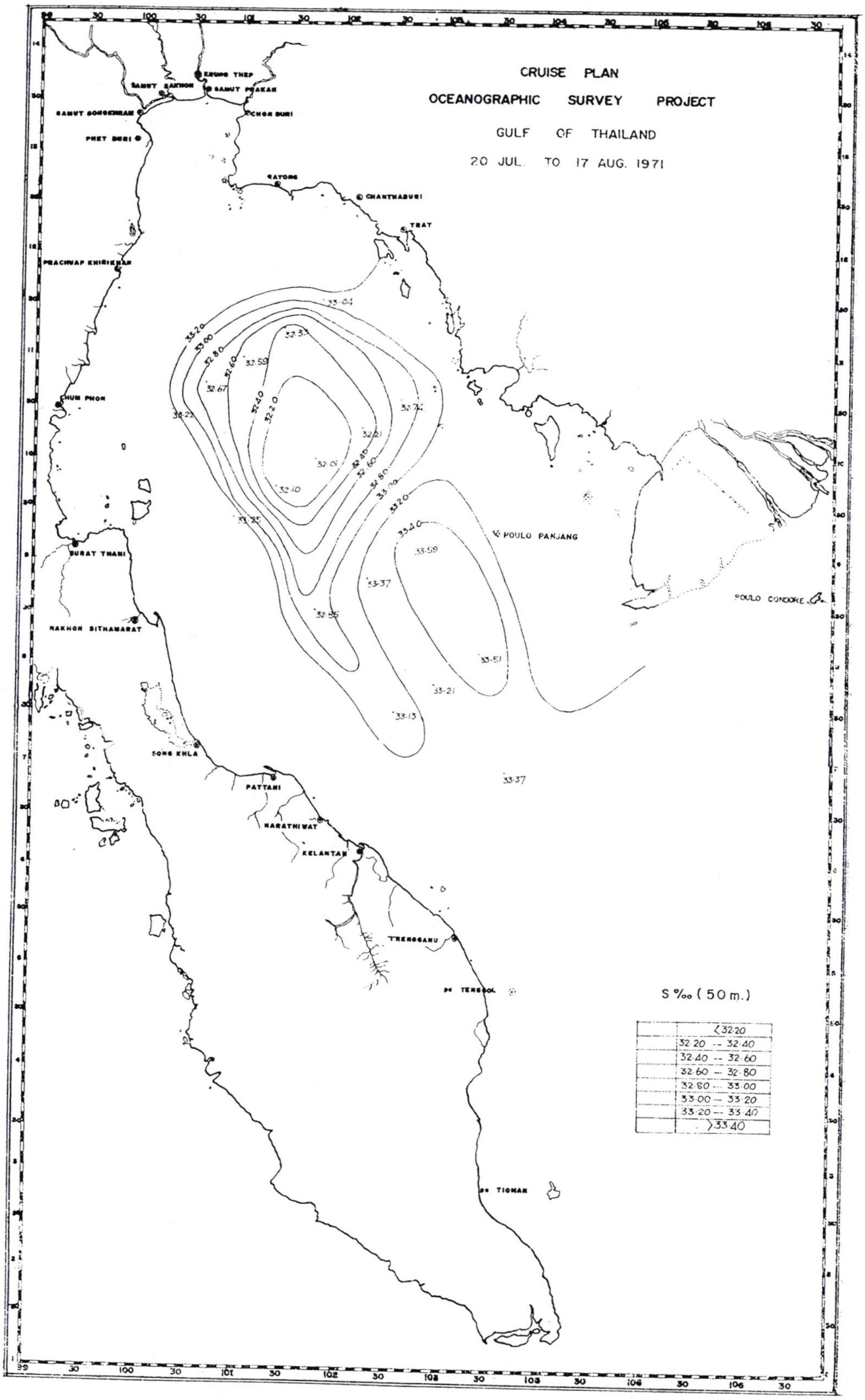

CRUISE PLAN
OCEANOGRAPHIC SURVEY PROJECT
GULF OF THAILAND
20 JUL. TO 17 AUG. 1971
POULO PANJANG
POULO CONDORE
S ‰ (50 m.)
<32.20
32.20 -- 32.40
32.40 -- 32.60
32.60 -- 32.80
32.80 -- 33.00
33.00 -- 33.20
33.20 -- 33.40
>33.40

Fig. 30

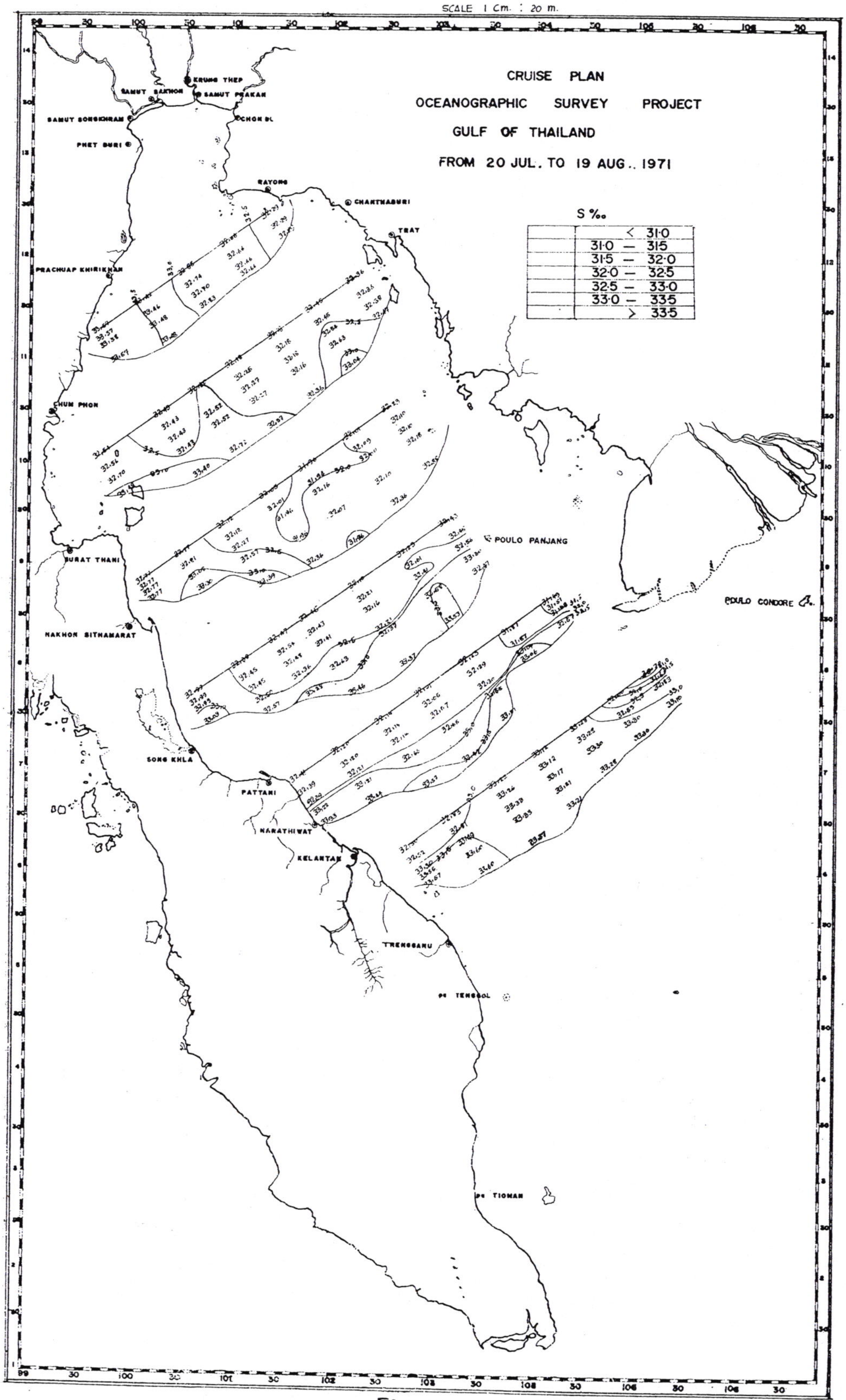


Fig. 31
Profile 31.1 - 31.6

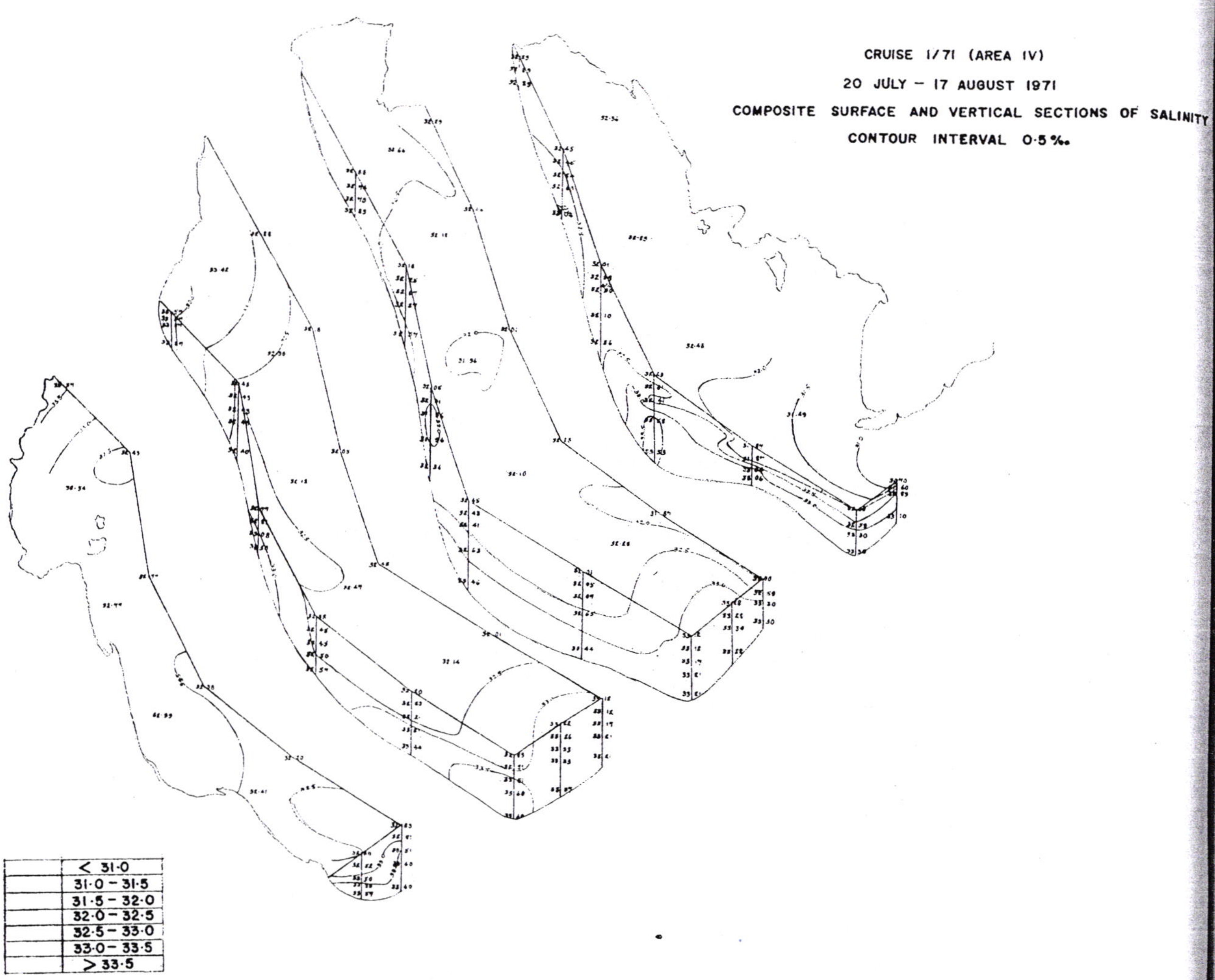


Fig. 32
Profile 32.1-32.4

1.2 MARINE SEDIMENTS IN THE NHATRANG AREA

by

Nguyen-Ngoc-THACH

Oceanographic Institute

Nhatrang, South Vietnam

INTRODUCTION

The study area, located at Central Vietnam, extends for approximatively 30 km. along the coast and 18 km. offshore. Concave seaward, the Nhatrang Beach is continuous over a distance of about 6 km. Northward, the DongDe Beach is more concave but shorter. Draining from mountainous regions, the Song Cai and Cua Be rivers supply abundantly terrigeneous materials during rainy season. Seaward, the Hon Lon island divides the Nhatrang bay into a northern part and a southern part. Besides the Hon Lon island, a great number of smaller islands spread over the study area. Among them should be mentioned the Hon Mieu, Hon Tam, Hon Mot, Hon Mun, Hon Ho, Hon Dung.

The Prevailing winds are from southwest during Summer (February to September). In other months, they blow in the opposite direction.

From geological standpoint, the coastal region comprised between the Song Cai and Cua Be rivers is a plain formed by quaternary alluvium (Fig. 2). Northward and southward, the mountains are formed respectively by dacite and granite. With regard to the small islands such as the Hon Mieu, Hon Tam, Hon Mot, Hon Mun, they are of rhyolitic formation. Rhyolite also occurs partly the Hon Lon island, on an elongated band. Granites are reported to be common in the remaining part of this island and in Hon Ho, Hon Dung. The highest mountains are the 'Le Tondu' (643 meters), 'Hon Lon' (482 meters) and 'Hon Kho' (376 meters).

METHODS OF STUDY

115 sediment samples have been collected by means of a clam - shell snapper which was used since this study was concerned with the nature and areal distribution of marine sediments (Fig. 3). With regard to the beach sands, they were obtained from the beach foreshore about 5 feet above mean lower low water. 11 samples were taken along the Nhatrang beach and 6 along the DongDe beach by pressing a small glass sample jar into the sand surface.

In order to study the grain–size distribution pattern, mechanical analyses have been performed. The samples were wet sieved through a 62–micron mesh sieve to separate sand from silt and clay. The pipette method was used to analyse the mud fraction while the sand fraction was dried, weighed and then dry sieved. The results of sieving were combined with the pipette analysis data to obtain the final weight percentages.

The grain - size is expressed by $\varnothing$ which is deduced from the diameter d by the relation :

$$d = 2^{-\varnothing} \rightleftharpoons \varnothing = -\log_2 d$$

WENTWORTH' s scale is used for size–classification.

The calcium carbonate content was estimated gasometrically. It is deduced from the volume of carbon dioxide driven off by action of hydrochloric acid on calcium carbonate present in the sediment.

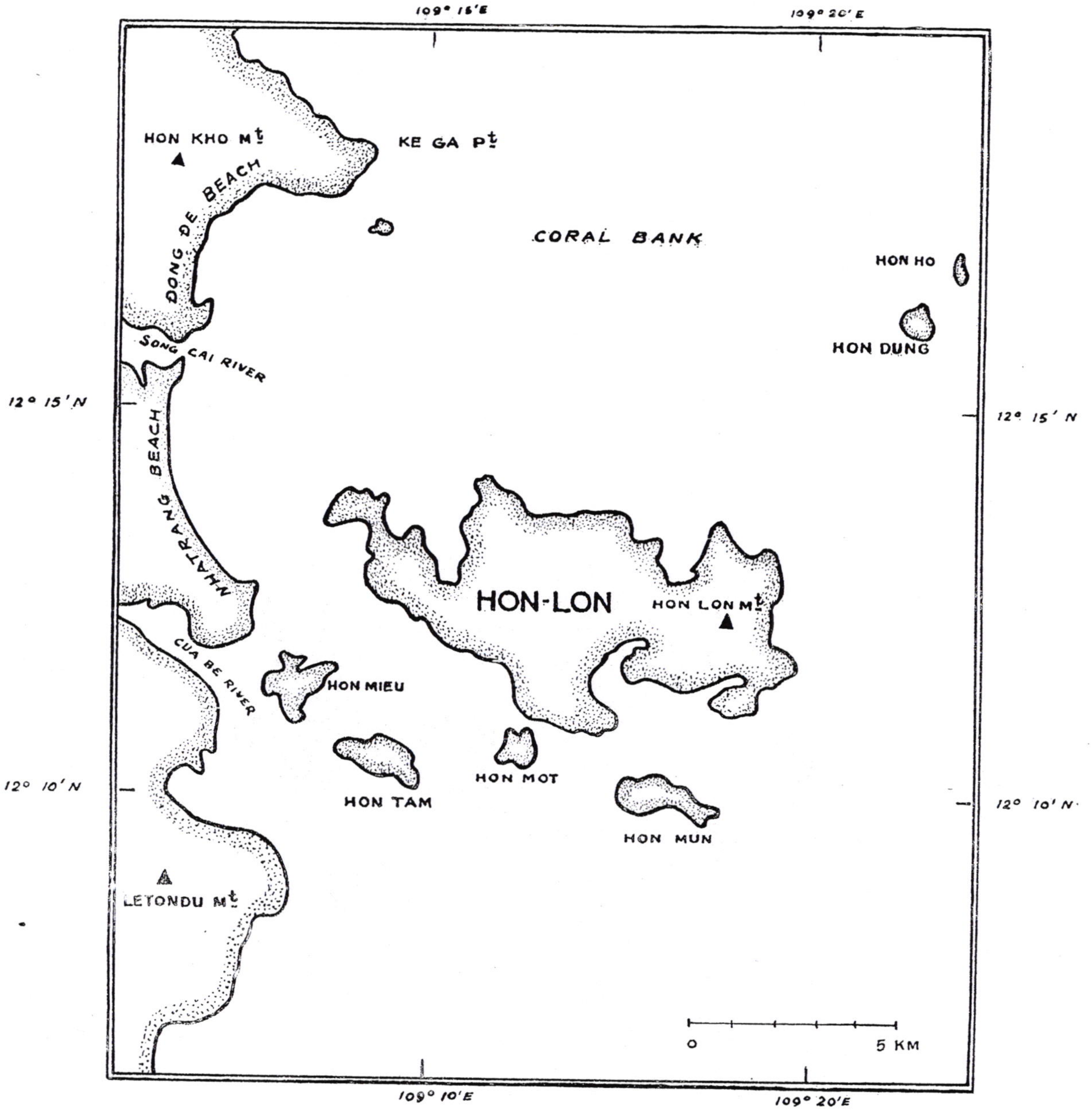
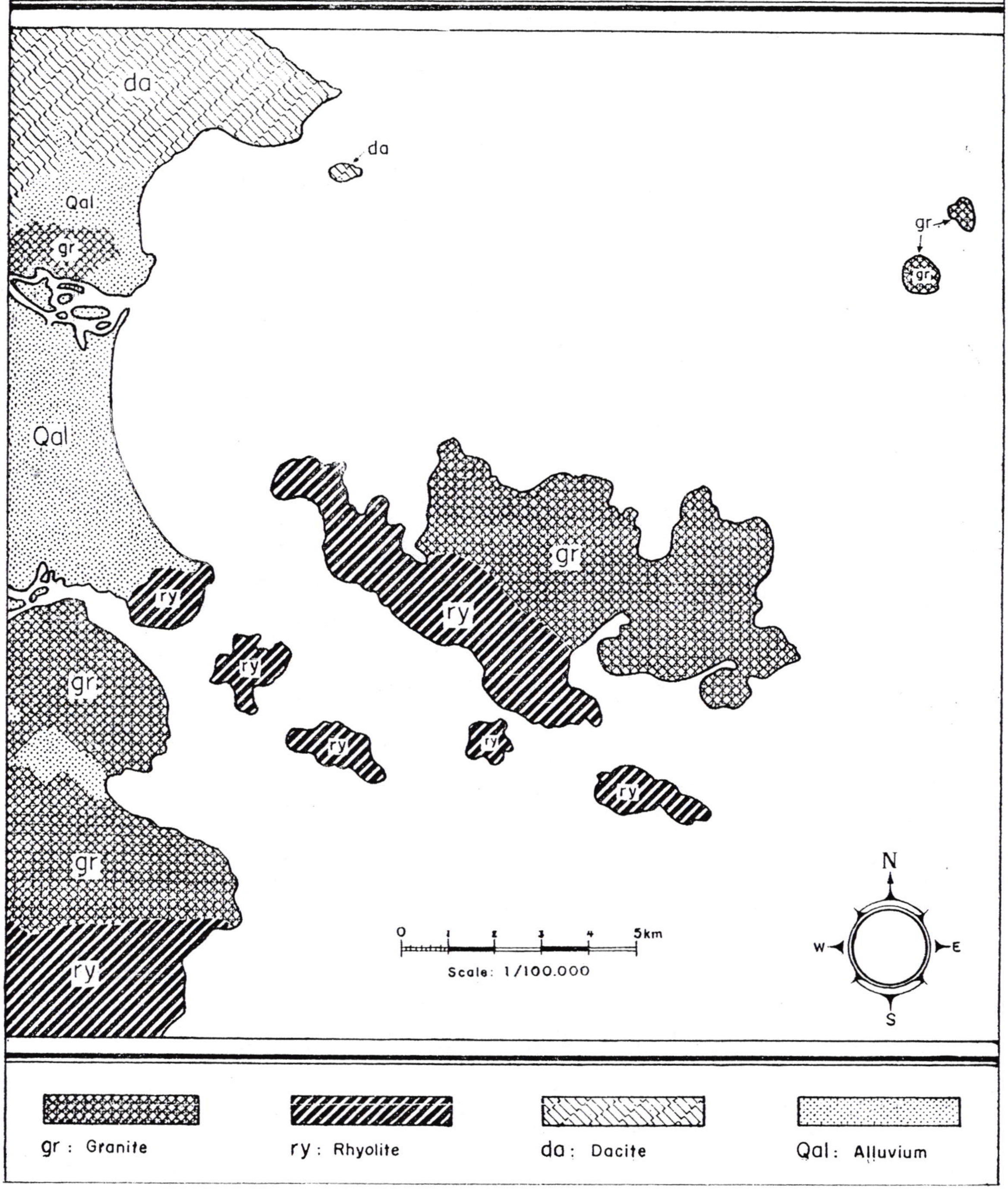


Fig I - LOCALITY MAP

Fig.2.-GEOLOGIC MAP OF THE NHATRANG AREA



$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 \nearrow + H_2O$$

If m grammes of sediment are used for analysis and V is the volume of carbon dioxide measured, the calcium carbonate content will be :

$$CaCO_3\ \% = 0.4 \frac{V}{m} \qquad (1)$$

BEACH SANDS

The Nhatrang beach in covered by medium sand: median diameters vary from 0.22 ∅ to 2.12 ∅ around an average of 1.47 ∅. For the DongDe beach, they are within a range of 2 ∅ to 2.65 ∅ with an average of 2.40 ∅. This shows the predominance of fine sand on the DongDe beach. Variations of median diameters along the beach are slight.

Beach sand are deposits which median diameters range from 0 to 3∅. Earlier reports concerning beach sands of different countries show the same results.

These beach sands are well–sorted with the Phi Standard Deviations ranging from 0.25 to 1.25. Using a diagram with the Phi Median Diameter plotted against Ox and the Phi Standard Deviation against Oy, we found the best sorting for sands of Median Diameters around 2 ∅.

The Phi Skewness Measure is almost negative. In other words, the modal group lies to the fine side of the median diameter. Sometimes skewness is positive but deviates slightly from O.

There is a striking difference between the calcareous matter amount in these 2 beaches. The Nhatrang beach sands exhibit an extremely low content of $CaCO_3$ (less than 2 %). On the contrary, the DongDe beach sands are of biogenic origin: they are highly calcareous with $CaCO_3$ content reaching 70 %. Their calcareous matters are contributed by the dead corals in DongDe.

MARINE SEDIMENTS

Based on the grain-size distribution pattern, the surface sediments of Nhatrang Bay can be classified into 3 types (Fig. 4):

(1) sand

(2) mud

(3) sediments associated with the Coral Bank.

1. The sand belt

Sandy sediment covers most of the northern part of Nhatrang bay and occurs for about 15 km. from shoreline and along the Nhatrang and DongDe beaches. The continuous stretch running from Cua Be estuary to Ke Ga point is named offshore sand belt to distinguish it from the proper sand belt located at the north of Hon Lon island.

2. The mud belt

Silt covers the widest part, forms the southern, eastern and northernmost boundaries of the study area. The proportion of sand in these marine deposits is very low, compared to that of the sand belt. Coarse shells and shell fragments were rarely found: $CaCO_3$ contents are less than 30 %.

3. Sediments associated with the Coral Bank

Around the Coral Bank, marine deposit consists mostly of corals, skeleton debris, plant fragments and is very unsuitable for sample collection.

Gravels and fine sands are also present but only in minor quantities. The coral debris exhibit a large range of coarseness. Calcareous matter amounts exceed 70%.

CALCAREOUS MATTER

The calcareous material is present in all sediment of the study area. Its amount varies from less than 10 % to more than 90 %.

THE NHAIRANG BAY

SAMPLE LOCATIONS

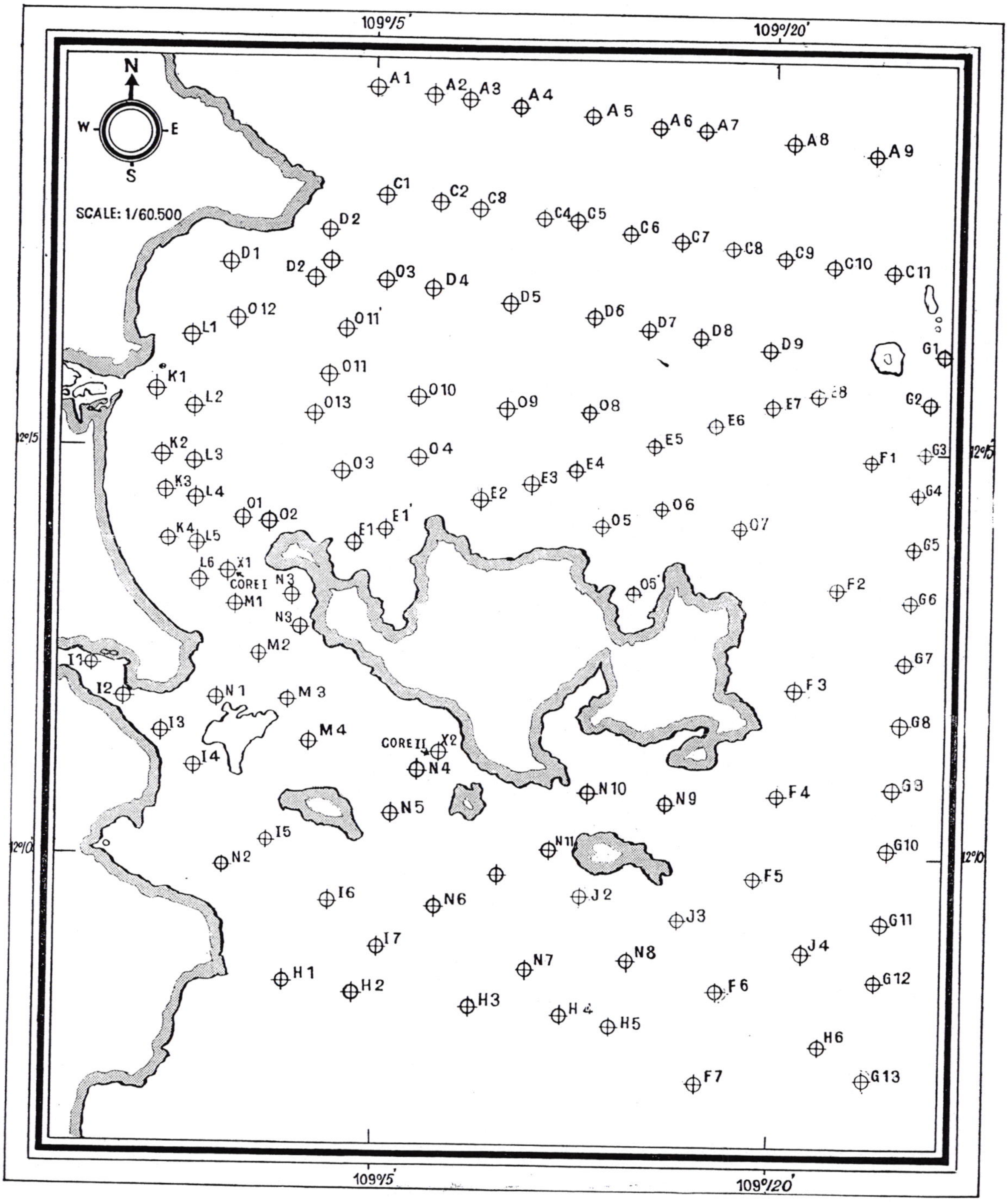


Fig. 3 Sample Locations

THE NHATRANG BAY

SEDIMENT NATURE

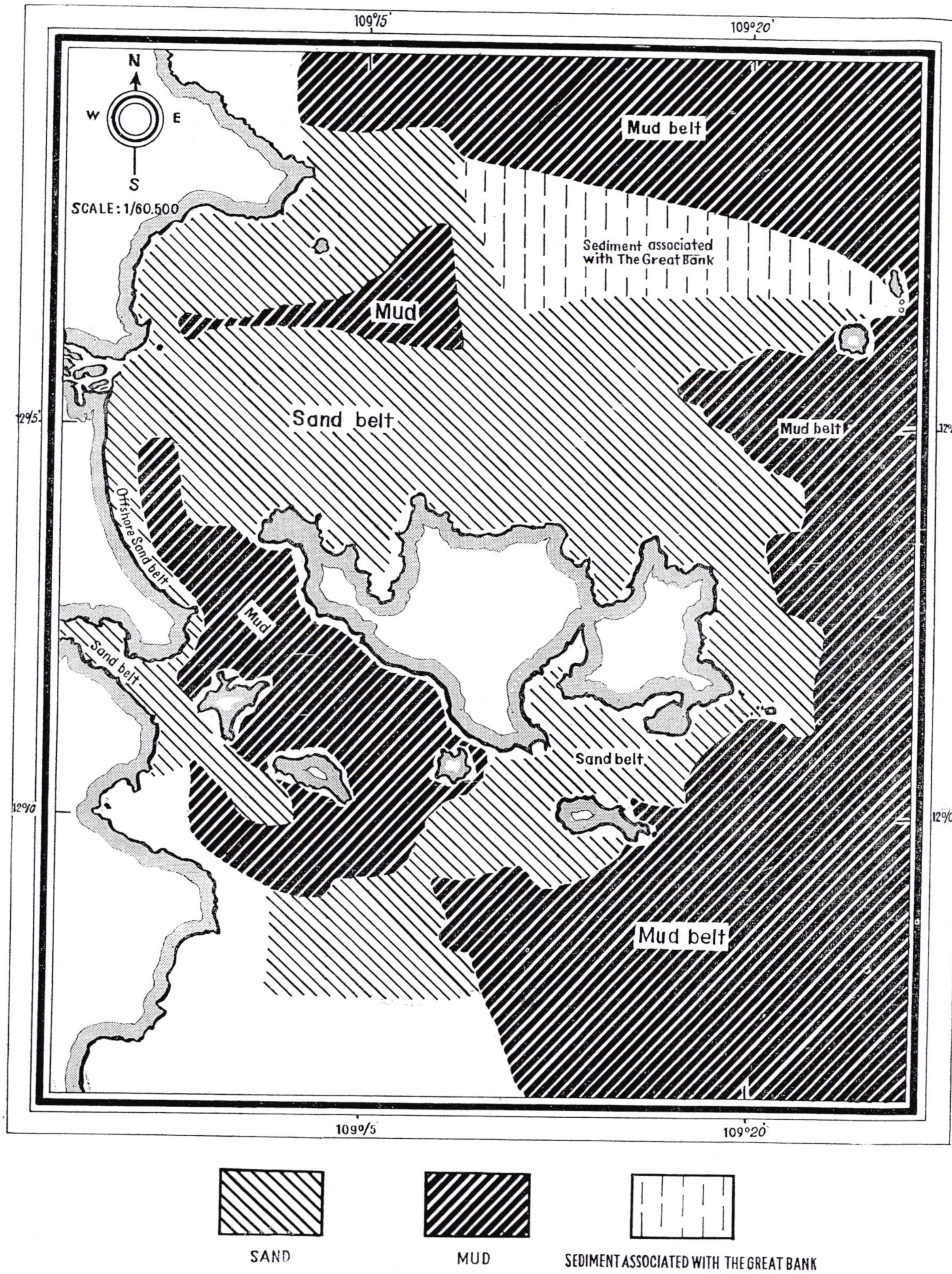


Fig. 4

The most important carbonates in marine sediments are :

- calcite $CaCO_3$
- aragonite $CaCO_3$
- dolomite $Mg,Ca\ (CO_3)_2$

However, the emphasis should be placed upon the percentage of carbonate rather than upon the character of calcareous material.

The results calculated from the relation (1) are higher than the calcium carbonate content because the carbon dioxide can be generated by action of hydrochloric acid on other carbonates such as dolomite, magnesite, siderite. Fortunately, $CaCO_3$ cohstitutes more than 90 % of total carbonate in most evironment sediments. On the other hand, the reaction used for $CaCO_3$ content estimation was realized at ordinary temperature – no heating – hence the actions of Mg^{++}, Fe^{++} are negligible.

The calcareous matter has many origins : detrital, authigenic or biogenic. In the study area, the main source of calcareous material is thought to arise from the biogenic origin.

1.3 TIDAL PREDICTION BY A COMPUTER

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Abstract

In 1952 the Hydrographic Department, Royal Thai Navy, purchased a standard tidal predicting machine from the Lègé Scientific Instrument Company Limited, France. Since then the tidal prediction by the harmonic method in Thailand had started. Nowadays most of the tidal institutes have developed their predictions done by means of computer. The tidal predicting machine is rarely used in the standard work, or quitted to be constructed.

When the Thai Military Supreme Command Head Quarters established the Data Processing Center, the Hydrographic Department took chance to develop the tidal prediction to be done by means of computer.

Fortran IV was selected as the program language. The mathematical model was derived from P. Schurman's formula for tidal prediction and it was intended to keep the program as simple as possible.

The computer finished the prediction which was previously spent 2–3 weeks by the Kelvin machine in only half an hour with better accuracy. However, the programs still have some weakness which must be improved for better performances, less redundancy and more efficiency in processing in the future.

HISTORY

The Hydrographic Department, Royal Thai Navy has been the authority in predicting of tides in the Thai Waters for over 20 years. At the beginning, the prediction was only done for one station, for the purpose of serving the ships to pass the Bangkok Bar.

Before 1952 the U.S. Hydrographic Department was contracted to do these computations. In 1952 The Hydrographic Department of Thailand bought a standard tidal predicting machine of 30 components from the Légé Scientific Instrument Company Limited, France. By the end of that year the tidal prediction was really started in Thailand.

Ever since 1952, our only tidal predicting machine has been in excellent condition and provided us with good results. Number of stations to be predicted has increased from time to time in order to serve the needs of public and military.

At the present time, it is almost impossible to have predictions of about 24 to 28 stations completed in time due to the speed of the machine.

We have learned that nowadays most of the tidal institutes already developed their predictions to be done by means of computer. The standard tidal predicting machine is rare to be found in uses. As of 1952, perhaps the tidal institute of Thailand is the only one for whom the predicting machine is still serving.

When the Military Supreme Command Head Quarters established the Data Processing Center with IBM 360/40 computer, the Hydrographic Department took that opportunity to ask for the cooperation in starting the development of the tidal prediction to be done by means of computer.

After 4 months of analysis and programming, we got the first correct results. However we knew that there still be a lot of things needed to be studied and corrected in order to get better results in the future.

The tidal predicting machine is still used from time to time in the purpose of checking the outputs and maintaining the condition of the machine itself.

MATHEMATICAL PROCEDURE

The height of tide at any time as given by Paul Schurman[1]

$$h = H_0 + \sum_{n=1}^{N} f_n H_n \cos \left[a_n t + (V_0+u)_n - K'_n \right]$$

in which,

- h is the height of tide at any time
- H_0 is the mean height of water level above datum used for prediction. For places on the open coast, the mean water level is identical with mean sea level but the upper portions of tidal river that have an appreciable slope or in the gulf, the mean water level may somewhat be different from the mean sea level.
- H_n is the mean amplitude of any constituent. It is a harmonic constant, determined by a tidal analysis. Each place will have its own set of harmonic constants H_n and K_n : once determined will be available for all times, except that they may be slightly modified from better series of observations or by changing in the physical conditions.

---

(1) Paul Schurman, *Manual of Harmonic Analysis and Prediction of Tides*, Special Publication No.98, U.S. Coast and Geodetic Survey Washington, D.C., 1958,317 pp.

f_n is the node factor for reducing the mean amplitude to be true amplitude for year of prediction.

a_n represents the angular speed of any constituent per unit time. In prediction of tides, a_n are usually given in degrees per mean solar hours.

$(V_0+u)_n$ is the value of equilibrium argument of a constituent at the initial instant from which the value of this reckoned, i.e., when t=0.

K'_n is the modified epoch any constituent.

N is the number of constituents.

t is the time expressed in mean solar hour.

PROGRAMMING TASKS

One can also program a computer to "think" like a human being to a certain degree; therefore, a program cannot be developed to be capable equally to man's instinct to perform. There would be some exceptional steps in a certain task, which has some sort of "ill" characteristics, that cannot be prevented from the existence of uncertainty. On the other hand, there are all sorts of errors resulting from man's performances which can be completely eliminated by the computer's preciseness. Hence, it all depends on man's decision whether which kind of tasks are to rely on a computer and which type of computer would be suitable.

When first started, it was not to our realization how complicated the programming task of this computation could get; therefore, correction has been made whenever a problem occurred. It took a little than a month to finish up a program for calculating the hourly values of astronomical tide.

This program simply reads data input from cards, processes then prints the output values, daily. It does not account for any error which may occur from the input data, since there is no logical way of detecting the relationships of associated corresponding data, under the provided circumstances.

It is more desirable to leave this workable program alone and write a new one to compute and search for the time and height of high and low water.

This other program is still in the process of being modified. It uses the same logic as of the first program, plus several more functions and routines. Even though the program is not in "good" condition, it has been working quite satisfactorily to a certain extent. More testing conditional routines are needed in attempting to have this program work at near perfection.

It was intended to keep programming as simple as possible, i.e., a set of instructions performs one or two things at the most. The efficiency has not been concerned as yet. Thus, the existence of awkwardness is undenyable.

FORTRAN IV was selected as the most suitable language upon the facility availability. The mathematical model used, derived from Schurman[2] can be written as

$$h = H_0 + \sum_{i=1}^{n} f_i H_i \cos(a_i t + \propto_i), \qquad \text{where}$$

h is the height of tide at time t,

H_0 is the mean height of water level above datum at the location,

f_i is the factor for reducing mean amplitude to year of prediction,

H_i mean amplitude of constituent A_i,

$(a_i t + \propto_i)$ is the phase shift of constituent A_i w/r time t.

The input of f_i, H_i and $\propto_i$ are readjusted per period of 4 months in order to minimize the errors occurring due to prolonged duration of time.

(2) See page 90

Descriptions, input/output samples, logic flow charts and listings of the programs are presented. (see appendices)

PROGRAM DESCRIPTION

The following program steps are for describing the subsequential programming logic of the first program.

REF : APPENDIX C.

1) Read in the number of station (s) (1 up to 9).

2) Read in the number of constituents and H_0.

3) Print the title page.

4) Read in the first set of data input : H_i , f_i ,$\propto_i$ and a_i.

5) initialize value for the number of days per month.

6) Test if new set of f_i and $_i$ are to be read in.

7) Read in the station name, year of prediction and month for page heading.

8) Test end of page.

9) Calculate the hourly values.

10) Print the hourly values.

Y) Function DEGCON converts degree to radian (limiting from 0 to 2)

Z) Subroutine VASET resets the hourly values to be truncated, rounded off or equal to 0 the truncated value + .5.

The following steps describe the programming steps of the second program.

REF : APPENDIX D.

1) Similar to (1) of the first program.

2) Read in station name, year of prediction. And the number of constituents and H_0.

3) Similar to (3) of the first program.

4) Data initializations.

5), 6) Similar to (5,6) of the first program.

7) Similar to (9) of the first program.

8) Searching for interval which high tide might exist.

9) Set the time accordingly with the step (8) above.

10) Calculating and searching for the maximum height.

11), 12), 13) Similar to (8,9,10) above but for the minimum of tide height.

14) Call subroutine VASET.

15) Output routine.

A) Subroutine NEGCSE calculates time to the nearest minutes, reset the index when maximum or minimum found in the previous day.

B) Similar to Z of the first program.

C) Print heading.

D) Similar to X of the first program.

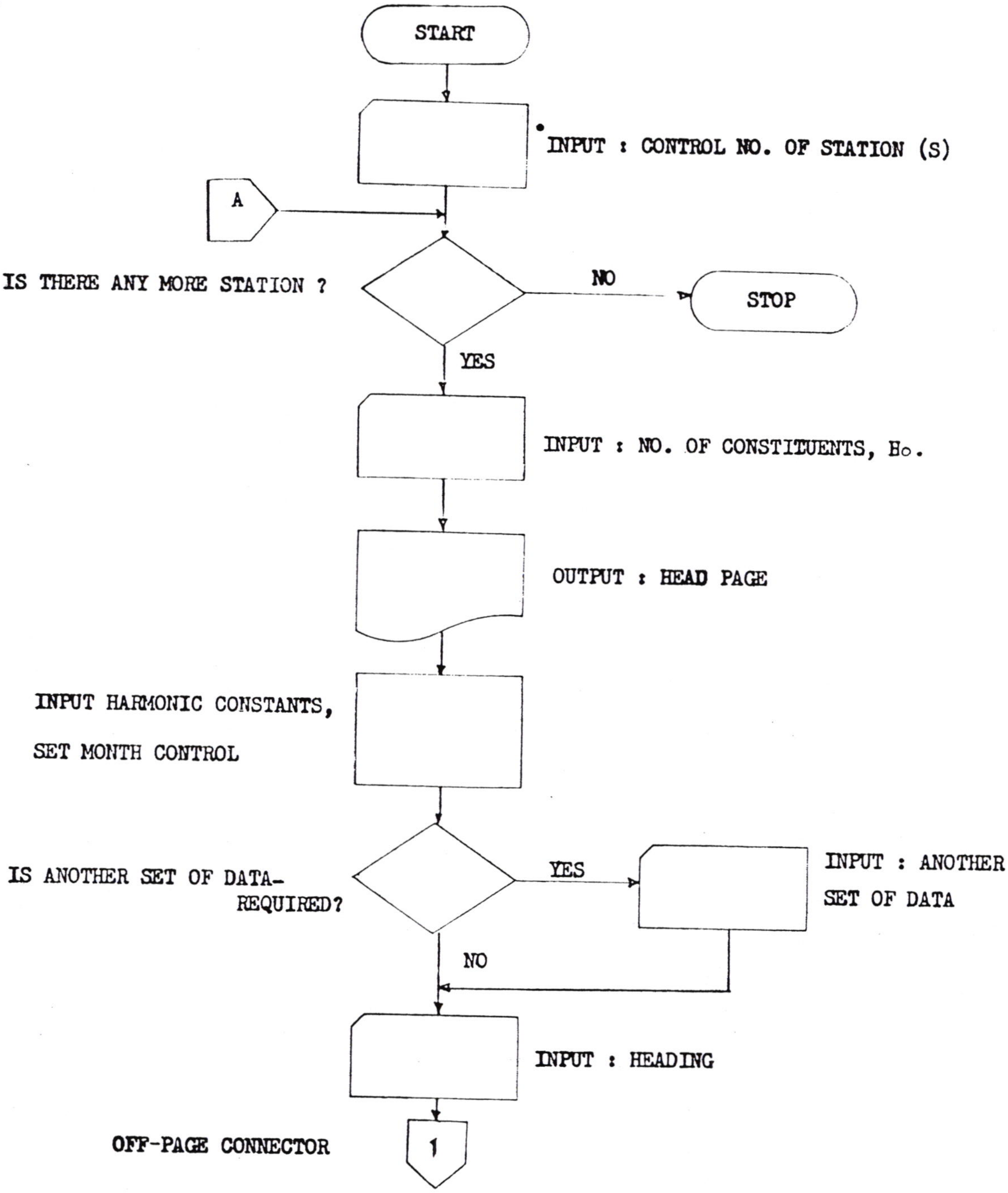
CONCLUSION

These two programs have their weaknesses which can be improved for better performances, less redundancy and more efficiency in processing.

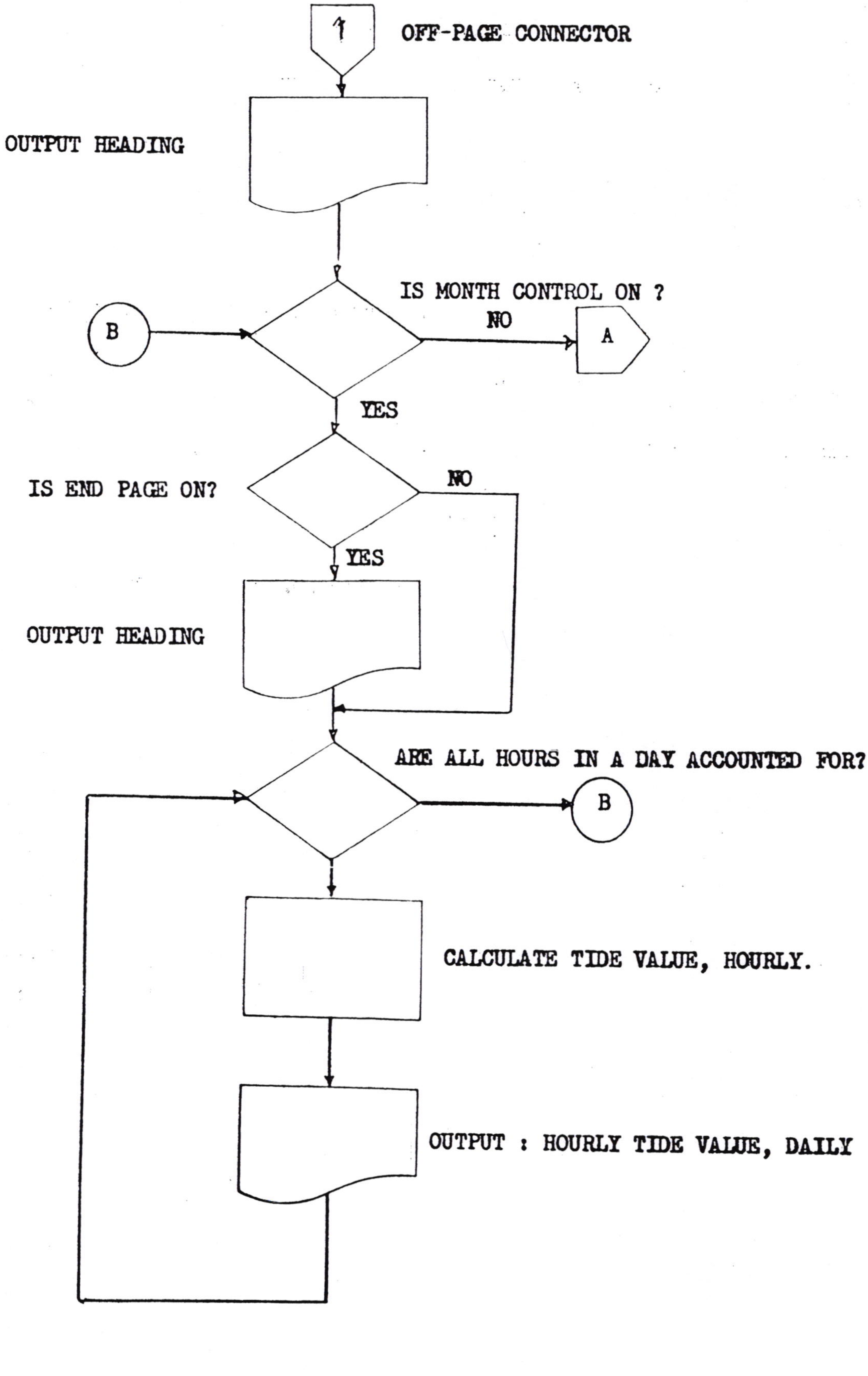
There is an extension to this project; that is to write a program for the harmonic analysis. It is still questionable whether the core storage available is large enough to hold the program. In case it is feasible, special tricks and techniques will be required. Hence, in computerizing the whole system of the astronomical tide prediction, much more time and more understanding of the problem (s) will be needed.

APPENDIX A

LOGICAL FLOW CHART,HOURLY PREDICTION

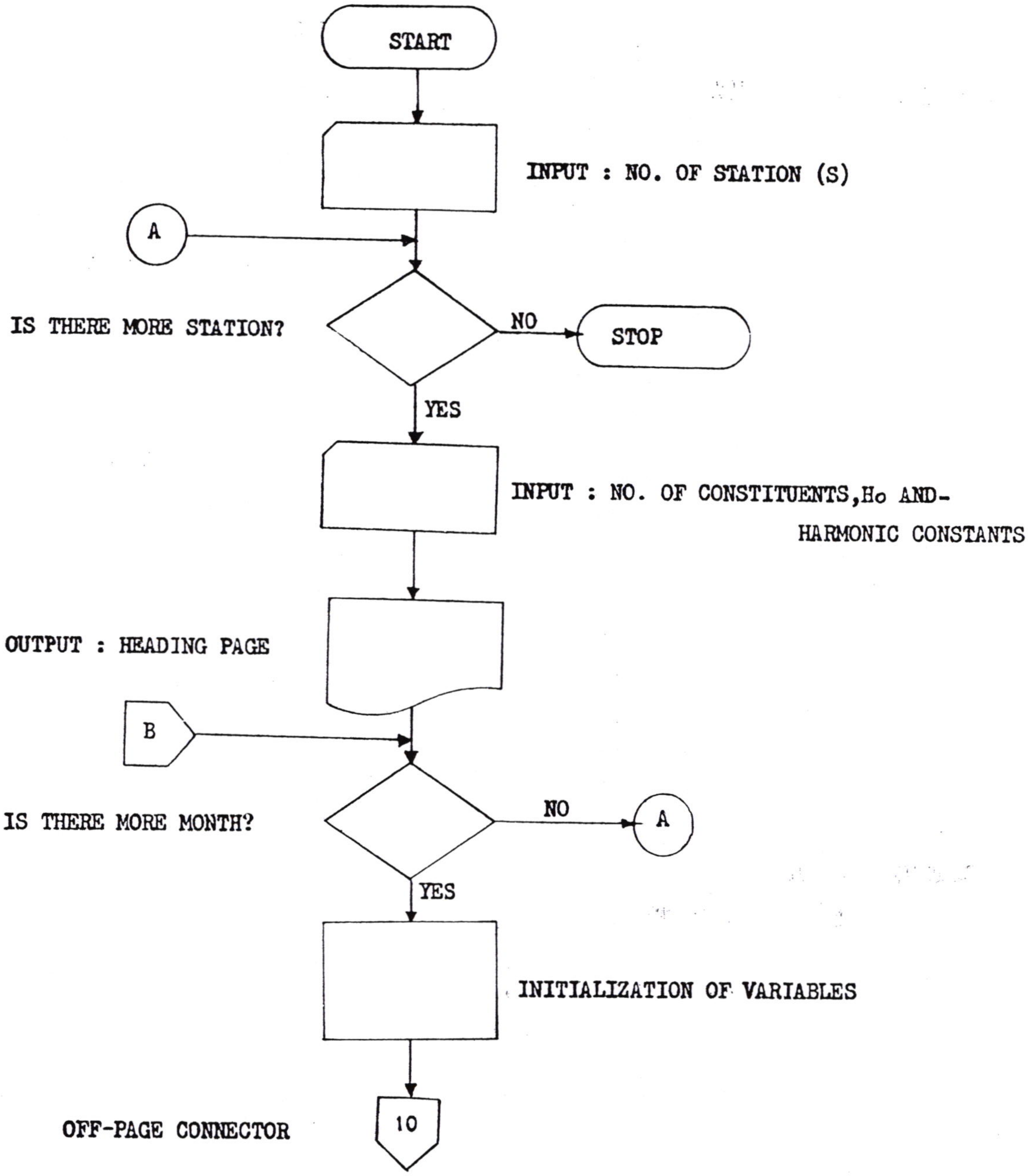


A - 1

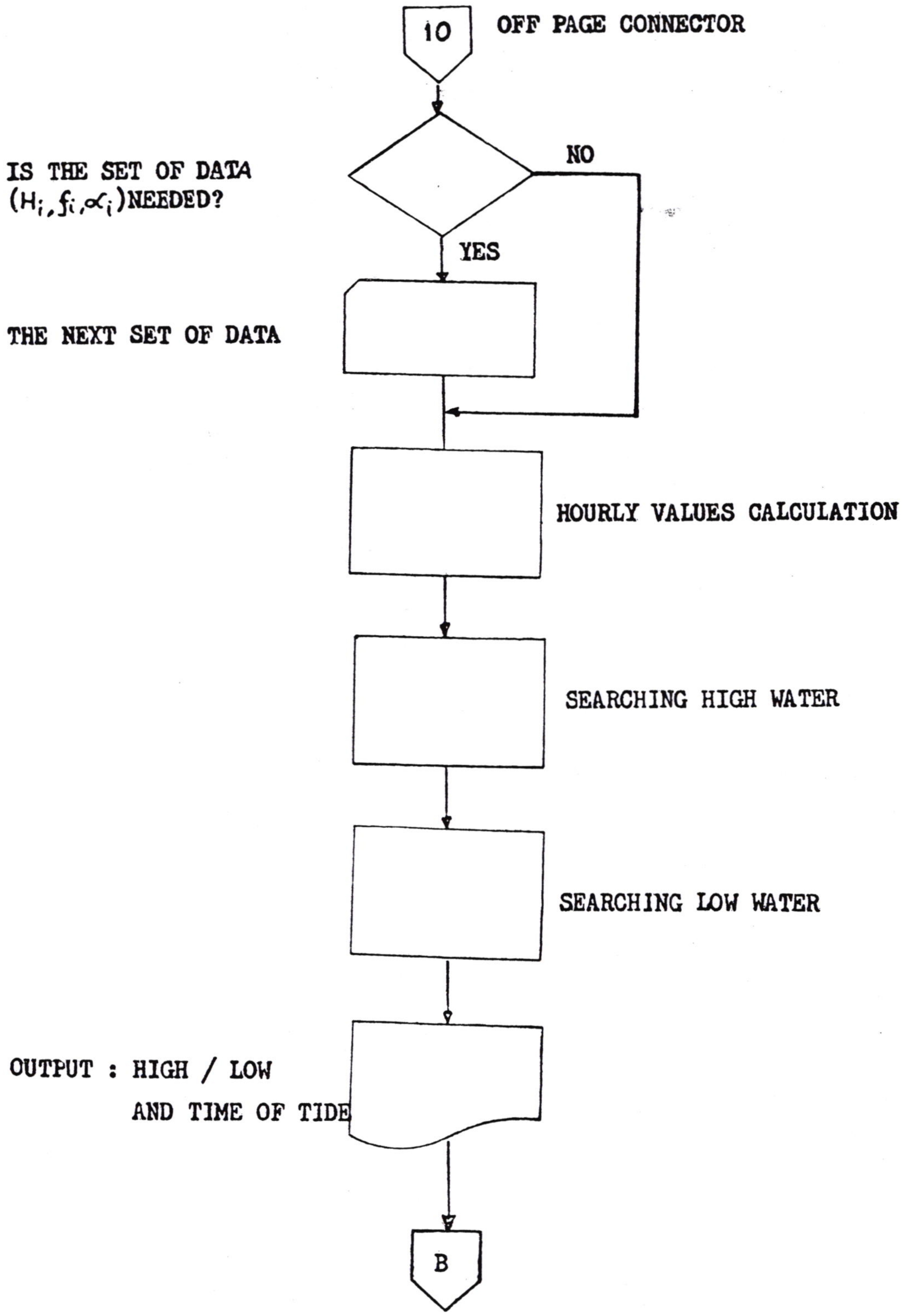

1
OFF-PAGE CONNECTOR
OUTPUT HEADING
IS MONTH CONTROL ON ?
B
NO
A
YES
IS END PAGE ON?
NO
YES
OUTPUT HEADING
ARE ALL HOURS IN A DAY ACCOUNTED FOR?
B
CALCULATE TIDE VALUE, HOURLY.
OUTPUT : HOURLY TIDE VALUE, DAILY

APPENDIX B

LOGICAL FLOW CHART, HIGH / LOW WATER PREDICTION



B - 1


10
OFF PAGE CONNECTOR
IS THE SET OF DATA
(H_i, f_i, α_i) NEEDED?
NO
YES
THE NEXT SET OF DATA
HOURLY VALUES CALCULATION
SEARCHING HIGH WATER
SEARCHING LOW WATER
OUTPUT : HIGH / LOW
AND TIME OF TIDE
B

B - 2

APPENDIX C : PROGRAM, HOURLY PREDICTION


```
      C ******************************************************************************
              COMMON SUMH(26)
              DIMENSION H(100),F(100),ALP(100),ANG(100)
          500 FORMAT (F6.3,1X,F6.4,1X,F5.1,1X,F9.6)
          510 FORMAT ('                                                  ')
          520 FORMAT  (F6.4,1X,F5.1)
          540 FORMAT (10X,I1)
          550 FORMAT (10X,I2,8X,F6.2)
         1000 FORMAT ('1')
         1006 FORMAT ('0','DATE/HOUR',3X,24(2X,I2,1X))
         1010 FORMAT ('0', 2X,I2,8X,24F5.1  )
         1400 FORMAT ('0',//////////, 5X,'PROGRAM BY KRISDA KIANGSIRI,    SUPREME
             *COMMAND D.P. CENTER    JUN.-JUL., 1972')
         1450 FORMAT ('1',//////////, 60X,'TIDE TABLES')
         1470 FORMAT ('0',40X,'(VALUES APPEARING IN TABLES SPECIFIED IN DECIMETE
             *RS)')
      C ******************************************************************************
      C
                READ (1,540) NUMB
                                                     DO   999 IJK =1,NUMB
                READ (1,550) NOCONS, HCONST
                  JJ = 0
                    IHOUR = 0
             WRITE (3,1450)
             WRITE (3,1470)
             PRINT 1400
                    DO 1 I=1,NOCONS
              READ (1,500) H(I),F(I),ALP(I),ANG(I)
            1 CONTINUE
             DO 5  II=1,14
                 JCOUNT = 0
                 PRINT 1000
               JCOUNT = JCOUNT + 1
               GO TO (100,6,2,6,4,6,4,6,6,4,6,4,6,102) , II
          100    LIM = 3
                 JJ = -72
               GO TO 12
          102    LIM = 3
               GO TO 12
            2 LIM = 28
              GO TO 8
            4 LIM = 30
              GO TO 8
            6 LIM = 31
            8   GO TO (12,12,12,12,10,12,12,12,12,12,10,12,12,12),II
           10         DO  7 I=1,NOCONS
              READ (1,520)        F(I),ALP(I)
            7 CONTINUE
                   JJ=0
           12   READ  (1,510)
                WRITE ( 3,510)
                PRINT  1006,' IHOUR, (N,N=1,23)
                JCOUNT = JCOUNT + 1
             DO 9  I=1,LIM
```

APPENDIX C : PROGRAM, HOURLY PREDICTION

```
DOS FORTRAN IV 360N-FO-479 3-5          MAINPGM          DATE   28/02/16      TIME     11.11.17         PAGE 0002

              IF  (JCOUNT .LT. 50) GO TO 333
                JCOUNT = 0
              PRINT 1000
            WRITE (3,510)
              PRINT 1006, IHOUR, (N,N=1,23)
              JCOUNT = JCOUNT + 1
  333           DO  11  J=2,26
                 SUMH(J)=0.0
                      DO  15 K=1,NOCONS
                AA      = ANG(K)*(JJ+J-2)+ALP(K)
                AA = DEGCON (AA)
                      SUMH(J)  = SUMH(J)+ H(K)*F(K)*COS(AA)
   15             CONTINUE
                  SUMH(J) = SUMH(J) +    HCONST
   11          CONTINUE
           CALL VASET
                    JJ =  JJ + 24
               IF (II .NE. 1) GO TO 110
             MO = I+28
               PRINT 1010, MO, (SUMH(J),J=2,25)
             GO TO 9
  110           PRINT 1010,  I, (SUMH(J), J=2,25)
               JCOUNT = JCOUNT + 2
    9      CONTINUE
    5   CONTINUE
  999                                            CONTINUE
          STOP
        END
```

DOS FORTRAN IV 360N-FO-479 3-5 DEGCON DATE 28/02/16 TIME 11.10.27 PAGE 0001

```
      FUNCTION DEGCON (BARE)
         BARE = BARE/360
         IBARE = BARE
         DEGCON = (BARE-IBARE)*360/57.29578
         RETURN
         END
```

DOS FORTRAN IV 360N-FO-479 3-5 VASET DATE 28/02/16 TIME 11.10.53 PAGE 0001

```
            SUBROUTINE VASET
          COMMON AS (26)
           DO 31 KL = 2,25
             IAS = AS(KL)
             HAS = AS(KL) -IAS
            IF (HAS .LT. 0) GO TO 40
             AS(KL) = IAS + .5
             IF (HAS .LT. .3) AS(KL) = IAS
             IF (HAS .GT. .7) AS(KL) = IAS + 1
          GO TO 31
   40     AS(KL) = IAS -.5
          IF (HAS .GT. -.3) AS(KL) = IAS
          IF (HAS .LT. -.7) AS (KL) = IAS-1
   31     CONTINUE
          RETURN
          END
```

2

```
C **************************************************************************
       COMMON HIGH (3,93),ALOW(3,93)
      COMMON  /CONTRL/ II
      COMMON /MONLMT/LIM
      DIMENSION H(30),F(30),ALP(30),ANG(30), SUMH(26)
       DIMENSION  FILL(10),  FILR(10)
       DIMENSION                                   ITIME(3,93),JTIME(3,93)
  500 FORMAT (F6.3,1X,F6.4,1X,F5.1,1X,F9.6)
  520 FORMAT  (F6.4,1X,F5.1)
  540 FORMAT (10X,I1)
  550 FORMAT (10X,I2,8X,F6.2)
  560 FORMAT ('                                         ')
 1006 FORMAT (' ','DATE/HOUR',3X,24(2X,I2,1X))
 1010 FORMAT ('0', 2X,I2,8X,24F5.1  )
 1400 FORMAT ('0',//////////, 5X,'PROGRAM BY KRISDA KIANGSIRI,  SUPREME
     *COMMAND D.P. CENTER    JUN.-JUL., 1972')
 1450 FORMAT ('1',//////////, 60X,'TIDE TABLES')
 1470 FORMAT ('0',40X,' VALUES APPEARING IN TABLES SPECIFIED IN DECIMETE
     *RS')
 7001 FORMAT (' ', 'THE INTERVAL BETWEEN TWO PRINTING OUTPUTS VARIES
     * 5 TO 10 MINUTES    BE PATIENT')
 7000 FORMAT ('1')
C **************************************************************************
      WRITE (15,7001)
C
        READ (1,540) NUMB
        PRINT 540, NUMB
                                            DO  999 IJK =1,NUMB
      READ (1,560)
        READ (1,550) NOCONS, HCONST
      PRINT 7000
        PRINT 550, NOCONS, HCONST
            DO 1 I=1,NOCONS
      READ (1,500) H(I),F(I),ALP(I),ANG(I)
    1 CONTINUE
      WRITE (3,1450)
      WRITE (3,1470)
     PRINT 1400
        IO = 1
C**************************************************************************
      DO 5  II=1,14
      GO TO (80,82,80,80,82,80,80,82,80,80,82,80,80,80), II
   82 IO = 1
       DO  3 IZ=1,3
       DO  3 IX=1,93
         ITIME(IZ,IX) = 0
         JTIME(IZ,IX) = 0
         HIGH (IZ,IX) = 0.0
         ALOW (IZ,IX) = 0.0
    3 CONTINUE
   80     GO TO (100,6,2,6,4,6,4,6,6,4,6,4,6,102) , II
  100       LIM = 3
            JJ = -72
          GO TO 12
```

```
 102       LIM = 3
        GO TO 12
   2 LIM = 28
     GU TO 8
   4 LIM = 30
     GU TU 8
   6 LIM = 31
   8     GU TO (12,12,12,12,10,12,12,12,12,12,10,12,12,12),II
  10           DO  7 I=1,NOCONS
     READ (1,520)       F(I),ALP(I)
   7 CONTINUE
              JJ=0
C*********************************************************************************
  12       DO 9 I=1,LIM
      KCOUNT = I*3-2
      LCOUNT = KCOUNT
        SUMH(1) = SUMH(25)
         DO `11  ,J=2,26
          SUMH(J)=0.0
                DO  15 K=1,NOCONS
          AA    = ANG(K)*(JJ+J-2)+ALP(K)
          AA = DEGCON (AA)
                SUMH(J) = SUMH(J)+ H(K)*F(K)*COS(AA)
  15         CONTINUE
             SUMH(J) = SUMH(J) +    HCONST
  11      CONTINUE
C
C *********************************************************************************
C DO 21 IS TO FIND MAXIMUM LEVEL OF DAILY TIDE, SUBINTERVALLING 10 TIMES
C IF NECESSARY.
C
 5000 DO 21 IA=2,25
         CU = IA
         IF (SUMH(IA) .GT. SUMH(IA-1)) GO TO 20
           GO TO 21
  20     IF (SUMH(IA) .GT. SUMH(IA+1)) GO TO 22
           GO TO 21
  22     BACK = JJ +IA-2
         TACK = JJ +IA-2
         IBUN = 14
       DO  23 IB=1,9
        DU   = IB
            FILR(IB) =0.0
            FILL(IB) =0.0
          IF (IBUN.EQ.16)  GO TO 24
          TACK1= TACK + DU/10.
           DO  25  IC=1,NOCONS
           AREA = ANG(IC)*TACK1+ ALP(IC)
           SUB. = DEGCUN(AREA)
          FILR(IB) = FILR(IB)+H(IC)*F(IC)*COS(SUB)
  25   CONTINUE
          FILR(IB) = FILR(IB) + HCONST
     IF (IB .EQ. 1) GO TU 24
          IF (FILR(IB) .GT. FILR(IB-1))  GO TO 23
```

```
      HIGH(IO,KCOUNT)= FILR(IB-1)
           ITIME(IO,KCOUNT)=(CU-2)*100+60*((DU-1.)/10.)
          KCOUNT = KCOUNT + 1
        GO TO 21
24      BACK1= BACK - DU/10.
          DO  27 ID=1,NOCONS
          AREA = ANG(ID)*BACK1+ ALP(ID)
          SUB = DEGCON(AREA)
         FILL(IB) = FILL(IB)+H(ID)*F(ID)*COS(SUB)
27    CONTINUE
        FILL(IB) = FILL(IB) + HCONST
    IF (IB .GT. 1)  GO TO 28
    IF (FILR(IB) .GT. FILL(IB)) GO TO 30
    IF (FILL(IB) .LT. SUMH(IA)) GO TO 32
    IBUN = 16
    GO TO 23
28  IF (FILL(IB) .GT. FILL(IB-1)) GO TO 23
     IF (IO .EQ. 1 .AND. KCOUNT .EQ. 1) GO TO 21
      HIGH(IO,KCOUNT) = FILL(IB-1)
            ITIME(IO,KCOUNT)=(CU-3)*100+60-(60*((DU-1.)/10.))
       KCOUNT = KCOUNT + 1
     IF (ITIME(IO,KCOUNT-1) .GE. 0) GO TO 21
       KCOUNT = KCOUNT - 1
     ITIME(IO,KCOUNT) = 60-(60*((DU-1.)/10.))
    CALL NEGCSE (KCOUNT,IO,FILL,ITIME,HIGH)
     KCOUNT = I*3-2
     ITIME(IO,KCOUNT) = 0
    HIGH(IO,KCOUNT) =0.0
34      GO TO 21
30  IF (FILR(IB) .GT. SUMH(IA)) GO TO 23
32    HIGH(IO,KCOUNT) = SUMH(IA)
        ITIME(IO,KCOUNT) = (IA-2)*100
          KCOUNT = KCOUNT + 1
        GO TO 21
23  CONTINUE
21  CONTINUE
C
C ***************************************************************************
C DO 31 IS FOR SEARCHING LOWEST LEVEL OF DAILY TIDE  DIVIDING THE HOUR INTO
C 10 INTERVAL IF  NEEDED.
C
 6000 DO  31 IA=2,25
        CU = IA
         IF (SUMH(IA) .LT. SUMH(IA-1)) GO TO 40
          GO TO 31
40       IF (SUMH(IA) .LT. SUMH(IA+1)) GO  TO 42
          GO TO 31
42       IBUN = 14
        TACK = JJ +IA-2
        BACK = JJ +IA-2
      DO  33 IB=1,9
        DU  = IB
            FILR(IB) =0.0
            FILL(IB) =0.0
```

D - 3

```
          IF   (IBUN .EQ. 16) GO TO 44
          TACK2= TACK + DU/10.
           DO    35 IC=1,NOCONS
           AREA = ANG(IC)*TACK2+ ALP(IC)
           SUB = DEGCON(AREA)
          FILR(IB) = FILR(IB)+H(IC)*F(IC)*COS(SUB)
 35    CONTINUE
         FILR(IB) = FILR(IB) + HCONST
     IF  (IB .EQ. 1) GO TO 44
          IF   (FILR(IB) .LT. FILR(IB-1)) GO TO 33
      ALOW(IO,LCOUNT)  = FILR(IB-1)
            JTIME(IO,LCOUNT)=(CU-2)*100+60*((DU-1.)/10.)
          LCOUNT = LCOUNT + 1
         GO TO 31
 44      BACK2= BACK - DU/10.                                        13
          DO 37 ID=1,NOCONS
          AREA = ANG(ID)*BACK2+ ALP(ID)
          SUB = DEGCON(AREA)
         FILL(IB) = FILL(IB)+H(ID)*F(ID)*COS(SUB)
 37    CONTINUE
          FILL(IB) = FILL(IB) + HCONST
     IF (IB .GT. 1) GO TO 48
     IF  (FILR(IB) .LT. FILL(IB)) GO TO 50
     IF  (FILL(IB) .GT. SUMH(IA)) GO TO 52
     IBUN = 16
     GO TO 33
 48 IF   (FILL(IB) .LT. FILL(IB-1)) GO TO 33
      IF (IO .EQ. 1 .AND. LCOUNT .EQ. 1) GO TO 31
       ALOW(IO,LCOUNT) = FILL(IB-1)
           JTIME(IO,LCOUNT)=(CU-3)*100+60-(60*((DU-1.)/10.))
       LCOUNT = LCOUNT + 1
      IF (JTIME(IO,LCOUNT-1) .GE. 0) GO TO 31
       LCOUNT = LCOUNT - 1
     JTIME(IO,LCOUNT) = 60-(60*((DU-1.)/10.))
    CALL NEGCSE (LCOUNT,IO,FILL,JTIME,ALOW)
     LCOUNT = I*3-2
    JTIME(IO,LCOUNT) = 0
    ALOW(IO,LCOUNT ) = 0.0
 54       GO TO 31
 50 IF (FILR(IB) .LT. SUMH(IA))  GO TO 33
 52     ALOW(IO,LCOUNT) = SUMH(IA)
           JTIME(IO,LCOUNT)=(IA-2)*100
          LCOUNT = LCOUNT + 1
        GO TO 31
 33  CONTINUE
 31 CONTINUE
            JJ =  JJ + 24
  9 CONTINUE
C*******************************************************************************************
2001 FORMAT  (' ')
3000 FORMAT ('0',4X,I2,7X,2(I4,4X,F4.1,5X),10X,2(I4,4X,F4.1,5X),9X,
    *2(I4,4X,F4.1,5X))
3002 FORMAT ('+',13X,I4,4X,F4.1)
3004 FORMAT ('+',30X,I4,4X,F4.1)
```

D - 4

```
3006 FORMAT ('+',57X,I4,4X,F4.1)
3008 FORMAT ('+',74X,I4,4X,F4.1)
3010 FORMAT ('+',100X,I4,4X,F4.1)
3012 FORMAT ('+',117X,I4,4X,F4.1)
3014 FORMAT ('0',4X,I2)
C ***************************************************************************************
        IDATE   = 0
        GO TO (90,90,90,92,90,90,92,90,90,92,90,90,92,90), II
   92 CALL VASET
      DO 41 KA=1,93,3                                                                    14
        IDATE   = IDATE+1
        IF   (KA .EQ. 1) GO TO 70
        IF   (KA .EQ. 37) GO TO 70
        IF   (KA .EQ. 73) GO TO 70
      GO TO 72
   70 PRINT 560
      CALL PRTHDG
   72 IF (KA .GT. 84) GO TO 94
        PRINT 3000,IDATE,ITIME(1,KA),HIGH(1,KA),JTIME(1,KA),ALOW(1,KA)
     1              ,ITIME(2,KA),HIGH(2,KA),JTIME(2,KA),ALOW(2,KA)
     1              ,ITIME(3,KA),HIGH(3,KA),JTIME(3,KA),ALOW(3,KA)
   96 PRINT 2001
      IF (HIGH(1,KA+1).NE.0.0) PRINT 3002,ITIME(1,KA+1),HIGH(1,KA+1)
      IF (ALOW(1,KA+1).NE.0.0) PRINT 3004,JTIME(1,KA+1),ALOW(1,KA+1)
      IF (HIGH(2,KA+1).NE.0.0) PRINT 3006,ITIME(2,KA+1),HIGH(2,KA+1)
      IF (ALOW(2,KA+1).NE.0.0) PRINT 3008,JTIME(2,KA+1),ALOW(2,KA+1)
      IF (HIGH(3,KA+1).NE.0.0) PRINT 3010,ITIME(3,KA+1),HIGH(3,KA+1)
      IF (ALOW(3,KA+1).NE.0.0) PRINT 3012,JTIME(3,KA+1),ALOW(3,KA+1)
      PRINT 2001                                                                        15
      IF (HIGH(1,KA+2).NE.0.0) PRINT 3002,ITIME(1,KA+2),HIGH(1,KA+2)
      IF (ALOW(1,KA+2).NE.0.0) PRINT 3004,JTIME(1,KA+2),ALOW(1,KA+2)
      IF (HIGH(2,KA+2).NE.0.0) PRINT 3006,ITIME(2,KA+2),HIGH(2,KA+2)
      IF (ALOW(2,KA+2).NE.0.0) PRINT 3008,JTIME(2,KA+2),ALOW(2,KA+2)
      IF (HIGH(3,KA+2).NE.0.0) PRINT 3010,ITIME(3,KA+2),HIGH(3,KA+2)
      IF (ALOW(3,KA+2).NE.0.0) PRINT 3012,JTIME(3,KA+2),ALOW(3,KA+2)
      GO TO 41
   94 PRINT 3014, IDATE
      IF (HIGH(1,KA   ).NE.0.0) PRINT 3002,ITIME(1,KA),HIGH(1,KA)
      IF (ALOW(1,KA   ).NE.0.0) PRINT 3004,JTIME(1,KA),ALOW(1,KA)
      IF (HIGH(2,KA   ).NE.0.0) PRINT 3006,ITIME(2,KA),HIGH(2,KA)
      IF (ALOW(2,KA   ).NE.0.0) PRINT 3008,JTIME(2,KA),ALOW(2,KA)
      IF (HIGH(3,KA   ).NE.0.0) PRINT 3010,ITIME(3,KA),HIGH(3,KA)
      IF (ALOW(3,KA   ).NE.0.0) PRINT 3012,JTIME(3,KA),ALOW(3,KA)
      GO TO 96
   41 CONTINUE
   90   KKK =0
        IO = IO + 1
    5 CONTINUE
C***************************************************************************************
  999                                   CONTINUE
      STOP
      END
```

```
      SUBROUTINE NEGCSE (KLCO,IOD,FI,NOTME,HID)
      COMMON /MONLMT/LMT
      DIMENSION FI(10),NOTME(3,93),HID(3,93)
       KKK = 0
        IKM=IOD
        IF (LMT .EQ. 1) IKM=IOC-1
        KN=KLCO-1
112     IF (NOTME(IKM,KN) .NE. 0) GO TO 110
        KN=KN-1
       KKK = KKK + 1
       IF (KKK .EQ. 3) GO TO 110
        GO TO 112
110     NOTME(IKM,KN+1)=2300+NOTME(IOD,KLCO)
        HID(IKM,KN+1)=HID(IOD,KLCO)
        RETURN
        END
       SUBROUTINE VASET
       COMMON AHI(3,93),ALO(3,93)
       DO 51 IK = 1,3
       DO 51 IL = 1,93
       IF (AHI (IK,IL) .EQ. 0.0) GO TO 70
       IH = AHI (IK,IL)
       H = AHI (IK,IL) -IH
       IF (H .LT. 0) GO TO 80
       AHI (IK,IL) = IH+0.5
       IF (H .LT..3) AHI (IK,IL) = IH
       IF (H .GT..7) AHI (IK,IL) = IH+1
        GO TO 70
 80    AHI(IK,IL) = IH- .5
       IF (H .GT. -.3) AHI(IK,IL) = IH
       IF (H .LT. -.7) AHI(IK,IL) =IH-1
 70    IF (ALO (IK,IL) .EQ. 0.0) GO TO 51
       IH = ALO (IK,IL)
       H = ALO (IK,IL) -IH
       IF (H .LT. 0) GO TO 82
       ALO (IK,IL) = IH+0.5
       IF (H .LT..3) ALO (IK,IL) = IH
       IF (H .GT..7) ALO (IK,IL) = IH+1
       GO TO 51
 82    ALO(IK,IL) = IH - .5
       IF (H .GT. -.3) ALO(IK,IL) = IH
       IF (H .LT. -.7) ALO(IK,IL) = IH - 1
 51    CONTINUE
       RETURN
       END
      SUBROUTINE PRTHDG
      COMMON  /CONTRL/ IN
1030  FORMAT (' ',3X,'DATE       TIME      HIGH      TIME      LOW')
1032  FORMAT ('+',57X,'TIME     HIGH      TIME      LOW')
1034  FORMAT ('+',100X,'TIME     HIGH       TIME       LOW',///)
2000  FORMAT ('0',25X,'JANUARY',36X,'FEBRUARY',37X,'MARCH',///)
2002  FORMAT ('0',25X,'APRIL',40X,'MAY',40X,'JUNE',///)
2004  FORMAT ('0',26X,'JULY',40X,'AUGUST',35X,'SEPTEMBER',///)
2006  FORMAT ('0',25X,'OCTOBER',35X,'NOVEMBER',35X,'DECEMBER',///)
```

```
      GO TO (90,90,90,92,90,90,94,90,90,96,90,90,98,90), IN
92    PRINT 2000
      GU IO 70
94    PRINT 2002
      GO TO 70
96    PRINT 2004
      GO TO 70
98    PRINT 2006
70    PRINT 1030
      PKINT 1032
      PRINT 1034
90 KKK=0
      RETURN
      END
      FUNCTION DEGCON (BARE)
           BARE = BARE/360
           IBARE = BARE
           DEGCON = (BARE-IBARE)*360/57.29578
           RETURN
           END
```

APPENDIX E : THE SAMPLE OUTPUT, HOURLY TIDE PREDICTION

JANUARY................SATTAHIP 1971

DATE/HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	11.0	11.5	13.5	17.0	21.0	26.0	30.0	33.5	36.0	37.0	37.0	36.5	35.5	34.5	33.5	33.0	32.5	31.5	30.0	28.0	25.5	22.5	19.0	16.0
2	14.0	13.0	14.0	16.5	20.0	24.0	28.0	32.0	34.5	36.0	36.5	36.0	34.5	33.0	32.0	31.5	31.0	30.5	30.0	29.0	27.5	25.5	22.5	20.0
3	18.0	16.5	16.5	18.0	20.5	23.5	27.0	30.5	33.0	35.0	35.5	35.0	33.5	32.0	30.5	29.5	29.0	28.5	28.0	28.0	27.5	27.0	25.5	23.5
4	22.0	20.5	20.0	21.0	22.0	24.5	27.0	30.0	32.0	34.0	34.5	34.0	32.5	30.5	29.0	27.0	26.0	25.5	25.5	25.5	26.0	26.5	26.5	26.0
5	25.0	24.5	24.0	24.5	25.0	27.0	28.5	30.5	32.0	33.0	33.5	33.0	32.0	30.0	27.5	25.0	23.5	22.5	22.0	22.5	23.0	24.0	25.5	26.0
6	27.0	27.5	27.5	28.0	28.5	29.5	30.5	32.0	32.5	33.5	33.5	33.0	31.5	29.0	27.0	24.0	22.0	20.0	19.0	19.0	19.5	21.0	23.0	25.0
7	27.0	28.5	29.5	31.0	31.5	32.5	33.0	33.5	34.0	34.0	34.0	33.0	31.5	29.5	27.0	24.0	21.5	19.0	17.5	16.5	16.5	17.5	19.5	22.0
8	25.0	27.5	30.0	32.0	33.5	34.5	35.0	35.0	35.0	35.0	34.5	33.5	32.0	30.0	28.0	25.0	22.0	19.0	17.0	15.0	14.0	14.5	16.0	18.5
9	22.0	25.0	28.5	31.5	34.0	35.5	36.0	36.5	36.5	36.0	35.0	34.0	33.0	31.0	29.0	26.5	23.5	20.5	17.5	15.0	13.5	13.0	13.5	15.5
10	18.5	22.0	26.0	30.0	33.0	35.0	36.5	37.0	37.0	36.5	35.5	35.0	33.5	32.0	30.5	28.0	25.5	22.5	19.5	16.5	14.0	12.5	12.0	13.0
11	15.5	19.0	23.0	27.0	31.0	34.0	36.0	37.0	37.0	36.5	36.0	35.0	34.0	33.0	31.5	30.0	28.0	25.0	22.0	19.0	15.5	13.0	12.0	12.0
12	14.0	16.5	20.5	24.5	28.5	32.0	35.0	36.5	37.0	36.5	36.0	35.0	34.0	33.5	32.5	31.0	29.5	27.5	24.5	21.5	18.0	15.0	13.0	12.0
13	13.0	15.0	18.0	22.0	26.5	30.5	33.5	35.5	36.0	36.0	35.5	34.5	34.0	33.0	32.5	32.0	31.0	29.0	27.0	24.0	21.0	17.5	15.0	13.5
14	13.0	14.5	17.0	20.5	24.5	28.5	32.0	34.5	35.5	36.0	35.0	34.0	33.0	32.5	32.0	32.0	31.0	30.0	29.0	26.5	23.5	20.5	17.5	15.5
15	14.5	15.0	17.0	20.0	23.5	27.0	30.5	33.5	35.0	35.5	35.0	33.5	32.5	31.5	31.0	31.0	31.0	30.5	29.5	28.0	26.0	23.5	20.5	18.0
16	16.5	16.5	17.5	20.0	23.0	26.5	29.5	32.5	34.0	35.0	34.5	33.0	31.5	30.5	30.0	29.5	29.5	29.5	29.5	29.0	27.5	25.5	23.5	21.0
17	19.5	18.5	19.0	21.0	23.0	26.0	29.0	31.5	33.5	34.0	34.0	32.5	31.0	29.5	28.0	28.0	28.0	28.0	28.0	28.5	28.0	27.0	25.5	24.0
18	22.5	21.5	21.5	22.5	24.0	26.5	29.0	31.0	32.5	33.5	33.0	32.0	30.0	28.5	27.0	26.0	25.5	26.0	26.5	27.0	27.5	27.5	27.0	26.0
19	25.0	24.5	24.0	24.5	26.0	27.5	29.5	31.0	32.0	33.0	32.5	31.0	29.5	27.5	25.5	24.5	23.5	23.5	24.0	25.0	26.0	27.0	27.5	27.5
20	27.0	27.0	27.0	27.0	28.0	29.0	30.0	31.5	32.0	32.5	32.0	30.5	29.0	27.0	25.0	23.0	22.0	21.5	22.0	22.5	24.0	25.0	26.5	27.5
21	28.0	28.5	29.0	29.5	30.0	31.0	31.5	32.0	32.5	32.5	32.0	30.5	28.5	26.5	24.0	22.0	20.5	19.5	19.5	20.0	21.0	22.5	24.5	26.0
22	28.0	29.0	30.0	31.0	32.0	32.5	33.0	33.0	33.5	33.0	32.0	31.0	29.0	27.0	24.5	22.0	20.0	18.5	17.5	17.5	18.0	19.5	21.5	24.0
23	26.5	28.5	30.5	32.0	33.0	34.0	34.5	34.5	34.5	34.0	33.0	32.0	30.0	28.0	25.5	23.0	20.5	18.0	16.5	16.0	16.0	16.5	18.5	21.0
24	24.0	27.0	29.5	32.0	34.0	35.0	35.5	36.0	35.5	35.0	34.0	33.0	31.5-	29.5	27.0	24.5	22.0	19.0	16.5	15.0	14.0	14.0	15.0	17.5

APPENDIX F : THE SAMPLE OUTPUT, HIGH AND LOW TIDE PREDICTION

SATTAHIP 1971

DATE	JANUARY TIME	JANUARY HIGH	JANUARY TIME	JANUARY LOW	FEBRUARY TIME	FEBRUARY HIGH	FEBRUARY TIME	FEBRUARY LOW	MARCH TIME	MARCH HIGH	MARCH TIME	MARCH LOW
1		0.0	17	11.0	830 2048	34.0 29.0	111 1505	21.5 24.0	700 2017	32.0 31.0	36 1330	23.5 21.0
2	948	36.5	54	13.0	823 2311	33.5 29.0	136 1548	25.5 21.0	648 2142	32.0 31.5	105 1405	27.0 18.5
3	1000	35.5	130	16.5	800	33.5	123 1636	28.5 19.0	623	33.0	130 1442	30.0 17.0
4	1000 2123	34.5 26.5	154 1736	20.0 25.5	730	34.0	1730	17.0	5 600	32.0 33.5	48 1530	32.0 16.0
5	1000	33.5	205 1805	24.0 22.0	654	35.0	1836	16.0	542	34.5	1623	16.0
6	936	33.5	1842	19.0	636	36.0	1936	15.0	542	35.0	1736	16.0
7	848	34.0	1923	16.0	642	36.0	2036	14.0	548	34.5	1900	16.0
8	723	35.5	2011	14.0	654	36.0	2130	14.0	548	34.5	2011	16.0
9	705	36.5	2100	13.0	705	35.5	2211	14.0	554	34.0	2105	16.5
10	717	37.0	2142	12.0	717	35.0	2254	15.0	600	33.0	2154	17.0
11	736	37.0	2223	12.0	723	34.5	2323	16.0	605 1500	33.0 28.5	1200 2236	28.0 18.5
12	800	37.0	2305	12.0	736 1611	34.0 30.0	1305 2354	29.0 18.0	611 1630	32.0 29.0	1154 2311	26.0 20.0

1.4 INTERMEDIATE WATERS NORTH OF NEW-GUINEA

by

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Abstract

The Cromwell current gains its main hydrological properties north of New-Guinea, in subsurface. There, the vertical distribution of oxygen at 154°E indicates that three water masses participate to the formation of the subsurface waters located at a depth greater than 200 m and with a thermosteric anomaly smaller than 300 cl/t.

South of the equator, with a core on the 160 cl/t surface, there is a poorly oxygenated water with a concentration lower than 3.0 ml/l; its salinity varies between 35.7 ‰ and 34.9 ‰ and it derives from the oxygen minimum formed off the Peru coast. North of 2°N, a water, the salinity of which is lower than 34.6 ‰, has an oxygen concentration smaller than 2.0 ml/l; its core, on the 135 cl/t isanosteric surface, is deeper than that of the north Pacific intermediate water which is located on the 160–170 cl/t isanosteric surface; it derives from the oxygen minimum formed off the north and central America coast. At the equator and between these two minima, a water relatively richer in oxygen is found; it has an oxygen content greater than 3.4 ml/l, its salinity is close to 35.0 ‰ and it originates in the Coral sea.

The oxygen distribution on the 160 cl/t isanosteric surface, in the lower part of the Cromwell current, on the 125 cl/t surface in the oxygen minimum water of Central

America and on the 100 cl/t surface near the core of the Antarctic intermediate water, is highly influenced by the currents such as they were measured directly and computed from the density distribution.

Introduction

Since the region of New-Guinea is the meeting place of the westward currents and the zone of formation of the eastward flows of the equatorial Pacific, it has a special importance on the Pacific dynamics and hydrology. Cruises of the Ryofu-Maru (Masuzawa 1967, 1968, 1970, Akamatsu and Sawara 1969) have studied it every year since 1967 along the meridian 137°E and several Russian and Japanese cruises have been devoted to its description. Nevertheless, the distribution and density of observations between 140°E and 155°E was inadequate, to permit a good and detailed understanding of the water masses, of their movements and of the time variations which can occur due to the well known seasonal changes in the surface circulation and in the meteorological conditions in the western equatorial Pacific.

Two cruises of the N.O. CORIOLIS, research vassel of the "Centre ORSTOM de Nouméa", New-Caledonia, FOC 1 (January-February 1971) and FOC 2 (June-July 1971) have thus been devoted to the study of this region (Fig. 1). They include four equatorial cross-sections, 180-300 miles spaced, with hydrological observations and current measurements at stations distant of 30 miles.

Figure 1

The water masses

Results of observations show that at subsurface, due to the presence of waters of different origins (Masuzawa, *op. cit.*) and like what has been found at 170°E, further east (Rotschi *et al.*, 1973), the hydrological structure is fairly complicated. This shows well on the salinity distribution where the north Pacific intermediate low salinity water and the subtropical south Pacific high salinity water are easily identified (Fig. 2), north of 2°N, between 200m and 300m and south of the equator at 200m respectively. But because the oxygen content of the various sources of water is more contrasted than their salinity and nutrient salts content, the hydrological structure is more clearly seen on the oxygen distribution (Fig. 3) which can be used with success in the analysis of the different water masses.

Figure 2

Figure 3

Former studies at 170°E (Colin and Rotschi 1970) having shown that the water circulation below the surface layer, in the equatorial region,is close to geostrophic, it appears justified to make an isentropic analysis of the distribution of the most significant hydrological properties along some isanosteric surfaces of special interest. Isanosteric surfaces 160 cl/t (26.4 g/l), 120 cl/t (26.9 g/l) and 100 cl/t (27.1 g/l) have been chosen to study the distribution of oxygen. In the equatorial central Pacific, the former, used by Tsuchiya (1968) is located in the lower part of the Cromwell current. The second is specific, in the northern Pacific, of the north Pacific intermediate water (Reid 1965) and, according to Masuzawa (1970), is characterized, in the western Pacific, by a vertical salinity maximum between the north Pacific intermediate water and the Antarctic intermediate water and by a vertical oxygen minimum originating along the coast of central America. The last one is close to the density at which is found the Antarctic intermediate water (Johnson 1972).

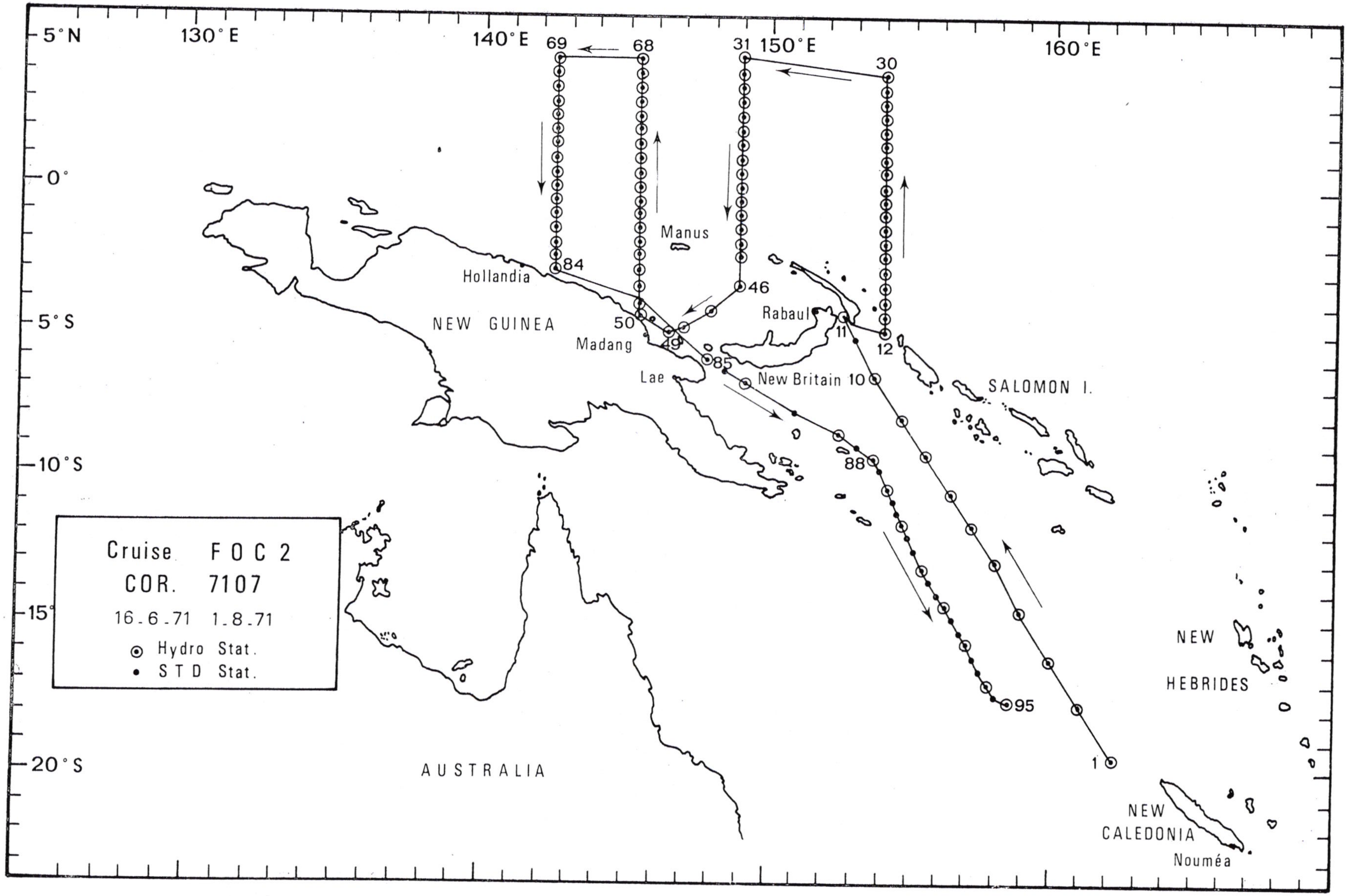

Fig. 1 : Itinerary of the cruise FOC 2 of the R.V. CORIOLIS in June–July 1971

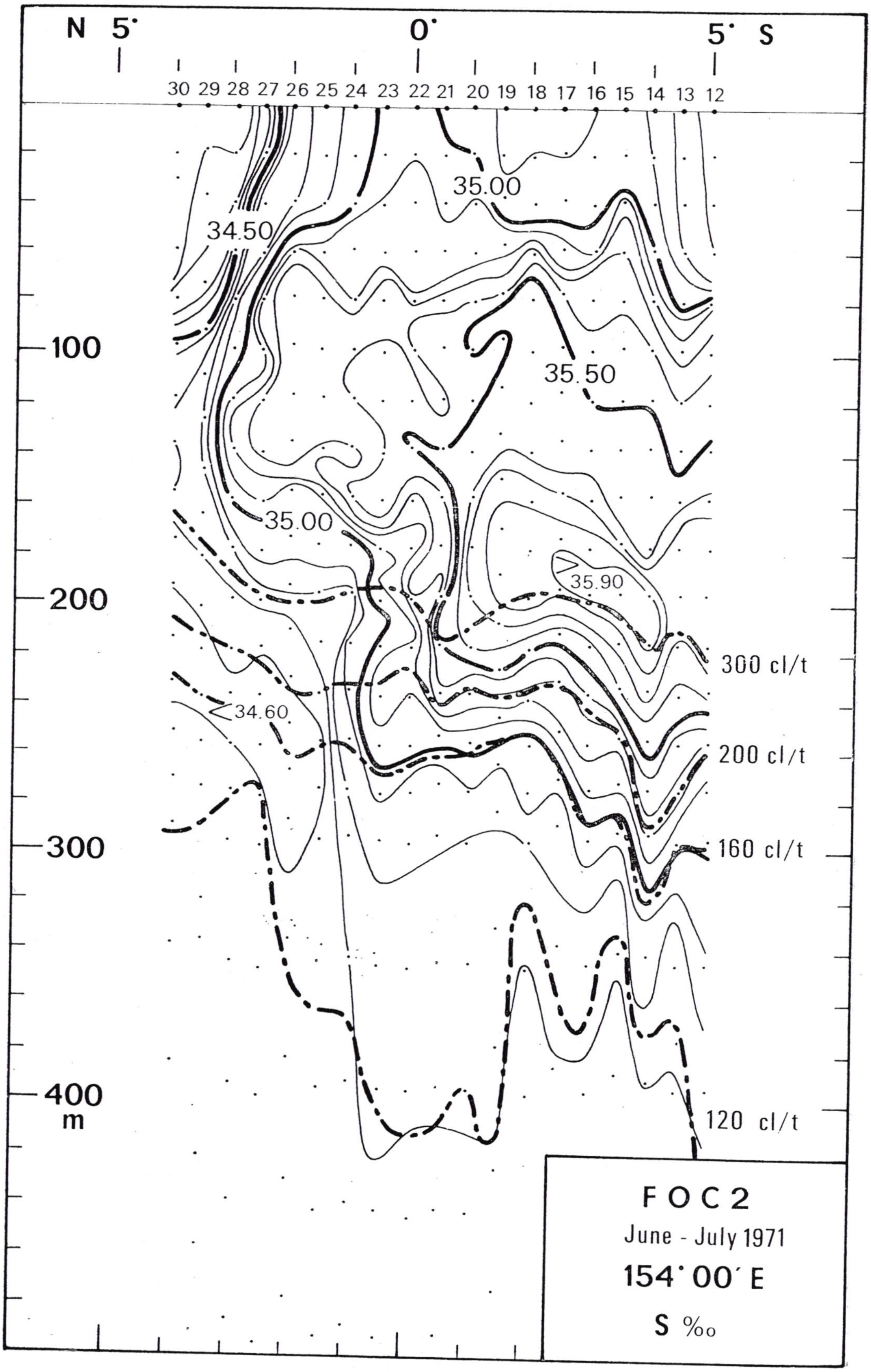

Fig. 2 : Vertical salinity distribution at 154°E, in June–July 1971

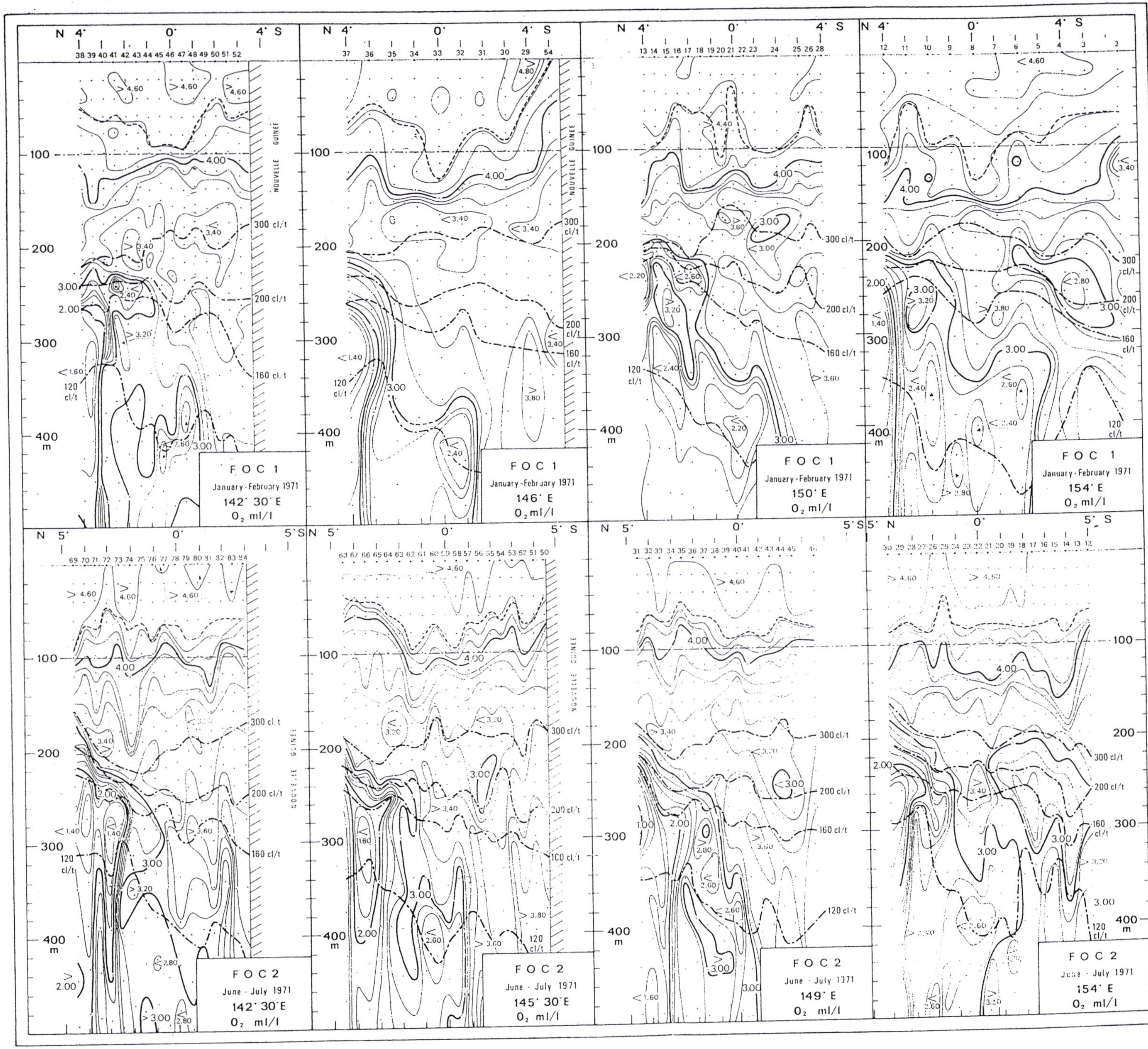

Fig. 3 : Vertical oxygen distribution, north of New-Guinea a) in January-February 1971, cruise FOC 1 b) in June-July 1971, cruise FOC 2

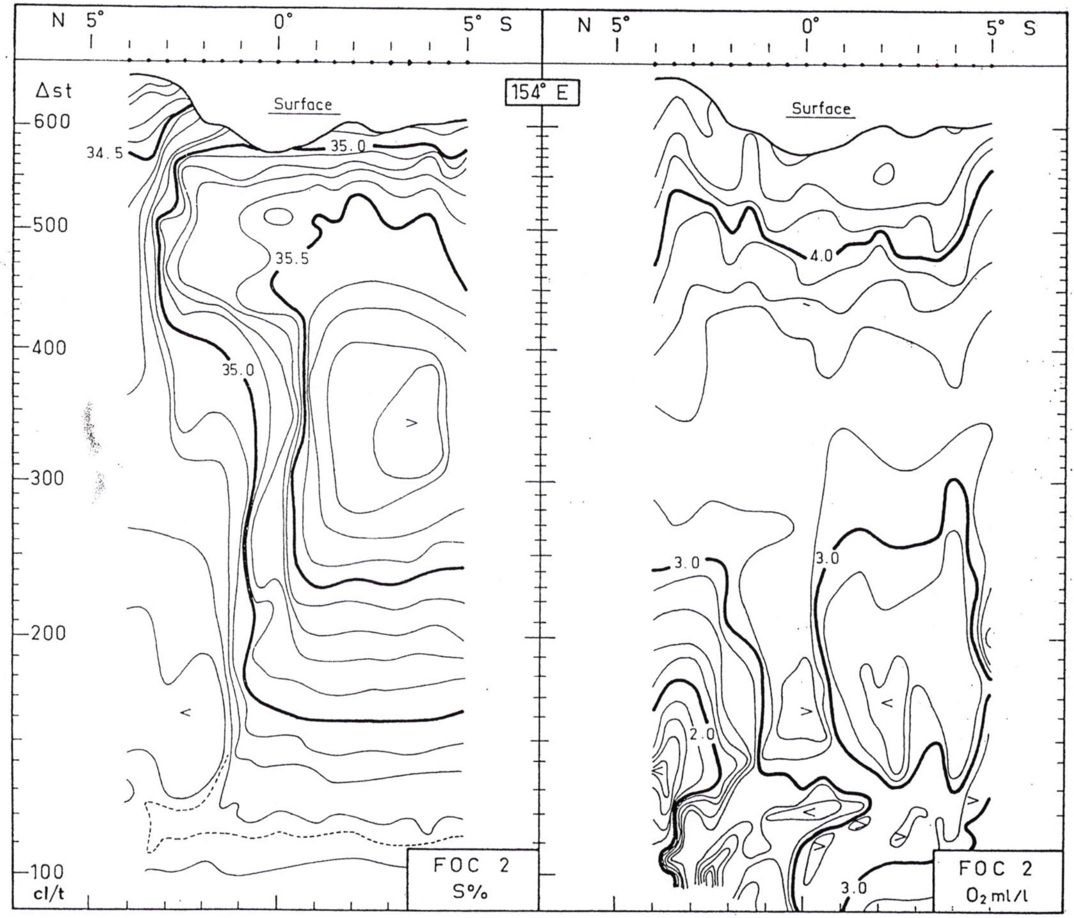

Fig. 4 : Salinity and oxygen distribution versus thermosteric anomaly, at 154°E, in June-July 1971

Water masses at 160 cl/t.

In June–July 1971, the meridional sections of oxygen against thermosteric anomaly show that at 160 cl/t three different water masses are encountered. South of the equator, at 154°E, there is water with an oxygen content lower than 3.0 ml/l and a salinity close to 35.0‰ (Fig. 4). West of 154°E its core lies at a smaller density; this water which is fairey abundant at 154°E, almost absent at 145°30E and totally absent at 142°30E gets lighter westwards. On surfaces with a higher thermosteric anomaly of the order of 210 cl/t it still shows at 145°30E but apparently not at 142°30E. Thus it dilutes with adjacent water westwards and this indicates a general westward displacement. South of the equator the only possible source for such a water is the oxygen minimum off Peru the core of which, according to Tsuchiya (1968) flows westwards south of the equator, on the 160 cl/t isanosteric surface.

Figure 4

North of the Peru water and right at the equator there is a water characterized by a lateral and vertical oxygen maximum with a concentration greater than 3.4 ml/l. It has a salinity near 35.0‰ and is more abundant at 145°30E than at 154°E. Thus, it is likely to move eastwards. Tsuchiya (*op. cit.*) and Rotschi and Wauthy (1969) have shown that this is Coral sea water entering the region mostly through the Vitiaz straight, flowing along the northern coast of New–Guinea and taken eastwards at the equator by the Cromwell current.

Further north, the water has a low oxygen content and salinity. It is water of the northern hemisphere oxygen minimum (Masuzawa, 1967), the core of which is found near the 125 cl/t isanosteric surface (Reid, 1965) and which shows during the cruise FOC 2 (June–July 1971) at 130–140 cl/t.

Figure 5 The oxygen distribution and the acceleration potential (Fig.5) on the isanosteric surface 160 cl/t in June and July 1971 clearly confirm the existence of the three water masses defined above and of their displacements indicated by the vertical distributions. The core of the Coral sea water appears south of 5°S with an oxygen content higher than 3.80 ml/l. It extends to the north-west, along the northern coast of New Guinea where the geostrophic currents are westwards. Having reached the equator it turns eastwards with the lower part of the Cromwell current. During this displacement its oxygen content is slowly reduced by lateral mixing with less oxygenated adjacent waters. At 4S°, 154°E the core of the Peru water is seen with an oxygen content lower than 2.80 ml/1. It is associated with a westward geostrophic current. Further west it mixes with Coral sea water. To the north it returns eastwards as a mixture.

A tongue of oxygen content lower than 1.80 ml/l extends in the northern hemisphere at a latitude which varies with longitude. In the west of the region under study it seems associated to a westward geostrophic flow. The water located south, with an oxygen content lower than 3.0 ml/l has an eastward geostrophic flow. This poorly oxygenated water of the northern hemisphere minimum, formed off the central America coast is thus likely to move westwards as well as eastwards. Moving westwards, it is part of a west flow evidenced at 170°E during almost all the cruises of the N.O. Coriolis (Magnier *et al.*, 1973), located at about 3°N, north of the northern deep extension of the Cromwell current, and having an oxygen content lower than ever found earlier at this latitude in the central Pacific. When it moves eastwards it belongs to the lower part of the north equatorial countercurrent (Tsuchiya *op.cit.*) and was formerly within

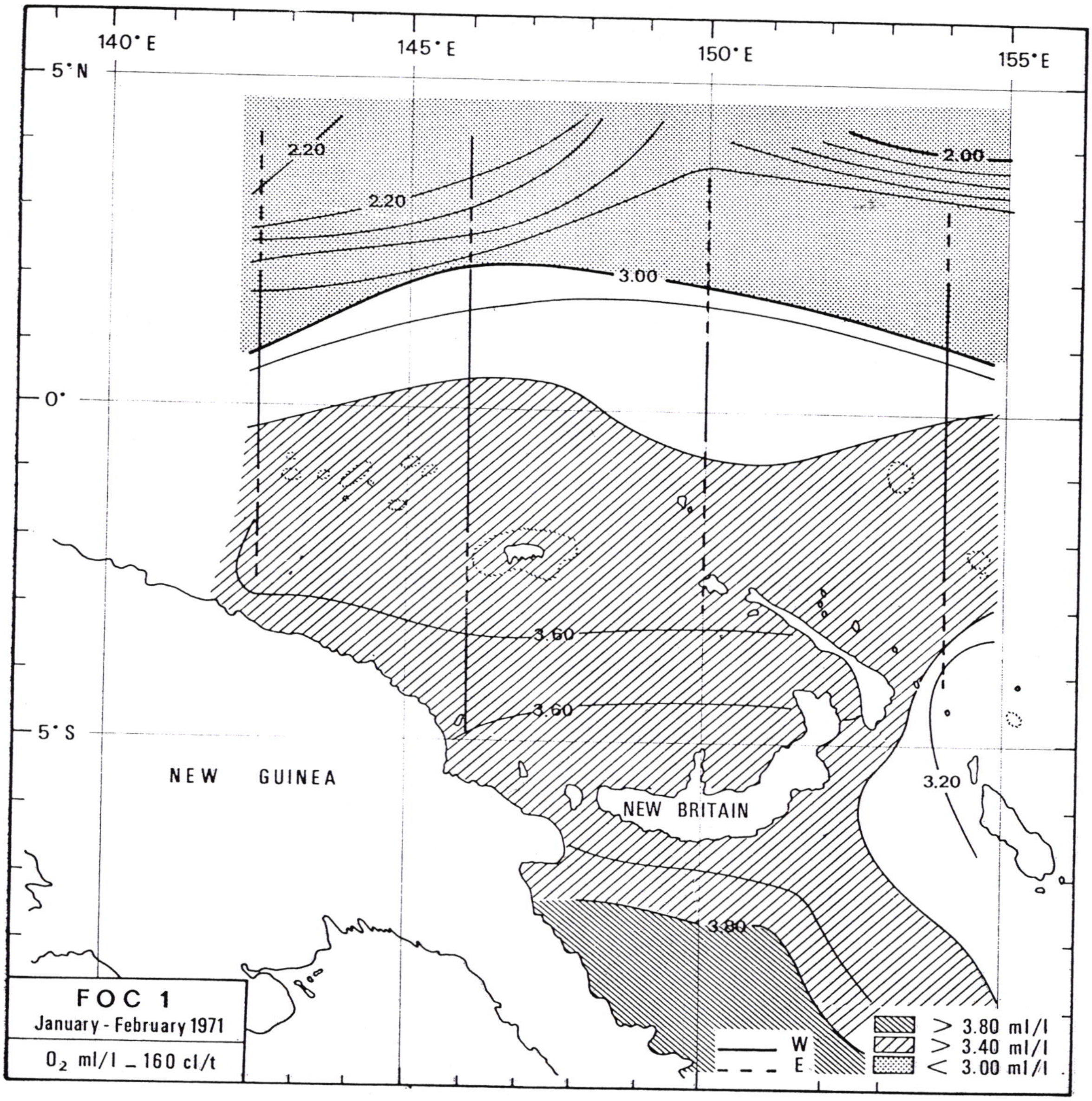

Fig. 5 : Oxygen distribution on the 160 cl/t isanosteric surface and main geostrophic flows in June–July 1971.

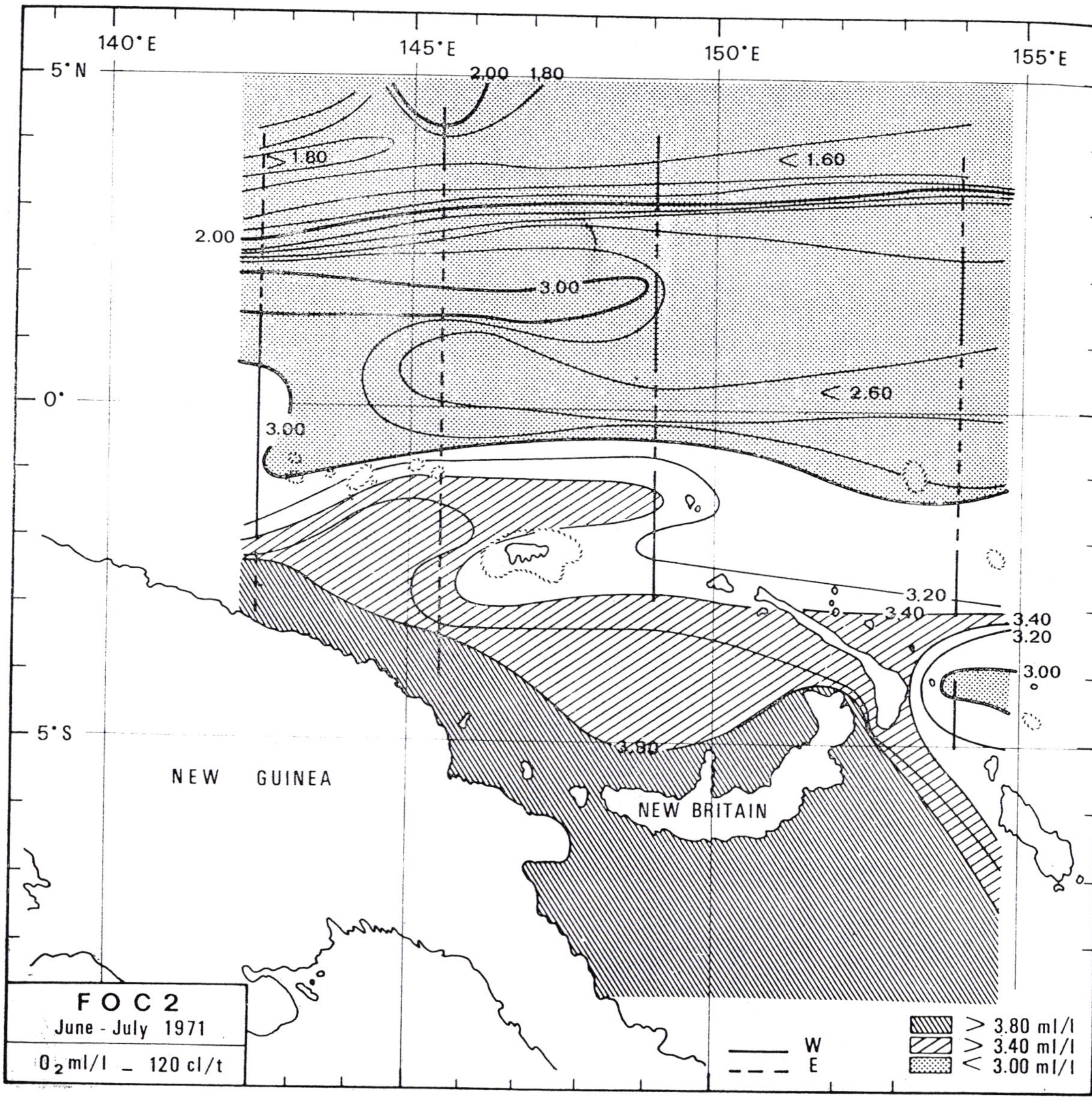

Fig. 6 : Oxygen distribution on the 120 cl/t isanosteric surface and main geostrophic flows in June–July 1971

the lower layers of the southern portion of the north equatorial current (Masuzawa 1967).

Compared to the distributions indicated by Tsuchiya (*op.cit.*), in June–July 1971 the Peru water had a greater westward extension. The Coral sea water was more extended to the north, particularly in the Solomon sea and it was less diluted along the equator. But Tsuchiya confirms the existence, north of the Solomon islands, of a cyclonic gyre transporting poorly oxygenated water westwards in its northern portion and eastwards in its southern one.

Water masses at 120 cl/t.

At 120 cl/t, the Peru water has almost entirely disappeared south of the equator (Fig. 4). Nevertheless, besides a slight minimum at 4°S, 154°E, it is well identified by an oxygen minimum, at the equator, below the Coral sea water. There, the oxygen concentration is lower than 2.6 ml/l, and the salinity of the order of 34.7 ‰. The eastern origin of this water is clearly shown by Reid (1965), Rual (1969), Hisard and Rual (1970) and it is confirmed by its westward erosion and disappearance at 142°30E. It is the trace of the equatorial intermediate current found at 170°E to flow westwards, below the Cromwell current, from a depth of about 300m down (Rual, 1969).

North and south of the equator, both sides of the oxygen minimum, there is water with a higher oxygen content. The vertical distribution at 145°30E (Fig. 3) shows that south of the equator, it is Coral sea water evidently more abundant at 145°30E and 142°30E than at 149°E; at 154°E it does not seem to be present. This indicates that the eastward extension of this water might be temporarily hindered by an opposing westward flow. North of the equator a tongue with an oxygen content higher than 3.2 ml/l at 142°30E is seen to extend westwards and to disappear at 154°E. The only possible source for such a water is also the Coral sea water and the eastward erosion of this tongue suggests an eastward displacement.

North of 2°N there is poorly oxygenated water of the central America minimum, the core of which is at a higher thermosteric anomaly, between 140 cl/t and 130 cl/t, whereas the vertical salinity maximum noted by Masuzawa *et al.*, (1970) is readily found on this surface (Fig. 4). The oxygen distribution has a complicated structure suggesting on also complicated pattern of water displacements and mixing.

Figure 6

The dynamic topography of the 120 cl/t surface (Fig. 6) does somewhat contradict the oxygen districution on it and is not entirely in agreement with the above suggestions. In particular, the equatorial low oxygen content tongue, trace of the equatorial intermediate current is associated to an eastward flow. Since in January–February of the same year the geostrophic flow was westwards, consistent with the oxygen distribution, we can think that in the westhern Pacific the isanosteric surface 120 cl/t, near the limit between the eastward Cromwell current and the westward equatorial intermediate current, is found sometimes in one of these currents, sometimes in the other; circulation on it is transient and can contradict the observed distributions.

As noted above, south of the equator, there is a westward geostrophic current opposing the eastward progression of the Coral sea water. North of the equator, in the central America water, the pattern of geostrophic circulation is complex, as on the 160 cl/t surface, but the southern portion of this water is clearly integrated to the lower part of the north equatorial countercurrent.

Reid (*op. cit.*) shows on the 125 cl/t isanosteric surface, north of New Guinea, between about the equator and 3°N, an anticyclonic cell extending from 130°E to 155°E which is consistent with the above results.

Water masses at 100 cl/t.

Fiqure 7

The depth of the 100 cl/t isanosteric surface is greater than 500m. The oxygen distribution (Fig. 7) indicates that the three water masses found above are still present at that depth. Nevertheless, there are no conclusive indications of the crossing of the equator by the Coral sea water. At the equator and 154°E, there is an oxygen maximum between a well marked northern minimum and a less extended southern one; this maximum could correspond to an eastward transport which would imply that in June–July 1971 the Cromwell current was extending to a depth of more than 500m.

The oxygen distribution north of the equator with several cores of low concentration reflects that found above and is an indication that the pattern of circulation both vertical and horizontal might be complicated.

Nevertheless, the dynamic topography shows a flow mostly westwards, south of 1°S, in the Coral sea water and in the oxygen minimum of eastern origin. At the equator, the flow is eastwards and confirms that the Cromwell current at that time reached an unusual great depth. The westward flow north of the equator is the deep prolongation of the current found above.

Time changes of the hydrology at intermediate depths.

The cruise FOC 1 made in January–February of the same year shows the same water masses participating to the hydrology at intermediate depths north of New–Guinea. Nevertheless their distribution varies greatly from one season to another as does the circulation at these depths. For instance, on the 160 cl/t isanosteric surface, the Coral sea water which has a greater northward extension in January–February does not have an eastward equatorial extension (Fig.8). This is due to the fact that in January–February the current at the equator is westwards, whereas in June–July, it is eastwards. Similarly the Peru water is less abundant at 155°E in January–February than in June–July. The observed weakening, at the beginning of the year, of the north equatorial countercurrent (Kendall 1970, Wyrtki and Kendall 1967) might be connected to an increase of the observed oxygen content in the minimum of the central America water.

Figure 8

On the 120 cl/t isanosteric surface, it was noted above that in June–July the oxygen distribution at the equator contradicted the geostrophic circulation. In January–February on the contrary the well marked equatorial oxygen minimum is associated to a westward current and the lowest concentration is lower than in June–July. Consequently, there are clear hydrological indications that the depth of the lower limit of the Cromwell current fluctuates greatly with time since in January–

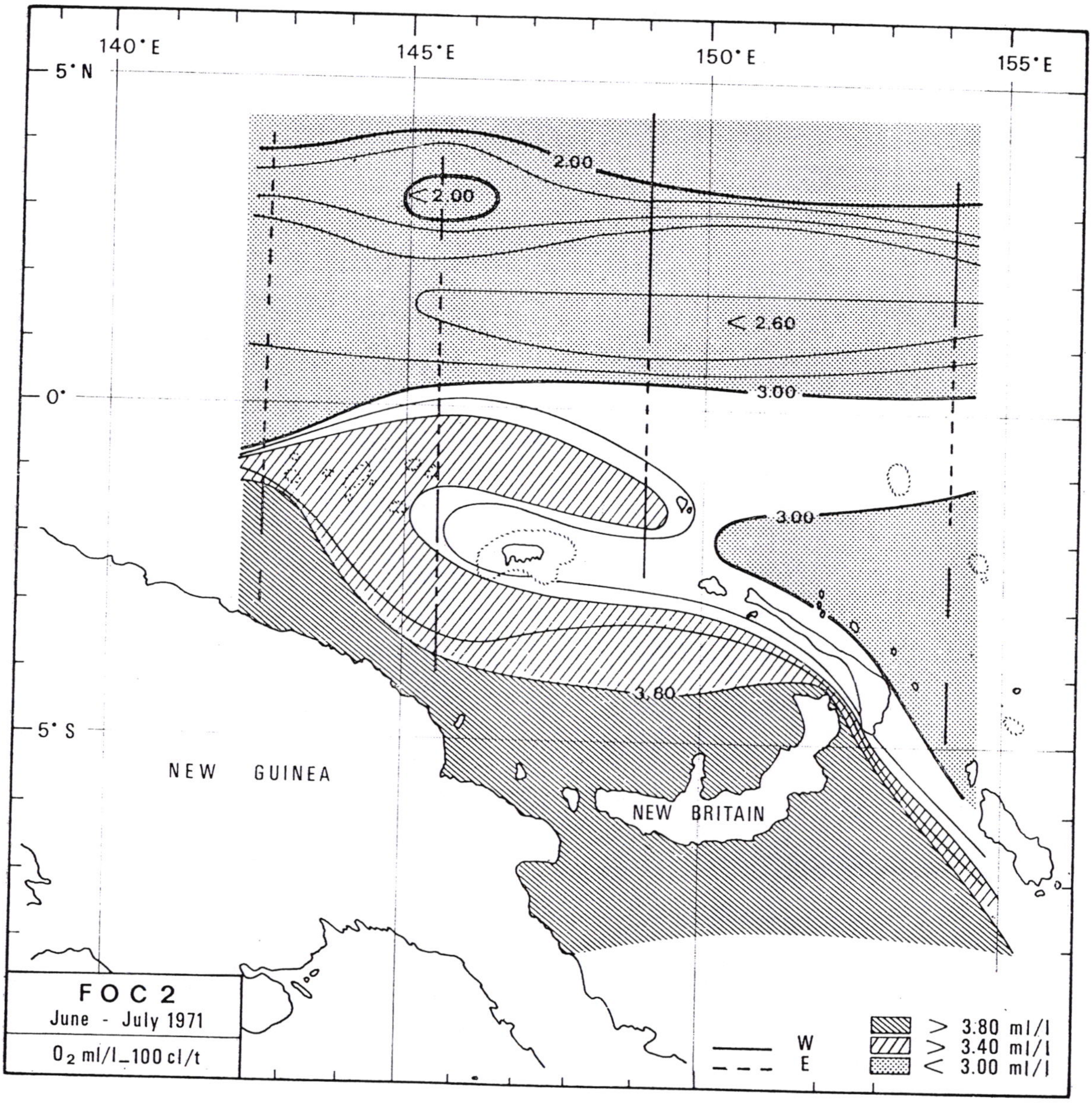

Fig. 7 : Oxygen distribution on the 100 cl/t isanosteric surface and main geostrophic flows in June–July 1971

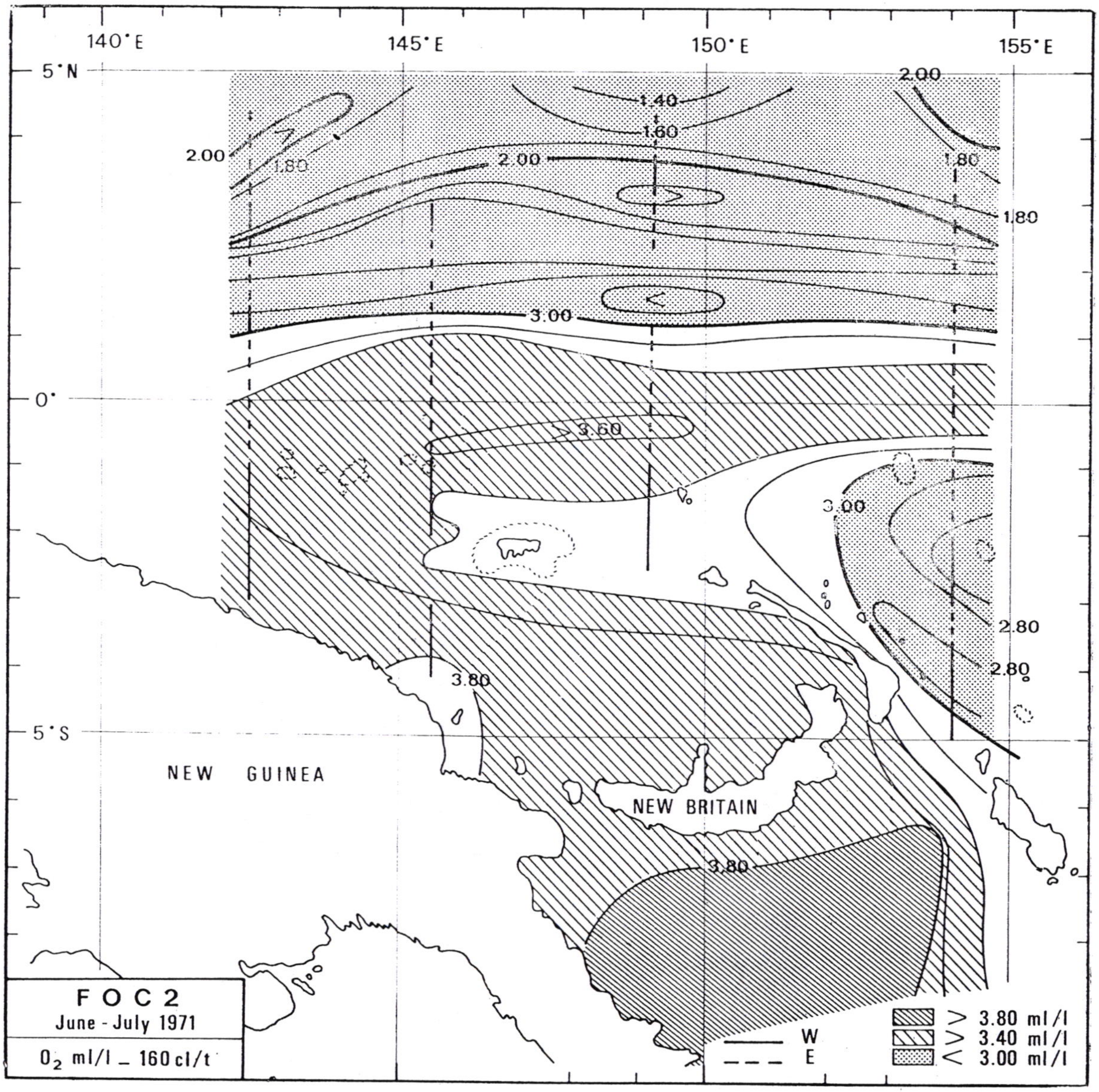

Fig. 8 : Oxygen distribution on the 160 cl/t isanosteric surface and main geostrophic flows in January–February 1971

February it was smaller than that of the 160 cl/t, whereas in June–July it was greater than that of the 120 cl/t. Important fluctuations can thus affect both the hydrology and the dynamics of the intermediate waters north of New–Guinea.

Summary and conclusions

In January–February and June–July 1971 two cruises of the research vessel Coriolis of the Centre ORSTOM de Noumea were devoted to the study of the hydrology, dynamics and productivity of the waters north of New–Guinea, between 155°E and 142°E. They showed that at intermediate depths, between the isanosteric surfaces 160 cl/t (approximate depth 300m) and 100 cl/t (approximate depth 500m) three water masses were present, better characterized by their oxygen content than by their salinity. The Coral sea water has the highest original oxygen content, over 3.80 ml/l, decreasing northwards and eastwards, mostly in the lower part of the Cromwell current, but also in the lower part of the southern portion of the north equatorial countercurrent. The Peru water reaches the region from the east with a core lower than but close to 3.00 ml/l. The northern hemisphere minimum, originating off central America has a concentration lower than 2.0 ml/l and flows eastwards with the lower part of the north equatorial countercurrent as well as westward with a westward narrow current found also elsewhere (Magnier *et al.*, 1973).

The geographical distribution of these water masses varies in time just like the distribution in space (case of the Cromwell current and of the equatorial intermediate current) or in time (case of the north equatorial countercurrent) of the currents varies.

Finally there is agreement between the hydrological situation, the geostrophic circulation, and the observed currents (Colin *et al.*, 1974) except in some cases where transient situations were met.

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1.5 UPPER WATERS NORTH OF NEW GUINEA IN 1971

by

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Abstract

Two cruises have been carried out by O.R.S.T.O.M. Oceanographic Division of Noumea (New Caledonia), aboard R.V. "Coriolis", to study the equatorial area north of New Guinea, in relation with meteorological situation : FOC 1 (January–February 1971) during the NW Monsoon and FOC 2 (June–July 1971) during the SE trade winds. Hydrological conditions are quite different during these two periods according to the wind systems.

The NW Monsoon generates an eastward surface circulation, specially along the coast when an induced upwelling gives rise to high fertility. On the other hand, during the SE trade winds, the general motion is westward for surface waters ; yet the Equatorial North Counter–Current is strengthened.

In subsurface, westward spreading, of "South Pacific subtropical surface water" characterised by its maximum salinity core and low oxygen content, along with feading of Cromwell Current with Coral Sea water, are best evidenced during FOC 2.

From both cruises it appears that fertility along the north coast of New Guinea and in Bismark Sea is higher than what is encountered offshore.

Introduction

Oceanographers from O.R.S.T.O.M. Center, Noumea, New Caledonia, have already devoted many years to study the equatorial currents system

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in western Pacific; BORA and CYCLONE cruises along 170°E have shown that the hydrological conditions at the equator are highly variable in connection with the currents, in particular the counter-currents (1); hence, it was thought that the area north of New Guinea from where these counter-currents flowing east through the Pacific originate, should be worth studying (2), (3), (4) or cruising.

In summer the convergence of the NE and SE trade winds is north of the equator so that north of New Guinea we have SE winds; in winter the monsoon disturbs this situation in the western part, the convergence is shifted south and we have NW winds north of New Guinea, bringing much rain.

Figure 1

From twice-daily meteorological observations charts, averaged direction and speed of the wind in Manus Island were obtained for ten-days periods, including calm-days. These results are shown in Fig. 1, from April 1969 to September 1971; the SE trades blow through that area from May to October, then the NW monsoon is present from November to April; hence the cruises schedule: the first cruise FOC 1 during January and February, the second cruise FOC 2, during June and July.

Both cruises had four legs along 154°E, 149°E, and 142°E from the coast of New Guinea to 4°N-Stations were half a degree apart, except for FOC 1 legs along 154°E and 146°E where the interval was one degree (Fig. 3). At each station a hydrological cast was performed (along with current measurements) at 24 levels to 1.000 m. At each level, temperature, salinity, oxyty and nutrients were measured.

South Pacific Subtropical Water Spreading

Figure 2

During SE trades the Equatorial Current (E.C) is fully grown, being unimpeded except at its bordering with the North Equatorial Counter-Current (N.E.C.C.), in contrast with the NW monsoon time when the opposing New Guinea Coastal Current (N.G.C.C.) flowing east develops. This is best evidenced by a comparison between the two cruises for salinity (Fig. 2) because the E.C. brings there salty water from the east where South Pacific Subtropical Water (S.P.S.W.) salinity maximum predominates. During FOC 1, salinity higher than 35,70 ‰ cannot be found west of 150° E but reaches at least to 142°30 E during FOC 2. The 35,50 ‰ line does not reach the equator during FOC 1 when it extends north well beyond during FOC 2, illustrating the fact that the Equatorial Undercurrent (E.U., or Cromwell Current) is fed with salty southern water in these months. The more than 35,50 ‰ layer is thicker during FOC 2 than during FOC 1 ; however the low salinity brought by NW monsoon is still noticeable at the surface during FOC 2.

The relationship between currents and physical or chemical properties of the carried water will be analysed on horizontal distributions at the sea surface and at 100 m for the surface layer, and on 300 and 200 cl/t isanosteric levels for the subsurface layer (Approximatively and respectively 200 m and 250 m in depth).

Surface layer

Figure 3

At the surface, the current vectors drawn at each station in Fig. 3 show that the E.C. is stronger in June-July (FOC 2) when SE trades are well settled, than in January-February (FOC 1) when NW monsoon

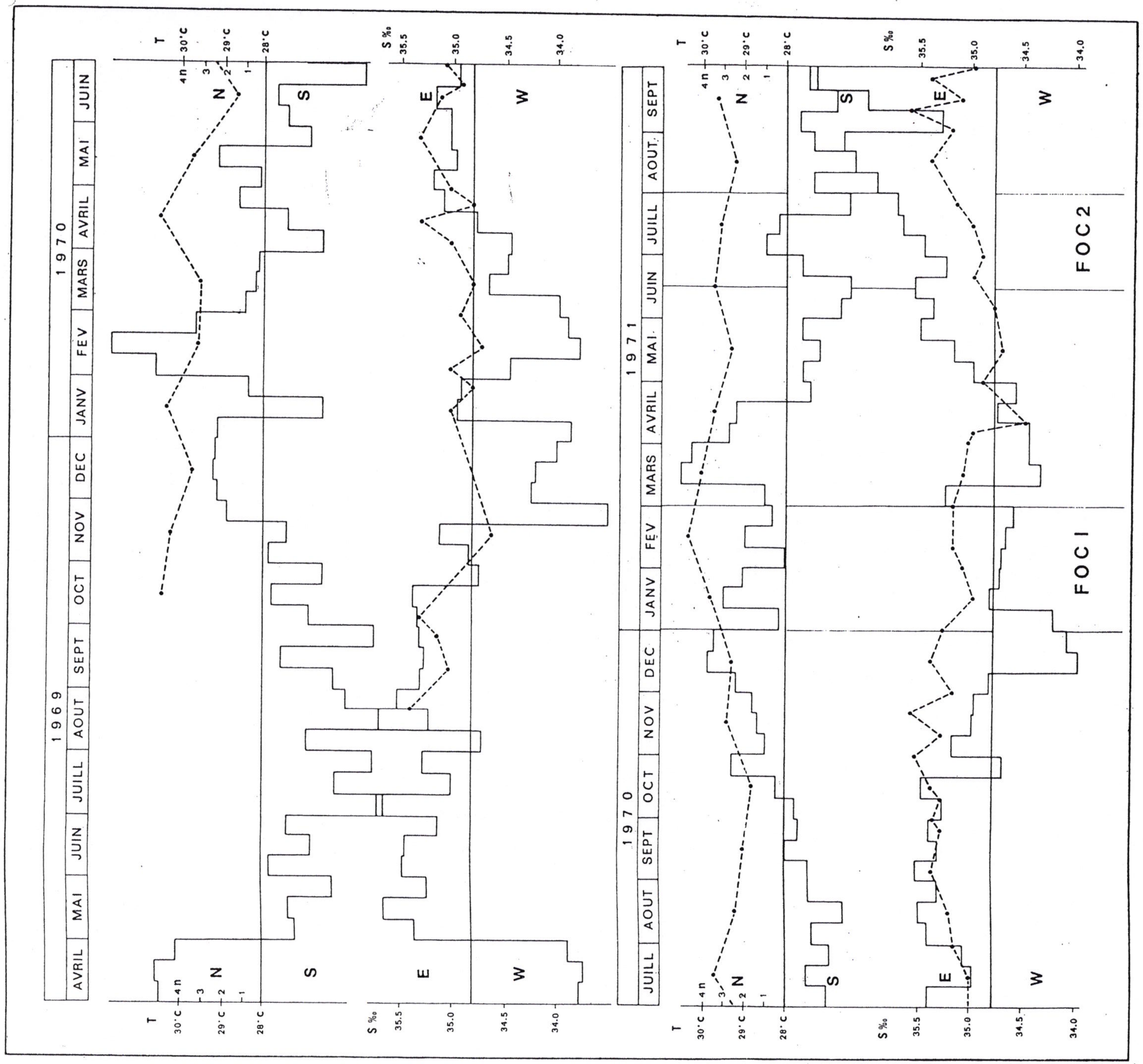

Fig. 1 East–West and North–South components of the wind in Manus Island from April 1969 to September 1971. Temperature and salinity of sea surface at the equator, between 150°E and 160°E, are reported from merchant ships observations.

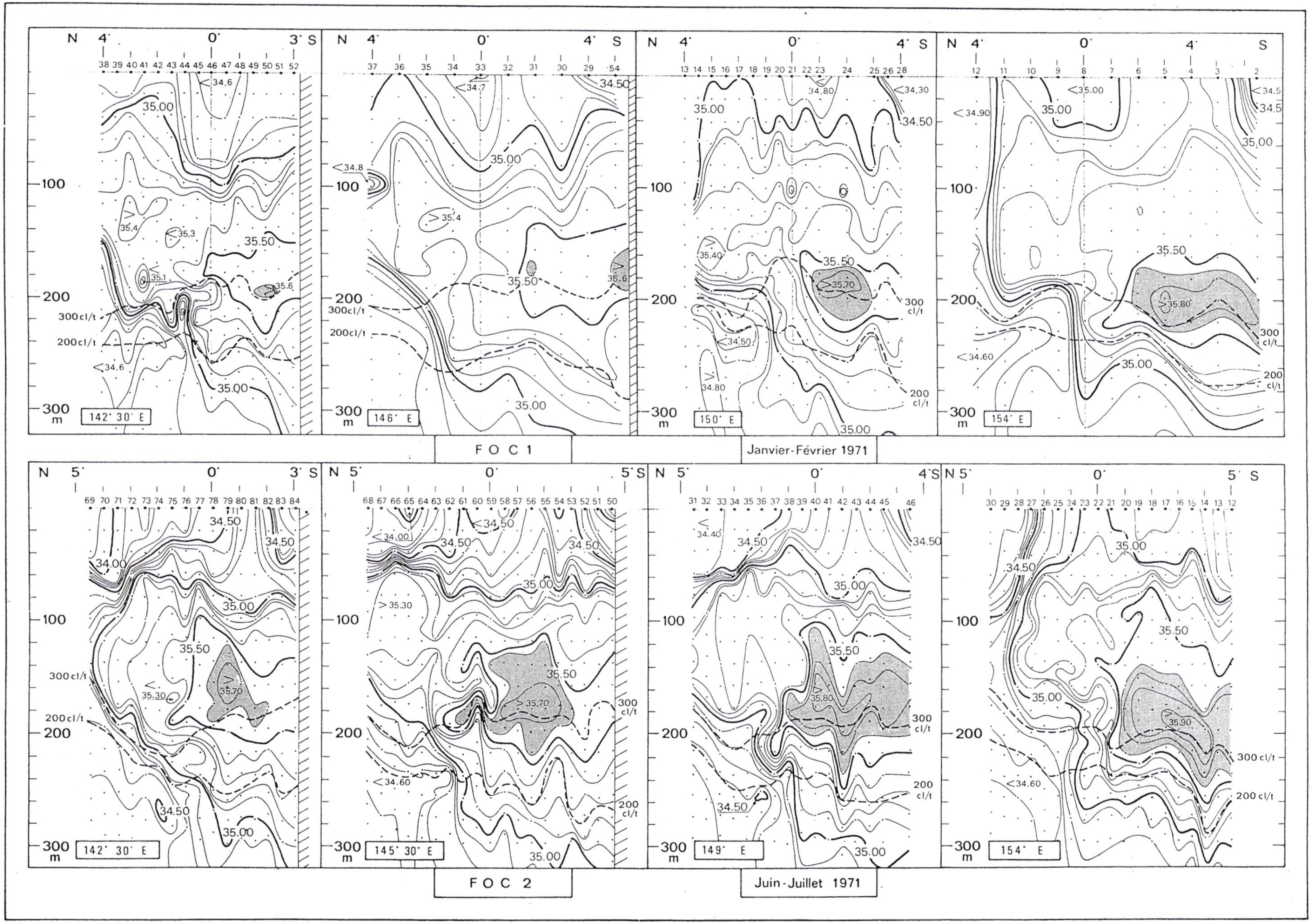

Fig. 2 Vertical distriburtion of salinity along four legs during cruises FOC 1 (January–February 1971) and FOC 2 (June–July 1971).

blows, inducing N.G.C.C. which, flowing east, deflects the E.C. to the north ; the C.C.E.N. is in turn deflected to the north by the E.C and weaker during FOC 1.

The surface salinity may look a little paradoxical since it is higher, as a whole, during FOC 1 than during FOC 2, but we can see than these distributions are transient ; during FOC 1, low salinity by advection from the west or by local rain, is slowly overflowing higher salinity formerly established here by summer time and left behind; during FOC 2 high salinity of upwelled water from beneath is just appearing at 154°E at the equator in the process of overcoming low salinity from winter time.

Figure 4

At 100 m depth (Fig. 4) the E.C is strengthened during FOC 1, being impeded at the surface by the NW monsoon ; however salinity over the whole area is lower than during FOC 2 and the negative westward gradient is stronger than during FOC 2. In monsoon time the N.G.C.C. induces a coastal upwelling characterized by an increased salinity.

Subsurface layer

Figure 5

Salinity analysis on the 300 cl/t level (Fig. 5) shows the E.C at its best, during trades time (FOC 2), with values higher than 35,60‰ over the area south of the equator and particularly in Bismarck sea; during monsoon time, the E.C has disappeared, allowing the eastward circulation to lower the salinity (Cromwell Current as well as N.G.C.C., albeit weak the latter be at that depth).

Below the salinity maximum, water carried from the east by the E.C is characterized by oxyty lower than that of Coral Sea Water

(C.S.W.) which occupies the southern part of Bismarck sea. A comparison between oxyty sections of the two cruises shows equally well the difference in strength of the E.C for the two seasons (Fig. 6): oxyty lower than 3 ml/l is found at least to 145°E during FOC 2, when it reaches only 150°E during FOC 1.

Figure 6

Figure 7

Oxyty on the 200 cl/t surface (Fig. 7) illustrates the spreading of these low values and is worth of some comments. The core of the Cromwell Current is known through the entire Pacific to have a higher oxyty than surrounding waters; here we can see the very place where this feature is tagged by C.S.W. which is feeding the E.U. all the year round; the feeding place should be further west, at least during FOC 2 where C.S.W. is spreading westward along the coast more than during FOC 1 where it is impeded by the N.G.C.C., weak but still noticeable at 142°30 E.

Effects of circulation on potential fertility

Figure 8

Phosphate distribution at the surface for the two cruises (Fig. 8) compared with salinity distribution (Fig. 3) shows clearly that potential fertility in equatorial area is directly related to salinity.

During FOC 2 we can see at 154°E rich and salty water from beneath welling up to the surface under trades and slowly replacing poorer and fresher water of the past monsoon time.

During FOC 1, we have just the opposite situation : slow overcoming of that rich and salty water of trades time by a poorer and fresher water flowing from the west, driven by the monsoon. Right along the N.G. coast low salinity is not related to low phosphate; this can be associated with coastal enrichment by upwelling induced by the N.G.C.C.

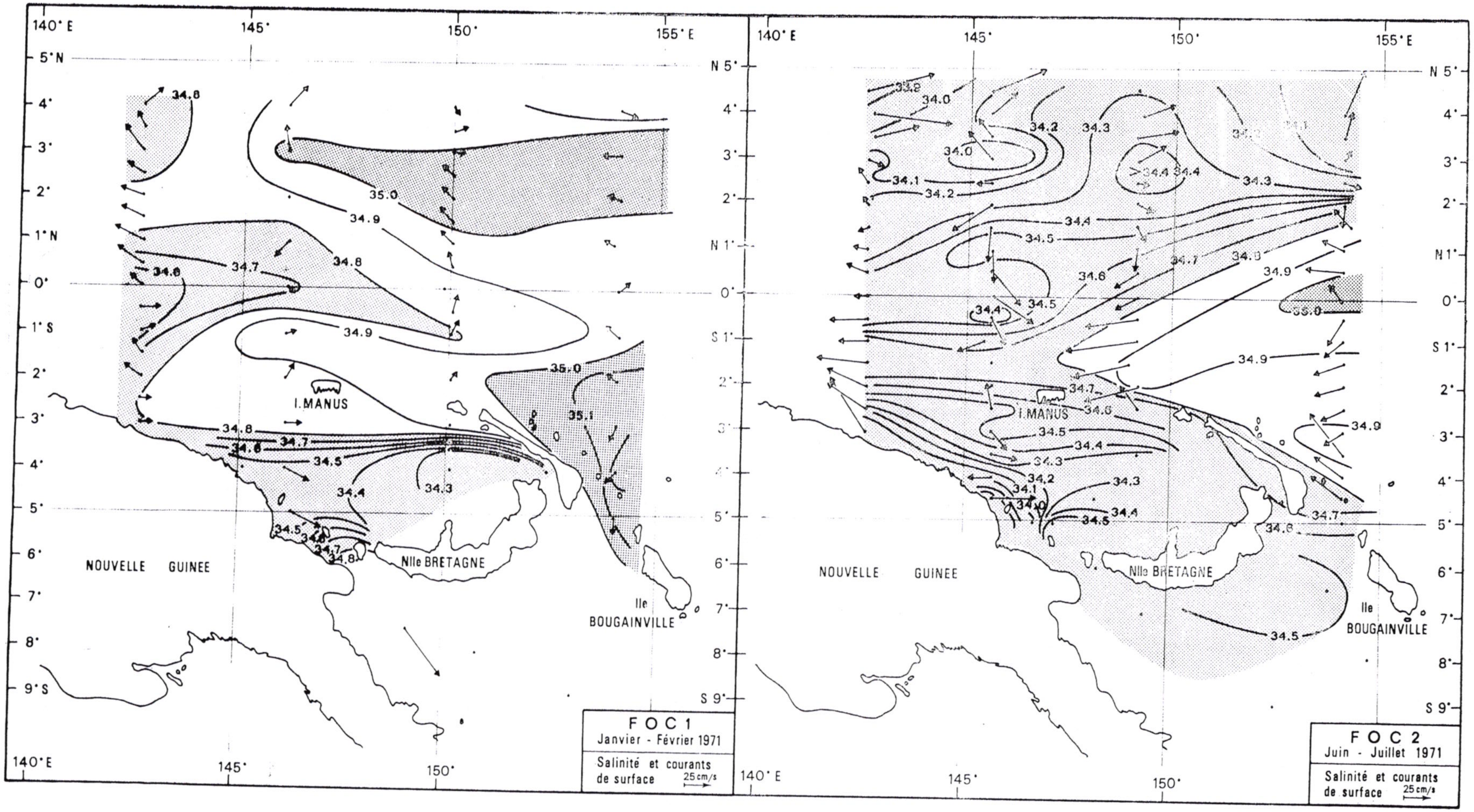

Fig. 3 Horizontal distribution of salinity and currents at the sea surface during cruises FOC 1 and FOC 2 (respectively January–February and June–July 1971).

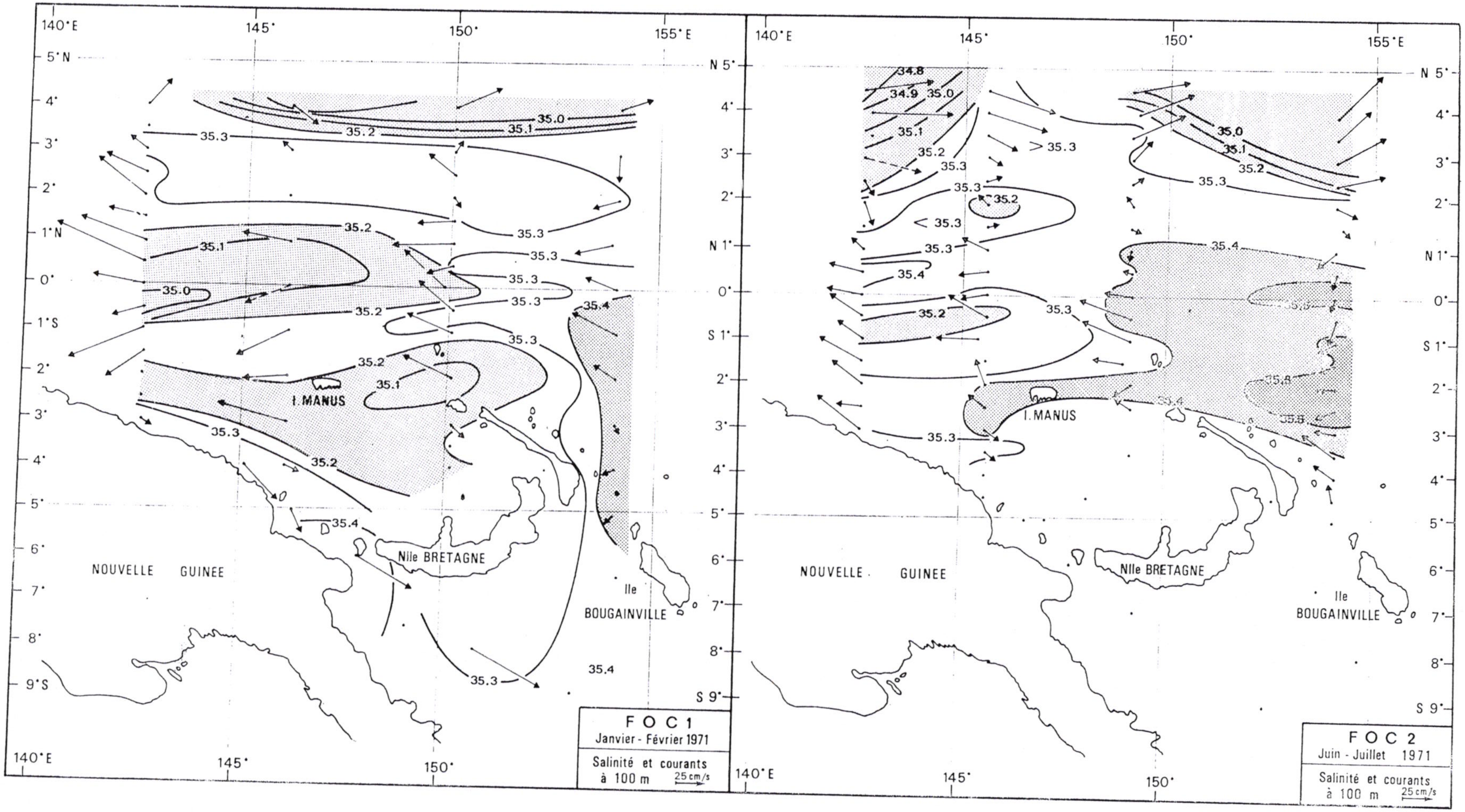

Fig. 4 Horizontal distribution of salinity and currents at 100 m level during cruises FOC 1 and FOC 2 (respectively January–February and June–July 1971).

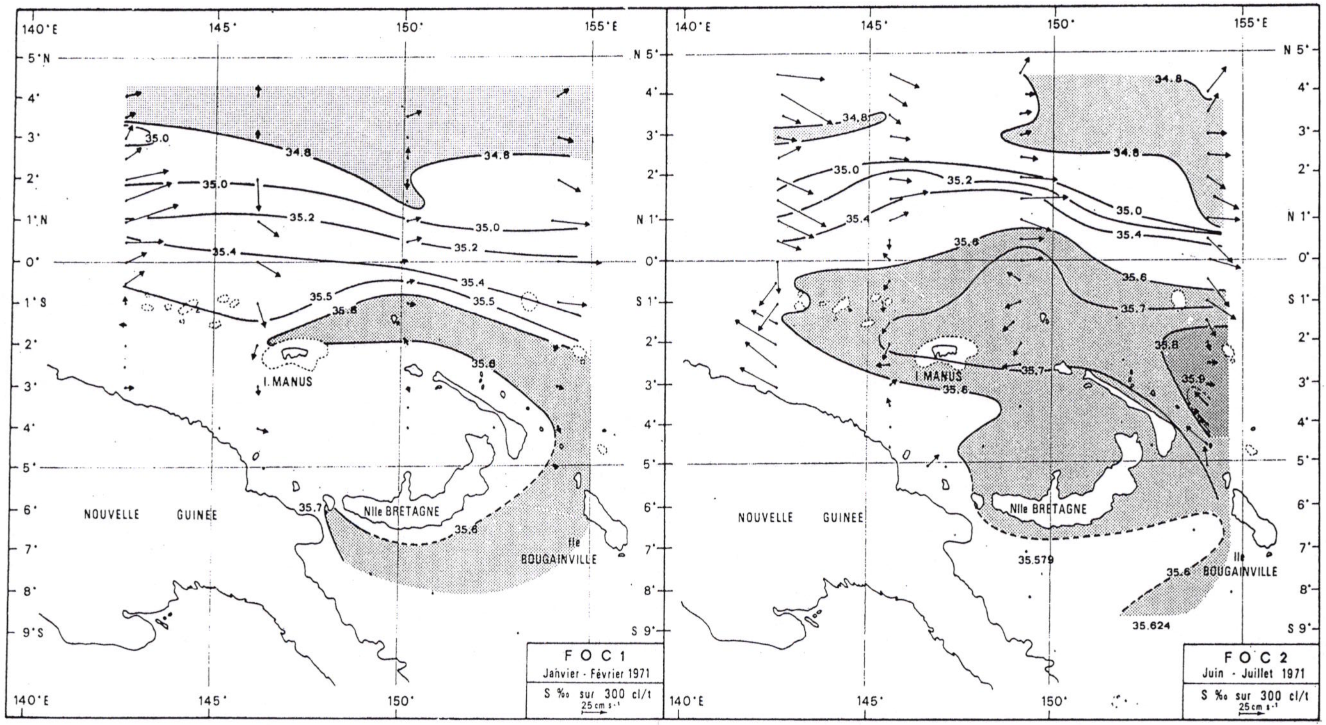

Fig. 5 Distribution of salinity and currents on the 300 cl/t isanosteric surface during cruises FOC 1 and FOC 2 (respectively January–February and June–July 1971).

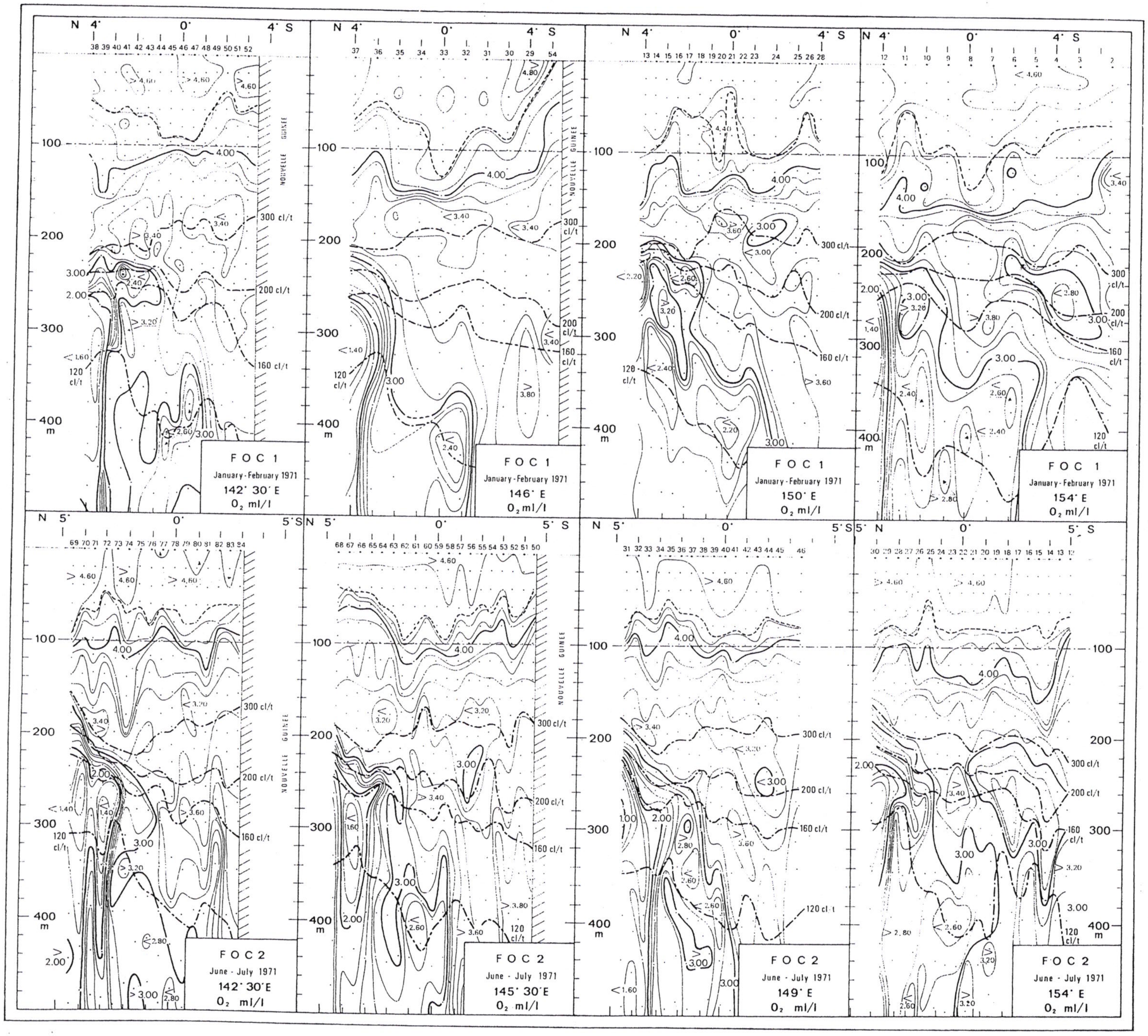

Fig. 3: Vertical oxygen distribution, nopth of New-Guinéa a) in January–February 1971, cruises FOC 1 b) in June–July 1971, cruise FOC 2

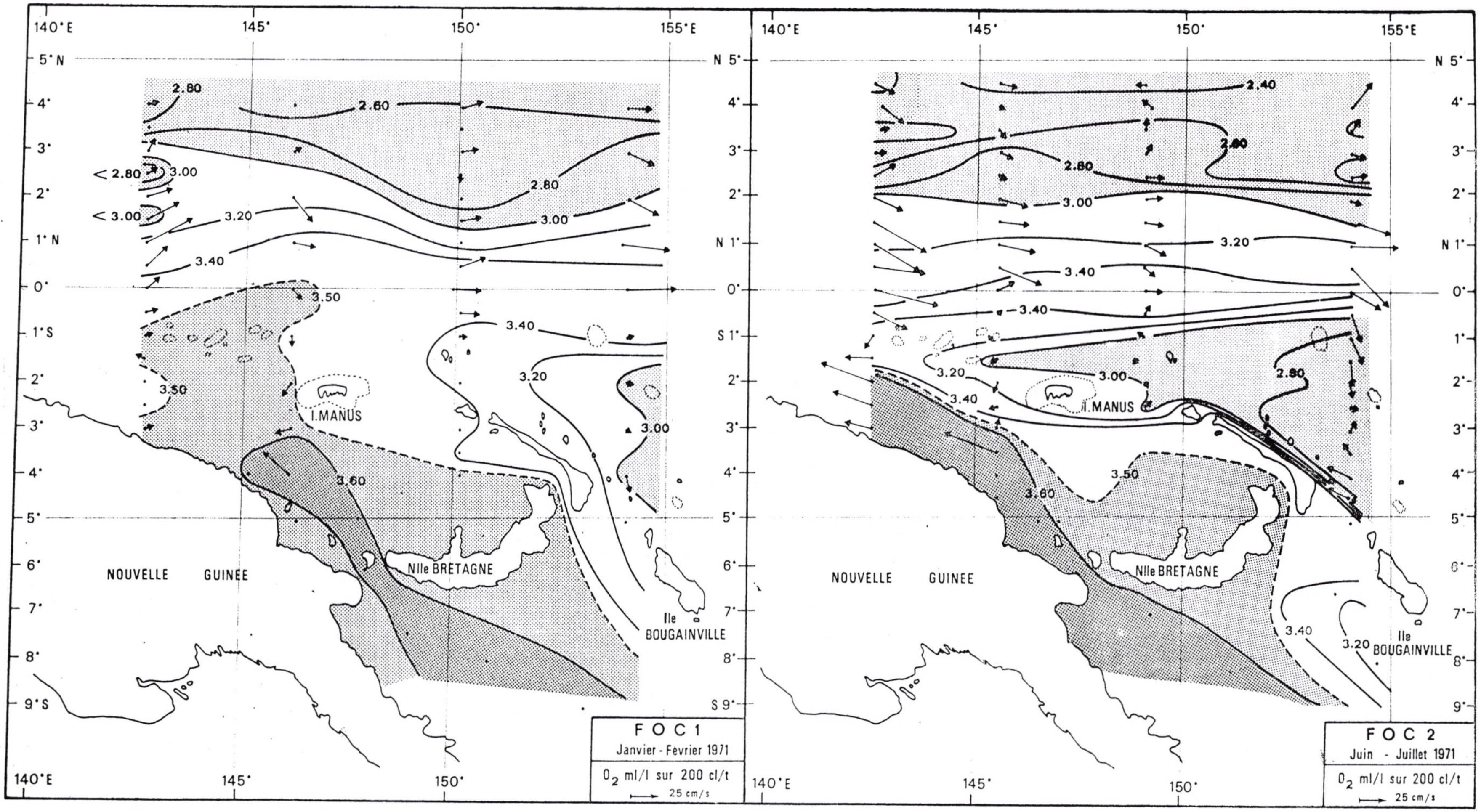

Fig. 7 Distribution of oxyty (ml/l) and currents on the 200 cl/t isanosteric surface during cruises FOC 1 and FOC 2 (respectively January–February and June–July 1971).

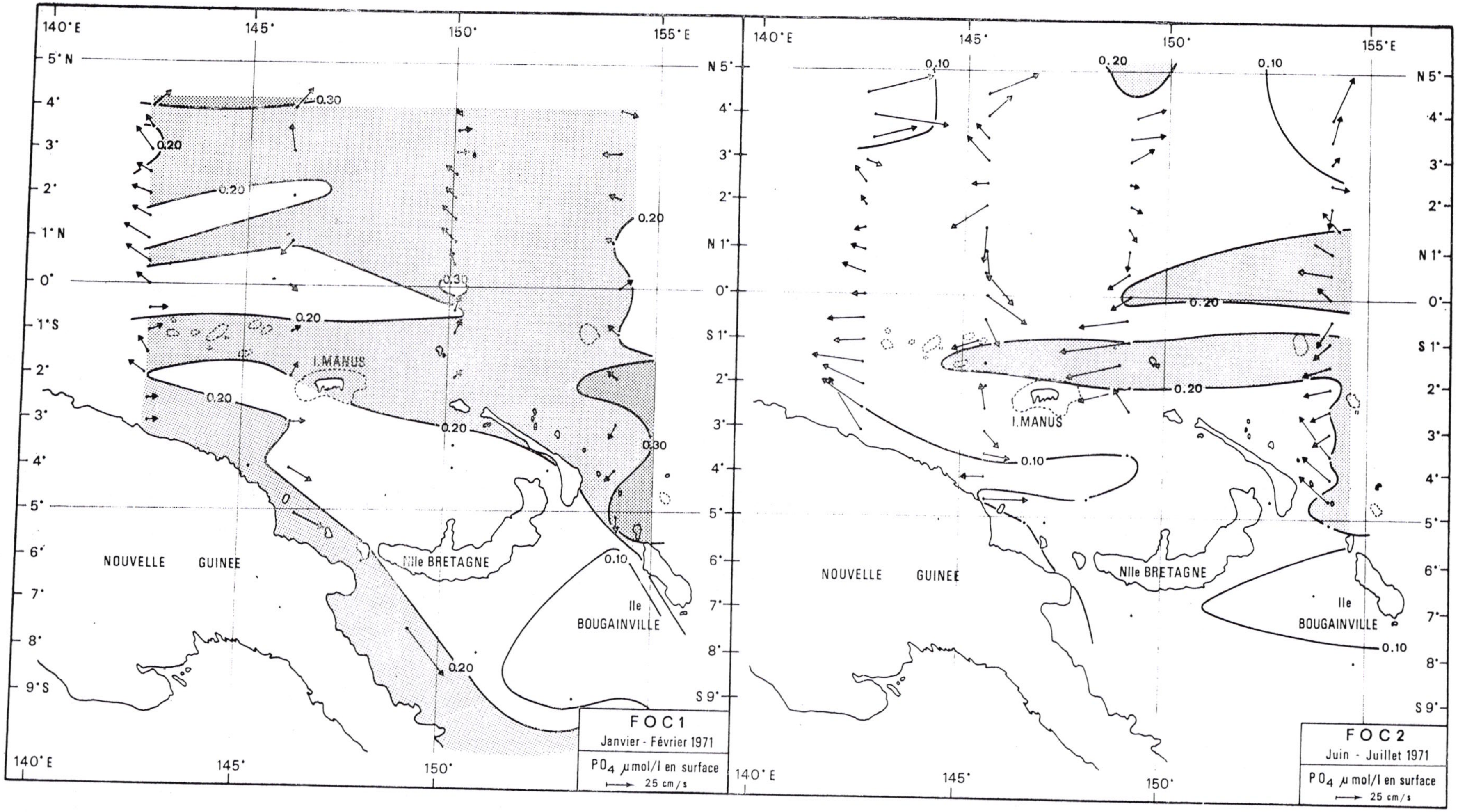

Fig. 8 Horizontal distribution of phosphate concentration (μmol/l) and currents at the sea surface during cruises FOC 1 and FOC 2 (respectively January–February and June–July 1971).

Figure 9

This process is clearly seen on nutrients sections at 146°E for FOC 1 (Fig 9) where we have isolines sloping up towards the coast in the 0–200 m layer, in relation with current to the east. These nutrients sections illustrate also the convergence situation at the equator where the poor surface layer is very thick, down to 100 m, and the vertical gradient for nutrients in the core of Cromwell Current which refutes the explanation of the oxygen homogeneity by turbulent mixing.

Discussion

We have established that changes in the hydrology of the area are the responses to the alternation of provailing winds, through induced currents.

The E.C generated by S.E. trades is found in the whole 0–250 m layer in June–July (FOC 2). When the monsoon starts, the trades fainting out, the E.C persists by inertia, but it is restrained at the surface by NW wind, shifted to the north of the equator by N.G.C.C. and impeded at depth by the U.C., so that its maximum speed depth is 100m for that season. The backwards circulation to the east, north of N.G, consists permanently of C.C.E.N for the surface and E.U. for the subsurface with C.C.E.N gathering strength in trades time and N.G.C.C. joining in monsoon time.

In subsurface, hydrological characteristics south of the equator are the result of an equilibrium between S.P.S.W., salty and oxygen depleted, brought from the east by E.C, and C.S.W, slightly fresher and more oxygenated, flowing west along the coast through Bismarck sea, then feeding the E.U. which carries it east. As soon as the E.C weakens before disappearing, in subsurface the equilibrium is upset and extreme

S.P.S.W. characteristics soon become blunted and replaced by those of C.S.W, hence the response of hydrology to circulation changes is quick in subsurface; but it is not so at the surface.

In the surface layer during FOC 2 we should have a higher salinity associated with a strong E.C; this is true at 100 m but not at the surface where almost the entire area is covered with less than 35 ‰ water. Desalting of surface water in Occidental Equatorial Pacific is brought by the monsoon by advection (N.G.C.C.) as well as by local rain; NW wind induces convergence of surface waters at the equator, so desalted layer is thick; farther to the east at 170°E salinity lower than 34,69 ‰ has been found in April 1967, brought to the equator from the low salinity C.C.E.N by surface convergence induced by west wind 1); that low salinity water, if carried west at one knot by the E.C, would enter the area north of New Guinea in June. So, the E.C which reappears at the surface when the S.E. trades blow anew, will carry from the east rather desalted surface water for some months and there is some lag before salty water from beneath begins to flow away the thick desalted surface layer out of the equator, as it can be seen at 154°E during FOC 2.

In the same manner, desalted water from the Celebes Sea, carried to the east by counter-currents, lags behind the setting up of the monsoon as it can be seen during FOC 1 where quite high salinity of the past season is still present in the eastern part of the area.

Conclusion

These two cruises north of New Guinea have given details on the building up of E.U hydrological characteristics:

- the feeding all the year round by highly oxygenated C.S.W.

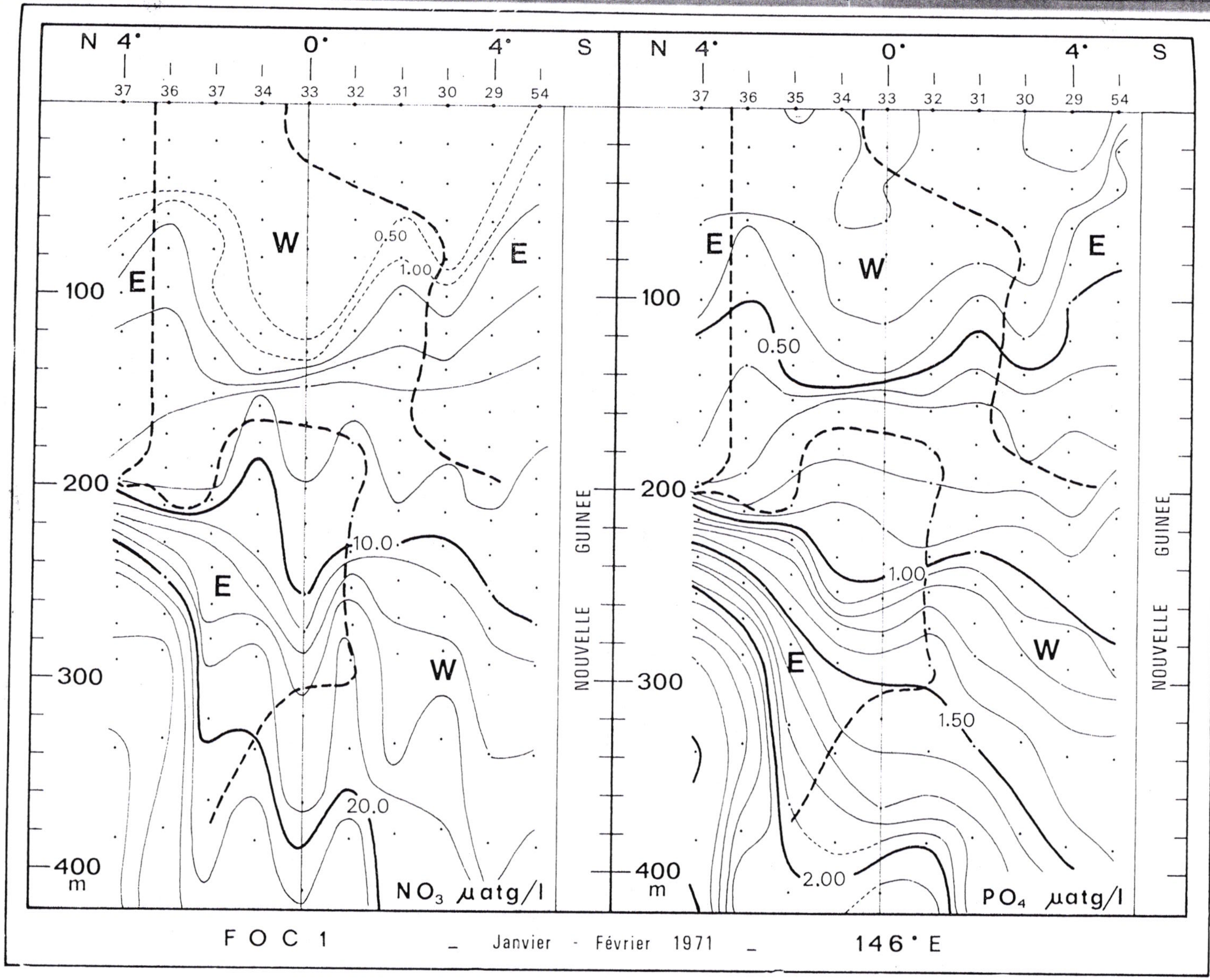

Fig. 9 Vertical distribution of nitrate concentration (umol/l) and phosphate concentration (umol/l) along 146°E leg during cruise FOC 1 (January–February 1971).

- the involvement of salty S.P.S.W, in this feeding in summertime.

  These details sustain the interpretation given earlier to explain the hydrological structure of E.U. observed at 170°E.

The continuity between the E.U. and the N.E.C.C. is corroborated, as well as the strenghthening of the latter in summer time.

In the surface layer, the setting up of the hydrological features characterizing each season lags behind the changes of winds, when the response in subsurface is rather quick.

North of New Guinea there is all the year round a good potential fertility, either from equatorial upwelling in trades time, or from coastal upwelling in monsoon time.

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1.6 EQUATORIAL CURRENTS SYSTEM NORTH OF NEW GUINEA

by

C. COLIN, F. JARRIGE, F. ROUGERIE, P. RUAL

Summary

Eight trans-equatorial cross sections giving zonal and meridional components of currents north of New-Guinea were carried out during the cruises FOC 1 and FOC 2 (January-February and June-July 1971) of the R/V CORIOLIS of the Centre ORSTOM of Noumea. The equatorial currents system is described during two contrasted wind regimes and comments are made on space-time variations of the main water drifts.

1. - Introduction

Following detailed studies at 170°E (MAGNIER *et al.*, 1973) the equatorial zone located north of New-Guinea has been investigated in 1971 by the R/V CORIOLIS of the Centre ORSTOM of Noumea during two different seasonal cruises, FOC 1 and FOC 2. WYRTKI (1961) described the peculiar nature of this zone where equatorial currents end and where are formed two main currents: the north equatorial counter-current and the equatorial under-current (Cromwell current). Russian (KORT and al., 1966) and Japanese (MASUZAWA, 1967) studies have confirmed the hydrological complexity of the region and pointed out the importance of time-repeated investigations. The main aim of the FOC cruises was to specify mechanisms by which the Cromwell current gains some of its hydrological characteristics observed at 170°E (ROTSCHI *et al.*, 1972) and to estimate the response of the superficial drift to the variations of the wind-regime.

The high density of the current measurements in the first 500 meters has permitted to precise the horizontal and vertical structures of the equatorial currents system between the north coast of New-Guinea and 5°N. In addition to these measurements, hydrological and physico-chemical parameters have been studied and results of these measurements have been used in others papers.

2. - Methodology

All current measurements were made with three self-recording Hydro-Products current meters, model 501 B; they were attached to the hydrological cable and lowered down from the ship ; measurements were made every 20 m from the surface to 500 m and every 40 m from 500 m to 1500 m; at each level, measurements of the speed and of the direction of the current were made every 8 seconds during 4 minutes. Only the average of those 4 minutes time series were considered.

Before lowering the current meters, 100 m of cable were paid out and the ship manoeuvred to obtain the lowest cable angle with vertical. Once this equilibration was found, the course and speed of the ship were maintained throughout the current measurements,

The accuracy, at the surface is, $\pm$ 10° for direction and $\pm$ 10 cm/s for velocity. For deeper recordings, it is $\pm$ 5° for direction and the velocity accuracy remains unchanged because the great length of the cable dampens all short-terms movements like waves and swell. The depth of each current meter is assumed to be the length of the cable corrected for the wire angle and for the length paid out. The great number of hydrological stations carried out in the same zone and under similar conditions indicates that this method introduces into the depth evaluations an error of overestimation not exceeding 2%.

In fine, current measurement obtained at each level is evaluated relatively to a given reference (500m for the eight trans-equatorial cross sections presented in this paper) by vectorial difference.

3. – Meteorological features

Because its position at the west border of south east Asia, New-Guinea is under a monsoon regime, specially in northern winter when high pressure are formed over the asiatic continent and low pressure over Australia. Between the high and the low, the monsoon develops ; in full monsoon regime the pressure distribution is stationary and winds have a high constancy, specially over the sea. However the wind force is generally small, except in storms and typhoons observed north of Australia and over the Coral Sea.

In the course of December the monsoon crosses the equator as a north wind and south of it turns to the east, where it appears as the northwest monsoon, as observed during the FOC 1 cruise. From April the equatorial pressure trough moves quickly to the north and lies at the equator. The southeast trade again reach 5°S and grows stronger until July. North of the equator the northeast wind system collapses in May and the south monsoon succeeds over the whole of southeast Asia and reaches its full development in July and August. During these months the low pressure is over Asia and the high over Australia. Over the open sea north of New-Guinea trade winds of force 4 are often exceeded as during the FOC 2 cruise. From October the equatorial trough begins to move rapidly southwards again and lies along a line from the center of the Bay of Bengal to the north coast of New-Guinea. Southeast trade winds weaken and begin to gradually collapse in November in a zone north of 5°S.

The diagram 1 summarizes the wind conditions observed from November 1970 to November 1971 at Manus island, located off the New-Guinea coast at 2°S and 147°E.

This variation of the atmospheric circulation finds its parallel in a corresponding variation of the oceanic surface drift, with however a delayed time response.

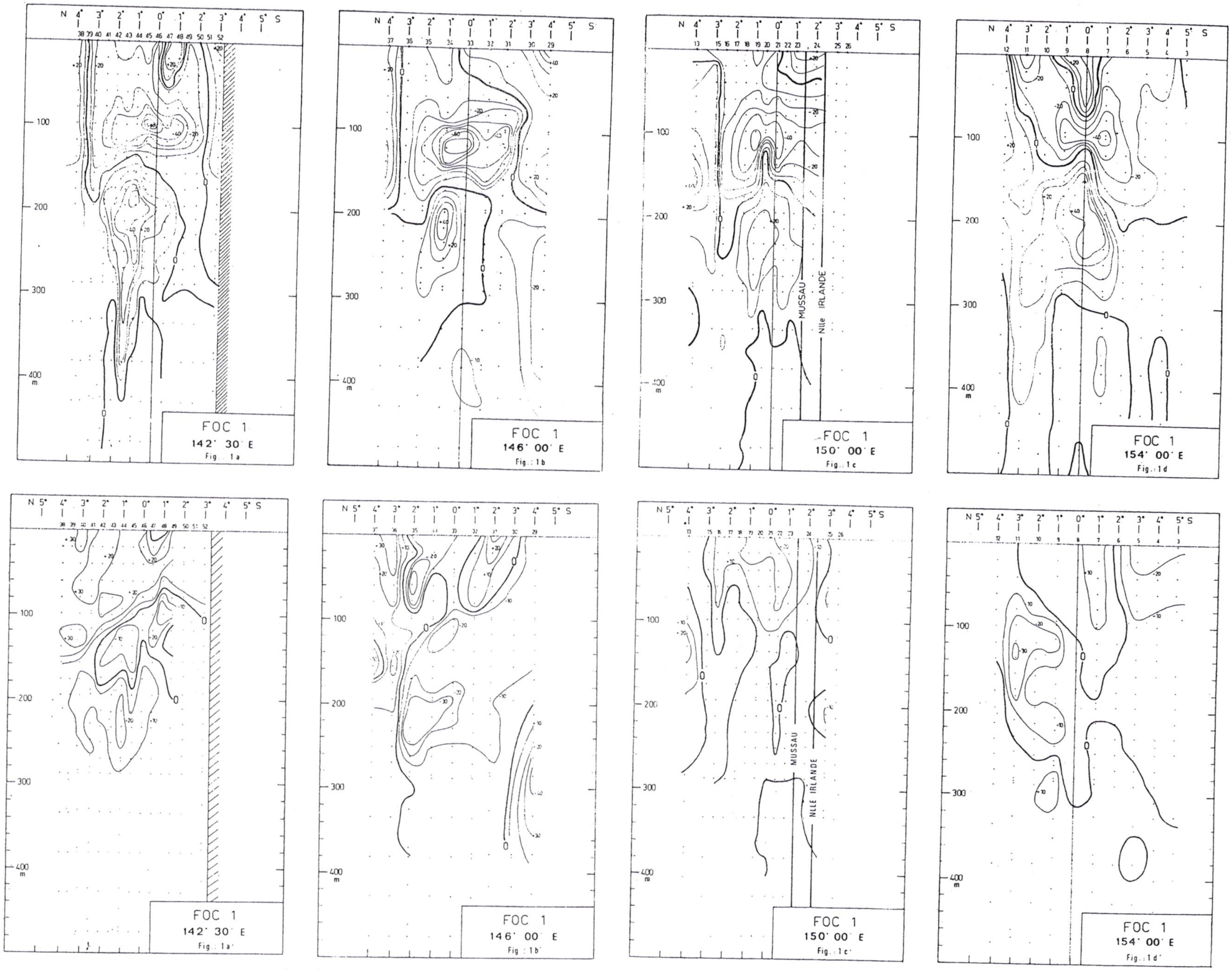

Fig. 1 : E-W (a, b, c, d) and N.S (a',b',c',d') components of current velocity at four equatorial cross section carried out during cruise FOC 1 (January–February 1971).

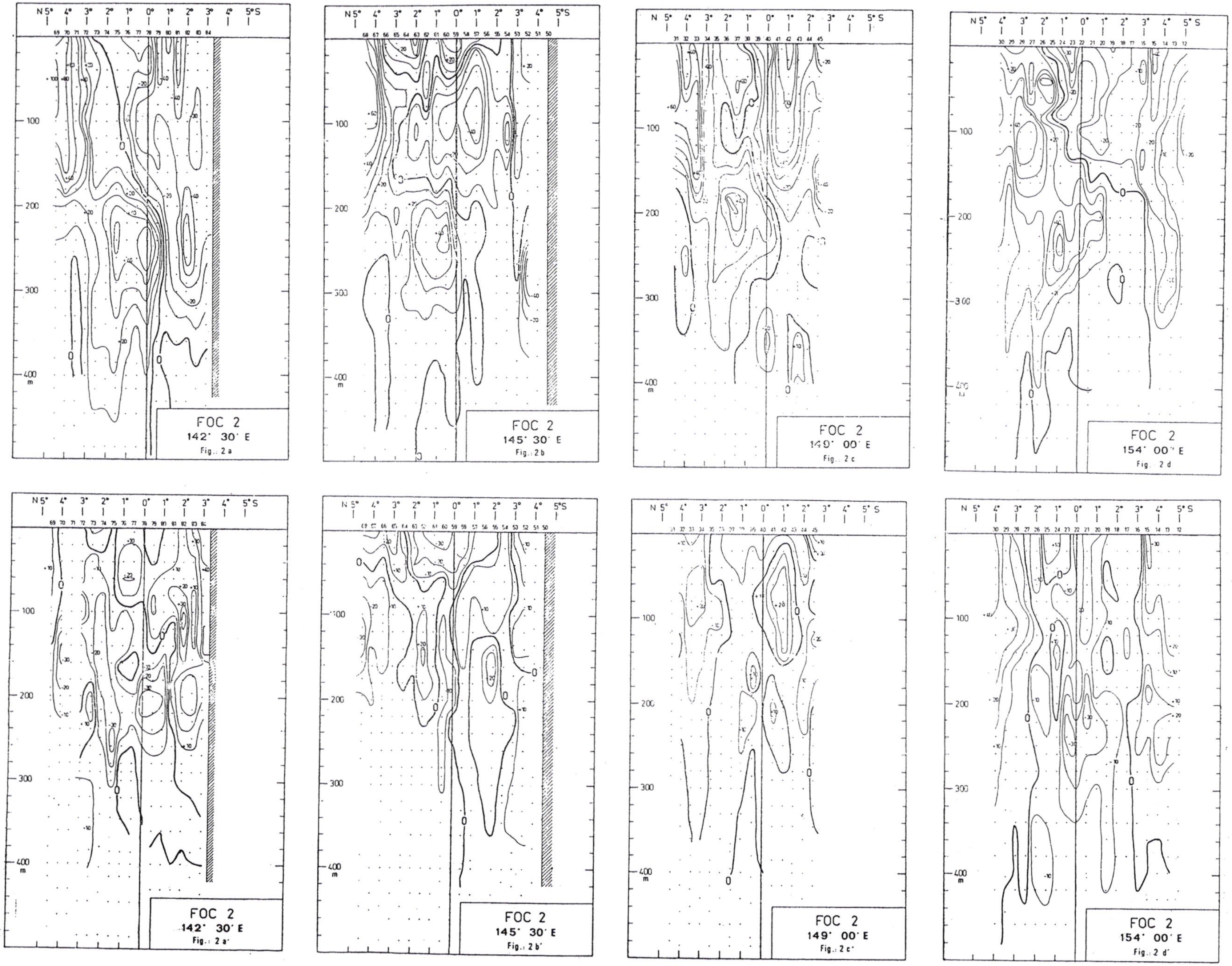

Fig. 2 : E-W (a, b, c, d) and N.S (a',b',c',d') components of current velocity at four equatorial cross section carried out during cruise FOC 2 (June–July 1971).

4. – Results

a) Currents :

The four trans-equatorial cross sections made during each FOC cruise present a structure chiefly characterized by the prevalence of zonal flows because the meridional components of the observed flows are generally weaker than the zonal components and their variability from a section to one another is more important.

During FOC 1 cruise (January-February 1971) there was, at the equator a superposition of opposed flows : near the surface, the water ran eastwards with an average speed of 20 cm/s; below, between 30 m and 150 m depth, there was an important core of westward flow, the speed of which was 50 cm/s. This current, named the equatorial current, reached the surface north of the equator. Its velocity core situated near 100 m depth was spreading roughly of two degrees on both sides of the equator and had swifter observed speed at 146°E and 142°30E (Fig. 1a and 1b); in fact that acceleration could be the result of the water stream narrowing between the coast and the south limit of the north equatorial counter current. Along the New-Guinea coast, the New-Guinea current ran sountheastwards with a maximum thickness not more than 200m. This coastal current can be linked with the equatorial superficial east flow like in figure 2a or be parted from it by a thin west flow like in figure 1a. Further east, the New-Guinea current moved off the equator towards the Coral sea, whereas at 154°E the equatorial superficial east flow kept close to the equator (Fig. 1d). In the first 200 m, the boundary between the equatorial current and the north equatorial counter current was well marked by an inversion along a vertical line located between 3 and 4°N of the meridional velocity gradient. North of this latitude the flow ran uniformly eastwards in the whole water column. At the equator and below 150 m the flow ran also eastwards and was characterized, between 200 m and 250 m by a core where the speed exceeded 40 cm/s. This flow is the equatorial undercurrent extending across the Pacific ocean to the Galapagos islands. The lower boundary of this current was, at the very equator, close to 300 m depth. Deeper there is a westward flow: the intermediate equatorial current (HISARD, RUAL, 1970). Both sides of the equator, the equatorial undercurrent was connected with two deep extensions going beyond 500 m depth, characteristics of which have been summarized in table 1.

Table 1

Longitude	142°30 E	146°E	150°E	154°E
Equatorial undercurrent lower limit (at the equator)	400m	320m	320m	300m
North extension	North of 3°N	poorly defined	North of 2°N	between 1°N 4°N
South extension	South of 0°30S	non existent	South of 2°S	between 2°30S and 3°30S

During FOC 2 cruise (June–July 1971), the circulation recorded in the superficial layers was somewhat different since the equatorial surface east flow had disappeared. In subsurface, the equatorial undercurrent had roughly the same features than in January, but its link with the north equatorial counter current seemed stronger. Below 300 m, the deep extension of the equatorial undercurrent was baly defined, except at 154°E (Fig. 2d).

b) Seasonal variations:

1) zonal components. From January to June, the main change in surface circulation is the quasi-disappearance of the New-Guinea current, only weakly remaining as a thin eastward flow close to the coast at 146°E (Fig. 2b). In the other three cross sections of FOC 2, the surface is occupied by a westward flow spreading from the south of the zone to approximatively 2°N. This water is the upper part of the equatorial current, the velocity core of which always found south of the equator, is

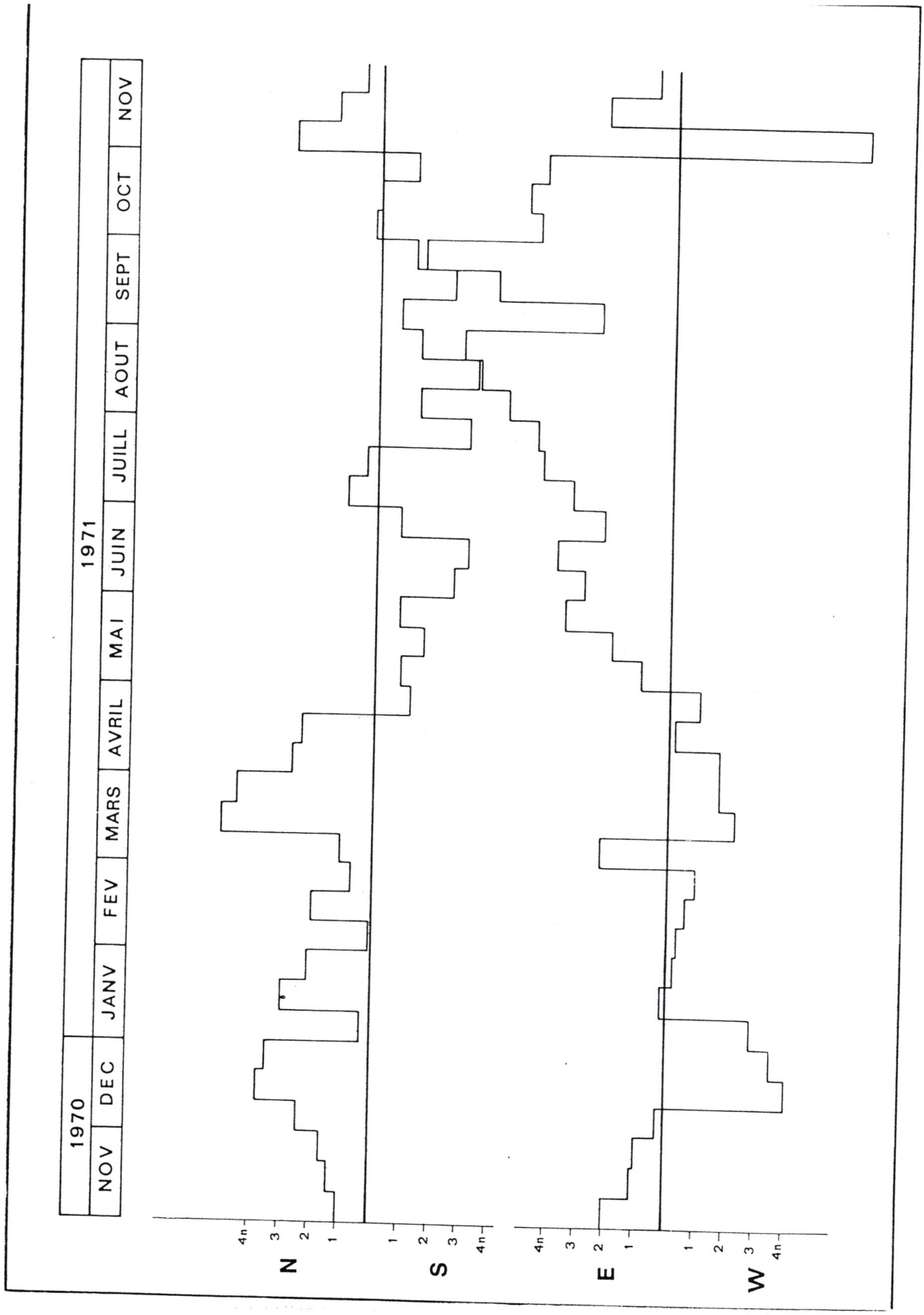

Diagram : 1 Wind conditions observed from November 1970 to November 1971 at Manus Island (the stepwise of the .curves is due to the average of the wind components over periods of ten days) either close to the surface (Fig. 2c and 2d) or in depth (Fig. 2a and 2b). This current is existing downwards to 400 m and is thus more developped than in January.

In June the southern limit of the north equatorial counter current is nearer to the equator than in January; its velocity core can exceed 60 cm/s as shown in figure 2a, 2b, 2c. Thus, in the south east trade winds season, it seems that the growth of the equatorial current has involved an equivalent strengthening of the north equatorial counter current. In January, the later, being poorly fed by the equatorial current, also weakens and has a minimal flow.

In subsurface, the equatorial undercurrent flow is scarcely altered by the reversing of the wind and its speed and depth features are roughly the same through the seasons. However its links with the north equatorial counter current are stronger in June : both currents are hardly separated and the equatorial undercurrent seems to be underlying part of the north equatorial counter current. One can assume that farther west both flows are mingled (BURKOW and al., 1960), assumption in accordance with the main features of their waters. On the contrary of what was shown in January, it is difficult in June to precise the lower limit of the equatorial undercurrent and to describe its deep extensions; only in the figure 2d, one can see two deep east flows, north of 3°N and between the equator and 3°S.

2) meridional components. The equatorial circulation system being essentially zonal, north-south components have weak intensities and show important space-time variations; along the cross sections, the reversal of these components makes the sequential analysis difficult.

During FOC 1 cruise, superficial waters were roughly drifting northwards, that motion being canceled near the New-Guinea coast, except at 146°E (Fig. 1b). At that season, there seemed to be no direct correlation between zonal and meridional components of the surface flows. At the level of its velocity core, near 100 m depth, the equatorial current was preferentially drifting northwards with a meridional speed not exceeding 20 cm/s. In subsurface layers, motions were more complicated at the equatorial undercurrent velocity core level, the meridional component was northwards at 142°30, southwards at 146°E, northwards at 150°E and non existent at 154°E. That alternation suggests that, in its eastwards movement, the equatorial undercurrent could follow a sinusoidal trajectory with an axis a little north of the equator. Below 300 m, meridional components were quasi inexistent and only at 150°E (Fig. 1c'), the intermediate equatorial current seemed to have a weak southward drift.

During FOC 2 cruise, the north–south components of the flow were stronger and less erratic than during FOC 1, and particularly north of the equator where the north equatorial counter current had a well pronounced northward drift at 149°E and 154°E (Fig. 2c' and 2d'). South of the equator, surface waters belonging to the equatorial current had often, from one cross section to another, components of opposite direction, but deeper the drift was preferentially northwards.

In subsurface, the equatorial undercurrent velocity core, defined by the 40 cm/s isotach, was at 1°N. Its meridional drift was more homogeneous and was southward for the four cross sections and this can explain that its southern boundary had moved from 1°S to 3°S between 142°30E and 154°E. On the three western cross sections nothing can be said about meridional components below 300 m; however at 154°E (Fig. 1d') the two deep extensions of the equatorial undercurrent have a weak northward and southward component respectively north and south of the equator.

5. – Conclusion

In situ records made during the year 1971 north of New–Guinea allow to describe the currents system and the wind driven circulation fluctuations during two opposite wind situations. It appears in fact that the influence of the wind regime not only exerts on the coastal New–Guinea current, but also disturbs the great oceanic drifts like the equatorial current and the north equatorial counter current. However, the equatorial undercurrent variations do not seem to be directly linked to variations of the surface hydroclimatic regime.

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1.7 WATER MASSES AND CURRENTS IN THE SOUTH CHINA SEA AND THEIR SEASONAL CHANGES

by

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Introduction

In the past, many oceanographic studies have been conducted in the South China Sea and the results have been published (e.g. M.Uda, 1941). Thus K. Wyrtki (1961) and E.C. LaFond (1963) reported the results of NAGA Expedition.

Many other results from CSK Program are on "The Kuroshio", the first CSK symposium volume edited by J.C. Marr (1970), "Kuroshio" by H. Stommel and K. Yoshida (1972), and "The Kuroshio II", the second CSK symposium volume edited by K. Sugawara (1972).

However, our basic knowledge of the hydrography in the South China Sea remains poor yet particularly during summer and winter monsoon seasons. From this point of view the authors present this paper for comparing the changes of water masses and currents in two seasons of summer and winter monsoons in the sea-region in question, aiming at tbe development of fisheries oceanography there.

Using the data from cruises of Hakuyo Maru, November 23, 1940 to January 20, 1941 and August 20-October 19, 1942, Toyama Maru, August 15-October 27, 1941, Yoko Maru, October 12-December 3, 1942, S.F. Baird, December 1,1948 to August 28, 1949, and Orlick, January 17-October 27,1960, and other data of CSK ranging from 1965 to 1968, they drew maps of the distributions of water temperature, salinity, transparency and color of the sea, dynamic anomaly AD, maximum and minimum in salinity, and the minimum in dissolved oxygen for two seasons of summer and winter monsoons.

Results and discussions

Currents

Fig. 1 and Fig. 2 show the difference in pattern of currents between the two seasons. Thus in the northern summer, Fig. 1. when Southwest monsoon prevails, northerly Monsoon Currents are dominant in the middle part of the South China Sea and Java Sea and inflow of oceanic water is strong through Celebes Sea and Flores Sea, while the water of South China Sea flows out through Taiwan Strait and Luzon Strait. (Fig. 1, 7, 8)

On the contrary in winter (Fig. 2) responding to the Northeast monsoon along the Asiatic Continent and Sunda Islands southerly flow of water prevails to cause a cyclonic pattern of surface water movement against an anticyclonic circulation pattern in summer.

As for the exchange of water with the outer ocean, in winter inflow of oceanic water is strong through Taiwan Strait and Luzon Strait and outflow from the South China Sea is strong through Flores Sea and to less but considerable degree through Celebes Sea. (See Fig. 2, 9, 10)

A conspicuous cold cyclonic eddy as evidenced off South Vietnam and upwellings (Fig. 3, 4, 5, 6, 7)

A conspicuous cold cyclonic eddy with upwelled water as a back-eddy was found in the northeast offing of South Vietnam characterized by low temperature, transparent and high salinity water. Obviously this eddy is caused as a combined effect of the Monsoon Current and topography (orographic effect) and may influence on the fisheries productivity varying year by year responding to the strength of the summer monsoon.

In winter, trend of upwelling in the broad area in the middle part of the South China Sea is seen corresponding to the cyclonic pattern of current north of Borneo and Palawan Islands (See Fig. 2, 9, 10, 11, 12).

From the distribution of oxygen-minimum in waters west of Luzon-Palawan Islands, 1.7–2.0 ml/1 at depths 100–900 m in summer and 1.5–2.0 ml/1 in at depths 200–800 m in winter, upwelling is evidenced in the north of Palawan Island especially in summer. (See Fig. 13, 14).

Water mass distribution (Figs. 1, 2)

As dominant coastal water mass areas the following can be mentioned: C_1 the area of offing of Hong Kong, C_2 the inner part of Tongking Bay, C_3 offing of South Vietnam having its origin mainly in Mekong River, C_4 Gulf of Thailand System, C_5 offing northwest of Borneo and Sarawaku and C_6 Java Sea System with the southern part of Makassar Strait.

Another separate coastal water mass area C_7 is in the west offing of Luzon Island. These waters are characterized by low transparency and low salinity particularly for continental coastal waters C such as C_1, C_2, C_3, C_4, C_5 and C_6, some of which are generally located in the estuaries along the equatorial rainy zone in the Austral-Asian Mediterranean Sea.

On the other hand the areas of transparent and high salinity water masses vary seasonally under the influence of the changes of water flow from and to the outer ocean. Thus salinity-maximum maps (Figs. 15 a, b 16 a, b) indicate the extension of the saline branch of the North Pacific Central Water aud the increase of salinity from summer with values 34.4–34.9 ‰ at depths 50–300 m to winter with values 34.6–34.9 ‰ at depths 50–300 m, while the salinity–minimum maps (Figs. 17 a,b 18 a,b) show the mixed extension of the North Pacific Subarctic Intermediate Water with salinity of 34.4 ‰ at depths 200 - 600 m in summer and with salinity of 34.4–34.6 ‰ at depths 100–900 m in a winter.

This fact indicates a stronger inflow of the Intermediate Water in summer.

Finally the authors point to the importance of further studies of the water exchange through Malacca Strait and other straits between the South China Sea and the Austral–Asiatic Mediterranean Sea and the Indian Ocean.

Furthermore the authors would like to add the followings;

(1) Our hydrographical results, particularly the cyclonic eddy in summer, may contribute to the fisheries production in future.

(2) The coastal water zones, $C_1 - C_7$, are feared to become polluted in future.

(3) Climatic change, particularly of Monsoons in winter and summer, may reflect in the fluctuation of oceanographic conditions and fisheries which should be studied intensively in future.

Acknowledgement

The authors are grateful to Prof. Ken Sugawara for his kind advice and assistance in preparing this paper.

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LaFond, E.C. (1966): South China Sea. *Encyclopedea of Oceanography* (edited by R. Fairbridgge), pp. 829–837., in which Fig. 6 on p.834 and the following sentences already pointed out the upwelling in the offing of Vietnam; "The thermocline rises, and pronounced upwelling takes place near the coast, with water of less than 26°C at the surface........ However, the maximum upwelling occurs off the Central South Vietnam Coast in mid–summer."

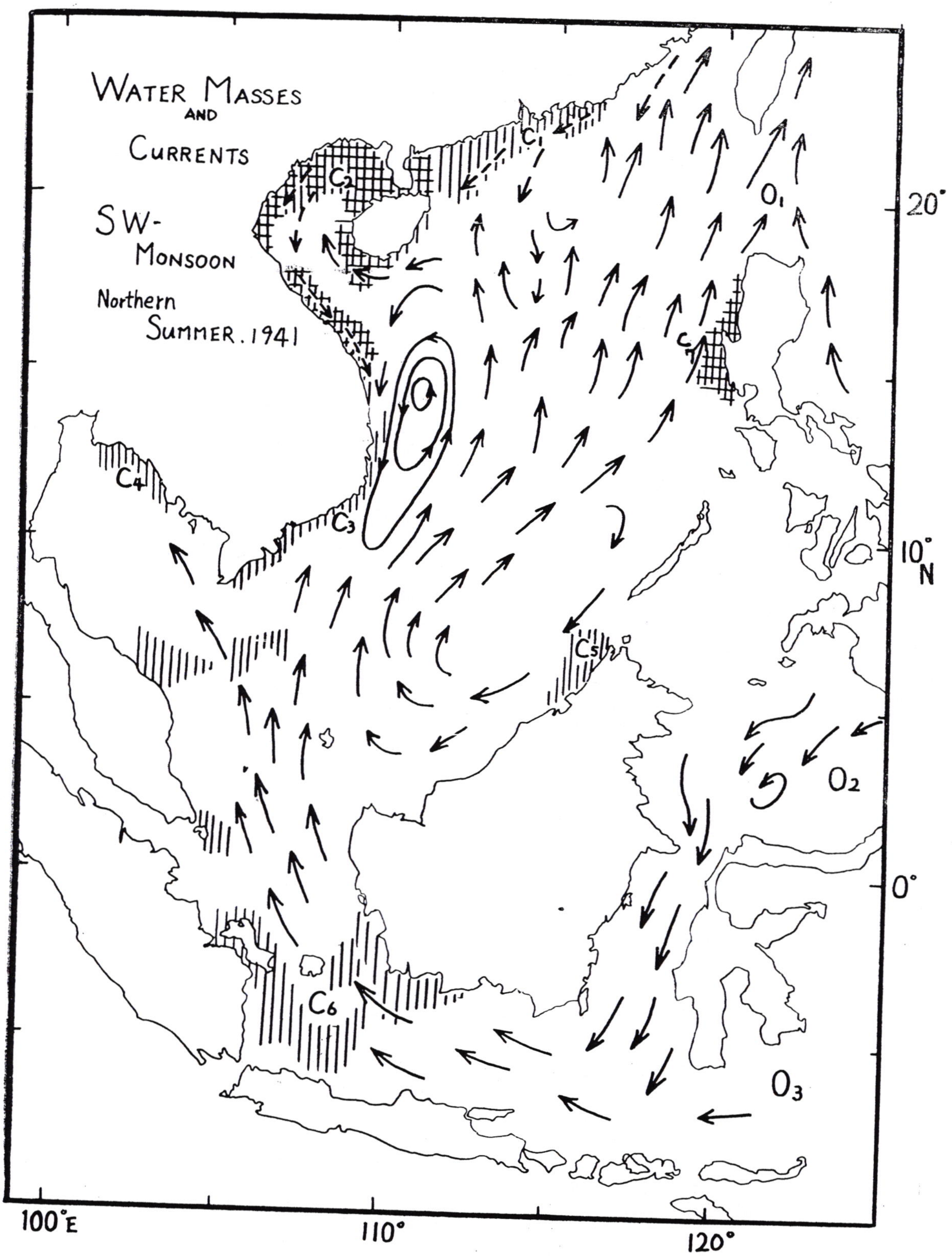
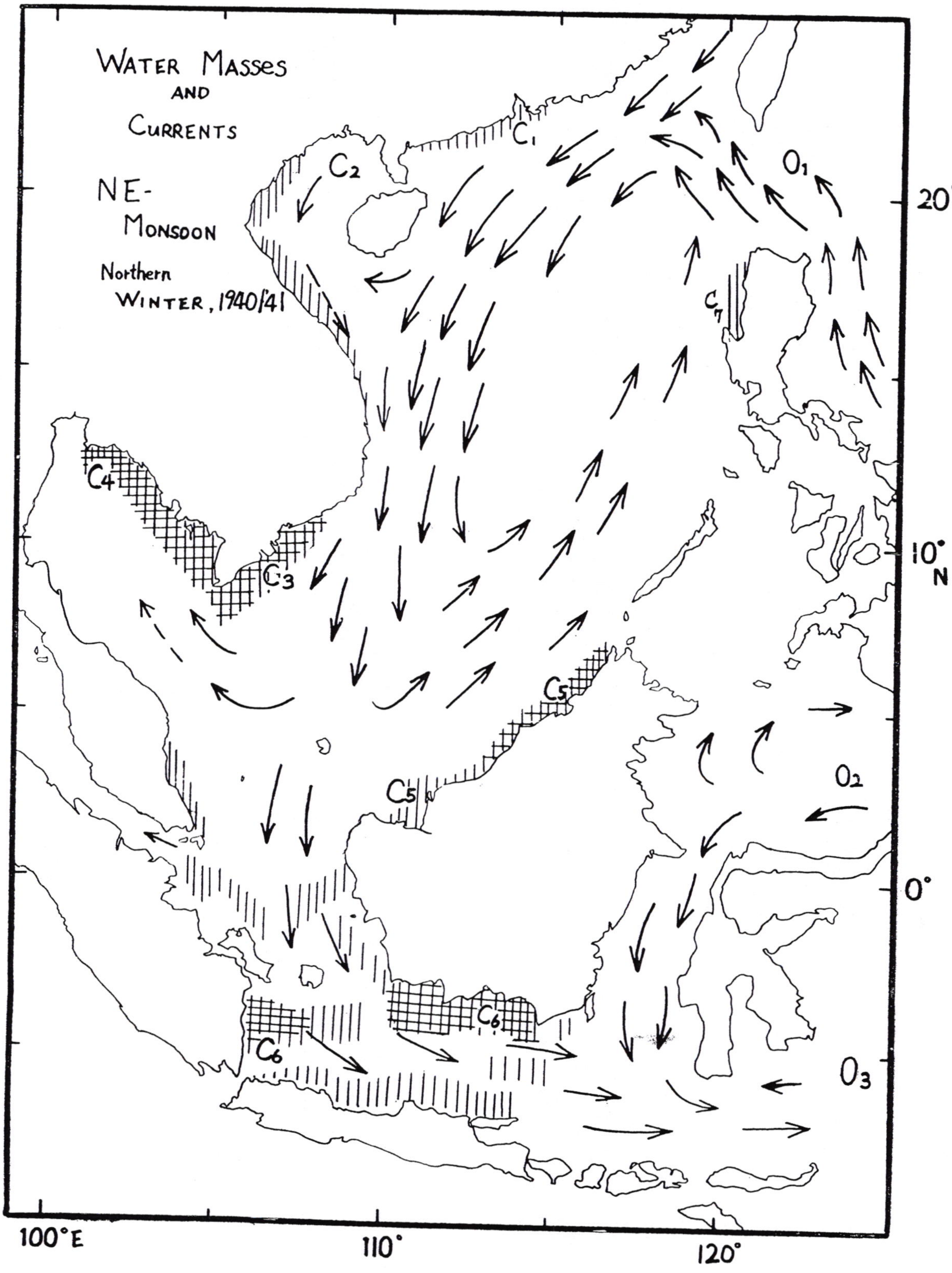

WATER MASSES AND CURRENTS
SW-MONSOON
Northern SUMMER. 1941
C1
C2
C3
C4
C5
C6
C7
O1
O2
O3
20°
10° N
0°
100°E
110°
120°

Fig. 1



WATER MASSES
AND
CURRENTS
NE-
MONSOON
Northern
WINTER, 1940/41
C1
C2
C3
C4
C5
C5
C6
C6
C7
O1
O2
O3
20°
10°
N
0°
100°E
110°
120°

Fig. 2

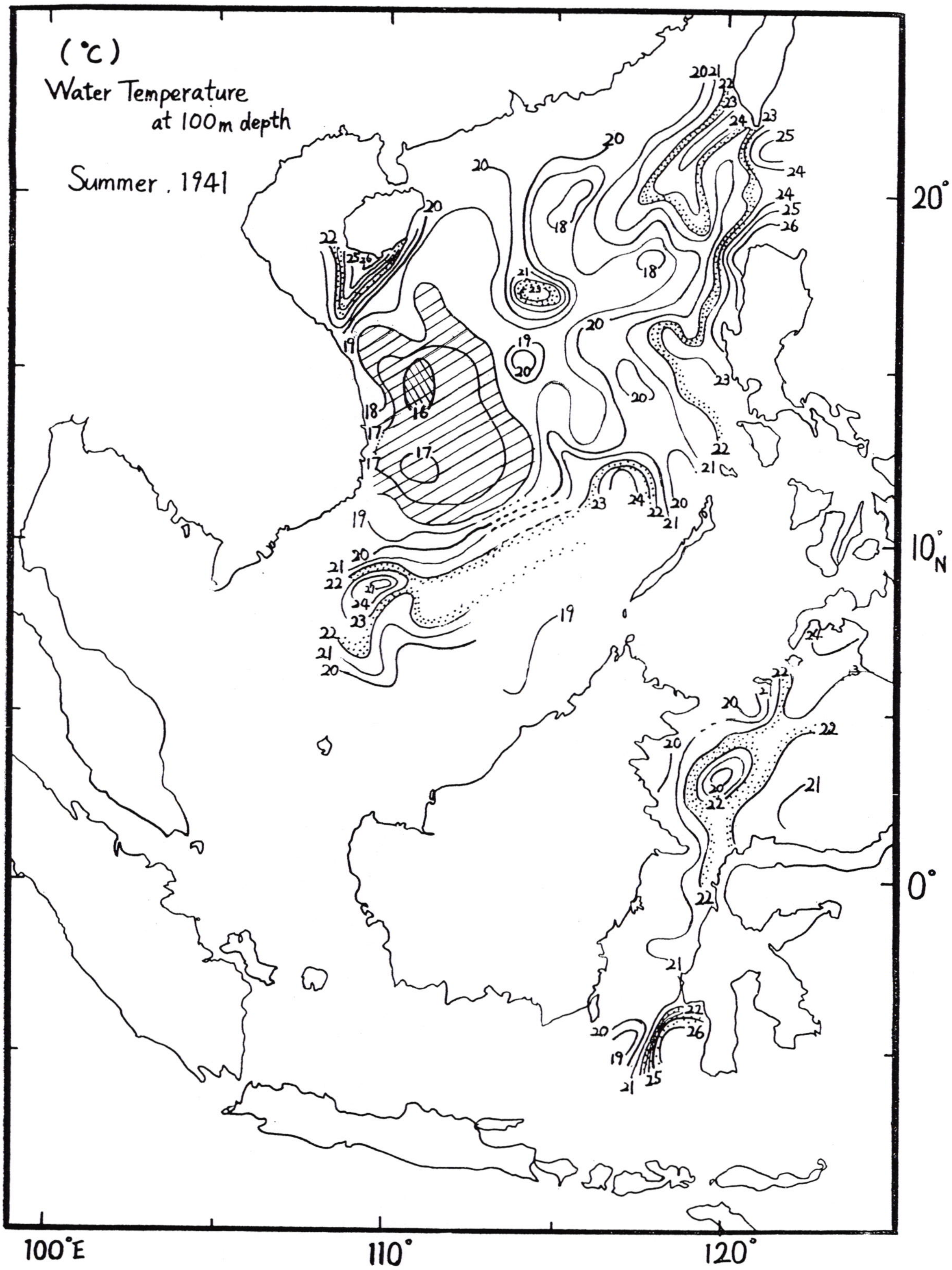

(°C)
Water Temperature
at 100m depth
Summer, 1941
20°
10°N
0°
100°E
110°
120°

Fig. 3

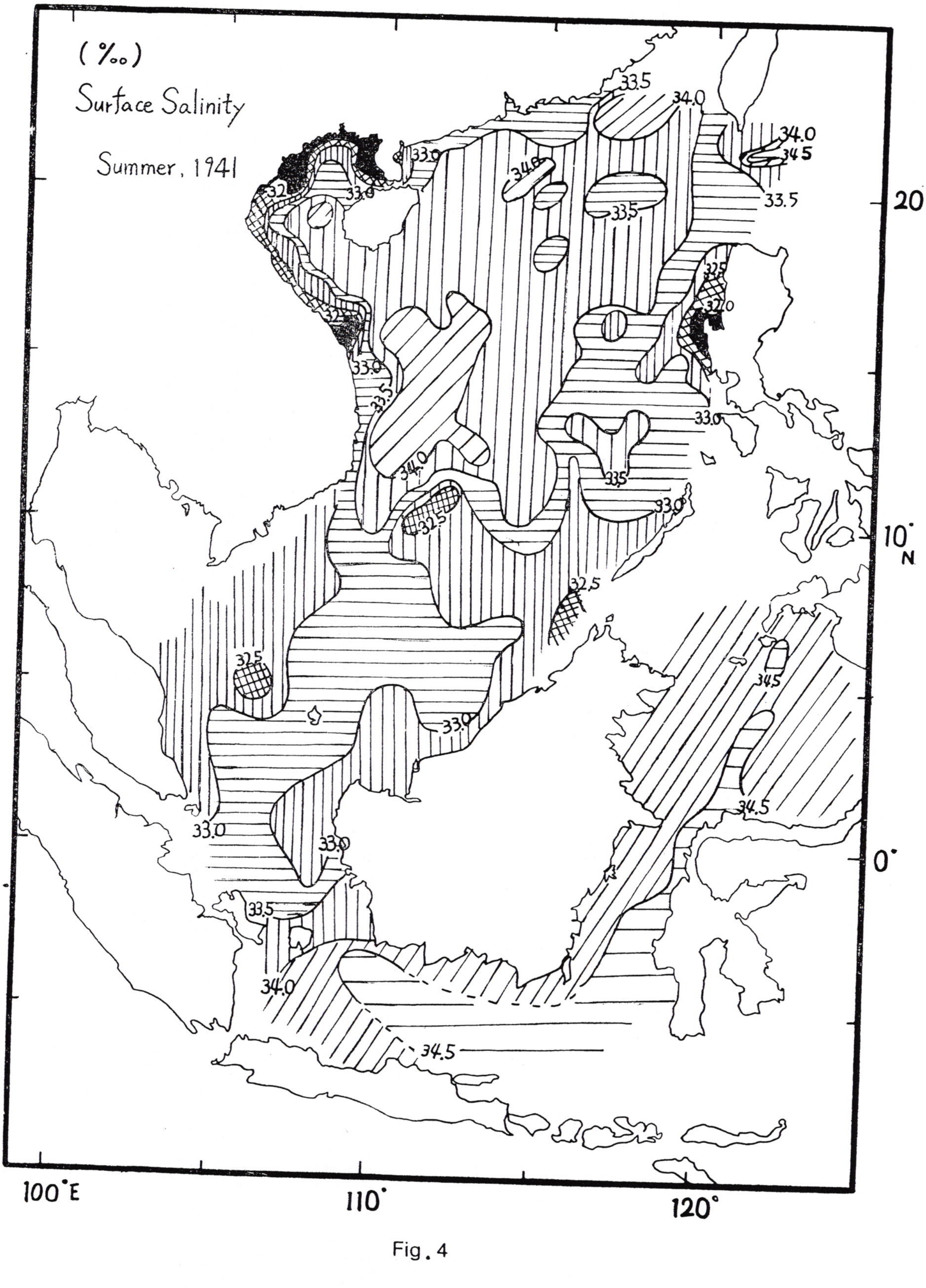


Fig. 4

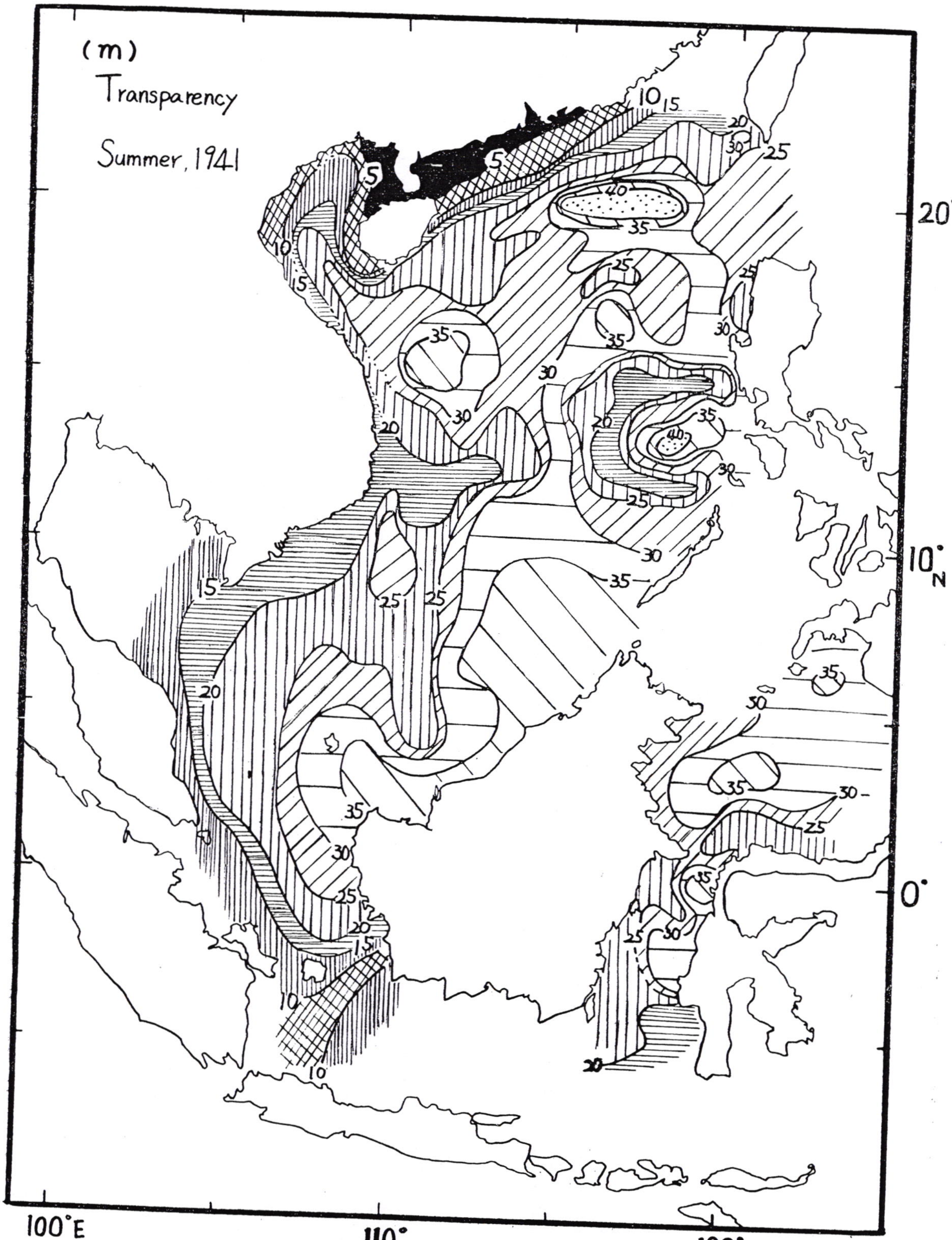
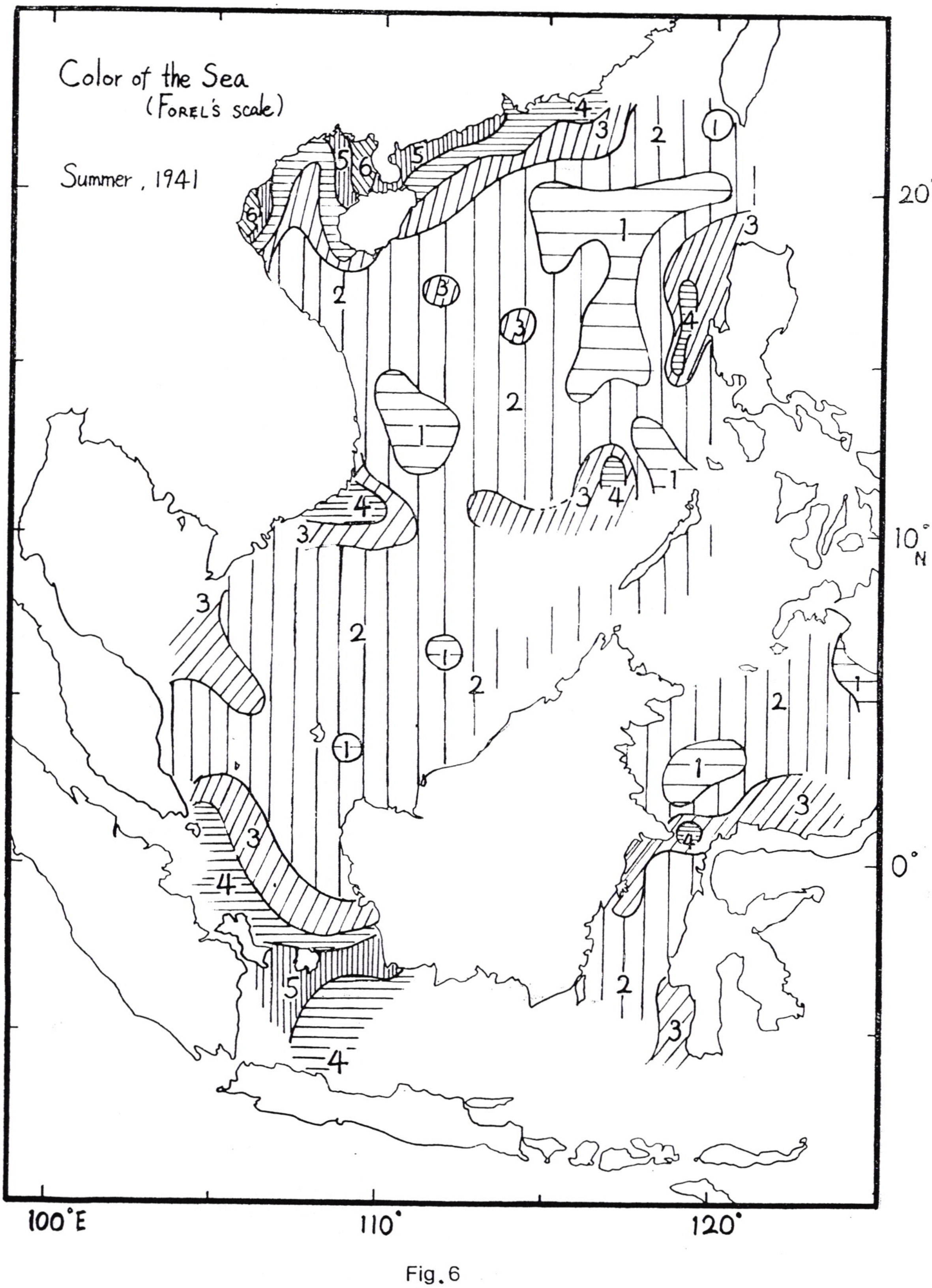


Fig. 5



Color of the Sea
(Forel's scale)
Summer, 1941
20°
10° N
0°
100°E
110°
120°

Fig. 6

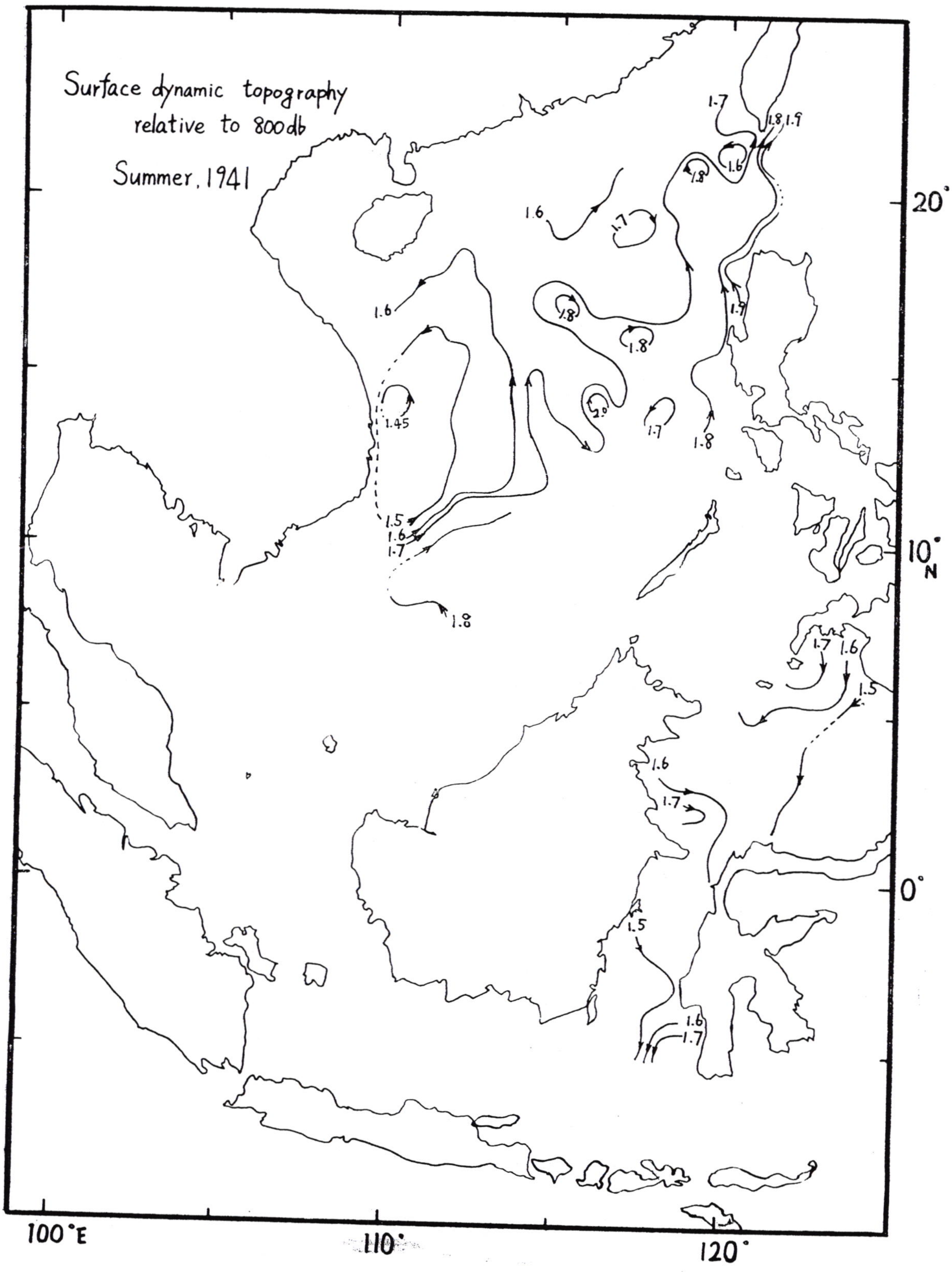
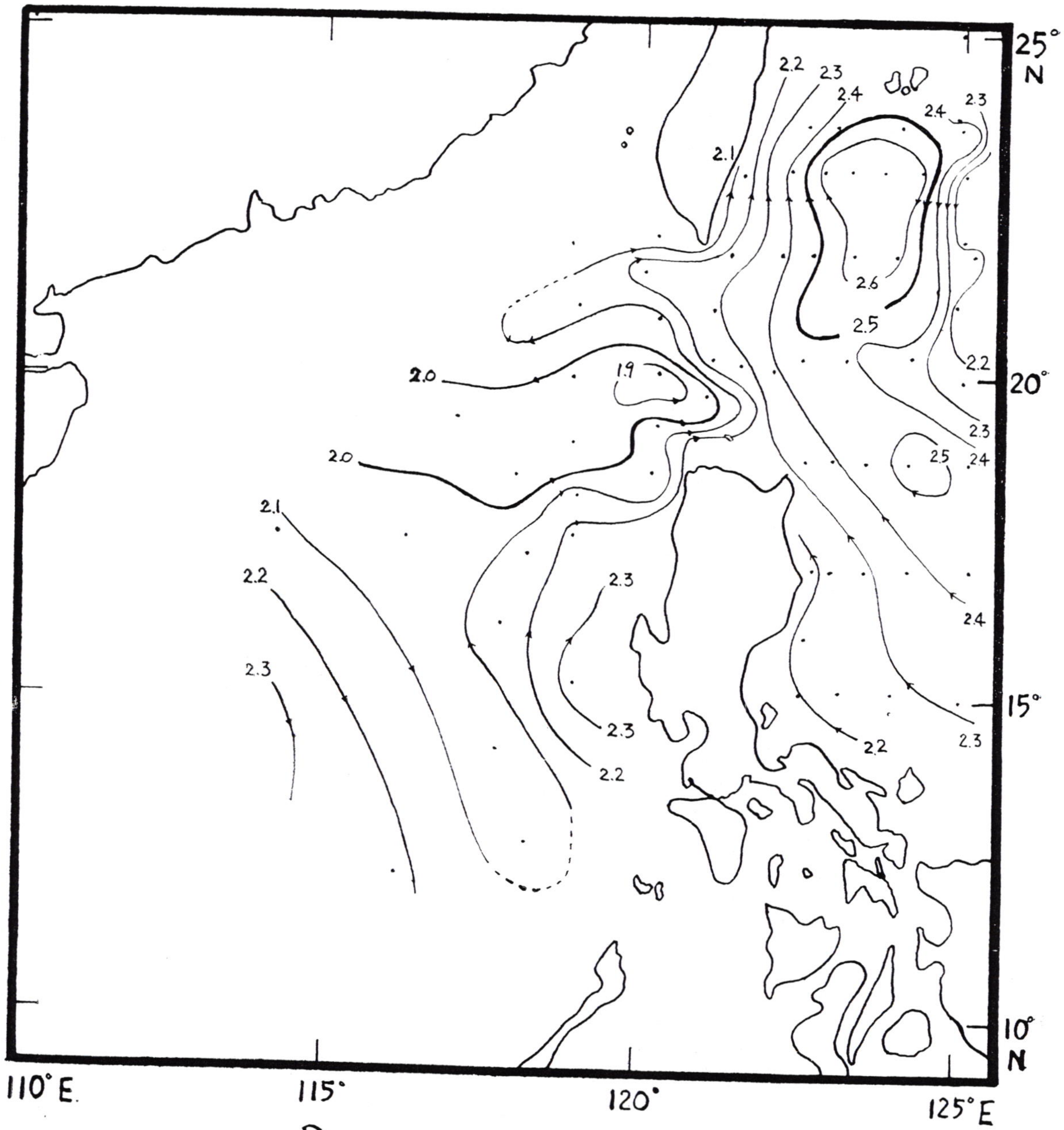

Surface dynamic topography
relative to 800db
Summer, 1941
20°
10°
N
0°
100°E
110°
120°

Fig. 7



Dynamic Depth Anomalies (dyn. m.)
(0/1200 db.) Summer 1966

Fig. 8

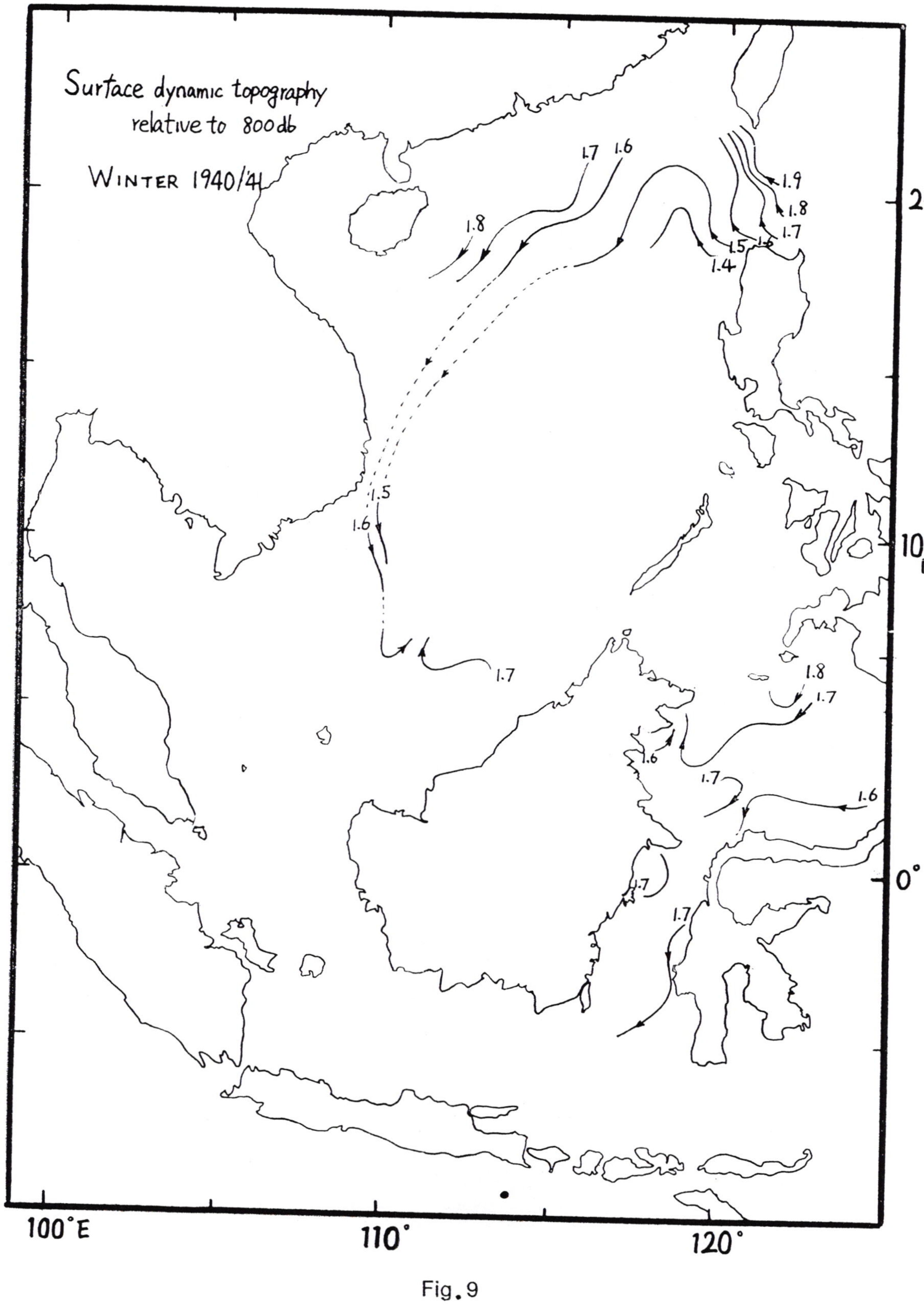

Surface dynamic topography
relative to 800db
WINTER 1940/41
1.7
1.6
1.9
1.8
1.7
1.8
1.5
1.4
1.5
1.6
1.7
1.8
1.7
1.6
1.7
1.6
1.7
1.7
20°
10°N
0°
100°E
110°
120°

Fig. 9

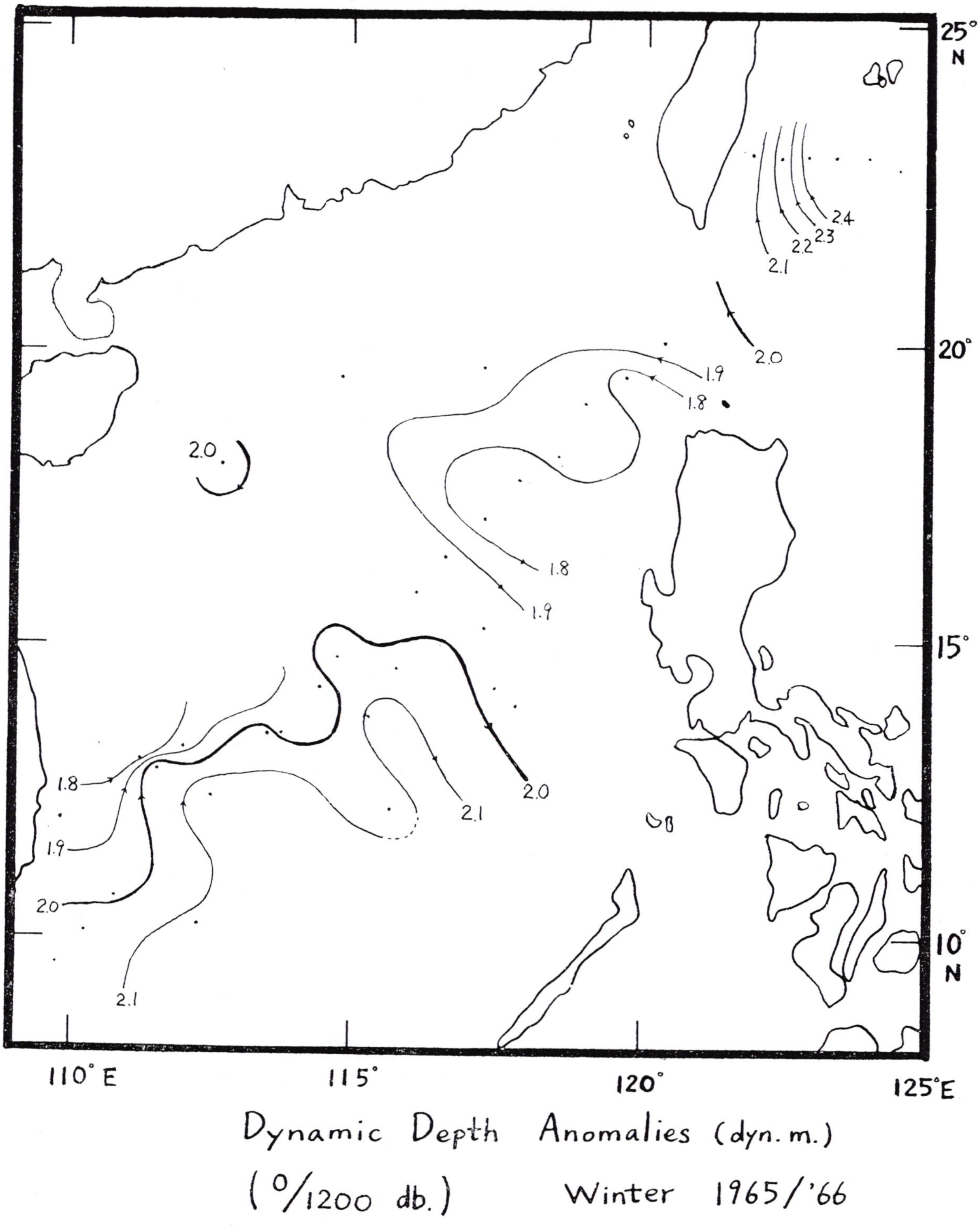
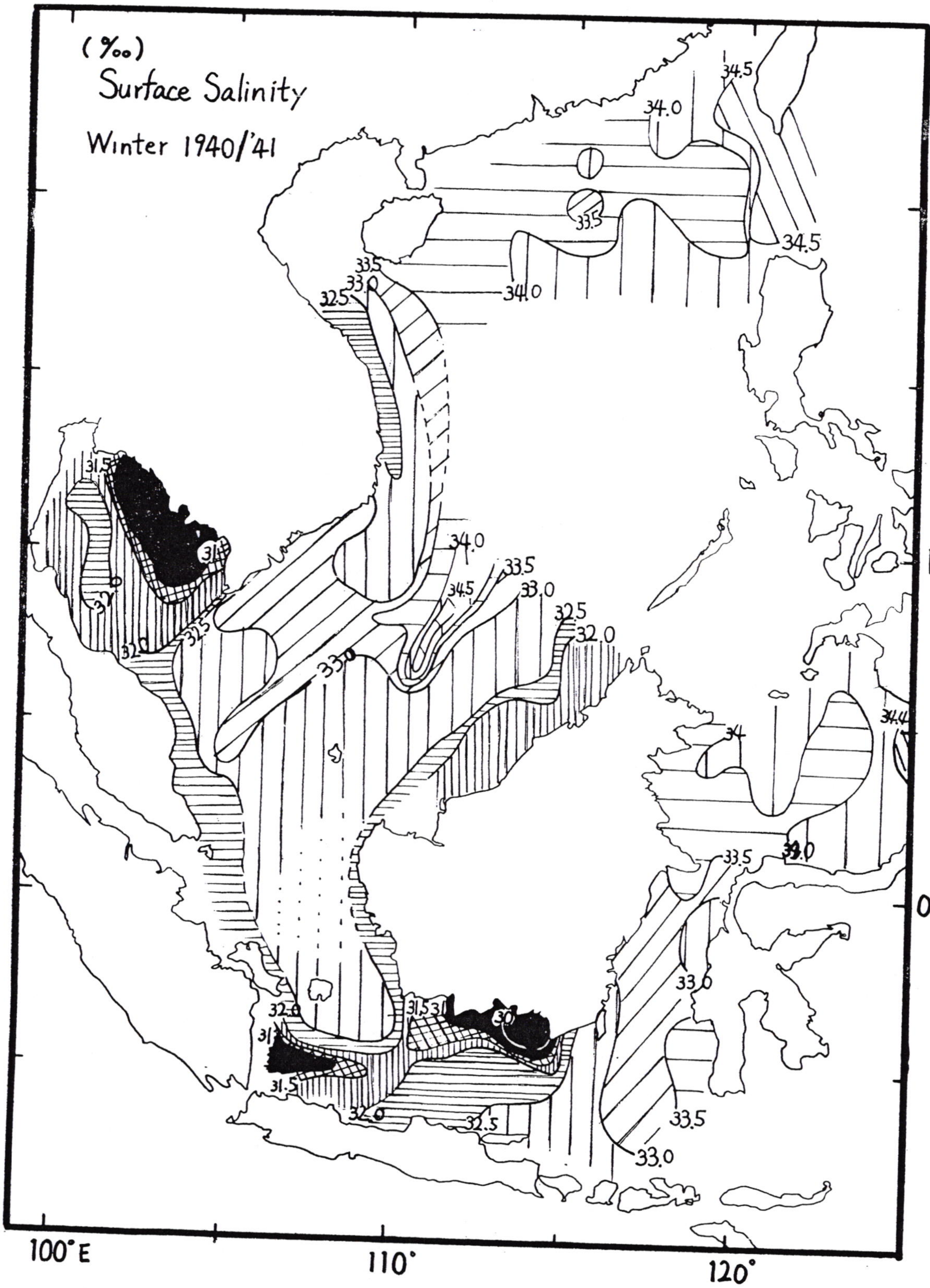

25°
N
20°
15°
10°
N
110° E
115°
120°
125°E
2.4
2.3
2.2
2.1
2.0
1.9
1.8
2.0
1.8
1.9
1.8
1.9
2.0
2.1
2.0
2.1
2.1
Dynamic Depth Anomalies (dyn. m.)
(0/1200 db.) Winter 1965/'66

Fig. 10.



(‰)
Surface Salinity
Winter 1940/'41
34.5
34.0
33.5
34.5
34.0
33.5
33.0
32.5
31.5
31.5
32.0
32.5
34.0
33.5
34.5
33.0
32.5
32.0
33.0
34
34.4
33.5
34.0
33.0
32.0
31.5
30
31.5
32.0
32.5
33.5
33.0
20°
10°N
0°
100°E
110°
120°

Fig. 11

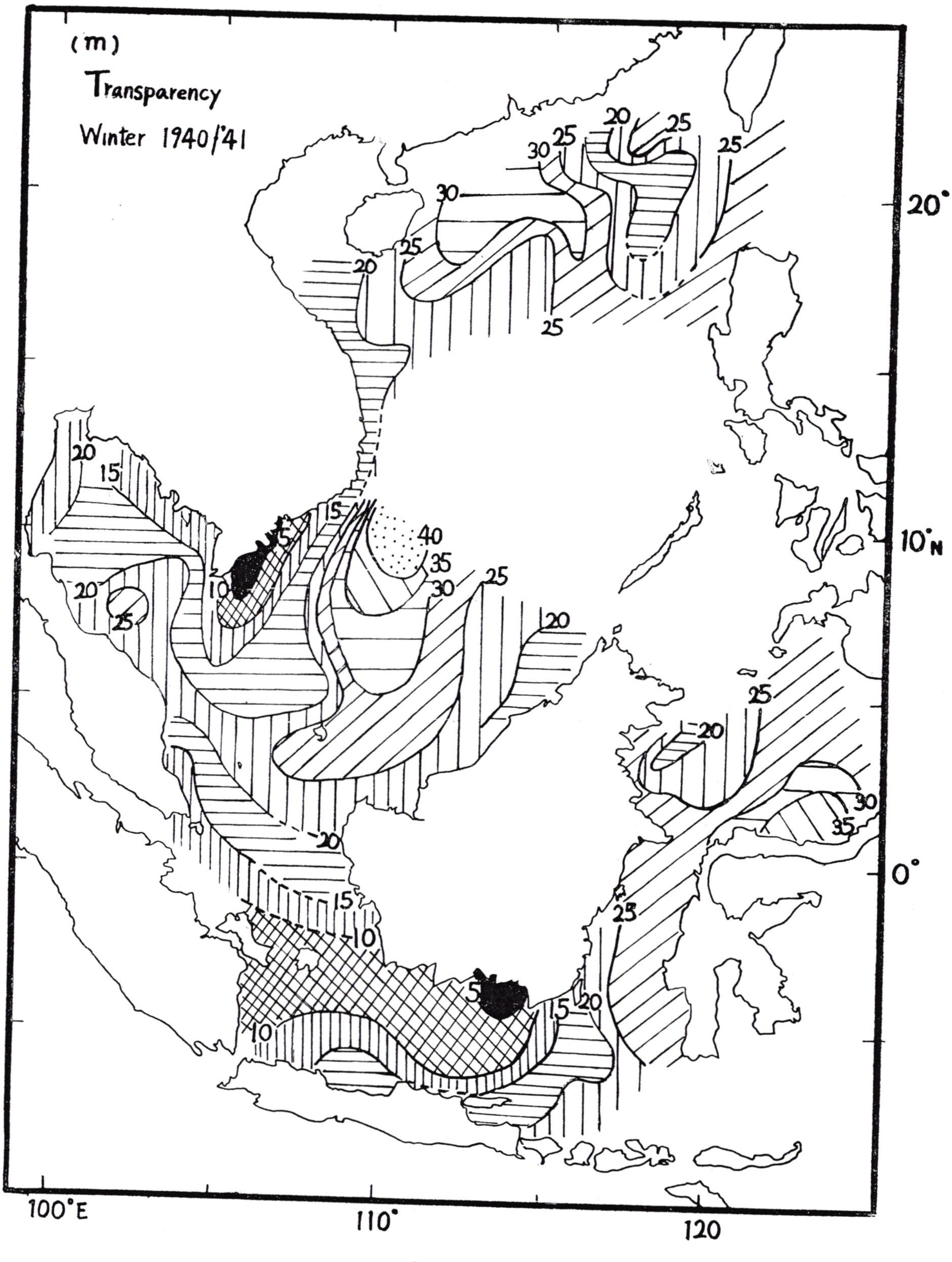
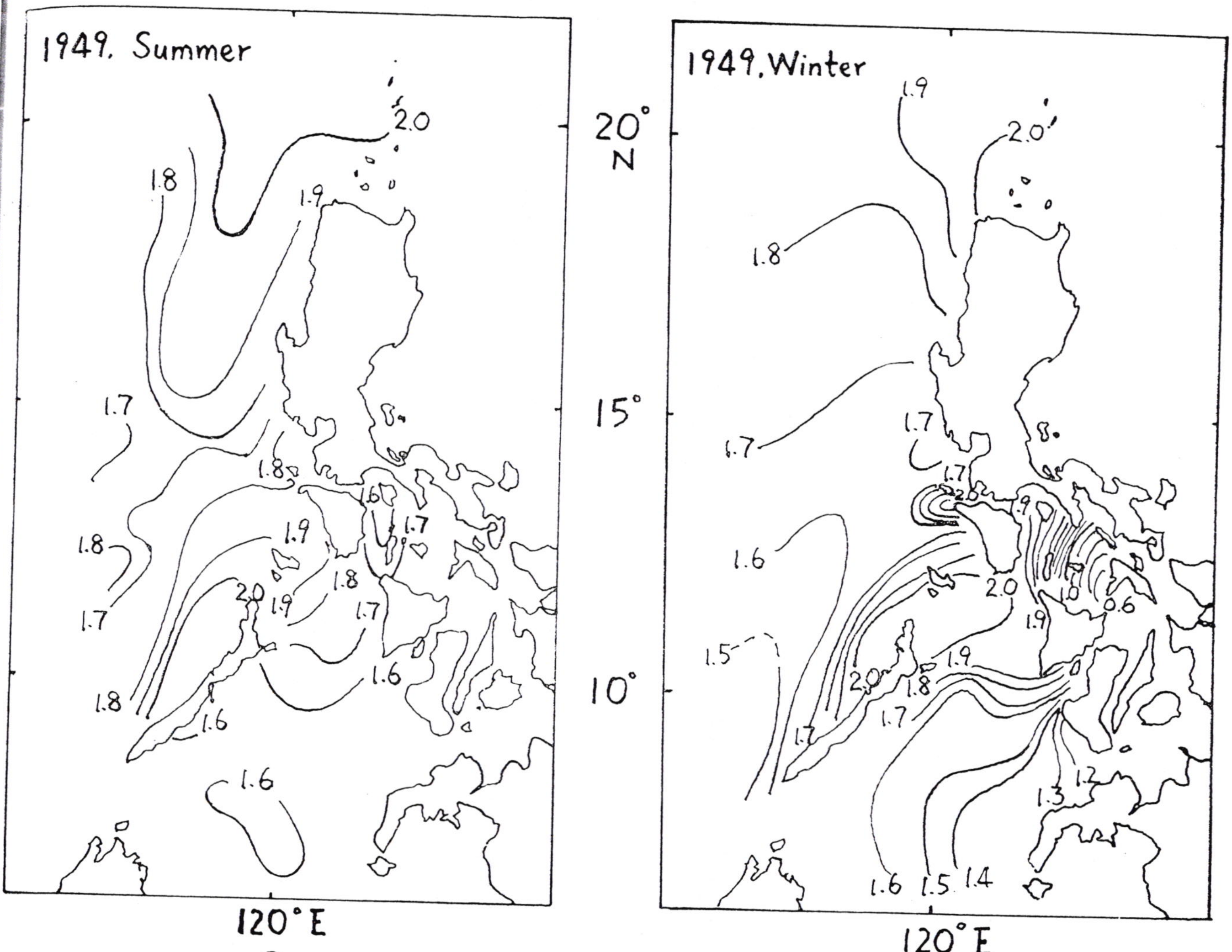
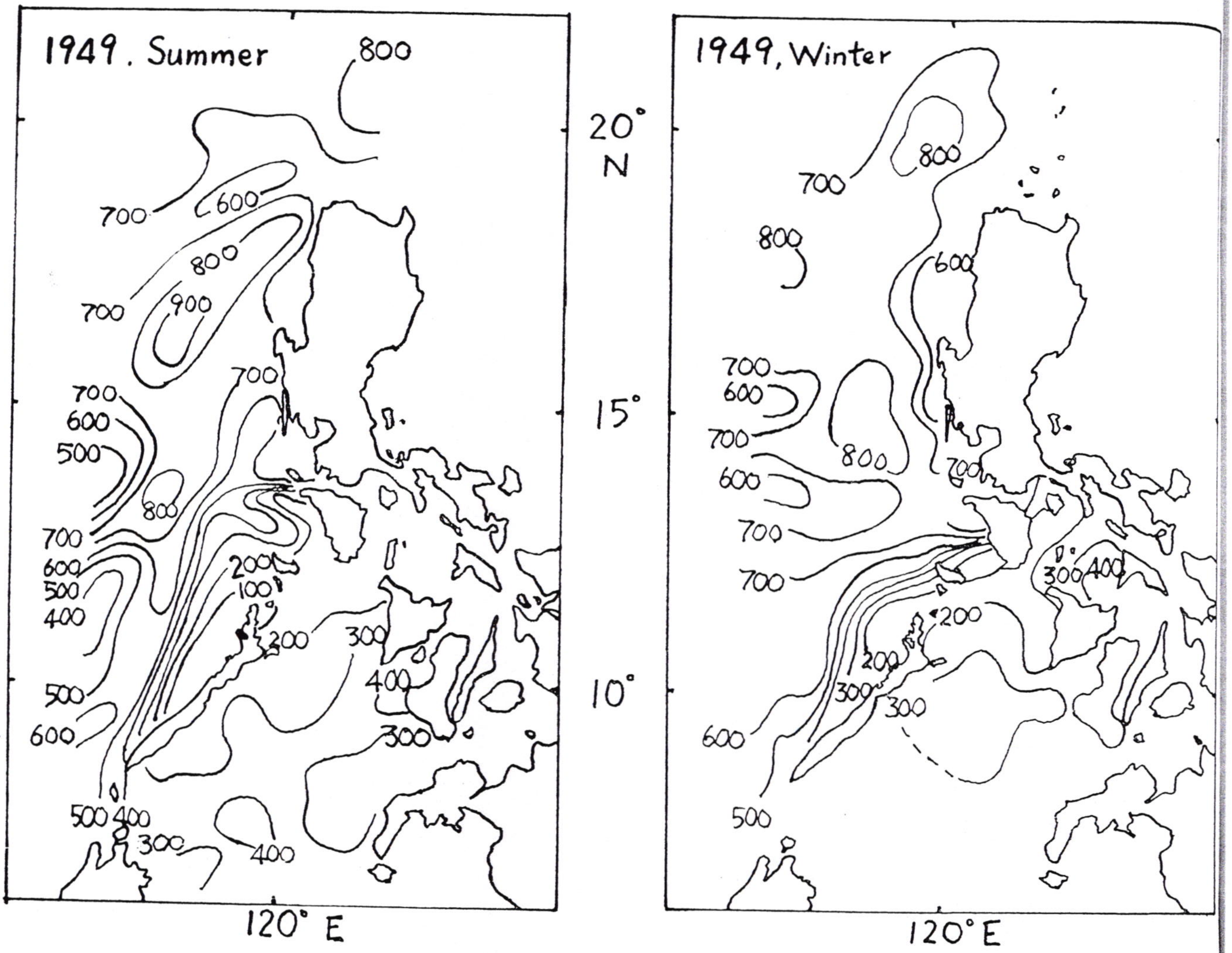


Fig. 12



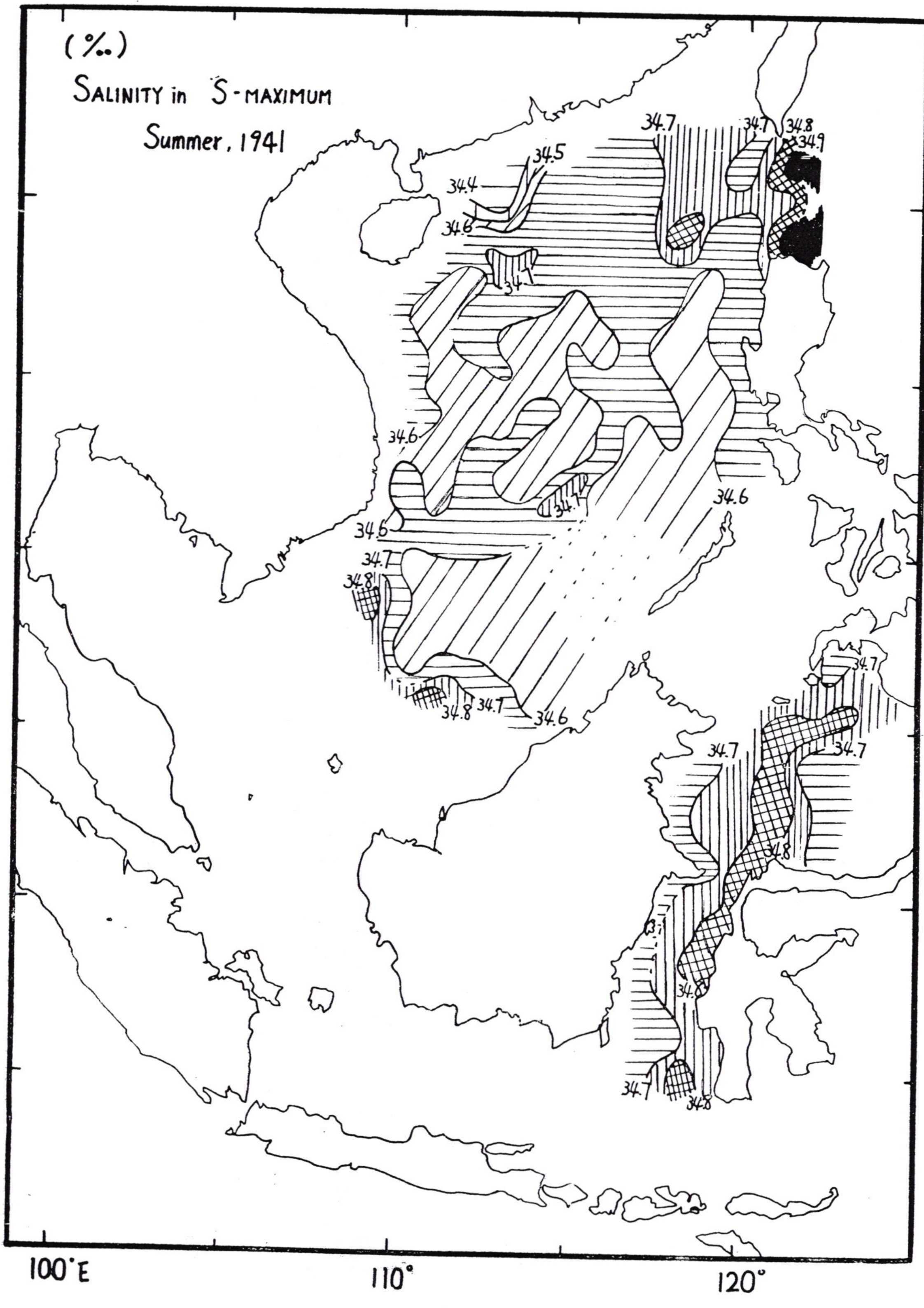
Oxygen content (ml/l) in the oxygen minimum

Fig. 13 a., b.



Depth (m) of the oxygen minimum

Fig. 14 a., b.



(‰)
SALINITY in S-MAXIMUM
Summer, 1941
34.7
34.7
34.8
34.9
34.5
34.4
34.6
34.7
34.6
34.7
34.6
34.6
34.7
34.8
34.8
34.7
34.6
34.7
34.7
34.7
34.8
34.8
34.7
34.8
20°
10°N
0°
100°E
110°
120°

Fig. 15 a

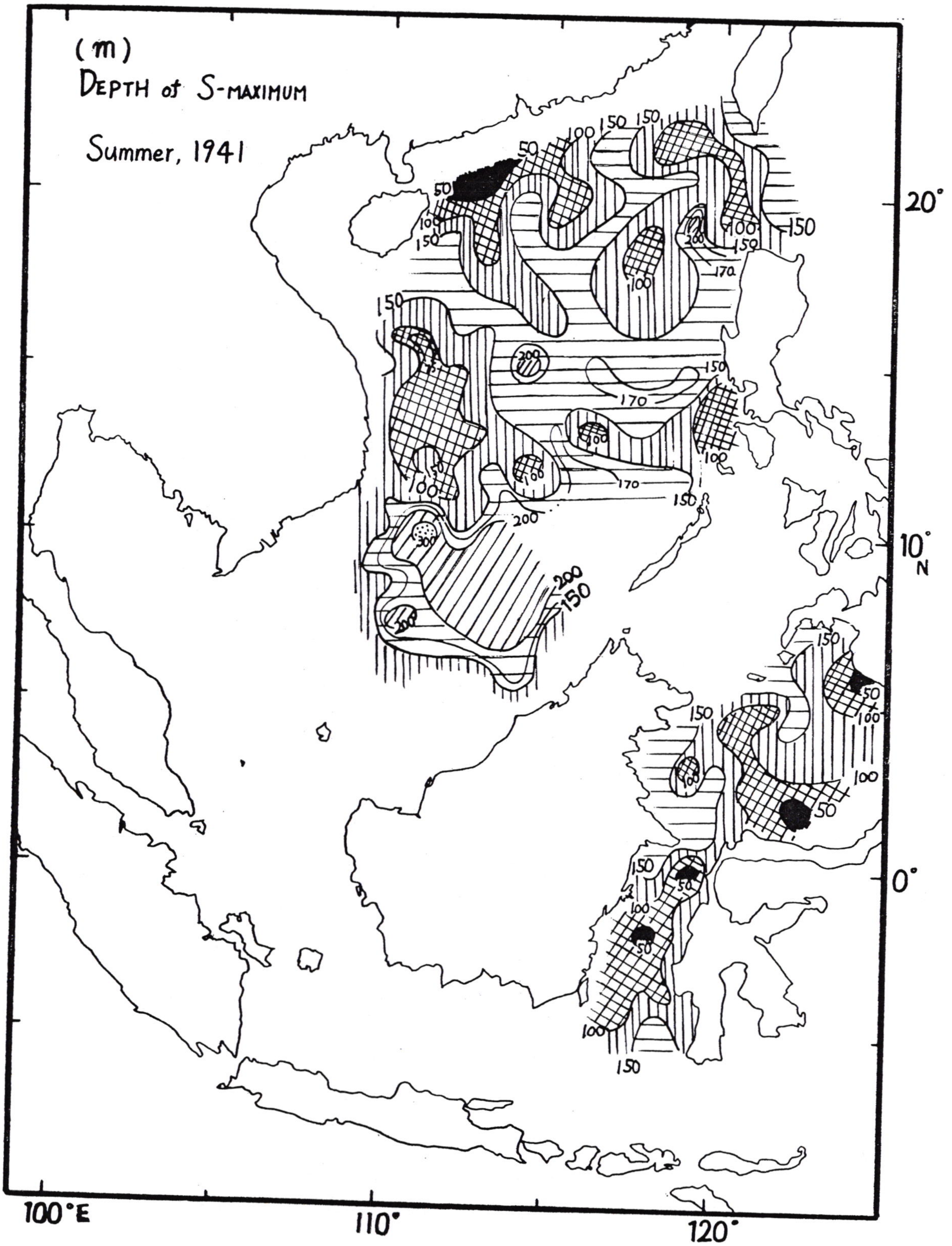
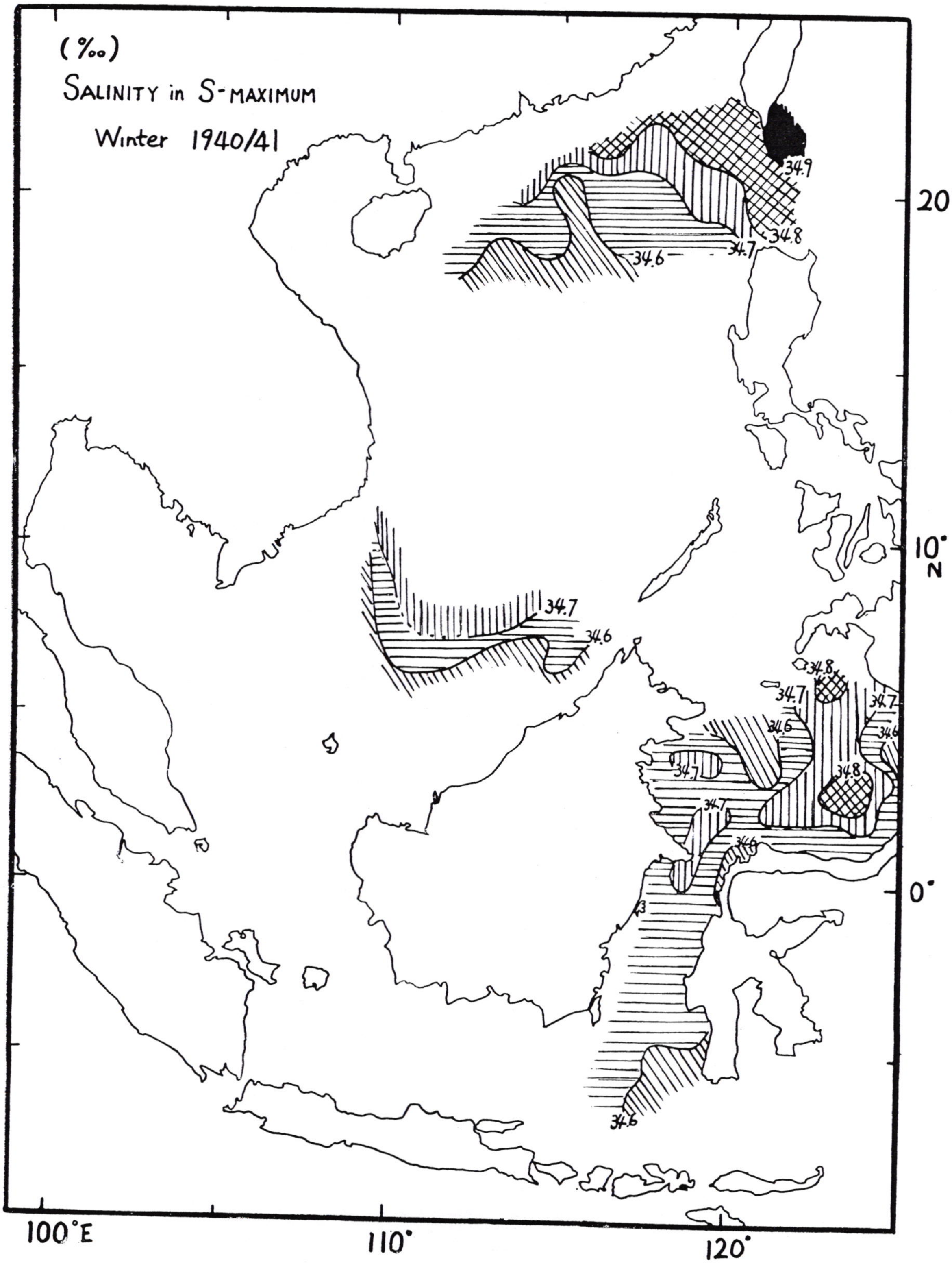


Fig. 15 b



(‰)
SALINITY in S-MAXIMUM
Winter 1940/41
34.9
34.8
34.7
34.6
20°
10° N
0°
100°E
110°
120°

Fig. 16 a.

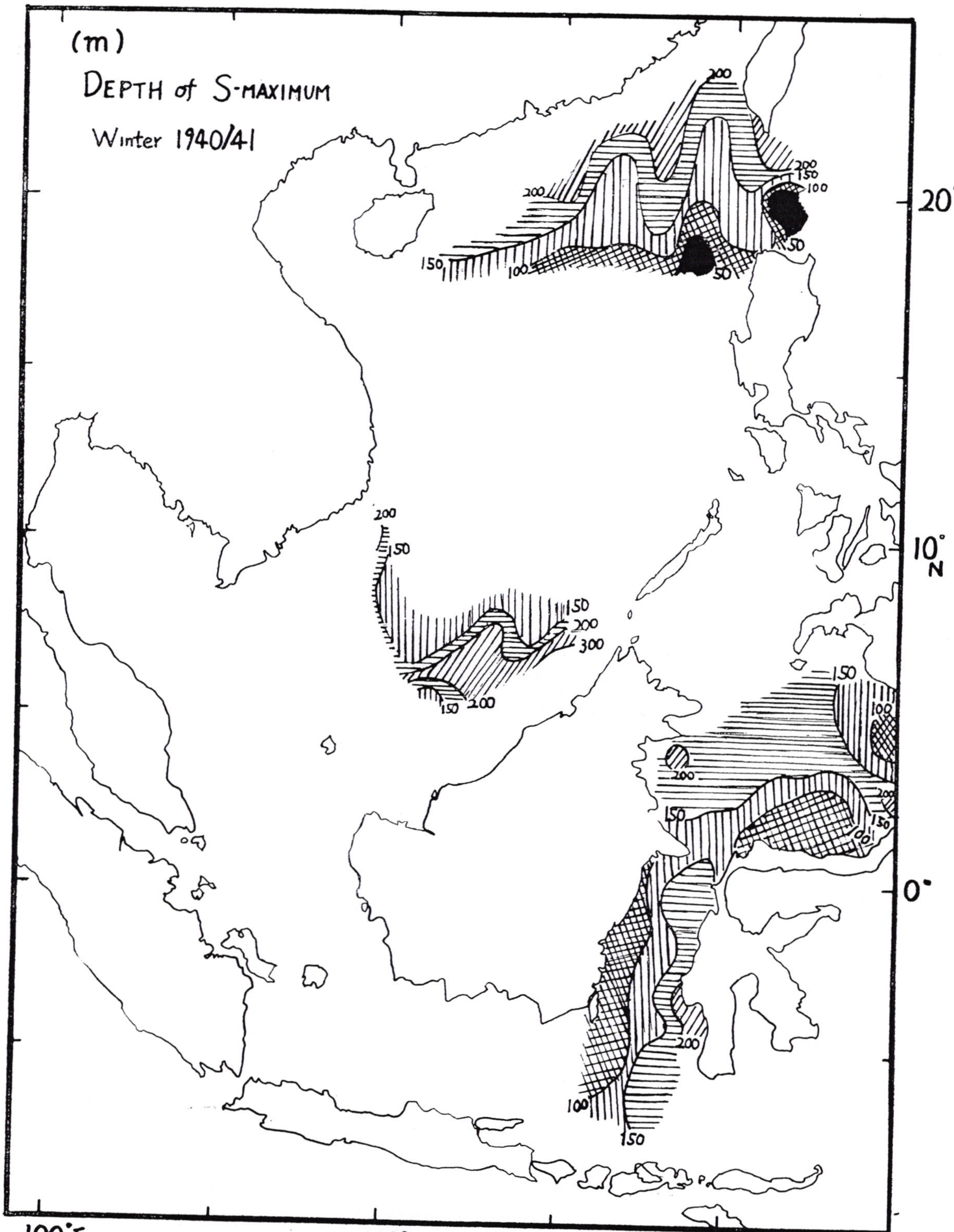


Fig. 16 b.

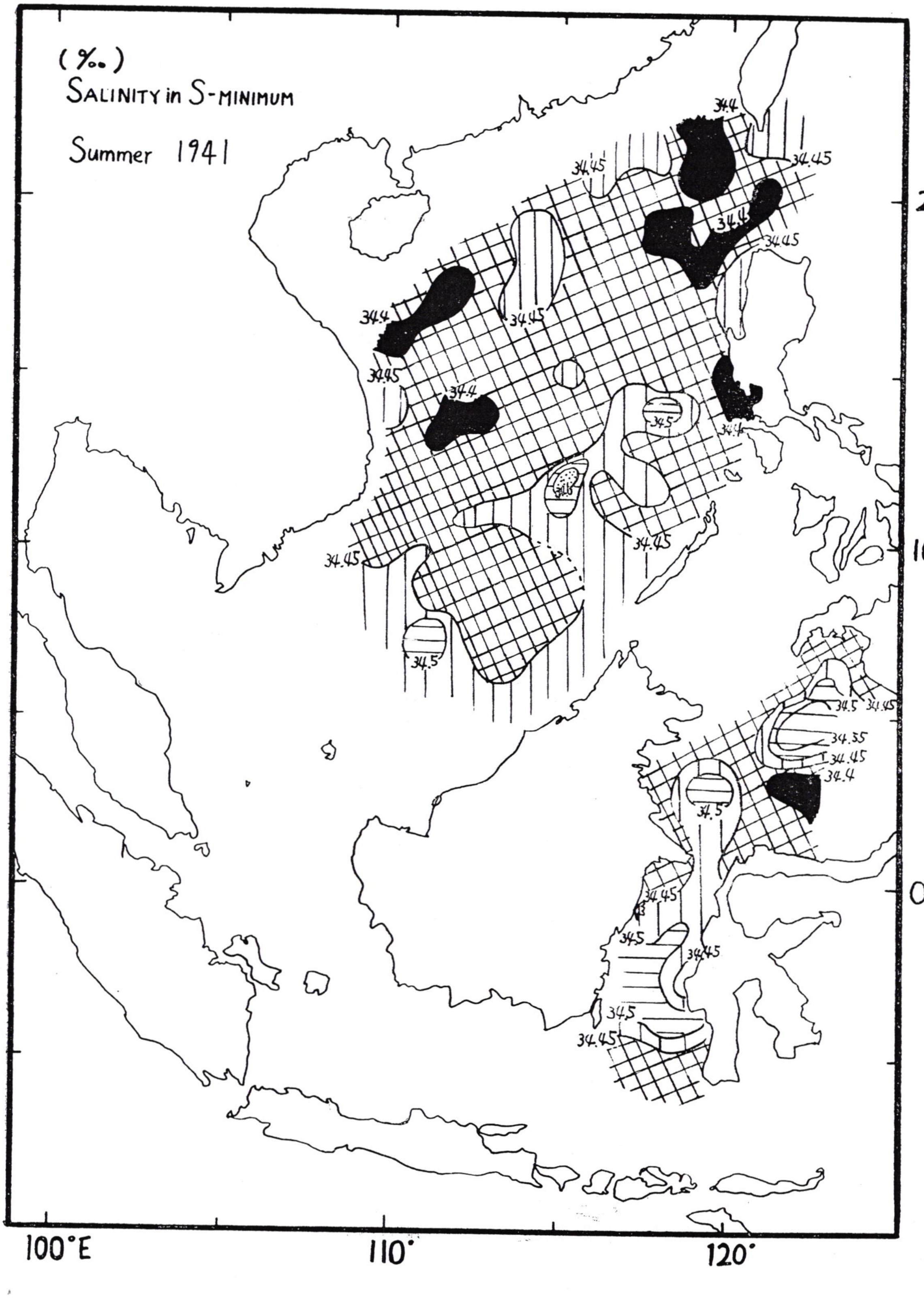

(‰)
SALINITY in S-MINIMUM
Summer 1941
20°
10°
N
0°
100°E
110°
120°
34.4
34.45
34.5
34.35

Fig. 17 a.

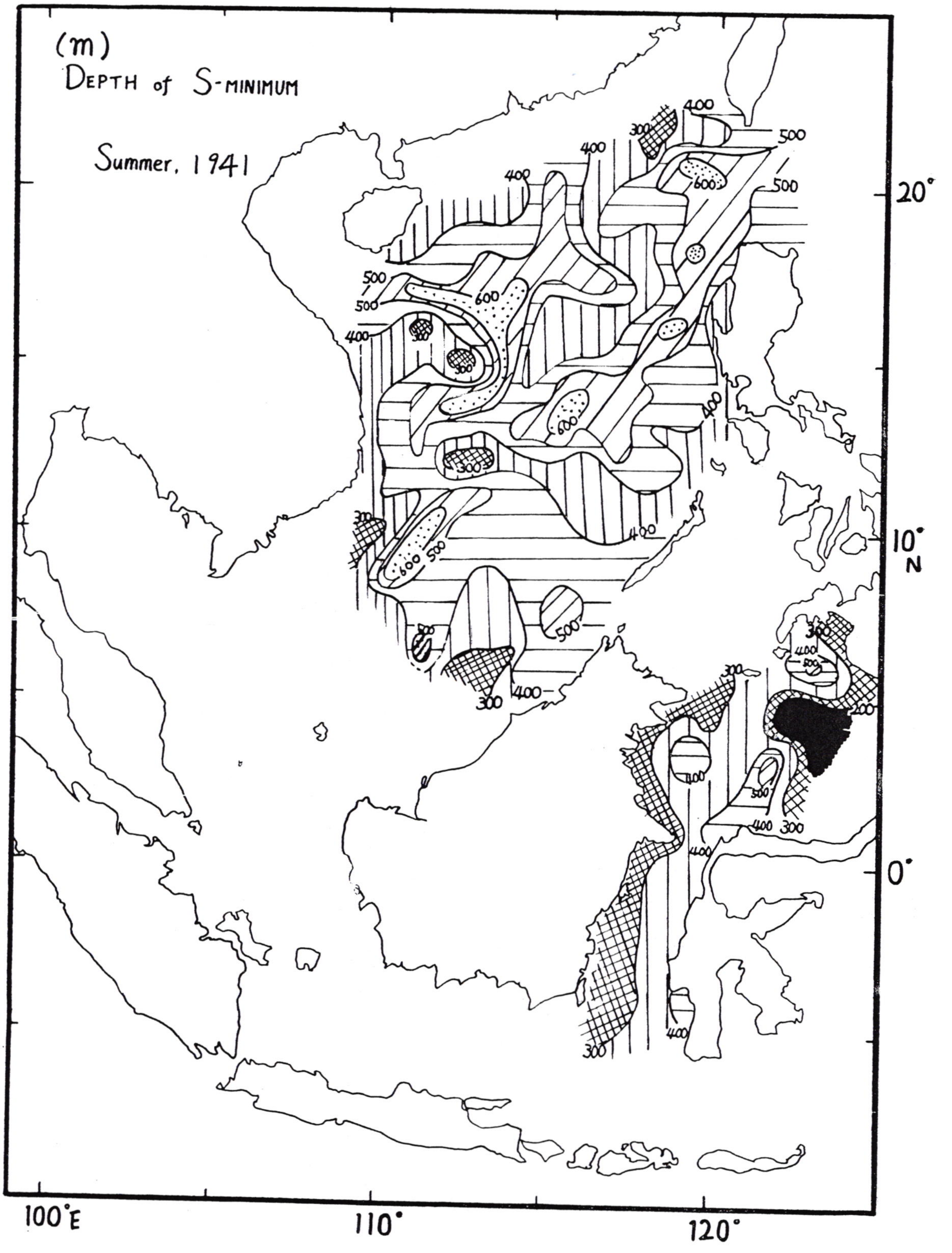


Fig. 17 b.

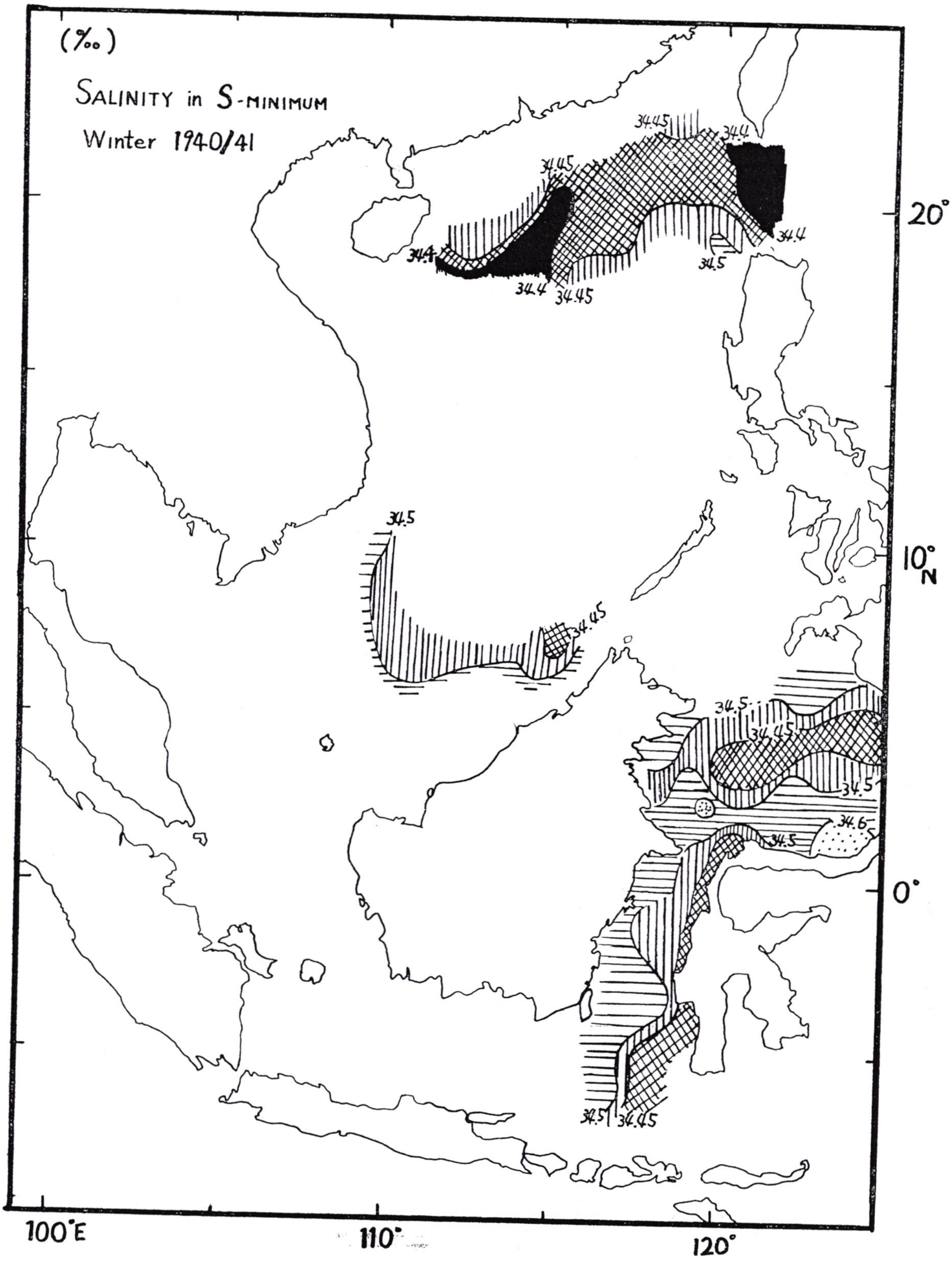

(‰)
SALINITY in S-MINIMUM
Winter 1940/41
34.45
34.4
34.45
34.4
34.4
34.5
34.4
34.45
34.5
34.45
34.5
34.45
34.5
34.6
34.5
34.5
34.45
20°
10° N
0°
100°E
110°
120°

Fig. 18 a.

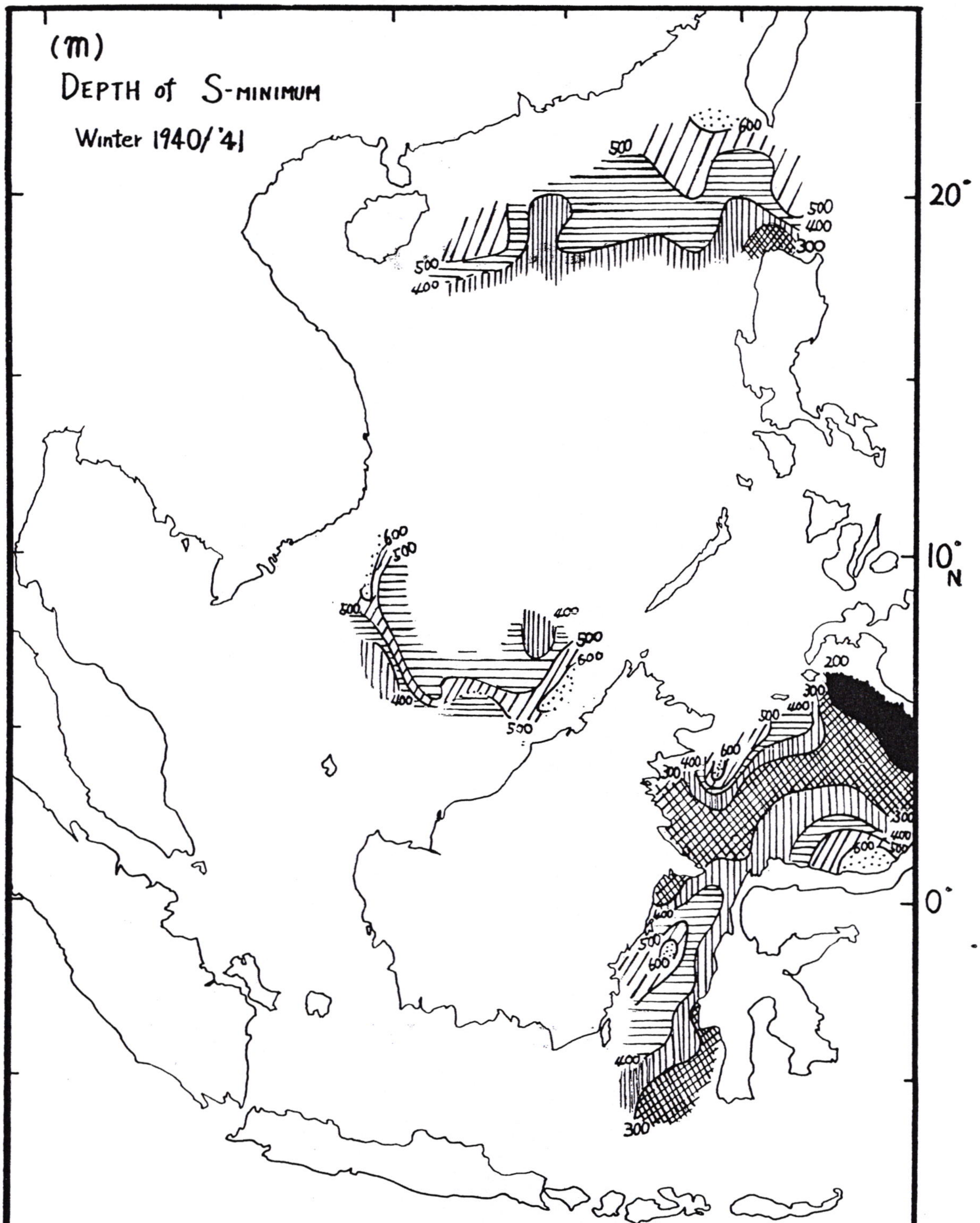


Fig. 18 b.

1.8 Thermohaline Diversity of the Japan Sea

by

O. I. Mamayev*

Abstract

Shannon's diversity index $H(X,Y)$, or entropy, was applied to the volumetric T–S diagrams of the Japan sea, presented in the paper of M. Yasui et al (1967). Namely, bivariate distributions for four seasons for the entire Japan Sea were selected for this purpose. Besides $H(X,Y)$, which is the entropy for the joint system (X is the system varying with respect to salinity only, Y with respect to temperature only), values $H(X)$ and $H(Y)$, as well as other diversity parameters, were calculated.

It was found that thermohaline diversity $H(X, Y)$ of the Japan sea is quite small (mean value of 1.3 bits) which is due to the extreme homogeneity of the sea in salinity and temperature. From winter to autumn there is a gradual increase of $H(Y, X)$ from 1, 1 to 1,6 bits, due to the summer heating This increase actually means loss of the Japan Sea.

The thermohaline redundancy of the Japan sea appear to be sufficiently high (near to 70%).

Introduction

In the present work the question is considered of the possibility of application of the Shannon's index, known from the information theory,

$$H(X) = -\sum_{i=1}^{n} P_i \log_2 P_i, \tag{1}$$

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which serves as a measure of information, or uncertainty (diversity) of the statistical system and which represents its entropy,** to the temperature–salinity relations of the World Ocean, particularly to the volumetric and statistical T–S diagrams.

In formula (1) X denotes some system which can assume majority of states x_i $(i=1, 2, \ldots, n)$, $\bar{\bar{P}}_i = \frac{n_i}{N}$ – probability of the event x_i where n_i is the number of occurrences of event x_i and $N = \sum_{i=1}^{n} n_i$, $\sum_{i=1}^{n} P_i = 1$

We shall assume here that the reader is familiar with the main properties of the function H (Shannon and Weaver, 1949), namely:

1. $H = 0$ if and only if all values of $\bar{\bar{P}}_i$ but one (and in this case being unity) are zero.

2. $H_{max} = \log_2 n$ when $P_1 = P_2 = \ldots = P_n = \frac{1}{n}$; in this case H is a monotonic increasing function of n.

3. Any tendency towards equalization of probabilities $\bar{\bar{P}}_1, \bar{\bar{P}}_2, \ldots, \bar{\bar{P}}_n$ lead to the increase of H.

4. H is additive function (entropies are summed when systems are united).

Application to T–S diagrams.

Let us consider a T–S diagram, properly divided into classes by temperature and salinity, bearing quantitative characteristics of the waters (volume, frequency etc) belonging to each of the T–S classes. Such kind of a T–S diagram, divided into classes filled with numerical characteristics referred to, obviously represents joint system by two variables–temperature and salinity.

** more precisely, entropy with a negative sign, or negentropy (Brillouin, 1956, p. 161).

Having recalculated the above quantitative characteristics into probabilities, we obtain bivariate frequency table, or probability distribution, with temperature and salinity as the two variates.

It is known, that the entropy of the joint event (complex system) is defined by the expanded formula (1), namely:

$$H(X,Y) = -\sum_{i=1}^{n}\sum_{j=1}^{m} P_{ij} \log_2 P_{ij} \tag{2}$$

where n and m are the number of states of systems X and Y, respectively (n.m is the number of possible states of the system); P_{ij} is the probability of the joint occurrence of the event x_i and event y_j.

For the T-S diagram referred to, formula (2) is interpreted as follows:

X – the system varying only with respect to salinity and assuming states x_i ($i = 1, 2, \ldots\ldots, n$);

Y – the system varying only with respect to temperature and assuming states y_j ($j = 1, 2, \ldots, m$);

P_{ij} – probability of occurrence of a definite class of T–S diagram measured in some way (frequency, percentage of total volume, etc).

The value H (X, Y) will be denoted in this context as *thermohaline diversity* as well as "entropy."

We will assume further that the systems X and Y are dependent; being applied to the T–S diagram this statement points on the existence of relation T =f (S) or, in other terms, means that the values of temperatures cannot generally change without corresponding change of salinity (one of the particular cases – the principle of conservation of stratification).

In this case we then will have the entropies or diversities of the systems X and Y as following:

$$H(X) = -\sum_{i}^{n}\sum_{j}^{m} P_{ij} \log_2 \sum_{j}^{m} P_{ij}, \tag{3}$$

$$H(Y) = -\sum_{j}^{m}\sum_{i}^{n} P_{ij} \log_2 \sum_{i}^{n} P_{ij}, \tag{4}$$

it being known that

$$H(X, Y) \leq H(X) + H(Y) \tag{5}$$

(the sign of equality corresponds to the independent systems, when $P_{ij} = P_i P_j$).

The quantities H (X) and H (Y) represent in this case the diversity by salinity and diversity by temperature correspondingly. It follows from the formula (3) that H (X) does not account for the probabilities of separate classes within each isohaline stripe (i. e., differences due to temperatures are not taken into account), and when calculating H (X) the summary values of probabilities for each of such stripes are taken.

Formula (4) represents the same, but with respect to the temperature. Applying formulae (1) – (4) to statistical T–S diagram, we shall present the results of calculations on the example of volumetric T–S diagrams of the Japan Sea, presented in the paper of M. Yasui *et al* (1967). Namely, bivariate distributions of volume for four seasons for the entire Japan Sea were selected for this purpose (Figs. 5a – 5d in the paper by M. Yasui *et al.* In this case of Japan Sea we deal with potential temperature (θ) chlorinity (Cl) diagrams).

The results of the calculation of the characteristics of thermohaline diversity are presented in Table 1, explanations to which (numbered according to the columns of the Table) are following:

TABLE 1

Entropy (Diversity) Characteristics of Japan Sea Waters

Japan Sea	Number of occupied classes	Number of occurrence of "events"	H_{max}	$H(X,Y)$	$H(Y)$	$H(X)$	$H_x(Y)$	$H_y(X)$	$\frac{H(X,Y)}{H_{max}}$	$1-\frac{H(X,Y)}{H_{max}}$
	1	2	3	4	5	6	7	8	9	10
(a)Winter	33 (51)	17200	5.044	1.110	1.023	0.277	0.834	0.087	0.220	0.780
(b)Spring	44 (86)	17200	5.459	1.253	1.052	0.396	0.857	0.202	0.229	0.771
(c)Summer	61 (109)	17200	5.931	1.285	1.104	0.503	0.782	0.182	0.217	0.783
(d)Autumn	63 (99)	17200	5.977	1.599	1.104	0.737	0.862	0.495	0.268	0.732

1. **Number of occupied classes** – for the Japan Sea, classes $1^{\circ}C \times 0.1^{\circ}/_{oo}$ are considered in the range $-2^{\circ} < T < 28^{\circ}C$, $18 < Cl < 19.3^{\circ}/_{oo}$ (cf. also item 2 below).

2. **Total number of occurrence** of volumes in all classes, in units $10^2 km^3$. In recalculating into probabilities ($\sum_i \sum_j P_{ij} = 1.000$) the latter were rounded to 10^{-3} and those classes having values below 10^{-3} were casted away for the purpose of simplicity (say, 33 classes out of total 51 have been retained in winter diagram etc).

3. **Maximal entropy** $H_{max} = \log_2 n$ is the value which would be observed if the probabilities were the same for each class.

4. **Entropy** (diversity by temperature and salinity) of the joint system in bits (per chosen unit of volume), calculated with the aid of five decimal tables of the function $-P\log_2 P$* and rounded to 10^{-3}.

5. **Entropy** (diversity) of the system with respect to temperature alone.

6. **Entropy** (diversity) of the system with respect to salinity alone.

7. **Conditional entropy**

$$H_x(Y) = -\sum_i^n \sum_j^m P_{ij} \log_2 P_i(j), \tag{6}$$

where

$$P_i(j) = \frac{P_{ij}}{\sum_j P_{ij}} \tag{7}$$

is the conditional probability that Y assumes the value y_j under condition that X already has the value x_i (for the details of Shannon and Wiever 1949, or Brillouin, 1956). With respect to the T-S diagram this value defines mean entropy (mean diversity) of the data by temperature (Y) if the distribution by salinity (X) is known (fixed).

* Thanks are expressed to Dr. Steyaert (UNESCO) for providing these tables.

Also

$$H\ (X,Y) = H\ (X) + H_x\ (Y) \tag{8}$$

8. **Conditional entropy** defining mean diversity of data by salinity (X) with known temperature (Y):

$$H\ (X,\ Y) = H\ (Y) + H_y\ (X) \tag{9}$$

9. **Relative entropy**

$$H' = \frac{H\ (X,\ Y)}{H_{max}} \tag{10}$$

10. **Redundancy** (Shannon and Wiever, 1949)

$$R = 1 - \frac{H\ (X,\ Y)}{H_{max}} \tag{11}$$

Discussion

Examining Table 1, we can come to the following very preliminary conclusions regarding the thermohaline diversity of the Japan Sea.

1. The entropy of statistical distribution, or diversity, of Japan Sea waters seems to be a very small quantity. From the oceanographic point of view this could be explained by the extreme thermohaline homogenuity of the Japan Sea.

2. Diversity with respect to temperature, H (Y) and H_x (Y) is in general higher than diversity with respect to salinity, H (X) and H_y (X). This seem obvious.

3. Seasonal changes of entropy are also very small and are characterized by small increase from winter to summer. This increase of the entropy characterizes the loss of information on the thermohaline state of the sea (wider scatter of volumetric values among the classes of the T–S diagram). The smallness of the seasonal changes of the entropy from the oceanographic point of view could be

explained by the fact that seasonal changes of the temperature and salinity in the Japan Sea are confined only to the upper layer of about 200 m thickness whereas the depth of the sea (in the central basin) has the order of 3500 m. In other words, the Japan Sea in general is very stable in thermohalinity: Yasui *et al* point out that 84% of the entire volume of Japan Sea waters have characteristics between 0° and 1°C and between 18.8 and 18.9 $^\circ/_{\circ\circ}$ chloriniry.

4. The gain of entropy, referred to above, could be put in conformity with equally insignificant seasonal heating of the Japan Sea from winter to autumn. For the comparison in Table 2 are presented mean-weighted values of temperature ($\bar{\theta}$) and chlorinito ($\overline{Cl}$) by seasons (these values have been calculated from the volumetric diagrams of Yasui *et al*).

Table 2

Mean values of temperature and chlorinity of the entire Japan Sea

	Winter	Spring	Summer	Autumn
$\bar{\theta}$ $^\circ$C	1.09	1.16	1.43	1.44
$\overline{Cl}$ $^\circ/_{\circ\circ}$	18.85	18.85	18.84	18.85

From this table we can see that the mean temperature slightly changes during the year, whereas the mean salinity practically remains constant.

5. The thermohaline redundancy (column 10, Table 1) is near to 70%, which could be regarded as quite a high value. Relatively high redundancy of T-S characteristics for the entire Japan Sea is due to its relative homogenuity as compared to the surface waters, which have much more wide spectrum of characteristics. This matter might be expressed as follows: any additional observations on the distribution of temperature and salinity through the depth of the entire Japan Sea will not

contribute much to the information already contained in the volumetric diagram of the $0.1^{\circ} \times 0.1^{\circ}/_{oo}$ class.

6. Finally the figure 1 is presented which shows the comparison of the entropies of statistical distribution of the Japan Sea waters with the mean temperatures by seasons. Despite the fact that these values are calculated independently, one can see obvious correlation between them (dashed lines are not regression lines, but are plotted as illustrative).

The application of Shannon's entropy (of statistical distribution) in the T S analysis might provide additional quantitative parameters of ocean water masses.

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Yasui M., T. Yasuoka, K. Tanioka and O. Shiota, 1967. Oceanographic Studies of the Japan Sea (1) Water characteristics. *The Oceanographical Magazine,* vol. 19, n° 2.

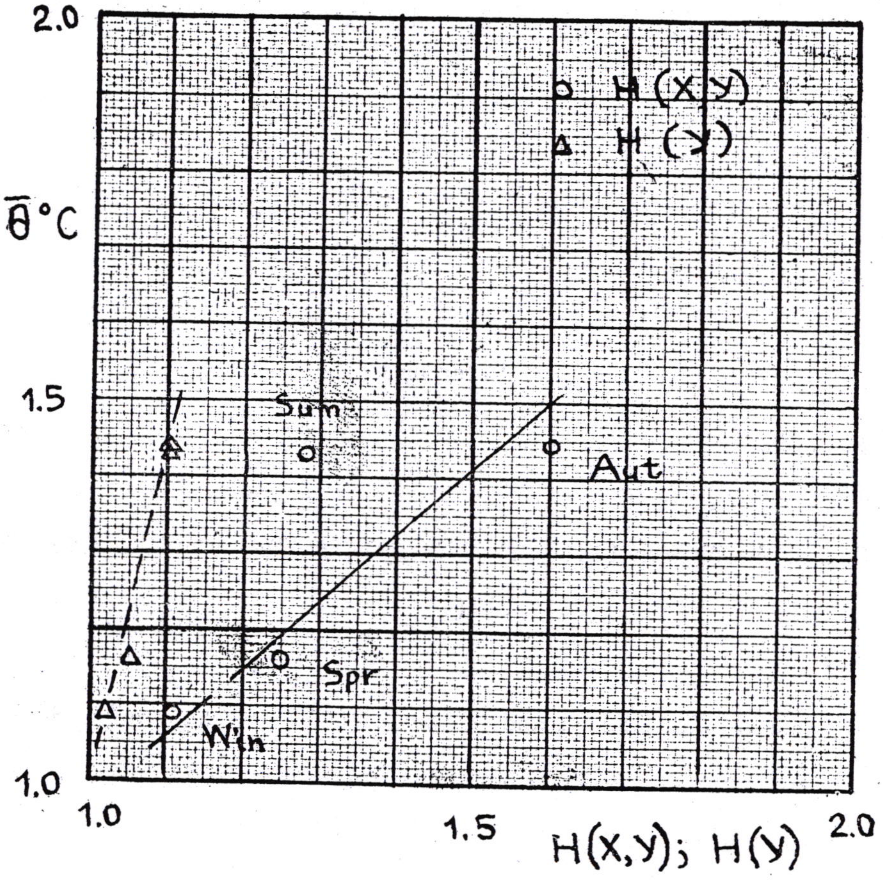

Fig. 1 (cf. text)

1.9 Cyclonic Cold Eddies along the Edge of the Kuroshio Current in Relation to the Genesis and Passage of Cyclones.

I. WATERS NORTH OF TAIWAN

by

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Shimizu, Shizuoka-Ken, Japan

Introduction

Along the line of the recent world program, Air Mass Transformation Experiment, AMTEX, of Global Atmospheric Research Project, GARP, the present study was initiated as the extension of the previous studies by Uda (1941, 1943a, 1943b, 1957).

Thus the authors, based upon the CSK (1965-1969) and other Japanese data (1932 and 1939), constructed the distribution maps of water temperature and salinity at the surface and at a depth of 50 m, and also the map of Tw, water temperature, minus Ta, the air temperature near the surface, in the southern waters of the East China Sea and studied them in the light of the records of the genesis of extratropical cyclones in winterspring and those of tropical cyclones in summer and their passages.

Results and discussion

1. Winter (Table 1)

A cold water mass with salinity lower than 34.3‰ is clearly noticed in the north of Taiwan. A domain of maximum $\triangle T=Tw-Ta$ is found near the water mass to its east-southeast (Fig. 1, 2, 3, 4. Table 1). The domain just corresponds to the frontal zone of the Kuroshio Current constitutes the area where cyclones are often generated and over which they find their paths as seen in Fig. 1.

2. Summer (Table 2)

Beside the cold back-eddy northeast of Taiwan another cold eddy is remarkable to the west of Okinawa along 125°E near the shelf-edge along the Kuroshio Current as discerned from the 50m depth temperature distribution map of Fig. 5, 6, (1965). In 1966 a similar pattern of cold water mass is seen, one to the north of Taiwan and another west of Okinawa at the embayment of continental shelf-edge (Fig. 7.). Again, in the summer of 1967 (Fig. 8) cold back-eddies are discerned. Uda (1941) has already found this type of cold eddy from his survey during June-July, 1939 (Figs. 9, 10) in the northeast of Taiwan separated from the east lying Kuroshio warm water mass with a sharp temperature gradient as large as 5°C.

3. Spring and Fall (Table 1)

In both spring and fall similar isolated cold water masses were ascertained. Thus in the observations in November 1967, (Fig. 11) April-May of 1968 and April-May of 1969 (Fig. 12, 13, 14,) cold water masses were found in the northern waters of Taiwan with $\triangle T$ maximum domains to their east, and in July 1932 the cold back-eddy was found to extend in a range of 50-60 sea-miles northeast of Taiwan.

Summarizing, a cold back-eddy persists through the year north of Taiwan near the boundary between the Kuroshio warm, high salinity water and the northern cool, low salinity continental shelf-water, in other words at the confluence of the cold intrusion from the north toward the northern part of Taiwan and the northward flowing Kuroshio Current. It is also certain that another low salinity cold eddy exists along 125°E west of Okinawa near the shelf-edge.

Our major interest is in the great zonal area with high $\triangle T=Tw-Ta$ of northeast of Taiwan along the continental shelf-edge where the value of $\triangle T=Tw-Ta$ often exceeds 10°C as seen in Fig. 4. It is remarkable that tropical cyclones in summer and extratropical cyclones, the "Taiwan Depression" called "Taiwan Bozu" in Japanese, in winter to spring are generated preferentially in this area and the paths of cyclones run over this area away from the cold water areas. Seemingly a strong heat transfer and evaporation from the water surface of the sea favor the formation of the cyclone and breed the formed cyclone to pass over the area.

The authors would add that the waters around the cold eddies referred to above give favorable fishing and spawning grounds to scombroid and other species of fishes and stress the importance of further studies in this key area.

Aknowledgement

The authors are grateful to Prof. Ken Sugawara for his kind advice and assistance for the preparation of the present paper.

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Table 1

Water Temperature at 0 m

Year	Month	Tmax.	Tmin.	Dist.	Grad.
1966	Jan.-May	26.27 (°C)	21.60 (°C)	45 (sm)	1.04/10sm
1967	Jan.-May	25.40	21.20	57	0.74
1967	Nov.	26.00	24.50	59	0.25
1969	Apr.-May	27.20	24.90	81	0.28

Water Temperature at 50 m

1966	Jan.-May	26.12	17.99	80	1.02
1697	Jan.-May	24.48	18.97	60	0.92
1967	Nov.	25.12	19.89	54	0.97
1969	Apr.-May	24.34	20.25	30	1.36

Salinity at 0 m

Year	Month	Smax.	Smin.	Dist.	Grad.
1966	Jan.-May	34.87(‰)	34.51(‰)	14 (sm)	0.26/10sm
1967	Jan.-May	34.76	34.29	45	0.11
1967	Nov.	34.98	34.45	50	0.10
1969	Apr.-May	34.96	34.11	73	0.12

Salinity at 50 m

1966	Jan.-May	34.96	34.40	67	0.08
1967	Jan.-May	34.82	34.16	30	0.22
1967	Nov.	34.95	34.49	72	0.06
1969	Apr.-May.	34.81	34.45	20	0.18

Temperature Anomaly

Year	Month	△Tmax.	△Tmin.	Dist.	Grad.
1966	Jan.–May	7.1 (°C)	−3.56 (°C)	93 (sm)	1.15/10sm
1967	Jan.–May	+3.3	−1.1	57	0.82
1967	Nov.	+6.0	−1.62	60	1.27
1669	Apr.–May	+3.5	−1.9	180	0.30

Table 2

Water Temperature at 0 m

Year	Month	Tmax.	Tmin.	Dist.	Grad.
1965	Jul.–Sept.	29.06 (°C)	26.64 (°C)	84 (sm)	0.29/10sm
1966	Jul.–Sept.	28.14	24.81	50	0.67
1967	Aug.–Sept.	27.00	24.40	60	0.43
1968	Aug.–Sept.	–	–	–	–

Water Temperature at 50 m

1965	Jul.–Sept.	28.12	22.45	96	0.59
1966	Jul.–Sept.	27.89	24.30	30	1.20
1967	Aug.–Sept.	29.41	21.70	50	1.54
1968	Aug.–Sept.	25.19	17.80	90	0.82

Salinity at 0 m

Year	Month	Smax.	Smin.	Dist.	Grad.
1965	Jul.–Sept.	34.09 (‰)	32.74 (‰)	30 (sm)	0.45/10sm
1966	Jul.–Sept.	34.71	33.23	35	0.42
1967	Aug.–Sept.	34.58	33.73	29	0.29
1968	Aug.–Sept.	34.56	33.21	35	0.39

Salinity at 50 m

1965	Jul.–Sept.	34.51	33.97	53	0.10
1966	Jul.–Sept.	34.67	33.89	54	0.14
1967	Aug.–Sept.	34.79	34.74	31	0.02
1968	Aug.–Sept.	–	–	–	–

Temperature Anomaly

Year	Month	△Tmax.	△Tmin.	Dist.	Grad.
1965	Jul.–Sept.	+0.06 (°C)	–3.05(°C)	60(sm)	0.52/10s
1966	Jul.–Sept.	+1.5	–1.2	33	0.82
1967	Aug.–Sept.	–	–	–	–
1968	Aug.–Sept.	–0.5	–3.0	30	0.83

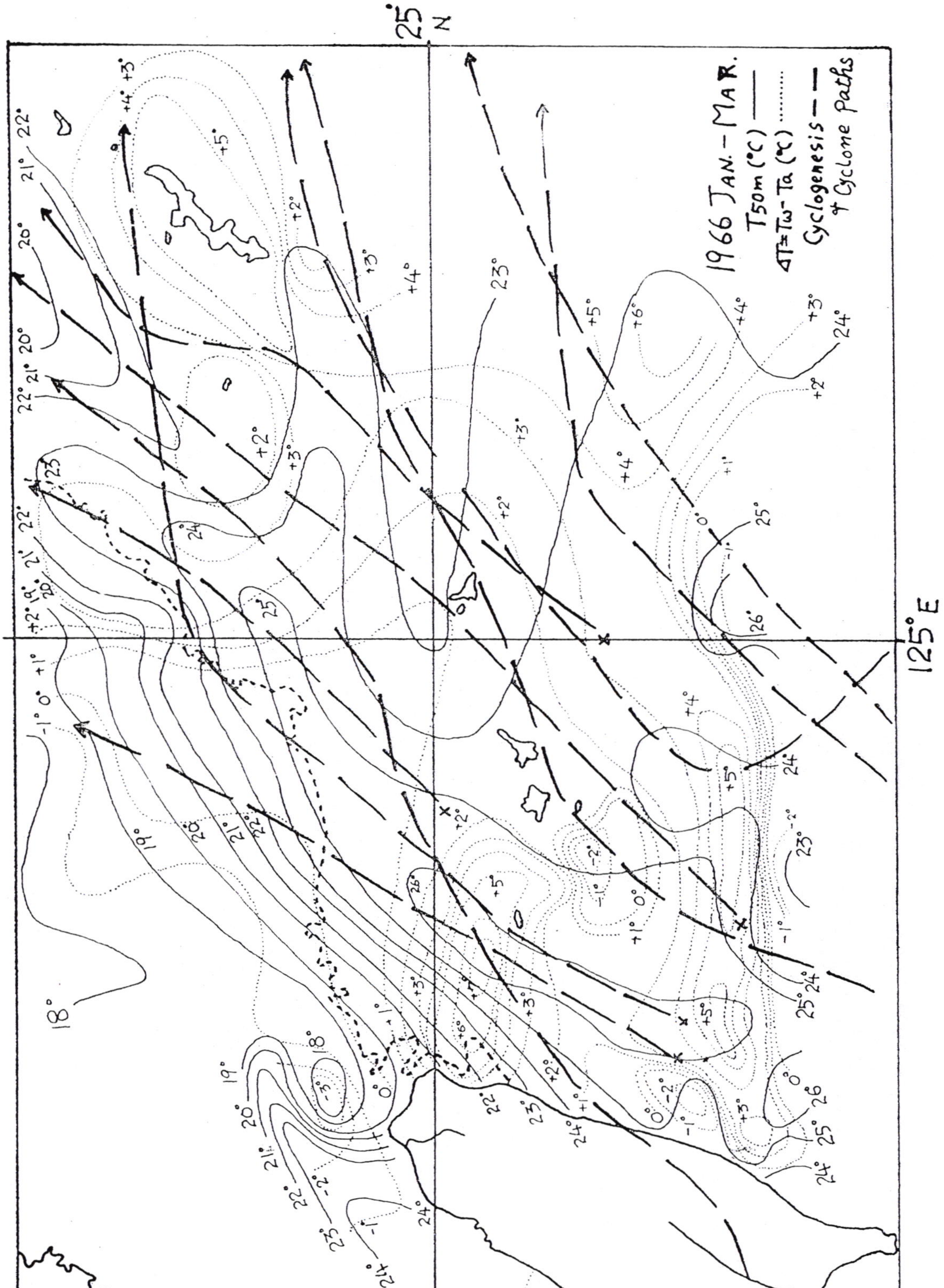
1966 JAN.-MAR.
T50m (°C)
ΔT=Tw-Ta (°C)
Cyclogenesis
+ Cyclone Paths
25° N
125° E

Fig. 1

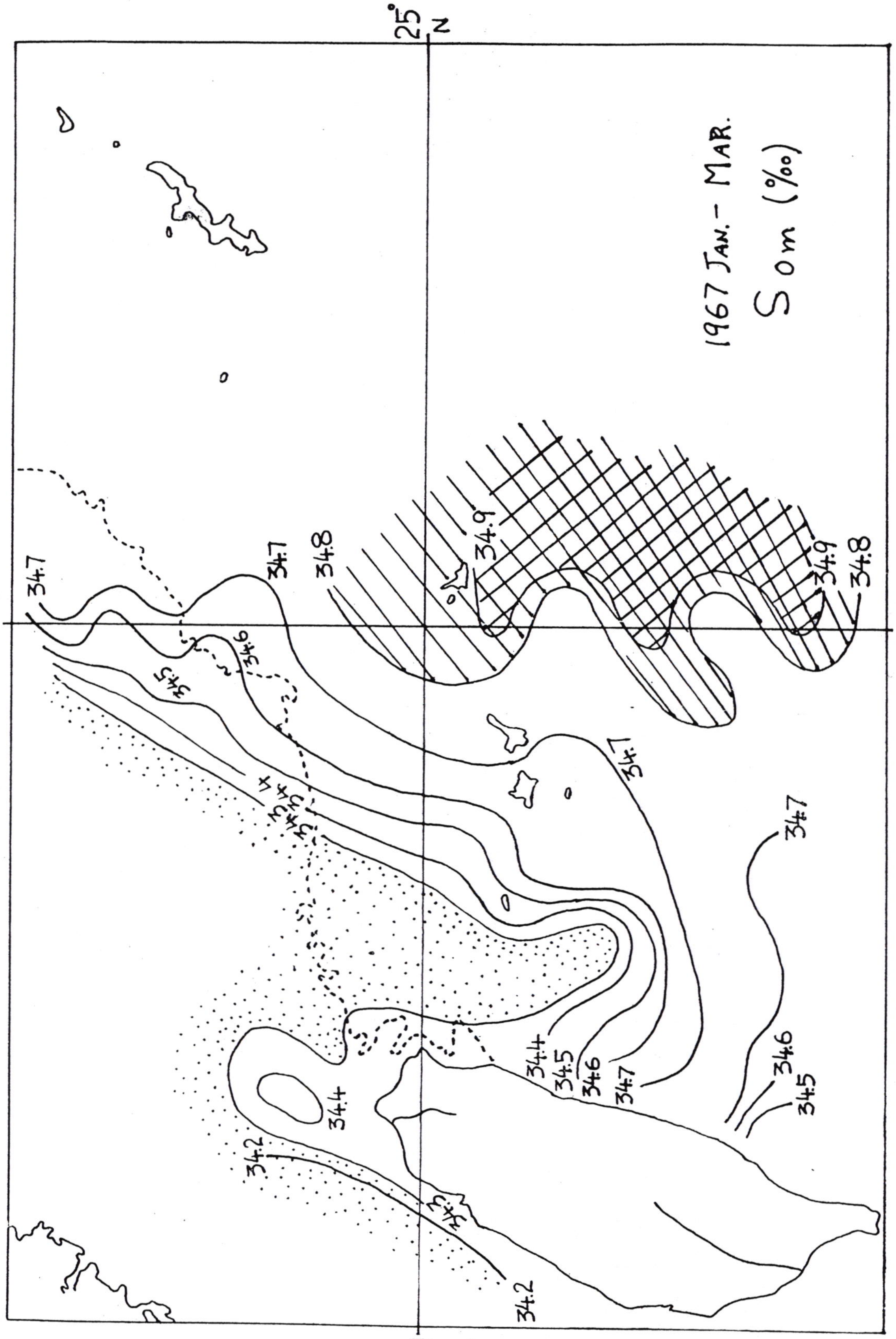

Fig. 2

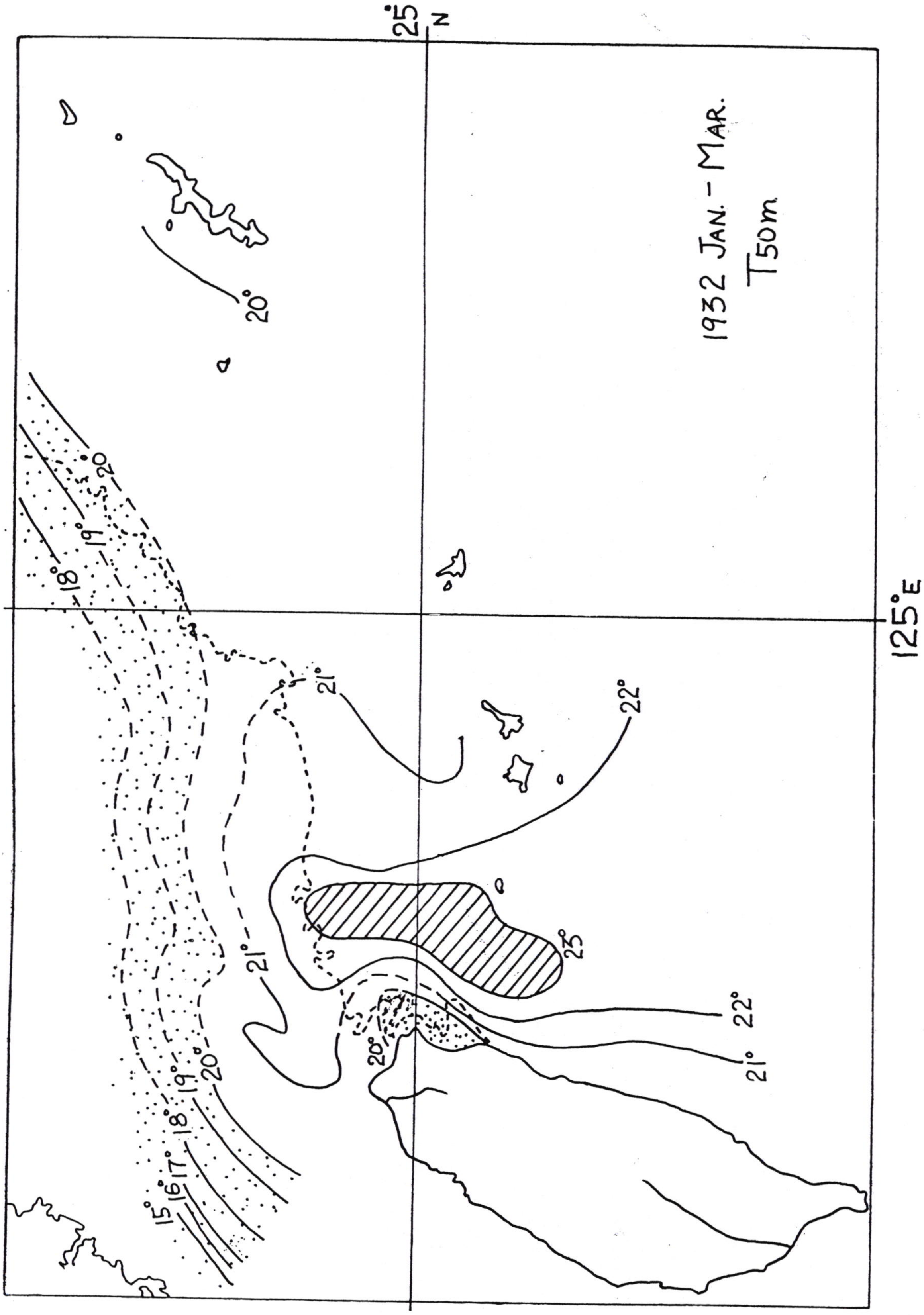

Fig. 3

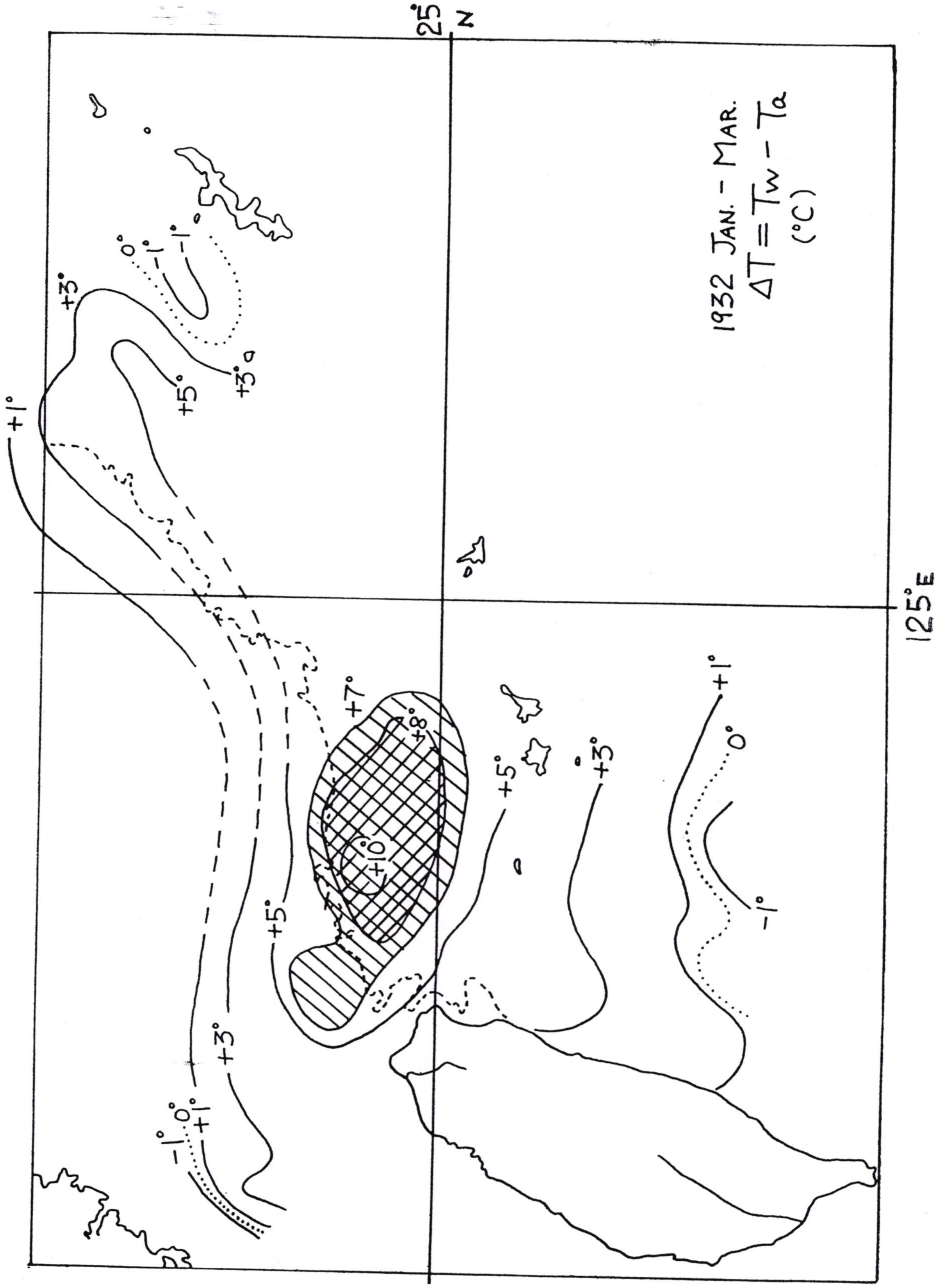

Fig. 4

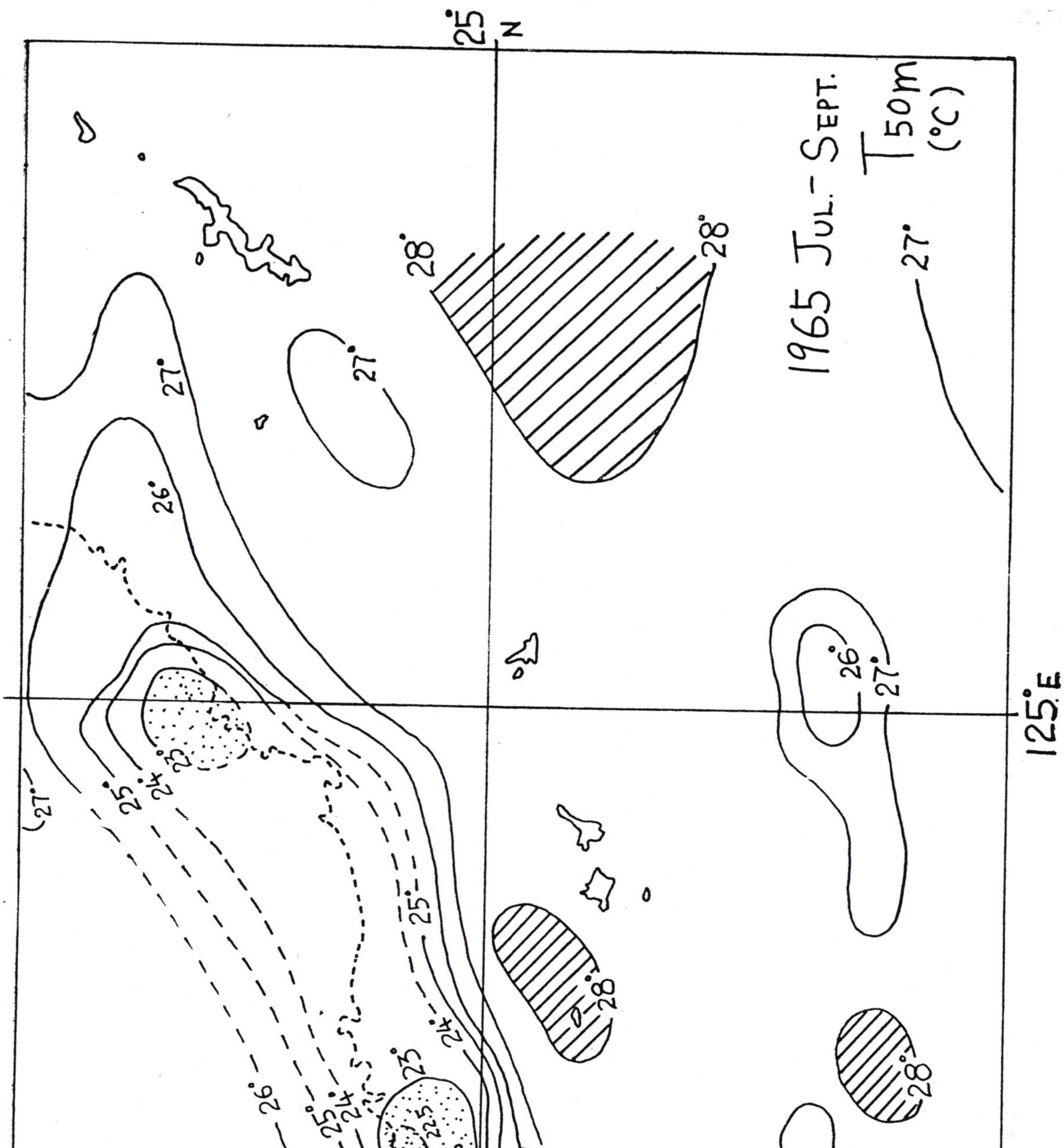

Fig. 5

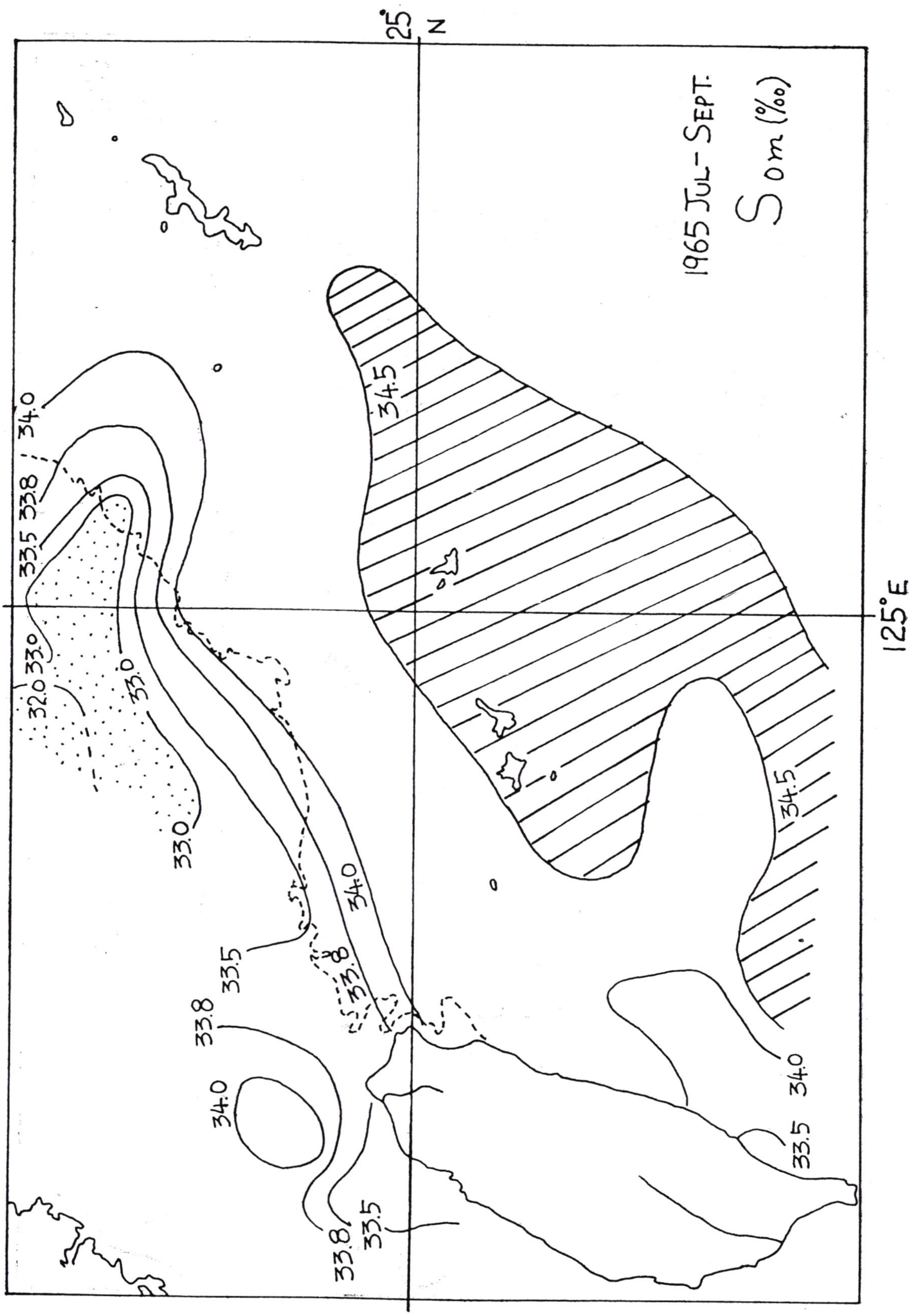
1965 JUL-SEPT.
S 0m (‰)
25° N
125° E
34.5
34.5
34.0
33.8
33.5
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Fig. 6

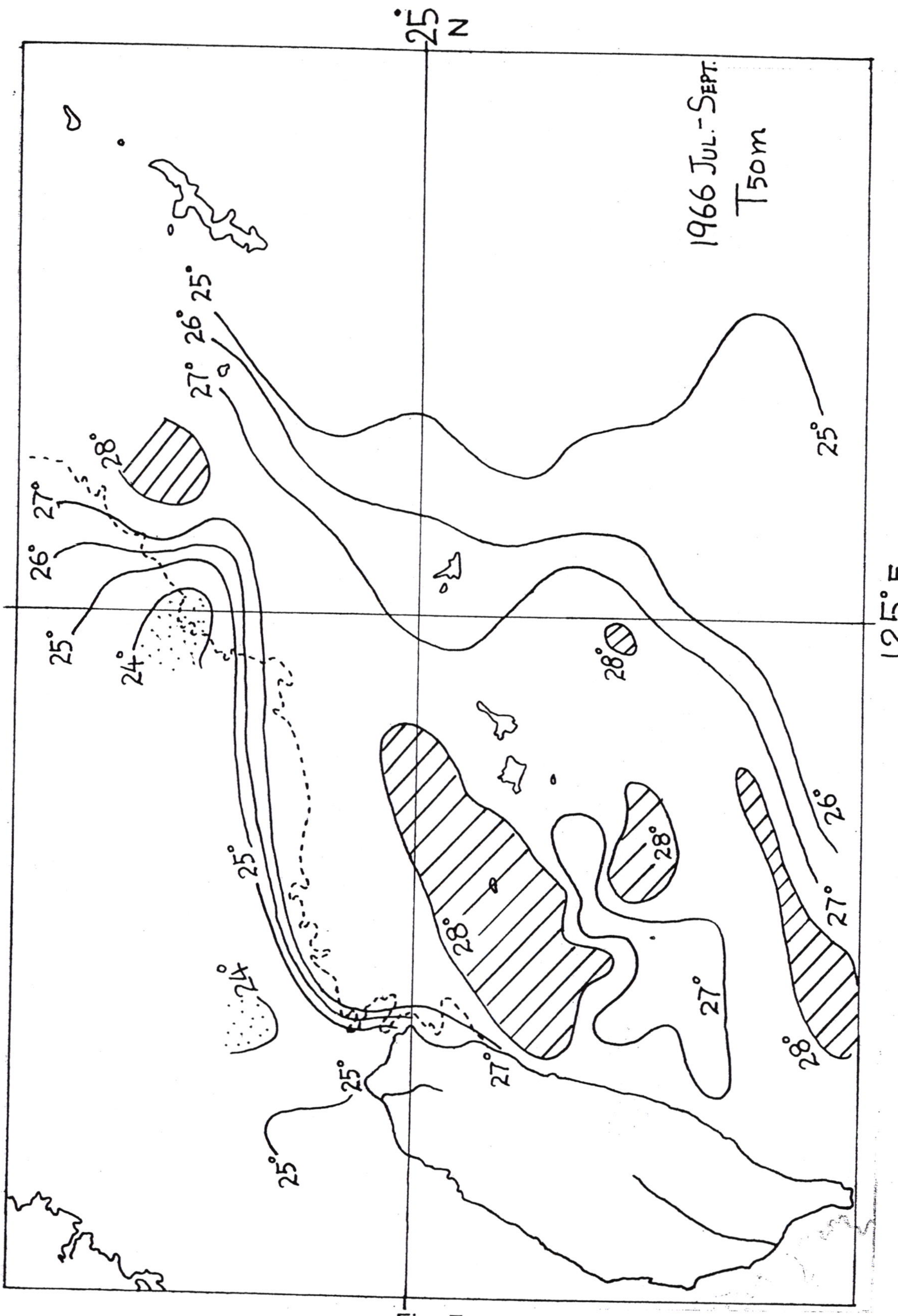


Fig. 7

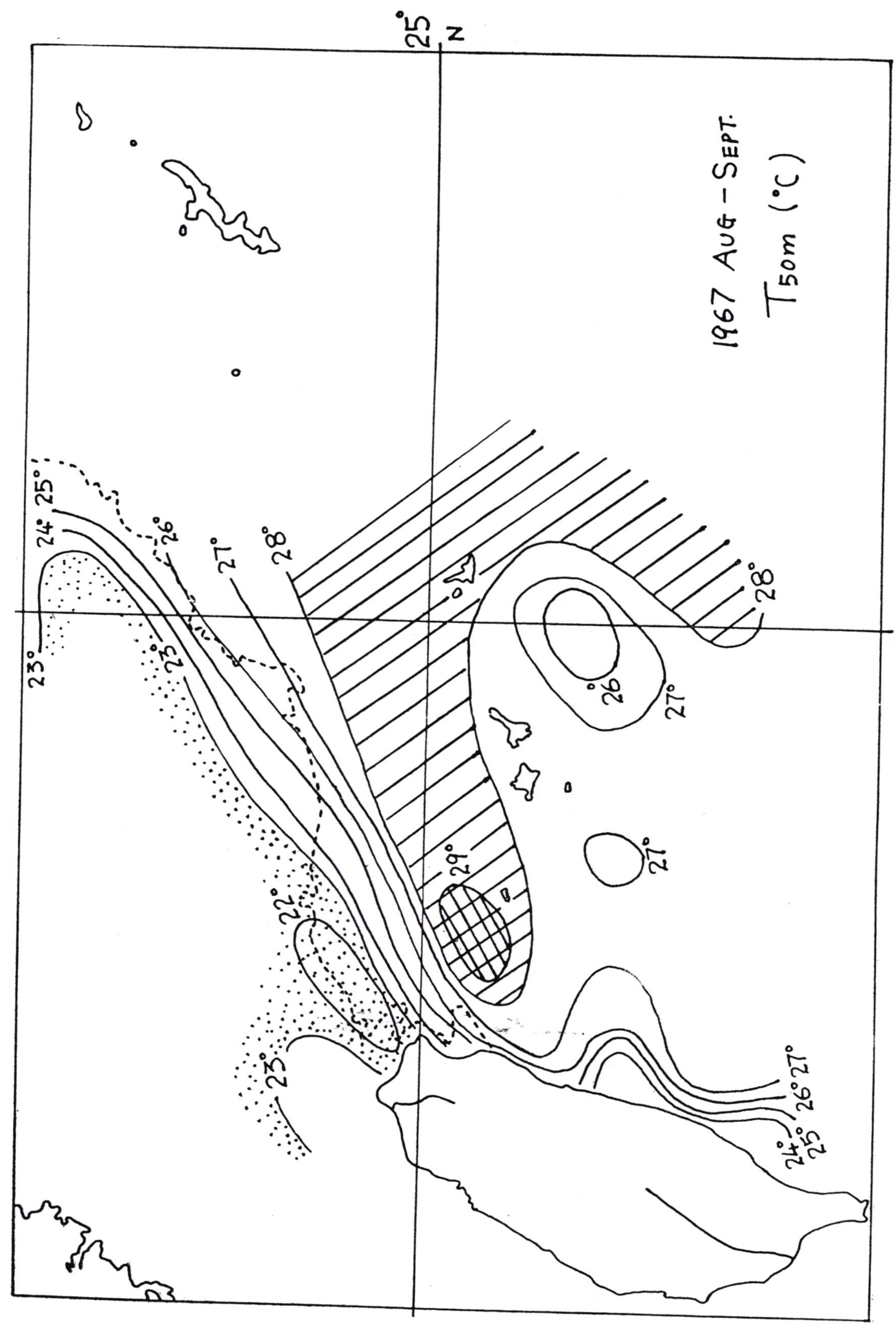


Fig. 8

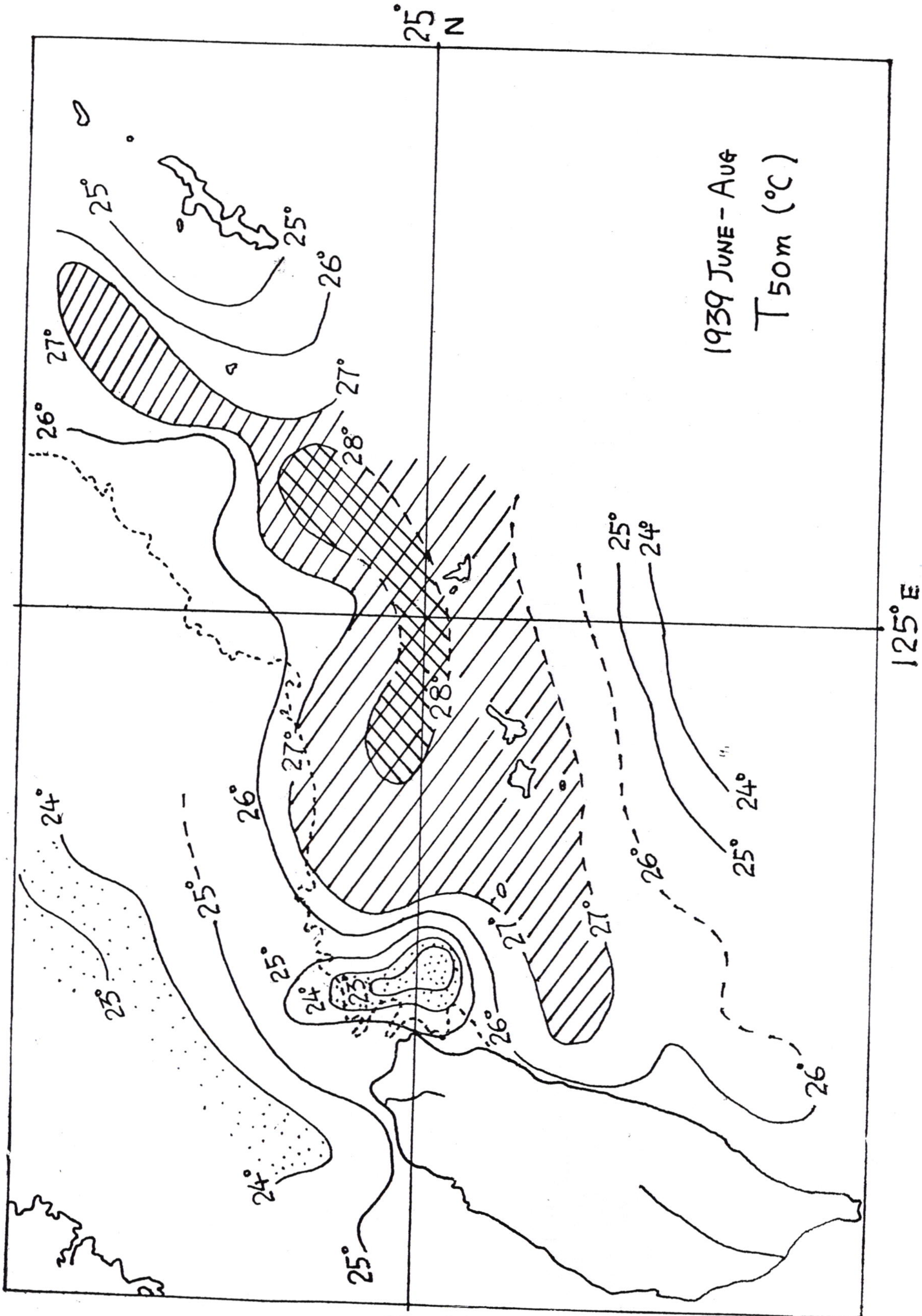
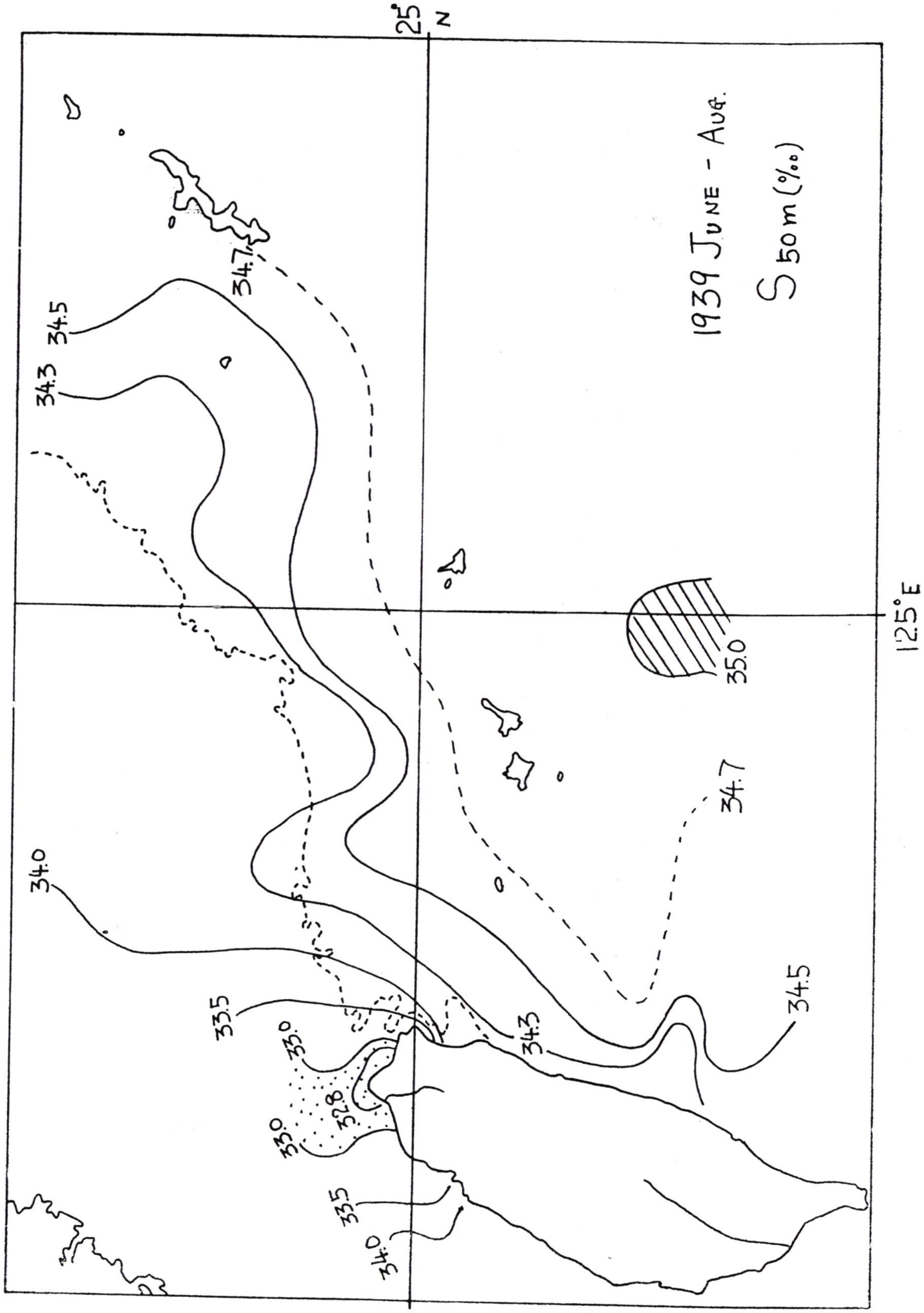


Fig. 9


25°N
125°E
1939 June - Aug.
S 50m (‰)
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34.5
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33.0
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Fig. 10

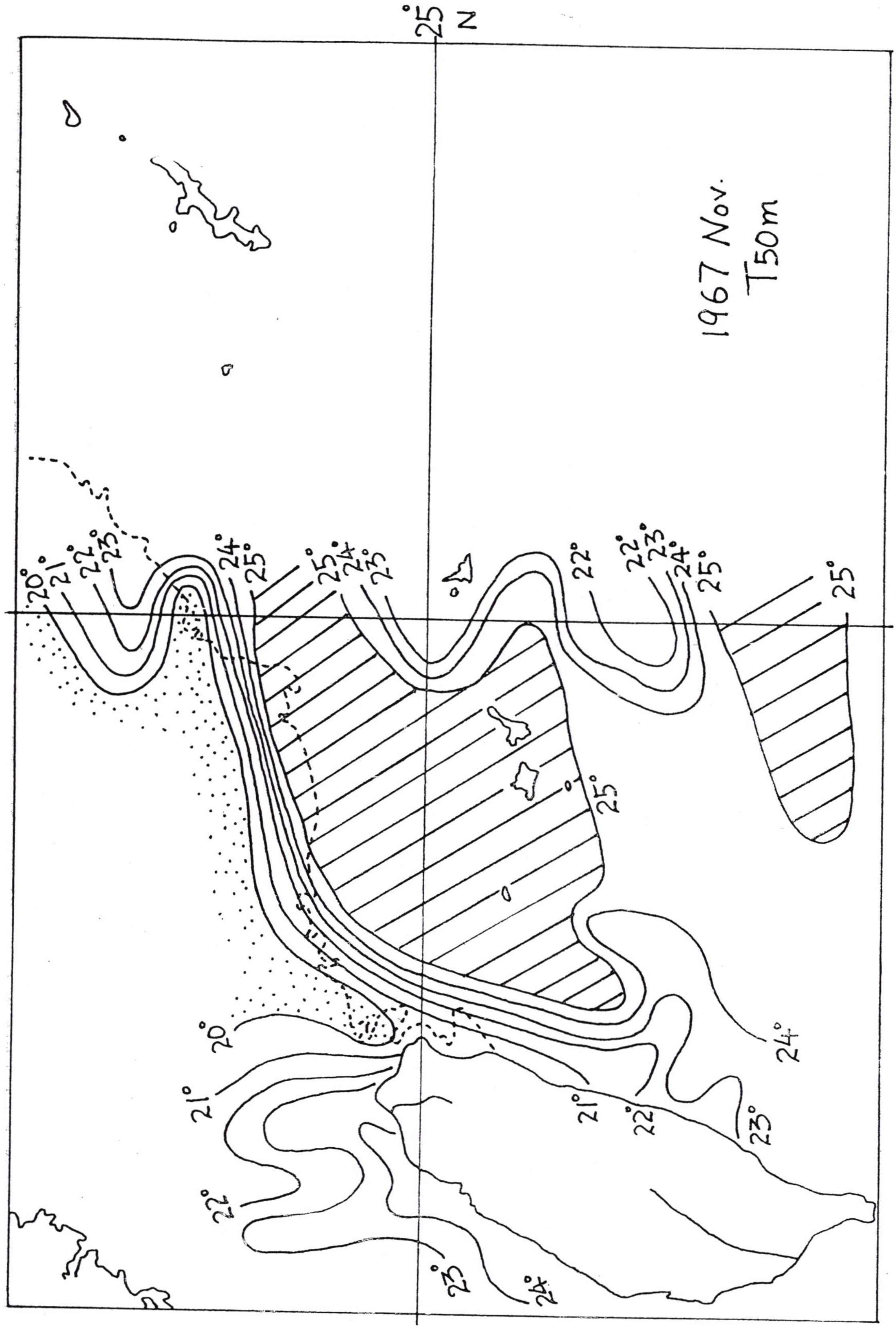


Fig. 11

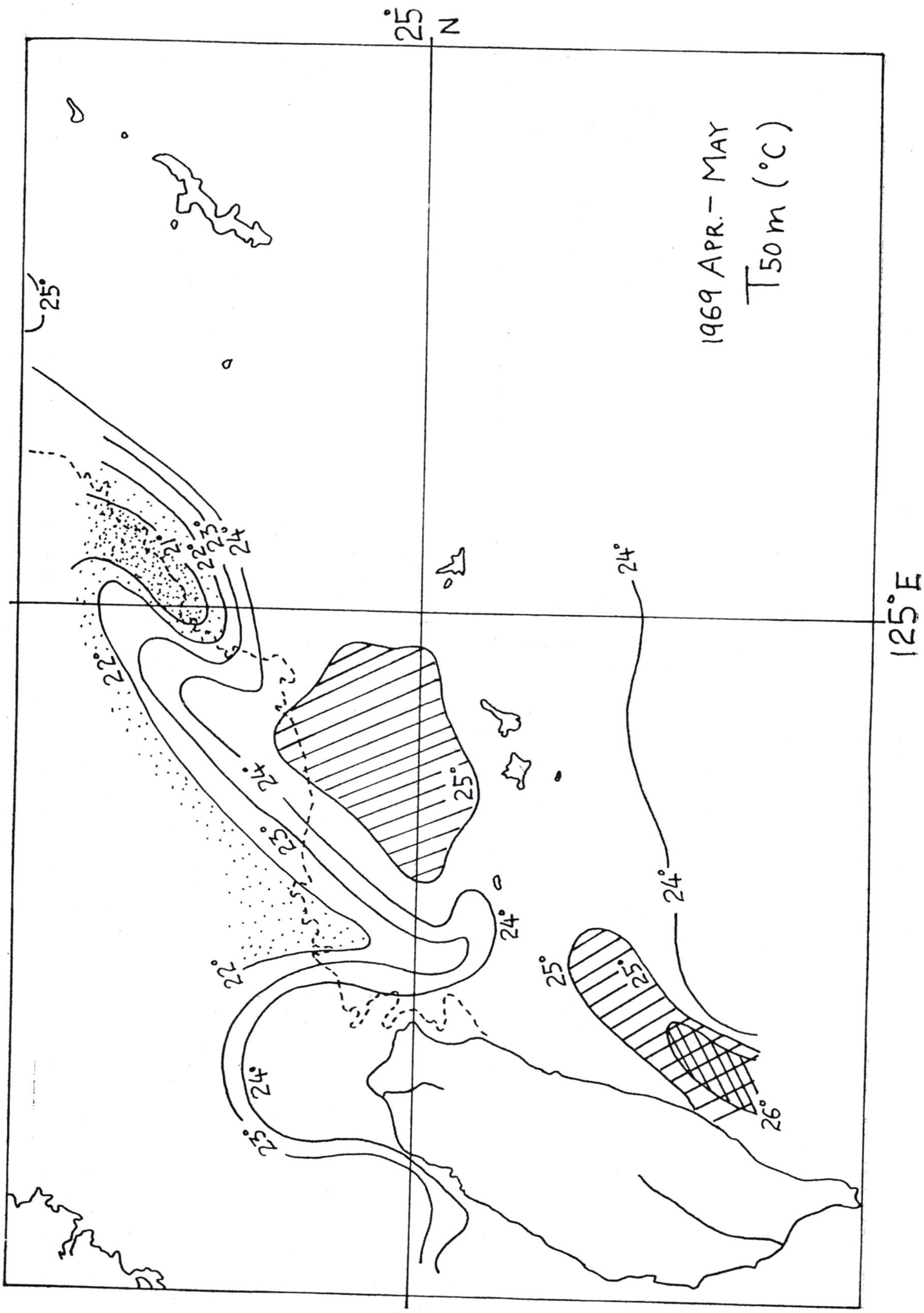
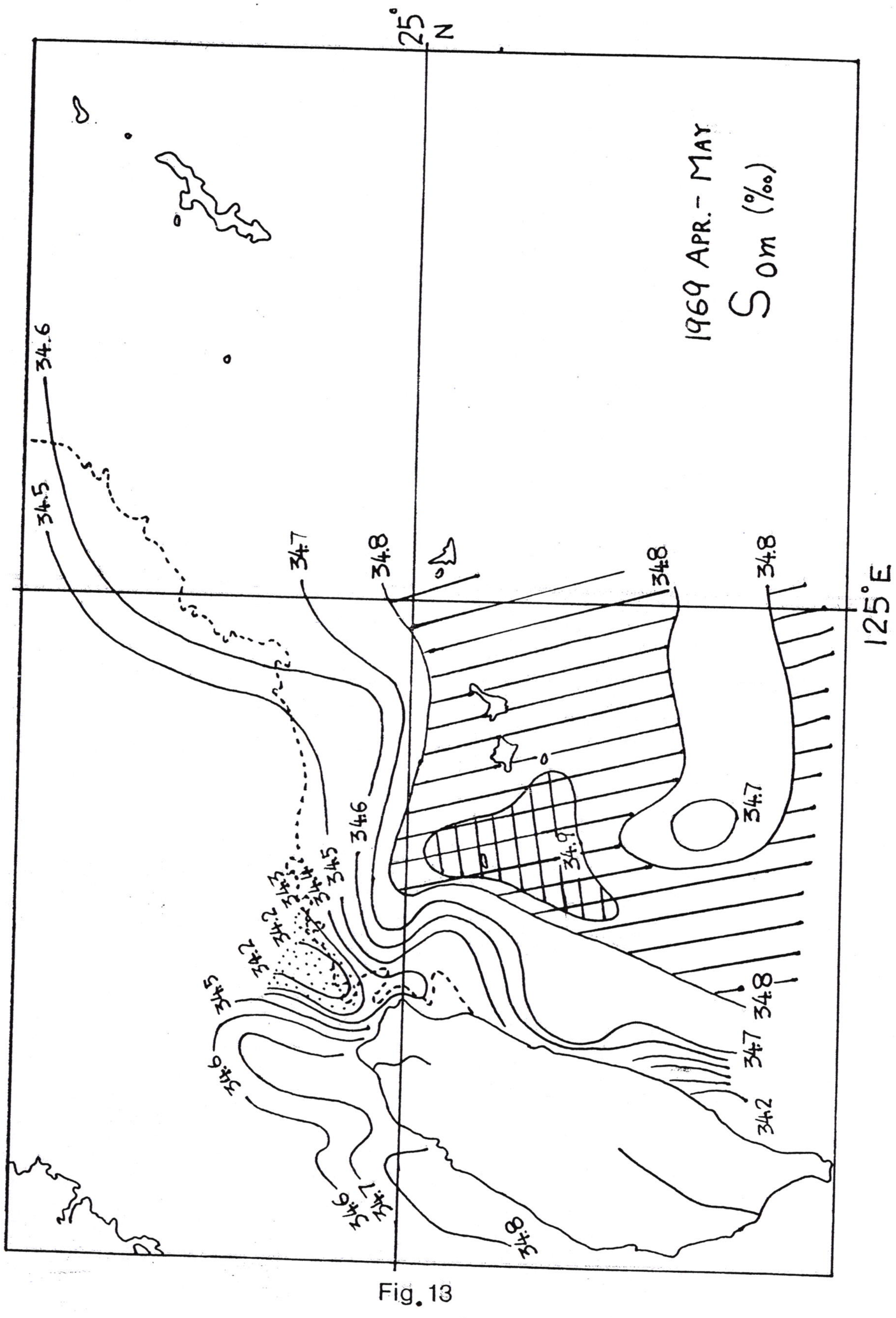


Fig. 12


1969 APR. - MAY
S 0m (‰)
25° N
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34.7
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Fig. 13

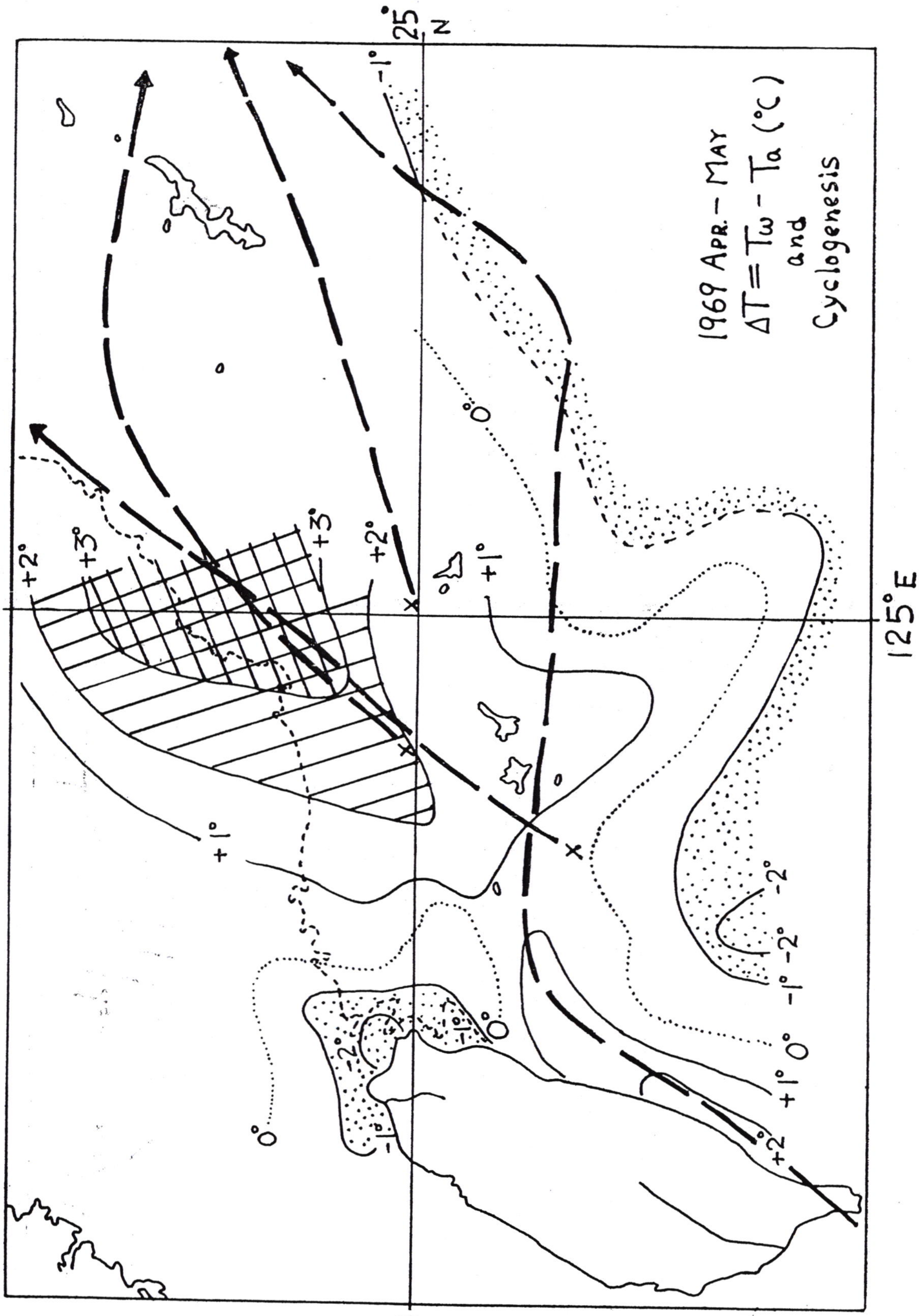


Fig. 14

SESSION II

Biology and Biochemistry

2.1 PHYTOPLANKTON IN THE SEA AREA OF THE SOUTHEAST ASIA

by

RYNZO MARUMO

(Ocean Research Institute, University of Tokyo)

1. Introduction

The present paper deals with the standing crop and community of phytoplankton on the basis of results obtained on the Cruise of Hakuhō Maru (KH-72-1) which was carried out in the Philippine Sea, Celebes Sea, Sulu Sea, South China Sea and Indian Ocean (12°S) from May to August, 1972 (Fig. 1).

2. Method

Phytoplankton samples were collected by two kinds of methods, Norpac net (45 cm in mouth diameter and 0.1 mm in mesh aperture) and Van Dorn sampler. In the first method the net was hauled from the depth of 150 m to the surface and samples were used for species identification. In the second method 500 ml of sea water obtained from various depths down to 300 m were filtered through Millipore filter HA (0.45 μ in porosity). This filter was dried and made transparent by Cargille's oil B and prepared to the permanent slide. For diatoms, cell bearing pigments (living cell) and cell bearing no pigments (dead cell) were separately counted. For coccolithophorids, the relative abundance was only compared.

3. Hydrography (Figs. 2–5)

The distribution of water temperature and salinity along Section II from the Philippine Sea to the South China Sea through the Celebes Sea and Sulu Sea and along Section III in the South China Sea is shown in Figs. 2–5.

4. Results and discussion

(1) Geographical distribution of chlorophyll a (Fig. 6)

Chlorophyll a content was the largest in the Sulu Sea and next to it in the Celebes Sea. The content in the Sulu Sea is comparable to that of the Oyashio water containing 50--100 mg/m^2, while that in the Philippine Sea, South China Sea and Indian Ocean is comparable to that of the Kuroshio water containing 25--50 mg/m^2 (Kawarada and Sano, 1972).

The mean value is 95 mg/m^2 (59--126 mg/m^2 in the range) in the Sulu Sea, 59 mg/m^2 (31--81 mg/m^2) in the Celebes Sea, 37 mg/m^2 (31--51 mg/m^2) in the Philippine Sea, 41 mg/m^2 (34--48 mg/m^2) in the South China Sea and 47 mg/m^2 in the Indian Ocean.

(2) Vertical distributional pattern of phytoplankton groups (Fig. 7)

(a) Diatoms

Living cells show the subsurface maximum in the 75--100-m layer, being few in layers shallower and deeper than this. Dead cells show the maximum also in the same layer as in living cells but it is distributed fairly uniformly in the whole layer. The subsurface maximum of living cells is considered to be supported by the high population which habitat is limited by the downward penetration of solar radiation and the upward transport of nutrient salts, while the relatively gentle vertical distribution of dead cells will be formed mainly by vertical mixing and sinking. Ohwada (1972), however, reported that dead cells appear in the deeper layer than in living cells in the Japan Sea.

(b) Silicoflagellates

The maximum occurs in the subsurface layer between 50 and 75 m slightly shallower than in diatoms.

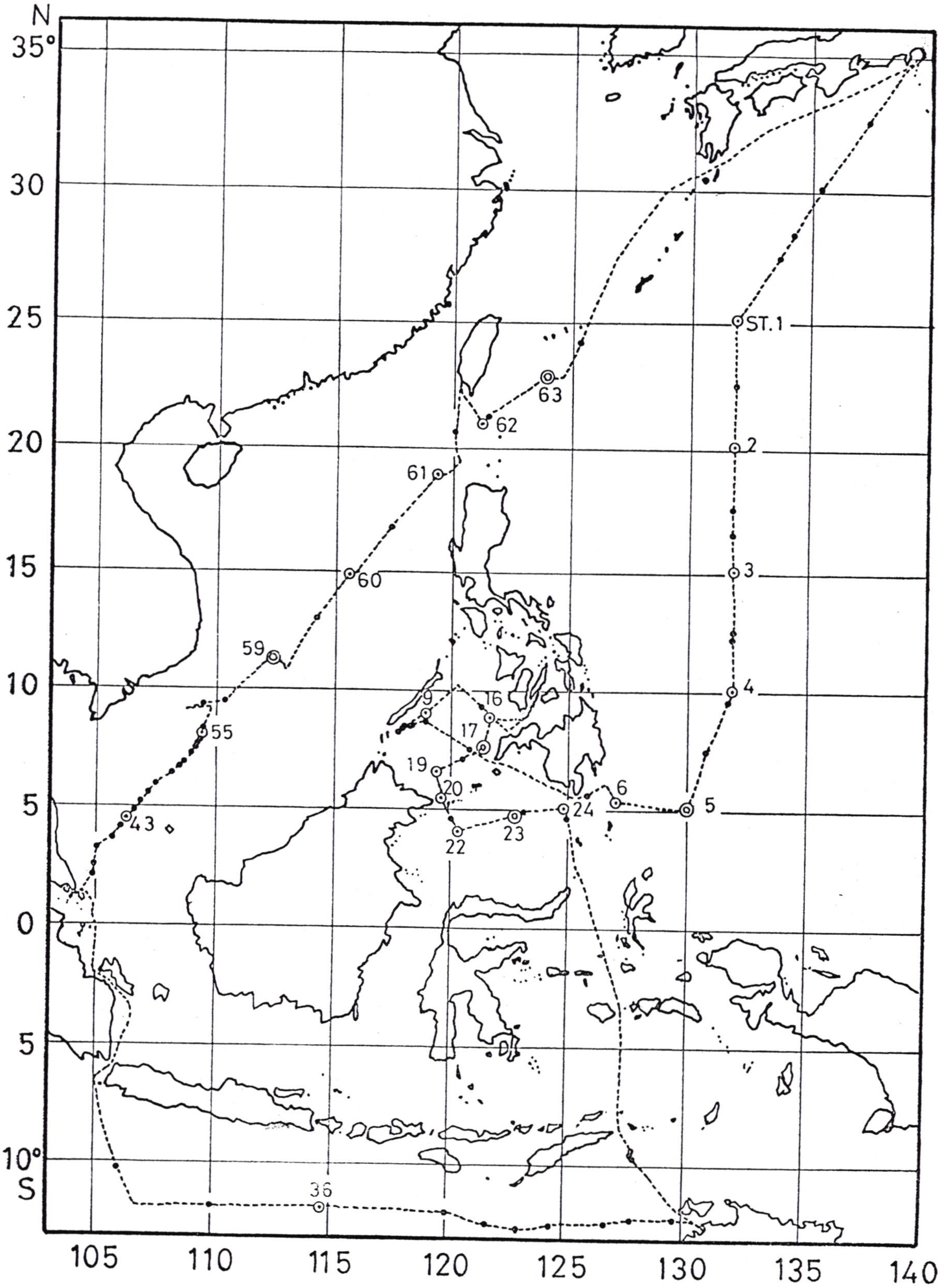


Fig. 1. Sampling stations.

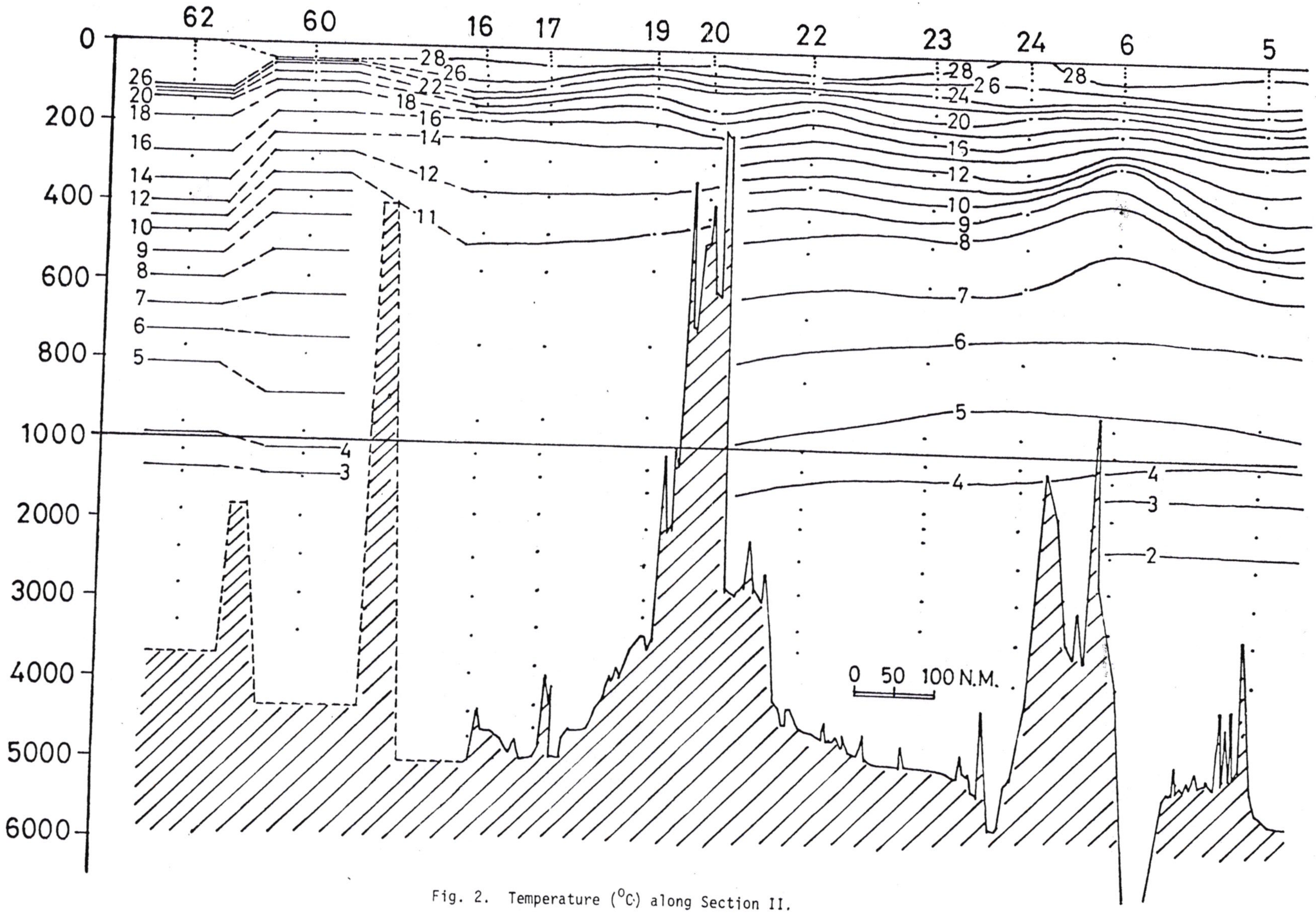


Fig. 2. Temperature (^{o}C) along Section II.

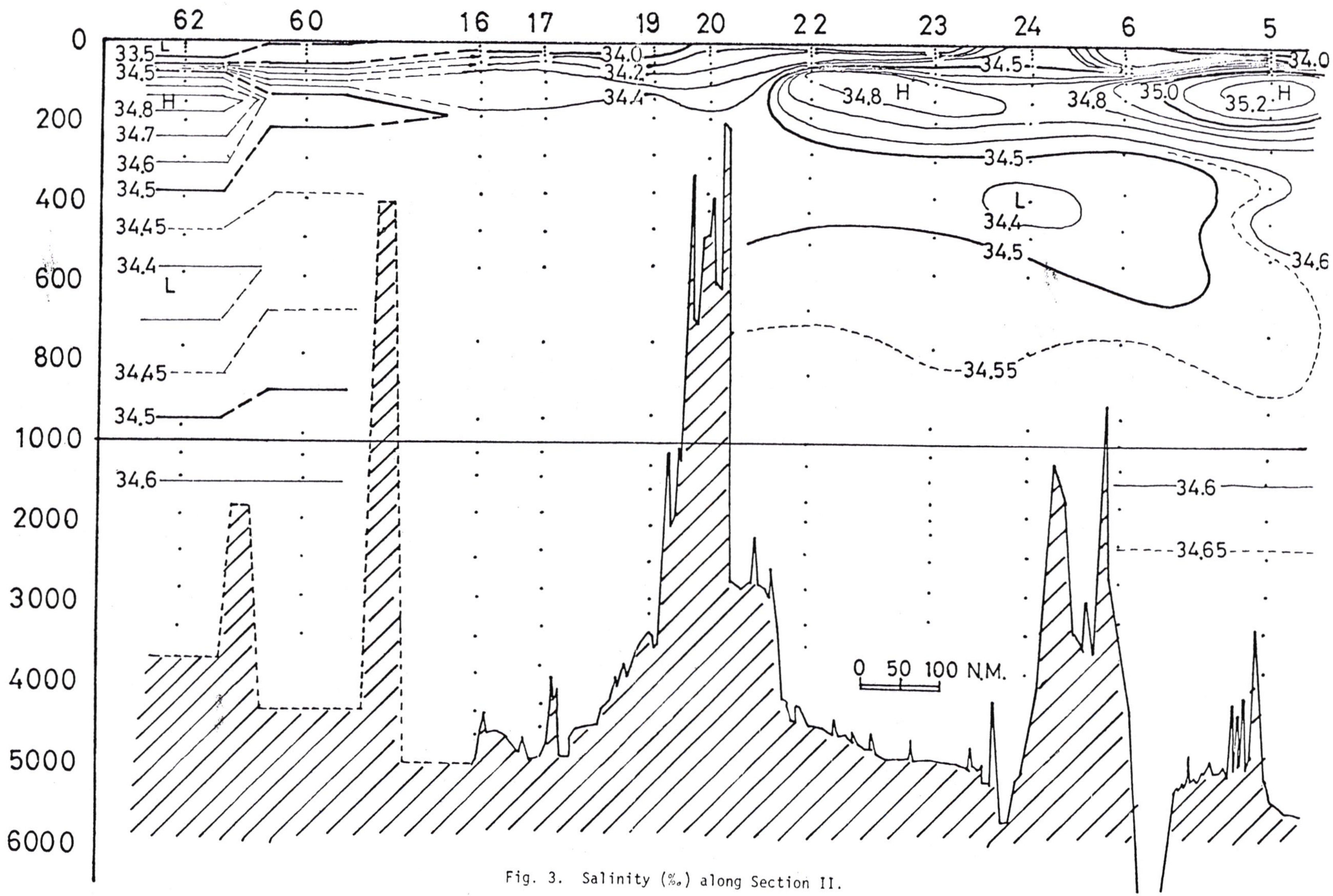


Fig. 3. Salinity (‰) along Section II.

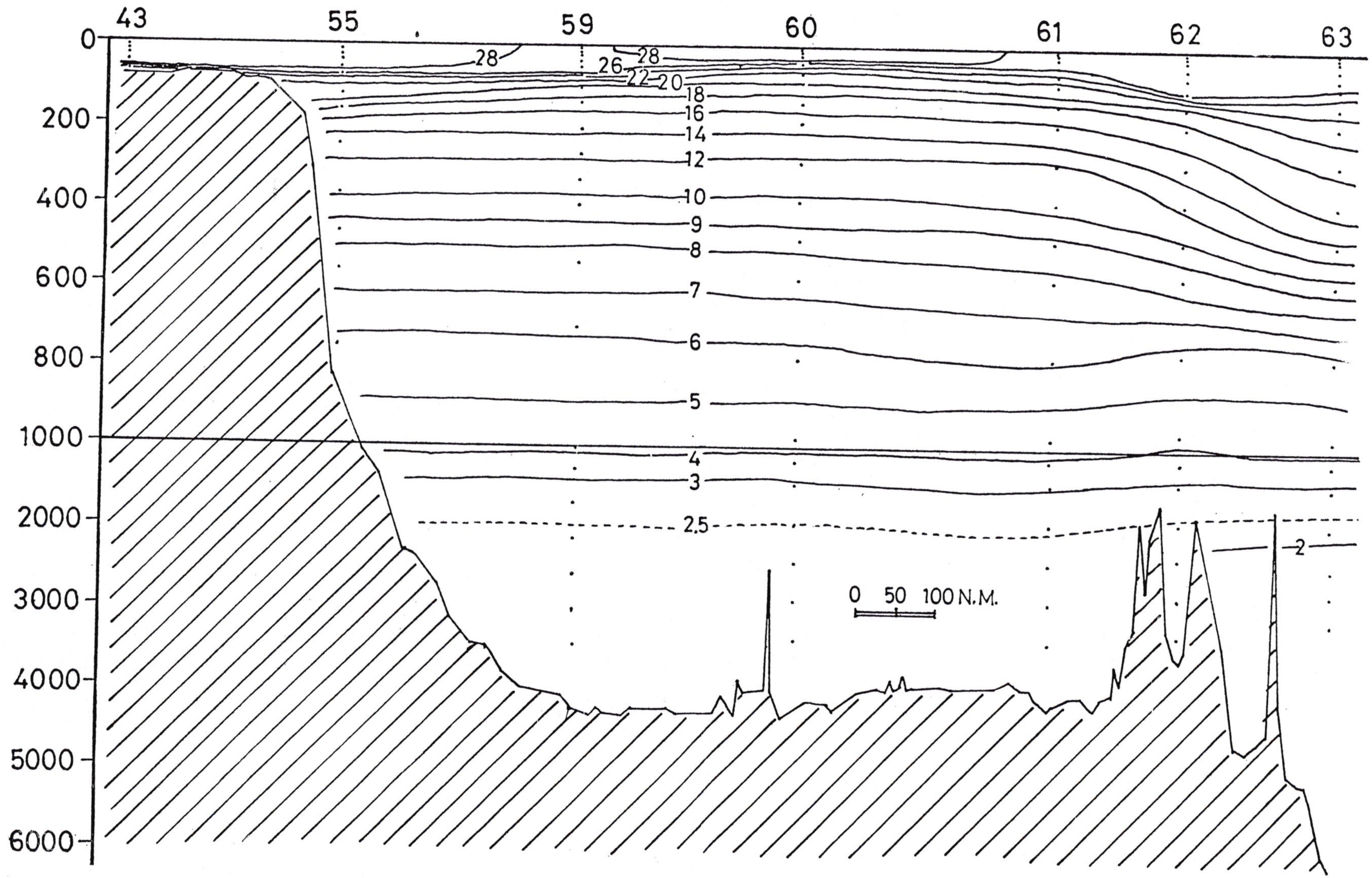


Fig. 4. Temperature (^{o}C) along Section III.

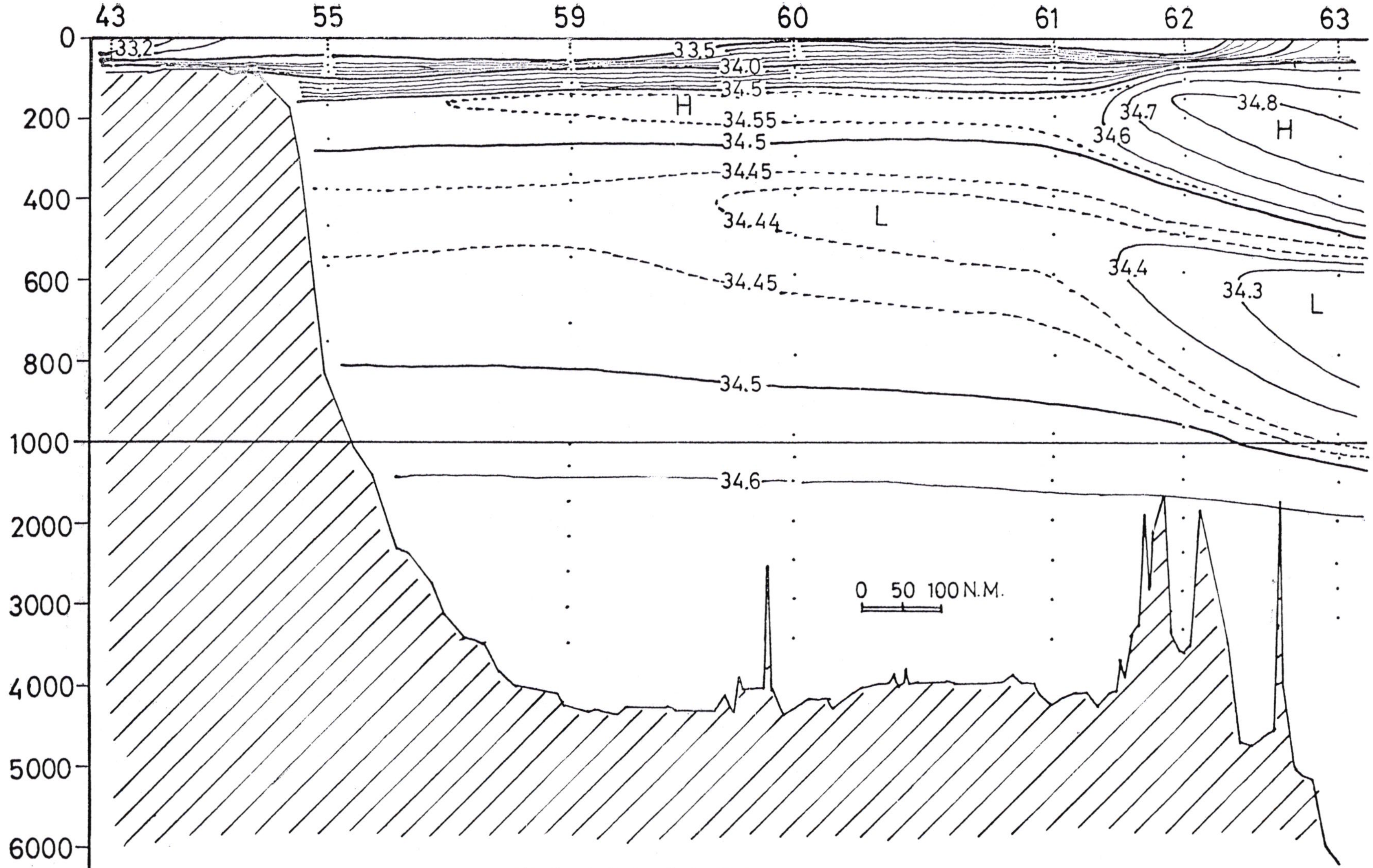


Fig. 5. Salinity (‰) along Section III.

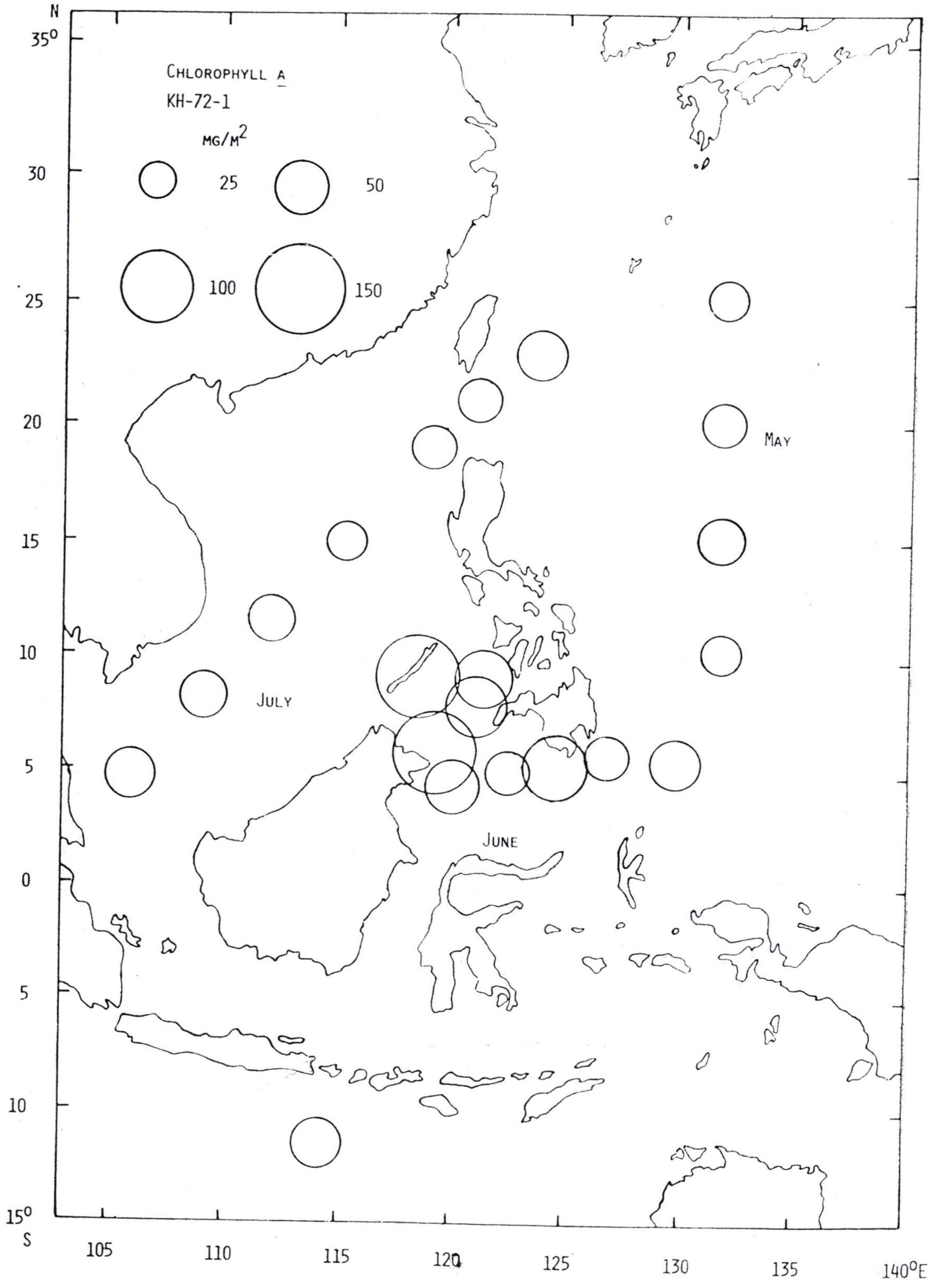


Fig. 6. Distribution of chlorophyll a.

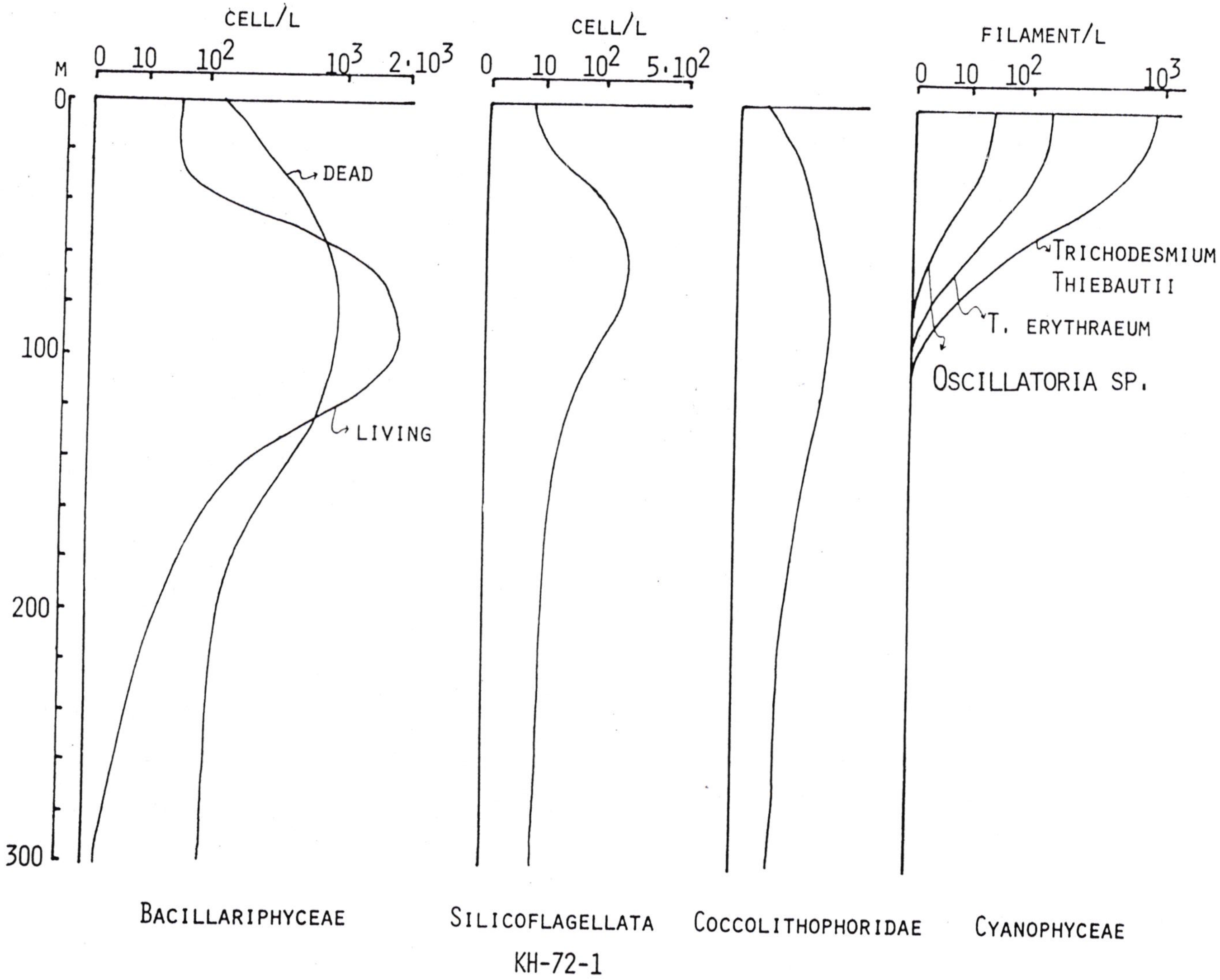


Fig. 7. Schema of vertical distribution of phytoplankton groups.

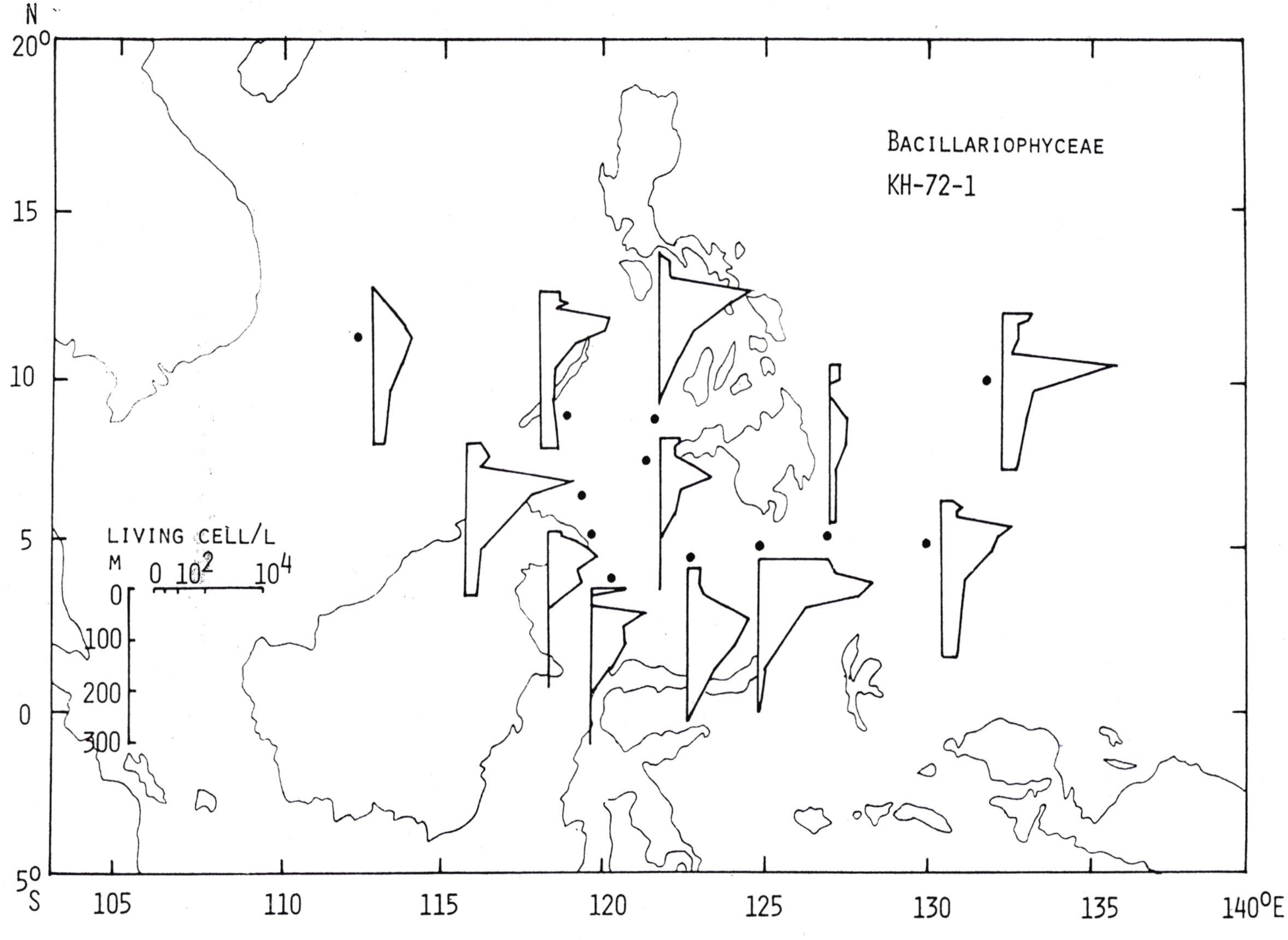


Fig. 8. Distribution of diatoms.

(c) Coccolithophorids

Minute coccolithophorid cells are numerously found at most stations, though the cell was not quantitatively counted. The maximum appears between 50 and 100 m. The cell number exceeded 2,000/l in 75 m at st. 23.

(d) Blue-green algae

Trichodesmium thiebautii is the most predominant and *T. erythraeum* is next to it and *Oscillatoria* sp. is very few. The habitat of these species is peculiar compared with that of other phytoplankton groups; it is concentrated in the upper 50 m and decreases remarkably with depth below this layer,

(e) Other phytoplankton

In addition to phvtoplankton groups mentioned above, dinoflagellates (mostly *Ceratium*) were found in small numbers in water samples and in fairly large numbers in net samples (Table 1). In this study, fragile organisms such as μ-flagellates on which recently the importance as primary producers has been remarkably empasized were not counted, because these are easily broken or shrinked in the preservative solution such as formalin.

(3) Distribution of diatoms

(a) Geographical distribution (Table 1, Fig. 8)

The number of diatom species identified is large, 47--54, at sts. 9, 17 and 23 in coastal water such as the Celebes Sea and Sulu Sea, and small, 7--32, in oceanic water such as the Philippine Sea, South China Sea and Indian Ocean (Table 1).

The maximum of diatom cell number appeared in one of 50, 75 and 100-m layers throughout sampling stations, though their vertical pattern was quite different station by station. The cell exceeded 10,000/l in three layers, namely in 50 m at st. 4, 75 m at st. 19 and 50 m at st. 24. In these samples *Nitzschia* sp. was always the most dominant component.

The cell number amounted to 3,000/l in the surface layer at st. 24. Such a high standing crop is considered to have been made by the sufficient supply of nutrient salts up to the surface layer by upwelling, judging from the distribution of water temperature (Table 2) and salinity (Table 3).

(b) Vertical distribution (Table 2, Figs. 9 and 10)

The number of diatom species is the largest in the 50--150 m layer, and becomes fewer in layers shallower than 30 m and deeper than 200 m (Table 2). Such a tendency corresponds well to the vertical distribution of cell number.

At st. 5, the maximum standing crop of total diatoms was found in 50 m. *Chaetoceros atlanticus* v. *neapolitana* and *Rhizosolenia styliformis* inhabited between 50 and 100 m, while *Thalassiothrix delicatula, Thalassionema nitzschioides* and *Nitzschia* sp. were widely distributed down to 200 m (Fig. 9). At st. 19, however, the total diatoms showed the maximum in 75 m and the distribution of each of five important species resembles very well, being concentrated in 75 m (Fig. 10). At st. 24, many diatom species mostly belonging to *Chaetoceros* were found in the surface layer with a large standing crop, but *Nitzschia* sp. occurred only in 100 m.

(4) Distribution of silicoflagellates (Figs. 11 and 12)

The vertical distribution of silicoflagellate cell number is very similar at each station and the cell number in the maximum layer is in the range from 76/l to 436/l throughout all of 13 stations and the average is 233/l (Fig. 11). *Dictyocha fibula* was the most abundant and *Mesocena polymorpha* was next to it. The vertical distribution of these species at st. 59 was shown in Fig. 12.

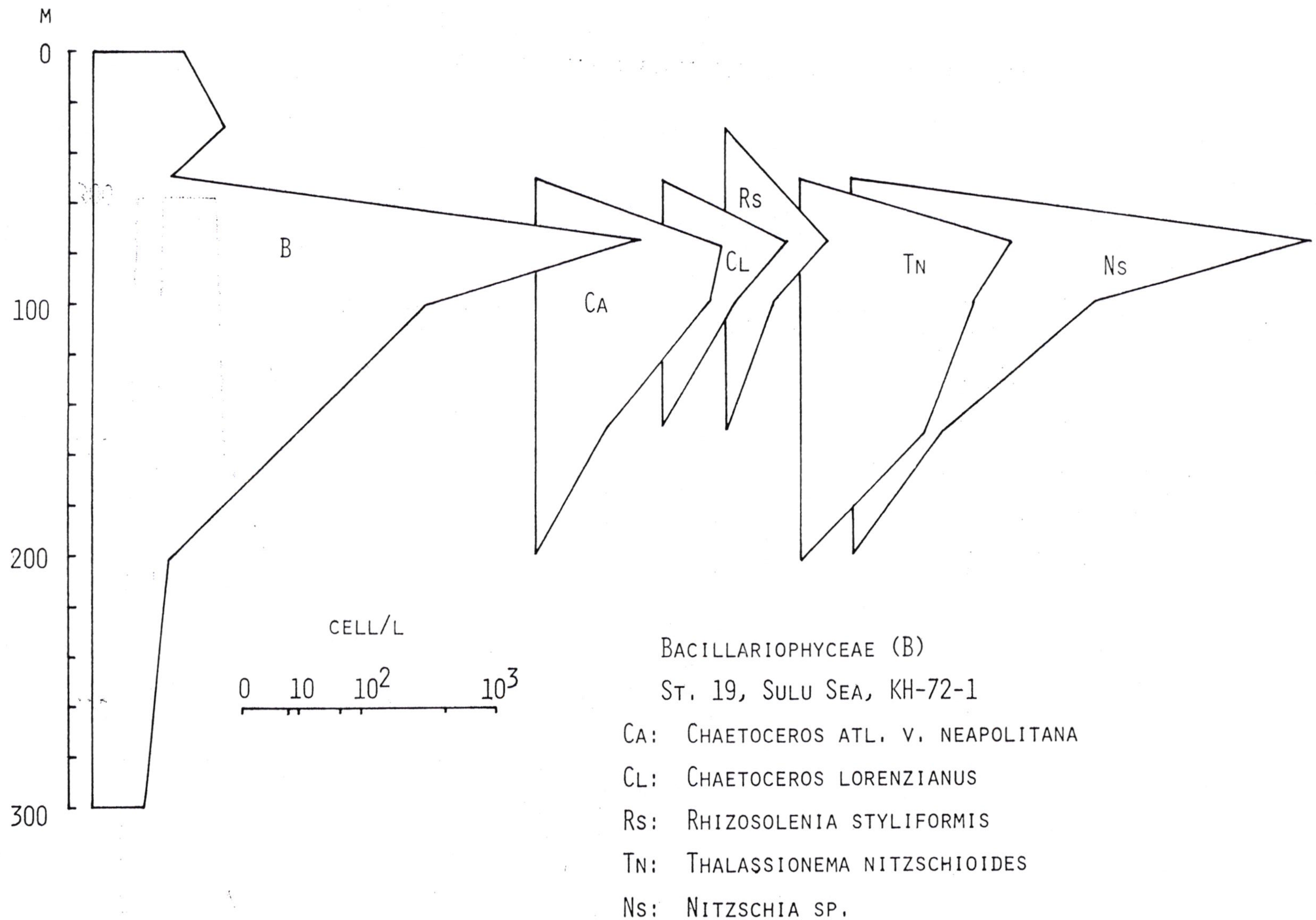


Fig. 9. Vertical distribution of diatoms at st. 5.

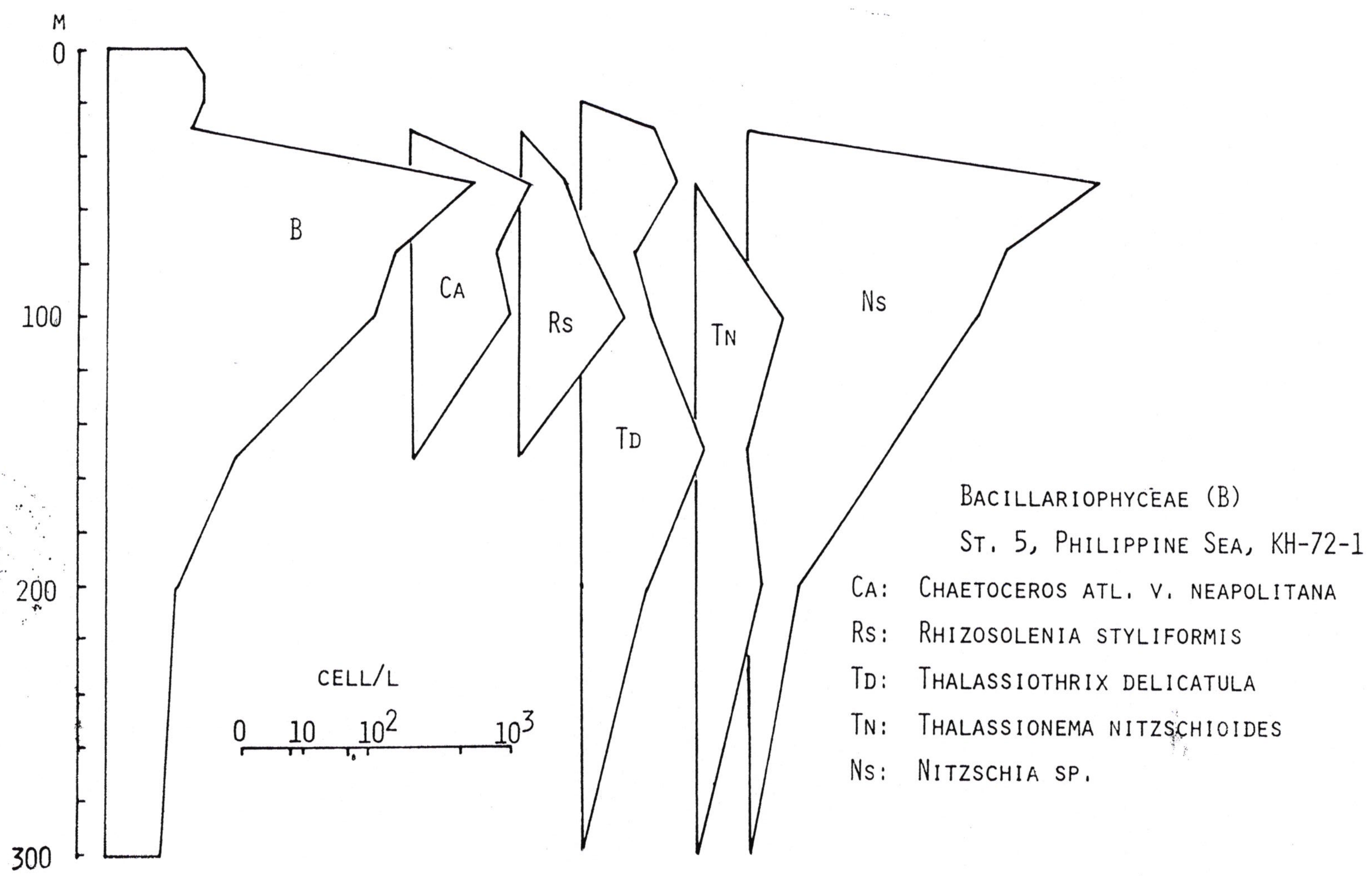


Fig. 10. Vertical distribution of diatoms at st. 19.

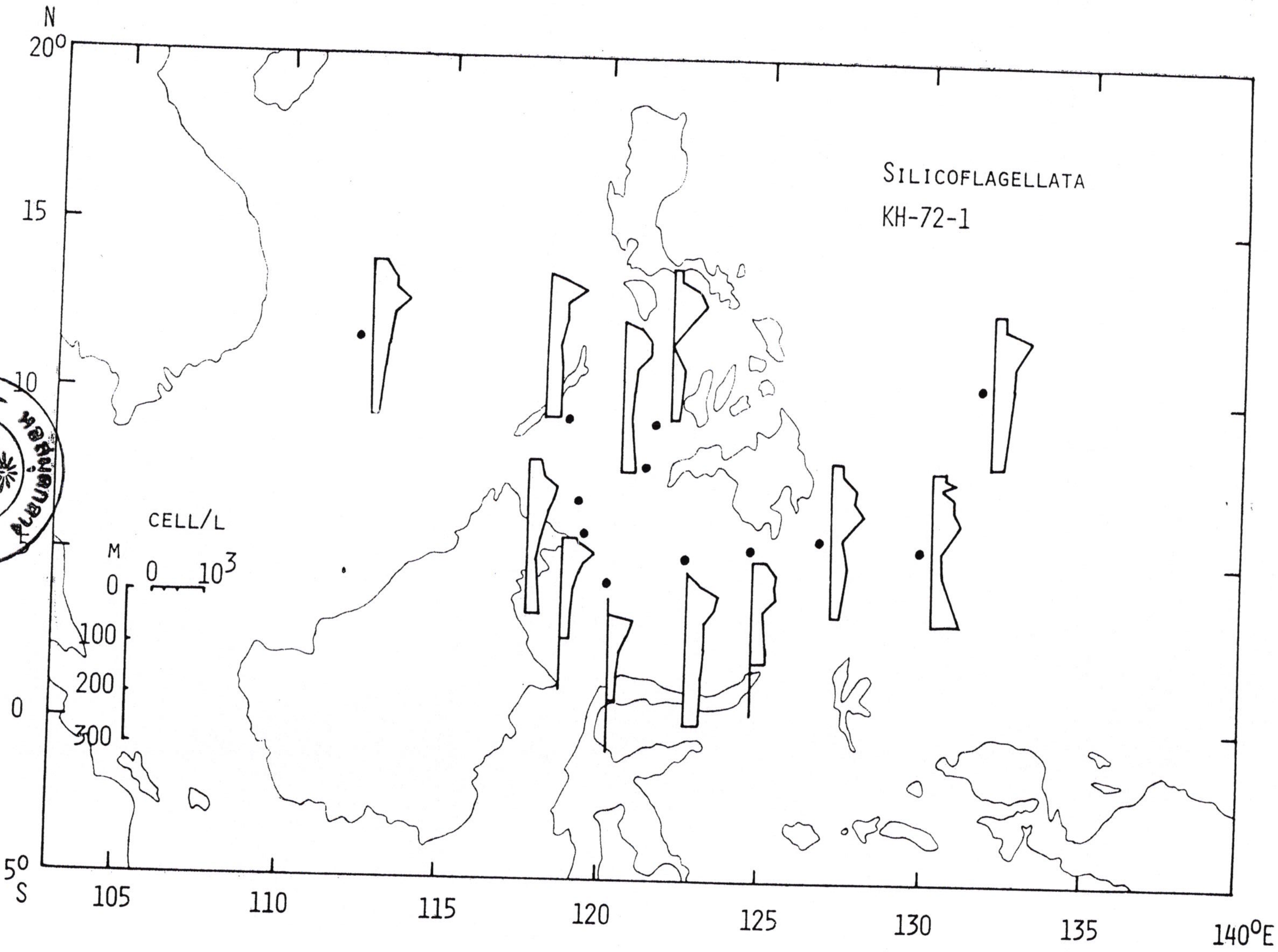


Fig. 11. Distribution of silicoflagellates.

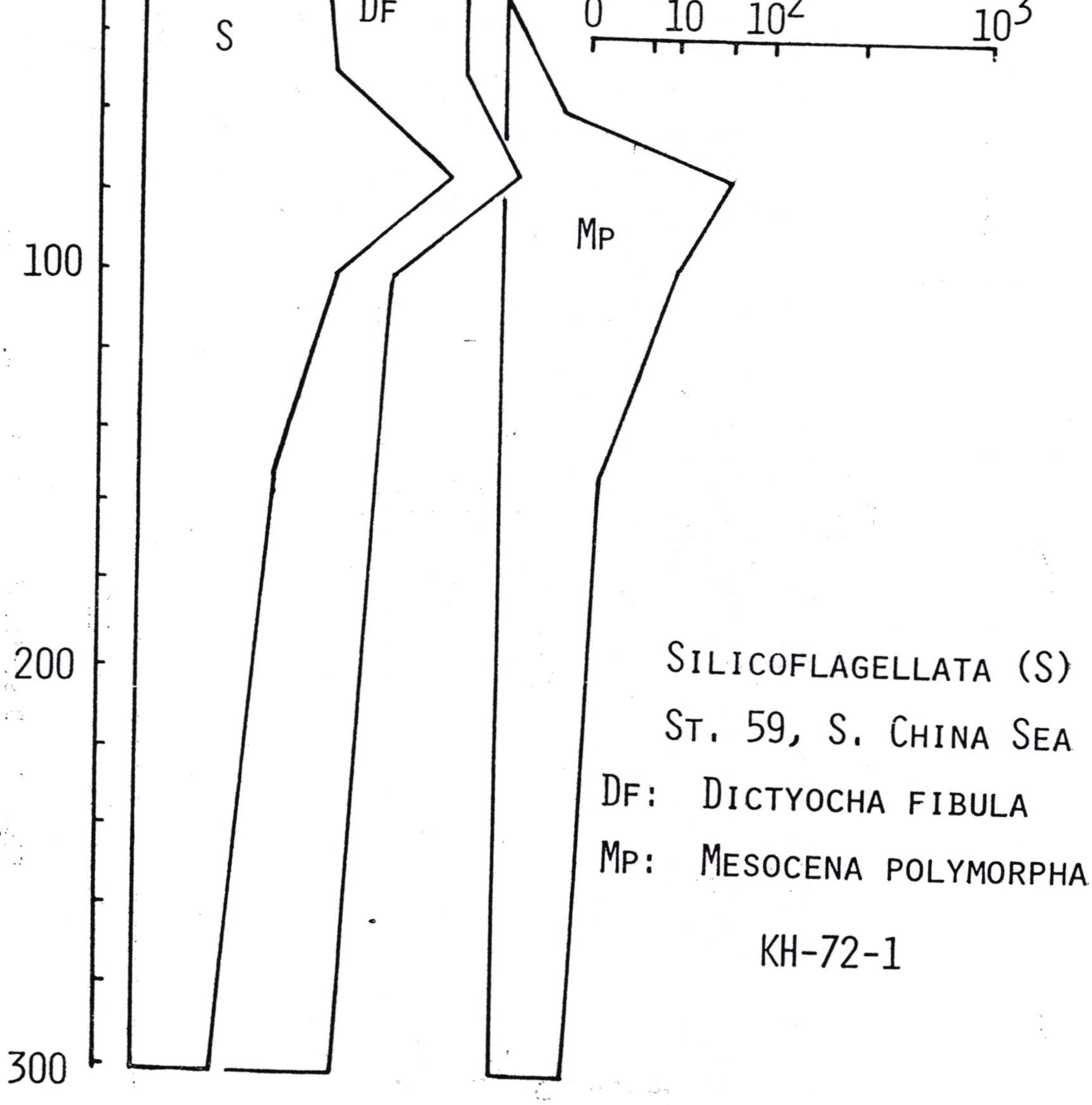


Fig. 12. Vertical distribution of silicoflagellates at st. 59.

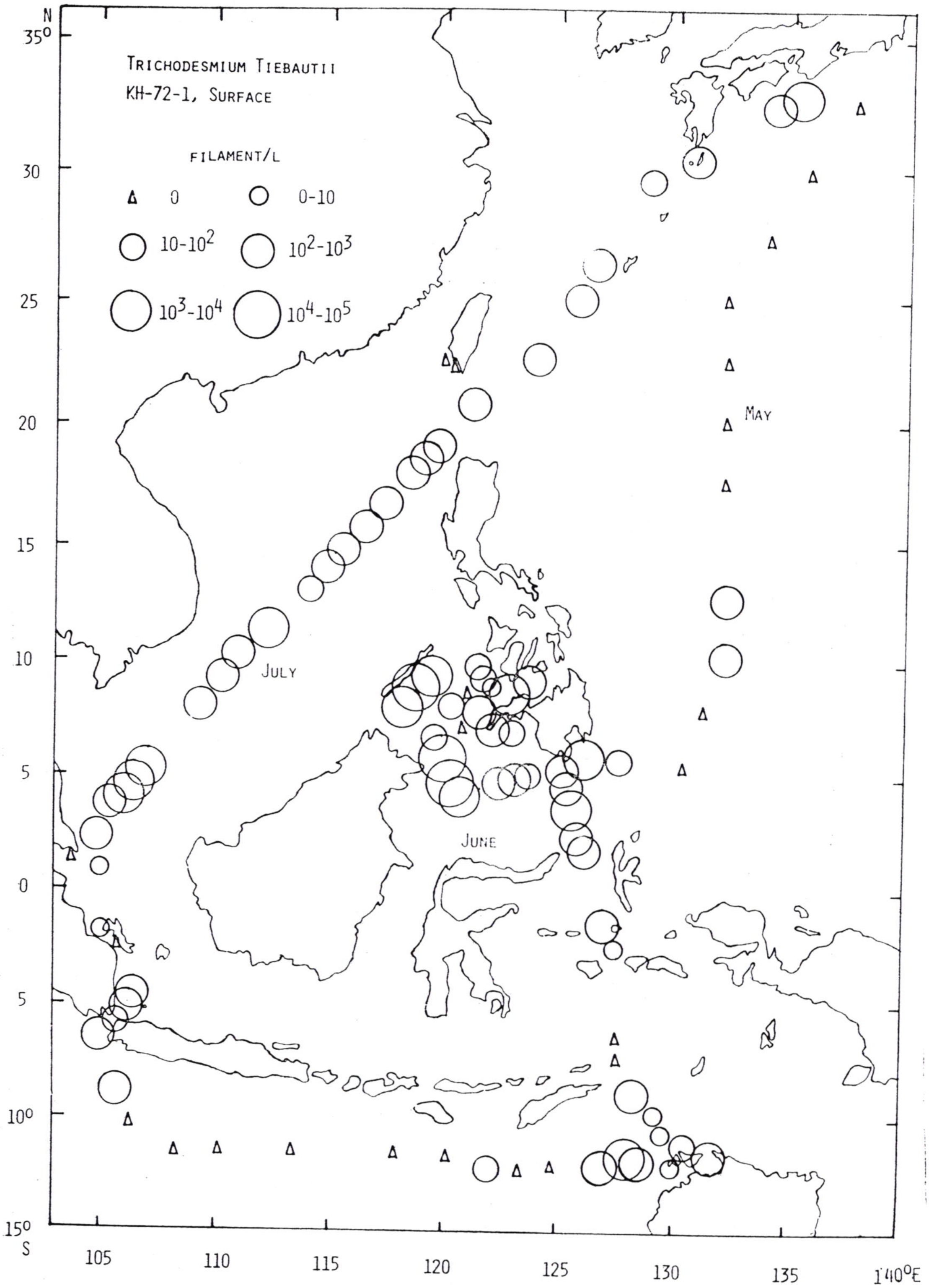


Fig. 13. Distribution (0 m) of Trichodesmium thiebautii.

TABLE I. PHYTOPLANKTON SPECIES* IDENTIFIED.

	Station							
	1	5	9	17	23	36	59	63
CYANOPHYCEAE								
Katagnymene spiralis		–	–	–	+	–	+	+
Oscillatoria sp.		–	+	+	+	–	+	+
Trichodesmium erythraeum		–	+	–	+	–	+	+
T. thiebautii		+	+	+	+	+	+	+
NO. OF BLUE-GREEN ALGAE SPECIES		1	3	2	4	1	4	4
BACILLARIOPHYCEAE								
Asterolampra grevillei	–	+	+	+	–	–	–	–
Asteromphalus flabellatus	–	–	+	–	+	–	–	–
A. heptactis	–	+	+	–	+	+	+	–
A. robustus	–	–	–	+	–	–	+	–
Bacteriastrum comosum	–	+	–	+	+	+	–	–

*Samples were collected with Norpac net and Van Dorn sampler.

Table I (Continued)

	Station							
B. Delicatulum	−	−	−	−	−	+	+	−
B. elongatum	−	−	+	−	+	−	+	−
B. hyalinum	−	−	+	+	+	−	−	+
B. varians	−	−	+	+	−	−	−	−
Bellerochea malleus	−	−	+	−	−	−	−	−
Biddulphia mobiliensis	−	−	+	−	+	−	−	−
B. sinensis	−	−	−	−	−	+	−	−
Cerataulina sp.	−	−	+	+	+	−	−	−
Chaetoceros at. v. neapolitana	−	+	+	−	+	+	−	+
C. coarctatus	−	+	+	+	+	+	+	+
Chaetoceros dadayi	−	+	−	+	−	−	+	−
C. pendulus	−	+	+	−	+	−	−	+
C. peruvianus	−	+	+	+	+	+	+	+
C. rostratus	−	−	+	+	−	−	−	−
C. saltans	−	+	+	+	−	−	+	−

Table I (Continued)

	Station							
C. seychellarum	−	−	+	−	+	+	−	+
C. tetrastichon	−	+	+	−	+	−	−	−
C. affinis	−	−	+	+	+	+	+	+
C. brevis	−	−	+	−	+	−	−	−
C. compressus	−	−	+	+	+	−	+	−
C. curvisetus	−	−	−	+	+	−	−	−
C. didymus	−	−	+	+	−	−	+	−
C. diversus	−	−	+	+	−	−	+	−
C. laciniosus	−	+	+	−	+	−	−	−
C. lorenzianus	−	+	+	+	+	+	+	+
C. messanensis	−	+	+	+	+	+	+	+
Climacodium frauenfeldianum	−	+	+	+	+	+	+	+
Coscinodiscus asteromphalus	−	+	+	+	−	+	−	−
C. excentricus	−	+	+	+	+	+	−	−
C. gigas	−	−	−	−	−	+	−	+

Table I (Continued)

	Station							
C. granii	−	−	−	+	−	−	−	−
C. lineatus	−	+	+	+	+	−	−	−
C. marginatus	−	−	−	+	−	−	−	−
C. radiatus	−	+	−	+	−	+	−	−
Coscinosira polychorda	−	−	−	−	−	+	−	−
Dactyliosolen mediterraneus	+	+	+	+	+	−	+	+
Ditylum sol	−	−	−	+	+	−	−	−
Eucampia zoodiacus	−	−	+	+	+	−	−	−
Gossreliella tropica	−	+	+	+	+	+	−	−
Guinardia flaccida	−	−	−	+	+	−	+	−
Hemiaulus hauckii	+	−	+	+	+	−	+	+
H. membranaceus	−	−	+	−	−	−	−	+
H. sinensis	−	−	+	+	+	−	−	−
Hemidiscus cuneiformis	−	+	−	−	−	+	−	−
Lauderia borealis	+	−	+	+	−	−	−	−

Table I (Continued)

	Station							
Planktoniella sol	-	+	+	+	+	+	-	+
Rhizosolenia acuminata	-	-	-	+	-	-	-	-
R. alata	-	+	+	+	+	+	+	+
R. bergonii	-	+	+	+	+	+	+	+
R. calcar avis	-	-	+	-	+	+	+	+
R. castracanei	-	-	-	-	+	+	-	+
R. cylindrus	-	-	+	-	+	-	-	-
R. fragilissima	-	-	-	-	+	-	-	-
R. im. v. shrubsolei	-	+	+	+	+	+	+	+
R. robusta	-	-	-	-	-	+	-	+
R. setigera	-	-	+	+	+	-	-	-
R. stolterfothii	-	-	-	+	+	+	-	+
R. styliformis	+	+	+	+	+	+	+	-
R. sty. v. latissima	-	-	+	-	-	+	-	-
Schröderella delicatula	-	-	+	+	+	-	-	+

Table I (Continued)

	Station							
Skeletonema costatum	+	–	–	–	–	–	–	–
Stephanopyxis palmeriana	–	–	+	–	+	–	–	–
Streptotheca thamesis	–	–	+	–	+	–	–	–
Thalassiosira sp.	–	–	+	–	+	–	–	–
Triceratium sp.	–	+	+	–	+	+	–	–
Nitzschia closterium	–	–	–	+	–	+	–	–
N. delicatissima	–	–	+	–	–	–	–	–
N. seriata	–	–	–	+	–	–	–	–
Pseudoeunotia doliolus	–	–	+	+	–	–	–	–
Thalassionema nitzschioides	+	+	+	+	+	–	+	+
T. frauenfeldii	–	–	–	–	–	–	–	–
T. delicatula	+	–	+	+	+	+	–	+
NO. OF DIATOM SPECIES	7	27	54	46	47	32	24	25

Table I (Continued)

	Station							
DINOPHYCEAE								
Amphisolenia bidentata	−	+	+	+	+	+	+	+
A. globifera	−	−	−	−	+	−	−	−
Ceratium belone	+	−	−	−	−	−	−	−
C. carriense	+	−	−	+	−	+	−	+
C. candelabrum	−	−	+	−	+	−	−	+
C. contortum	−	−	−	+	−	+	+	+
C. deflexum	−	+	+	+	−	+	+	−
C. extensum	+	−	+	+	+	−	−	+
Ceratium fusus	+	+	+	+	+	−	−	−
C. furca	−	−	+	+	−	−	−	−
C. incisum	−	−	+	−	−	−	−	−
C. inflexum	+	+	+	+	+	+	+	+
C. kofoidii	−	+	−	+	−	−	−	−
C. longissimum	−	−	+	−	−	−	−	−
C. lunula	−	−	−	+	−	−	−	−

Table I (Continued)

		Station							
C.	*macr, galicum*	−	−	−	+	+	+	−	+
C.	*massiliense*	+	+	−	−	+	+	+	−
C.	*palmatum*	−	−	−	−	−	+	−	−
C.	*pennatum*	−	+	+	−	−	+	−	+
C.	*pulchellum*	−	+	−	+	−	+	−	+
C.	*reticulatum*	−	−	−	+	+	−	−	−
C.	*sumatranum*	−	+	+	+	−	−	+	+
C.	*tenue*	−	+	−	+	−	+	+	−
C.	*trichoceros*	+	+	+	+	+	+	+	+
C.	*tripos*	−	+	−	+	−	−	−	−
C.	*vultur*	−	−	−	+	−	−	−	−
Ceratocorys	*horrida*	+	−	+	+	+	−	+	+
Ornithocercus	*serratus*	−	−	−	+	+	−	−	+
Oxytoxum	*sp.*	−	−	−	−	−	+	−	−
Peridinium	*divergens*	−	+	+	+	−	−	−	−

Table I (Continued)

	Station							
P. faltipes	–	–	–	+	–	–	–	–
Pyrocystis fusiformis	+	–	–	–	–	+	+	+
Pyrocystis hamulus	+	–	+	–	+	–	+	+
P. lunula	–	–	+	–	–	–	–	+
P. pseudonoctiluca	+	+	+	+	+	+	+	+
Pyrophacus horologicum	–	–	–	+	+	–	+	–
NO. OF DINOFLAGELLATE SPECIES	11	14	17	24	15	15	13	17

+ : PRESENT, – : ABSENT

Table II. Frequency of appearance of diatom species* in each layer at sts. 4, 5, 6, 9, 16, 17, 20, 22 and 23 (KH – 72 – 1).

Depth (M)	0	10	20	30	50	75	100	150	200	300
Actinoptychus undulatus							1			
Asterolampra grevillei					1					
Asteromphalus heptactis					1	1		1		
A. robustus					1					
Bacteriastrum comosum					1		1			
B. delicatulum					1		1			
B. elongatum					1		1	1		
B. sp.					1	2				
Biddulphia mobiliensis					1		1	1	1	
B. sinensis							1			

* Sample waters (500 ml) were obtained from Van Dorn sampler.

Table II (Continued)

Depth (M)		0	10	20	30	50	75	100	150	200	300
Chuetoceros	*atl. v. neapolitana*		1			3	2	4	1	2	1
C.	*coarctatus*		1	1	1						
C.	*dadayi*		1	1							
C.	*pendulus*	1		1			1	1	1		
C.	*peruvianus*	1				2	1	1			
C.	*seychellarum*				1	1					
C.	*affinis*				1	2	2		1		
C.	*brevis*					2		1			
C.	*compressus*					3	2	1	1		
C.	*curvisetus*				1	1	1	3			
C.	*laciniosus*										
C.	*lorenzianus*	1		1	2	5	3	3	1		
C.	*messanensis*					1	2	1	1		
C.	*sp.*				1	2	3	2	1		
Climacodium	*frauenfeldianum*	1									

Table II (Continued)

Depth (M)	0	10	20	30	50	75	100	150	200	300
Coscinodiscus asteromphalum								2		1
C. excentricus						3	4	1		
C. granii				1						
C. lineatus					1	1	2			
C. radiatus						2				
C. sp.	1	1	1	3	4	6	8	4	3	2
Dactyliosolen mediterraneus					1	1				
Gossreliella tropica					1				1	
Hemiaulus hauckii	2	1	1		3	1	2			
H. sinensis				1	1	1				
Hemidiscus cuneiformis						1		1		
Planktoniella sol							2	1		
Rhizosolenia alata				1	2	1	4	2		
R. bergonii							1		1	
R. setigera		1						1		

Table II (Continued)

Depth (M)	0	10	20	30	50	75	100	150	200	300
R. styliformis	2	3	3	1	6	2	4	2		
Schroederella delicatula						2	1			
Triceratium sp.	1					1	3			
Nitzschia sp.					1	6	7	4	4	1
Thalassionema nitzschioides					1	4	5	5	2	
Thalassiothrix delicatula	1			1	2	2	4	3	2	1
NO. OF DIATOM SPECIES	9	7	7	12	29	26	29	21	8	5

(5) Distribution of blue-green algae

(a) *Trichodesmium thiebautii* (Figs. 13 and 14)

This species is the most predominant in the pelagic blue-green algae in the Pacific Ocean (Nagasawa and Marumo, 1967; Marumo, 1974). It occurred almost at all stations except the Philippine Sea and Indian Ocean (Fig. 14). The absence in the Philippine Sea may be owing to the early sampling season such as May when *Trichodesmium* does not yet flourishly propagate. The maximum filament number was 56,000/l in the surface layer at st. 22 in the Sulu Sea. The inhabiting layer is always restricted to the shallow water, but it goes down little deeper in the South China Sea (Fig. 14).

(b) *Trichodesmium erythraeum* (Fig. 15)

The distributional pattern of this species resembles that of *T. thiebautii*, but the filament number is about one order lower than that of *T. thiebautii* (Fig. 15). The highest standing crop was 55,000/l at a station and 21,000/l at st. 23 in the Sulu Sea and 10,000/l at a station in the Indian Ocean.

Red tide mainly formed by this species was observed in three regions, namely near Port Darwin, south of Timor and east of Sumatra. In the last region the red tide covered about 20-km area, though the distribution was restricted to the surface skin layer.

(c) *Oscillatoria* sp. (Fig. 16)

Oscillatoria sp. was found only in small areas of the Sulu Sea and Celebes Sea which waters are of neritic characteristic. The filament number was the highest, 5,100/l at a station in the Sulu Sea and less than 1,000/l at other stations.

The pre-stage of red tide phenomenon formed by this alga together with *T. thiebautii* was observed twice, near Palawan Island and east of North Borneo.

This condition is different from the case of *T. erythraeum* red tide mentioned above; *Oscillatoria* sp. secretes mucous substances in abundance around its trichome, and consequently, the water rich in this alga seems to be remarkably sticky.

(6) Distribution of *Trichodesmium* and chlorophyll a in the South China Sea (Figs. 17--19)

On the distribution of *T. thiebautii* and *T. erythraeum* along Section II in the South China Sea, the high standing crop over 500 filaments/l of the former species and over 100 filaments/l of the latter one occurred at sts. 43, 59 and 63 (Fig. 17).

The chlorophyll a content in the South China Sea was 250--500 $\mu g/m^3$ in the upper 100-m layer, being comparable to that in the Kuroshio water (Kawarada and Sano, 1972). At all stations, chlorophyll a was rich in the surface layer and decreased to the minimum around 20 m and it again increased to the maximum between 75 m snd 100 m (Fig. 18). The high content of chlorophyll a was observed in the surface layer at sts. 43, 59 and 63, just as in filament numbers. It is reasonably resulted from the comparison between Figs. 18 and 19 that chlorophyll a in the surface layer and the subsurface maximum layer is supported mainly by *Trichodesmium*, and diatoms and other phytoplankton groups, respectively, as schematically shown in Fig. 19.

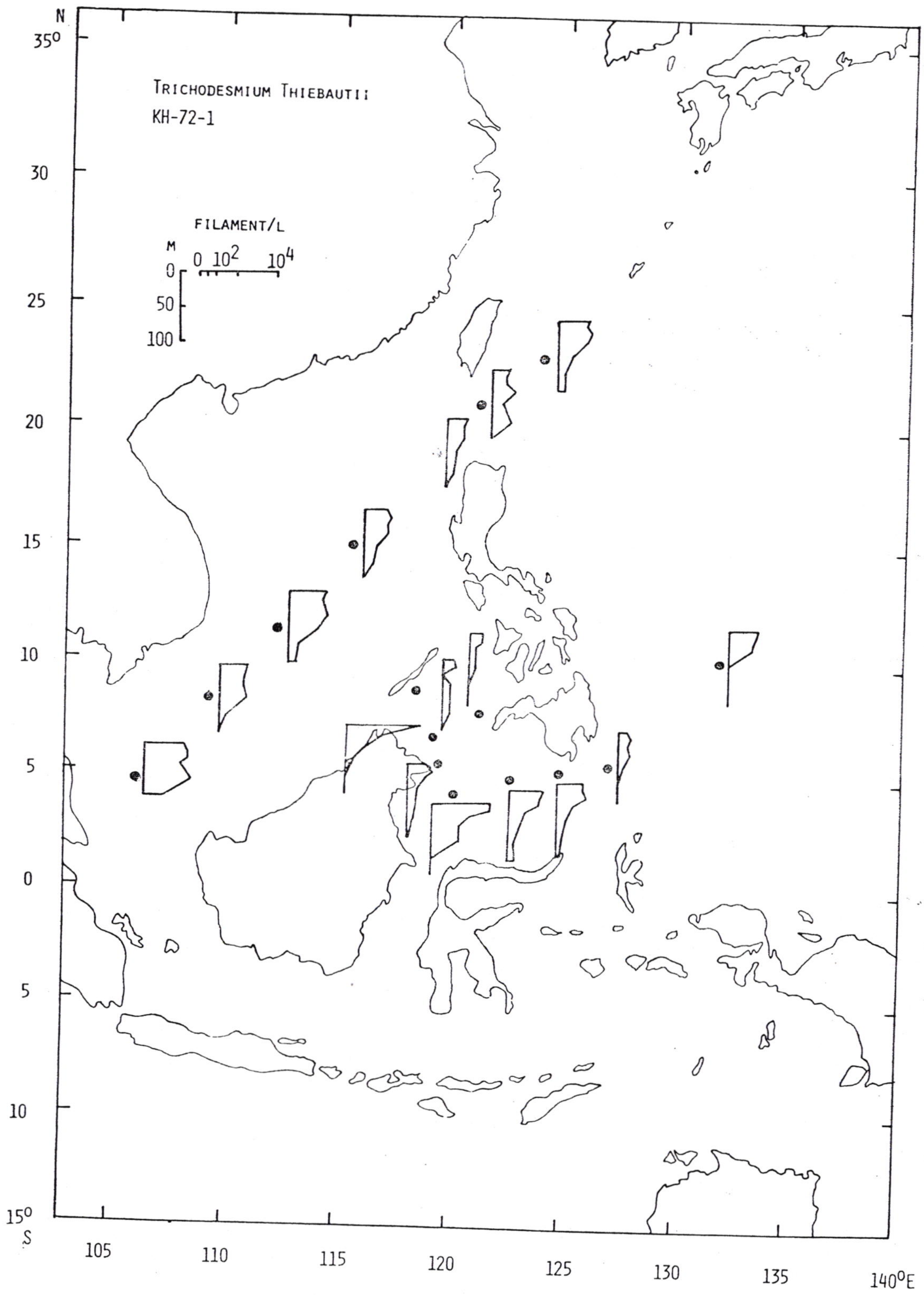


Fig. 14. Distribution (0--100 m) of Trichodesmium thiebautii.

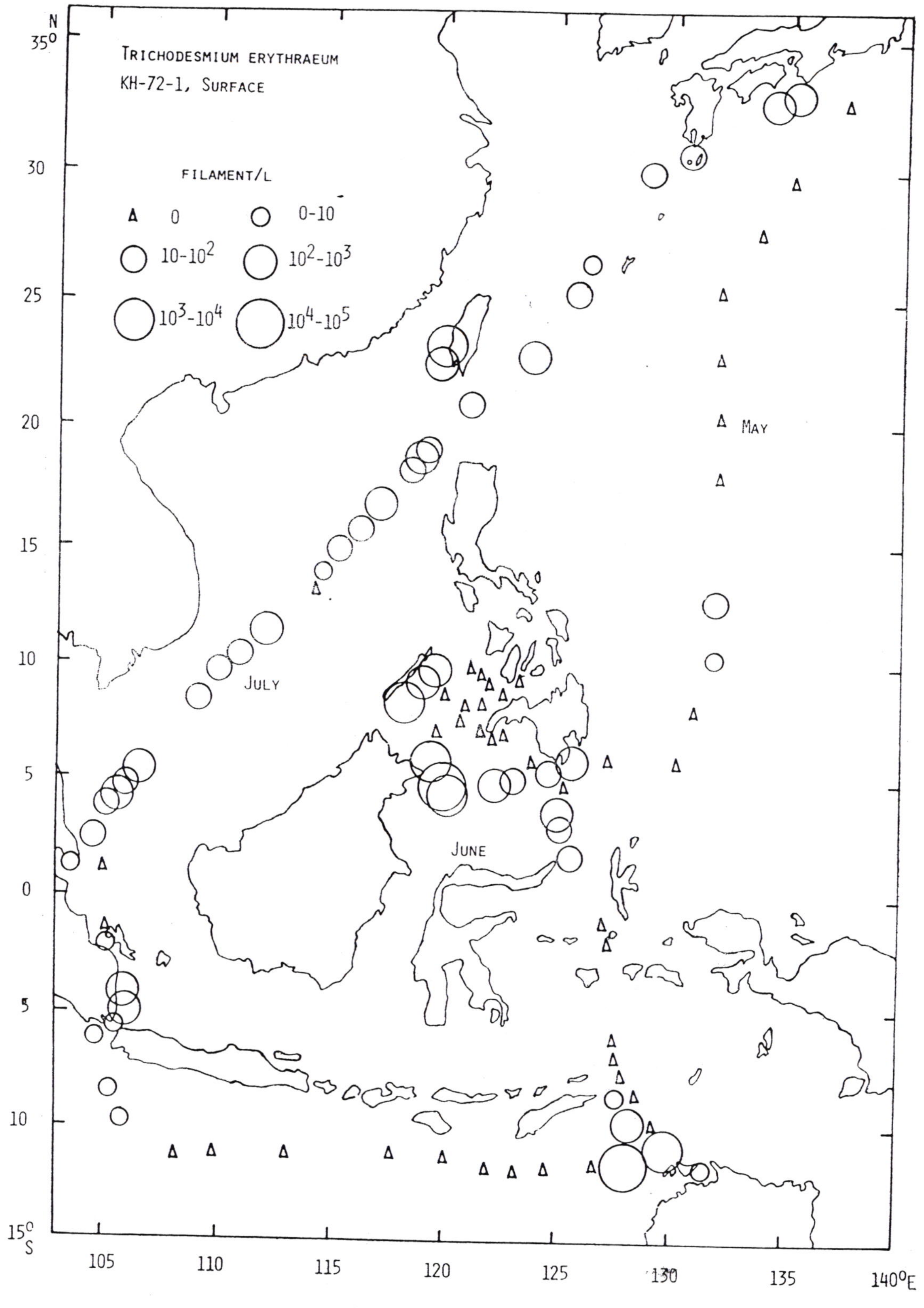


Fig. 15. Distribution (0 m) of Trichodesmium erythraeum.

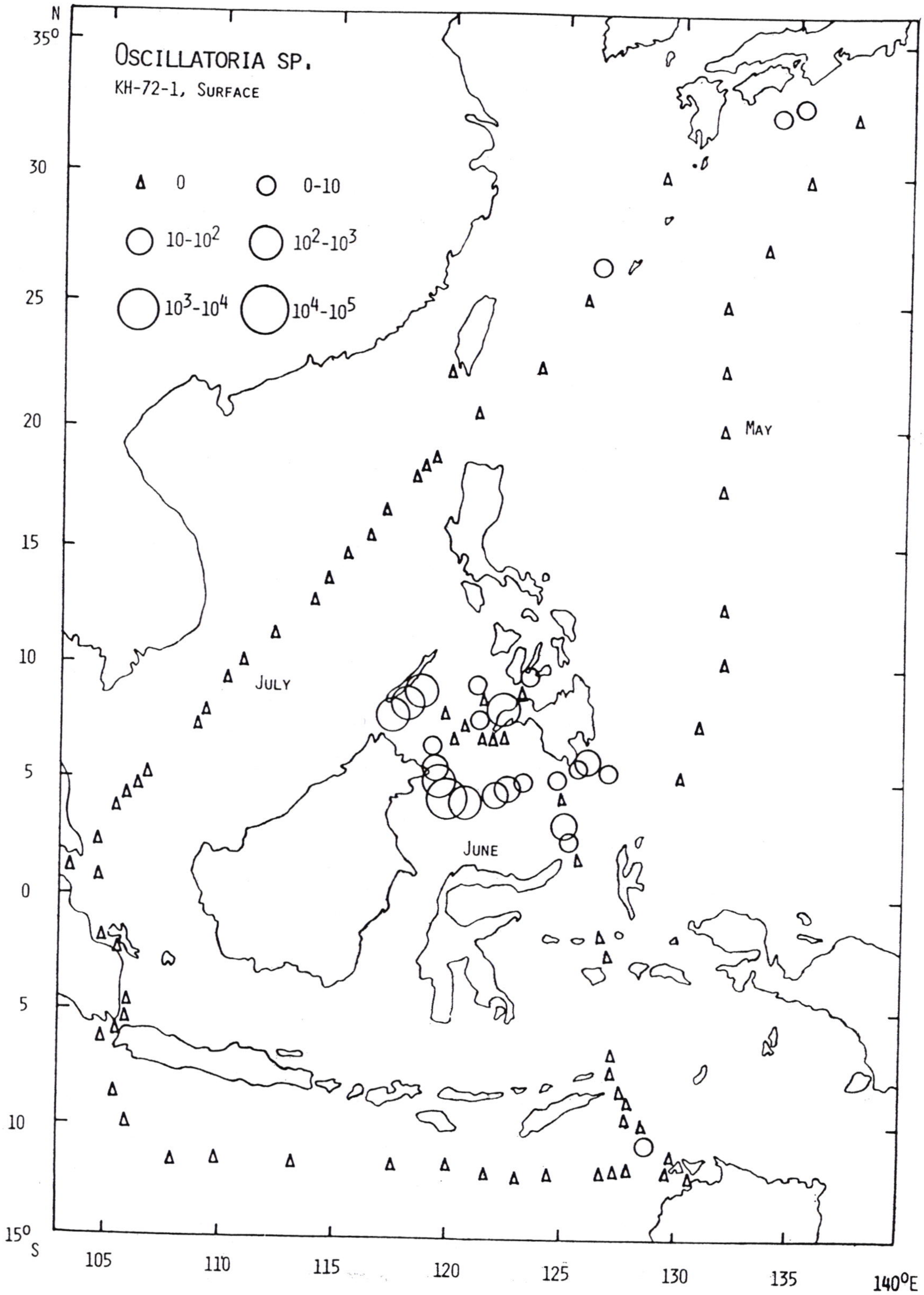
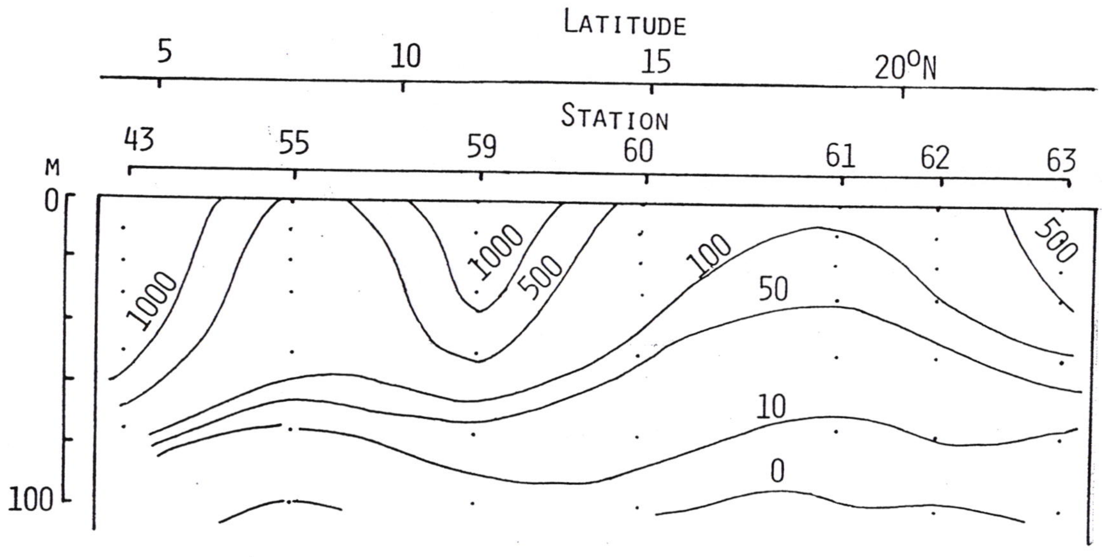
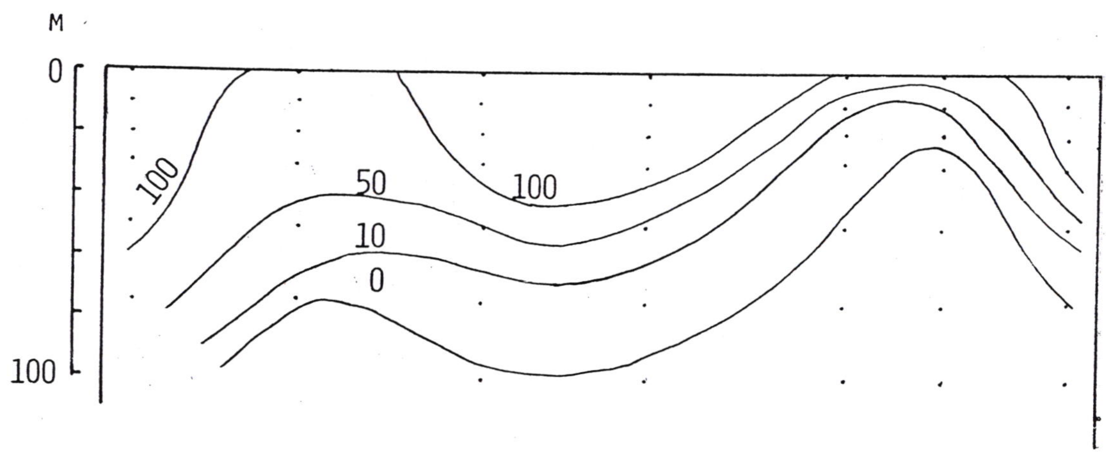


Fig. 16. Distribution (0 m) of Oscillatoria sp.



TRICHODESMIUM THIEBAUTII



TRICHODESMIUM ERYTHRAEUM

FILAMENT/L, SECTION III, KH-72-1

Fig. 17. Distribution of Trichodesmium thiebautii and T. erythraeum in the South China Sea.

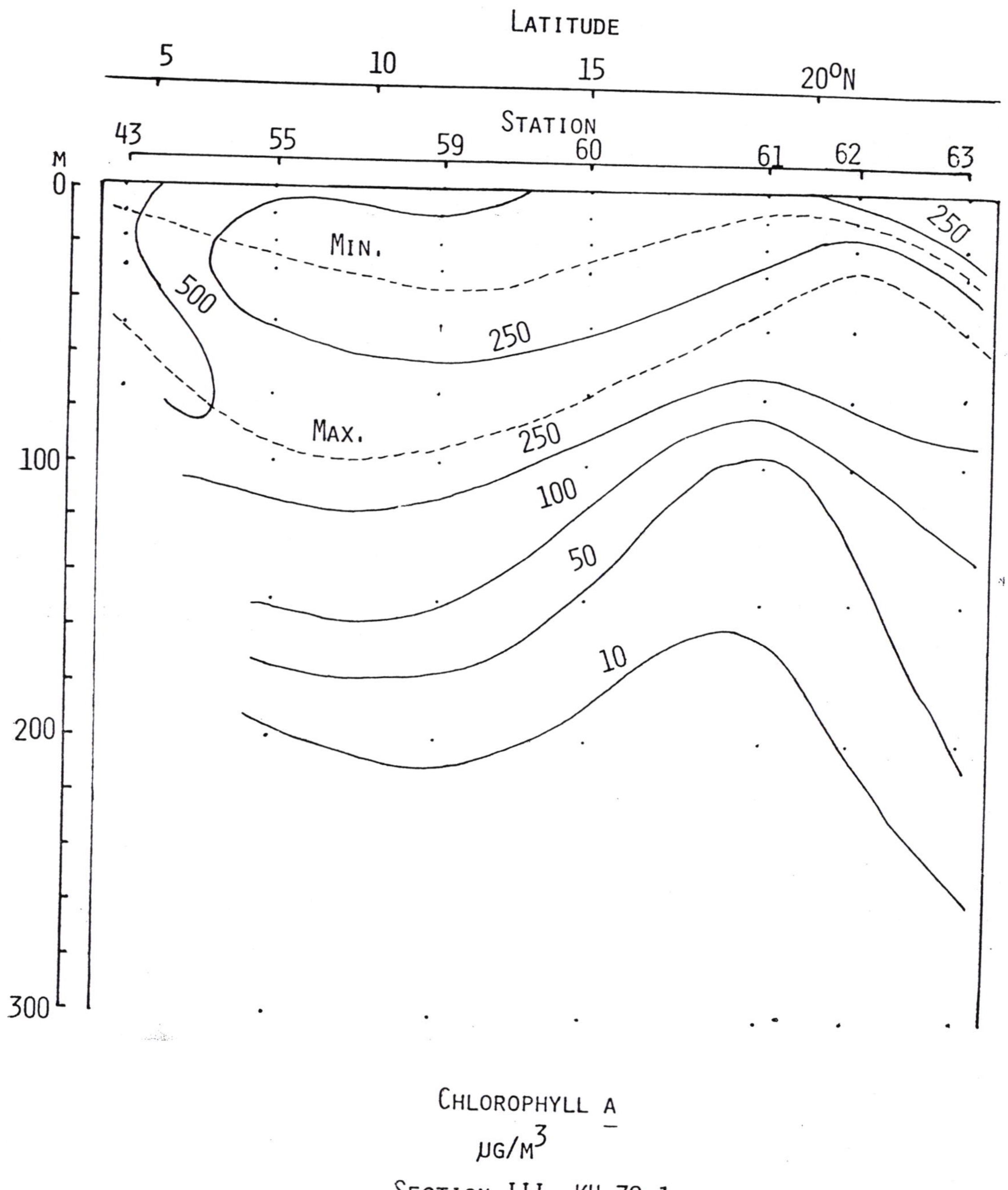


Fig. 18. Distribution of chlorophyll a in the South China Sea.

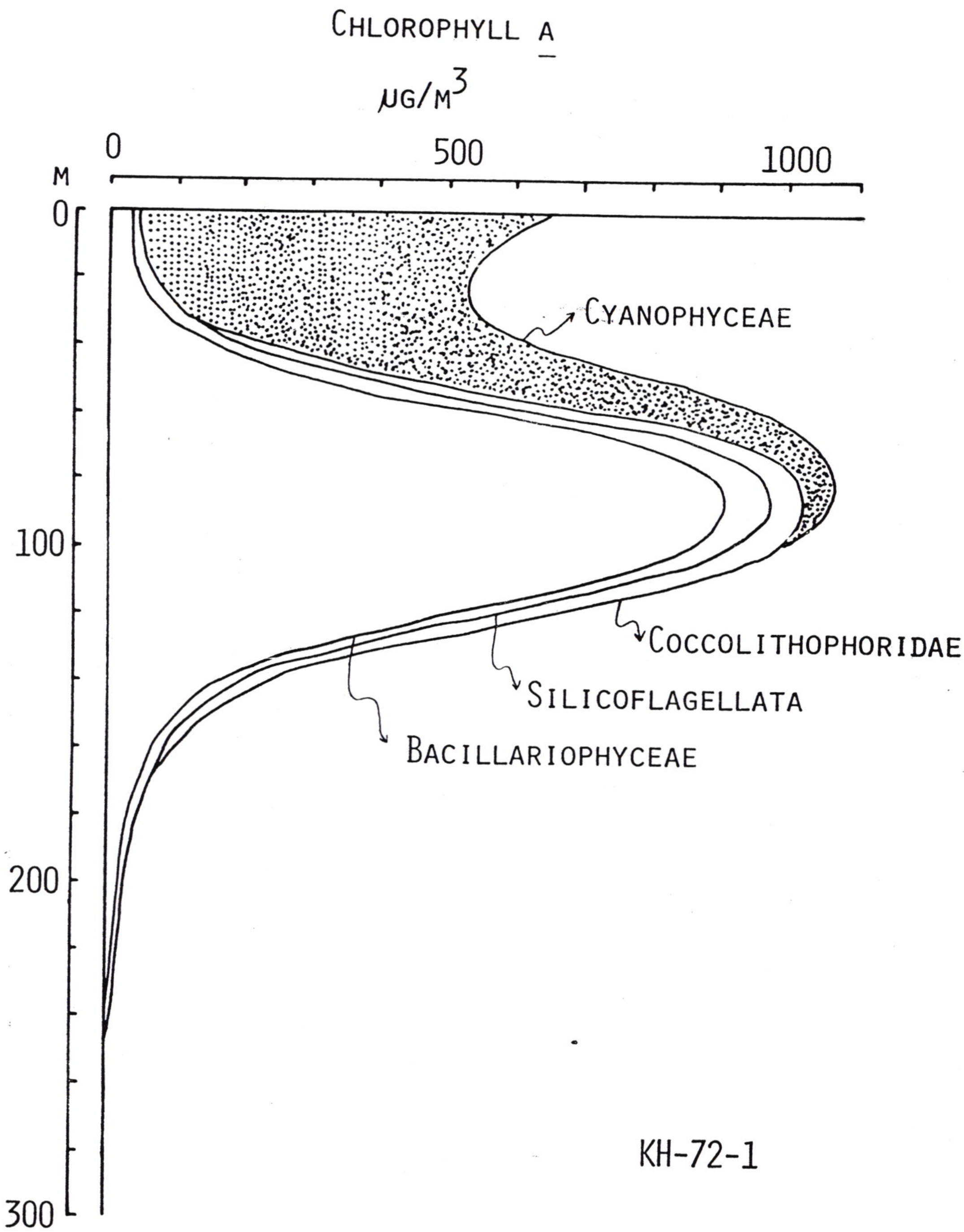


Fig. 19. A schema of chlorophyll a and its taxonomical composition.

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2.2 SEASONAL VARIATION OF SOME PLANKTONIC ORGANISMS IN THE BAY OF NHATRANG

by

NGUYEN THUONG DAO AND LE THI NGOC-ANH

Introduction

Nhatrang Bay is located on the east side of the Indo-Chinese Peninsula, at 12°N latitude and 109°E Longitude. The weather of this region is influenced by the tropical monsoon, and the seasons are divided into two: the dry season from January to August and the rainy season from September to December.

It receives the waters of the Cai river in the north and of the Cua Be river in the south.

The study on the seasonal variation of the plankton biomasses had been carried out by Dawydoff (1936), Yamashita (1957-1958) and Shirota (1966). Shirota had also reported the local distribution of the plankton biomasses at the estuary and in the open sea.

This paper deals with the preliminary study of the plankton biomass and the seasonal variation in quantity of the dominant planktonic organisms.

The samplings were taken horizontally on the surface layer twice a month in the period running from July 1970 to June 1971 at the 5 different stations: station I in the estuary, stations II, III, IV in the bay of Nhatrang, station V farthest from the estuary.

Japanese made nylon plankton nets No XX 13 and No GG 56 were used.

The Surface temperature was read each time on a normal mercuric thermometer graduated in 0.1 °C.

The salinity was obtained by $AgNo_3$ method.

The plankton biomass was measured by volume (ml/M^3) and the number of plankton species was counted on the stried slide. The transparency was measured with a Secchi disk.

Results and General Considerations

Salinity (S °/..): The ranges of salinity found at station I go from 26.26 in January to 33.67 in March, at station II from 27.01 in December to 33.96 in July, at station III from 27.41 in December to 33.58 in July, at station IV from 27.83 in November to 33.69 in July, and at station V from 31.50 in November to 34.05 in July.

The salinity decreases in the rainy season. The greatest variation was found at station I and the smallest at station V.

Water temperature: The lowest temperature were observed at the beginning of the dry season from January to February (23–24°C) and the highest in June (29–29.5°C).

Transparency: The degrees of transparency found at station I ranged from 1.25 m in December to 4.0 m in May, at station II from 2.5 m in January to 9.5 m in May, at station III from 5.5 m in January to 17.5m in June, at station IV from 3.75 m in January to 14.5 in June, and at station V from 6.25 in January to 24.5 in June.

Plankton observations: Both phytoplankton volume and zooplankton increase at all 5 stations in the rainy season and decline in the dry season.

1. Phytoplankton population :

Diatoms contribute 80 % of the phytoplankton found in the Bay of Nhatrang. The most common and/or dominant genera are *Chaetoceros, Bacteriastrum, Thalassiothrix, Rhizosolenia, Skeletonema, Hemiaulus* and *Coscinodiscus*.

Dinoflagellates represent 10–15 % of the popalation. The most common genera are *Ceratium* and *Peridinium*.

Specimens of all of these genera occur at all 5 stations all the year round. Their numbers generally increase in the rainy season as showed in the figures 1–5. However, *Cocinodiscus*, which is abundant at station I, is scarcer at the stations far from the estuary, and *Skeletonema* disappears in the dry season.

The volume of phytoplankton increases at all stations in the rainy season, though the biomass at station V is usually smaller than at these other stations. The highest phytoplankton biomasses found at the stations I, II, III, IV, V are respectively 9.57 ml/M^3 in November, 18.55 in October, 14.55 in November. 15.96 in January and 7.93 in December (Fig. 1–5).

Generally, the phytoplankton populations increase in the rainy season between October and January, but the biomasses at stations I, II, III, IV decrease suddenly in December when the salinity falls below 28 ‰.

Chaetoceros, Bacteriastrum, and *Thalassiothrix* are dominant all the year round. They develop exclusively in the rainy season mostly in the estuary and in the bay, where the densities may reach 10^6 to 10^7 cells/M^3. However, in a period of abundance between October and January, the cell numbers inexplicably decreased suddenly in December, most remarkably at station I, quite obviously at stations II, III, IV, only slightly at stations V.

Rhizosolenia is frequent all the year round though in low density, its cell numbers in the rainy season reaching about 10^5 cells/M^3.

Hemiaulus is likewise common in the rainy season, its cell numbers reached 10^5 cells/M^3.

Skeletonema is abundant only in the rainy season, in number up to 10^6 cells/M^3, it seems to be scarcer in the stations further from the estuary.

Cocinodiscus is frequent at station I, and becomes dense in the rainy season, with the highest recorded cell number of 256, 000 cells/M^3 in December. It is scarcer further from the estuary, and almost absent at station V.

2) Zooplankton population :

The most common or abundant groups in zooplankton organisms are *Copepoda, Oikopleura. Chaetognatha* and *Zoea* larva. However, the amount of volume of zooplankton is not mainly built up by these abundant groups. This quantity increases in the rainy season, mainly from September to November in a range lower than that of phytoplankton and its maximum reaches in the period of abundance of phytoplankton. The highest biomass of zooplankton found at station I is 1.03 ml/M^3 in October, at station II is 1.39 in November, at station III is 1.25 in November, at station IV is 0.78 in November, at station V is 1.15 in November.

The main groups dominant in abundance are *Oikopleura* and *Copepoda.* Their numbers generally present two peaks in the year, one in the rainy season and a lower one in the dry season, except at station III, where the latter group is abundant only in the rainy seaon.

The highest densities of *Oikopleura* found at these 5 stations ranges from 100 to 470 individuals/M^3 (Fig. 6–10).

Chaetognaths are not abundant in the Bay of Nhatrang, though they are commonly seen, the highest density found is 75 indiv./M^3.

Zoea larva appear abundant at station I with the highest densities of 562 indiv./M^3 in September and 52 indiv./M^3 in May. They are scarce and poor at the other stations, chiefly at station V.

Summary

In the rainy season the water temperature falls to its lowest value and the water from Cua Be river pours into regions under investigation, inducing a decline of salinity and of transparency. Correlated with these changes, the total plankton biomass, as well as the numbers of individual species, increases considerably.

The river water, evidently influences the biological conditions of the bay, promotions the development of the plankton populations to the maximal abundance. The plankton biomass at station V, the farthest from the estuary, is always lower than at the stations nearer the estuary.

Although the decreased salinity could be directly responsible for the increased density of plankton in the Bay of Nhatrang during the rainy season, but it seems not a favourable condition intervening in the abundance of the plankton populations, except for some plankton groups which like *Coscinodiscus* and *Zoea* larva might be favoured by low salinity condition.

During the period of maximal development, in December, the net plankton biomass, as well as the cell number of dominant species, decreases suddenly and simultaneously at stations I, II, III, IV, where the salinity is reduced below 27°–28/₀₀, and slightly station V where the salinity is only slightly reduced.

In the dry season, though the density of phytoplankton organisms is reduced to a minimum, the dominant zooplankters such as *Copepoda* and *Oikopleura* reach a second peak of abundance, especially at stations I, II and IV (in the bay)

(Fig. 6, 7, and 9). Possibly, in the Bay of Nhatrang zooplankters graze not only on phytoplankton but also on suspended organic particles. To test this hypothesis, a study of the composition of river water entering the Bay of Nhatrang would be needed.

Cocinodiscus and *Zoea* larva are abundant in the estuary but are scarcer in the stations far from the estuary and nearly absent at station V.

The above considerations indicate the following conclusions :

Diatoms are the main group of phytoplankton in the Bay of Nhatrang, the dominant genera comprising *Chaetoceros, Bacteriastrum, Thalassiothrix, Rhizosolenia, Skeletonema* and *Coscinodiscus*. The presence of dinoflagellates has also been noted, but they occur in only negligible numbers. Copepods and *Oikopleura* are dominant all the year round.

The biomasses of phytoplankton and of zooplankton, as well as the cell numbers of the dominant species, reach their maxima in the rainy season.

Evidently, water from Cua Be river brings to the bay the essential nutrients for the growth of plankton.

However, the reduction of salinity below 27–28 ‰ seems to inhibit the growth of diatoms (*Chaetoceros, Thalassiothrix, Bacteriastrum, Skeletonema*) and consequently to reduce the phytoplankton biomass.

April 1973

Laboratory of Plankton
Oceanographic Institute
Nhatrang–Vietnam

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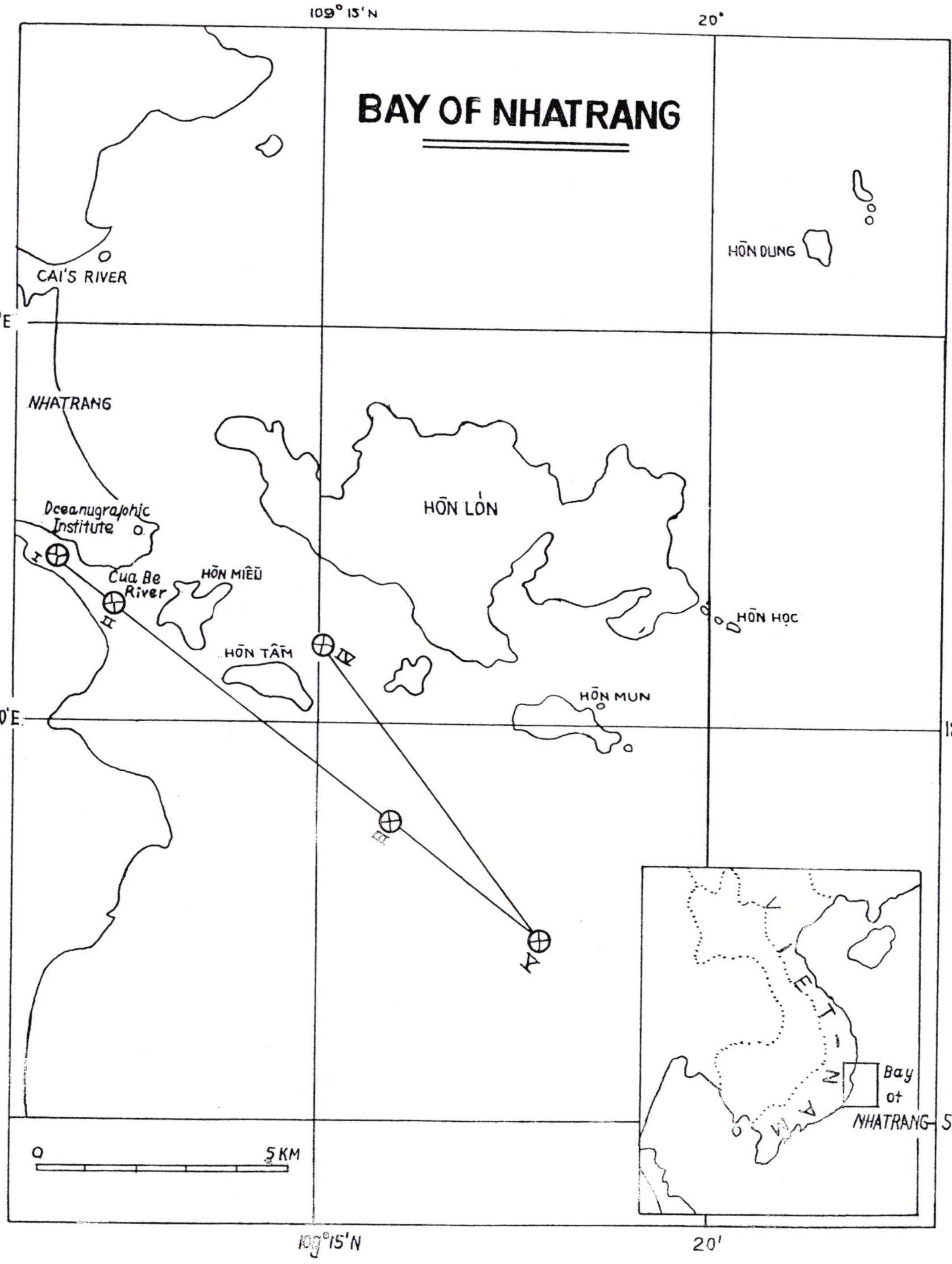

BAY OF NHATRANG
109° 15' N
20°
CAI'S RIVER
10'E
15'E
NHATRANG
Oceanugraphic Institute
Cua Be River
HÔN MIÊU
HÔN LÓN
HÔN DUNG
HÔN HỌC
HÔN TÂM
HÔN MUN
12° 10'E
12°10'E
5'E
0
5 KM
109°15'N
20'
VIET-NAM
Bay of NHATRANG
5'E

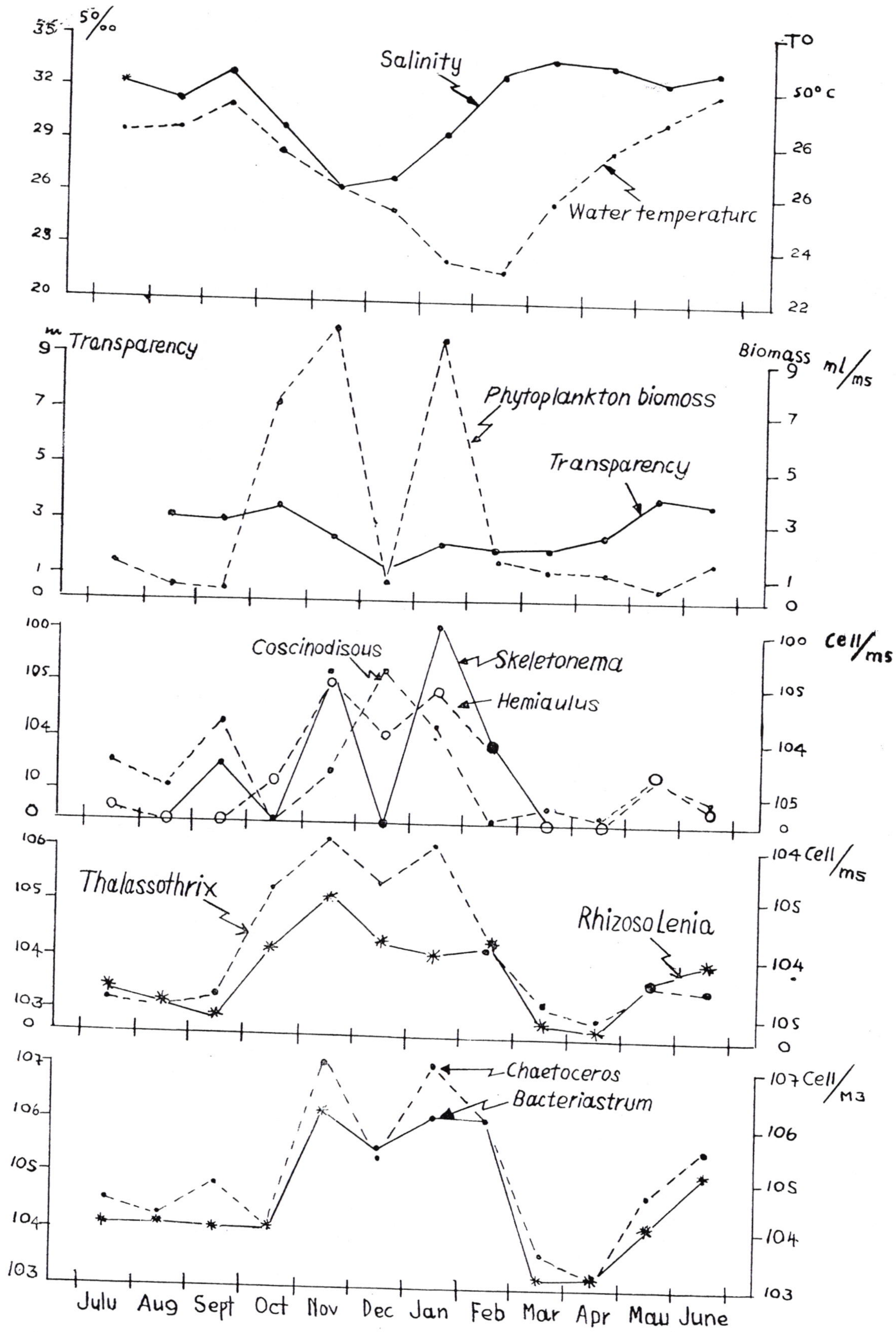


Fig. 1. Results on phytoplankton and physical factors collected at station I between June 1970 and July 1971

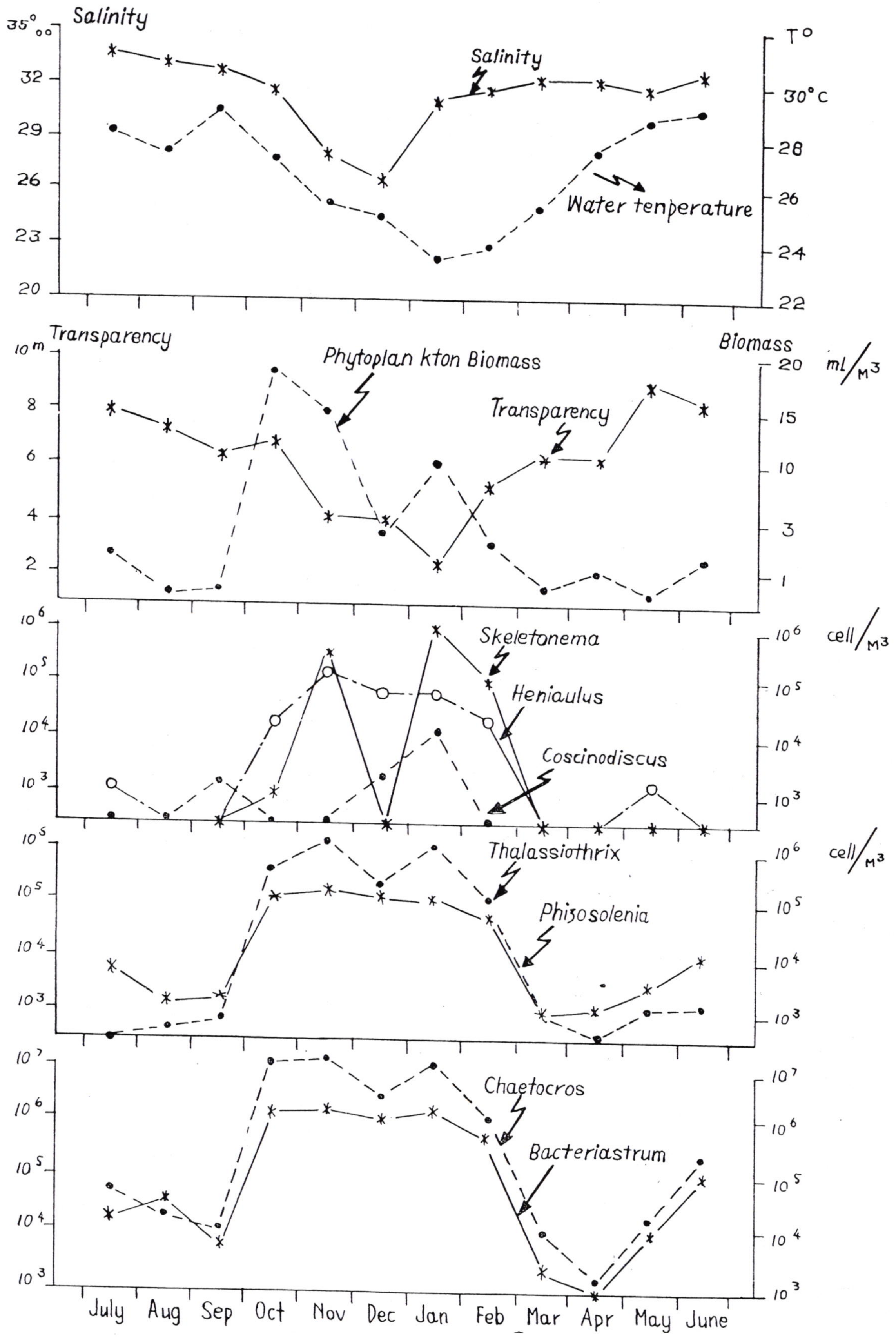


Fig. 2. Results on phytoplankton and physical factors collected at station II between June 1970 and July 1971

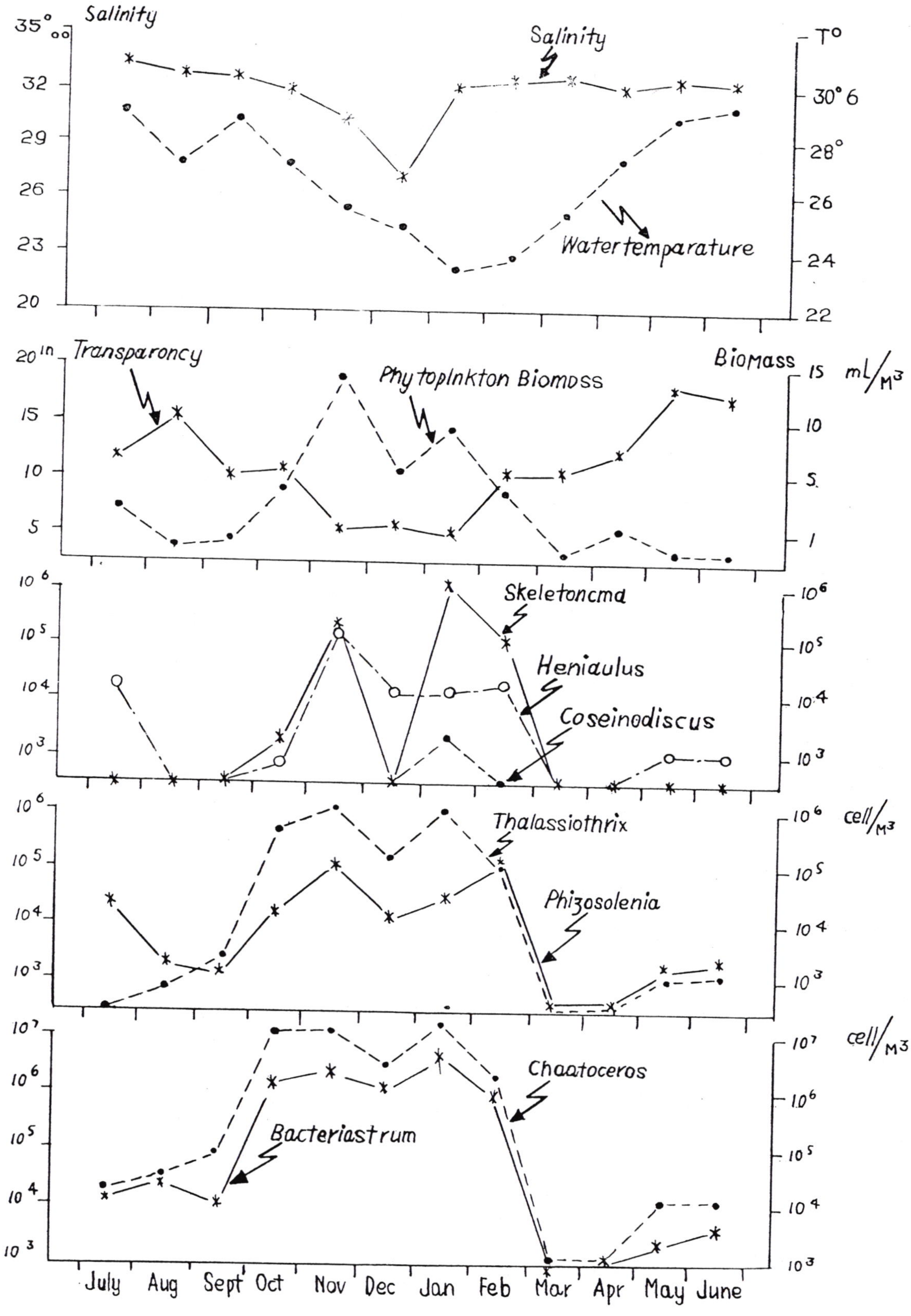


Fig. 3. Results on phytoplankton and physical factors collected at station I between June 1970 and July 1971

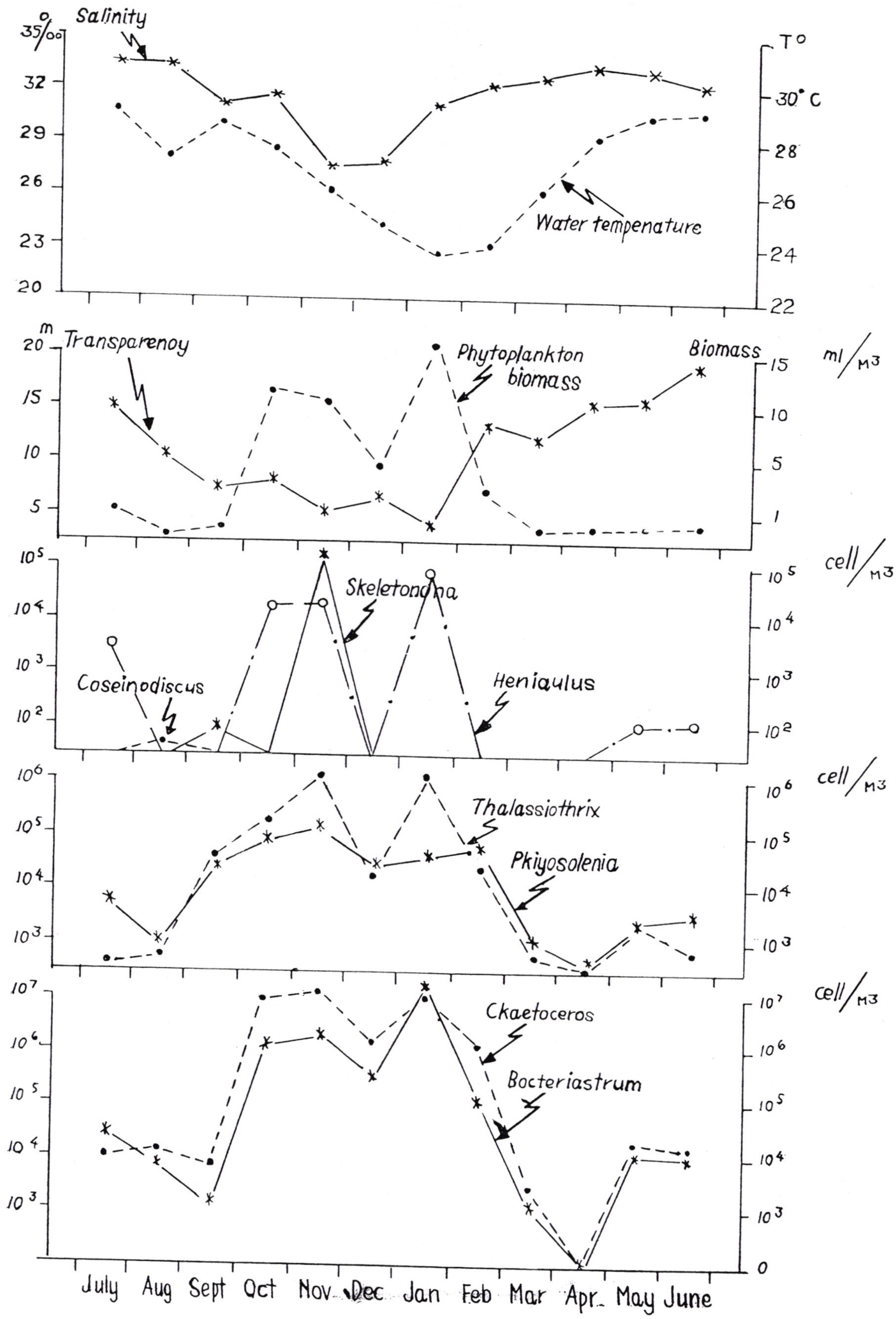


Fig. 4. Results on phytoplankton and physical factors collected at station IV between June 1970 and July 1971

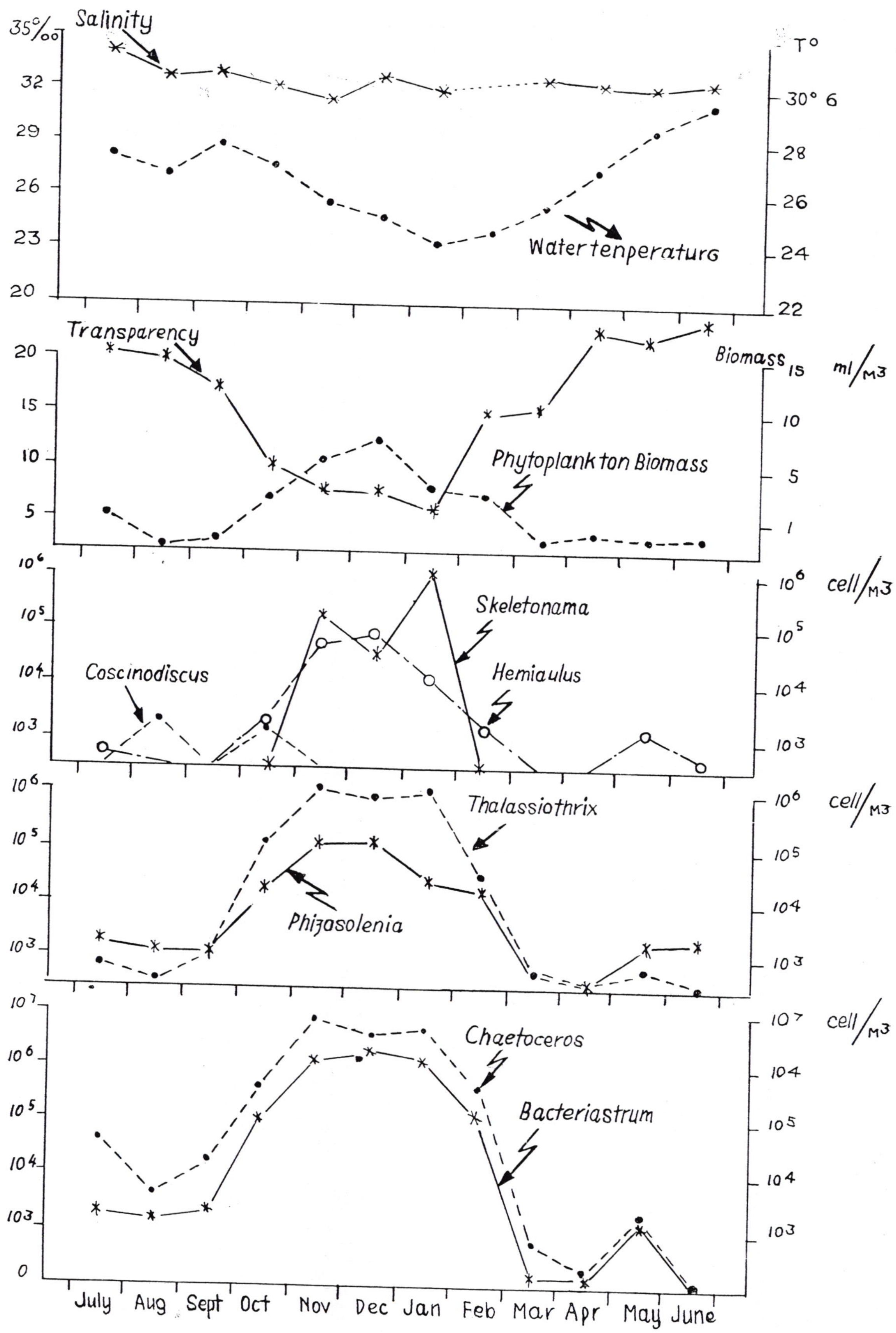


Fig. 5. Results on phytoplankton and physical factors collected at station V between June 1970 and July 1971

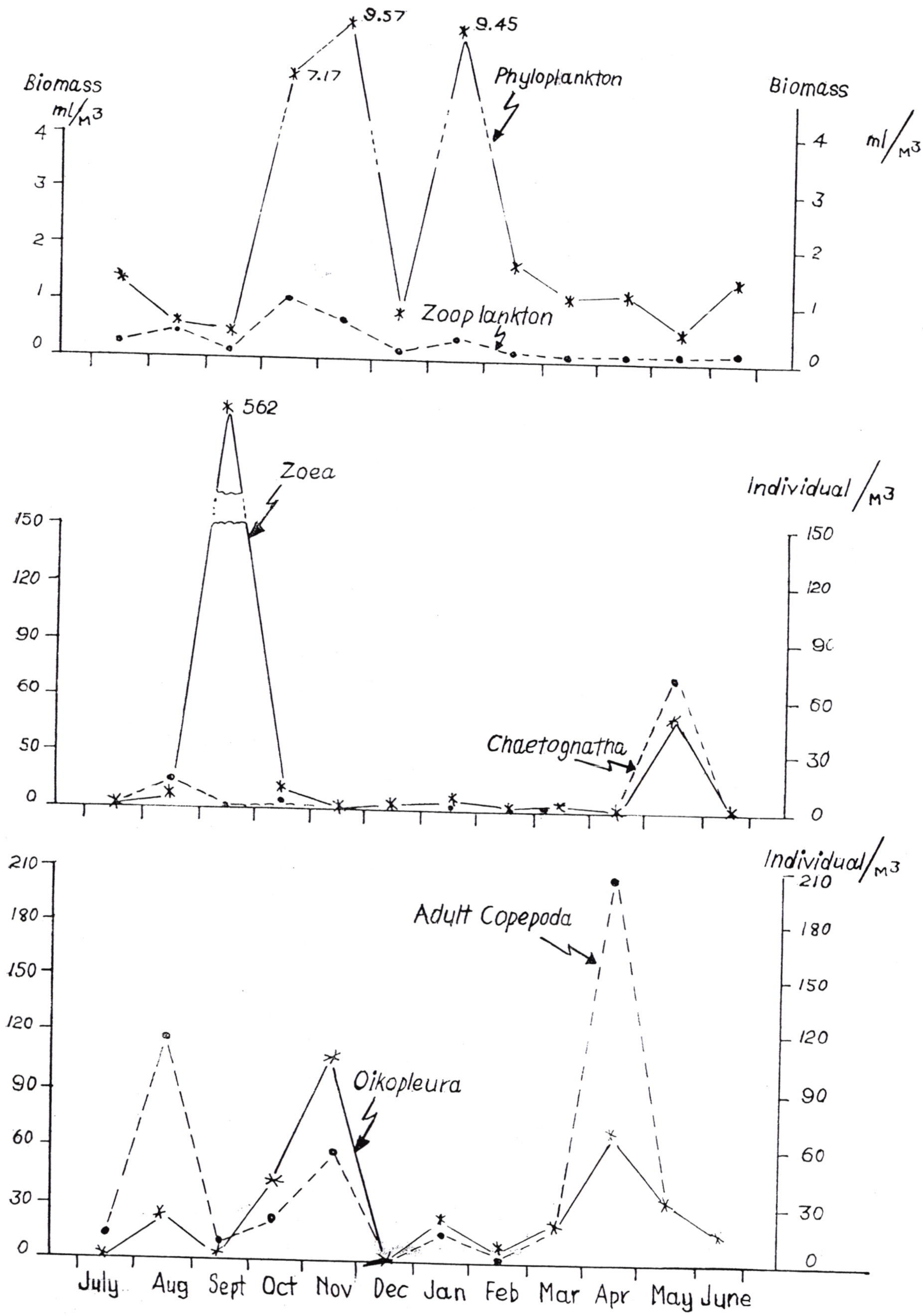


Fig. 6. Results on zooplankton collected at station I between June 1970 and July 1971

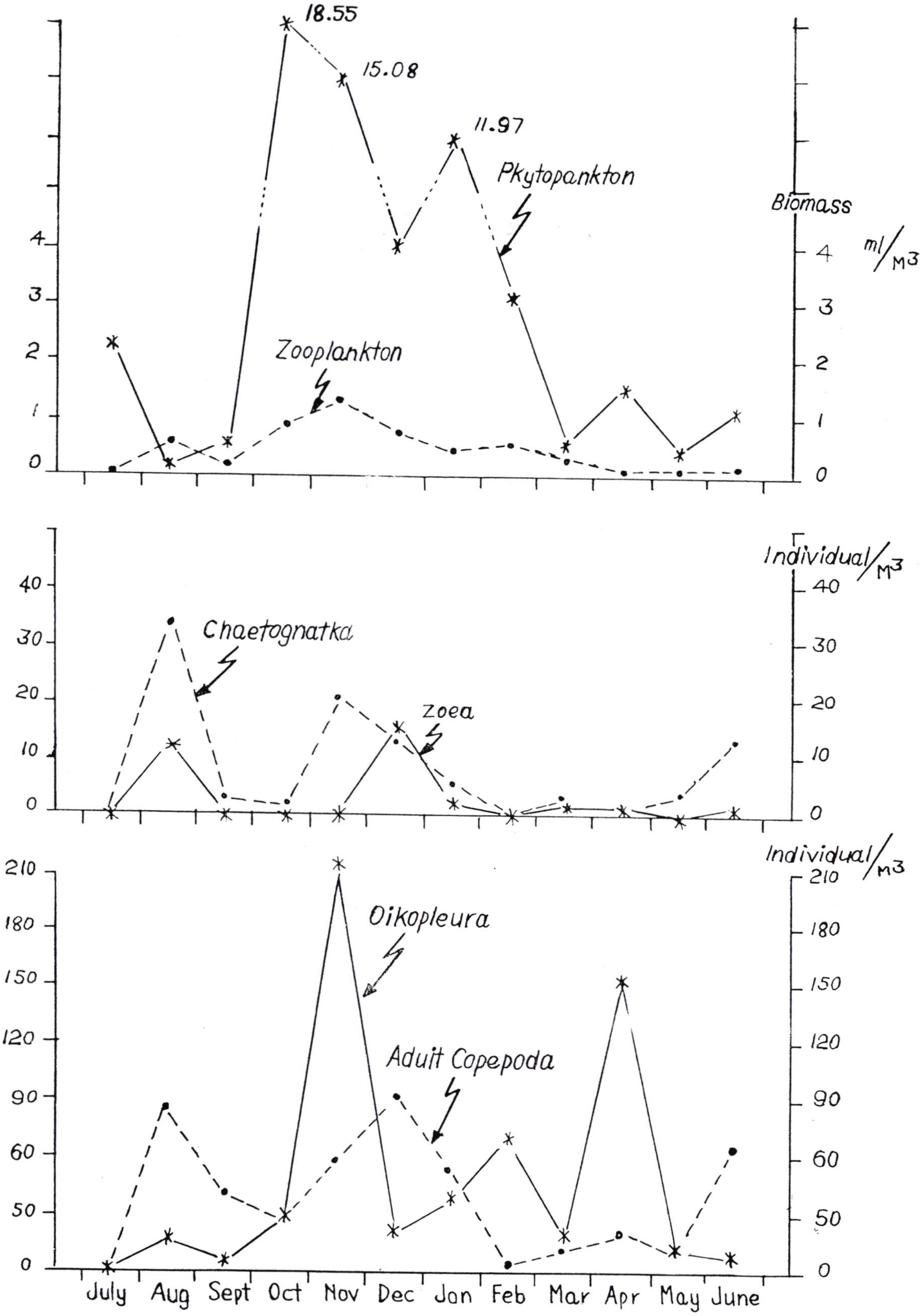


Fig. 7. Results on zooplankton collected at station II between June 1970 and July 1971

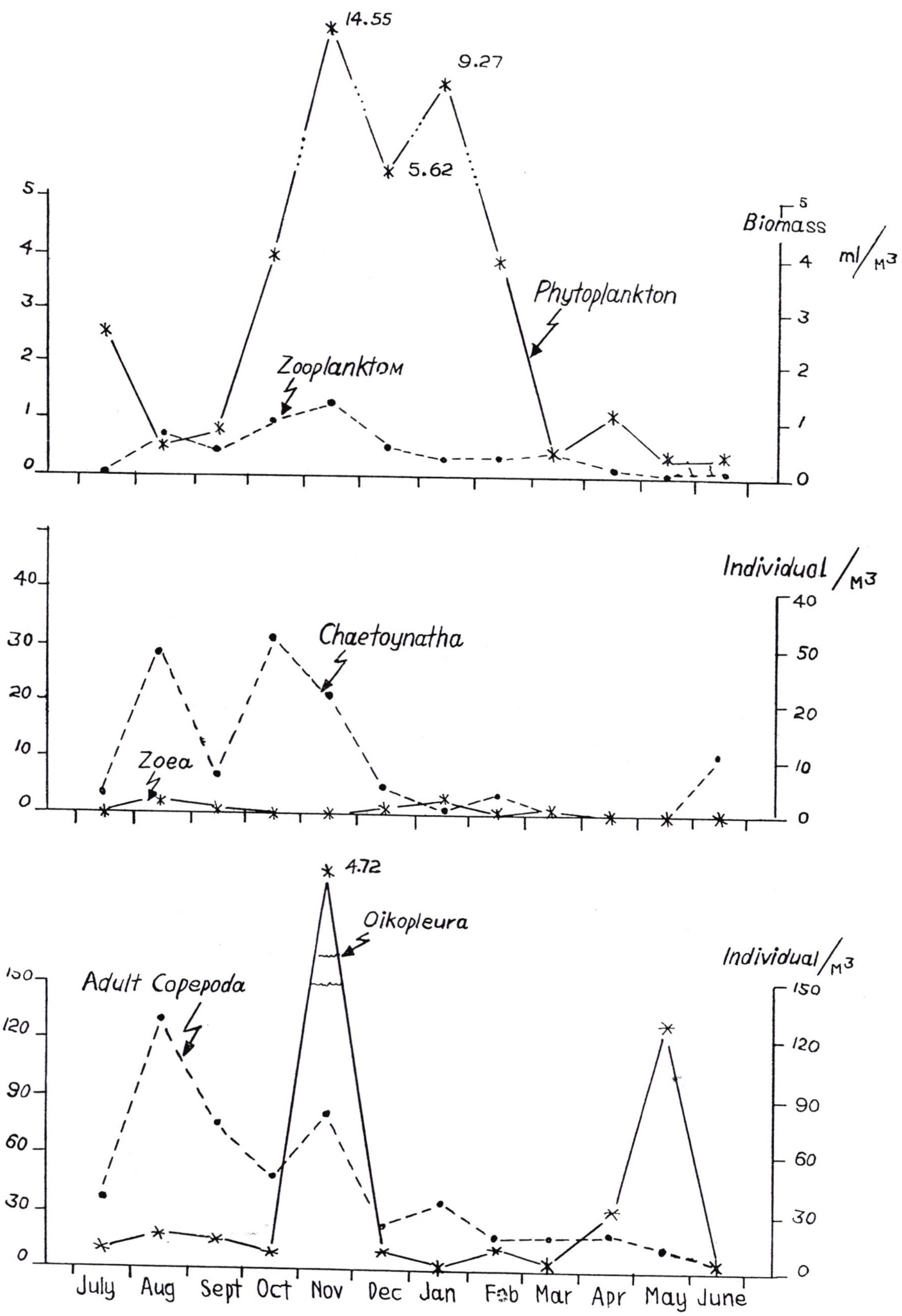


Fig. 8. Results on zooplankton collected at station III between June 1970 and July 1971

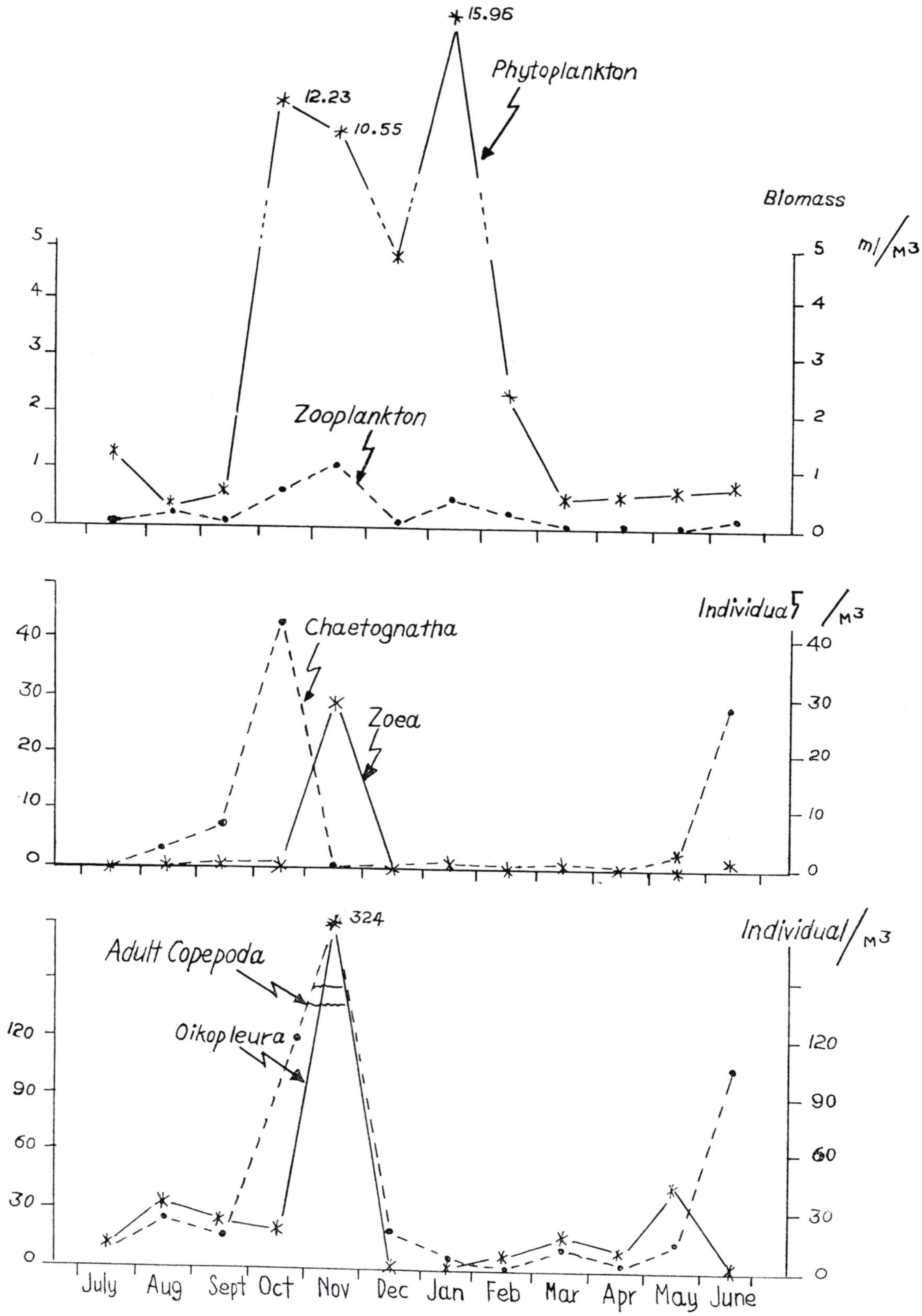


Fig. 9. Results on zooplankton collected at station IV between June 1970 and July 1971

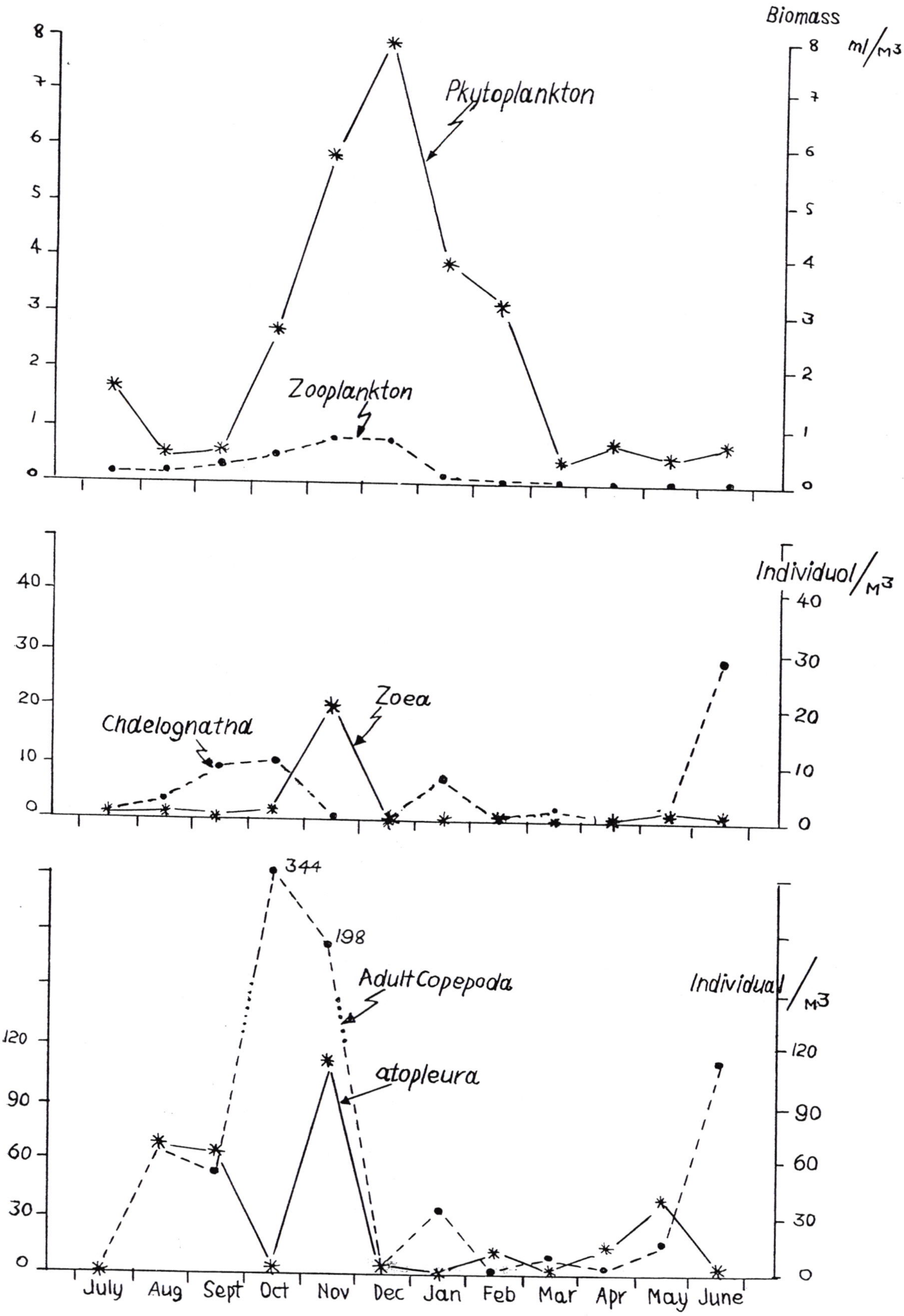


Fig. 10. Results on zooplankton collected at station V between June 1970 and July 1971

2.3 ZOOPLANKTON DISTRIBUTION

Off Mindoro Island and Balayan Bay, Luzon Island, Philippines–South China Sea

by

Jose A. Ordonez, Rizalina M. Legasto & Nicanor Metrillo

Bureau of Fisheries

Intramuros. Manila

I. Introduction

The purpose of the survey cruise made on board the RESEARCHER of the Bureau of Fisheries, was to undertake experimental otter trawl fishing in Balayan Bay and longline fishing at CSK stations which are known paths of tuna and to conduct oceanographic and biological observations.

During this survey cruise, fifteen (15) CSK stations and two (2) Master stations (A & B) were occupied in a period of seven (7) days from 31 March 1971 to 7 April 1971. During this period 34 plankton samples using the NORPAC net, 17 samples using the stramine larvae net and 12 samples using the nylon net were collected, thus giving a total of 63 plankton samples.

II. Materials & Method

Three (3) plankton nets were used in the collection of zooplankton samples in almost all the stations covered by the survey cruise. These are the Norpac net, the stramine larval net and the oblique tow net (fish eggs and fish larvae net). The Norpac net is the standard quantitative net adopted by the conference on Pacific Oceanography (Feb. 1956) and used principally for collecting zooplankton. Its length is 180 cm. with a mouth diameter of 45 cm. The stramine net is used in collecting fish eggs and fish larvae and floating organisms. It is towed just below the surface of the water. It is also considered an effective and efficient gear for inventory purposes of the total fish larvae concentration in the area. Eight to ninety per cent of fish larvae was gathered by this net.

For the Norpac net, vertical plankton hauls were made from a depth of 150 meters to the surface. The stramine net was lowered at the surface of the water just enough to collect some surrounding and floating organisms. An oblique tow was made with the nylon net (fish eggs and larval net) at a depth of 10-20 fathoms. A 30-minute towing time was used for both stramine and nylon nets at the speed of 3 knots.

A flow meter used to calibrate the volume of water that was filtered was mounted at the opening of the net. All the plankton samples collected were properly labelled and preserved in 4% formalin. With the aid of a graduated cylinder, the net displacement method was used for measuring plankton volume. The "short-cut method" was used in order to get the quantitative amount of zooplankton by percentage composition of the entire plankton volume.

Discussion of result

After the plankton volume was determined, the sorting of fish eggs and fish larvae followed. Then the identification of the fish larvae was done. The percentage of fish larvae by families is shown in Figure I.

After removing the fish eggs and fish larvae, the quantitative analysis of the zooplankton was performed from the remaining plankton samples. A total of 200 organisms was counted and identified from each station. The identification was limited to family but some organisms were identified to species. The zooplankton components were divided into 8 major groups. The percentage composition of zooplankton distribution in each station is shown in Table I. The percentage composition of the major groups of zooplankton for the whole area was computed and shown in Figure 2. The percentage distribution of the plankton samples for copepods and crustaceans is shown in Figure 3 while that for chaetognaths and mollusks is shown in Figure 4.

The zooplankton samples were composed mainly of the following: copepods (*Calanus*, *Eucalanus*, *Rhincalanus*, *Euchaeta*, *Candacia*, *Labidocera*, *Oncea*, *Corycaus*, *Temora*, *Sapherina* and *Copilla*); crustacean larvae (phylliopoda, *Evadne*, *Pseudoconchacia*, Mysis, amphipod, Isopoda, *Penaeus* nauplius, *Lucifer*, euphasiids and megalop); coelenterates (medusae, *Diphyes*, *Leriope*, *Aglaura*, *Abylopsis*); annelid; chaetognaths (*Sagitta*); echinoderm larvae; mollusks (*Creseis*, pelycepod, *Limacina*); tunicates (*Salpa*, *Doliolium*, *Oikopleura*); and fish eggs and fish larvae.

Among the groups mentioned, the Chaetognaths, copepods and crustaceans predominated.

The highest plankton volume (620 ml) was recorded at Station 9 (nine miles off Maricaban Island just at the entrance to the Balayan Bay). This was followed by Stations 2 and 3 shown in Figures 5 & 6 of the cruise tract with values of 57 ml and 46 ml, respectively.

The minimal plankton volume was found in Station 6.

Figure 6 shows the cruise tract of the trip & Table II shows the station number & their coordinates.

Fish Larvac and Composition

Fish larvae were observed to be present in great number in almost all the stations occupied, showing that the area itself abound in fishes, mostly of the commercial species, as found by the identification and classification of the larvae and young fish that were collected.

The larval samples were identified, sorted and recorded as to family and some to species. The following families were represented: Engraulidae, Clupeidae, Mullidae, Triglidae, Serranidae, Monacanthidae, Ophidiideae. Mugilidae, Bothidae, Sphyraenidae. Gobiidae, Leiognathidae, Apogonidae, Exocoetidae, Scombridae, Myctophidae, Trichiuridae, Scorpionidae, Istiophoridae, Gonostomidae, Atherinidae, Belonidae, Gadidae, Stromatidae, Eleotridae. Thunnidae and Syngnathidae.

The highest concentrations of fish larvae listed in order were found located at the following stations: R71-5/3 (745 fish larvae) 8.5 miles off Ilin Is., west coast of Mindoro; R71-5/12 (654 fish larvae) inside the Balayan Bay; R71-5/4 (592 fish larvae) northeast of Busuanga Is. near northern Palawan.

Minimal counts of fish larvae were observed at the following stations; R71-5/A (55 fish larvae) in central Manila Bay; R71-5/B (11 fish larvae) north of Lubang Is., R71-5/6 (8 fish larvae) West of Lubang Is.; and lastly, R71-5/4 & 5/15 inside the Balayan Bay.

Table I. The percentage composition of zooplankton distribution in each station

R - 71 - 5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Copepod	49.12	59.25	64.50	40.75	70.00	63.75	68.00	58.25	50.00	58.75	66.75	54.25	45.00	65.50	39.25
Crustacean	9.25	4.00	11.50	24.50	10.75	8.00	3.75	13.00	14.50	14.25	8.75	16.75	13.50	10.00	12.25
Chaetognaths	31.63	31.25	17.00	29.00	11.50	25.25	22.75	20.25	28.75	19.25	15.50	18.75	32.25	17.25	41.00
Coelenterates	2.25	.75	2.00	.75	2.00	1.00	1.75	1.75	2.25	2.75	2.75	1.00	1.00	1.25	1.25
Annelid	2.25	2.50	1.00	.50	.50	1.00	.50	.50	2.00	.75	1.00	1.00	2.25	1.25	1.25
Echinoderm	.25	0	0	.25	.75	0	.00	.25	.25	.25	.75	.75	.75	.0	.0
Mollusks	3.38	1.00	4.00	3.50	3.00	.75	1.50	3.75	1.25	1.75	1.50	5.50	2.25	1.25	1.50
Tunicate	1.75	1.25	0	.75	1.50	.25	1.50	2.25	1.00	2.25	2.50	2.00	3.00	3.50	2.25
Others	.12	0	0	.25	0	0	.25	0	0	0	.50	0	0	0	0
Total Percentage	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table II – Station number & the Coordinates

Station	Latitude	Longitude
1	12°39.3'	120°00'
3	12°10'	120°55'
4	12°11'	120°11.5'
5	12°07.5'	119°11.5'
6	13°50'	119°54.8'
7	14°145'	119°29.0'
8	12°07.5'	119°11.5'
9	13°34.5'	120°25'
10	13°46.3'	120°46.3'
11	13°42.5'	120°51'
12	13°46.5'	120°54.3'
13	13°53'	120°52.3'
15	13°50'	120°50.3'
Master A	14°28.7'	120°41.8'
Master B	14°50'	120°26.0'

As regards the commercial fishes, the tuna larvae dominated with 378 fish larvae mostly of *Auxis* spp. (359 larvae): *Thunnus albacares* (13 larvae); and *Katsuwonus pelamis* (6 larvae). Those larvae were taken at station R71-5/3 near Ilin Island, west of Mindoro. The Carangidae (349 larvae) was the next family represented. The larvae were collected from stations R71-5/4, 5/3, and 5/1 within the vicinity of Busuanga Island. This group was followed by Serranidae (302 larvae), which was represented in all stations occupied. The anchovies were abundant in station R71-5/12 near the coastal area in Balayan Bay. The family Gobiidae with 200 larvae occupies the fifth position which was slightly ahead of that unidentified family with a total count of 107 larvae from all of the stations accomplished.

Of the non-commercial fishes, the lantern fishes (Myctophidae) got the highest number of larvae. It was followed by the genus *Bregmaceros*.

All in all, 3248 fish larvae and fish were collected aut of the 17 stations accomplished (80% larvae were being identified) while 20% remained unidentified.

Fish Fggs Density

A very low concentration of fish eggs was observed at almost all stations occupied, thus giving only a total of 69 fish eggs which were taken from stations R71–5/9, R71–5/10 and R71 - 5/15 compared to that of the fish larvae which were present at all stations occupied.

Conclusion

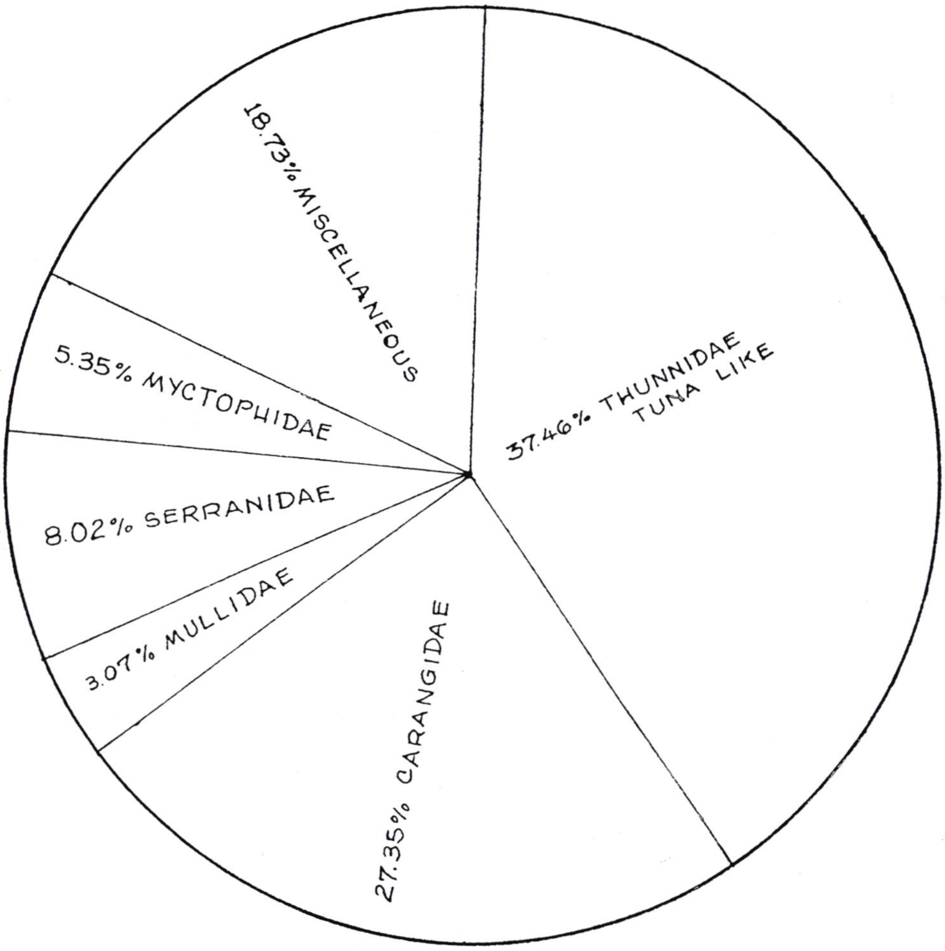
The area off Mindoro and Balayan Bay, Luzon, Philippines has a high concentration of zooplankton. The majority of plankton animals were copepods, chaetognaths and crustaceans which are the primary food of most pelagic fishes.

The presence of a high concentration of fish eggs, larvae and juvenile fishes in the plankton samples. led us to recognize that the same area or adjacent region is the spawning ground of fish such as Thunnidae, Carangidae, Serranidae, Mullidae, etc. The hydrographic conditions are being analyzed in order to determine the specific spawning area of the region.

References

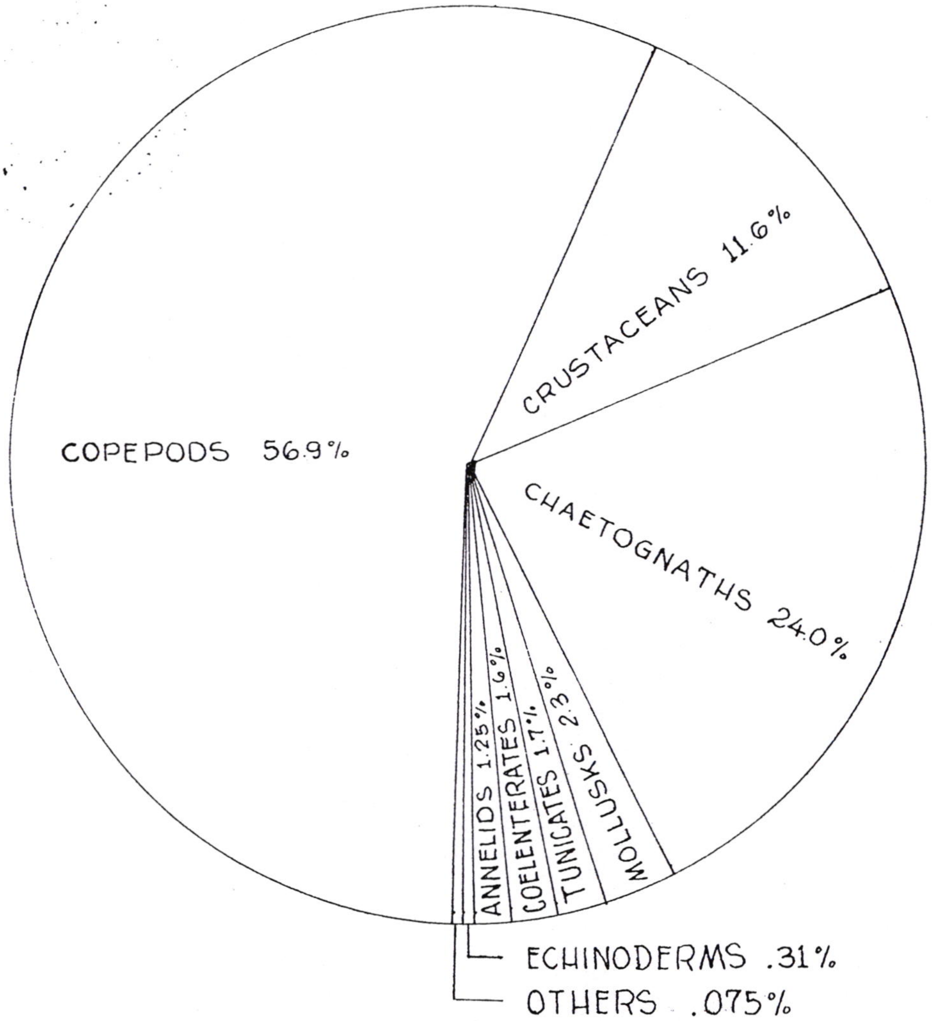
Hallgrimsson Ingvar 1958 : A short-cut Method of Estimating Zooplankton Composition at Sea, RIT Fiskideildar 2 (b), 6 pp.

FIGURE - 1



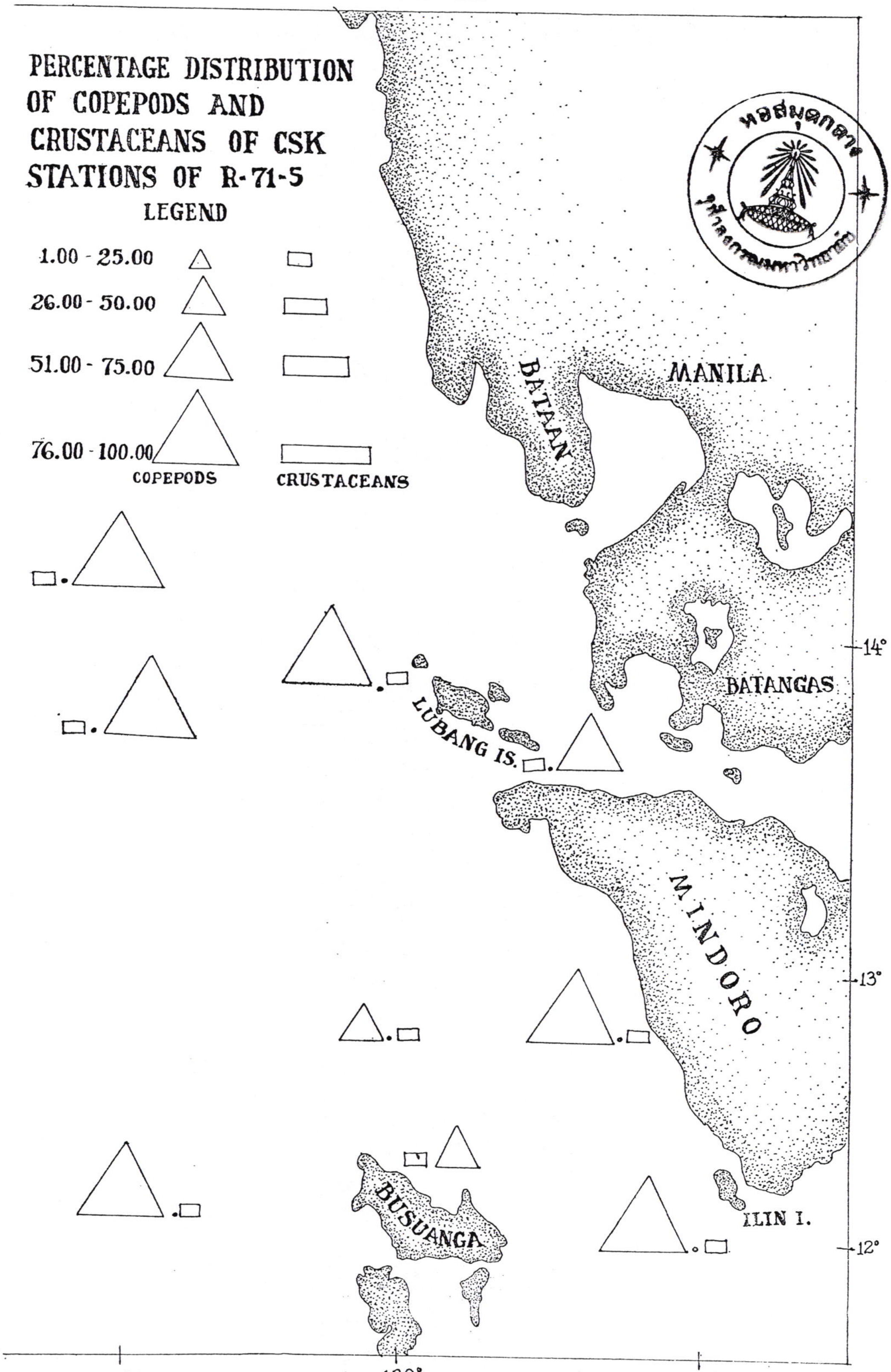
PERCENTAGE COMPOSITION OF FISH LARVAE AND JUVENILE OF SOUTH CHINA SEA (STRAMINE SURFACE TOW)

FIGURE - 2



PERCENTAGE COMPOSITION OF ZOOPLANKTON IN THE CSK SOUTH CHINA SEA CRUISE

FIGURE - III



PERCENTAGE DISTRIBUTION OF COPEPODS AND CRUSTACEANS OF CSK STATIONS OF R-71-5
LEGEND
1.00 - 25.00
26.00 - 50.00
51.00 - 75.00
76.00 - 100.00
COPEPODS
CRUSTACEANS
BATAAN
MANILA
BATANGAS
LUBANG IS.
MINDORO
BUSUANGA
ILIN I.
14°
13°
12°
119°
120°
121°

FIGURE IV

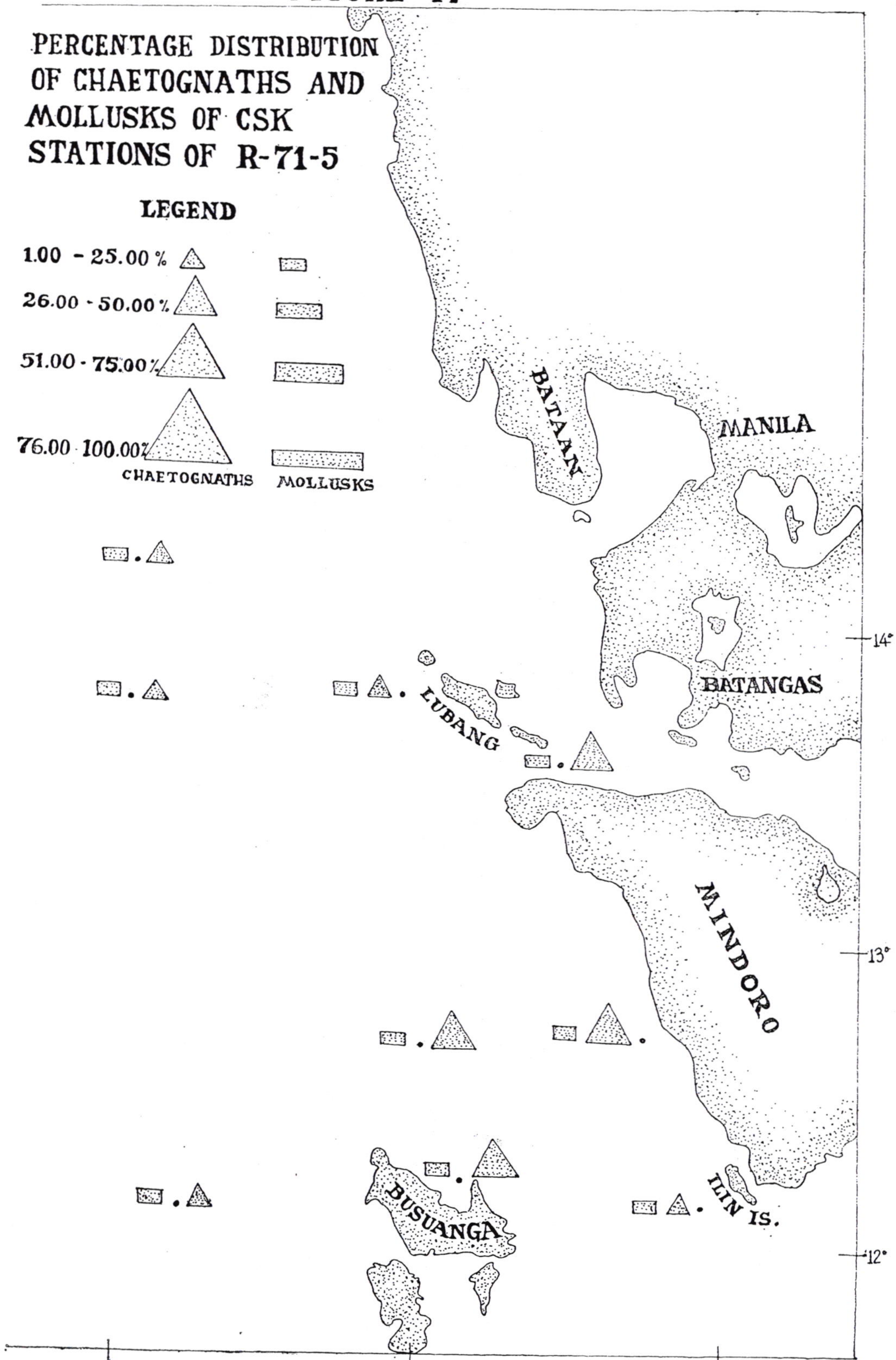
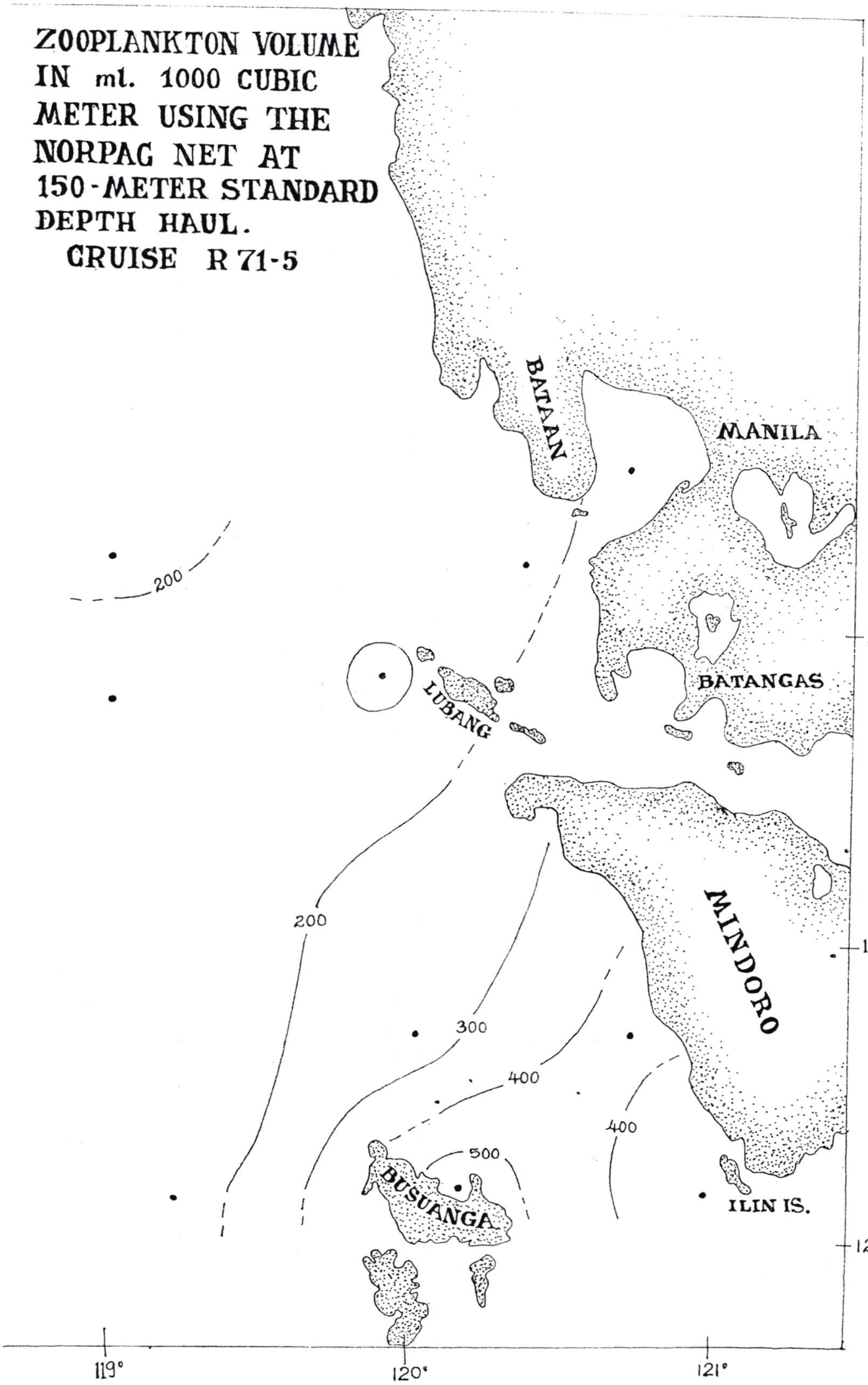
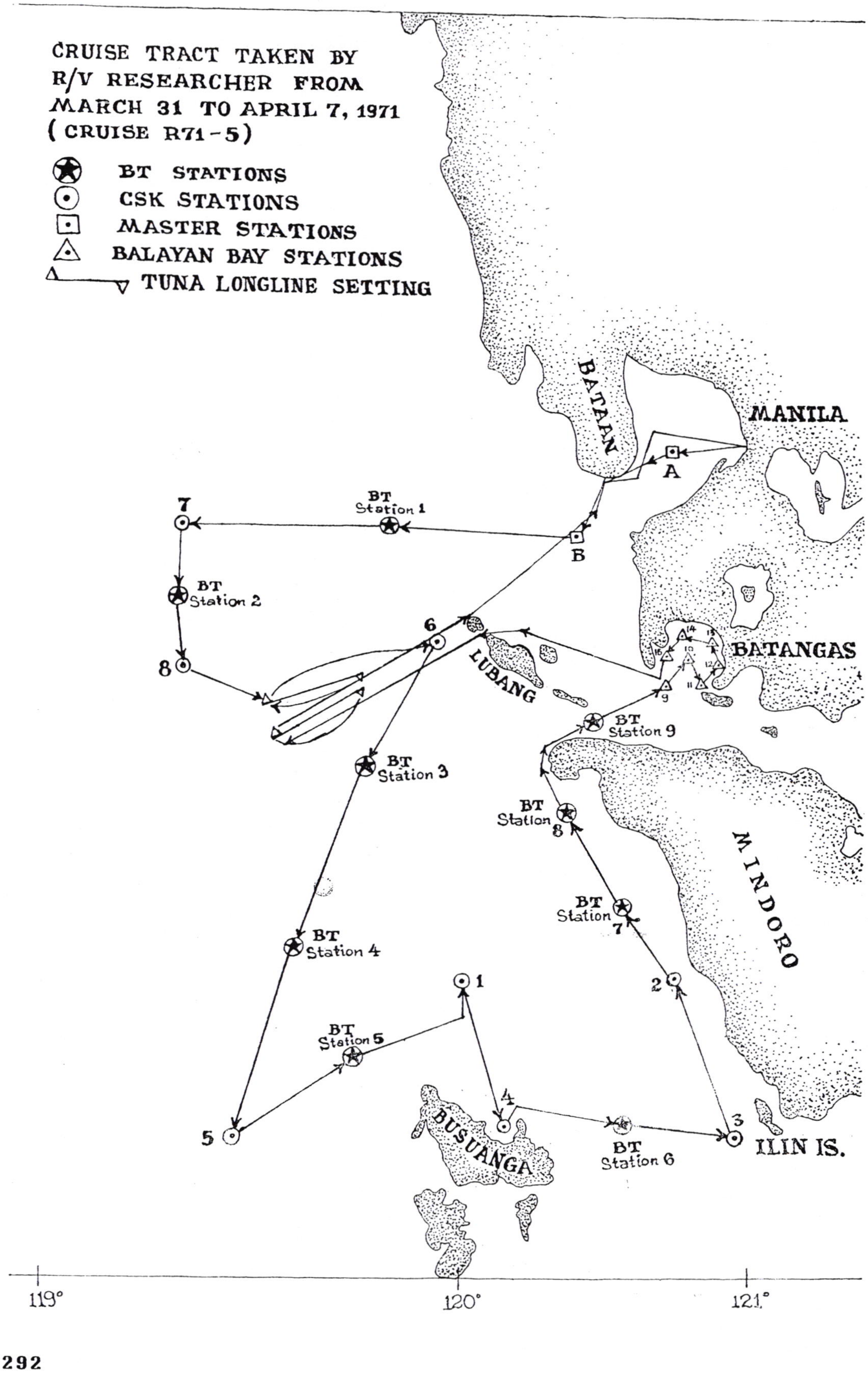

PERCENTAGE DISTRIBUTION OF CHAETOGNATHS AND MOLLUSKS OF CSK STATIONS OF R-71-5
LEGEND
1.00 - 25.00 %
26.00 - 50.00 %
51.00 - 75.00 %
76.00 100.00%
CHAETOGNATHS
MOLLUSKS
BATAAN
MANILA
BATANGAS
LUBANG
MINDORO
BUSUANGA
ILIN IS.
14°
13°
12°
119°
120°
121°

FIGURE - V



ZOOPLANKTON VOLUME
IN ml. 1000 CUBIC
METER USING THE
NORPAC NET AT
150-METER STANDARD
DEPTH HAUL.
CRUISE R 71-5
BATAAN
MANILA
BATANGAS
LUBANG
MINDORO
BUSUANGA
ILIN IS.
200
200
300
400
400
500
14°
13°
12°
119°
120°
121°

FIGURE VI



CRUISE TRACT TAKEN BY
R/V RESEARCHER FROM
MARCH 31 TO APRIL 7, 1971
(CRUISE R71-5)
BT STATIONS
CSK STATIONS
MASTER STATIONS
BALAYAN BAY STATIONS
TUNA LONGLINE SETTING
BATAAN
MANILA
A
B
BT Station 1
7
BT Station 2
8
6
LUBANG
BATANGAS
BT Station 9
BT Station 3
BT Station 8
MINDORO
BT Station 7
BT Station 4
1
2
BT Station 5
4
3
5
BUSUANGA
BT Station 6
ILIN IS.
119°
120°
121°

2.4 THE DISTRIBUTION OF PLANKTONIC HYPERIIDS (CRUSTACEA, AMPHIPODA) IN THE SOUTH CHINA SEA AND THE RELATIONSHIP TO THE DISTRIBUTION IN THE GULF OF THAILAND

by

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Introduction

The planktonic amphipods upon which this study is based were obtained from the Naga Expedition, 1959-61. This expedition was an oceanographic investigation of the marine biota and its environment in the Gulf of Thailand and the part of the South China Sea lying to the east of South Vietnam. The expedition was sponsored by the governments of the United States of America, South Vietnam, and Thailand.

Among the marine planktonic crustacea, the amphipods frequently play an important role in the economy of the sea. In general, they rank third in numerical abundance; they are far exceeded by the copepods and euphausiids (Bowman, 1960: 343). Many authors have pointed out that in the cool-water regions, the pelagic amphipods sometimes appear extremely abundant (Edward, 1868 :167, Bate and Westwood, 1868 : 526; Norman, 1909 : 26, Ritchie, 1913 : 398, Behning, 1939 : 356), but in the tropical and subtropical regions they are not usually found in large numbers (Bowman, 1960 : 343).

Although extensive and valuable reports have been published on the hyperiids collected by various oceanographic expeditions, only few of these reports are for the collections from some part of these study areas (Colosi, 1918, Fage, 1960, and Shih 1969). All of the earlier works beginning with Aristotle's "De Animalibus Historiae", have been summarized and revised by Bovallius (1887a, 1887b, 1889, 1890) and Stebbing (1888). Since then, some groups have been revised again e.g., Vosseler (1901), Stephensen (1918, 1924, 1925), Bowman (1953), Fage (1960), Vinogradov (1960), Shih (1969), but systematic problems still remain.

Wyrtki (1961), based on oceanographic observations made prior to the Naga Expedition, described the physical oceanography of the Southeast Asian Waters. There is a semi-closed circulation within the China Sea itself, forming one or two eddies (Wyrtki, 1961, plates 1b 2b, 4b 5b, 6b,).

Brinton (1963) divided the area of investigation off the eastern coast of South Vietnam in the South China Sea into 3 areas. The first area is the narrow shelf region extending from Nhatrang Bay northward to 17°N., at the mouth of the Gulf of Tonkin. The second area is the broad Sunda Shelf region, contiguous with the Gulf of Thailand. The third area is the deep oceanic basin of the South China Sea bounded at its eastern edge by a broad submarine plain from which rise numerous atolls and reefs.

He also pointed out that the abundance of zooplankton in the Gulf of Thailand may be appropriately discussed in relation to coastal regions. These are the regions of high plankton production, directly influenced by the seasonal reversal of the monsoon winds by tidal mixing, and by land drainage. The first region is the shallow northern part of the Gulf north of Koh Chang, 12°15'N., in the eastern Gulf an Koh Rad, 11°45'N., in the western Gulf. The second region is the coastal area of the western part of the Gulf, to a distance of about 70 miles from shore. The third region is the area along the eastern margin of the Gulf, which encompasses coastal waters of southeastern Thailand, Cambodia, and the southwestern part of Vietnam.

LaFond (1963) has given the major results in physical oceanography of the five cruises in the South China Sea of the Naga Expedition. He has given the general regime of water motion and thermal structure, and its variation with the changes in the meteorological regime. The Naga data add much detail to observations of these parameters by Wyrtki (1961) in the South China Sea.

The objectives of this research are restricted to three parts:

1. To investigate the distribution of the hyperiids in these areas with references to some physical oceanographic conditions.
2. To observe the seasonal variations of their distribution.
3. To investigate the relationship between the oceanic form in the South China Sea and the shallow water form in the Gulf of Thailand.

The success of this investigation was due to the help and guidance of Dr. A.H. Banner, Zoology Department, University of Hawaii for which the author is very grateful.

Materials and Methods

The Naga Expedition was conducted from October 1959 to February 1961. Biological samples were collected during five cruises in the Gulf of Thailand and five in the western portion of the South China Sea, in the area adjacent to South Vietnam. The plankton samples used for this study were obtained from the samples collected by using a plankton net of 1-meter mouth diameter, 0.65 mm. mesh aperture width, with flow meter mounted in the mouth. The tows were made obliquely to a depth of about 150 meters, or within 10 meters of the bottom where the depth of water was less than 150 meters.

With the aid of Folsom's plankton splitter, the volume of most of the plankton samples collected was divided into one half for sorting of the hyperiid amphipods. In some cases they were sorted from the whole sample or from a smaller fraction, as small as 1/8 of the sample.

The hyperiid amphipods available from the Naga sample are so extensive that it is not practicable to include here all of them. Accordingly, from each of these four divisions, at least one family has been selected for this present study. Six families. Scinidae. Cystisomatidae, Vibiliidae, Paraphronimidae, Phronimidae and Oxycephalidae were selected. Most of these families have been selected on the basis of the number of species represented in the family, or because that family presents some problems which need to be solved.

Family Scinidae

From the Naga samples examined, only 2 genera out of 3. *Acanthoscina* and *Scina* are represented, with one species of *Acanthoscina* and 15 species of *Scina*. In this present study three new species and one new variety, all of genus *Scina*, are found, but the descriptions will not be included in this paper.

All species of this family were found only in the region of the deep South China Sea basin. Besides those which were considered as rare, all except one species *S. uncipes*, ranged southward to the southern topographical limit of the deep basin. *S. uncipes* was found in the central and northern portions of the studied area of the deep basin.

The distributional patterns of all species found from the Naga samples examined can be distinguished into the following groups:

1. Common

S. borealis	*S. tullbergi*

2. Not common but present all year round

A. acanthodes	*S. curvidactyla*
S. marginata	*S. stenopus*
S. nana	*S. similis*

3. Not common, and not present all year round

S. uncipes	*S. damasii*
S. rattrayi var. nov. No. 3	*S.* sp. nov. No. 4

4. Rare, (1-4 specimens) present only below the surface layer

S. incerta	*S. submarginata*
S. sp. nov. No. 1	*S. rattrayi*
S. sp. nov. No. 2	

Family Cystisomatidae

Only one specimen of *Cystisoma fabricii* had been found in the Naga samples examined. It was from the surface layer of the deep South China Sea basin.

Family Vibiliidae

Only one genus, *Vibilia*, was collected during the Naga Expedition, it is represented by 7 species. *Vibilia viatrix* is the only species which was found throughout the year in the Gulf of Thailand and during some periods in the South China Sea. The remaining, except one, *V. chuni*. were the offshore oceanic species of the deep South China Sea basin, but 2 of these species, *V. pyripes* and *V. stebbingi*, were also found overlying offshore part of the Sunda Shelf during the northeast monsoon period. *V. chuni* was found along the coast, in the deep basin, and over the Sunda Shelf. The distributional patterns of all these species found can be distinguished into the following groups :

I. Present both in the Gulf of Thailand and in the South China Sea

1. Common in the Gulf, but not common in the South China Sea

   V. viatrix

II. Present only in the South China Sea

1. Common

   V. armata — *V. woltereckí*

   V. stebbingi

2. Not common, but present all year round

   V. chuni — *V. pyripes*

   V. gibbosa

Family Paraphronimidae

Both species of *Paraphronima* were found from the Naga samples examined in the deep South China Sea basin. *P. gracilis* was very common in the area, while *P. crassipes* was found at few scattered localities all year round.

Family Phronimidae

Both genera of this family were found represented in the Naga samples examined, of which 1 species belongs to the genus *Phronimella (P.)* and 4 species belong to the genus *Phronima (Ph.)*. *Ph. solitaria* is a widely distributed species which was found throughout the year both in the Gulf of Thailand and in the South China

Sea, while *Ph. pacifica*, the South China Sea species, was transported to the west coast of the opening of the Gulf prior to the southwest monsoon period. *P. elongata* is a common species of the South China Sea, which is distributed widely over the deep basin, overlying the Sunda Shelf, and along the coast line. *Ph. sedentaria* is the offshore species of the deep South China Sea basin which occurred throughout the year, ranging constantly to the southern limit of the deep basin while *Ph. curvipes* and *Ph. pacifica* also overlying the offshore portion of the Sunda Shelf. The distributional patterns of all the species found can be distinguished into the following groups :

I. Present both in the Gulf of Thailand and in the South China Sea

1. Common in both areas

   Ph. solitaria

2. Not common in the Gulf, but common in the South China Sea

   Ph. pacifica

II. Present only in the South China Sea

1. Common

   P. elongata *Ph. sedentaria*

   Ph. curvipes

Family Oxycephalidae

Out of the 10 genera of this family, 16 species (includes one new species) from 8 genera were found in the Naga samples examined. Of these, 2 species, *Cranocephalus* sp. nov. No. 5 and *Tullbergella cuspidata*, are the neritic species which were found in the Gulf of Thailand, over the Sunda Shelf, and in the shallow water along the coast of the South China Sea. Another 4 species, *Glossocephalus milne-edwardsi*, *Streetsia porcella*, *Rhabdosoma whitei*, and *Oxycephalus clausi*, were found not only in the Gulf of Thailand but also over the Sunda Shelf, along the coast, and in the deep basin of the South China Sea. The remaining are the offshore oceanic species which were usually found in the deep South China Sea basin, of which *Streetsia steenstrupi* also spread over the offshore portion of the Sunda Shelf and invaded the outer portion of the Gulf in certain seasons, and the other 3 species *Cranocephalus scleroticus*, *Leptocetis tenuirostris* and *Oxycephaluspiscator*, were sometimes found overlying the offshore portion of the Shelf. The distributional patterns of all species found can be distinguished into the following groups :

I. Present both in the Gulf of Thailand and in the South China Sea

1. Common in both areas

   Rhabdosoma whitoi

2. Common in the Gulf, but not common in the South China Sea

   Glossocephalus milne-edwardsi

   Tullbergella cuspidata

3. Not common in the Gulf, but common in the South China Sea

   Streetsia porcella

4. Not common in both areas

   Cranocephalus sp. nov, No. 5

   Oxycephalus clausi

   Streetsia steenstrupi

II. Present only in the South China Sea

1. Common

   Leptocotis tenuirostris *Rhabdosoma minor*

2. Not common, but present all year round

   Cranocephalus scleroticus *Streetsia challengeri*

   Streetsia mindanaonis *Oxycephalus piscator*

3. Rare, (1-4 specimens) present only in the surface layer

   Calamorhynchus pellucidus *Rhabdosoma armatum*

   Oxycephalus latirostris

TABLE

World distribution of the species of hyperiids studied

	Atlantic					Pacific									
	North temperate	North tropical	South tropical	South temperate	Mediterranean	North temperate	North tropical	South tropical	South temperate	Indian Ocean	Red Sea	Arctic	Antarctic	Gulf of Thailand	South China Sea
Acanthoscina															
acanthodes	X	X	X	X			X		X	X					X
Scina															
curvidactyla	X	X	X	X	X	X	X	X		X					X
incerta	X	X	X	X		X	X	X	X	X					X
marginata	X	X	X		X		X	X	X	X					X
submarginata	X	X	X	X	X	X	X			X					X
uncipes	X	X	X	X		X	X	X		X			X		X
borealis	X	X	X	X	X	X	X	X	X	X		X	X		X
damasii	X						X	X							X
stenopus	X	X	X	X	X	X	X			X					X
sp. nov. No. 1							X								X
sp. nov. No. 2							X								X
rattrayi	X	X	X	X	X		X			X			X		X
rattrayi var.															
nov. No. 3							X								X
sp. nov. No. 4							X								X
nana		X	X	X		X	X			X			X		X
tullbergi	X	X	X	X	X	X	X	X	X	X					X
similis	X	X	X		X		X			X					X
Cystisoma															
fabricii	X	X	X	X			X	X		X					X

	Atlantic					Pacific									
	North temperate	North tropical	South tropical	South temperate	Mediterranean	North temperate	North tropical	South tropical	South temperate	Indian Ocean	Red Sea	Arctic	Antarctic	Gulf of Thailand	South China Sea
Vibilia															
chuni	X	X	X			X	X	X							X
armata	X	X	X	X	X		X	X		X					X
pyripes	X	X	X	X		X	X	X	X	X					X
wolterecki						X	X								X
stebbingi	X	X	X	X	X		X	X	X						X
viatrix	X	X	X	X	X	X	X	X	X	X				X	X
gibbosa	X	X	X			X	X								X
Paraphronima															
crassipes	X	X	X	X	X	X	X	X	X	X					X
gracilis	X	X	X	X	X	X	X	X							X
Phronimella															
elongata	X	X	X	X	X	X	X	X	X	X					X
Phronima															
sedentaria	X	X	X	X	X	X	X	X	X	X	X				X
solitaria	X	X	X	X	X	X	X	X	X	X	X			X	X
curvipes	X	X	X	X	X	X	X	X	X	X					X
pacifica	X	X	X	X	X		X	X	X	X	X			X	X
Glossocephalus															
milne–edwardsi	X	X	X		X		X	X		X	X			X	X
Cranocephalus															
scleroticus	X	X	X	X	X	X	X	X	X	X					X
sp. nov. No. 5							X							X	X

	Atlantic					Pacific									
	North temperate	North tropical	South tropical	South temperate	Mediterranean	North temperate	North tropical	South tropical	South temperate	Indian Ocean	Red Sea	Arctic	Antarctic	Gulf of Thailand	South China Sea
Streetsia															
porcella	X	X	X		X	X	X	X	X	X				X	X
challengeri	X	X	X	X	X	X	X	X	X	X					X
mindanaonis		X	X			X	X	X		X					X
steenstrupi	X	X	X	X		X	X	X	X	X				X	X
Leptocotis															
tenuirostris	X	X	X	X		X	X	X	X	X					X
Calamorhynchus															
pellucidus	X	X	X	X	X	X	X	X		X					X
Tullbergella															
cuspidata							X	X		X				X	X
Rhabdosoma															
minor	X	X	X				X	X		X					X
armatum						X	X	X		X					X
whitei	X	X	X	X	X	X	X	X		X	X			X	X
Oxycephalus															
latirostris	X	X	X			X	X	X	X	X					X
clausi	X	X	X	X		X	X	X	X	X	X			X	X
piscator	X	X	X	X	X	X	X	X	X	X					X

Discussion

There are fewer species of these 6 families in the Gulf of Thailand than in the South China Sea, and all species present in the Gulf are also present in the South China Sea. Those which were found in the Gulf showed some connections with the populations outside the Gulf, but some of them showed that they also maintained their populations by circulating in the Gulf, following the pattern of water circulation which was worked out by Robinson (1963 : 34) from the Naga's data.

To judge from their distributional patterns, it is evident that some portions of the populations of *Glossocephalus milne-edwardsi*, *Tullbergella cuspidata*, *Cranocephalus* sp. nov. No. 5, and *Oxycephalus clausi*, were transported out of the Gulf, while *Streetsia porcella* found in the South China Sea was brought deep into the Gulf, and *Phronima pacifica*, and *Streetsia steenstrupi* were carried to the outer portion of the Gulf.

Most of the species which were found only in the South China Sea were found in the areas of the deep South China Sea basin, with their southern ranges to the topographical limit of the deep basin, or slightly overlying the edge of the Sunda Shelf during some periods. *Vibilia chuni* and *Phronimella* elongata were found along the coast, over the Sunda Shelf, and in the area of the deep basin. *Vibilia stebbingi* was found overlying the offshore part of the Sunda Shelf. *Scina uncipes* was found only in the central and northern portion of the studied area in the deep basin.

Few species were rare, only 1 to 4 specimens were found in the samples examined. Some of these species were found only when the depth of haul was below the surface layer (below 150 m.). Since only 4 stations from the whole expedition which were taken from such depth, this might be the reason for not finding more specimens of these species.

Conclusion and Summary

Most of the species found of the six families studied, Scinidae, Cystisomatidae, Vibiliidae, Paraphronimidae, Phronimidae, and Oxycephalidae, were represented only in the South China Sea, while the rest were represented both in the Gulf of Thailand and the South China Sea. None was found only in the Gulf of Thailand. Those species which were found in the Gulf showed some connection with the populations outside of the Gulf, but some of them were shown to maintain their populations inside the Gulf. Certain species were brought from the South China Sea into the Gulf, or to the opening of the Gulf. Most species which were found only in the South China Sea distributed only in the area of the deep South China Sea basin, the rest distributed along the coast or overlying part of the Sunda Shelf. Certain species were rare, and some were found only from the samples below the surface layer of water (below 150 m.).

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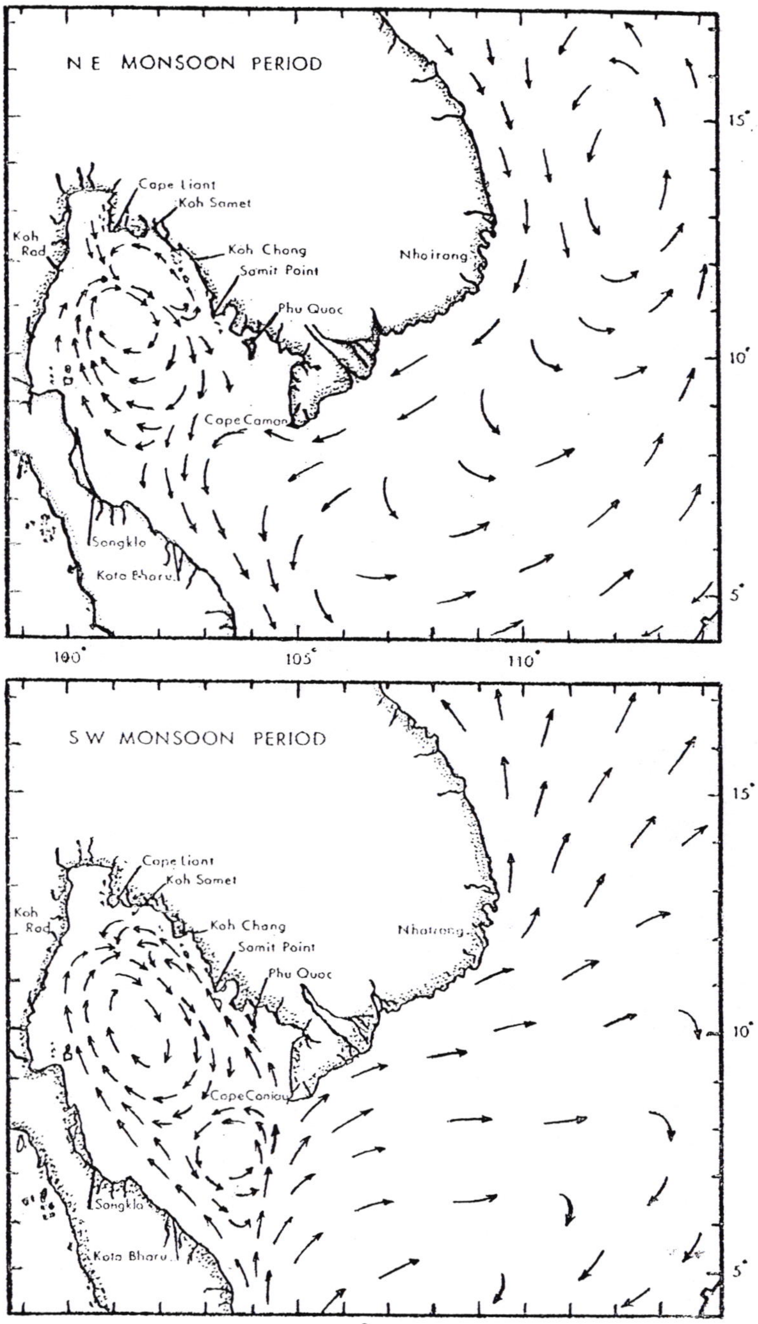
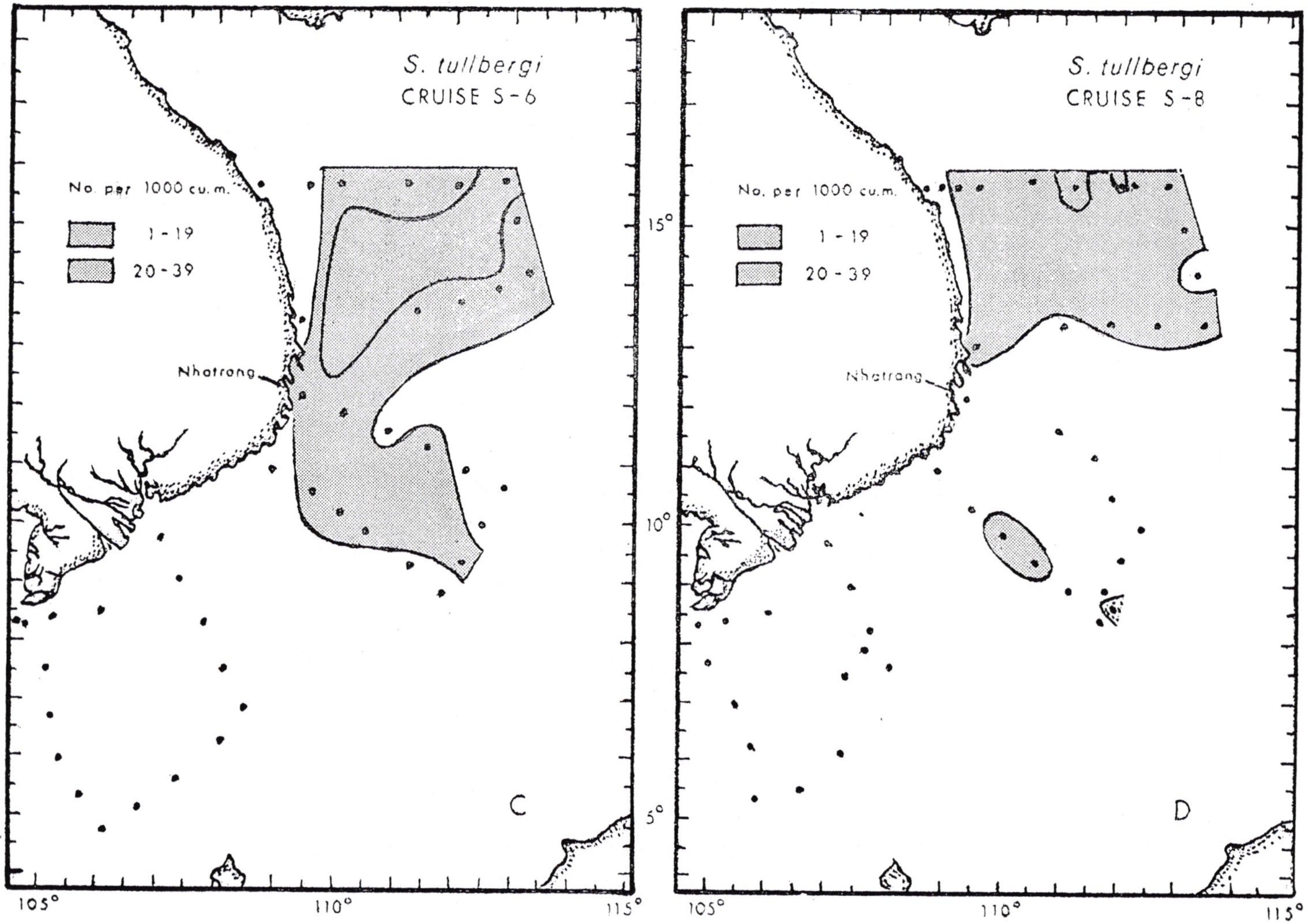
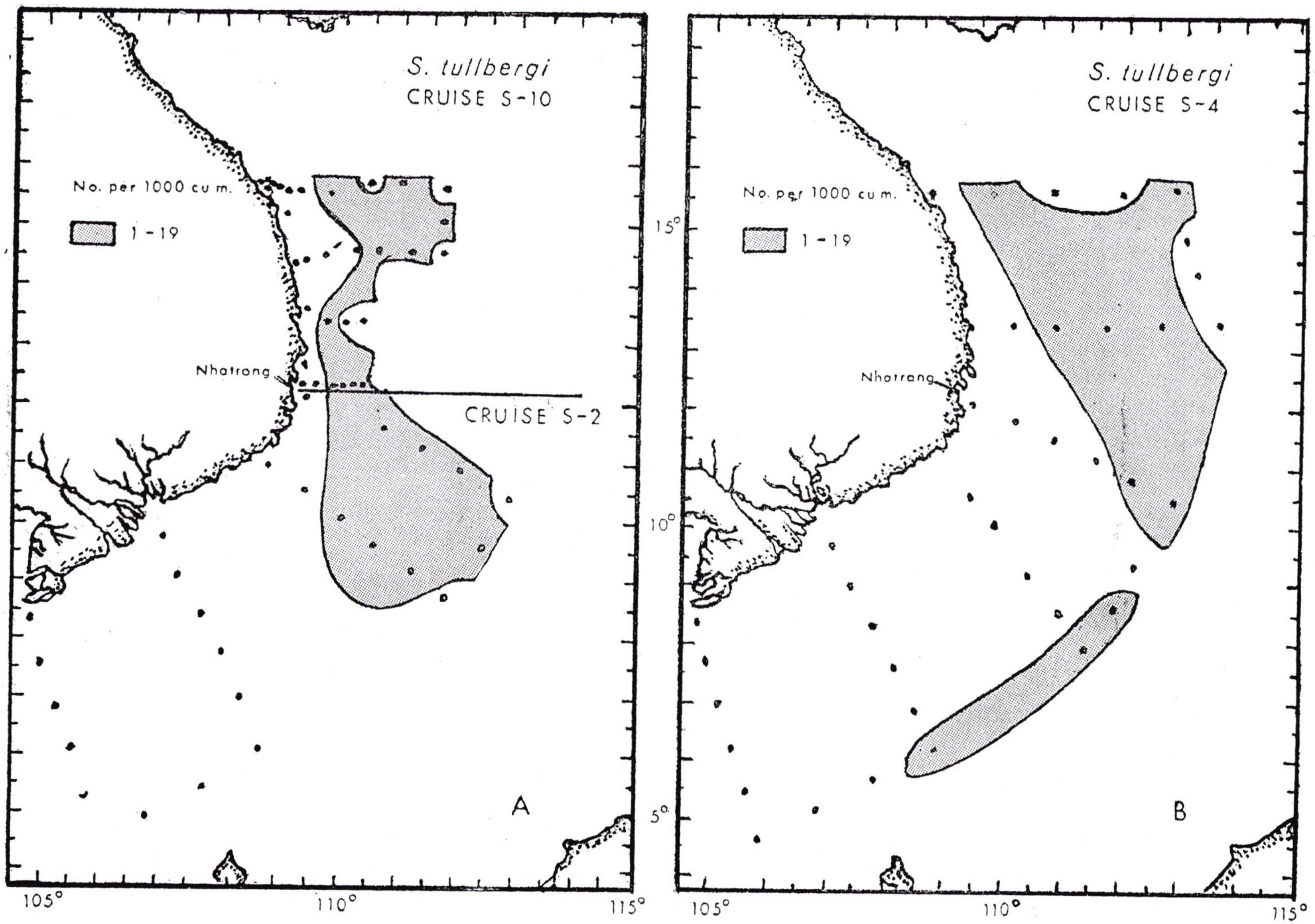


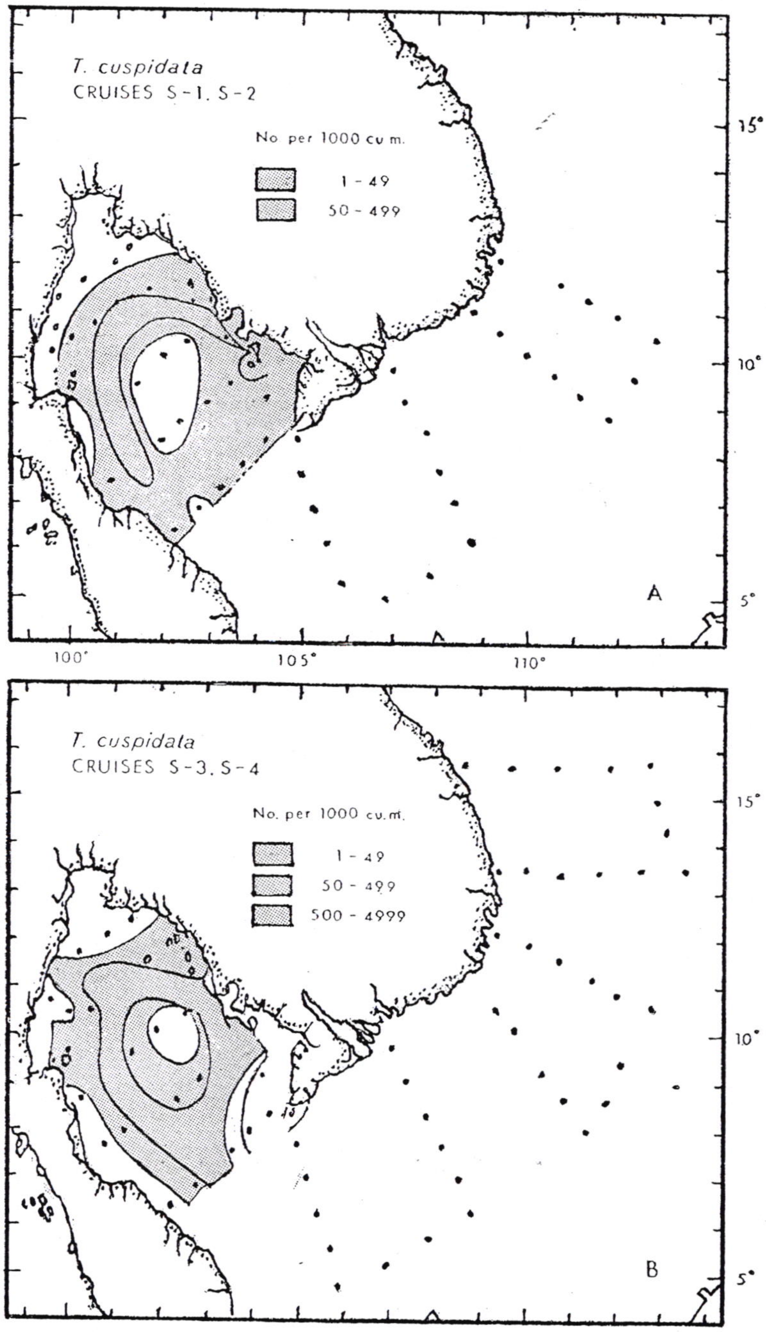
Maps showing the oceanographic currents during the northeast and southwest monsoon periods (modified from LaFond, 1963; Robinson, 1961; Wyrtki, 1961).



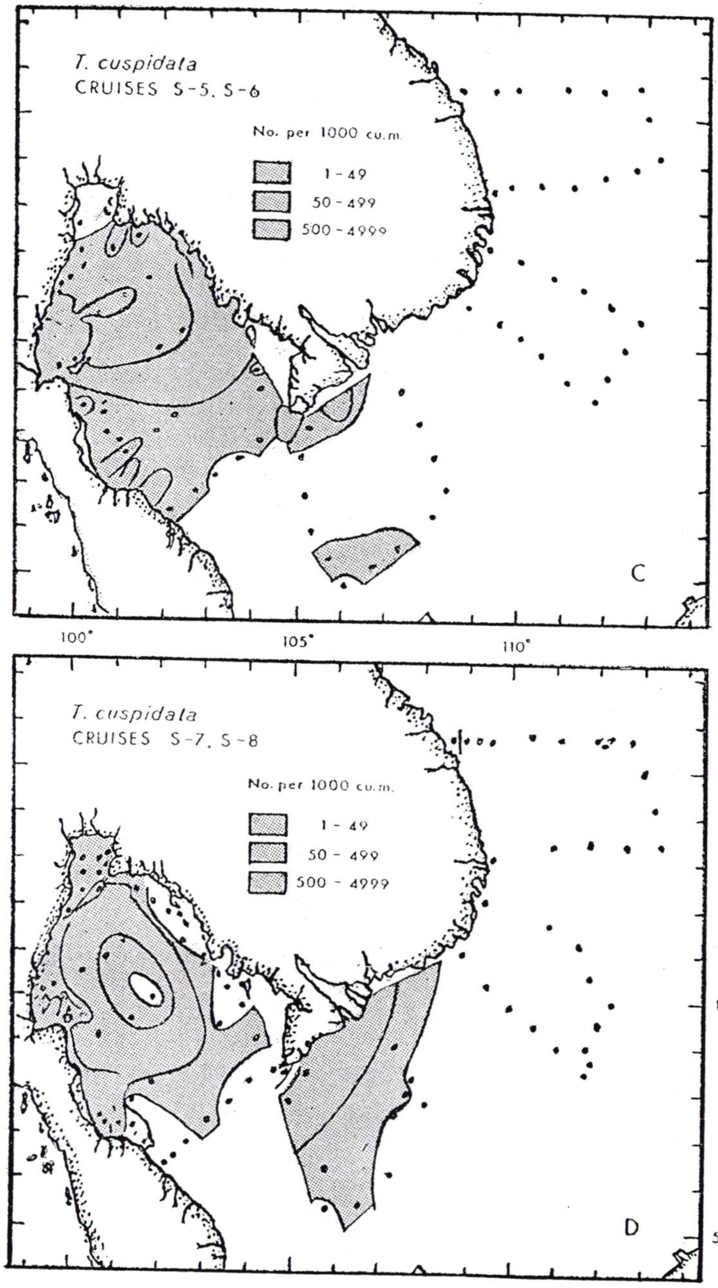
Maps showing the seasonal distributional patterns of *S. tullbergi*.



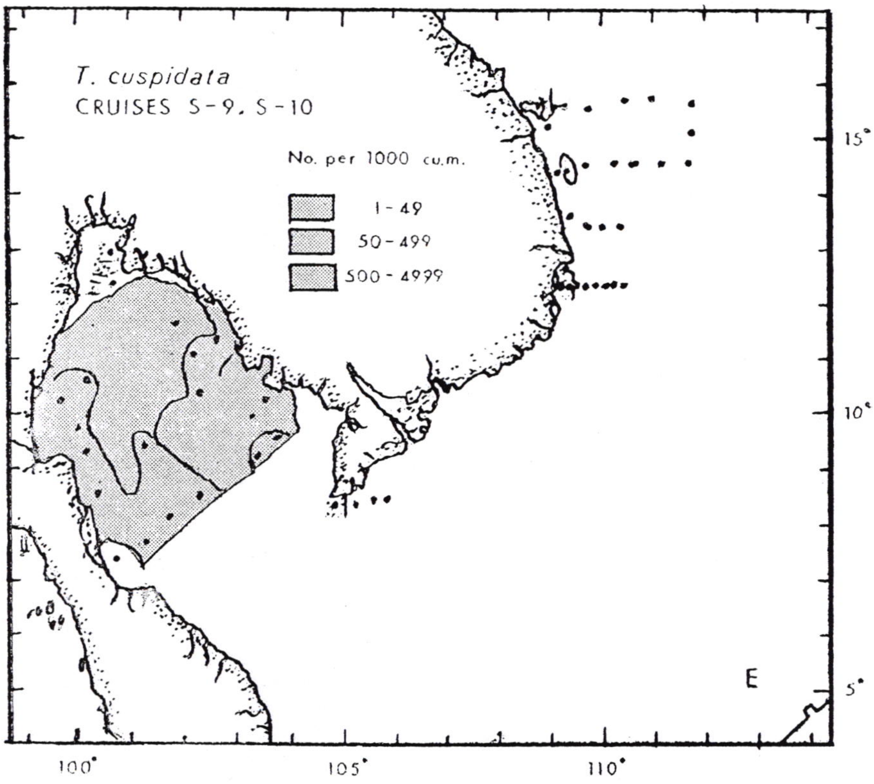
Maps showing the seasonal distributional patterns of *S. tullbergi* (continued)



Maps showing the seasonal distributional patterns of *T. cuspidata*



Maps showing the seasonal distributional patterns of *T. cuspidata* (cont.)



Maps showing the seasonal distributional patterns of *T. cuspidata* (cont.)

2.5 PHYTOPLANKTON AND CIRCULATION NORTH OF NEW GUINEA IN SUMMER 1971

by

BRUNO WAUTHY*

Abstract

Phytoplankton biomass was measured as "active chlorophyll a" along with detritus of phytal origin as "phaeopigments" by the fluorescence method. Samples were taken from hydrological samplers. Both chlorophyll a and phaeopigments vertical distributions show a clear stratification with a well-marked deep maximum.

The relations of this stratification with density, production and vertical circulation are discussed. Nitrite accumulation in the pycnocline is presented and its possible connection with the mineralization of organic matter emphasized.

Introduction

During FOC 2 cruise (June-July 1971) north of New Guinea by ORSTOM Noumea Center oceanographers, photosynthetic pigments were measured. The cruise had four legs along meridians, (154°E, 149°E, 145°30E 142°30E,) from the coast of N.G. to 4°N, with stations half a degree apart. The method was the fluorometric determination according to Strickland aud Parsons (1) with a few modifications: Millipore filters H.A. 0,45 μ were used instead of glass fiber filters, acetone extraction volume was 5 ml, grinding lasted one minute, centrifugation was 3.000-4.000 g for 15 minutes; the TURNER fluorometer was fitted with a "high sensitivity door", a F4 T4-BL lamp, a red sensitive photomultiplier R 136 replacing the standard one, and Corning glass filters, CS-5-60 for excitation and CS-2-64 for emission.

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Calibration was made with terrestrial plant pigments and the maximum acidification ratio obtained on healthy surface phytoplankton in upwelling area during the cruise was 2, 6. Sensitivity was very high and although the sample volume was kept down to 100 ml, neutral density filters had to be used for some samples. The method is quick and reliable and thus we have been able to carry out a chlorophyll a and hydrological Niskin samplers at each of the ten upper level at every station phaeopigments measurement on subsamples taken directly from 0 to 200 m. The originality of these measurements lies in their high number ahd tneir direct relevance to the physical and chemical properties of the water sampled. The total amount to more than 700 samples measured for the four transects.

THE AREA CRUISED is shown in Fig. 1. The current vector measured at the sea surface is drawn at each station ; all these vectors give a good picture of the surfuce circulation in the equatorial area for the region at that time of the year ; the most conspicuous is the Equatorial Current which flows west at the equator, between the line of islands (New Ireland, Admiralty Islands, Ninigo Group) and 2-3°N; north of 2-3°N is the North .Equatorial Counter-Current flowing east. The circulation in the Bismark sea proper seems rather sluggish with a possible clockwise whirling of the E.C. past Manus Island.

The 0-50m column chlorophyll a has been chosen as a crude index of productivity; the variability is rather important; the higher values are found near the N.G. coast and inside the islands arch, as well as in the north of Coral sea ; the lower values are found off shore with the exception of the more than 10 mg/m^2 band at the equator in the eastern part; this band is associated with upwelled water and consistent with the surface divergence of the currents along 154°E at the equator. The high values close to the coast of N.G. could e related with a local upwellihg induced by the east flow of the whirling of E.C. and/or with the fertilizers brought at sea by rivers and land run-off.

CHL a DISTRIBUTION (Fig. 2)

Chl a vertical distribution is characterized by the presence of a subsurface maximum at all stations, except those close to the N.G. coast, so that for the sake of convenience, we may distinguish three layers.

1/The surface layer, above the maxima, is typically poor off shore (less than 0,10 mg/m^3) and richer in the inland Bismark sea with high values near N.G. coast (more than 0,40 mg/m^3). The poor off shore waters have a thermosteric anomaly higher than 600 cl/t.

2/The maximum layar may be defined as the more than 0,20 mg/m^3 chl a layer; the values of the maxima are variable; except for near-shore or inland Bismark sea area, the layer is generally under the compensation depth defined by the sursaturation values for oxyty; at 154°E and 149°E, we still have at the equator part of the maximum layer above the compensation depth, but this part is small at 145°30'E and almost nil at 142°30'E. The thickness of the layer is variable, but its limits 0,20 mg/m^3 isolines) follow very well the 500 and 580 cl/t lines. The lower limit of the layer may be as deep as 160m at st. 74 or as shallow as 100m at st. 70 and 77.

3/The bottom layer: under the maximum layer the chl a gradient seems to fit in rather well with the density gradient as shown by the 0,10 mg/m^3 isoline.

PHAEOPIGMENTS DISTRIBUTION (Fig. 3)

Phaeopigments distribution matches practically in all respects the chlorophyll a one. However the maximum layer is deeper and the maxima are higher than for chl a. But for a few surface samples, phaeopigments content is usually higher than corresponding chl a content. The bulk of phaeopigments may be seen to lay under the compensation depth and isolines to follow pycnoclines (or more precisely haloclines). Salinity of poor surface water is less than 34,5‰ and the maximum layer salinity is between 35,0 and 35,4‰ . Nitrite distribution (0,5 mmol NO_2/m^3 drawn in Fig. 3) seems to be linked with phaeopigments distribution.

Discussion

In the western intertropical area, heating from the sun, desalting by the rain, and mixing by the wind, join to produce a very ligh surface layer; beneath, lies the maximum salinity layer; the density gradient which results is very steep and the stability very high; the surface layer is thus isolated from the layer below. Phytoplankton developing in the well lighted surface layer will consume very quickly all the nutrients available since there is no or little renewal of nutrients from the rich layer below; so, the surface layer is generally very poor off shore, far from the fertilizing effect of land run-off and river discharges.

Circulation can promote phytoplankton production by bringing up into the photic zone rich water from below; this process is called up-welling and we can see an occurence at the equator, 154°E where dense, salty subsurface water (580 cl/t, more than 35‰ S) is brought to the surface by divergence of the surface current, contrasting with the poor off shore surface water typically more than 600 cl/t and less than 34,5‰ S) (Fig. 1,2,3).

The maximum layer is much of a puzzle. The relevance to phytoplankton cells count is not clear. Although identification and count of cells made for the cruise (cf. Desrosières (2)) do indicate the predominance of Coccolithophorids and a maximum of the dominant species usually at 80m, the number of cells would give account of only a few tenths of the chl a found. So, apparently, either ratios of cell carbon to chl a can very in the water column or the method used for determining dominant taxa is inadequate.

The association between the depths at which chl a maxima accur and the depths of pycnoclines has been attributed (3) to the distribution of nutrients near pycnoclines: plant cells of the chl a maximum are trapping nutrients diffusing into the nutrient-poor surface water. Thus nutrient limitation of phyto-cells growing in nutrient-poor water could decrease near pycnoclines. If this explanation can hold for the depth of occurrence of the top of the maximum layer it does not do so for the bottom: the depth of the lower limit of the maximum layer should not depend on nutrients which are no more limiting there, but rather on available light and therefore be more or less constant for a given area; we have seen that, on the contrary, the lower limit fluctuates much in depth and actually follows isanosteres.

Another often put forward reason for a variable depth of the maxima is that the depth to which phyto-cells can reproduce must be regulated by subsurface light intensity and cellular capacity to adapt to low light intensities; indeed, the taxonomical work (2) has provided a crude distinction between surface taxa (0-80m), medium depth taxa (40-120m), and deep taxa (80-160m), but not with such clear-cut results as presence of deep taxa at st. 74, 160m and absence at st. 70 and 77. Moreover it would be left to us to explain why....taxa do follow isopocnes.

So, it appears that taxonomical or physiological reasons cannot explain satisfactorily the discrepancy between stations as far as maximum chl a depth is concerned.

The chl a maximum depth relatively to compensation depth casts some doubt on the "in situ" production to give account of the bulk of phaeopigments; most of these phaeopigments should result from the grazing of cells produced when the water was in a better position for photosynthesis; The linking of phaeopigments with nitrite considered as a further step in the degradation of organic material would favour the idea of an already long history for that production.

We are left now with the picture of phytal cells and detritus passively wandering, carried along by a distinctive water for a long time ; that is not to be wondered at........it is exactly the definition of phytoplankton !

The distinctive water is shown to have a salinity between 35,0 and 35,4 $^{\circ}/_{\circ\circ}$ with a thermosteric anomaly between 500 and 580 cl/t. This water may be found at the equator between 150°E and 170°E when upwelling is active (4). In this salty, rich and dense upwelled water rising at the surface to replace desalted, poor, and light water driven aside from the equator by eastern wind, a high primary production starts and builds up as long as this dense water remains in the euphotic layer. Later, upwelled water is continuously driven away from the equator at a distance north and south where the active divergence disappears and there, this water, carrying its plankton and dissolved organic matter recently produced, sinks under the lateral light waters and spreads into the top of thermocline. Then, cells could be grazed, producing phaeopigments and organic detritus, the mineralization of which could follow, with the noticeable step of nitrite accumulating in a layer. Ultimately this water could return to the equator to feed the upwelling, thus closing a production–grazing–mineralization–upwelling cycle. This vertical and meridian circulation model is consistent with our observations at 170°E. Of course, the maximum pigment layer so built would have been brought from the east into the New Guinea area by Equatorial Current.

Conclusion

This cruise has shown that north of New Guinea in the eqatorial zone, photosynthetic pigments distribution seems closely associated to a distinctive water, presumably upwelled water, the distribution of which results from the vertical, meridian and zonal circulation. Although the importance of the physiological condition of the cells, in connection with external factors such as light, temperature and nutrients, cannot be overlooked, it is clear that phytoplankton is first of all passively following water in the intricacy of its displacements. Understanding of the long left aside surface water circulation is thus a prerequisite to any theory of the distribution of phytoplankton in the ecean.

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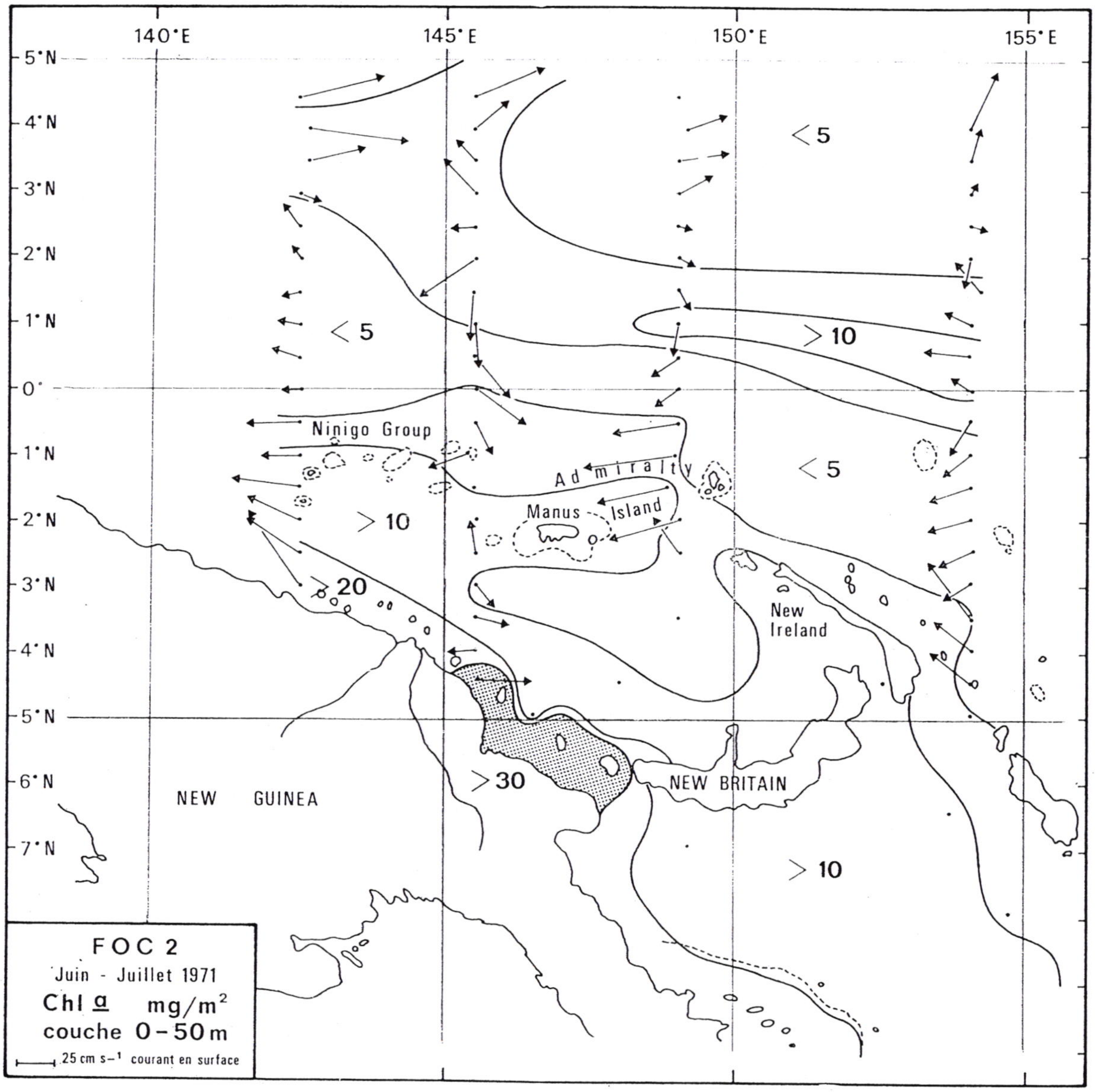
140°E
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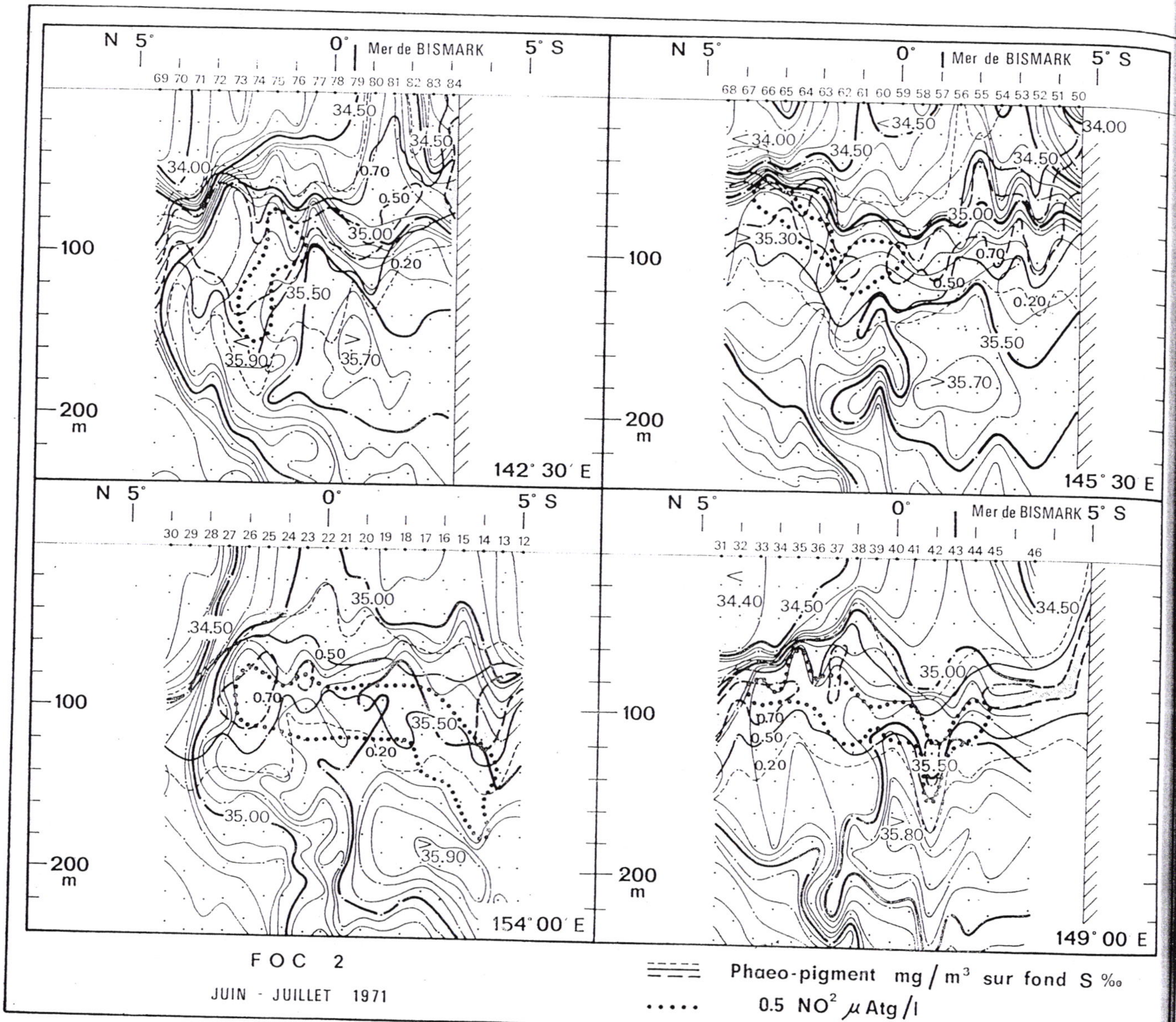
4°N
5°N
6°N
7°N
< 5
< 5
> 10
< 5
> 10
> 20
> 30
> 10
Ninigo Group
Admiralty
Manus Island
New Ireland
NEW BRITAIN
NEW GUINEA
FOC 2
Juin - Juillet 1971
Chl a mg/m²
couche 0-50 m
25 cm s⁻¹ courant en surface

Fig 1


N 5°
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Mer de BISMARK
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69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
34.50
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m
142° 30′ E
68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50
34.00
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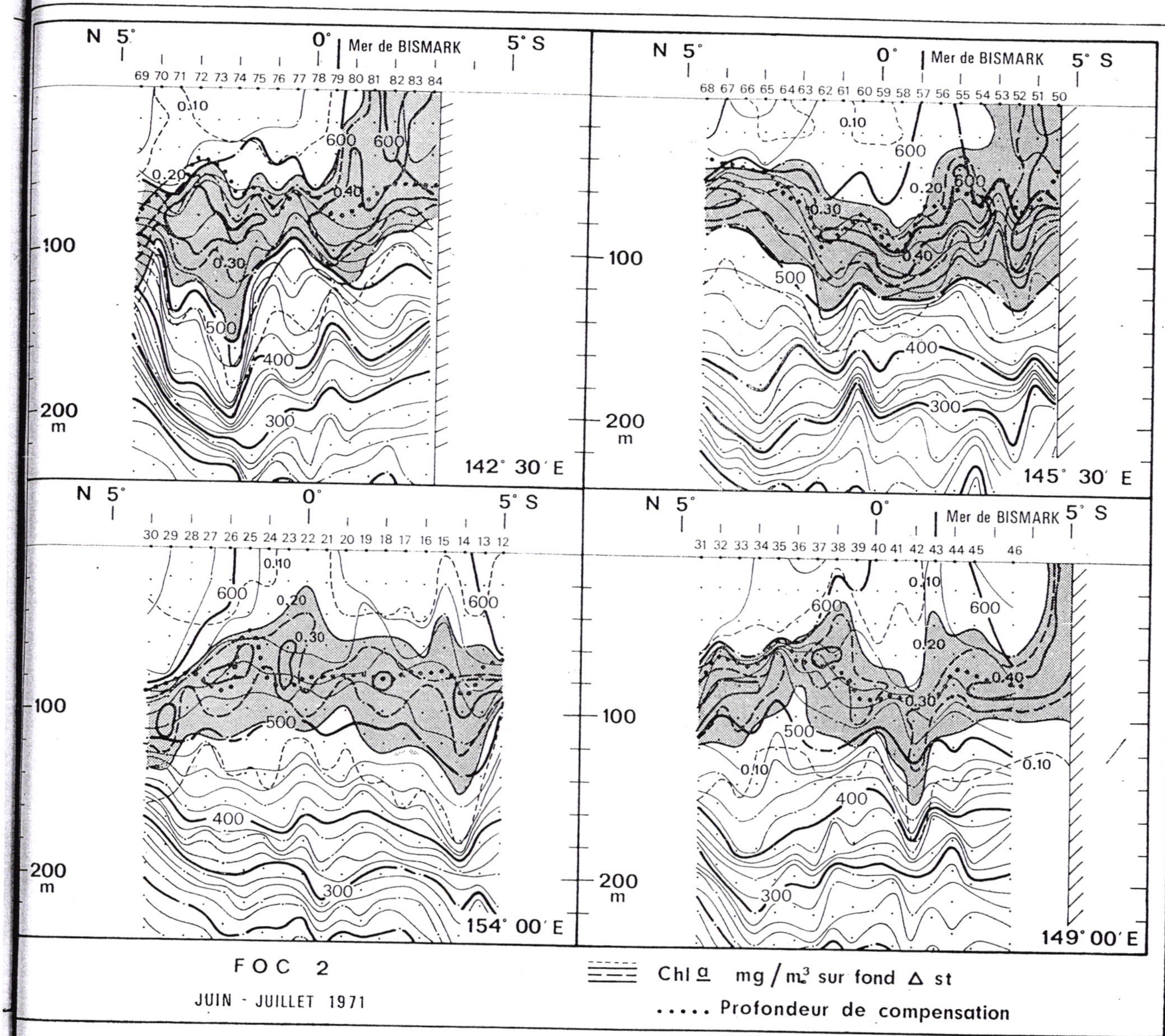
30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12
154° 00′ E
31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
34.40
35.80
149° 00 E
F O C 2
JUIN - JUILLET 1971
Phaeo-pigment mg / m³ sur fond S ‰
0.5 NO² µ Atg / l

Fig. 2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145° 30′ E
30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12
154° 00′ E
31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
149° 00′ E
100
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m
FOC 2
JUIN - JUILLET 1971
Chl a mg / m³ sur fond Δ st
..... Profondeur de compensation

Fig. 3

2.6 PRÉDOMINANCE DES COCCOLITHOPHORIDÉS DANS LE PHYTOPLANCTON AU NORD DE LA NOUVELLE-GUINEE (JUIN-JUILLET 1971)

(DOMINANCE OF COCCOLITHOPHORIDS IN THE PHYTOPLANKTON OF THE WESTERN EQUATORIAL PACIFIC WATERS IN JUNE JULY 1971)

par

ROGER DESROSIÈRES

Abstract

The present paper stresses the importance of Coccolithophorids in the plankton of a little studied area: the equatorial Pacific Ocean, north of New Guinea.

500 ml samples from 35 stations were collected at five depths (0, 40, 80, 120 and 160 m) and preserved with 5 ml potash neutralized formalin; examination, identification and counting of the phytoplankton organisms were performed in the laboratory some months later with an inverted microscope using two sedimentation cells, one for "macrophytoplankton", the other for "microphytoplankton",

In offshore waters, macrophytoplankton, essentially large Diatoms and Dinoflagellates, was insignificant, while microphytoplankton was almost solely Coccolithophorids; no relation between organism distribution and hydrology has been clearly established, however, as a whole, Coccolithophorid population in that region did show various vertical distributions according to species. In coastal waters, phytoplankton was more abundant and its floristic composition different.

As taxonomy and identification of Coccolithophorids has to rely upon electron microscopy, which is an elaborate and costly technique, an address is made here in favor

of a catalogue drawn up with both electron and optical photographs, emphasizing features which can be seen through a good optical microscope.

Introduction

Depuis la communication présentée à Cambridge en 1967 par Mme GAARDER, à l'occasion du symposium sur la micropaléontologie des sédiments marins (GAARDER, 1971), qui exposait les données acquises à cette date sur la distribution des Coccolithophoridés dans les océans, de nouvelles contributions à la connaissance de la biogéographie de ce groupe dans l'Océan Pacifique sont parues. Un échantillonnage lâche, mais couvrant l'ensemble de l'océan, a permis à McINITYRE *et al.* (1970) de déterminer une répartition zonale, liée à la température, relative aux principales espèces ; OKADA (1970) et OKADA et HONJO (1970) ont publié l'étude qualitative et quantitative de quatre sections du Pacifique nord et équatorial ; USCHAKOVA (1971), MICHEL *et al.* (1971) et DESROSIERES (1971) ont analysé des récoltes provenant d'aires plus limitées du Pacifique central.

Le présent article fait ressortir l'importance des Coccolithophoridés dans le phytoplancton apparent d'une région à ce jour peu explorée : le Pacifique équatorial au nord de la Nouvelle-Guinée.

Materiel et Methode

35 stations ont été occupées, du 25 Juin au 24 juillet 1971, selon l'itinéraire représenté à la Fig. 1. A chaque station, cinq échantillons de 500ml d'eau de mer ont été récoltés aux profondeurs nominales de 0 m, 40 m, 80 m, 120 m, et 160 m, et fixés par 5 ml d'une solution de formol du commerce neutralisé à la potasse, de façon à conserver le phytoplancton dans un milieu formolé à 1%, légèrement alcalin.

L'étude au laboratoire a été conduite selon la méthode décrite par DESROSIERES (1971), qui consiste essentiellement en deux examens successifs du même échantillon au microscope inversé, dans deux cellules de sédimentation différentes, adaptées l'une à l'observation à un grossissement moyen (objectif 10 x) qui convient à l'étude du "macrophytoplancton", l'autre à l'observation à un fort grossissement et surtout avec un pouvoir séparateur élevé (objectif 100x, ouverture numérique aussi grande que possible) nécessaires à l'anayse du "microphytoplancton" ; l'objectif utilisé dans ce dernier cas est le "Planapochromat, 100x, 1, 3 N.A., à immersion de Zeiss.

Macrophytoplancton

Les grandes Diatomées et les grands Dinoflagellés constituent l'essentiel du "macrophytoplancton", défini par le grossissement peu élevé que requiert son observation. Il apparaît très clairsemé au nord de la Nouvelle-Guinée : en tout et pour tout, quatre espèces de Diatomées, *Planktoniella sol, Climacodium frauenfeldianum Gossleriella tropica* et *Thalassiothrix* sp., ont été observées, à raison de quelques unités par litre, aux stations pélagiques, encore que seule *P. sol* puisse être considérée comme courante, en figurant sous cette très faible densité, dans la plupart des échantillons. La liste des espèces de Dinoflagellés rencontrés, fond commun de tous les phytoplanctons tropicaux, est longue, mais le nombre d'individus de chacune, observés çà et là, reste insignifiant. Jamais abondant (quelques cellules par litre), l'étrange flagellé (?) *Danasphaera indica* est présent dans toute la région étudiée. Après les indications fournies par BELYAEVA (1971), KAWARADA *et al.* (1968), KOLBE (1954) et DESROSIERES (1969), les observations présentées ici confirment la pauvreté du nord de la Nouvelle-Guinée en macrophytoplancton.

Les trois stations les plus proches des côtes ont été qualifiées de "néritiques" à cause de leurs caractéristiques florales : apparition d'autres espèces de Diatomées (*Rhizosolenia bergonii* et *Thalassiothrix frauenfeldii*) et d'une Cyanophycée *Trichodesmium* sp.).

Microphytoplancton

Définition

Est désignée sous l'appellation de "microphytoplancton", la fraction du phytoplancton dont l'observation et l'analyse nécessitent un fort grossissement (de l'ordre de 1000×) et surtout un objectif doué d'un pouvoir séparateur élevé; il s'agit, de façon approximative et évidemment conventionnelle, d'organismes mesurant moins de 20 microns; les microflagellés nus, qui ne supportent pas la fixation, étant éliminés, le microphytoplancton apparaît constitué, dans le cas de la présente étude, uniquement de Coccolithophoridés. Dans certaines circonstances (DESROSIERES, 1971) de petites Diatomèes (Pennées) et de petits Péridiniens peuvent venir s'y ajouter.

Remarques préliminaires sur la détermination et taxonomie des Coccolithophoridés

A part pour quelques pionniers particulièrement habiles ou inspirés, stimulés peut-être par la difficulté du problème, tels que LOHMANN, SCHILLER, et KAMPTNER, le groupe des Coccolithophoridés est resté, pour nombre de phytoplanctonologistes, un monde à peu près inexploré, faute de moyens de détection et d'observation suffisamment puissants. En effet, si la limite extrême de résolution des meilleurs systèmes optiques peut théoriquement atteindre 0, 2 micron, le pouvoir séparateur utile, pour des raisons diverses, se situe en fait plutôt vers 1, voire 2 microns. Or l'identification taxonomique précise des Coccolithophoridés se fait sur des caractères morphologiques de dimensions nettement inférieures à cette limite pratique. L'apparition de la microscopie électronique, qui s'est emparée de ce sujet de choix, a opéré une véritable mutation. Elle a permis d'éclaircir bien des situations en précisant la définition de nombreuses espèces, en en créant quelques nouvelles et en effectuant aussi eertains regroupements. Cependant, alors qu'il a entraîné l'étude structurale des coccolithes vers des sommets de raffinement, l'emploi du microscope électronique (M.E.) a laissé quelque peu sur sa faim l'océanographe qui ne possède qu'un microscope optique (M.O.), et ne lui a pas rendu parfaitement le service qu'il pouvait en attendre. Dans le meilleur des cas, les auteurs juxtaposent les deux diagnoses (M.O. et M.O.) et les deux séries de clichés correspondants, mais aucune étude n'est conduite dans le souci d'être directement utilisable par le chercheur qui ne dispose que d'un M.O. Se trouvant dans cette situation, l'auteur est amené à faire le remarques et suggestions suivantes :

Il semble qu'un taxon qui a été observé, décrit et nommé à l'aide d'un M.E. peut ensuite être reconnu, par le même chercheur, au M.O. C'est de cette expérience qu'il faut impérativement faire profiter les chercheurs saulement "opticiens," en entreprenant à leur intention la confection d'un catalogue-guide, qui centiendrait des photographies (M.E. et surtout M.O.) mais qui, avent tout et systématiquement, attirerait l'attention sur des caractères, des aspects typiques, sur des allures ou des traits particuliers, même sans valeur taxonomique sensu stricto, mais en fait distinctifs, qui seraient perceptibles au M.O. et déduits de l'observation et de l'analyse au M.E. Ce catalogue de "descriptions comparées" éviterait les tâtonnements et les imprécisions— et aussi, inversement, certaines affirmations hâtives et péremptoires - dans les déterminations. Aucune biogéographie, aucune étude écologique ne peut être abordée qui ne repose sur des identifications solides.

Dans le présent travail, deux espèces pourtant bien typées sous le M.O., n'ont pu être identifiées avec certitude, illustrant le profond hiatus qui sépare les deux techniques d'observation :

1 - "*Coccolithus meteori*". La seule description de cette espèce, à ma connaissance, apparaît dans la légende d'une illustration très schématique de SCHILLER (1930); c'est pourtant à cette espèce que j'attribue un Coccolithophoridé de surface très

courant, présentant des coccolithes si embrassants que deux ou trois suffisent à enrober toute la coccosphère, faute de pouvoir le rattacher à une quelconque des espèces pourtant si méticuleusement décrites et représentées grâce au M.E.; n'ayant rencontré aucun spécimen à rapporter à *Umbellosphaera tenuis*, j'ai pourtant encore douté de l'exactitude de cette déterminafion, mais aucune représentation de *U. tenuis* ne m'a convaincu et je me suis résigné à conserver l'identification *C. meteori* et à constater l'absence d'*U. tenuis* dans la région étudiée.

2. – "*Cyclococcolithus fragilis*". L'espèce la plus abondante du matériel récolté au nord de la Nouvelle-Guinée n'a pu être déterminée avec certitude. Il s'agit d'une petite forme dont le diamètre varie de 5 à 8 microns, qu'après HASLE (1960), qui a insisté sur l'impossibilité des distinctions spécifiques à l'intérieur de certains groupements, j'assimile à un "*C. fragilis*" de petite taille.

Les Coccolithophoridés au nord de la Nouvelle-Guinée

Les Coccolithophoridés constituent la plus grande partie du phytoplanction recensé au nord de la Nouvelle-Guinée. Ils sont présents à toutes les stations et toutes les profondeurs et atteignent une fois, à 80 m, la densité de 27 900 cellules par litre. Les variations en densité et en caractéristiques floristiques peuvent être importantes d'une station à l'autre. sans que pour autant, sur une aire aussi réduite, puissent être mises en évidence. ni aires de richesse particulière, ni distribution géographique des espèces. L'hydrologie très complexe de cette zone de renverse du système des courants et contre-courants équatoriaux. zone sujette, qui plus est. à un balancement saisonnier consécutif au régime des moussons (DEFANT, 1961 ; "Morskoi atlas", 1953) n'a pu, non plus, être éclairée par la localisation d'espèces indicatrices de masses d'eau. En conséquence, il a été estimé préférable de traiter statistiquement l'ensemble des résultats des numérations phytoplanctontques et de caractériser l'ensemble de la région étudiée par une valeur moyenne et un intervalle de confiance sur cette moyenne pour chacun des taxa repertoriés en chacune des profondeurs échantillonnées. Ce mode de traitement des résultats des numérations fait ressortir une répartition bathymétrique des espèces particulièrement claire et d'autant plus sûre qu'elle est établie à partir d'un grand nombre de valeurs (32 données pour chaque niveau, les stations à caractère néritique ayant été éliminées des calculs).

Les résultats sont résumés sur la Fig. 2, sur laquelle est reportée la distribution des sept principales espèces, avec,pour chaque profondeur, la moyenne des densités par litre et l'intervalle de confiance à 95% sur cette moyenne. *Coccolithus meteori* et *Umbellosphaera irregularis* sont des espèces nettement superficielles ; *Gephyrocapsa oceanica* et *Umbilicosphaera sibogae*, avec un maximum à 80 m et des densités non négligeables en surface et à 40 m, sont subsuperficielles. *Cyclococcolithus fragilis* est l'espèce deloin la plus abondante ; elle a son maximum à 80 m. Deux espèces sont nettement profondes : *Deutschlandia anthos* et *Deutschlandia* sp. A, cette dernière étant peut-être une variété de *Florisphaera profunda*, espèce nouvellement créée par OKADA et HONJO (1973).

La disparité d'uue station à l'autre, manifestée par l'amplitude des intervalles de confiance, confirme les observations de OKADA et HONJO (1970) sur les eaux de surface ue la même région ; les densités moyennes trouvées par ces auteurs sont du même ordre que celles vui sont présentées ici (quelques centaines à quelques milliers de cellules par litre).

A titre subsidiaire, la Fig. 3 fait apparaître la composition spécifique relative, en chacune des profondeurs échantillonnées, pour permettre d'éventuelles comparaisons avec les auteurs qui ont adopté ce mode de représentation.

La répartition bathymétrique rencontrée des différentes espèces coïncide assez bien avec les quelques données antérieures en particulier celles de HASLE (1959 et 1960) et de OKADA et HONJO (1973).

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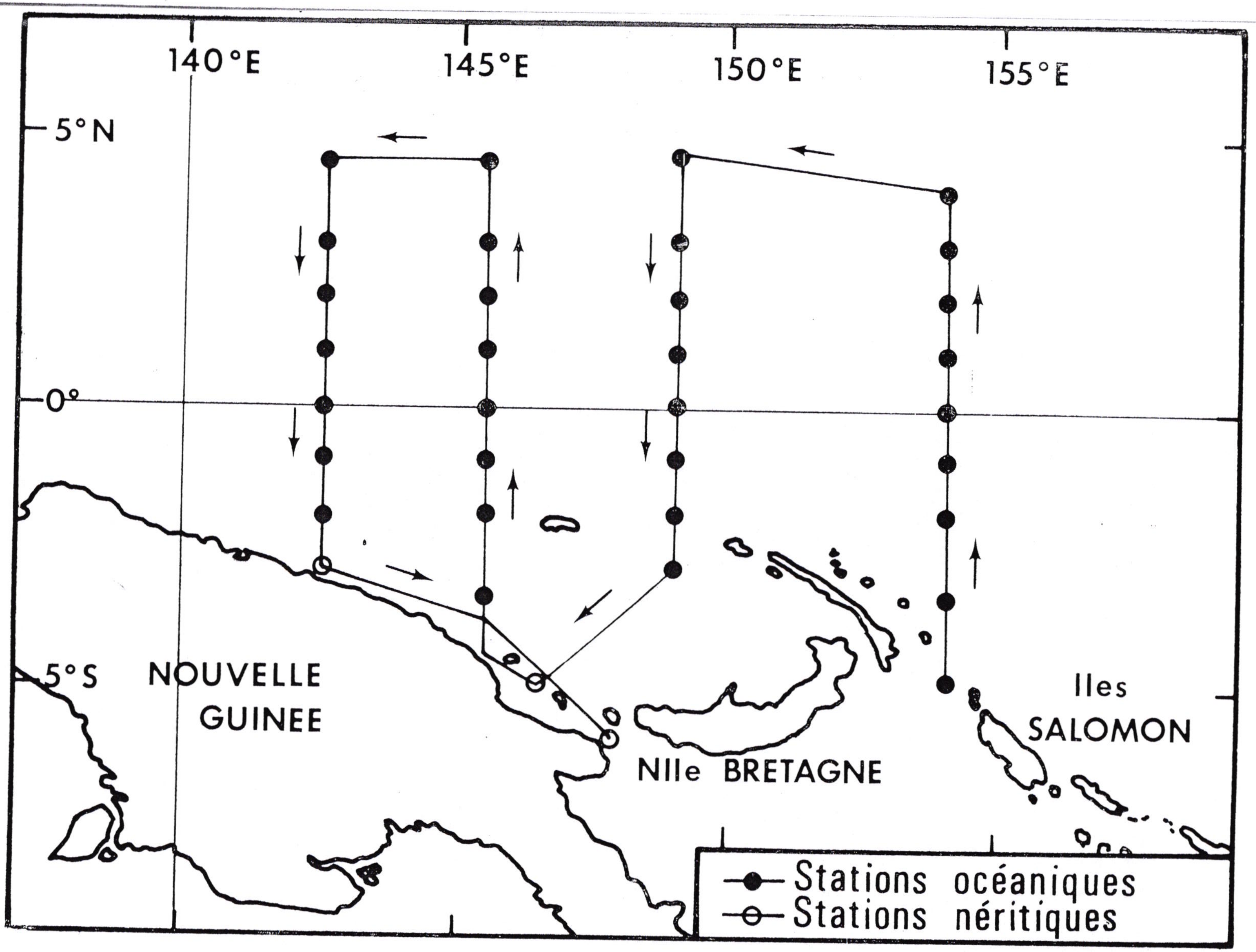

Fig. 1 Itinéraire ce la croisière et localisation des stations

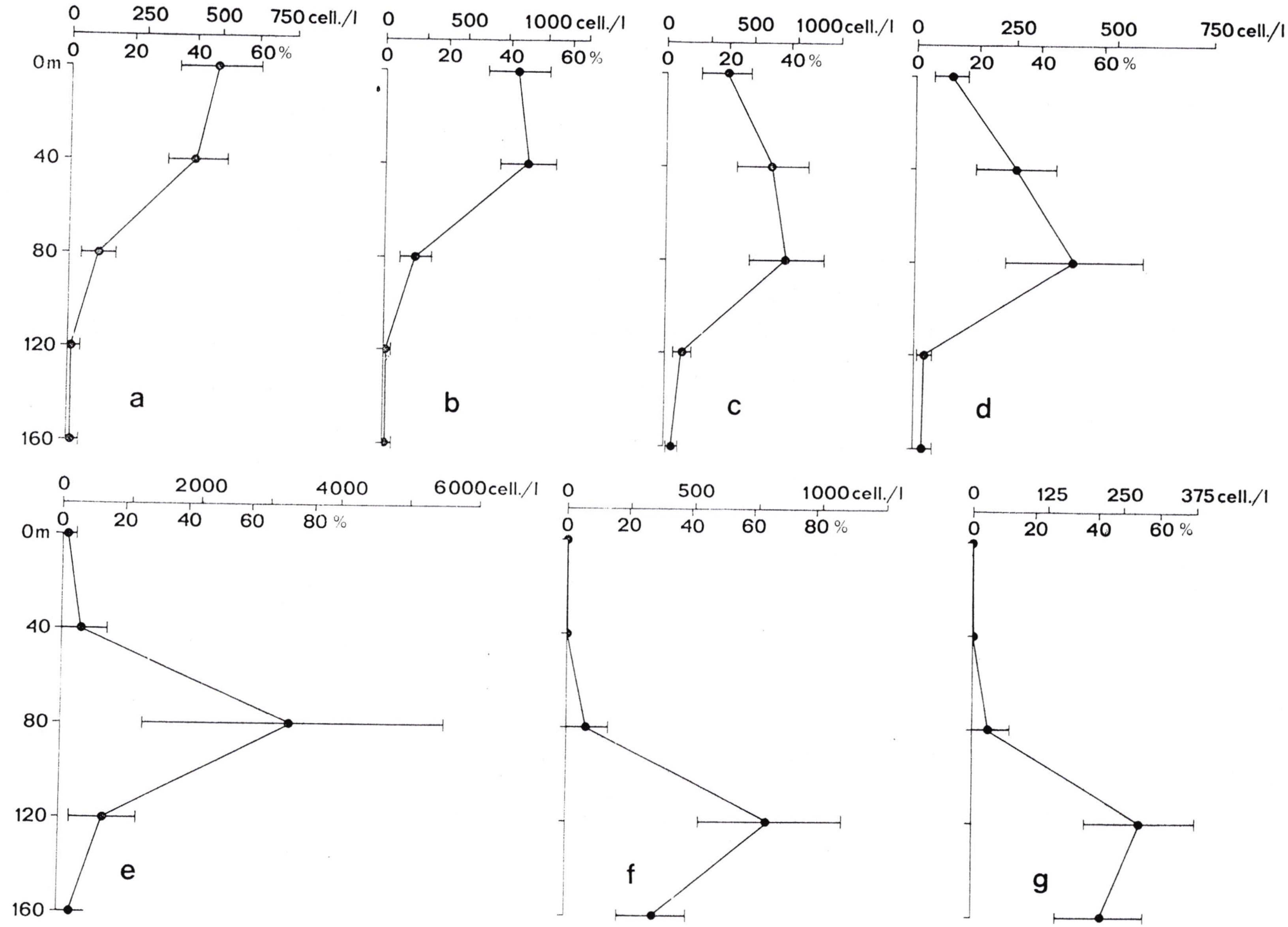

Fig. 2 Distribution bathymétrique statistique des principaus taxa, en valeur absolue et en pourcentage : moyenne pour chaque profondeur et intervalle de confiance à 95% sur la moyenne. a, *Coccolithus meteori* : b, *Umbellosphoera irregularis* ; c,

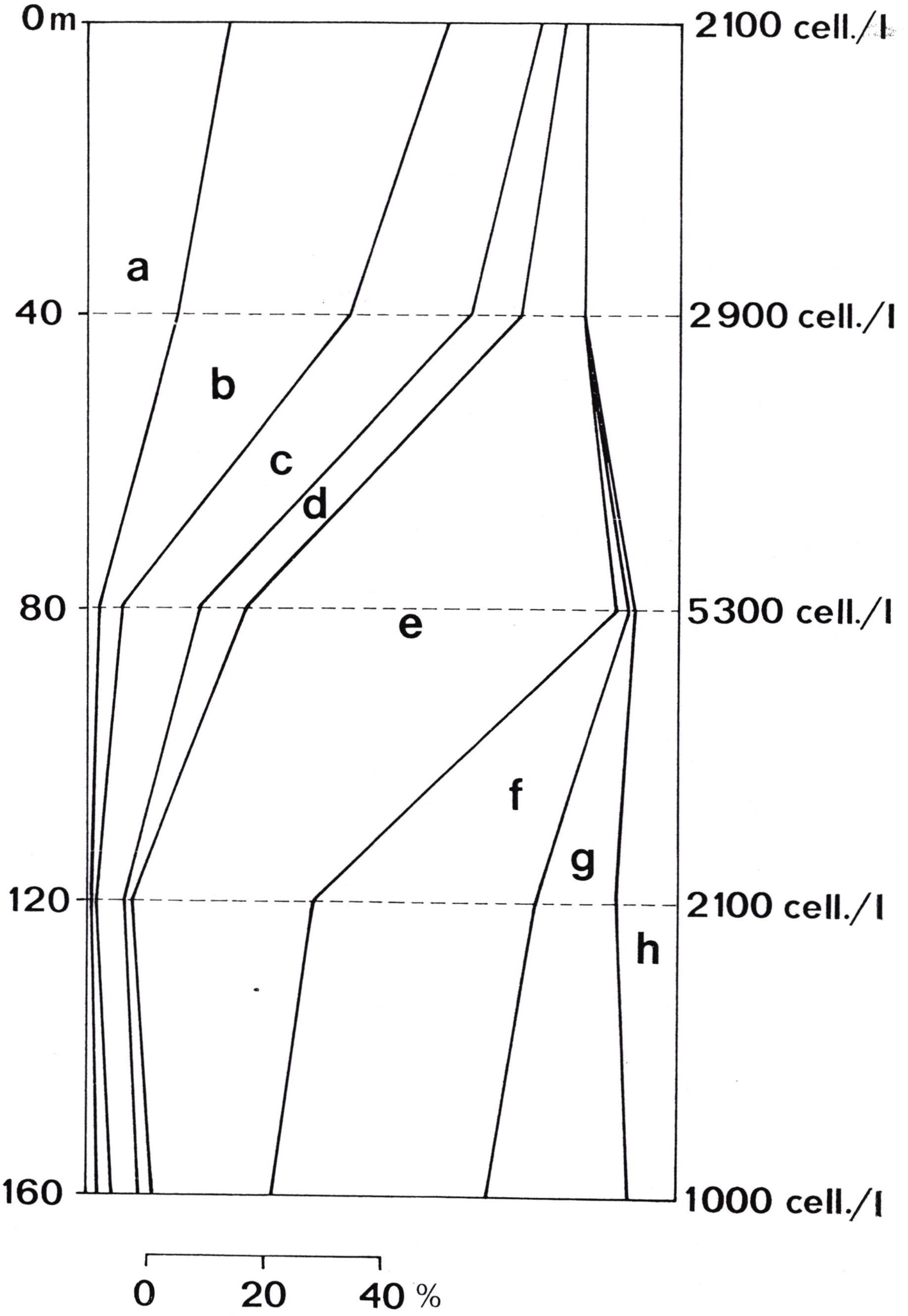

Fig. 3 Pourcentage relatif des taxa recensés aux différentes profondeurs. a, *Coccolithus meteori*; b, *Umbellosphaera irregularis*; c, *Gephyrocapsa oceanica*; d, *Umbilicospaera sibogae*; e, *Cyclococcolithus fragilis*; f, *Deutschlandia* sp. A; g. *Deutschlandia anthos*; h, autres taxa.

2.7 THE ESTIMATION OF PHYTOPLANKTON PRODUCTION IN THE GULF OF THAILAND FROM CHLOROPHYLL, OXYGEN DETERMINATION AND LIGHT DATA,

AMPAN LURSINSAP

&

MANOP CHAROENRUAY

Abstract

The organic production beneath a unit of sea surface may be estimated from the chlorophyll content or oxygen determination of the water, the total daily solar radiaiion reaching the sea surface, and the extinction coefficient of visible light in the water column.

A mean value of 3.7 mg C assimilated/hour/mg/ chlorophyll was obtained from the expression of Ryther and Yentsch, 1957 and from data present in the literature. The relationsip was determined between photosynthetic rate at light saturation and chlorophyli content in natural populations.

A well-developed subsurface chlorophyll a maximum is presented at the depth where the surface light is reduced to 32% in 1971 and is presented at 3.2% in 1972. It appears that a photosynthetically active phytoplankton community is adapted to low light intensity and the highest production is at the 32% level in 1971 and also at the same depth in 1972.

Introduction

The Marine Fisheries Laboratory has launched a program of primary productivity assessment unit since 1968. Progress by, the results from the investigations in 1971–72 are of considerable importance for understanding the processes going on in nature.

Generally, when primary production measurement are made in the Gulf of Thailand, the selection of sampling depth is based on the rather arbitary definition of a euphotic zone, that is the region extending from the surface to a depth where it is shallower than 1% of surface light level for the depth of part of the working area in the Gulf of Thailand from the shallow area to the deepest area is about 5 meters to 57 meters.

In situations that phytoplankton populations are patchynessly distributed with depth, an absolute value of daily photosynthesis by the entire phytoplankton population may be obtained from the expression of Ryther and Yentsch, 1957 as

$$P = \frac{R}{K} \times p\ (sat) \qquad (1)$$

where

P = photosynthesis of the phytoplankton population in mg carbon/m^2/day,

R = relative photosynthesis from Figure 1 (broken line) from the appropriate value of surface radiation,

K = extinction coefficient, per meter, as measured,

p (sat) = photosynthesis of a sample of the population at 18,000 lux, as measured in mg carbon/m^3/hour.

Results and Discussion

A graph was constructed, reproduced here as the broken line in Fig. 1, showing the daily relative photosynthesis (R) beneath a unit of sea surface and at the depths where the surface light intensity is reduced by specified amounts. The value for photosynthesis when divided by the extinction coefficient of the visible in the water column in meter (K), gives photosynthesis per cubic meter per hour at light saturation. The solid lines show daily photosynthesis per cubic meter (the left-hand ordinate in Fig. 1) which are related to photosynthesis per cubic meter per hour at light saturation at the sea surface (I_o) and at the depth where the surface light intensity is reduced to 50%, 30%, and 10% respectively. Daily photosynthesis beneath a square meter of sea surface could be calculated by graphic integration of the values so obtained for each depth by means of the "light and dark bottle" technique.

The chlorophyll *a* maximum observed at the depth where the surface light is reduced to 32%, is most likely a result of phytoplankton growth there (1971) a large part of the chlorophyll *a* increase may be result from adaptation to low light, but it's maximum at 3.2% level in 1972 (Fig. 4 and 5). Maximum chlorophyll concentration were generally two times those in surface waters. Processes that explain chlorophyll maxima in other area has involved consideration of cell sinking from above and subsequent concentration at depth (Anderson, 1969, Riley, Stommel and Bumpus 1949).

Photosynthesis exhibited a peak in the maximum layer (32% light level) see Fig. 4 at same depth as that chlorophyll *a*. From the data presented in Fig. 4, the contribution of oxygen by photosynthesis at chlorophyll *a* maximum is approximately 4.50 ml. $liter^{-1}$ in 1971. The peak for photosynthesis in 1972 is maximum at 32% light level and the chlorophyll maximum observed at depth of 3.2% level is most likely a result of phytoplankton growth there (Fig. 5)

The relationship between photosynthesis and chlorophyll at light saturation

Photosynthesis measurements were made under 180 watts of fluorescent illumination in an incubator cooled by running sea water. Photosynthesis was determined from the difference in dissolved oxygen concentration (Winkler method).

The five cruises, during February 1971 to September 1972, covered large area in the Gutf of Thailand extending from the east to the West coast is more than 180 nautical miles. Chlorophyll was determined by filtering 1-9 litres of sea water through a millipore filter and extract the pigments with 90% acetone. Light absorption of the acetone extract was measured in a Beckman Model DU-2 spectrophotometer the chlorophyll a, chlorophyll b aud chlorophyll c were calculated by using the equation given by Richard and Thomson (1952).

Measurements were made in February, July, and September, 1971. The mean ratio (photosynthesis: chlorophyll) and standard deviation of approximately three cruises, 175 measurements at the sea surface (I_o) and at the depths where the surface light intensity is reduced to 10%, 3.2% and 1% respectively, as shown in Table 1. Although relative values tended to be lowest in February, (1.5387). being higher in September (4.1303) and highest in July (5.4295), which is rainy season, and temperature has no effect on the production. In the Table 1, the ratios complied are in such close agreement that the mean from all sources has been taken as a working value, which is approximatety 3.7 mg carbon/hour/mg chlorophyll.

The correlation regression for chlorophyll a to gross photosynthesis is 0.88, the chlorophyll a seems good correlated to the gross photosynthesis in 1971 (Fig. 2), the reason that explain chlorophyll and photosynthesis maxima at the same area in 1971 and the value of correlation regression of them is 0.88 have been considered that it seems correlated to phytoplankton photosynthesis but it seems not quite corralated to the photosynthesis in 1972 because the maxima areas of them are different (Fig. 3 and 5).

The estimation of production from chlorophyll and light data

It may be estimated the production of phytoplankton population, chlorophyll contents and extinction coefficient by assuming that 3.7 milligram carbon are assimilated per hour at light saturated for each milligram of phytoplankton chlorophyll, Equation (1) may be written

$$P = \frac{R}{K} \times C \times 3.7 \qquad (2)$$

where

C = mg chlorophyll/m^3 in a sample of a patchynessly distributed population

Some production values are obtained from *in situ* "light and dark bottle" oxygen experiments (Yentsch, Ryther & Yentsch, 1957) are given in Table 2 Also included in Table 2 are data of chlorophyll, and extinction coefficient, measured of estimated as indicated in the Table.

The vertical distributions of chlorophyll a, photosynthesis, dissolved oxygen and temperature at light saturation at the sea surface and at the depths where the surface light intensity is reduced to 32%, 10%, 3.2% and 1% respectively which shown in Figure 4 and 5. The correlation between gross photosynthesis and chlorophyll a were showed in Figure 2 (1971) and shown in Figure 3 (1972).

Furthermore, the mean relative productivity at right saturation which were calculated from the Equation (1) is also 3.7. The calculated productivity values were reported in Table 2, besides those were obtained from the *in situ* measurements. The highest productivity is in July 1971 ; 100.57 mgC.m^{-3}. day and also in July 1972 ; 100.35 mgC.m^{-3}. day. being lower in September ; 73.52 mgC.m^{-3}. day (1971) and 71.74 mgC. m^{-3}. day (1972), and the lowest is in February 1971 : 53.15 mgC. m^{-3}. day and in Dec.–Jan. 1972 ; 55.01 mgC.m^{-3}. day. The sea surface productivity or at the light saturation productivity is highest in July also oth in 1971 and 1972; 107.62 mgC.m^{-3}. day and 97.49 mgC.m^{-3}. day respectively, being lower in September ; 75.48 mgC.m^{-3}. day (1971) and 71.51 mgC.m^{-3}. day (1972), and the lowest in February 1971 ; 61.50 mgC.m^{-3}. day and in Dec.–Jan. 1972 ; 60.47 mgC. m^{-3}.. day.

The contour line of gross photosynthesis beneath a cubic meter per hour for each cruise (1971) were shown in Fig. 6, 7, 8, and the average gross photosynthesis in 1971 shown in Fig. 9.A daily photosynthesis under a water column (1971, 72) were shown in Fig. 15 and 16 respectively.

Summary

Water temperature, water transparency, rate of photosynthesis and chlorophyll pigment analysis of the water in the Gulf of Thailand were measured for period of February, July, September, 1971 and January, April, July, September in 1972. Twenty two stations were established in the collection of water samples for this study. The water temperature in the Gulf of Thailand ranged from 26.01°C to 31.01°C in 1971 and ranged from 24.93°C to 30.20°C in 1972. The extinction coefficient ranged from 0.052 to 0.575 per meter in 1971 and ranged from 0.051 to 0.652 per meter in 1972.

The average rates of photosynthesis were most productive in July; 0.100 $gC.m^{-3}$. day (1971) and 0.100 $gC.m^{-3}$. day (1972) being lower in September; 0.074 $gC.m^{-3}$. day (1971) and 0.072 $gC.m^{-3}$. day (1972), and lowest in February; 0.053 $gC.m^{-3}$. day (1971) and in January; 0.055 $gC.m^{-3}$. day (1972) (Table 2). The highest photosynthesis was at 32% of surface light intensity level and lowest at 1% light level (Fig. 4, 5) both in 1971 and 1972.

In 1971, the most productive area was on the inner Gulf, 23.75 $mgC.m^{-3}$. hr, and in 1972, the most productive area was on the West coast, 18.93 $mgC.m^{-3}$. hr. Other area that being lower productive was on the inner part of the Gulf (Fig. 9 and 14). This dues to the nutrient from water runoff from river.

The average chlorophyll a concentration were highest at 32% light level; 0.75 mg Chl.a.m^{-3} (1971) and at 3.2 % light level; 0.80 mg Chl. a. m^{-3} (1972), and the lowest at sea surface (100% light level), 0.44 mg Chl.a.m^{-3} (1971) and 0.51 mg Chl.a.m^{-3} (1972), but the other peak of chlorophyll a concentration at 1% light level was an accumulation of plants being sunk.

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Table 1

The ratio of photosynthesis at light saturation to chlorophyll (mg carbon/hour/mg chlorophyll) in phytoplankton population

Cruise	Light intensity %	No. Measurement	Temp. (°C)	Extinction coefficient per meter (K)	R Mean	R Std. dev.
1	100	22	27.38	0.126	1.5387	1.1236
	10	22	27.23			
	3.2	12	26.98			
	1	1	27.31			
2	100	22	28.26	0.184	5.4295	2.8125
	10	22	28.11			
	3.2	9	27.81			
	1	9	28.05			
3	100	22	29.21	0.142	4.1303	1.6485
	10	21	29.10			
	3.2	11	28.83			
	1	2	28.65			
Mean					3.7	1.86

Table 2

Comparison of experimented productivity measurements chlorohyll contents, and extinction coefficient, 1971–72

Cruise	Extinction coefficient per meter (K)	Chlorophyll ($mg.m^{-3}$)	Calculated Production ($mg\ C.m^{-3}.\ day$)	Production at light saturation ($mg\ C.m^{-3}.\ day$)
1 (1–19 Feb, 1971)	0.126	1.0444	53.1461	61.4954
2 (7–27 Jul, 1971)	0.184	0.7887	100.5718	107.6203
3 11–29 Sept, 1971)	0.142	0.6595	73.5246	75.4852
4 (Dec.–Jan. 1972)	0.132	0.4623	55.0125	60.4723
5 (Mar.–Apr.1972)	0.139	0.5569	62.1507	68.1023
6 (Jun.–July 1972)	0.215	0.9117	100.3477	97.4880
7 (September 1972)	0.126	0.6440	71.7430	71.5065

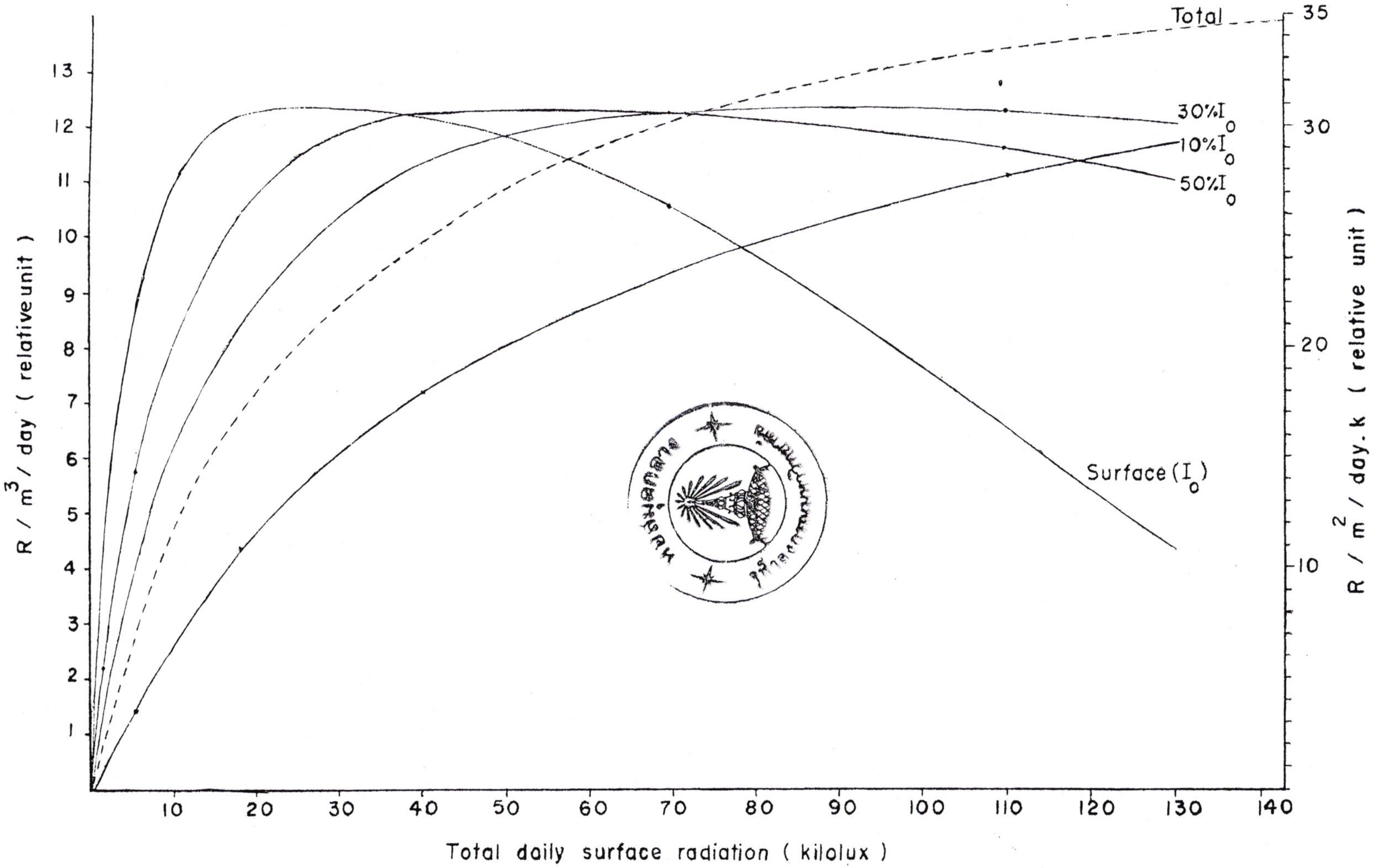

Fig. 1 The relationship between daily relative photosynthesis (R) and total daily surface radiation below a unit of sea surface (broken line) and at the depths where the surface light intensity is reduced by specified amounts (solid line).

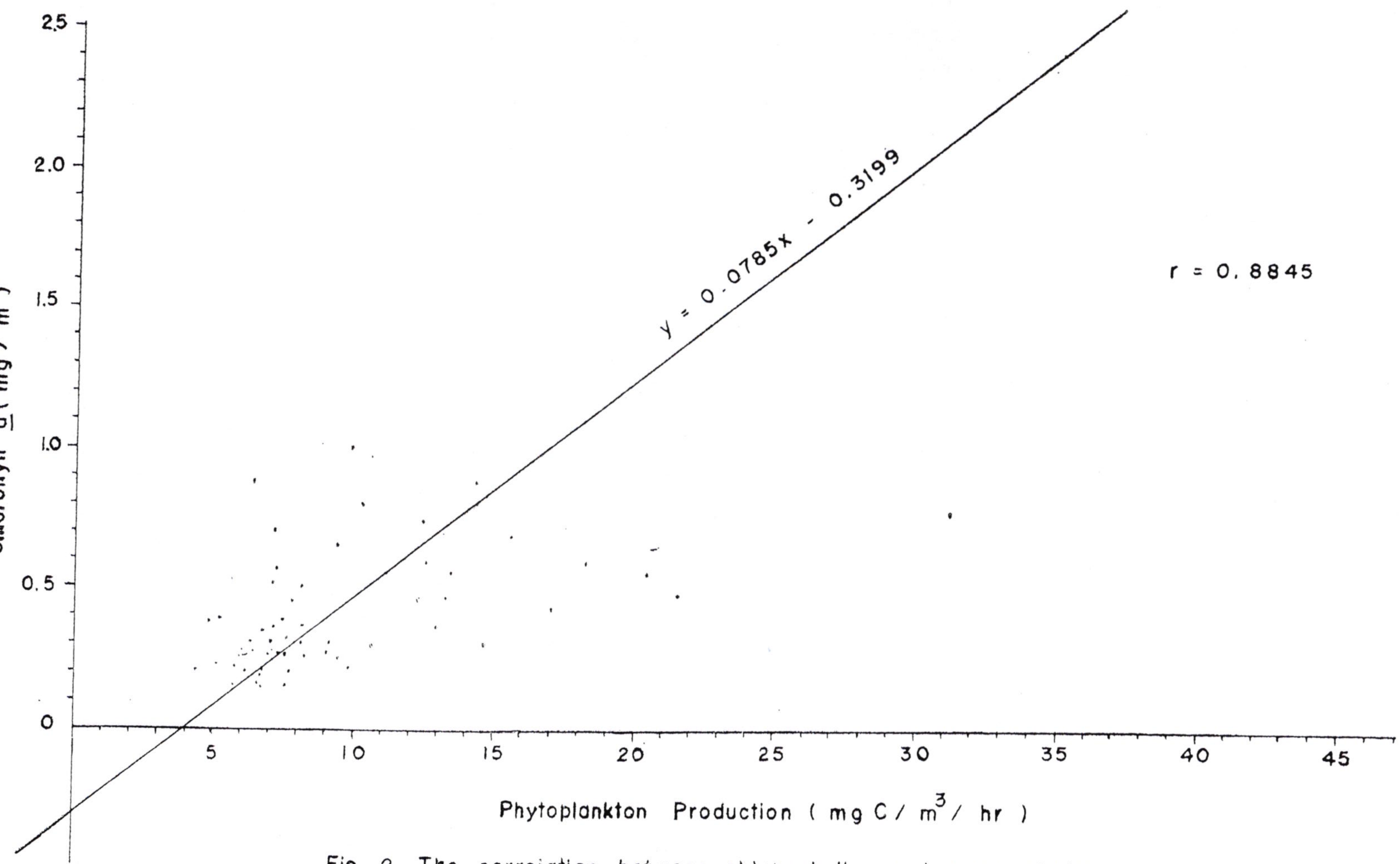

Fig. 2 The correlation between chlorophyll a and gross photosynthesis in the Gulf of Thailand, 1971

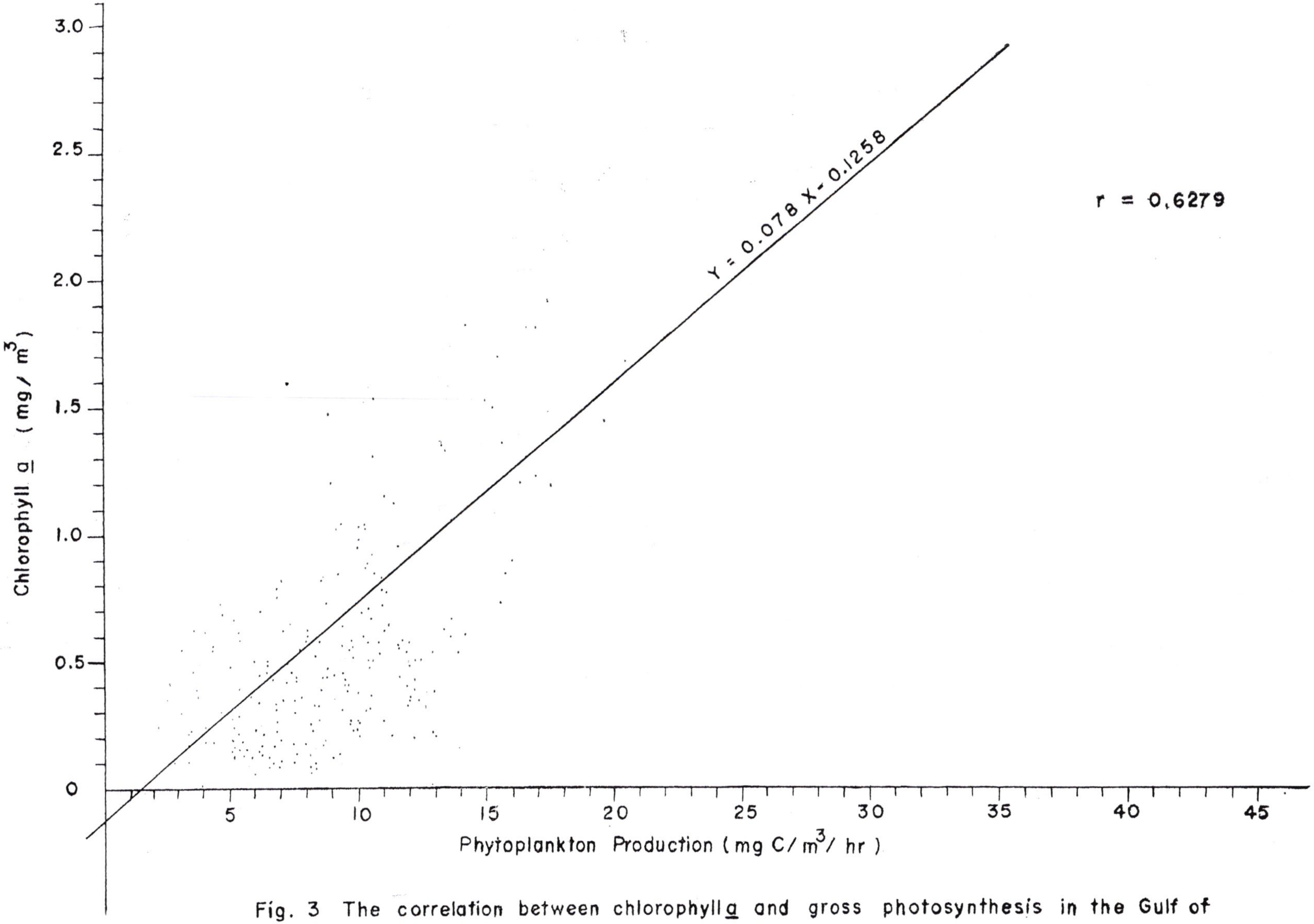

Fig. 3 The correlation between chlorophyll $\underline{a}$ and gross photosynthesis in the Gulf of Thailand, 1972

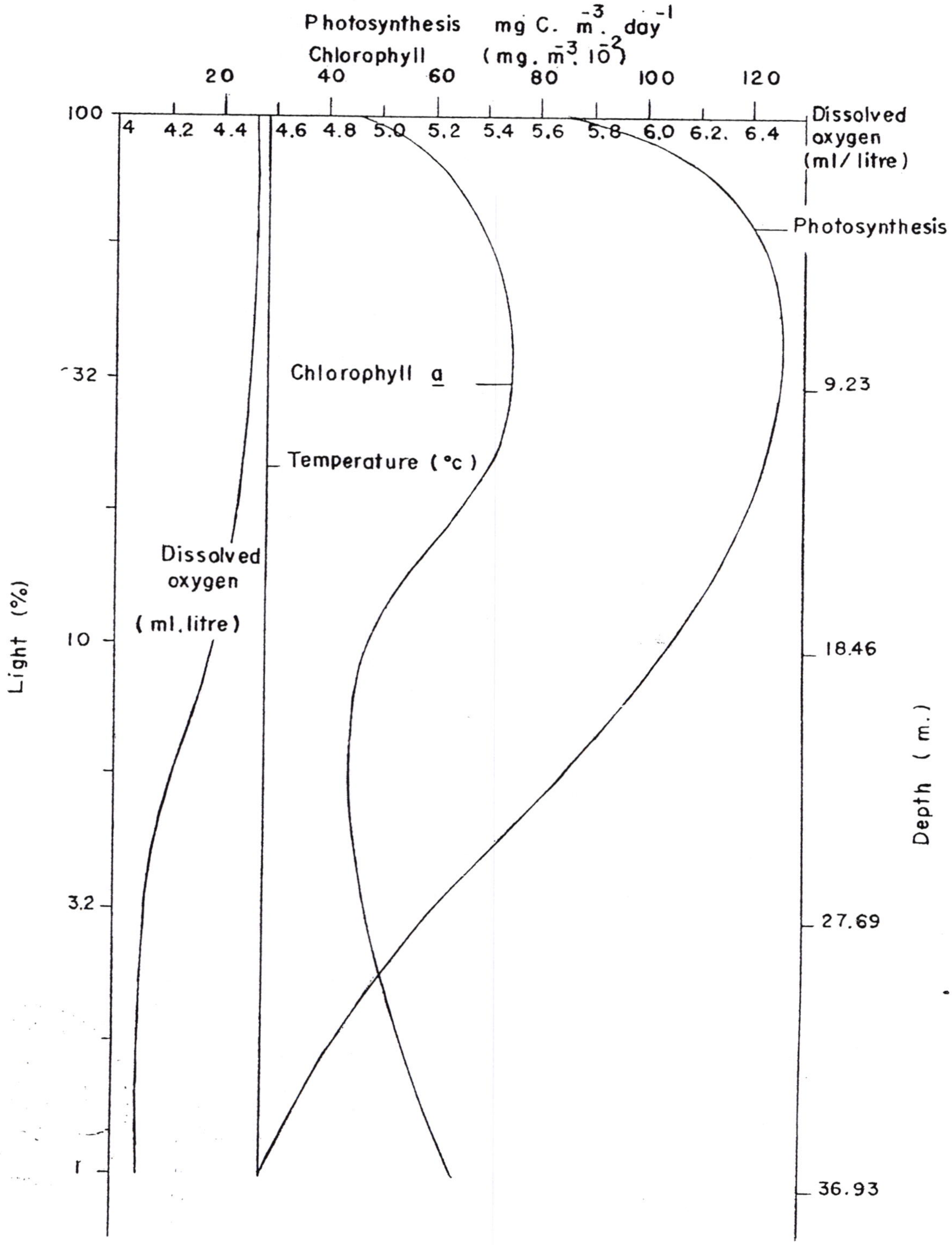

Fig. 4 Vertical distributions of chiorophylla,phatosynthesis, dissoived oxygen and temperature at the depths to which specified amounts of surface light penetrate, expressed as percentage of light at the sea surface. (1971)

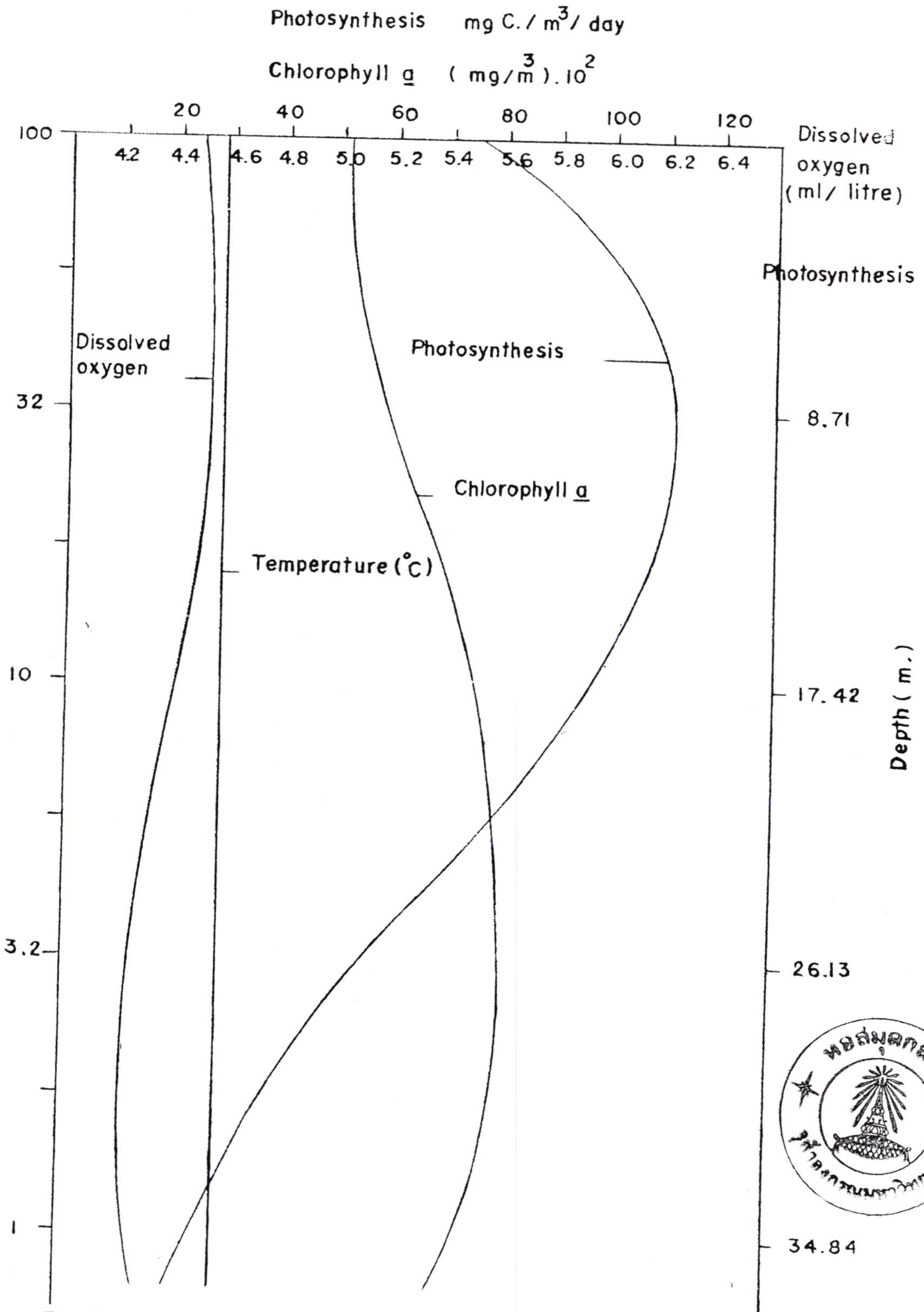

Fig. 5 Vertical distributions of chiorophyll a, photosynthesis, dissoived oxyen and temperature at the depths to which specified amounts of surface light penetrate, expressed as percentage of light at the sea surface. (1972)

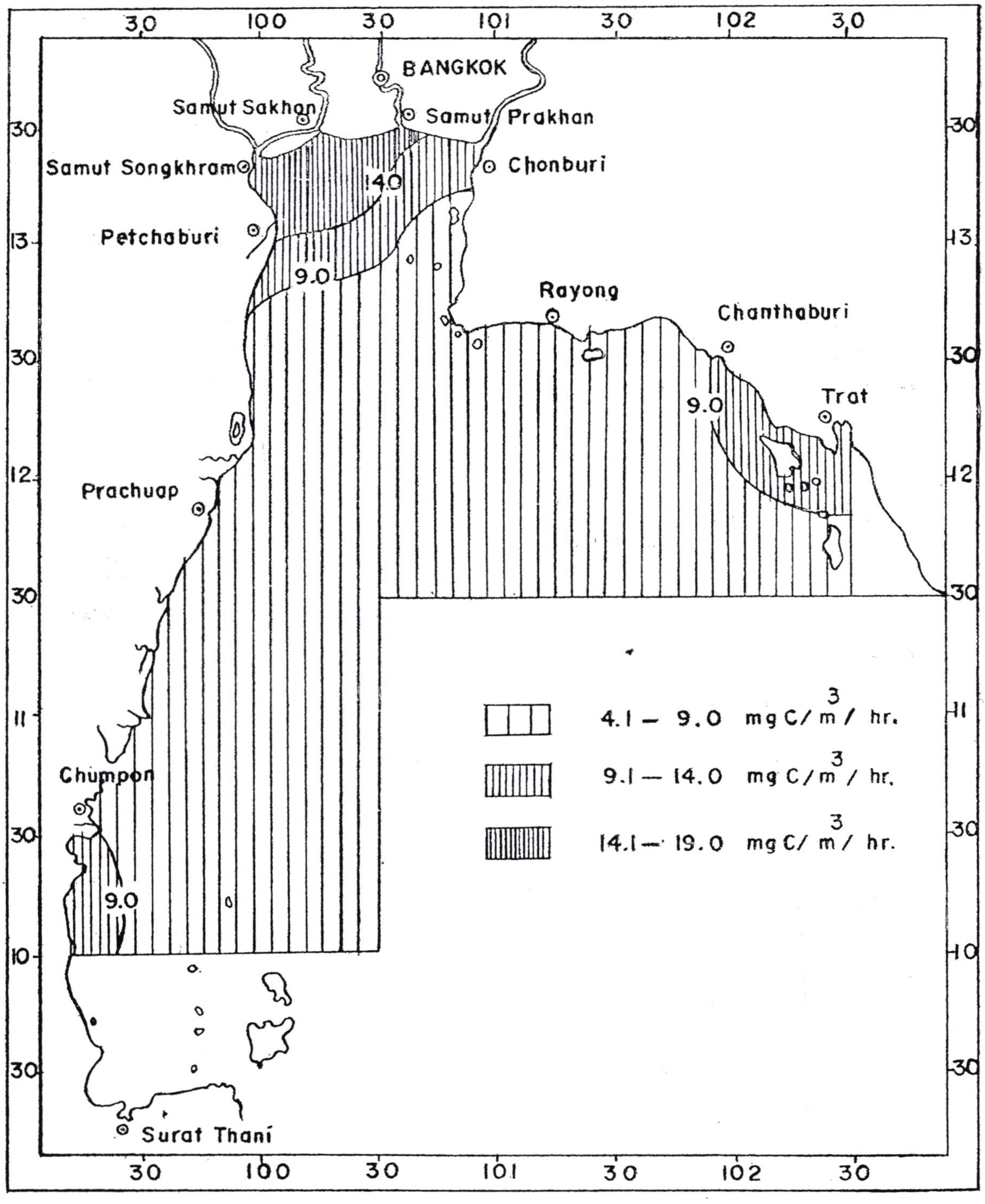

Fig. 6 Studied area showing distribution of gross photosynthesis in February, 1971 in the Gulf of Thailand.

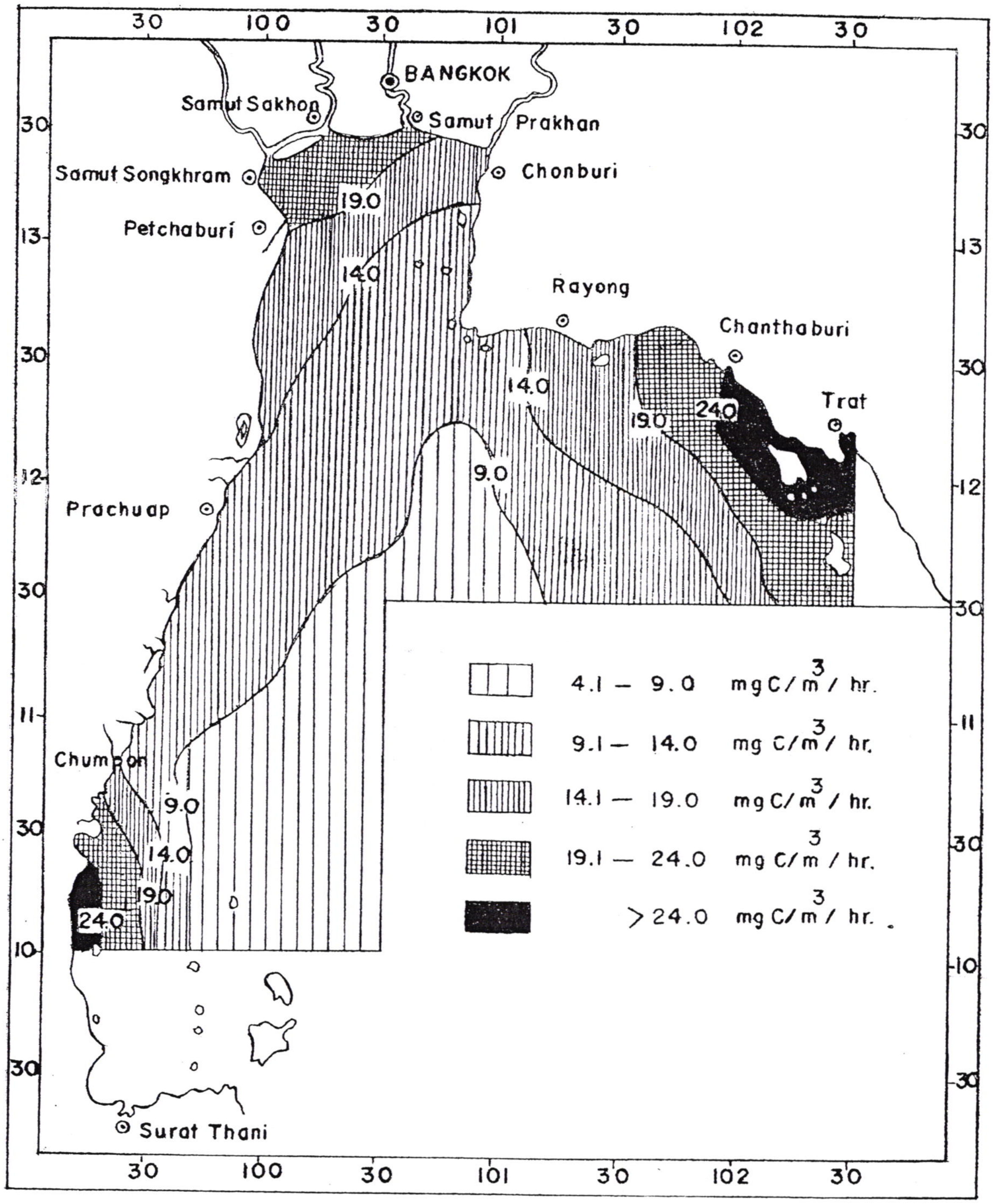

Fig. 7 Studied area showing the distribution of gross photosynthesis in July, 1971 in the Gulf of Thailand.

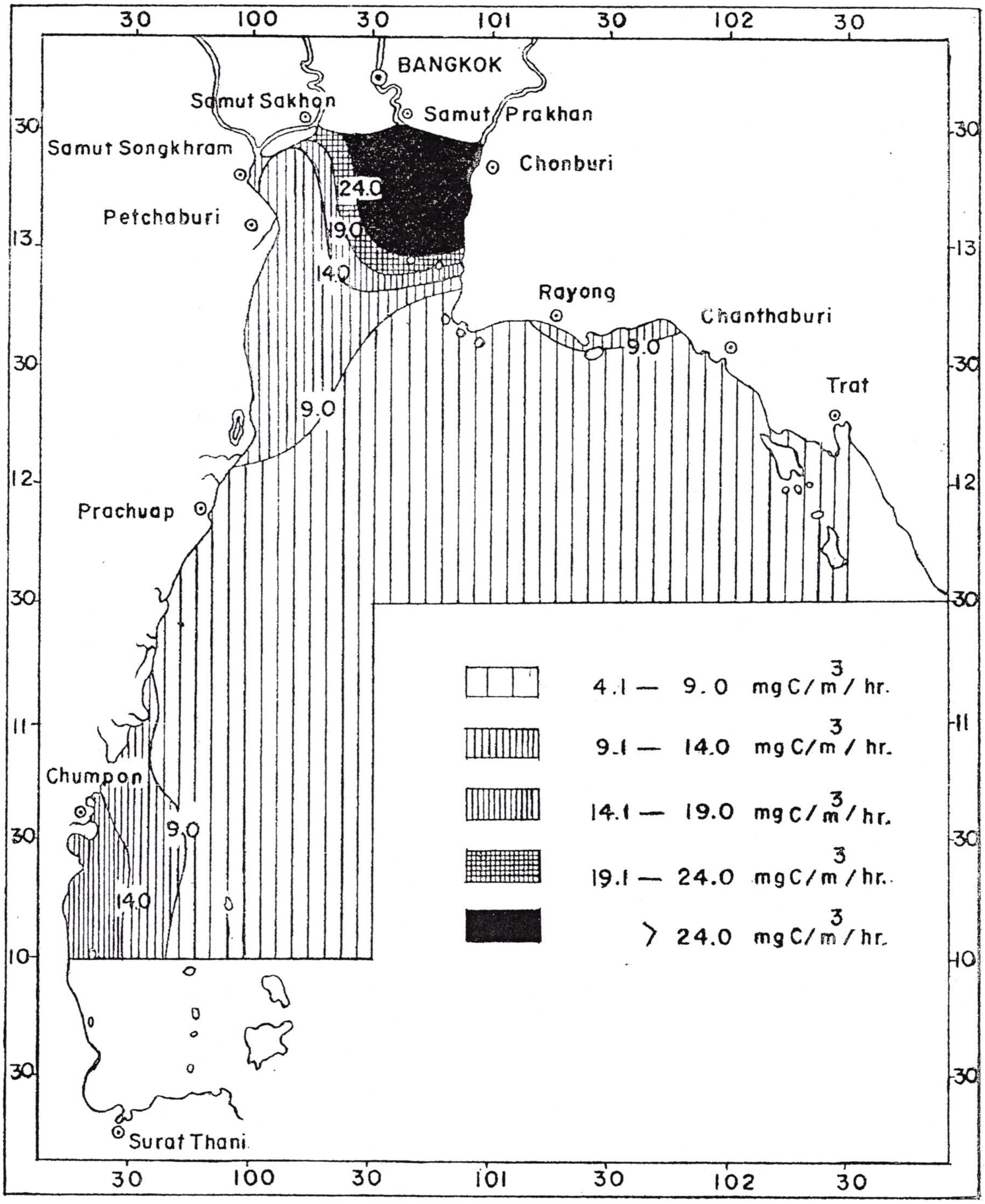

Fig. 8 Studied area showing the distribution of gross photosynthesis in September, 1971 in the Gulf of Thailand.

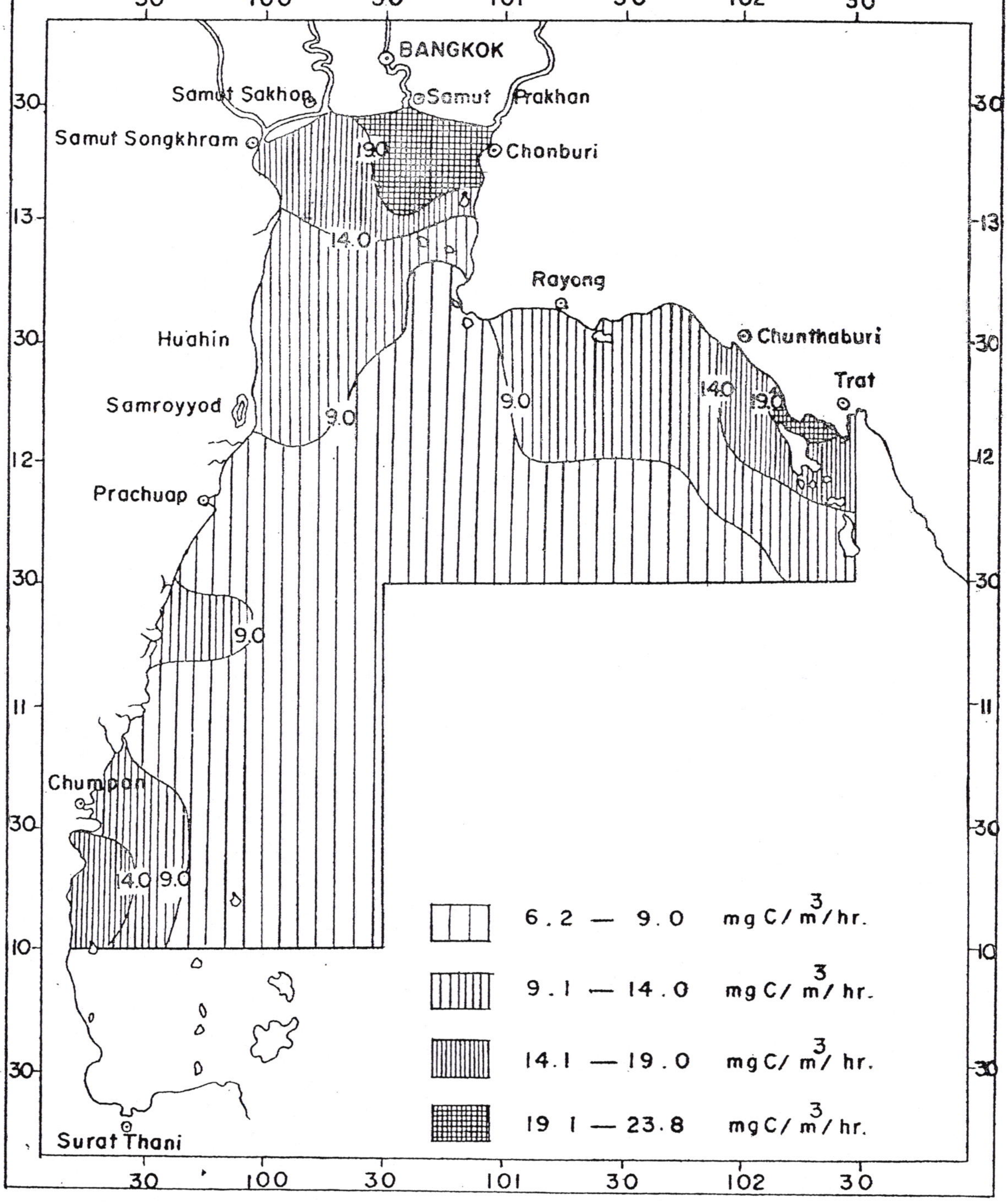

Fig 9 Studied area showing the distribution of average values (Feb, July, Sept,) of gross photosynthesis beneath a cubic meter per hour of sea surface under tank experiment (18,000 lux), in the Gulf of Thailand 1971.

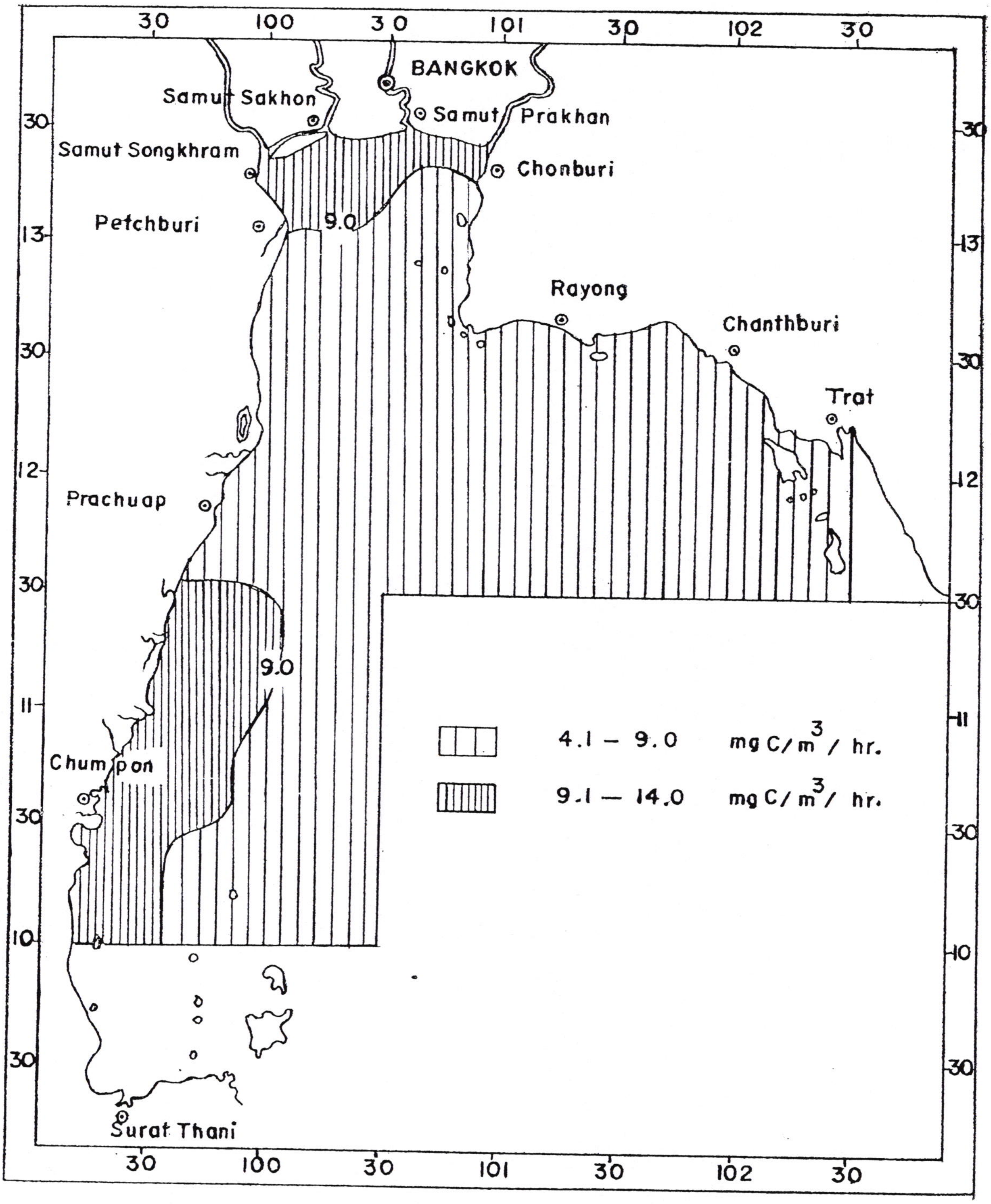

Fig. 10 Studied area showing the distribution of gross photosynthesis in January, 1972 in the Gulf of Thailand.

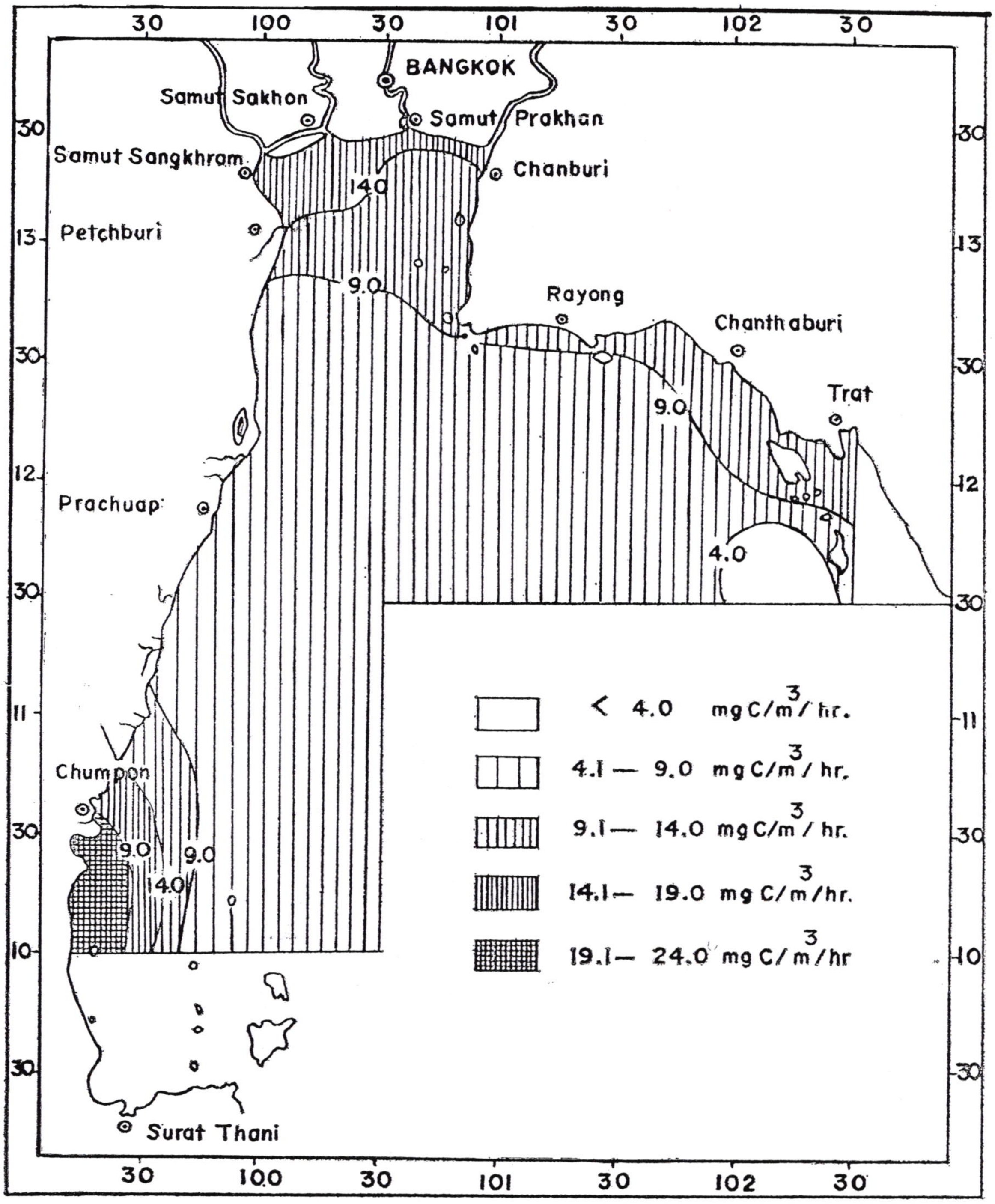

Fig. 11 Studied area shawing the distribution of gross photosynthesis in April, 1972 in the Gulf of Thailand.

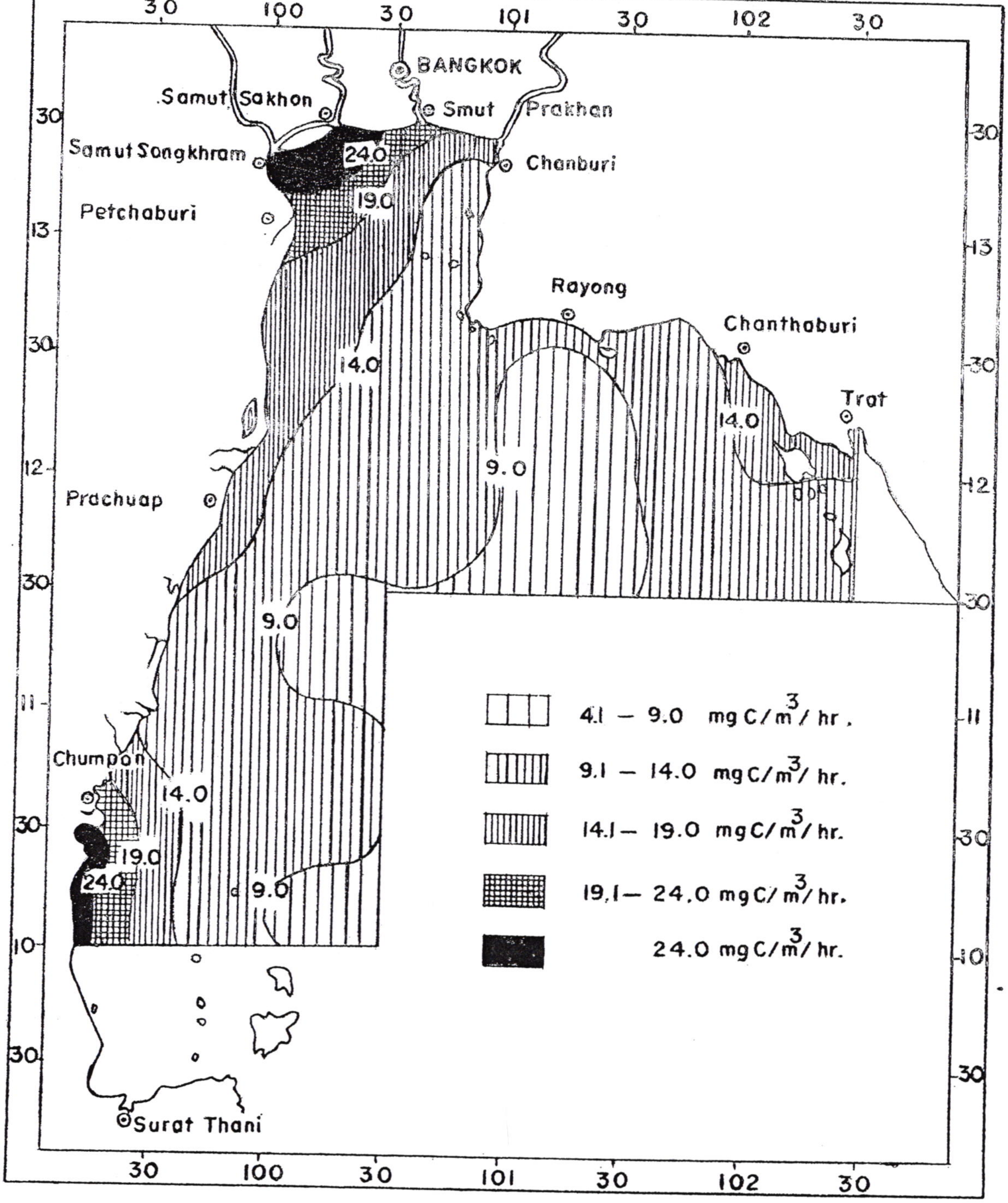

Fig. 12 Studied area showing the distribution of gross photosynthesis in July, 1972 in the Gulf of Thailand.

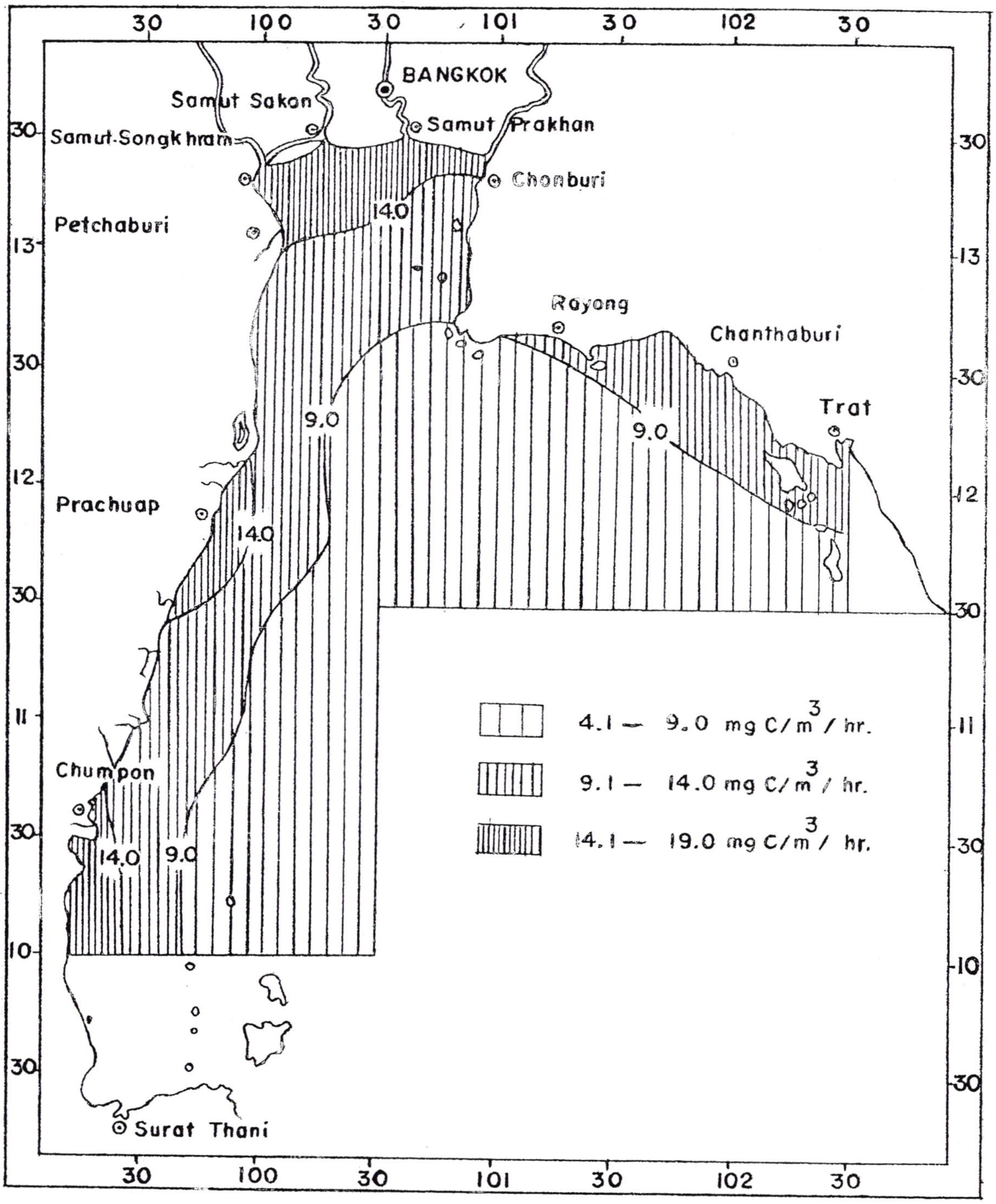

Fig. 13 Studied area showing the distribution of gross photosynthesis in September, 1972 in the Gulf of Thailand.

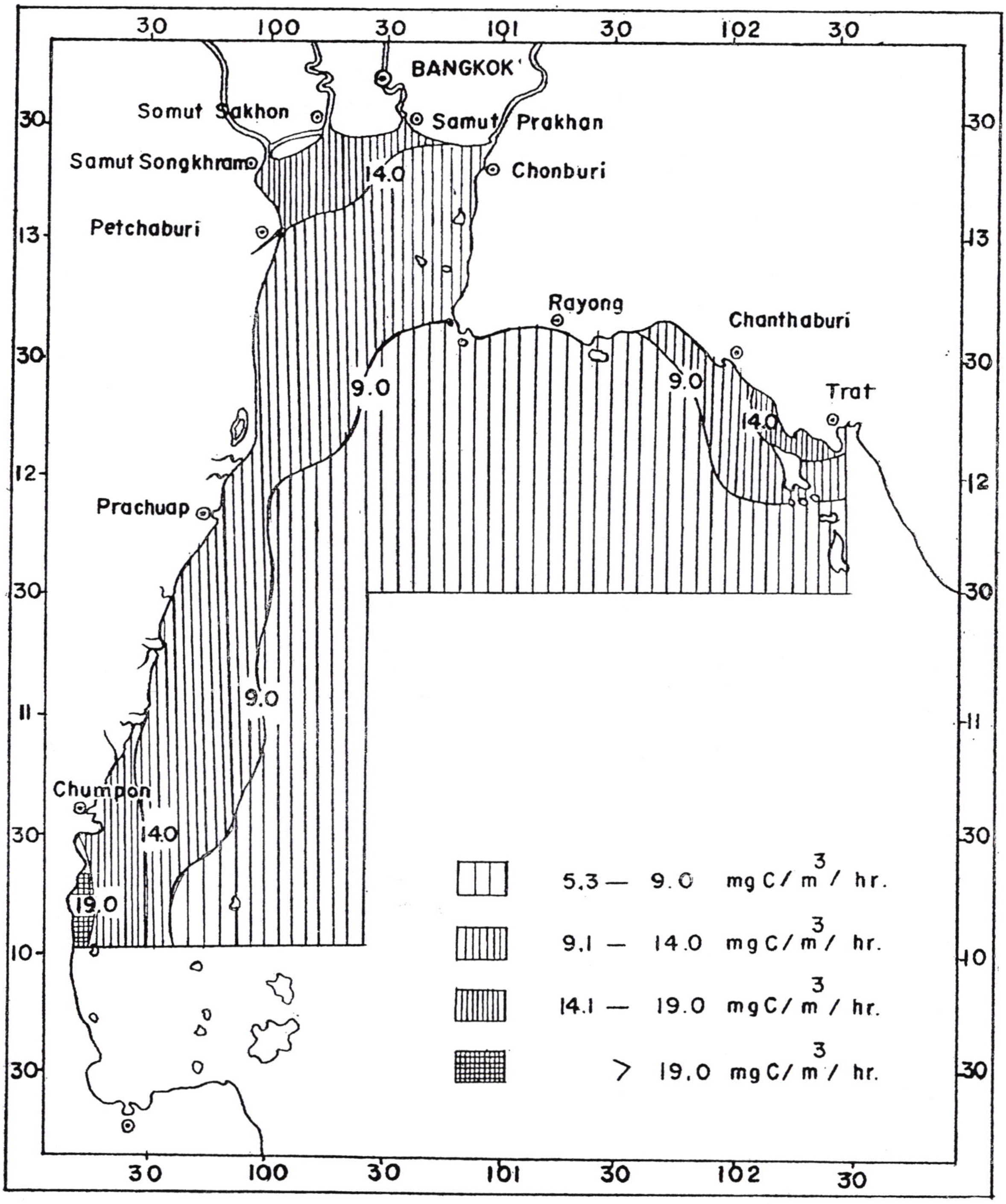

Fig. 14 Studied area showing the distribution of the average values (Jan, Apr, July, Sept) of gross photosynthesis beneath a cubic meter per hour of sea surface, under tank experiment, in the Gulf of Thailand, 1972

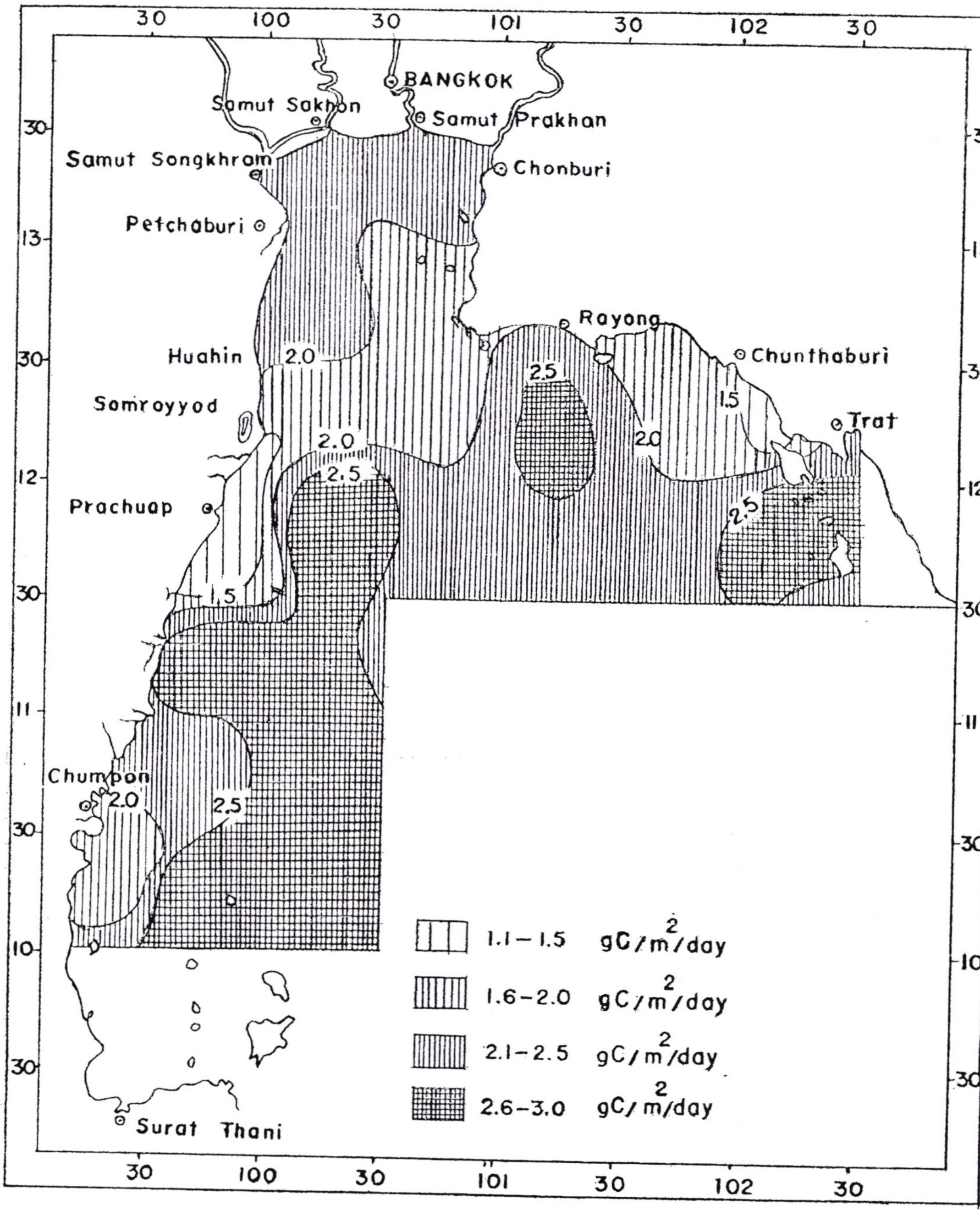

Fig. 15 Map of study area showing distributions of daily photosynthesis under a water column of the sea in the Gulf of Thailand, 1971.

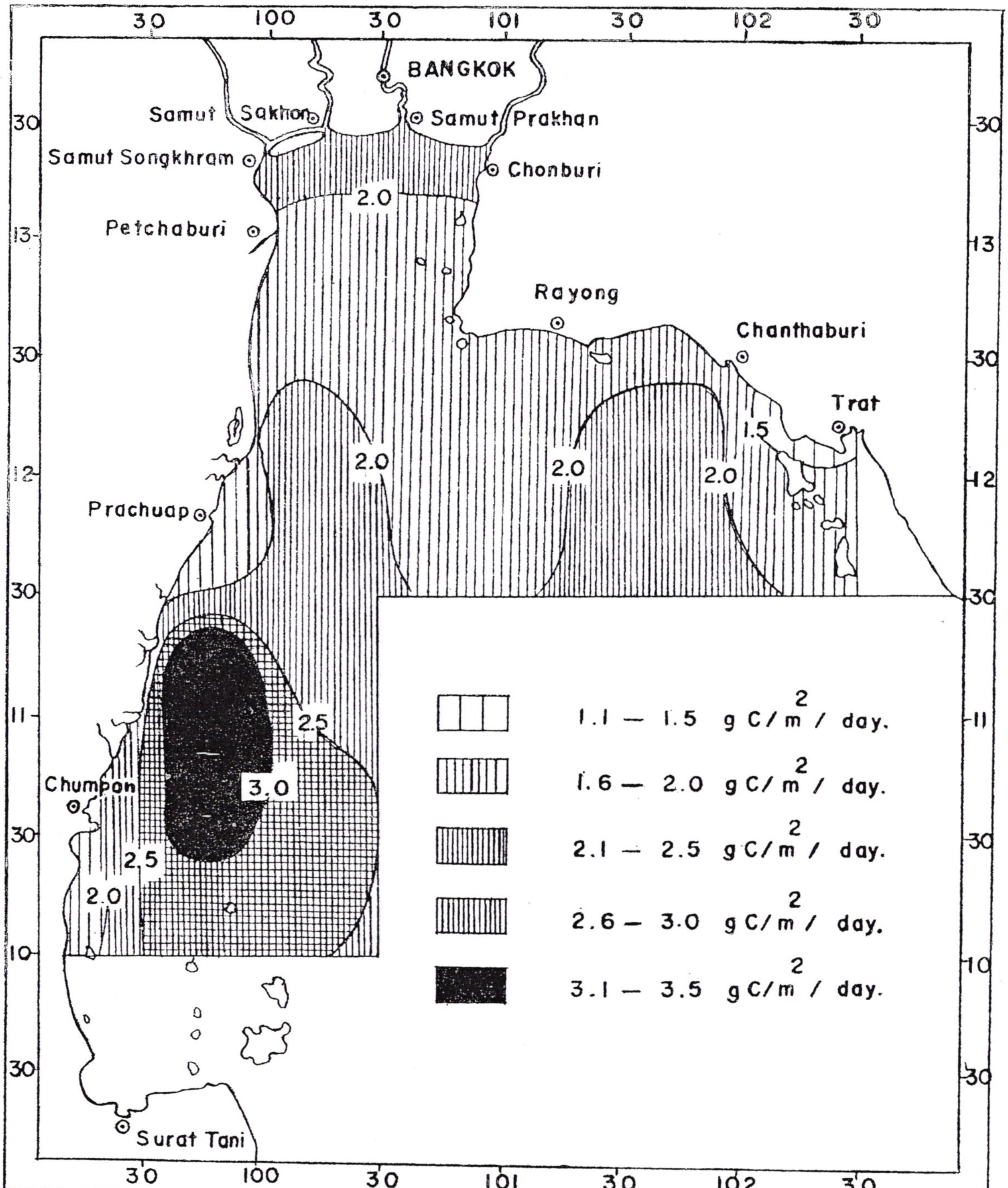

Fig. 16 Map of study area showing of daily photosynthesis under a water column of the sea in the Gulf of Thailand, 1972.

SESSION III

Fisheries

3.1 A preliminary report on a bottom trawl survey of the north shelf region of the South China Sea, March, 1972 to March, 1973.

by

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Abstract

Mean data from 5 cruises conducted on four approximately equally spaced transects, extending from 37–275 m between longitudes 111° & 117°E, show that the over-all gross catch rate was very low at 78 Kg/hr. In general, catch rates increased with increasing depth although this relationship was upset at those stations where shoals of <u>*Monacanthus spp.*</u> *were encountered. The edible component of the gross catch averaged 40 Kg/hr over the whole depth range and 48.6 Kg/hr over the range to 180m exploited commercially. In view of the large gross catches made at depths greater than this, it is suggested that trawling fleets should expand their area of exploitation to include these deeper waters since landings of Research Vessel catches made in Hong Kong have indicated that there is a seasonal demand for hither-to unfamiliar species, many of which have been found to be directly suitable for human consumption. It is estimated that the total potential commercial mean catch rate would be of the order of 70 Kg/hr. The unfamiliar deep water species landed by the Research Vessel are at present utilised only for bait and/or feed for aquaculture concerns, but an assured constant supply of such species might stimulate either the domestic consumption of a wider variety of fish than at present, or the establishment*

of fish meal plant, since Hong Kong imports the latter product as an additive to animal feed.

Introduction

Although the Research Vessel 'Cape St. Mary' has been used to conduct several oceanographic and fishing surveys of the South China Sea since her acquisition by the Government of Hong Kong in 1960, very few reports detailing the results of the fishing surveys have been published. Lester (1967), Menasveta (1970) and Shindo (1972) have made some reference to catch data collected during cruises carried out between 1961 and 1964; Lester (1968) and Lee (in press) have utilized collected material to describe the diet of different commercial fish species. This is in contrast to the well documented oceanographic work carried out on board (see Chan, 1970; Williamson, 1970; Watts, 1971 a and b; 1972 a and b and in press) and has arisen in part through the difficulties associated with the processing of the large volumes of data collected.

Commercially, landings of fresh marine fish sold through the Hong Kong Fish Marketing Organization (FMO) have undergone their greatest rate of increase since 1966, when they totalled 46,361 metric tons, to reach a maximum in 1970 of 71,399 metric tons. Since 1970 landings have fallen slightly; by 1.8% in 1971 to 70,100 metric tons and again by 0.5% in 1972 to 69,736 metric tons (data from cyclostyled FMO annual statistical summaries). Both the rise and fall occurred at a time when the overall size of the commercial fleet was decreasing, as the following data relating to the total numbers of trawlers, long liners, gill netters and purse seiners indicate: the estimated number in September, 1965 was 7,844; the numbers ascertained by direct count in February 1967,1969 and 1973 were 6,523, 5,893 and 5,011 respectively. Modern hulled vessels however, were introduced to Hong Kong in 1965 (Stather, 1971) and now total 169, gradually replacing sailing craft of native design. In the absence of catch and effort data it is not possible therefore to relate the changes in catch to the decline in the fleet size, since it is unlikely that the fishing ability of the vessels comprising the fleet has remained unchanged. The fleet is capable of exploiting grounds extending from the Gulf of Tong King in the west to Swatow in the east. Recent work by Lee (pers. comm.) indicates that the major trawling effort is now concentrated between longitudes 111°E (off Hainan Island) and 117°E, slightly to the east of Swatow, out to a depth of approximately 164 m (90 fm). Over the period 1968–1972, trawler landings accounted for 59–68% by weight of the fresh marine fish sold through FMO.

Against this background a series of bottom trawling surveys of the north shelf of the South China Sea was initiated in March 1972, following a preliminary exploratory and shake-down cruise in late 1971, to assess the present state of the trawlable demersal resource and to explore the unexploited deeper area at the edge of the shelf. This report presents the preliminary results of these survey cruises with particular reference to the data derived from deep water tows conducted between depths of approximately 180 and 275 m.

Gear and Method

The Research Vessel "Cape St. Mary" has been previously described by Mitchell and McConnell (1959) and although slightly modified since, her salient features remain the same, namely : LOA of 35.7 m (117 ft); gross tonnage of 238; powered by a National diesel delivering 385 h.p. at 170 r.p.m. Basically, she is a North Sea side-trawler with a hydraulically operated winch holding 900 m (500 fm) of 6.35 cm (2.5 ins) steel warp on each barrel.

A modified Granton trawl net with a head rope length of 29.3 m (96 ft), ground rope length of 46.1 m (151 ft) and stretched cod end mesh size of 51 mm (2 ins) was used throughout the survey period with large doors and sweep wires of

64 m (35 fm) length. This is the standard gear used since 1963 and was retained to enable direct comparisons to be made between the catch data of the present and past surveys.

Based on the results of the preliminary cruise in October/November, 1971, five survey cruises were planned over a 12-month period. Each survey was conducted on a grid of preselected stations arranged along four transects, referred to as A, B,C and D lines, theoretically spaced at intervals of 1,609 km (100 mls), running at approximately right angles to the general slope of the shelf i.e. very approximately in a north-westerly, southeasterly direction (Fig. 1). All cruises were carried out in two parts with a return to Hong Kong for re--victualling, re-icing and sale of fish at the conclusion of fishing on either A and B, or C and D transects. An occasions, bad weather and sea conditions also forced the vessel to seek shelter in Hong Kong. Seven stations were fished on each transect between the following depth ranges: 37–55 m (20 – 30 fm), 55–75 m (30– 40 fm), 75 – 91 m (40–50 fm), 91 – 110 m (50–60 fm); and as close as possible to the following depths 137 m (75 fm), 183 m (100 fm) and 275 m (150 fm). Each station is denoted by the alphabetic prefix referring to the transect, and a numeric suffix from 1–7 referring to the above depths respectively. Thus, the stations extend from A1 centred on 20°41'N, 111°28'E, the shallowest station in the west, to D7 centred on 21°36.5'N, 116°55'E, the deepest station in the east (Fig. 1).

Areas shallower than 37 m could not be fished due to political considerations and the "Cape St. Mary" did not approach closer than 37 km (20 n. ml) to the coast except in Hong Kong territorial waters where an additional station, CO, was fished at approximately 25 m (14 fm).

It was planned to carry out three one hour tows at a trawling speed of 3 knots at each station on each cruise, commencing shortly after sunrise to complete

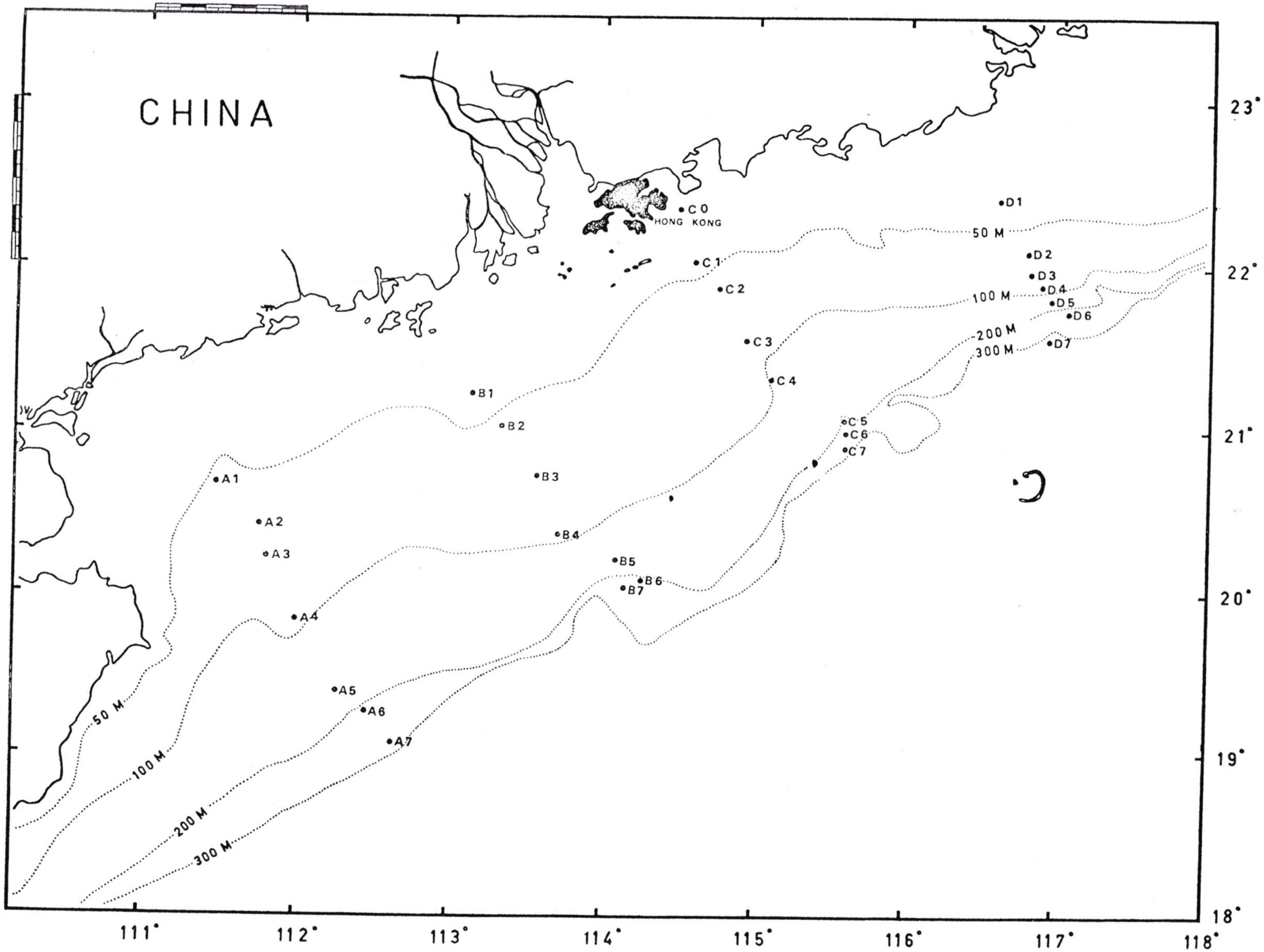

Fig. 1 The mean position of bottom trawl stations on the north shelf of the South China Sea occupied from March 1972 to March 1973

one station well before noon and to use the less productive mid-day period to steam to the next station, which was usually completed before sunset. In general, this plan was adhered to but on occasions torn nets or crossed warps and heavy seas delayed proceedings and it was not always possible to complete the three tows at each station. Tows which were completed with an undamaged net or with only minor tears in the wings or belly are referred to as successful in Table 1 and it is only the data from these which are considered in any detail.

The catches from each tow were sorted and identified as far as possible (usually at least to genus) and the gross weight of each taxon obtained. Either all individuals or a weighed random subsample of the commercial and potentially commercial taxa were measured and subsamples of the measured fish sexed and their degree of maturity assessed.

Cruise data

A summary of the pertinent information relating to each cruise is set out in Table 1. As planned, five cruises were carried out heavy seas and strong winds restricted fishing during Cruise 7210 to the three shallowest stations on A, B, and C transects and to stations D1-5. Full information relating to the cruise is set out in Table 1 but in further tabulations the data from stations D4 and D5 for this cruise have been ignored and data from all five cruises utilized only for stations 1-3 on each transect i.e. to a depth of approximately 90 m. Beyond this depth, the data are derived from the four cruises 7203, 7205, 7207 and 7302 i.e. March/April, May/June, September and February/March respectively.

Gross Catch

Table 1 shows that a number of unsuccessful tows were made during each cruise, reducing the gross catch rates by between three and six percent from those of

Table 1

Summary of bottom trawl survey cruise data from the north shelf of the South China Sea over the twelve month period March, 1972 to March, 1973

	Cruise No. 7203	7205	7207	7210	7302	Total
Date of first tow	16/III/72	23/V/72	1/IX/72	22/XI/72	13/II/73	–
Date of last tow	21/IV/72	21/VI/72	28/IX/72	17/XII/72	9/III/73	–
Days at sea	22.5	22.5	20.0	16.0	19.0	100
Days fishing	14.5	14.5	15 5	7.5	14.5	66.5
Hours fishing	87.10	88.05	89.03	44.75	90.00	398.93
Total no. of tows	88	89	90	45	90	402
No. of successful tows	82	83	86*	43	87	381
Total gross catch (m tons)	5.39	7.51	7.45	2.38	5.33	28.06
Gross catch in successful tows (m tons)	5.35	7.45	7.42	2.36	5.31	27.89
Gross catch rate from total hrs. fishing (kg/hr)	61.9	85.3	83.7	53.2	59.2	68.7**
Gross catch rate in successful tows (kg/hr)	65.2	89.8	86.4	54.9	61.0	71.5**

* includes one tow of 53 mins. at D4

** mean values

the successful tows. Considering the latter, the gross catch rates made during each cruise are very low and underwent a regular fluctuation over the survey period to give a mean value of only 71.5 kg per hour. This value howeuer, is depressed by the poor catch rate shown for Cruise 7210, caused by the lack of data from the deeper stations. This is apparent from inspection of Table 2, the first section of which demonstrates that, in general, greater gross catches are made at the greater depths. This generalization however, is not apparently true for transect A where some of the greatest gross catches per tow (maximum 1.24 m tons) were made during Cruises 7205 & 7207 (May/June and September) at Stations A1, A3 and A4. *Monacanthus modestus* comprised the greatest part of such catches. Similarly at station D1 during Cruise 7210 (November/December) one tow produced 0.7 m tons of *Monacanthus sulcatus*. These catches are so relatively disproportionate to those made for other taxa that they heavily weight the mean gross catch rates upwards, obsuring the general relationship Nevertheless, the grand mean of 78.2 kg/hr shown in Table 2 gives a better indication of the overall mean gross catch rate obtained during the survey since it is derived from equally weighted temporal and spatial observations.

Edible Catch

Table 2 also shows the mean catch rates of edible fish at each station. The species and genera or families included in this category are presented in Table 3 which is based on the taxa used by the Fish Marketing Organization to report landings sold in Hong Kong, plus certain genera not named in the FMO statistics but included in the group 'mixed fish'. A very different distribution from that observed for the gross catch rates is apparent, with the maximum catches per hour occurring at A4, B5, C4 and D3, (although the values at A1 and D1 are the largest on their respective transects they have not been considered here due to the reasons given above), and the minima at the deep water stations 6 or 7 on each transect i.e. at depths greater than 180 m. These latter catch rates are in marked contrast to those of the gross rates and represent a low percentage of them, indicating a considerable change in the faunistic composition on the edge of the continental slope. Since there is no commercial fishing carried out at these depths the species are, in many cases, completely unknown to the Hong Kong fish market.

Returning however, to the stations at which the maximum mean edible catches were made, the catches per hour of the four major edible taxa taken at each of these stations during any cruise are shown in Table 4. The table demonstrates that at least at these stations the major part of the edible catch is composed, on average, of only a limited number of the taxa named in Table 3. It may be seen that there are considerable differences in their catch rates at each station from cruise to cruise i.e. seasonal differences, and in consequence the predominant taxon changes seasonally at any station. In the table, the mean values shown for each taxon are column means and there is a discrepancy of 0.2 kg between their sum and the mean of the 'total' column for station A4 due to the method of rounding off.

The grand mean of 40.4 kg per hour (Table 2) represents a biased estimate proportional to the mean standing crop of 'edible' fish present on the shelf between depths of approximately 40 and 275 m. The bias is due to the differences in area existing between the various depth ranges fished and is weighted towards the deeper, apparently less productive stations The commercial fleet however, fishes down to a maximum of 164 m i.e. to the series of number 5 stations, and the mean catch rate of edible fish to this depth is estimated as 48.6 kg/hr. It is noteworthy that the proportion of edible fish in the mean gross catch is very constant between the number 2 and 5 series of stations, fluctuating around a mean value of 78.3%.

Table 2

The mean catch rates (kg/hr) of gross and edible fish at each station over the period March, 1972 to March 1973

	Mean gross catch rate (kg/hr)					Mean edible catch rate (kg/hr)					Mean ebible catch as % of mean gross catch
Station	A	B	C	D	Mean	A	B	C	D	Mean	
0	–	–	22.1	–	–	–	–	19.3	–	–	
1	152.4	29.9	29.7	71.4	70.9	146.5	25.0	27.4	67.4	66.6	93.9
2	42.3	45.6	35.3	42.6	41.4	32.5	36.2	25.4	32.6	31.7	76.6
3	123.0	28.7	49.2	63.0	73.5	114.2	37.8	28.7	50.5	57.8	78.6
4	140.4	44.4	61.9	84.7	72.9	124.9	29.5	44.5	34.0	58.2	79.8
5	54.2	91.1	32.0	62.0	64.8	20.9	56.0	26.9	10.8	28.7	44.2
6	120.2	102.8	46.6	55.1	81.2	39.1	15.3	8.5	7.7	17.7	21.7
7	121.5	198.5	143.3	67.2	132.6	18.3	22.2	35.8	12.5	22.2	16.7
Mean	107.7	81.6	59.7*	63.7	78.2	70.9	31.5	28.2*	30.8	40.4	58.8

*data from CO not included

Table 3.

The orders, families genera and species included in the category 5 edible fish' in Table 2.

Order	Family	FMO categories: S = species, G = genus, F= family, O = order, M= mixed.	Edible genera or species caught during the survey cruises.
Clupeiformes	Clupeidae	Sardines (G)	*Sardinella* spp.
	Clupeidae	Other Fishes (M)	Other Clupeids
	Dussumieriidae	Round Herrings (F)	*Dussumieria* spp.
	Engraulidae	Anchovies (F)	Engraulids
	Chirocentridae	Other Fishes (M)	*Chirocentrus* spp.
Scopeliformes	Synodontidae	Lizardfishes (G)	*Saurida* spp.
	Synodontidae	Other Fishes (M)	*Trachinocephalus myops*
Siluriformes	Plotosidae	Other Fishes (M)	*Plotosus anguillaris*
Anguilliformes	Muraenosocidae	Conger-pike Eels (G)	*Muraenesox* spp.
Perciformes	Sphyraenidae	Other Fishes (M)	*Sphyraena* spp.
	Mugilidae	Other Fishes (M)	*Mungil* spp.
	Polynemidae	Other Fishes (M)	*Polynemus* spp.
	Syrranidae	Groupers (F)	*Epinephelus areolatus*
			Epinephelus awoara
			Epinephelus brunneus
			Epinephelus diacanthus
			Epinephelus latifasciatus
			Epinephelus sp.
			Trisotropis dermopterus
			Plectropomus leopardus
	Glaucosomidae	Other Fishes (M)	*Glaucosoma burgeri*
	Theraponidae	Other Fishes (M)	*Therapon* spp.

Order	Family	FMO categories: S = species G = genus, F = family, O = order, M= mixed.	Edible genera or species caught during the survey cruises.
	Priacanthidae	Big-eyes (G)	*Priacanthus macracanthus*
			Priacanthus tayenus
	Carangidae	Scads (G)	*Decapterus* spp.
		Crevalles (G)	*Caranx equula*
			Caranx spp. and *Atropus atropus*
		Other Fishes (M)	*Selar crumenophthalmus*
			Seriola nigrofasciata
	Lutjanidae	Red Snapper (S)	*Lutjanus sanguineus*
		Snappers (F)	*Lutjanus lineolatus*
			Lutjanus sebae
			Lutjanus vitta
			Pristipomoides typus
			Tangia carnolabrum
	Nemipteridae	Yellow Belly (S)	*Nemipterus bathybius*
		Meion Coat (S)	*Nemipterus japonicus*
		Golden Thread (S)	*Nemipterus virgatus*
	Pomadasyidae	Other Fishes (M)	*Plectorhynchus* spp.
			Parapristipoma trilineatum
			Pomadasys spp.
	Banjosidae	Other Fishes (M)	*Banjos banjos*
	Pentapodidae	Gingko (S)	*Gymnocranius griseus*
	Lethrinidae	Other Fishes (M)	*Lethrinus nebulosus*
	Sparidae	Breams (F)	*Taius tumifrons*
			Argyrops spinifer

Order	Family	FMO categories : S = species. G = genus, F = family, O = order, M= mixed.	Edible genera or species caught during the survey cruises.
			Evynnis cardinalis
			Chrysophrys major
	Leiognathidae	Other Fishes (M)	*Leiognathus* spp.
	Gerridae	Other Fishes (M)	*Gerres* spp.
	Sciaenidae	Croakers (F)	Sciaenids
	Mullidae	Red Goatfish (S)	*Upeneus moluccensis*
		Other Fishes (M)	*Upeneus bensasi*
			Parupeneus spp.
	Branchiostegidae	Horse-heads (G)	*Branchiostegus* spp.
	Acanthuridae	Other Fishes (M)	*Prionurus microlepidotus*
	Stromateidae	Melon Seed (S)	*Psenopsis anomala*
		Pomfrets (F)	*Stromateoides* spp.
			Formio niger
	Nomeidae	Fork-tail (S)	*Psenes indicus*
	Scomberomoridae	Mackerels (G)	*Scomberomorus* spp.
	Scombridae	Other Fishes (M)	*Pneumatophorus japonicus*
			Sarda orientalis
			Rastrelliger kanagurta
	Trichiuridae	Other Fishes (M)	*Trichiurus* spp.
Tetraodon-tiformes	Monacanthidae	Other Fishes (M)	*Monacanthus* spp.
Selachii	Heterodontidae	Sharks (O)	*Heterodontus zebra*
	Orectolobidae	Sharks (O)	*Stegostoma fasciatum*
	Triakidae	Sharks (O)	*Mustelus* spp.
	Carcharhynidae	Sharks (O)	*Carcharhynus* spp.

Deep Water Stations

Since many of the species taken from the deep water stations below 180 m were unknown on the Hong Kong fish market it is not strictly accurate to record as edible only those species common to both the shallow and deep water stations. Accordingly, the mean catches per hour from these stations are presented in Table 4 categorized as edible 'other commercial', 'potentially commercial' and trash. The 'edible' correspond with those shown in Table 3; the 'other commercial' refer to taxa which are occasionally found on the Fish Marketing Organization markets and which are usually included in the FMO category and mixed fish: they include certain edible species and those used as bait oa feed for aquaculture concerns; the 'potentially commercial' category refers to those species not found on the markets, certain of which could be utilized directly as a source of human protein: others might be utilized as feed or as bait, thereby indirectly adding to human protein intake. The sum of these categories at each station, which could be classed as the total potential commercial catch, gave an overall mean catch rate of 70 kg/hr, which by reference to Table 2 will be seen to exceed the mean edible (i.e. commercial) catch rates taken at any depth and is very close to the mean gross catch rates recorded.

Hong Kong imports fish and blood meal as additives to animal foodstuffs. During the calendar year 1972, imports of fish meal amounted to 2,727 m tons valued at HK$2.6 mill. (Hong Kong 1973). The demonstrated presence of what are, by Hong Kong standards, large populations of unexploited resources at the edge of the continental slope might possibly stimulate investment in fish meal plant if a constant supply of raw material was assured. At the deepest stations fished on A and B transects the mean catch per cruise never fell below 100 kg per hour and on C transect only did so during cruise 7203, reaching approximately 89 kg/hr.

Table 2 demonstrates that the mean survey catch at A, B and C7 considerably exceeded 100 kg as it did at A6 and B6. Such a supply is therefore, fairly well assured and if Hong Kong trawlers could be stimulated in the first instance to gear themselves for deep water fishing the results would be vnry worthwhile in the long term. In the short term, Research Vessel landings of certain of these deep water forms have demonstrated, after some initial hesitancy, that the market will accept strange species and that they will sell. Experience on board the vessel has also shown that many are acceptable cooked either in Cantonese or European style and the provision of what should be, in the first instance, cheaper types of fish on the markets might induce the local housewife to purchase specimens from a wider range of taxonomic families than she does at present.

Acknowledgements

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Table 4

The catches (kg/hr) of the dominant edible taxa taken during any cruise at stations selected on the basis that they provided the maximum edible catch on each transect.

Station	A4						B5						C4						D3					
Cruise No.	7203	7205	7207	7210	7302	Mean	7203	7205	7207	7210	7302	Mean	7203	7205	7207	7210	7302	Mean	7203	7205	7207	7210	7302	Mean
Sharks	—	—	2.2	NO FISHING	—	0.6	0.7	6.5	0.1	NO FISHING	—	1.8	—	—	—	NO FISHING	—		16.0	—	17.0	—	—	6.6
Saurida spp.	0.1	5.2	6.0		2.6	3.5	3.3	0.8	0.1		1.8	1.5	2.7	3.4	2.4		1.0	2.4	9.8	5.0	3.6	1.5	4.8	4.9
Trachinocephalus myops	—	—	—		—	—	—	—	—		—		—	—	—		—		—	1.5	5.4	8.5	14.0	5.9
Priacanthus macracanthus	0.1	0.5	1.2		4.3	1.5	5.8	0.4	9.0		0.2	3.9	2.8	0.6	5.8		5.9	3.8	9.7	0.2	6.2	0.5	—	3.3
Caranx equula	—	5.9	2.9		—	2.2	1.5	4.4	54.3		0.3	15.1	3.1	0.5	22.7		0.8	6.8	1.7	2.4	39.5	4.1	1.0	11.7
Nemipterus bathybius	15.5	7.4	13.7		6.1	10.7	21.8	26.0	19.6		8.1	18.9	0.9	8.8	25.0		1.1	9.0	2.5	1.9	3.3	1.4	3.9	2.6
Nemipterus virgatus	3.2	1.0	1.0		0.3	1.4	—	—	—		*	*	—	0.2	0.4		*	0.2	2.5	0.1	*	—	—	0.5
Taius tumifrons	0.9	8.4	3.9		9.1	5.6	16.2	6.1	—		2.2	6.1	6.1	9.0	7.1		3.0	6.3	0.6	1.8	0.2	0.3	—	0.6
Upeneus moluccensis	19.8	2.3	39.1		0.3	15.4	—	—	—		—	—	0.1	0.2	0.8		3.8	1.2	—	—	—	—	—	
Upeneus bensasi	2.2	1.4	2.2		2.5	2.1	0.5	1.4	0.4		2.7	1.3	1.7	5.9	6.7		1.4	3.9	10.3	5.8	23.3	11.2	1.0	10.3
Parupeneus spp.	—	—	—		*		8.5	1.3	3.7		—	3.4	—	*	—		0.1	*	—	0.1	0.3	0.1	*	0.1
Monocanthus spp.	*	155.7	154.3		*	77.5	*	*	—		—	*	*	*	2.0		0.2	0.6	2.3	0.4	1.6	1.6	0.1	1.2
Trichiuridae	1.2	0.4	—		0.8	0.6	—	0.2	—		—	*	5.5	—	0.2		0.2	1.5	—	—	—	—	—	—
Stromateoids	0.9	1.6			—	0.6	0.4	1.9	—		*	0.6	6.4	0.4	5.3		3.3	3.9	0.1	—	—	1.1	—	0.2
Others	13.0	28.7	18 7		15.0	18.9	30.4	25.3	39.7		58.8	38.6	21.0	18.1	24.7		26.3	22.5	10.6	30.5	26.3	6.8	10.7	15.0
Total	56.9	218.5	245.2		41.0	140.4	89.1	74.3	126.9		74.1	91.1	50.3	47.1	103.1		47.1	61.9	66.1	49.7	126.7	37.1	35.5	63.0

* present but less than 0.1

Table 5 The mean catches (kg/hr) of various taxa in different categories from the deep water survey stationssover the period March 1972 to March 1973

Category		Mean catch rate (kg/hr) in survey stations at depths exceeding 180 m							
		A 6	B 6	C 6	D 6	A7	B 7	C 7	D 7
Edible	*Saurida spp.*	2.2	0.8	–	–	–	*	*	–
	Muraenesox spp.	–	–	–	–	–	–	2.3	–
	Sphyraena spp.	–	–	–	*	–	–	–	–
	Glaucosoma burgeri	*	–	–	–	–	–	–	–
	P. macracanthus	11.4	1.7	0.3	0.7	0.6	3.3	25.6	2.1
	Caranx equula	1.0	0.2	0.2	1.1	–	–	–	–
	Decapterus spp.	0.2	*	–	–	–	–	–	–
	Selar crumenophthalmus	–	0.5	–	–	–	–	–	–
	Seriola nigrofasciata	–	–	–	–	–	–	–	–
	Tangia carnolabrum	–	0.6	–	–	–	–	–	–
	Nemipterus bathybius	0.6	2.8	*	–	–	–	–	–
	Banjos banjos	*	0.3	0.7	0.2	–	–	*	–
	Taius tumifrons	6.8	1.5	0.1	0.2	*	0.7	0.1	*
	Chrysophrys major	–	–	0.9	0.3	–	–	–	–
	Upeneus bensasi	0.3	*	*	*	–	–	–	–
	Branchiostegus spp.	*	–	–	0.2	*	–	–	–
	Psenesindicus	1.1	–	–	–	–	–	–	–

Group	Species								
	Psenopsis anomala	0.4	–	–	0.6	0.5	5.5	3.1	8.3
	Sarda orientalis	–	–	–	0.1	–	–	–	0.3
	Trichiurus spp.	*	0.1	–	0.5	*	–	0.4	0.3
	Monacanthus spp.	0.1	0.4	*	–	–	–	–	–
	Mustelus spp.	1.7	2.7	0.8	2.3	–	0.3	0.5	–
	Squalus spp.	13.7	3.5	5.5	1.5	17.2	11.0	1.9	1.5
	Carcharhinidae	–	–	–	–	–	1.4	1.7	–
	Total	39.5	15.1	8.5	7.7	18.3	22 2	35.6	12.5
Other commercial	*Synodus spp.*	–	*	*	*	*	–	–	–
	Fistularia spp.	1.9	0.3	*	–	–	–	–	–
	Holocentrus	*	–	–	–	–	–	–	–
	Ostichthys japonicus	*	2.9	0.4	–	–	0.6	–	–
	Soclopsis inermis	–	2.1	*	–	–	–	–	–
	Psuedopriacanthus niphoneus	–	2.6	0.5	–	–	–	–	–
	Histiopterus typus	*	1.0	*	–	–	–	–	–
	Hapalogenys spp.	*	0.1	*	–	–	–	–	–
	Small triglids	3.8	1.0	0.2	0.3	1.0	1.2	0.7	0.7
	Daicocus peterseni	0.1	2.2	–	*	–	–	–	–
	Ratabulus megacephalus	1.7	0.5	*	0.1	–	1.7	0.6	*
	Raja spp.	2.9	1.4	0.3	1.1	1.4	1.8	0.7	0.7
	Actobatus spp.	0.6	1.1	0.2	*	–	0.7	0.3	0.5
	Total	11.0	15.2	1.6	1.5	2.4	6.0	3.3	1.9

Category		Mean catch rate (kg/hr) in survey station at depths exceeding 180 m							
		A 6	B 6	C 6	D 6	A 7	B 7	C 7	D 7
Potential commercial	*Chloronthalmus spp.*	*	*	*	0.2	5.2	14.5	6.0	9.6
	Argentine spp.	0.3	0.4	0.1	2.8	3.1	1.3	0.3	0.3
	Rexea solandri	2.6	0.2	*	0.3	0.6	11.8	0.3	0.6
	Zeus/Zemopsis spp.	0.4	0.7	*	0.2	0.8	3.0	0.4	0.5
	Polymixia japonica	*	*	–	0.3	5.1	9.8	2.8	0.5
	Cubiceps spp.	6.5	0.3	*	0.3	4.0	7.0	17.1	1.3
	Malakichthys griseus	–	–	*	1.7	32.7	49.6	16.0	2.1
	Doderleinia	–	–	–	–	*	1.2	0.9	*
	Bembras japonicus	7.0	2.0	*	0.2	*	0.7	.3	0.2
	Uranoscopus spp.	0.2	0.1	1.7	3.9	1.7	0.6	3.1	4.5
	Bembrops spp.	*	*	–	–	4.6	4.4	0.6	0.4
	Chelidonichthys/kumu	0.5	0.3	–	–	–	–	–	–
	Large triglids	17.8	16.3	4.6	17.0	0.2	9.2	9.5	6.1
	Squatina spp.	1.7	–	0.5	–	9.5	12.2	3.5	1.0
	Dasyatids	–	–	9.4	–	0.3	14.8	16.2	6.6
	Total	37.0	20.3	16.3	26.9	67.8	140.1	77.0	33.4
Trash		32.7	52.2	20.2	19.0	33.0	30.2	30.7	21.3
Grand Total		120.2	102.8	46.6	55.1	121.5	198.5	143.3	67.2

* present but less than 0.1 kg

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3.2 Study on the Biology of *Psenopsis anomala* (Temminck and Schelgel) with a Note on its Fisheries in Hong Kong

by

R.P. CHUNG

A study has been made of the distribution, growth, reproduction and survival of Psenopsis anomala (Temminck and Schelgel) in the northern part of the South China Sea. Studies on age composition indicate that the South China Sea population consists of three age groups, only two of which contribute significantly to the fishery. Research vessel trawling records indicate that the species is concentrated in depths from 60 to 80 metres between longitudes 115° and 116° E. The theoretical maximum lengths have been estimated as 212 mm and 235 mm for males and females, with growth expressible by the equations $W = 1.150 \times 10^{-5} L^{3.140}$ *for males &* $W = 0.918 \times 10^{-5} L^{3.188}$ *for females respectively. Individuals mature early, with lengths at first maturity of 143 mm for males & 168 mm for females. Available data indicates that the spawning period falls between December and September, with the peak of spawning occurring in February and March and a possible minor peak in September. Stomachs of the species have been found to be heavily infested with trematodes. Unidentified soft bodied organisms (possibly salps, ctenophores & jelly fishes) form the major food items of the species, but substantial numbers of amphipods & copepods are also ingested. Available data suggests that the species feeds during daylight hours but the possibility of another night-time feeding cannot be discounted. The species feeds all the year round, although lower feeding intensities have been odserved in winter.*

On the northern shelf of the Sovth China Sea, in addition to being caught by Hong Kong fisherman, the species is also exploited by the Chinese fleet, for which no *catch statistics are available. A potential annual yield of the species, based on catches in 1955, amounted to 1200 metric tons, with the Hong Kong fleet landing approximately two–third of the total quantity. Seasonal variation in catches of the species has been noted, with landings rising to a peak in August, but reaching minimum in May. The fact that P. anomala has a relativety short life with only two age groups contributing significantly to the fishery exposes the population to fluctuation dependent on the success of a single year class. The very substantial quantities of juveniles of this species landed by the Hong Kong fleet might, therefore, eventually prove to be detrimental to the survival of the stock.*

3.3 The reproduction, growth, and survival of *Upeneus moluccensis* (Bleeker) in relation to the commercial fishery in Hong Kong

by

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Abstract

Investigations in the northern part of the South China Sea show that Upeneus moluccensis is mainly distributed in 55-110 m waters. Its spawning season lasts from March to September, with a peak in May. The growth rate of juvenile fish is rapid. Females grow faster than males. The common sizes landed by trawlers during 1967–68 were 12–17 cm for males and 13–21 cm for females. Spawning annuli are formed on scales, which are used for age determination. The common age-groups landed are 0 to 4, with the majority in age groups 1 and 2. The fecundity-length relation is $f = 20040\,(1-11.43)$, *where* f = *number of eggs and* 1 = *fork length in centimetres. The weight-length relations are* $W = 0.0146\ 1^{3.0873}$ *for males and* $W = 0.0126\ 1^{3.1526}$ *for females, where* W = *body weight in grammes. The annual survival rate of the stock is estimated at 14–17% from age group 2 onwards. It is concluded that catch and effort statistics are urgently required for a proper assessment of the stock.*

3.4 AN ANALYSIS OF THE GUT CONTENTS OF THE INDO-PACIFIC MACKEREL LARVAE

by

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Abstract

The food ingested by the Indo-Pacific mackerel, Rastrelliger neglectus (Van Kampen) post larvae was studied from 398 larval specimens collected from the western coast of the Gulf of Thailand in March, 1971. Copepods in various developmental stages comprised the major food items of the larvae with the sizes range from 2 to 4 mm., and the diatom Thalassiosira sp. were predominant in the guts of larvae 4.1–5.5 mm long. The feeding incidence of the mackerel larvae observed was very high. There was a slight difference of feeding incidence of the larvae by the time of towing.

Introduction

The experiment on artificial fertilization of the Indo-Pacific mackerel *Rastrelliger neglectus* (Van Kampen) was successfully carried out recently (Boonprakob and Dhebtaranon, 1972 a); however, the attempt to rare the larvae beyond the yolksac stage has not yet been successful. The reared larvae were fed first with cultured diatoms with the size ranging from 5 to 10 microns; unfortunately the post larvae could not feed on those microorganisms satisfactority. May (1970) noted that the greatest difficulty encountered in rearing of marine fishes through the larval stage was to provide a suitable food for the early stage larvae. The literature on rearing of marine fishes larvae are scattered in several languages. May *(ibid)* gave a good review on the feeding of larvae under laboratory condition, summarizing work which was undertaken from 1878 through 1969 with a valuable list of food types used in the experiments and a general discussion on the major food types. Morris (1955) discussed the size range of the food of early larval stages of marine fishes that feed almost exclusively upon invertebrates whose sizes ranging from 40 to 50 microns. The food and feeding habits of the lurvae of various species of fishes at Madras were reported by Vijayaraghavan (1957). This study was based on the analysis of the stomach contents of post larvae collected from the sea as well as on the feeding experiments on post larvae reared in the laboratory. But for the Rastrelliger larvae in the Indo-Pacific seas, very few studies have been reported so far. Kuthalingam (1956) gave some observations on the food and feeding habit of the larvae of Indian mackerel (*Rastrelliger kanagurta*), while no account on the food of post larvae of *Rastrelliger neglectus* has been made.

The present study is conducted to learn the types of food ingested by the Indo-Pacific mackerel larvae, based on the analysis of their gut contents, with the aim of applying this knowledge to rearing of these mackerel larvae under laboratory condition.

Material and Methods

A total of 398 larvae were examined for food organisms. Samples were collected in March 1971 by a series plankton tows made by the Pelagic Fisheries Investigations Unit, whose research projects include the study of the diel vertical distribution of the mackerel post-larvae. The larvae were collected at assigned stations in the waters off Prachuabkirikan Province on the west coast of the Gulf of Thailand. A detailed description regarding the methods employed in processing samples was given by Boonprakob and Dhebtaranon (1972 b).

The larvae were cleared with 95% glycerine for at least 24 hours (Ferner, 1959). The total length of each larva was measured after clearing; the larvae were separated into half-millimeter length groups. In our specimens, however, the materials in the intestine was not visible through the surrounding tissue, even if they were immersed in glycerine for days. However, the food particles could be seen only by dissecting out the digestive tract and teasing it apart on a microscopic slide. The gut contents were stained with one percent methylene blue in lacto-phenol to obtain better visibility. The contents then could be indentified as completely as practicable, and the number and lengths of the organisms presented were recorded using 100 and 400 x magnification.

The incidence of feeding

Digestion of most of the food items found in the guts of mackerel larvae was quite complete. Identification could only be done either on those body parts of the food material such as chitinous exoskeleton of crustacea or from the emptly frustule of diatoms. It is difficult to determine the feeding incidence of mackerel larvae in the present study; this is due to digested materials in the guts of all larvae observed and to the inability to see the food items through the surrounding tissue as in those anchoby larvae examined by Berner (1959) and in herring larvae by BjØke (1971). On the assumption that the feeding larvae were those that consumed food even if the food material in the gut was completely digested with some trace of food remaining for identification, the incidence of feeding of the Indo-Pacific mackerel larvae observed was remarkably high. Of the 398 larvae examined, 214 or 53 % showed the evidence of feeding. The feeding incidence of larvae of different size groups is shown in Table 4. The greater percentage of feeding was found in the larvae ranging from 3.6–4 mm in body length, and the least in those 2.6-3 mm long. However, the number of feeding larvae sampled at different periods were scattered (Table 3). The feeding incidence does not differ appreciably among larvae of various size groups. Mackerel larvae caught at 12.29 hrs, however, had a lower feeding incidence than those caught at 6.50 hrs and 8.34 hrs. There seemed to be a slight difference of feeding incidence by the time of towing.

Composition of the diet

It was observed that the post larvae started feeding as soon as they were 2 mm long, and that the post larvae were typical plankton feeders. The composition of food items found in the guts of the mackerel larvae used in this study is presented in Table 1. Table 2 shows that the food ingested by the post-larvae covers a great size range. Copepods in various developmental stages were the major food items of the larvae 2–4 mm in body length while the diatoms *Thalassiosira* sp. was found to be the largest number in the guts of larvae 4.1–5.5 mm long. Most of the diatoms found in the guts of the mackerel post larvae were either rod shape or cells which are united into irregular colony or long chain. The post larvae 3–4 mm in body length also ingested Cirripede larvae although copepods still formed the major proportion of the food items. One Sagitta with nine eggs and a few species of diatoms were found within the gut content of one post-larvae 11 mm long obtained in the morning surface haul.

There was no trace of food in the anterior part of the gut or aesophagus of all larvae examined. The food particles were present both in the middle and posterior portion of the guts. Digestion of food in the middle portion was as complete as the posterior portion.

Conclusions and Discussion

It may be conclude then, that the Indo-Pacific mackerel larvae are omnivorous and crustacea larvae, mainly copepod nauplii, are considered to be one of the most important of their food items. *R. kanagurta* (Russel), which has a very close taxonomic relationship to *R. neglectus*, is found to be strictly herbivorous, as it feeds on diatoms and algae (Kuthalingam. 1956). The difference in niche between the larvae of these two species may be affected by some different characters related to feeding.

The diatoms used as food rearing *R. neglectus* post larvae should be those species either having cells connected into long chain or rod shape, or the colonial species such as *Thalassiosira subtilis*, of which cells embedded in irreguar gelatinous masses. As diatoms comprised only a small percentage of the food composition of the post larvae, their nutritive significance is probably of little importance, however. this is difficult to assess. It is likely that small noncolonial diatoms or algae, or the unchain species could not be ingested by the mackerel larvae due to the absence of gill-rakers which are not fuly developed in the early post yolk-sec larvae. The 2 mm larvae has two teeth on the mandible and the other two on the upper jaw. The number of teeth increased to four upper and six lower teeth by 4 mm stage (Matsui, 1970). They may be able to catch and swallow some of microorganisms presented in the water of which the sizes of the organisms are not larger than what they can take into their mouths. but large enough to be retained by the teeth of the consumers.

Many scientists (Bhattacharyya, 1957; Blaxter, 1965; BjØke 1971; Bainbridge and Forsyth. 1971) pointed out that herring larvae showed preference of the food consumed. Taste and texture and not the size of the prey are known to influence the selection of food by herring larvae. Blaxter and Holliday (1958) suggested that herring selected food by eye regardless of size, shape or colour. but they selected food by tactile and chemical. Food of unsuitable consistency or taste would be rejected. Shelbourne (1953) discussed the phenomenon of food selection by plaice post larvae, with special reference to the part that vulnerability may play in limiting the number of species of prey available as food. Sherman and Honey (1971) suggested that herring larvae are also opportunistic, taking food organisms within a wide range of size as they become available in the plankton. Within the period of their collections, the larvae appeared to be selective for prey size only in their earliest stagees of development, when relatively large zooplankters were available. The results of the present work cannot conclude as to whether there is some selection of food by the mackerel post larvae; but indicate that copepods nauplii play an important part of the food items.

Previous authors (Lebour, 1921; Shelbourne, 953 Bhattacharyya, 1957; Berner, 1959) found that the feeding incidence among marine fish larvae is extremely low. The result of the present observation differed considerably from those of the previous authors mentioned, but agreed with Vijayaraghavan (1957) who studiee on the feeding habits of the post larvae of various species of fishes at Madras. He found that 46 percent of *Engraulis grayi* post larvae had food in the guts, and 70 percent of them at 9 to 16 mm long were feeding, and that the feeding incidence of *Stolaphorus tri* larvae were 74% Recently. BjØke (1971) found food in 51 percent of the Norwegian herring larvae examined. however, he assumed that larval food was abundant during the period of their investigation. Sherman and Honey (1971) in observing the seasonal variation in the food of larval herring found that the difference in the incidence of feeding among the seasons was significant; feeding decreased from autumn to winter and increased in spring. The percentage of larvae feeding in all seasons observed were above 51 %. The feeding incidence of marine fish larvae found by recent authors was found to be higher than those of the previous authors.

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Table 1 The percentage of food compositions in the guts of the Indo-Pacific mackerel post-larvae

Food item	Length of mackerel larvae in mm						
	2–2.5	2.6–3	3.1–3.5	3.6–4	4.1–4.5	4.6–5	5.1–5.5
Phytoplankton							
Bacteriastrum sp.	–	11.1	–	–	–	–	–
Chaetoceros sp.	10	–	–	–	–	–	–
Hemiaulus hauckii	–	11.1	–	–	–	–	–
Leptocylindrus sp.	20	–	–	–	–	–	–
Navicula spp.	–	11.1	5.5	5.1	30.4	2	24.4
Nitzachia spp.	–	–	16.6	–	3.4	2	4.9
Thalassiosira sp.	–	–	–	–	43.5	81	48.8
Thalassiothrix spp.	–	–	–	10.5	2.1	6	4.9
Zooplankton							
Copepod nauplii	40	22.2	–	36.9	–	9	2.4
Copepod copepodites	–	33.3	50.0	–	15.2	–	7.3
Cirripede larvae	–	–	5.5	10.5	–	–	–
Crustacea nauplii	30	11.1	11.0	31.6	–	–	–
Euphausiid nauplii	–	–	–	5.3	–	–	–
Crustacea (unident)	–	–	–	–	4.3	–	–
Unident. eggs	–	–	11.1	–	–	–	7.3

Table 2 Size of food* ingested by the Indo-Pacific mackerel post larvae

Length group mm	Food size micron	Major food items
2.0–2.5	14–150	Copepod nauplii
2.6–3.0	17–140	Copepod copepodites
3.1–3.5	17–140	Copepod copepodites
3.6–4.0	11–175	Copepod nauplii
4.1–4.5	10–150	Thalassiosira sp.
4.6–5.0	10–190	Thalassiosira sp.
5.1–5.5	10–200	Thalassiosira sp.

* Measured along longest axis.

Table 3 Comparison of feeding incidence among seven size groups of larval mackerel sampled at different time and depth

	Total number of larvae			Number of larvae feeding			Percentage of larvae feeding		
Depth of caught (m)	5–10	0–5	0–5	5–10	0–5	0–5	5–10	0–5	0–5
Time of caught	8.50	8.34	12.29	6.50	8.34	12.29	6.50	8.34	12.29
2.0–2.5	110	60	10	66	28	2	60.0	46.6	20.0
2.6–3.0	3	43	34	1	21	11	33.3	48.8	32.3
3.1–3.5	57	11	8	36	5	4	63.2	45.4	50.0
3.6–4.0	20	6	2	14	6	1	70.0	100	50.0
4.1–4.5	13	2	–	7	2	–	53.8	100	–
4.6–5.0	11	1	–	5	1	–	45.4	100	–
5.1–5.5	3	2	2	1	2	1	33.3	100	50.0
Total		398			214			53.7	

Table 4 Incidence of feeding of mackerel larvae collected in the waters of the western coast of the Gulf of Thailand, 1971

Length of larvae (mm)	Total number	Number of larvae feeding	Percentage of larvae feeding
2.0–2.5	180	96	53.3
2.6–3.0	80	33	41.2
31.–3.5	76	45	59.2
3.6–4.0	28	21	75.0
4.1–4.5	15	9	60.0
4.6–5.0	12	6	50.0
5.1–5.5	7	4	57.1
	398	214	53.7

3.5 ADDITIONAL PAPER TO THE IDENTIFICATION OF NEMIPTERUS SPP IN THAILAND

by

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Abstract

This paper is the further result of the study of nemipterid fishes (Pisces : Nemipteridae) in order to fulfill the need of the knowledge, which other species are also occured in the area. In the former paper, the same author described 11 different Nemipterus species and an unidentified one. In this second paper of the series will be found the descriptions of the other four newly recorded species four Thailand : N. metopias (Bleeker), N. bathybius Snyder, N. balinensis (Bleeker) and N. celebicus (Bleeker. A species which was recorded as the unidentified species by the same author in that previous paper is here redescribed as N. tambuloides (Bleeker). With the above four recently found species, the total number of the thread fin breams known form Thailand becomes sixteen. The artificial key for all of them is also herein provided with their distributions.

Introduction

In any study of the Thai–*Nemipterus* many questions will taxonomically arise. Most of these have been able to answer satisfactory at the present time ; except very few of them will need further investigations and additional materials or literatures. The author hopes to be able to come back to a study of these unanswered questions at some later date.

In the former paper of the Thai *Nemipterus* of Wongratana which was published in Proc. 2nd CSK. Symposium (1972), in which 12 different species were recorded, one of them was compiled and one was unidentified. Some more materials, have since come to hand, that it seems timely to bring up again our knowledge of this interesting group. In the present article it is the author's wish to make available for the biologist of this group the further results of the systematic study of the new materials representing the four newly recorded species for Thailand and a re-description of the unidentified species. This new collection adds many new facts to the *Nemipterus* of Thailand. As there are many species, other than those recorded from Thailand. have been already investigated in the neighboured waters, it is therefore anticipated that they might also occured in Thai-waters more or less in a certain season and area.

In this report, a new key to the 16 species: *Nemipterus nematophorus* (Bleeker), *N. japonicus* (Bloch), *N. mesoprion* (Bleeker), *N. nemurus* (Bleeker), *N. metopias* (Bleeker), *N. bathybius* Snyder, *N. balinensis* (Bleeker), *N. tolu* (Cuvier and Valenciennes), *N. oveniides* (Popta), *N. peronii* (Cuvier and Valenciennes), *N. delagoae* J.L.B. Smith, *N. celebicus* (Bleeker), *N. marginatus* (Cuvier and Valenciennes), *N. bleekeri* (Day), *N. hexodon* (Quoy and Gaimard), *N. tambuloides* (Bleeker), is given, followed with their distributions in the parenthesises. On this account, it has not been possible to include all the realistic distributions of each fish. Therefore, the geographical distributions given for each species were constructed from those of investigated specimens and from the literatures where the distributions or the illustrations were sufficient through and accurate to enable the author to identify the species with assurance. Finally, each of the newly recorded or redescribed species is discussed separatly together with its illustration. All of the studied specimens are representatively kept at the Reference Collection of the Marine Fisheries Laboratory, Bangkok.

It is noticeable that our knowledge of the nemipterid fishes in the Thai-waters or habitually in the Indo-West Pacific is as yet still very scantly and that a critical examination of the type specimens will be necessary to obtain certainly regarding their identities and synonyms. As the author will personally not be able to do this work in the near future. It may be very useful to publish here the additional paper to his previous work, accumulated while study the existing descriptions, though incomplete, it may be of value to other students of this genus. And, it is the author's hope that the arrangements adopted though it may hereafter be subject to revision, will fulfill the primary object to which this series is directed, namely that of overcoming hesitation about devoting study to these beautiful *Nemipterus*. For the literature cited or references, it is now underway togather all possible information pertaining to *Nemipterus*.

In this work during the participation in the Fish Taxonomy Seminar at Phuket, Thailand, the author has received the very courteous cooporation of Dr. David Eggleston of the Marine Department, Fisheries Research Division. Wellington, New Zealand, who kindly handled several interesting forms to the author and it is a great honor of the author to acknowledge him with many thanks.

Material and methods

During the course of the Seminar on Fish Taxonomy in Southeast Asia, held at the Phuket Marine Biological Center, Phuket province, on the Andaman coast of Thailand; which was organized by FAO and DANIDA under the cooperation of the Fisheries Department of Thailand from 6 November to 8 December 1972. The author had the opportunity to participate and engage the work on several families of marine fishes, including the Nemipteridae. At that time, several dozens of fresh *Nemipterus* specimens had been purchased from the local fish market in the middle of the town and some other specimens were caught by other broad bottom trawls of the R.V. Pramong 3. All of the interesting specimens were studied and identified. Most of which had been previously recorded by the author in his "Identification of *Nemipterus* in Thailand." The rest of them were many specimens of *Nemipterus metopias* (Bleeker) and four specimens of *N. balinensis* (Bleeker).

Later, on 18th and 30th April 1973, five and fifteen specimens of *N. celebicus* (Bleeker) and *N. bathybius* Snyder were respectively collected from the landing place of the Fish Market Organization in Bangkok.

In connection with the study of the interpelvic scales, the old collection of the previous study in the Reference Collection of the Marine Fisheries Laboratory together with the newly obtained examples are based in the work.

All the measurements and counts of the boby parts and scales used in the descriptions and identifications follow the form used by the same author in his previous study of the *Nemipterus*, unless noted otherwise.

This work was begun during the course of the Seminar on Fish Taxonomy and completed by the middle of May 1973.

It is seemly worthwhile to note here that besides the several external distinctive features of which the same author has taxonomically discussed as the taxonomic criteria in the former work, he resently found out that the interpelvic scale also shows more or less a useful character in distinguishing or separating the species into groups. In using this category one ought to remember that there is some slight changes in the length and shape of this scale during the growth of the fish. Normally, the said scale is scarcely and comparatively longer or slenderer in much bigger fish. The investigations also show that there is no variation among sexs. By using this character as a principal identification, all the Thai-nemipterid fishes, except *N. balinensis* and *N. oveniides*, can be separated into three (at least two) species groups. Those *Nemipterus* which have sharply or slenderly pointed interpelvic scals are *N. delagoae*, *N. tolu*, *N. peronii* and some individuals of *N. celebicus*; the obtusely rounded interpelvic scaled species are found among *N. bleekeri*, *N. mesoprion* and *N. tambuloides*; the rest are *N. hexoden*; *N. metopias*, *N. marginatus*, *N. bathybius*, *N. japonicus*, *N. nematophorus*, *N. nemurus* and *N. celebicus*, have moderate point in the said scale. The differences of the length and shape of the interpelvic scale of the above mentioned species are shown in plate 1 and 2.

Key to the sixteen species of Nemipterus known from Thai-Waters

1. Upper caudal rays with filamentous prolongation. 2

   Upper caudal rays pointed or sharply pointed.* 6

2. First two dorsal spines together, and produced into a very long filament.

   N. nematophorus

   (Distribution : ranging from Andaman sea, Sunda Islands, South China Sea to Philippines.)

   Dorsal spines normal. 3

3. Canines anteriorly in upper jaw only, lower uniform villiform. Dorsal base with a longitudinal yellow band broadest posteriorly, anal with two or several yellow streaks ; a brilliant spot on shoulder. 4

   Canines anteriorly in both jaws. Dorsal base and shoulder without vivid markings, anal with or without a median longitudinal yellow spots. 5

4. Anal with several irregular or wavy longitudinal yellow streaks, shoulder spot and caudal filament yellow.

   Head 3.1 – 3.5. First dorsal spine little longer than suborbital depth, or more than vertical diameter of eye.

   N. japonicus

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* In using this table one ought to think that in some individuals, belonging to species of the foregoing group, the caudal filament may be broken. It is therefore advisible to consult the group under 2 in the case of doubt.

(Distribution: very widely ranging from East coast of Africa Red Sea through Indian Ocean and Archipelago, Sunda Islands to East and South China Sea.)

Anal with 2 pale yellow streaks, shoulder spot and caudal filament rosy red. Head 3.4–3.7. First dorsal spine somewhat shorter than eye diameter or suborbital depth.

N. mesoprion

(Distribution: ranging from Andaman Sea through Straits of Malacca and Gulf of Thailand.)

5. Anal with a median longitudinal yellow spots, a red spot between tips of first and second dorsal spine, preorbital without brilliant yellow patch, belly silvery white Pectoral 3.5–4, half length or snout shorter than head, its tip reaching to above anus or beyond. Suborbital 1.4 – 2.3 in vertical eye diameters.

N. nemurus

(Distribution: ranging from East coast of Africa, Andaman Sea, Straits of Malacca, Gulf of Thailand, Vietnam to Philippines.)

Anal with a median longitudinal yellow spots, red spot between tips of first two dorsal spines absent, preorbital with a very well inclined bright yellow patch, occupies the space between anterior part of maxillary and lower border of eye, belly bright yellow. Pectoral 4.–4.5, little longer than head without snout, its tip not quite reaching to above anus. Suborbital 1.3–2. in vertical eye diameter.

(Figure 1) *N. metopias*

(Distribution : ranging from Seychelles, Ceylon, India, Andaman Sea to Philippines.)

Anal without markings, red spot between tips of first two dorsal spines absent, preorbital without brilliant yellow patch, belly conspicuously bright yellow.

Pectoral 3.3–3.6, less than half length of snout shorter than head, its tip reaching a short distance to above anal origin. Suborbital 2.2–3. in vertical eye diameter.

(Figure 2) *N. bathybius*

(Distribution : ranging from Kagoshima in Japan, Philippines to South China Sea and Thailand.)

6. Suborbital depth very narrow more than thrice in vertical eye diameter. Lower margin of eye far below horizontal through upper corner of pectorals. Gill rakers 11–12. A large yellow spot on sides behind upper pectoral axil usually present.

(Figure 3) *N. balinensis*

(Distribution : ranging from Phuket Island in Andaman Sea, Bali to Luzon in Philippines.)

Suborbital usually less than twice in vertical eye diameter.* Lower margin of eye above pectoral axil. Gill rakers 6–9. No yellow spot as above. 7

7. Dorsal spines much longer than rays, very slender; interspinous membranes distinctly and deeply notched.

N. tolu

(Distribution : very widely ranging from Red Sea to Andaman Sea and Sunda Islands southwards to New Guinea and Queensland, and northwards to Formosa.)

Dorsal spines more or less subequal with rays, membranes not notched. 8

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* Being not consulted with much smaller fishes, because they are apparently almost alike.

8. Body mostly uniform rosy with 9 very obscure saddle blotches on back; belly silvery. 9

Body with longitudinal yellow bands or streaks; sometimes yellow band along edge of belly. 10

9. Fifth and sixth dorsal spine longest. Conical teeth in front of lower jaw. Suborbital when produced reaching one scale before dorsal origin. *N. oveniides*

(Distribution: ranging from Sunda Islands, Gulf of Thailand to Philippines.)

Fourth and fifth dorsal spine longest. Both jaws with front canine teeth. Suborbital when produced reaching anterior part of dorsal fin. *N. peronii*

(Distribution: ranging from Andaman Sea through Sunda Shelf eastwards to New Guinea, southwards to North and Northeast Australia and northwards to Philippines.)

10. Five distinctly or slightly curved greenish-yellow longitudinal streaks below lateral line; anal with 3 longitudinal yellow streaks; tip of upper caudal lobe pale rosy. Depth 3.7-3.9. *N. delagoae*

(Distribution: ranging from East coast of Africa through Tropical Indian Ocean and Archipelago and Andaman Sea.)

A reddish yellow median lateral band on sides just below lateral line, anal with two yellow streaks, upper caudal rays yellow. Depth 3.4-3.5.

(Figure 4) *N. celebicus*

(Distribution: very widely ranging from Red Sea, Tropical Indian Ocean, South China Sea to East Indies and Louisiade Archipelago.)

Two to eight straight lateral yellow band or streaks on sides; base of anal with or without a single yellow streak; tip of upper caudal lobe yellow or sulphur yellow. Depth varies 3.0-3.7. 11

11. Two longitudinal yellow bands below lateral line, brilliant shoulder spot absent, anal uniform milky white.

Five or seven yellow streaks along back and sides or below, shoulder spot present or absent, dorsal and anal each with a basal yellow streak. 13

12. Dorsal and anal fin high, spines flexible, dorsal spines increasing in length posteriorly. Head very bluntly short 3.2–3.3 in length, hind preopercular edge serrate. Dorsal without basal band, belly silvery. Only upper jaw with canines front. *N. marginatus*

(Distribution : ranging from Bengal, Andaman Sea, Straits of Malacca, Gulf of Thailad, Tokin Bay to Philippines and very far east to Santa Cruze Islands.)

Dorsal and anal fin low. spines strong, dorsal spines subequal in length. Head pointed 3.–3.2 in length, preopercular edge entire posteriorly. Dorsal fin with a basal yellow streak, bright yellow band along edge of belly. Jaws with canines at front. *N. bleekeri* *

(Distribution : ranging from Madras, Ceylon through Straits of Malacca, Gulf of Thailand and Vietnam.)

13. Sides with seven narrowly yellow longitudinal streaks, a brilliant shoulder spot. Head 3.1–3.3 in length. Jaws with canines at front.

N. hexodon

(Distribution : very widely ranging from Zanzibar on East coast of Africa, Ceylon, Andaman Sea through Straits of Malacca, Sunda Islands, South China Sea and Philippines, eastwards to New Guinea and southwards to Timor Tea.)

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* In some cases, when consulted with the descriptions given by Bleeker (1876–77) together with his figure and Fowler (1933), this fish is closely related to *D. isacanthus* Bleeker.

Sides with five very well defined and straight yellow streaks, no spot on shoulder. Head 3.3–3.7 in length. Only upper jaw with 6–8 canines at front.

(Figure 5) *M. tambuloides*

(Distribution : ranging from Andaman Islands to Sunda Islands, South China Sea and Philippines.)

Nemipterus metopias (Bleeker)

(Figure 1)

Dentex metopias Bleeker, Acta Soc. Sci. Indo–Neerl., vol. 2, Achtste Bijdr, vischfauna Ambonia, p. 51, 1857; Bleeker, Atlas Ichtn., vol. 7, pl. 320, fig. 5, 1873–76; Bleeker, *ibid*., vol. 8, p. 87, 1876–77.

Synagris metopias Günther, Cat. Fishes British Mus., val. 1, p. 376, 1859; Fowler, Bull. 100 U.S. Nat. Mus., vol. 12, p. 89, 1933.

Nemipterus metopias Jordan and Seale, Bull. U.S. Bur. Fisheries, vol. 26, p. 22, 1907; Weber and de Beaufort; Fishes Indo–Australian Archipelago, vol. 7, p. 365, 1936; Smith and Smith, Fishes Seychelles, p. 29, pl. 95, B, 1963.

Description.– (Based on 174–282 mm. examples excluding caudal filament). Head 3.3–3.6, upper profile curved down at above nostrils to snout tip. Depth of head at hind preopercular edge equal to its length without operculum. Body comparatively slender, depth 3.9 to 4.4 in much smaller fish, or equal to half length of snout shorter than head. Least depth of caudal peduncle more or less equal to snout or sometimes a little shorter. Eye 3.5–3.8, about equal to snout in young to 1.2 in it with age. Snout little pointed, 3.1–3.3 in head or equal to horizontal diameter of eye. Interorbital nearly level. Jaws equal. Cleft of mouth somewhat below eye and level with or slightly above pectoral axil. Hind extremity of maxillary extending vertically to anterior fifth or sixth of eye. Outer row of teeth somewhat enlarged and conic, inner villiform in band at least anteriorly; upper jaw with 6 pointed canines at front, and 9–12 smaller ones on outer edge of mandibular symphysis. Suborbital bluntly round, slightly emarginate above hind part of maxillary, longer than broad in young but shorter in larger fish; its depth twice eye diameter in young to 1.3 with age. Hind border of suborbital oblique, forming more or less straight line, which, when produced, reaching the dorsal profile six scales before origin of dorsal. Hind margin of preoperculum finely serrate, naked flange in scaly part twice when young and 1.7 in largest fish.

Dorsal and anal moderately high, round posteriorly, spines rather strong. Dorsal rays X, 9; spines gradually and slightly increasing in length posteriorly, last spine 7.8–8.5 in length, rays higher than spines. Anal III, 7; lower than soft dorsal, first spine little shorter than half length of the second, anterior ray longest, the last ray sometimes little produced. Pectoral 1, 15; broadly falcate, 4.–4.5 in length, not quite reaching to above anus or only to below eigth or ninth dorsal spine or little longer than head without snout. Pelvics I, 5; first ray little produced and extending to behind anus in young but never to it with age. Caudal lobes pointed, upper ending in a short filament. Gill rakers 6–7 (mostly 7), very short tubercles and spinescent. Scales above lateral line to middle of spinous dorsal 3½, below to anal origin 11–11½, about 46–47 pores in lateral line.

Live colour –

Top of head and back largely rosy without colour bands or markings; horizontally below eye level rosy silvery. 7–8 narrowly yellowish longitudinal streaks on sides along each series of scale row from below lateral line and just behind head to caudal peduncle. the lower ones less distinct. Broad yellow paired bands beginning at isthmus extending along edge of abdomen and anal to lower rudimentary caudal rays, leaving middle of belly silvery white. Maxillary and cheek rosy. Mandible and chin silvery. Upper part of preopercle and opercle tinged with golden reflections. Inside of gill opening whitish. A very conspicuous greenish yellow patch or bar from below eye, where it is broadest, passing obliquely through preorbital to anterior part of maxillary. A smaller one from hind nortril horizontally through middle of eye and ends on posterior eye margin. Most part of dorsal fin dull greenish yellow, edge of spinous portion red, of soft portion yellow, both with a continuous narrowly submarginal blue band ; an inconspicuous basal longitudinal blue band of which sometimes breaking into elongated spots may be present. Anal uniform milky white, with a longitudinal yellow streak, usually breaking into series of quadrangular spots on membrane (suggest that of *N. nemurus* but slightly less prominent). Pelvics hyaline with axillary scale and base of fin yellow. Pectoral pale rosy with yellowish upper and inner axil. Caudal rosy, middle rays of lower lobe tinged with pale yellowish, inner edge reddish, filamentous prolongation yellow.

Remarks.

Key of Fowler (1933), he states "Anal without yellow band." Bleeker (1876-77) gives picture of this fish with no band or any marking on anal fin. Later in 1936 Smith and Smith give an outstanding colour picture of this fish with a row of yellow spots on this fin. The upper caudal lobe of which ending in a short filament, evidently broken in most of the marketing specimen.

The fish is known by its slender body; apparently, largely unicoloured body, bright rosy in life; preorbital and suborbital with a conspicuously large patch of sulphur yellow, otherwise resembling closely to *N. nemarus*.

N. metopias is somewhat abundant in the sea of Phuket Island and its vicinities. In November and December 1972 several hundreds of specimens were seen from time to time by some ichthyologists who participated and interested in fishes during the Seminar. It has never been found elsewhere in the Thai-water, no single specimen was collected during the author engaged in the other broad trawl surveys in the Gulf of Thailand and off the East coast of the Malay peninsula in the years 1966-1967 or even later.

Nemipterus bathybius Snyder

(Figure 2)

Nemipterus bathybius Snyder, Proc. U.S. Nat. Mus., vol. 40, p. 532, 1911.

Euthyopteroma bathybius Jordan and Thompson, Proc. U.S. Nat. Mus., vol. 41, p. 566, fig. 6, 1912.

Enthyopteroma bethybius Snyder, Proc. U.S. Nat. Mus., vol. 42, p. 415, 1912.

Synagris bathybus Fowler, Bull. 100, U.S. Nat. Mus., vol. 12, p. 100, 1933.

Description.- (Based on 137-205 mm. examples, excluding caudal filament). Head 3.-3.2, uppper profile more or less straight above eye and curved down at above nostrils to snout tip. Depth of head measured in vertical through hind border of preopercle little longer than head without opercle or equal head without snout. Depth 3.4-3.7 or half length of opercle shorter than head. Least depth of caudal peduncle about equal to snout. Vertical eye diameter 3.2 to 3.6 in bigger fish. Snout 3.5 to 3.9 in smaller fish. Interorbital rather flat in small individual but notably convex in bigger one. Jaws equal. Cleft of mouth opposit lower margin of eye. Maxillary reaching to vertical through anterior part of pupil or nearly so. Villiform teeth in broad bands in jaws, larger and simply conic laterally; 5-8 canines at upper jaw symphysis; anterior outer row at mandible with 7-12 smaller canines, well developed even in smaller fish. Suborbital bone with posterior angle obtusely rounded, a comparatively distinctive notch above hind end of maxillary, somewhat longer than broad; its greatest depth 3 in eye in young and 2.2 with age. Posterior border of preopercle very finely serrate with a slight gash above angle, lower entire; naked limb 1.3 to 1.6 in smaller fish.

Fins very high or long, pointed behind ; spines rather slender and flexible. Dorsal ray X, 9 ; first dorsal spine little shorter than the second, spines very gradually increasing in length posteriorly, last spine 6.8 to 8 in very young fish in length; soft dostal higher, the fifth, sixth or seventh the longest. Anal III, 7 ; similar to dorsal but much lower than it, spines strong, first spine only scarcely longer than half length of the second or nearly so. Pectoral 1, 15–16, falcate, 3.3–3.6 in length, about one third eye diameter shorter than head, its extremely posterior end reaching midway between anus and anal origin or little beyond. Pelvics I, 5 ; first ray greatly produced and reaching much beyond anus or sometimes to anterior anal rays. Caudal of medium size, uppermost rays considerably produced into a very long filament. Gill rakers 7–8, short tubercles and spinescent. Scales above lateral line to middle of spinous dorsal $3\frac{1}{2}$, below to anal origin $10-10\frac{1}{2}$, about 47–49 pores in lateral line.

Live colour:–

Head and back at level above lower margin of eye bright rosy, rose silvery on sides, below distinctly contrasted silvery white, a small region below suprascapula with silvery reflex. Body with two or three short longitudinal yellow stripes below lateral line, interspaces rosy silvery and broader. First yellow stripe from below origin of lateral line running straight and crossing the lateral line at anterior portion of caudal peduncle to upper caudal base. Second, sometimes present, shortest, occupied only middle part and along the intersection of fourth and fifth longitudinal scale rows below the lateral line. Third, from a short distance behind pectoral base where it is broadest and terminating before narrowest part of caudal peduncle. Belly with a broad pair of bright yellow band on each side from isthmus along edge of abdomen and anal to lower rudimentary caudal rays, leaving a narrow mid-ventral line silvery white. Iris largely yellowish pink. A small space between nostrils and front eye border yellowish. Middle part of scaly portion of preopercle and opercle, each with a large pale yellow blotch. Inside of gill opening mostly bright orange. Dorsal more or less foggy or smoky with yellowish, entire edge narrowly yellow, submarginal part bluish. Anal uniform milky white. Pelvics hyaline or second and third rays yellowish, axillary scale and base of fin cadmium yellow. Pectoral pale rosy, base of fin yellow. Caudal rosy, several upper caudal rays and especially its extremely long filament yellow.

Remarks:- *N. bathybius* is not included in Weber and de Beaufort's, the fishes of the Indo-Australian Archipelago. This fish is the latest record of *Nemipterus* species known from Thailand with questionable locality, though likely of the Kagoshima in Japan where the type and following specimens were found or of Batangas in Philippines by the records of Snyder (1911), Jordan and Thompson (1912) and Fowler (1933) respectively. The author, however, have seen many specimens in Hong Kong in October 1970. After comparing the several preserved specimens of *N. bathybius* from the later deposited at the Reference Collection of the Marine Fisheries Laboratory, Bangkok and those from Thailand, the author came to the conclusion, that they do not differ. The form of the suborbital and fins are the same in both and the number of canine teeth in both jaws are equally variable. The author can hardly believe and think this fish is caught in the Gulf of Thailand. As he has spent almost a year round in 1966 - 1967 for the experimental trawling in there; the result is partly appeared in his "Check list of the fishes caught during the trawl surveys in the Gulf of Thailand and off the East coast of the Malay Peninsula," and he found no single specimen of *N. bathybius*. It is more probable, that they have been caught out of Thai-water, in central South China Sea or further north due to the expansion of the Thai fisheries vessels in that area and the fish are brought back to market in Bangkok. It is also still very doubtful that the fish also occures and being caught in Indian Ocean, because most of the presently collected specimens were taken between *N. delagoae*, specimen of which is only obtainable from Andaman Sea. Or do they were sorted and mixed with each other before marketing at the Fish Market Organization in Bangkok?

N. bathybius is closely related to *N. flaviventris* (Steindachner) of Indian Ocean and South China Sea, except that the former has no broad bright greenish yellow lateral band on dorsal basally and the absence of subbasal longitudinal narrow yellow band or any other marking on anal fin.

Nemipterus balinensis (Bleeker)

(Figure 3)

Dentex balinensis Bleeker, Nat. Tijds. Ned.-Ind., vol. 17, p. 155, 1858-59; Bleeker, Atlas Ichth., vol. 8, p. 95, pl. 327, fig. 4. 1876-77.

Synagris balinensis Fowler, Bull. 100, U.S. Nat. Mus., vol 12, p. 103, 1933.

Nemipterus balinensis Weber and de Beaufort, Fishes Indo-Australian Archipelago, vol. 7, p. 375, 1936,

Description:-

(Based on 67-131 mm examples). Head 3.2-3.3 somewhat pointed, upper profile smoothly and evenly curved. Depth of head at hind preopercular edge equal to its length without opercle Depth 3.8 to 4.3 in very young fish or about half length of opercle shorter than head. Narrowest depth of caudal peduncle equal to vertical diameter of eye. Eye large 2.7-3. Snout 4.3-4.4 and much less than interorbital width in very young fish or equal to it in biggest example. Interorbital flat. Mouth comparatively oblique, gape considerable above lower eye margin but little above pectoral, upper axil of which also much above lower eye margin. Hind extremity of maxillary reaching anterior sixth of eye. Teeth villiform in band anteriorly in jaws; the outer row enlarged, those on lower more prominent than those on upper jaw; 6 canine teeth on maxillary symphysis, lower jaw with 8 conical teeth at front, the latter more or less flared outward in the 131 mm specimen. Suborbital considerably narrow, much longer than broad, comparatively much small in very young fishes (67-71 mm) and about one fifth of vertical eye diameter in 131 mm; irregularly curved below, slightly emarginate above hind part of maxillary; finely striated. Preopercular edge very minutely serrate posteriorly, its naked flange 2.1 or more in scaly part in much younger fish.

Dorsal and anal moderately high, somewhat rounded behind, spines little flexible. Dorsal rays X, 9; first few anterior spines shortest, few later little longer, the following ones very scarcely decreasing in length posteriorly; rays about equal in high to spines, posteriormost ones scarcely longer. Anal III, 7; first spine comparatively much longer than half length of the second, length of which slightly shorter than the third; first ray longest and longer than third spine, middle rays being shortest. Pectoral 1, 15; little falcate, very slightly shorter than head without opercle; its hindmost extremity reaching to below space between eighth and ninth dorsal spines. Pelvics 1, 5; of moderate length, somewhat longer than pectorals, first ray produced into a short filament and reaching midway between anus and anal origin (The position on anus of the 131 mm specimen is probable abnormally placed a little foreward than other usual specimens, see figure 3). Caudal lobes pointed without filamentous prolongation. Gill rakers on lower branch of first gill arch of the examined specimens

11–12, (Figure 6) their shapes more or less finger–like, spinescent. Scales above lateral line to middle of spinous dorsal $3\frac{1}{2}$, below to anal origin 11, about 47 in lateral line.

Live colour :–

Pale silvery rosy on top of head, back and upper sides, lower part of body silvery. With two to three pale yellowish bands horizontally along series of scales on sides. First running below lateral line and crossing it at front portion of caudal peduncle; second from behind pectoral base to caudal fin and touching lateral line inferiorly, between which is a silvery reflecting stripe (this is more prominent in very young fishes). Third, very indistinct, from below pectoral base to lower part of caudal peduncle. Along edge of belly to rudimentary caudal fin with yellowish silvery reflection. Sides on shoulder part just behind upper corner of pectoral base or at the beginning of the second yellow band with a more or less distinct golden yellow spot; this spot always present even in much small fishes. Tips of upper and lower lips reddish. Iris yellowish or orangish above. Nostrils greenish. Opercle largely silvery. Dorsal largely transparent pink; terminally edged with greenish yellow, this, broader but less distinct in young; its entire base with an ill defined greenish yellow streak. Anal uniform milky white without markings. Pelvics clear; first, second and third ray pale pink; base of fin with a very pale yellow tint, bordered posteriorly with whitish. Pectorals rosy. Middle part of each caudal lobe yellowish, leaving the rest of fin rosy; in much smaller fish (67–71 mm) only posterior half of upper caudal lobe yellowish.

Remarks:– Here described from only 4 following specimens, collected at Phuket Island, Andaman coast of Thailand.

131 mm total length, at Phuket fish market, 7 November, 1972. 67, 70 and 71 mm total length, by trawling of R.V. Pramong 3, off Rawai beach, Phuket, depth about 25 m, 22 November 1972.

Its shallow and thin suborbital together with its comparatively large eye and a yellow spot on sides at just behind upper corner of pectorals make the fish easily noticable when seen among the common *Nemipterus* of the Phuket area. Furthermore, the number of gill rakers on lower branch of first gill arch is 11–12 comparably distinguishing with 6–9 in all of other species, their shapes are very much longer than broad instead of palmate shape, but also spinescent (Figure 6). Bleeker described *D. balinensis* with produced caudal lobes, this, later copied by Fowler; but Weber and de Beaufort after seeing the types, 151 mm, in Leiden Museum, they only note that caudal is fork. All of the studied specimens from Thailand also show on filament on caudal fin, or it may be broken.

It seems reasonable to note here that the yellow band on base of dorsal fin and a yellow spot near base of pectorals have not been included in any detail of Bleeker and Fowler or other previous authors beyond Thai-waters.

Fowler (1933) includes *S. balinensoides* Popta, as the synonym of this species and states with reference to Bleeker (1876) that among the East Indian species, this has the shallowest preorbital. This is quite true when the present fish is proportionally compared with other fifteen species of Thai-waters. However, Weber and de Beaufort in their Fishes of the Indo-Australian Archipelago, vol. 7, 1931, when they compared all available details of the types of both species, separated *N. balinensoides* as an other valid species by the smaller eye, shallower suborbital, less steep hind suborbital edge and much shorter pectoral fins.

As far as the specimens were only occationally secured from various places by some previous ichthyologists, it seems to be very rare and being among the small *Nemipterus*. Its longest recorded length is not exceeding 151 mm.

Nemipterus celebicus Bleeker

(Figure 4)

Dentex celebicus Bleeker, Nat. Tijds. Ned.-Ind., vol 7, p. 245, 1854; Atlas Ichth., vol. 8, p. 88, pl. 332, fig. 2, 1876–77.

Synagris celebicus Günther, Cat. Fishes British Mus., vol. 1, p. 377, 1859; Fowler, Bull. 100, U.S. Nat. Mus., vol. 12, p. 93, 1933.

Nemipterus celebicus Weber and de Beaufort, Fishes Indo-Australian Archipelago, vol. 7, p. 362, 1936; Hardenberg, Treubia, vol. 16, p. 311, 1938; Fowler, Hong Kong Naturalist, vol 10, p. 42, 1940.

Description:– (Based on 150–195 mm examples). Head rather short 3.4–3.5, with moderately curved upper profile. Depth of head 4.1 to 4.4 in smaller fish or about half length of snout shorter than head. Depth of body equal to head length or only scarcely shorter than it in young. Least depth of caudal peduncle equal postorbital part of head. Eye relatively small, its vertical diameter 4. to 4.7 in big fish. Snout pointed, 3.–3.2, little shorter than postorbital part of head. Interorbital low, nearly level at all ages, 1.5–1.7 in eye. Gape of mouth much below eye particularly in larger fish. Maxillary reaching beyond front eye margin or quite to below front edge of pupil. Teeth villiform in band anteriorly in jaws; the outer row enlarged, 8–10 prominent canines in upper jaw symphysis, none on lower. Suborbital obtuse, much shorter than broad in proportion, without notch at above maxillary end, with obliquely fine striae; its depth of adult fish 0.9 to 1.3 in eye in young; its straight hind border which when produced reaching dorsal profile five to six scales before dorsal origin. Preopercular margin minutely serrate posteriorly, below entire; greatest depth of naked flange 1.4–1.7 in scaly portion.

Fin spines more or less rigid, anal spines strong. Dorsal rays X, 9; spines slightly increasing in length posteriorly; soft dorsal little higher than spinous part, somewhat rounded behind. Anal III, 7; lower than that of dorsal, little point, first spine short and not longer than half length of the second, middle rays scarcely shorter than others. Pectoral 1, 14–15; moderately long and falcate, about half length of snout shorter than head, its hindmost extremity reaching a short distance behind anus vertically. Pelvics I, 5; first ray little produced and reaching to midway between anus and anal origin or to anal origin. Caudal lobe not much falcate, without filamentous prolongation. Gill rakers on lower portion of first gill arch 7–8, short tubercles and spinescent. Scales above lateral line to middle spinous dorsal $3\frac{1}{2}$, below 10, 44–46 pores in lateral line.

Live colour:– Most part of head and entire upper portion of back rosy, below yellowish silvery, a small region below origin of lateral line with silvery reflex. Sometimes an ill defined yellow streak along back between lateral line and dorsal profile. A reddish yellow median lateral band about wide as pupil runing below lateral line from head and crossing the lateral line on anterior part of caudal peduncle to upper caudal base where it united with the upper one, this band bordered above and below by pinkish stripes with pearl reflections. A reddish shoulder spot present. A trace of additional but very broad yellow band from pectoral base to lower part of caudal peduncle covered three scales rows middlely and fading out inferiorly. A paired of very pale yellow band beginning at origin of anal fin and passing along scale rows at base of anal fin to lower rudimentary caudal rays. Head with a golden yellow band from anterior preorbital margin to lower eye edge bordered above by a silver blue band. A pale yellow band from behind eye, laterally through postorbital part of head to shoulder spot. Opercle largely blotched with yellow sheen. Iris exclusively pale yellow. Lips silvery pink. Inside of opercle yellow submarginally; greater area orange. Dorsal largely pale yellow with deep red spinous dorsal margin and yellow soft rayed margin, entire base of fin greyish blue. The pale yellow hue-like band on dorsal fin more distinctive superiorly, fading out interiorly, and deviding into three or four narrowly yellow streaks posteriorly, the upper branches or streaks relatively longer; interspaces bluish. Anal milky wite, whith two well defined longitudinal bands as broad as their interspaces. Pelvics with first two rays pinkish, inner rays hyaline; axillary scale and base of fin yellow. Pectoral pale rosy, inner axil inferiorly yellowish. Caudal bright rosy, its middle rays pale yellowish, uppermost rays yellowish.

Remarks:-

According to Bleeker (1854 and 1876-77), Fowler (1933, compiled), Weber ane de Beaufort (1936) who have examined the type of *Dentex celebicus* Bleeker from Dutch East Indias in the Amsterdam Museum and Hardenberg (1938) who made the description from a fish from Pelabuan Ratu (Wijnkoaps bay, South coast of Java), this fish is known by the yellow bands on dorsal and anal, also median lateral band, caudal not prolong into filament and mandibular tip with six distant canines in front and continued on the sides with a single row of about nine curved caninoid teeth. Unlike original descriptions of Bleeker and other following authors, five present specimens of this fish from Thailand show a small red spot on shoulder and there is no traces of canine teeth at front of lower jaw. This character difference (canine teeth), probably caused by the rate of growth. Nevertheless, the present specimens of the author are only slightly smaller than the type of Bleeker (197 mm) but much shorter than Hardenberg specimen (30 cm, tail damaged). However, the present examples agree very closely in most of the biometric description given by Hardenberg.

In colour appearance and teeth formation, *N. celebicus* markedly shares the characteristics with *N. mesopsion* and appears to be related to it. But, *N. celebicus* may be easily distinguished from the latter by the absence of caudal filament, relatively smaller eye, shorter pelvic fins, hind preopercular edge without gasp above its rounded angle, no short pinkish silvery streak behind shoulder spot and the middle caudal rays not contrasted yellow when fresh.

Nemipterus tambuloides (Bleeker)

(Figure 5)

Dentex tambuloides Bleeker, Nat. Tijds. Ned.-Ind., vol. 4, p. 465, 1853; Bleeker, Atlas Ichth., vol. 8, p. 92, pl. 328, fig. 1, 1876-77.

Synagris tambuloides Fowler, Bull. 100 U.S. Nat. Mus., vol. 12, p. 105, 1933.

Nemipterus tambuloides Weber and de Beaufort, Fishes Indo-Australian Archipelago, vol. 7, p. 374, 1936; Herre, Notes Fish. Zool. Mus. Stanf. Univ., p. 367, 1936.

Nemipterus sp. Wongratana, Contr. 13, Mar. Fish. Lab., Bangkok, p. 39, 1968 (species no. 166); Wongratana, Proc. 2nd CSK Symposium, Tokyo, p. 465, fig. 12, 1972.

Description:- (Based on 185-283 mm examples). Head 3.3-3.7, moderately short, comparatively long in young; upper profile gently curved, more or less straight above eye. Depth of head 1.1-1.2 in its length. Depth of body 3.4-3.7. Narrowest depth of caudal peduncle equal to snout length. Vertical diameter of eye 3.4 to 4.1 in very large fish. Snout pointed, slightly curved above, equal to or scarcely longer than postorbital part of head. Interorbital low. Mouth moderately oblique, lower jaw slightly longer. Gape of mouth much below eye and somewhat above pectoral base. Maxillary reaching to below anterior fifth of eye or only to its front border. Teeth in both jaws in villiform bands, broadest anteriorly: outer row enlarged those in lower jaw mostly conic; 6-8 rather large canines anteriorly in upper jaw only. Suborbital 1.3 to 2. in eye, obtusely rounded, slightly concave above hind end of maxillary, as broad as long in most specimens. Hind preopercular edge minutely serrate, flange with parallel marginal vennules, its greatest depth 1.8 to twice in scaly part.

Fin spines rather strong. Dorsal rays X, 9 ; first dorsal spine little shorter than the second, sixth or seventh spine somewhat longest ; soft dorsal slightly higher than spinous dorsal, first ray shortest, the following ones gradually and slightly increasing in length, posterior ones longest and forming pointed lobe. Anal III, 7; spines rigid, first spine little longer than half length of second one; fin somewhat concave below, anterior and posterior rays longest, last anal ray subequal to that of dorsal. Pectoral 1, 15; long and falcate, about half pupil shorter than head, its posterior tip reaching above anal origin or midway between it and anus. Ventral I, 5; first ray reaching to a short distance behind anus or slightly before anal origin. Caudal lobes terminating in sharp points, upper longer, no filamentous ray. Gill rakers 6–7 (rarely 8), short, spinescent tubercles. Scales above lateral line transversely to middle of spinous dorsal $3\frac{1}{2}$, 11 below to anal origin, about 47–48 in lateral line.

Live colour:–

All the colouration is very brilliant. Most part of head and back rosy, side paler, passing to silvery white below. Body with 5 bright and well defined sulphur yellow longitudinal streaks, each running straight along intersections of scale rows and much narrower than interspaces. Other very much paler streaks may be present on sides below level of pectoral fin. First streak shortest, running above lateral line and abruptly ending below last dorsal ray; second longest, from snout through eye, postorbital part of head, crossing lateral line below end of first streak to upper part of caudal fin base; third, also short, from behind head to front half of caudal peduncle; fourth and fifth from inner pectoral fin base along sides to caudal fin base and touching lateral line inferiorly. Belly with a bright sulphur yellow band on each side from isthmus and throat to lower rudimentary caudal rays, this band sharply contrasting with silvery reflections on abdomen and sides. Head scattered with 3–4 yellow spots, posterior edge of eye surrounded with yellowish hue. Two short yellow bars from below eye, one obliquely through preorbital and the other on suborbital bones. Upper lip marginally and anteriorly yellow, chin with a yellow spot at its extreme tip. Inside of gill opening orange. Dorsal largely rosy, edged sulphur yellow, inframarginal streak bluish grey; entire base with a bright sulphur yellow streak, the posterior of which always fading out in young example; sometimes (only big examples), traces of indistinct yellowish hues like stripes on upper half of fin just below inframarginal streak. Anal uniform milky white, with a basal sulphur yellow streak similar to the one on dorsal fin. Pelvic spine and first ray bluish grey, rest of fin pale yellowish; its base and the scaly axillary process yellow. Pectoral pale rosy, axil yellowish superiorly. Caudal bright rosy, extreme tip of upper lobe sulphur yellow.

Remarks:- Of this species, the most strinkingly coloured of the group know from Thailand, it was first described by Bleeker in 1853 from only a single specimen of 164 mm long, caught at Java; later he again recorded its occurance in his Atlas Ichth. vol. 8, p. 92, (1876-77) from Java and Celebes (Badjoa). The type specimens were said by Weber and de Beaufort (1936) to have been lost because the fish does not appear in the list of the sale of Bleeker's collection after his death. It was not reported elsewhere until the record of Herre (1936), who collected and listed a 109mm specimen from Southern coast of Luzon. This specimen is now deposited at the Standford University Museum.

In the author's previous article on *Nemipterus* he overlooked Fowler's (1933) mistakes* of *S. tambuloides* for the depth of suborbital bone, of which in Fowler's key to this species, Fowler gives $1\frac{1}{8}$ in eye but in the description it is $1\frac{1}{3}$; Fowler further describes (deduced from Bleeker's figure of *D. tambuloides*) this fish with short filamentous upper caudal lobe. According to Weber and de Beaufort (1931; also

* The same mistake can also be found in Fowler's *S. nematopus* (= *N. marginatus*).

compiled from Bleeker), they only note that suborbital is slightly less than vertical diameter of eye; but caudal lobes pointed. Therefore, these were the reasons that confused Wongratana (1972) and made him failed in the identification. In this additional paper, the author has certainly little doubt that his previously unidentified species resembles and agrees respectively in the most respects with *D. tambuloides* of Bleeker (1853), except that. Bleeker and others did not characterize the present species with a basaly longitudinal yellow streak on dorsal fin. Bleeker's original figure of *D. tambuloides* also shown a very short and thin upper caudal filament, which is absolutely absent in all specimens from Thailand. Nevertheless, when regarding to the basal yellow streak on dorsal fin of this fish, this coloured characteristic is very easy to overlook, especially when that fin is not fully erected. This is because the streak is at the most very restrictly closed to the base of the fin when it is compared with that of other species. In addition, it is reasonable that the small size fishes of 164 mm of Bleeker and the only 109 mm of Herre have much less prominent or not developed the yellow streak. Unfortunately, the author could find no specimen of less than 185 mm in length for closed examination; he, therefore, retained it with *N. tambuloides* (Bleeker).

During the course of the FAO/DANIDA Seminar on Fish Taxonomy in Southeast Asia held at the Phuket Marine Biological Center, Phuket, Thailand, on 6 November to 8 December 1972, this fish was discussed to be a new species and therefore it was temporarily named *N. pentalineata* by the present author.

As far as the author continuously encountered the work on *Nemipterus* of Thailand, the present species is noted by him as very abundant species of the Gulf of Thailand, South China Sea and the Andaman Sea, especially in deeper waters. It is landed in rather large quantities together with other common species throughout the year.

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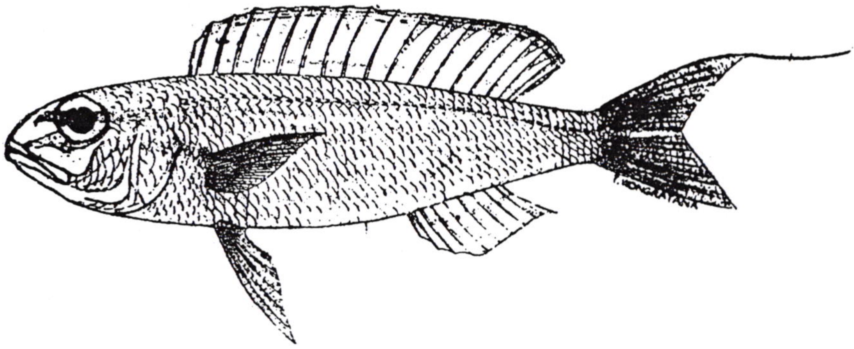

Fig. 1 *Nemipterus metopias* (Bleeker). Actual length (excluding filament) 239 mm.

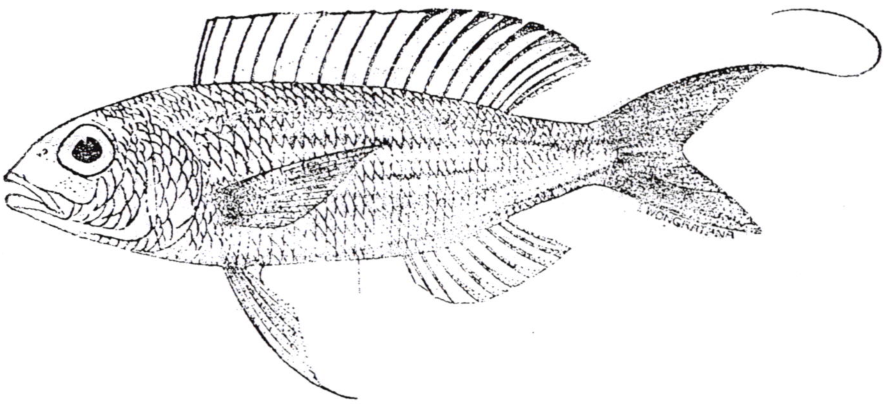

Fig. 2 *Nemipterus bathybius* (Snyder). Actual length (excluding filament) 188 mm.

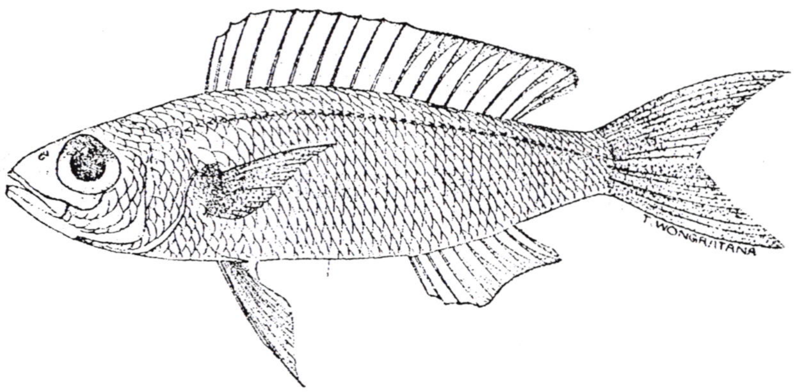

Fig. 3 *Nemipterus balinensis* (Bleeker). Actual length 131 mm.

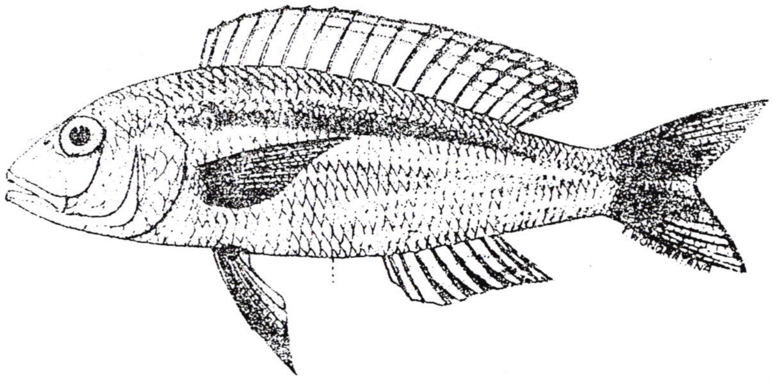

Fig. 4 *Nemipterus celebicus* (Bleeker). Actual length 170 mm.

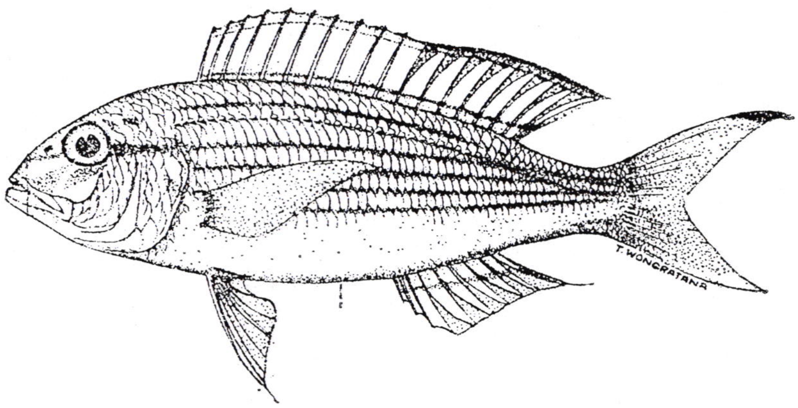

Fig. 5 *Nemipterus tambuloides* (Bleeker). Actual length 274 mm.

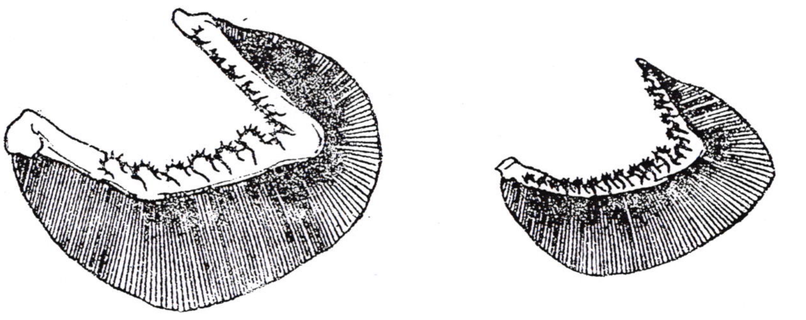

Fig. 6 Diagrammatic illustration of gill rakers of a. hypothetical nemipterid, 231 mm. in total length, and b. *Nemipterus balinensis* 131 mm in total length.

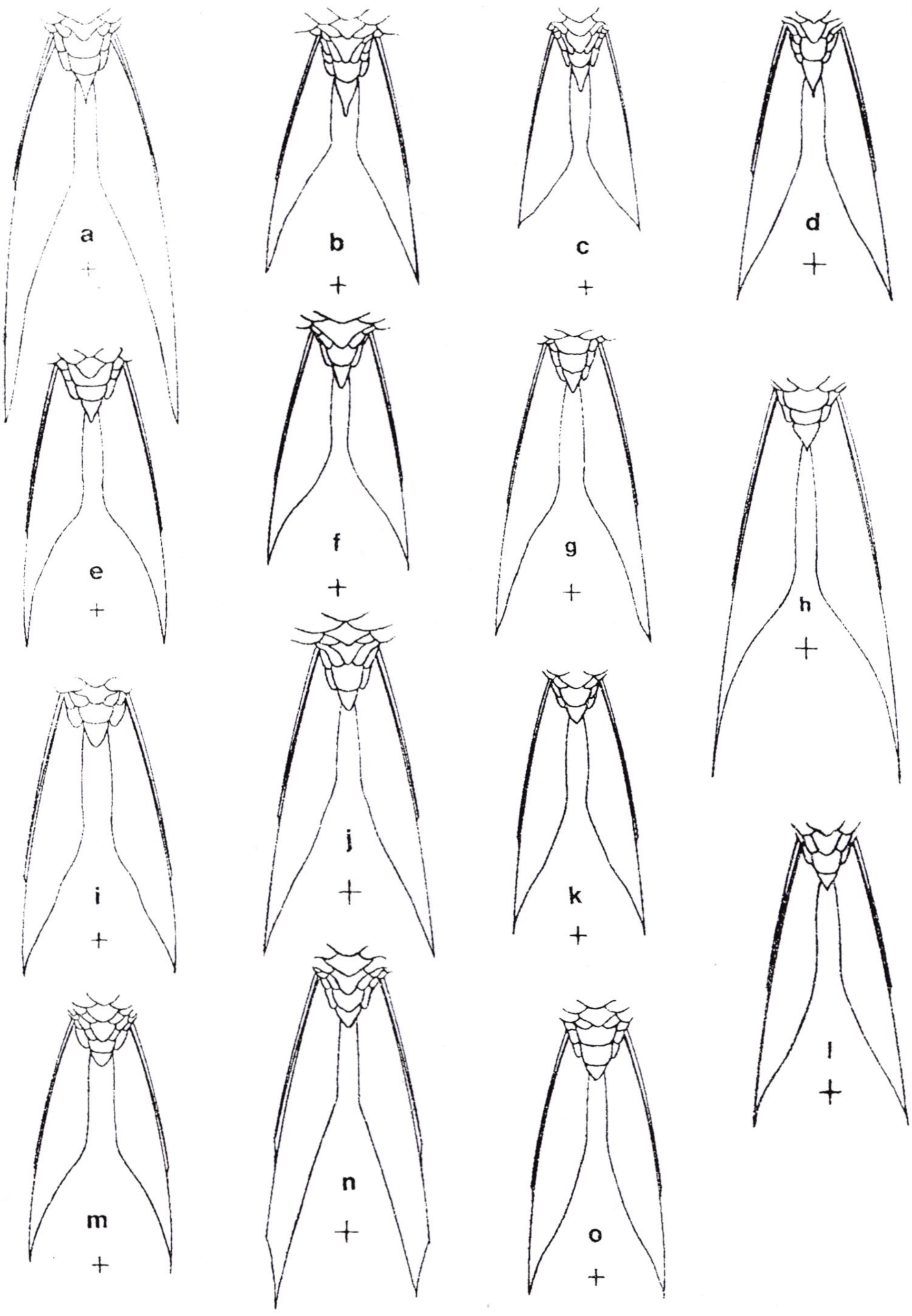

Plate 1. Diagrammatic illustration of interpelvic scale of various Nemipterus species except N. balinensis and N. oveniides known from Thai-water, and the relationships between the extreme tip of pelvic fin and anus position (+) , a. N. delagoae (273 mm), b. N. tolu (218 mm), c. N. peronii (255 mm), d. N. celebicus (182 mm), e. N. hexodon (213 mm), f. N. metopias (239 mm), g. N. marginatus (215 mm), h. N. bathybius (195 mm), i. N. japonicus (276 mm), j N. nematophorus (201 nm), k. N. nemurus (233 mm), i. N. celebicus (175 mm) , m. N. bleekeri (273 mm) , n. N. mesoprion (160 mm), o. N. tambuloides (274 mm) ,

Additional Paper

4. **Philippine Estuarine Research – I**

ON THE HYDRO-BIOLOGICAL AND FISHERIES SURVEY OF SORSOGON BAY, LUZON ISLAND

By

J. A. ORDOÑEZ*, F. M. ARCE*, R. A. GANADEN*

AND N. METRILLO, JR.**

Introduction

This survey was carried out in connection with the controversy on the banning of trawl fishing in Sorsogon Bay.

On January 14, 1972, Resolution No. 24 was unanimously approved by the provincial board entreating the President of the Philippines to declare Sorsogon Bay including the municipal waters of Magallanes, as a conservation area, banning trawls and other apparently destructive fishing methods. The Governor of the province ordered the apprehension of fishermen engaged in such fishing activities. As to trawl fishing the Governor averred that such fishing operation destroys the bottom marine life of the bay causing the fishery resources to be depleted to the detriment of the small fishermen.

A team of biologists from the Philippine Fisheries Commission (now Bureau of Fisheries) was sent to Sorsogon to conduct a survey to look on the relevance of the proposed conservation measure as embodied in the above-cited Resolution. The survey was conducted from April 18 to 28, 1972.

* of the Bureau of Fisheries

** now with the Philippine Atomic Research Center

The Survey Area

Sorsogon Bay is a small shallow bay of about 120 sq. km, about one fifth the area of Manila Bay. The mouth opens to a narrow channel leading out to Ticao Pass.

The bay has a mean depth of 5 fathoms. From the deepest part of the bay at 10 fathoms on the southwestern side there is a gradual shoaling of the generally muddy bottom towards the head of the bay.

The various river systems around the bay drain floodwaters during heavy downpour, thus contributing to the enrichment of the bay water. The high rate of siltation however has been responsible for the bay to become shallower and shallower.

Bottom sampling conducted during the survey showed thick layers of very soft mud or accumulated silt.

Materials and Methods

The hydro-biological survey work was conducted on board the fiberglass boat of the Juban Oyster Demonstration Farm of the Philippine Fisheries Commission. All in all 25 stations were occupied in the bay.

At each station, water temperature readings, surface water sampling for salinity determination, water transparency or visibility determination, plankton collections and bottom sampling were made. A reversing thermometer was used for obtaining temperature readings. For salinity determination the sample bottles were simply dipped in the water for collecting the samples.

An all-white Secchi's disc was used for determining the transparency of the water. A Maru-toku Type B net was used for collecting plankton, fish eggs and fish larvae. A vertical haul was made in each station. At selected stations horizontal tows for 10 minutes each tow were made to collect fish eggs and fish larvae.

An Ekman–Berge dredge was used for taking bottom samples to determine bottom nature and benthos concentration.

In the biological part of the work market samples were collected to study the fishes and minor sea products landed. The basic biological analyses made were on length and weight measurements, sex and sexual maturity.

Four trawling experiments were conducted in Sorsogon Bay on board a commercial baby trawler. The baby trawler was a 35–foot banca with bamboo outriggers. It was powered by a 10–H.P. gasoline engine. The dragging speed was from 1 to 2 knots. The opening of the trawl net was 6 meters wide. The towing warp was 22 feet and the mesh size of the cod–end or bag was $1\frac{1}{2}$ inches (4 cm) stretch.

Market surveys were made every morning in Sorsogon town market to determine the kinds of fish landed, current market price and methods of marketing. Fish samples were bought for laboratory analyses.

Results

1. HYDROGRAPHY

Figure 1 shows the distribution of surface temperature conditions in Sorsogon Bay. There are three major water masses inside the bay – a warm mass in the southeastern side, a cold mass in the center extending to the northeastern side and a similarly cold mass in the western side extending to the mouth of the bay to the narrow channel.

Salinity reading inside the Bay is low as shown in Figure 2. The pattern of salinity distribution appears to follow that of the temperature distribution.

2. PLANKTON

Figure 3 shows the distribution of zooplankton concentration in Sorsogon Bay in ml/m^2.

Plankton concentration is highest in the western side of the Bay especially near the mouth of the bay. A value of 8 ml and above up to 18 ml/m^2 has been observed near Dibughan Island. In the northwestern part of the bay a concentration of 8 ml up to 12 ml/m^2 has been noted. The area is quite large, about 1/6 of the entire bay. The area northeast of Sablayan Island also shows a concentration of 8 ml up to 12 ml/m^2 of plankton.

The eastern side of the bay shows concentration of less than 8 ml/m^2.

Figure 4 shows the distribution of fish egg concentration in Sorsogon Bay in number per square meter. It will be noted that the main area of concentration is in the center of the Bay with concentration values from 50 to above 500 eggs/m^2. The eastern side has a concentration from 50 to 100 eggs/m^2. The other parts of the bay have concentration less than 50 eggs/m^2.

Fish larvae distribution gives a different picture. Figure 5 shows that the highest concentration of fish larvae is found in the eastern side of the Bay with values ranging from 30 to above 50 fish larvae/m^2. Preliminary analyses of the fish larvae showed that they belong to families Gobiidae, Myctophidae, Bregmacerotidae, Serranidae, Scombridae, Gadidae, Clupeidae, in the order of abundance.

3. BENTHOS

Figure 6 shows the benthos or bottom fauna biomass distribution in Sorsogon Bay in gm/m^2. The highest biomass concentration is found in the northeastern side of the bay just off Sorsogon town, with values ranging from 100 grams to over 600 gm/m^2. Other areas of biomass concentration but of much lesser degrees are in the northwestern side off Castilla town with values ranging from 50 to above 200 gm/m^2 and in the areas southeast of Sablayan Island with values ranging from 100 and above gm/m^2.

As to population density (Fig. 7), the eastern side, northwestern side and the southeastern side predominate in terms of number of individual bottom animals/ m^2. The density in the eastern side reaches up to 900 individuals/m^2 while in the northwestern and southeastern sides the densities reach up to 700 individuals/m^2.

4. TRAWLING EXPERIMENTS

Two areas were chosen for the trawling experiments in Sorsogon Bay. One area was off Bucalbucalan in the northwestern side of the bay near Castilla. The other area was off Casiburan Island in the northeastern part of the bay near Sorsogon town. Two drags of 30 minutes each were made in each area, one at daytime and one at night.

Table 1 shows the result of the trawling experiments in these two areas, comparing the catch per hour between day and night trawling and between 2 different depth ranges. Deeper Bucalbucalan area showed higher catch per hour than shallower Casiburan area during the daytime draggings. The Bucalbubalan drag yielded 9.4 kg/hr catch while the Casiburan drag yielded 4.4 kg/hr. catch. The results also show that the Bucalbucalan area has a higher catch rate than the Casiburan area during the night draggings, being 16.8 and 10.8 kg/hr. , respectively.

The histograms on Figures 8 to 11 show the percentage composition by weight (in kg) of trawl catches in the two areas. A comparison of the catch composition between the two areas shows that the blue crabs (*Neptunus pelagicus*) or *Kasag* and the little green crabs (*Thalamita*) predominated more in the Bucalbucalan area than in the Casiburan area, and more especially so during the night dragging.

In trawling at day time in Bucalbucalan area, the slipmouths (*Leiognathus* spp.) or *sapsap*, more specifically *Leiognathus splendens* and *L. ruconius* predominated the catch. The other fishes predominating were *asu-os* or *Sillago*, *Apogon* sp. and flatfishes or *dapa*.

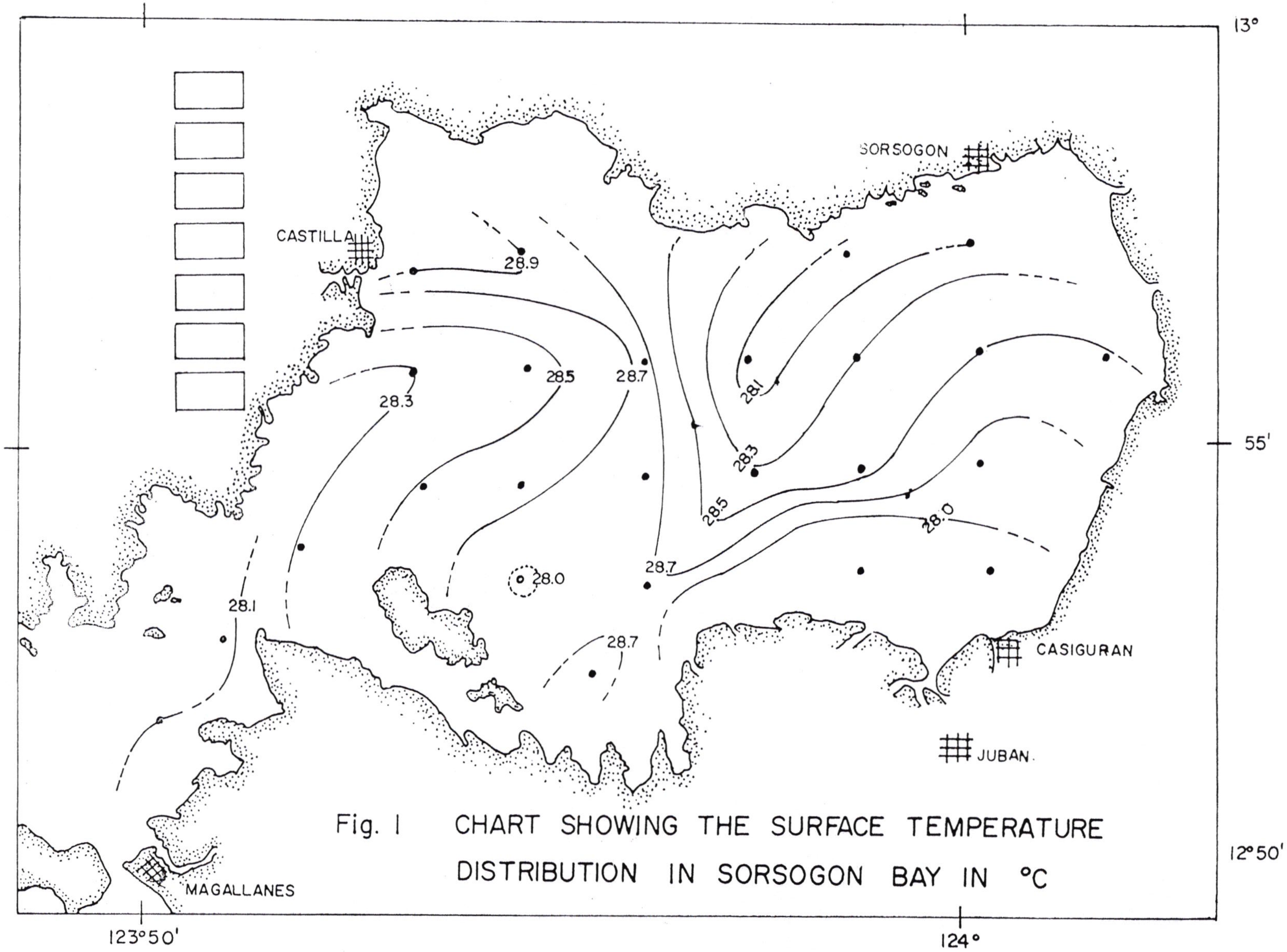

Fig. 1 CHART SHOWING THE SURFACE TEMPERATURE DISTRIBUTION IN SORSOGON BAY IN °C

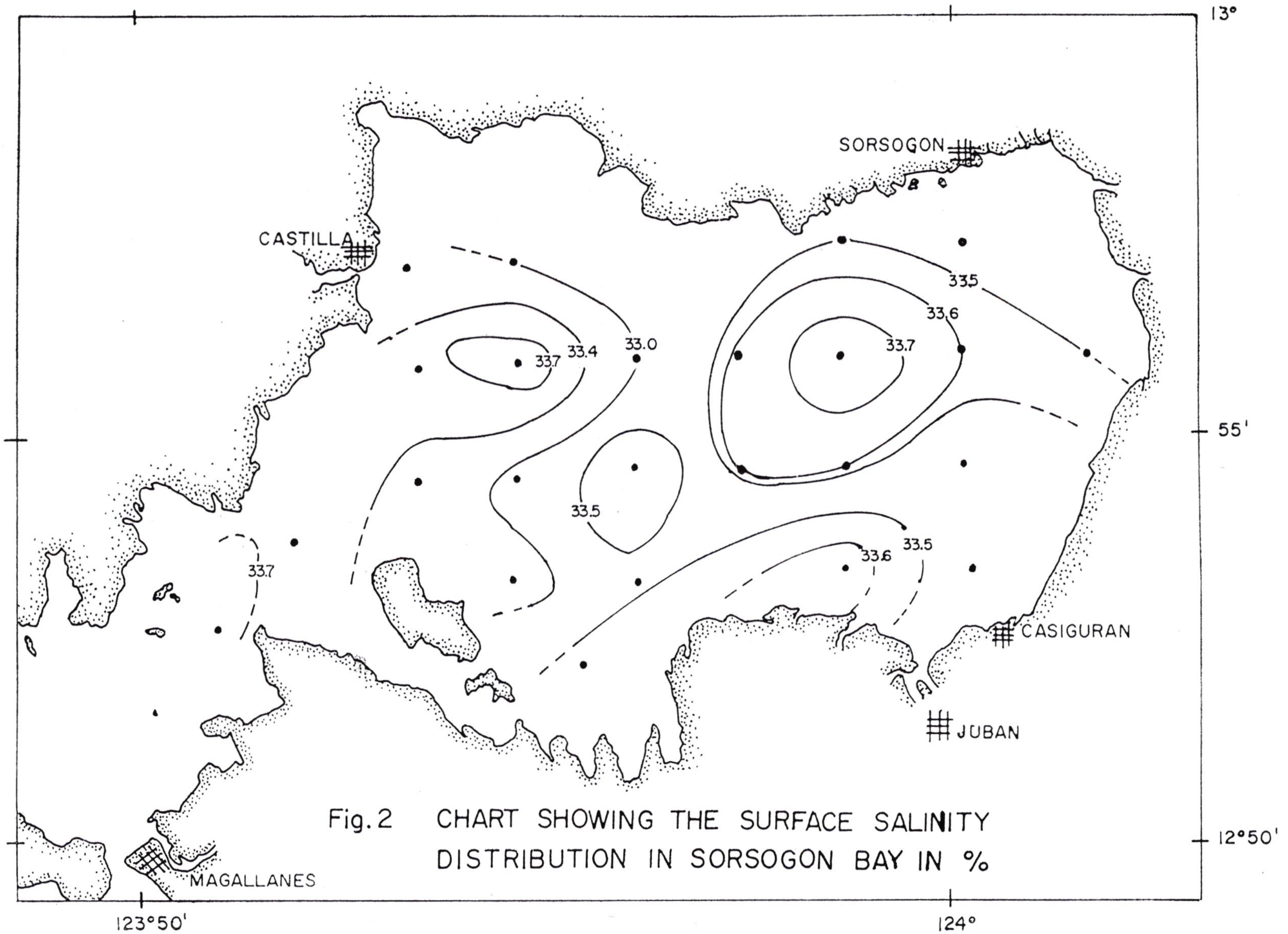

Fig. 2 CHART SHOWING THE SURFACE SALINITY DISTRIBUTION IN SORSOGON BAY IN %

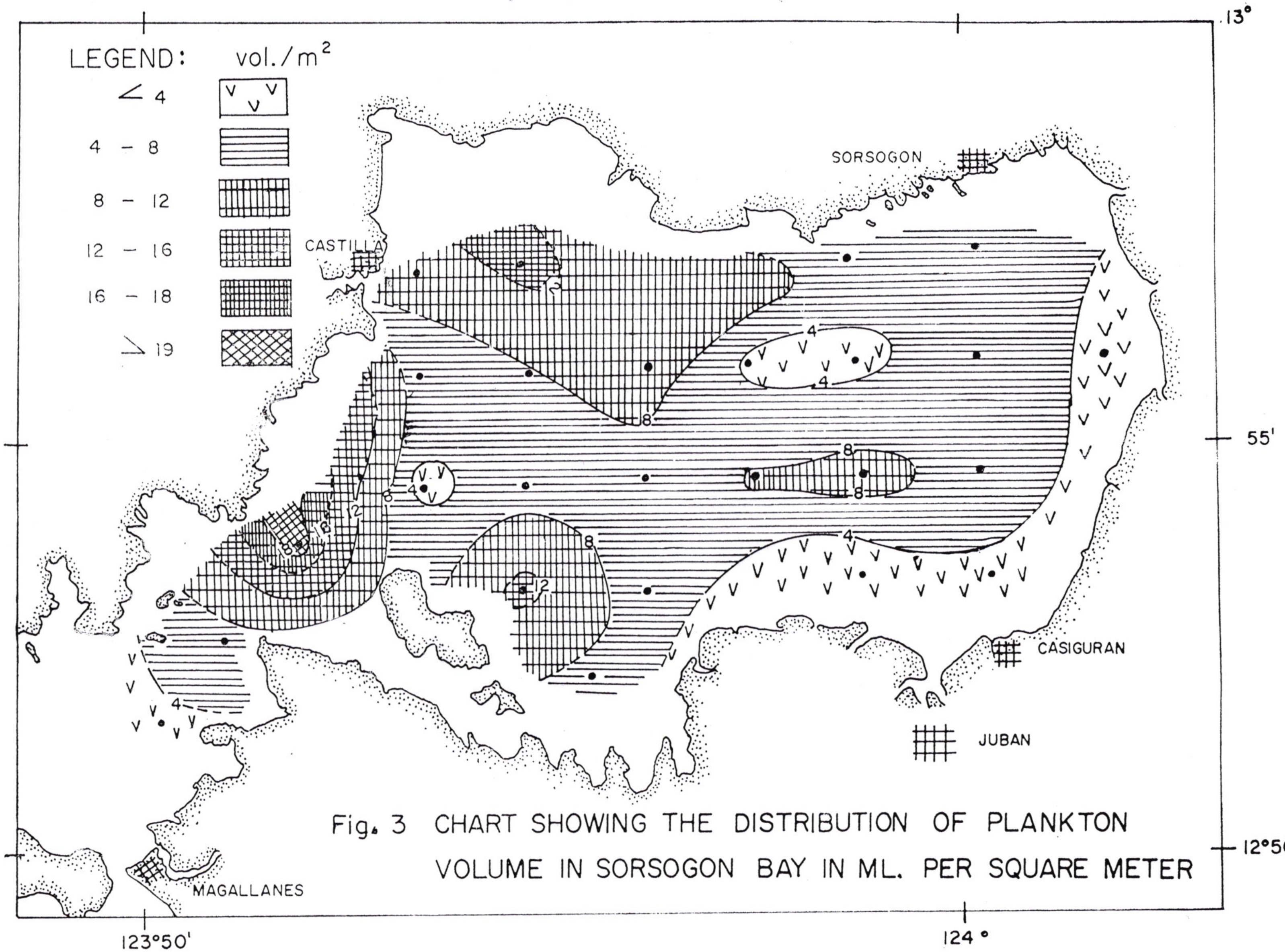

Fig. 3 CHART SHOWING THE DISTRIBUTION OF PLANKTON VOLUME IN SORSOGON BAY IN ML. PER SQUARE METER

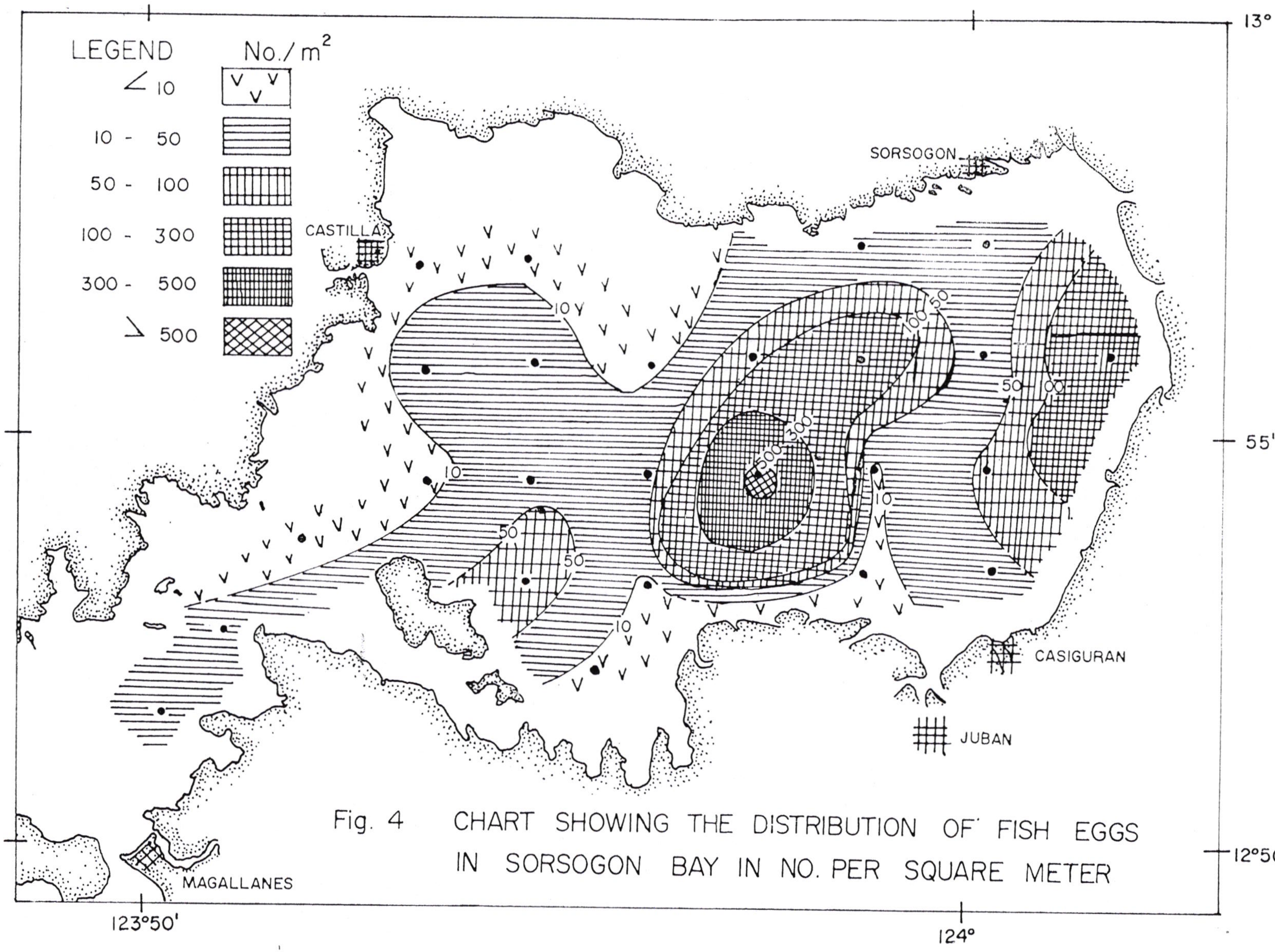

Fig. 4 CHART SHOWING THE DISTRIBUTION OF FISH EGGS IN SORSOGON BAY IN NO. PER SQUARE METER

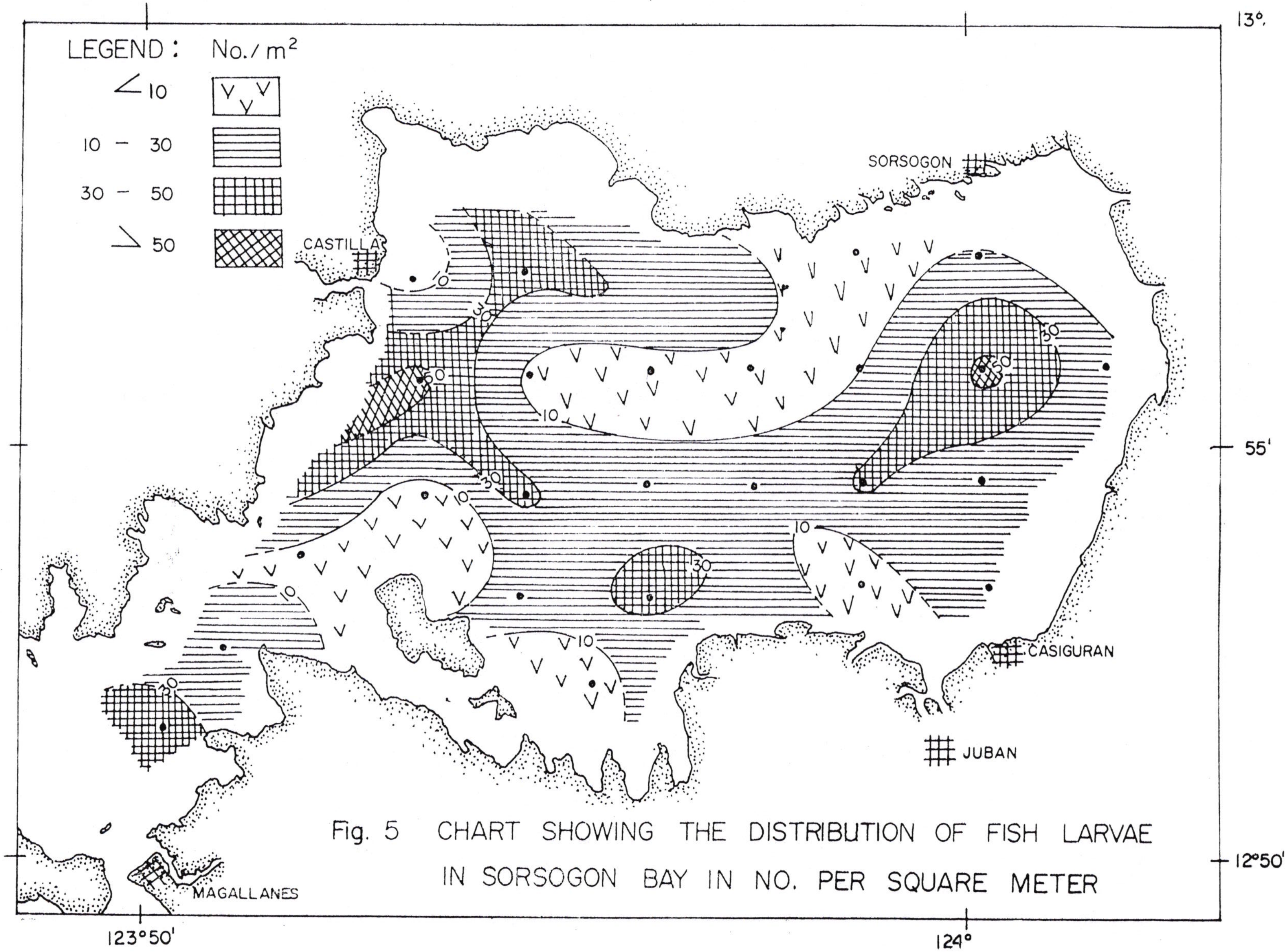

Fig. 5 CHART SHOWING THE DISTRIBUTION OF FISH LARVAE IN SORSOGON BAY IN NO. PER SQUARE METER

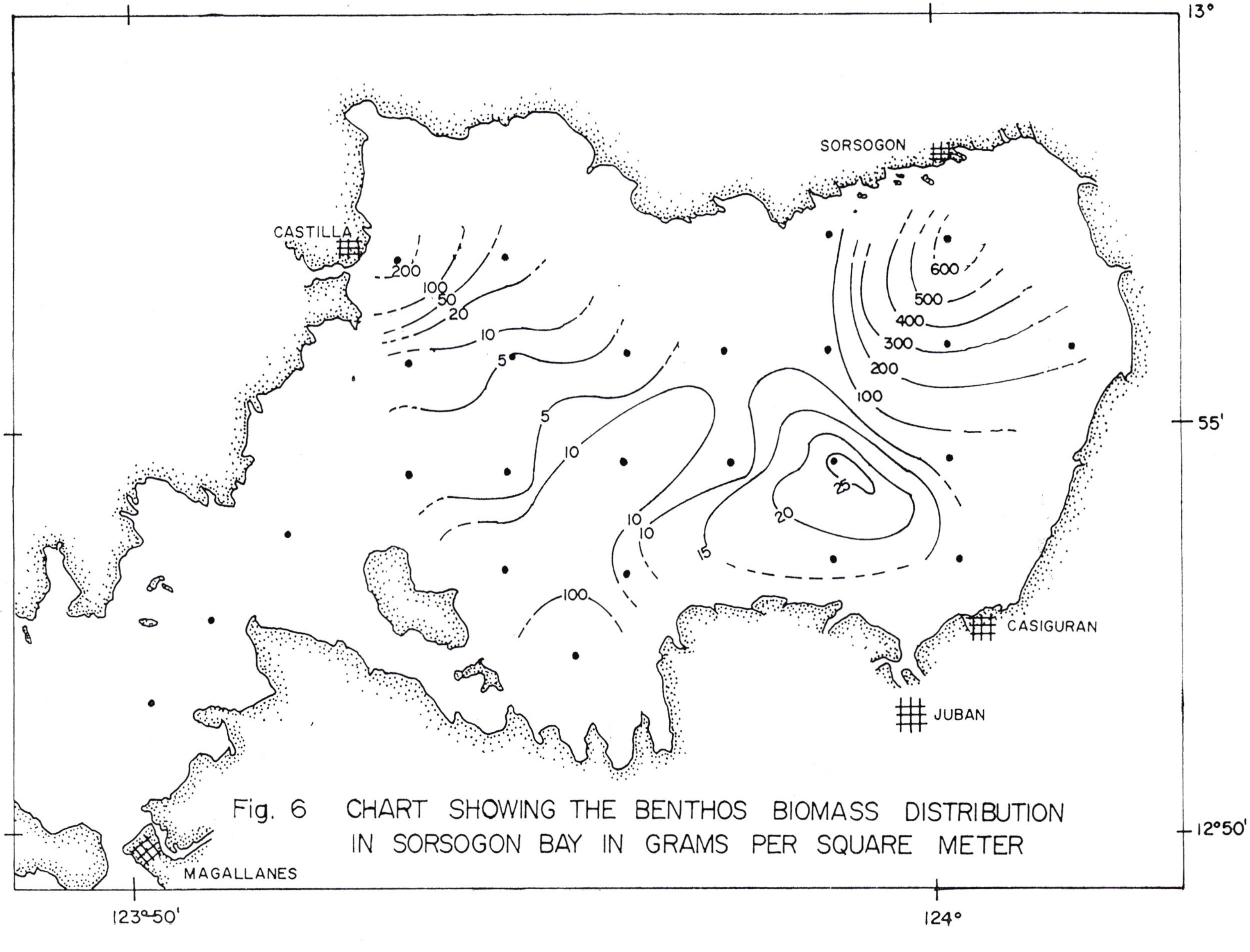

Fig. 6 CHART SHOWING THE BENTHOS BIOMASS DISTRIBUTION IN SORSOGON BAY IN GRAMS PER SQUARE METER

Table 1 Sorsogon Bay Trawling Experiments

Date 1972	Haul No.	Area	Depth range (fathoms)	Time		Trawling Time	Total Catch (Kilogram)	Catch per hour kg
				Set	Haul			
April 25	1	Bucalbucalan	3-4	0850H	0920H	30 min.	4.7	9.4
25	2	Casiburan	1-2	1008H	1038H	30 min.	2.2	4.4
25	3	Bucalbucalan	3-4	1818H	1848H	30 min.	8.4	16.8
25	4	Casiburan	1-2	1935H	2005H	30 min.	5.4	10.8

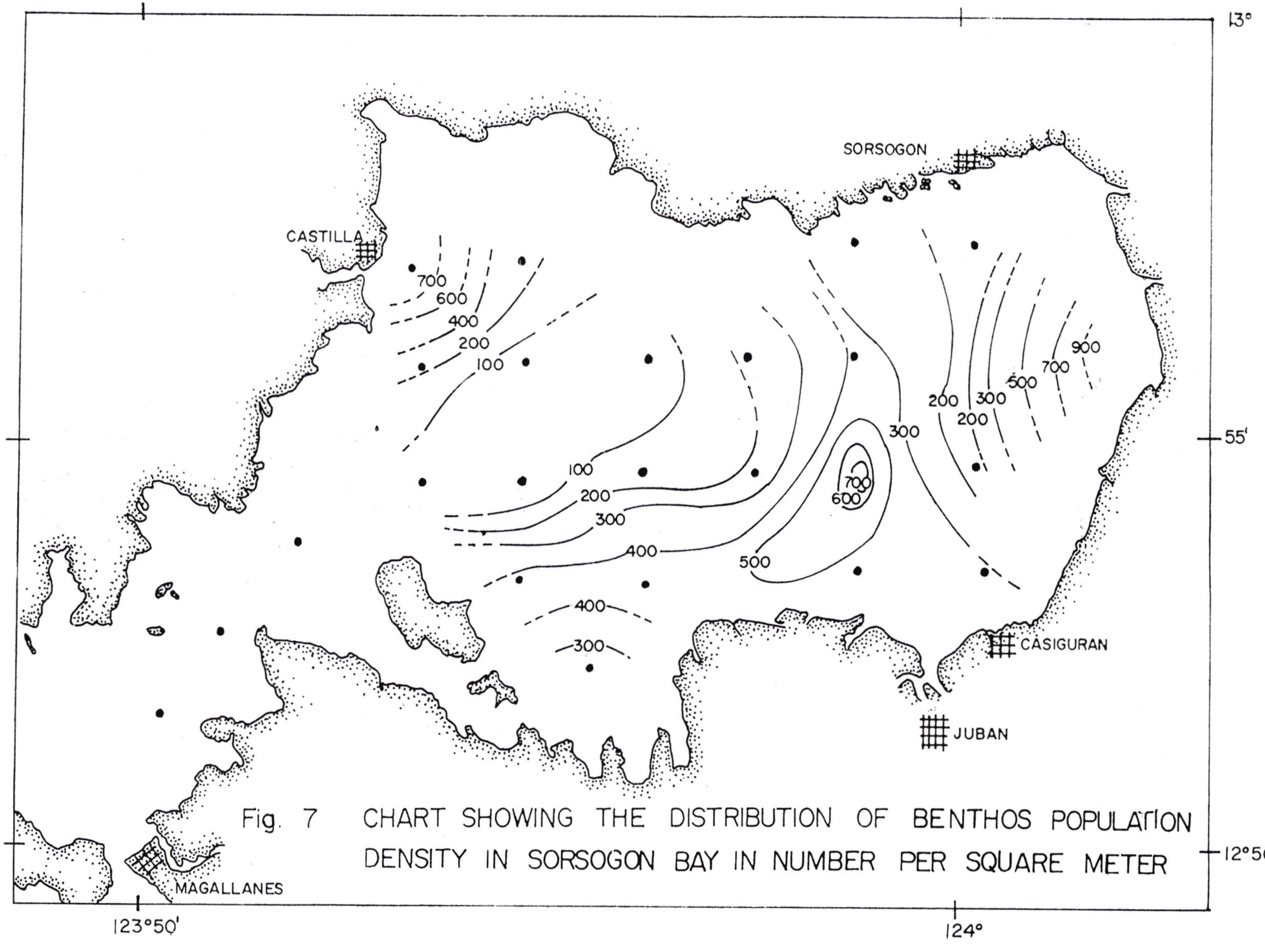

Fig. 7 CHART SHOWING THE DISTRIBUTION OF BENTHOS POPULATION DENSITY IN SORSOGON BAY IN NUMBER PER SQUARE METER

Area : Off Bucal-bucalan   Depth : 3-4 fms.   Date: 4-25-72   Trawling time : 30 mins.

Haul 1   Total cathc : 4.7 kgs. Time: 0850H-0920H Catch per hour : 9.4 kg./hr.

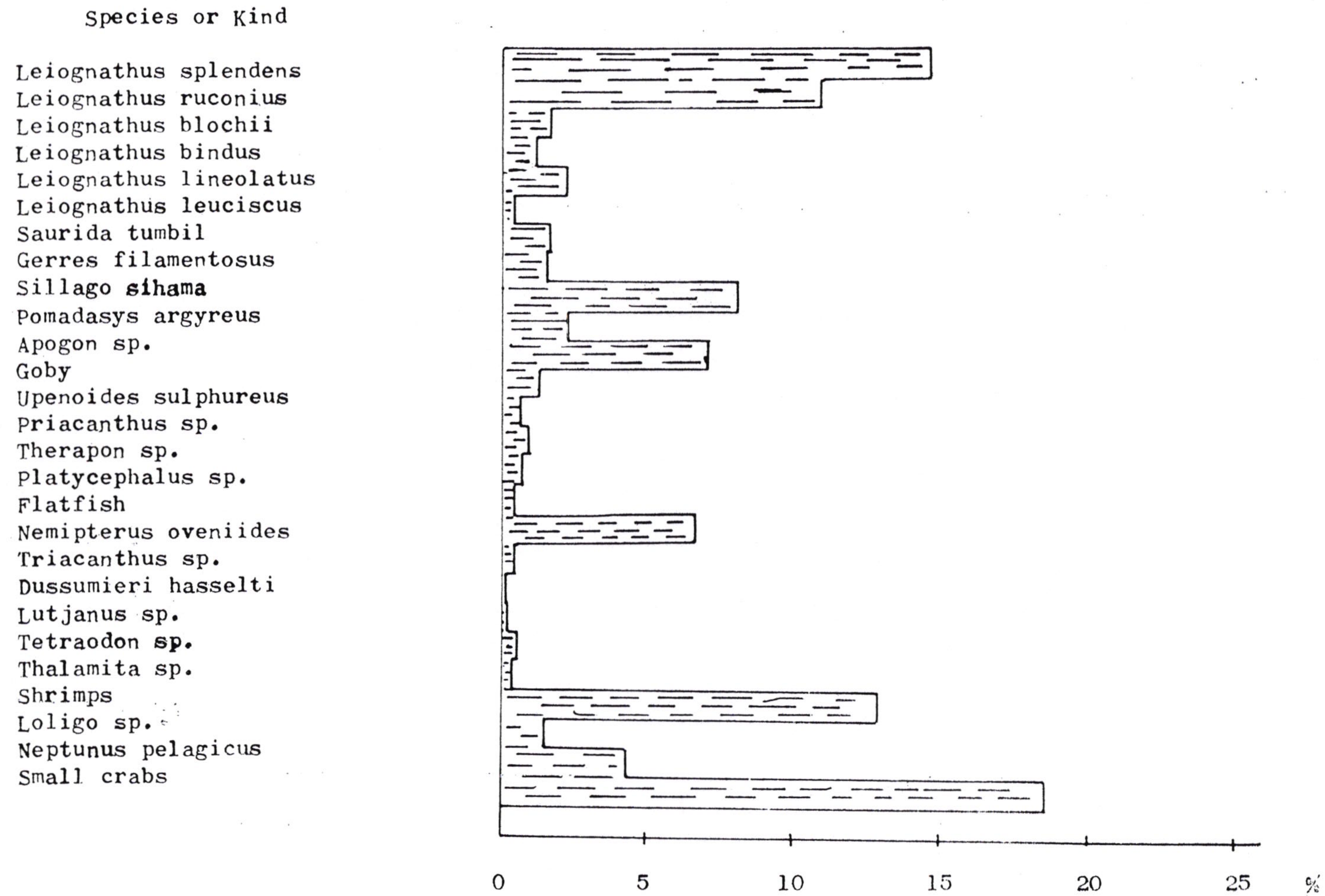

Fig. 8 CATCH COMPOSITION BY WEIGHT IN PER CENT

Area : Off Bucal-bucalan | Depth range : 3-4 fms. | Date : 4-25-72 | Trawling time : 30 mins.

Haul 3 | Total catch : 8.4 kgs. | Time : 1818H-1848H | Catch per hour: 16.8 kg./hr.

Species or Kind

Leiognathus splendens
Leiognathus ruconius
Leiognathus bindus
sillago sihama
Pomadasys argyreus
Apogon sp.
Goby
Flatfish
Monocanthus sp.
Triacanthus sp.
Sphyraena sp.
Ambassis sp.
Scorpaenidae
Moray eel
Thalamita sp.
Sepia
Shrimps
Loligo sp.
Neptunus pelagicus
Small crabs
Squilla sp.
Badoy (shell)

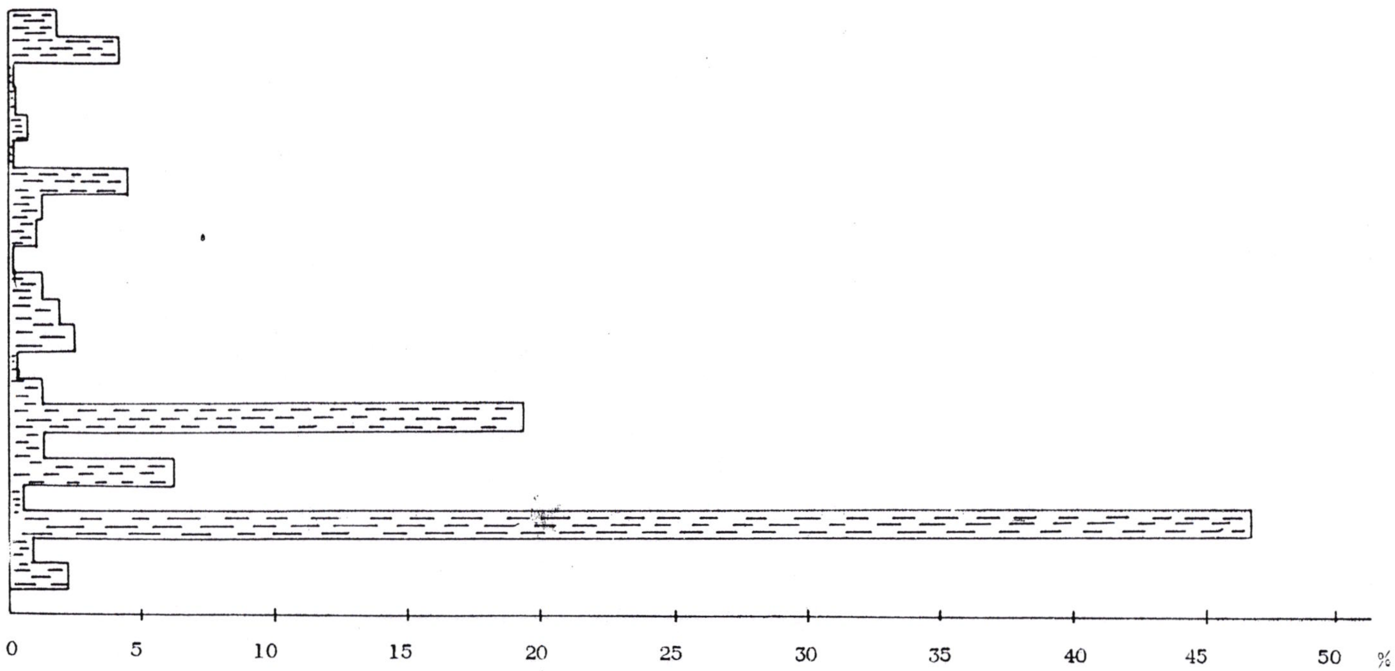

Fig. 9 CATCH COMPOSITION BY WEIGHT IN PER CENT

Area : Off Casiburan Island   Depth range : 1-2 fms.   Date : 4-25-72   Trawling time : 30 miss.

Haul 2   Total catch : 2.2 kgs.   Time : 1008 H-1038H Catch per hour: 4.4 kg./hr.

Species or Kind

Leiognathus splendens
Leiognathus ruconius
Leiognathus blochii
Leiognathus bindus
Saurida tumbil
Gerres filamentosus
Sillago sihama
Pentaphrion longimanus
Pomadasys argyreus
Apogon sp.
Goby
Upenoides sulphureus
Priacanthus sp.
Therapon theraps
Platycephalus sp.
Fistularia serosa
Flatfish
Nemipterus oveniides
Monocanthus sp.
Thalamita sp.
Sepia
Shrimps
Octupus
Loligo sp.
Neptunus pelagicus
Small crabs

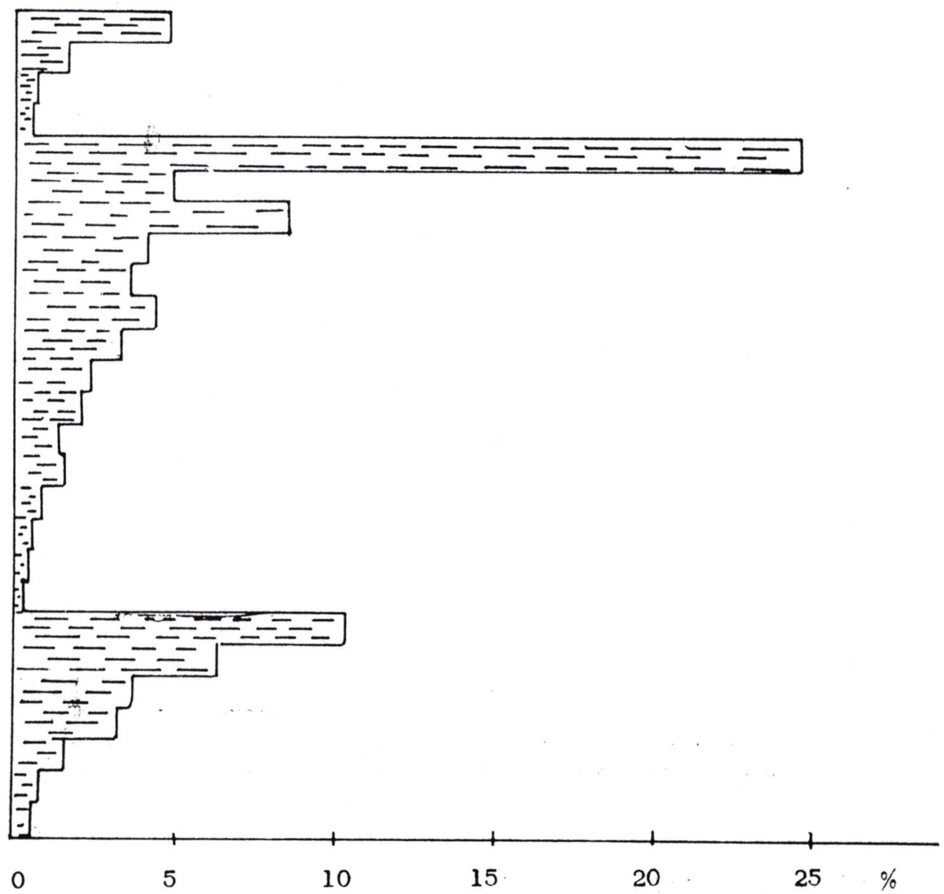

Fig. 10 CATCH COMPOSITION BY WEIGHT IN PER CENT

Area : Off Casiburan Island | Depth range : 1-2 fms. | Date : 4-25-72 | Trawling time : 30 mins.

Haul 4 | Total catch : 5.4 kgs. | Time : 1935H-2005H | Catch per hour : 10.8 kg./hr.

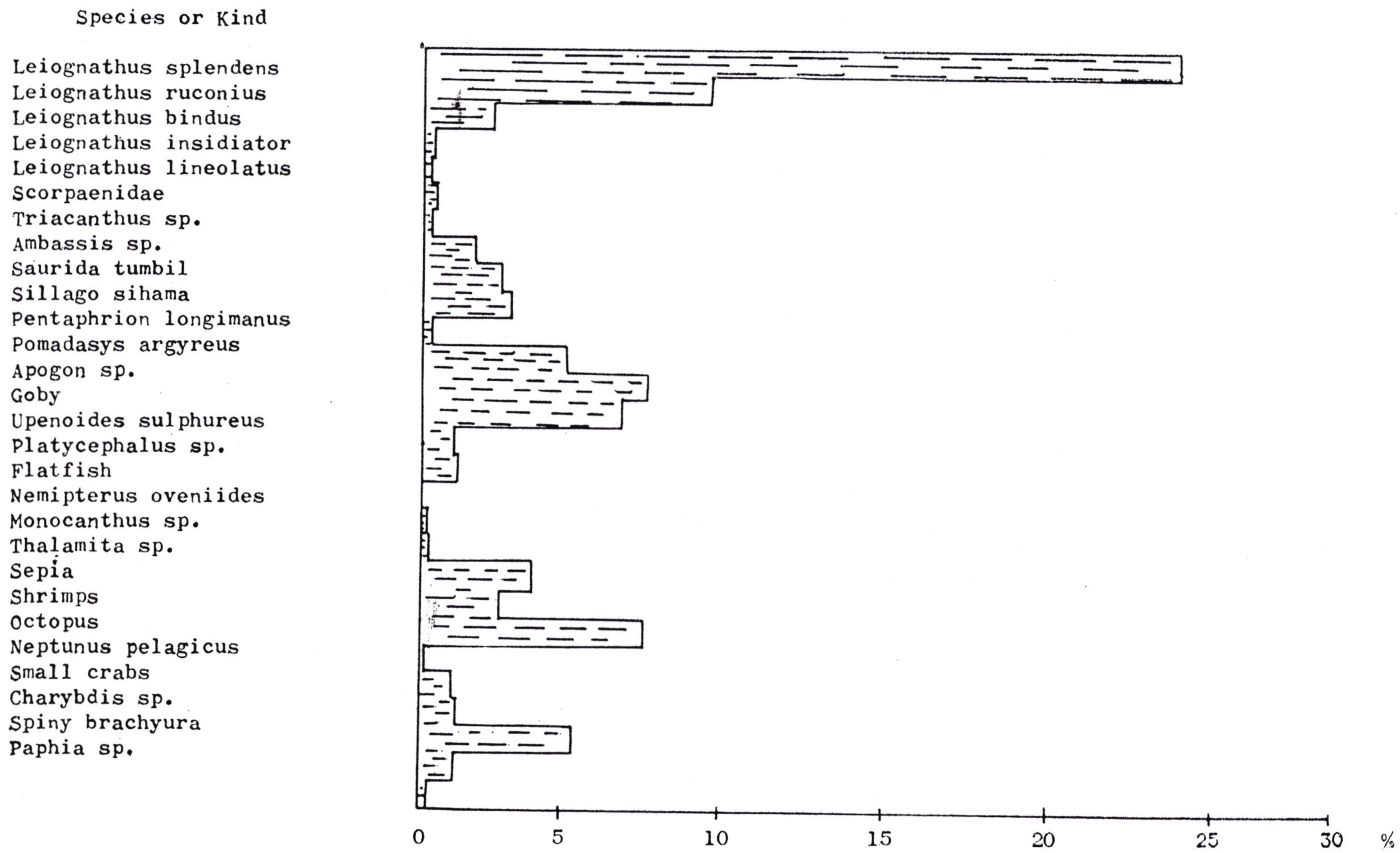

Fig. 11 CATCH COMPOSITION BY WEIGHT IN PER CENT

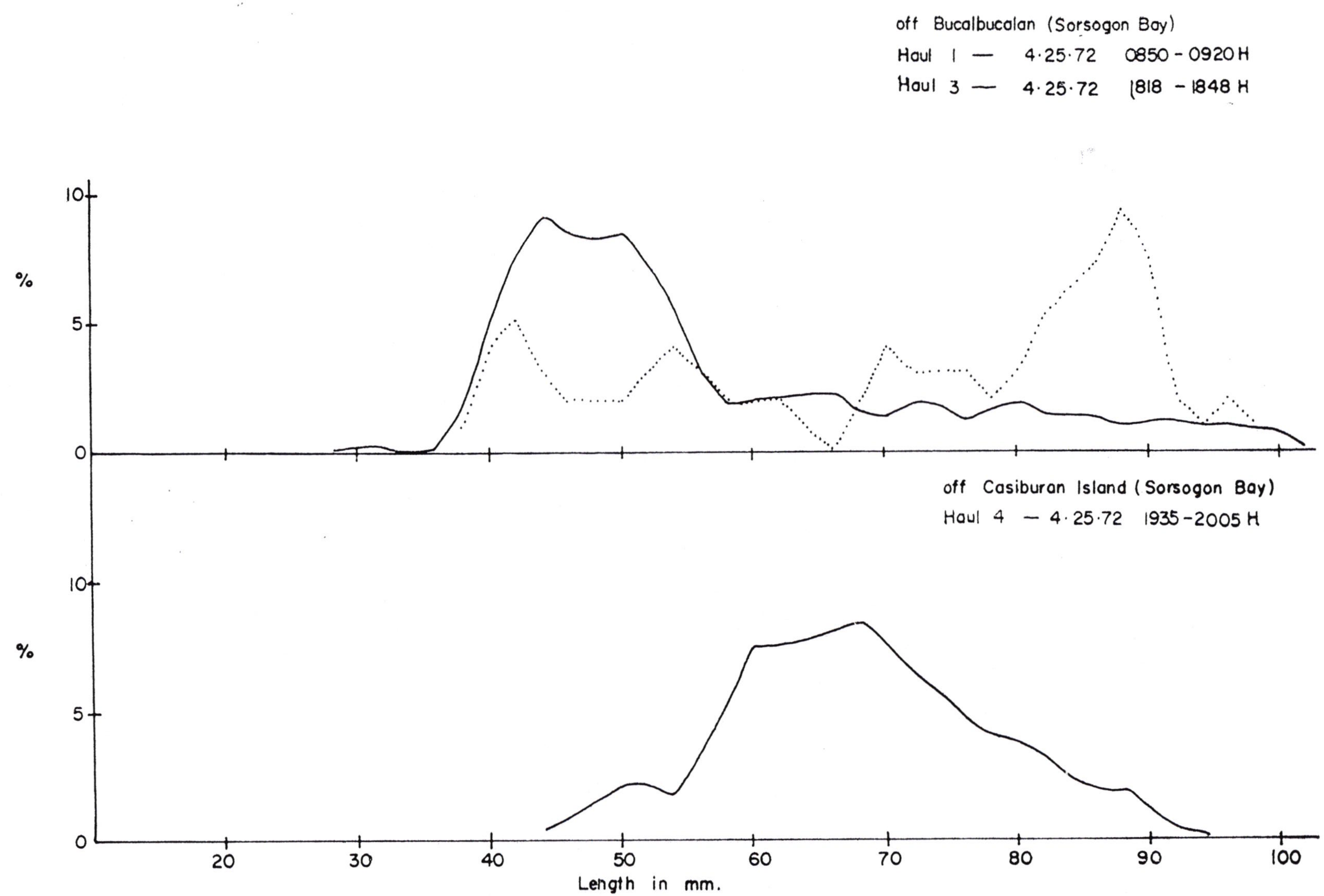

Fig 12 LENGTH COMPOSITION OF LEIOGNATHUS RUCONIUS

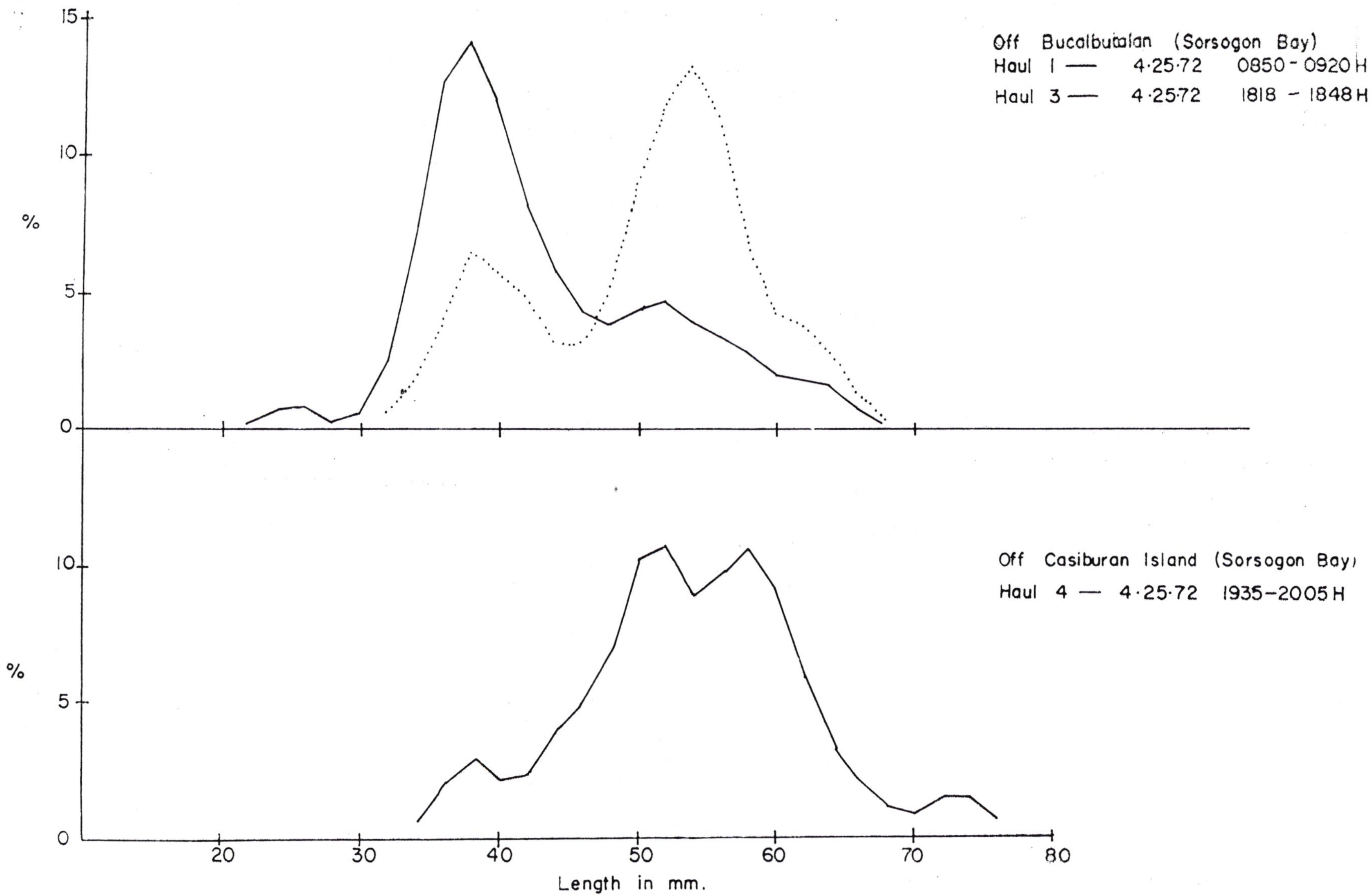

Fig. 13 LENGTH COMPOSITION OF LEIOGNATHUS RUCONIUS

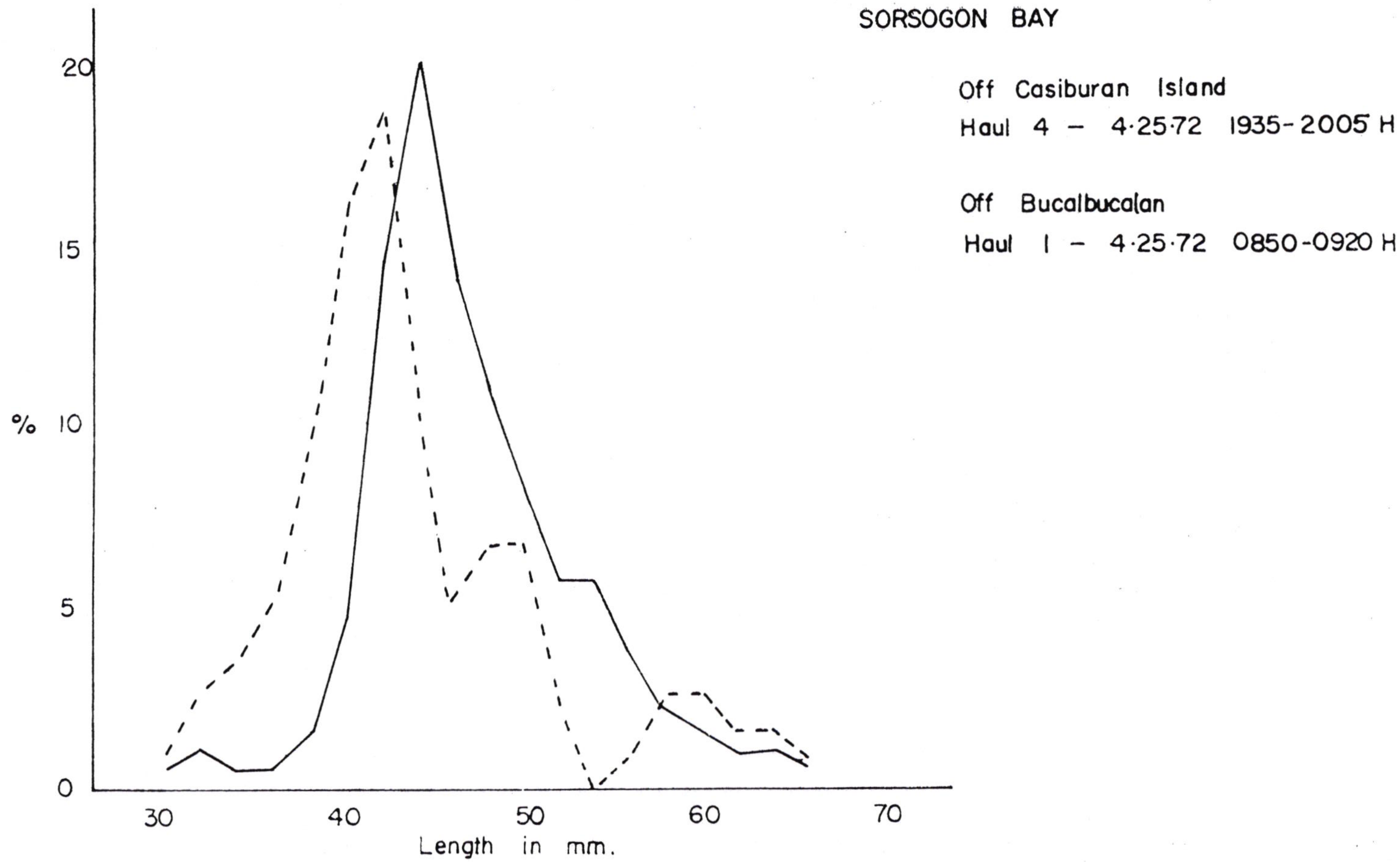

Fig. 14 LENGTH COMPOSITION OF LEIOGNATHUS BINDUS

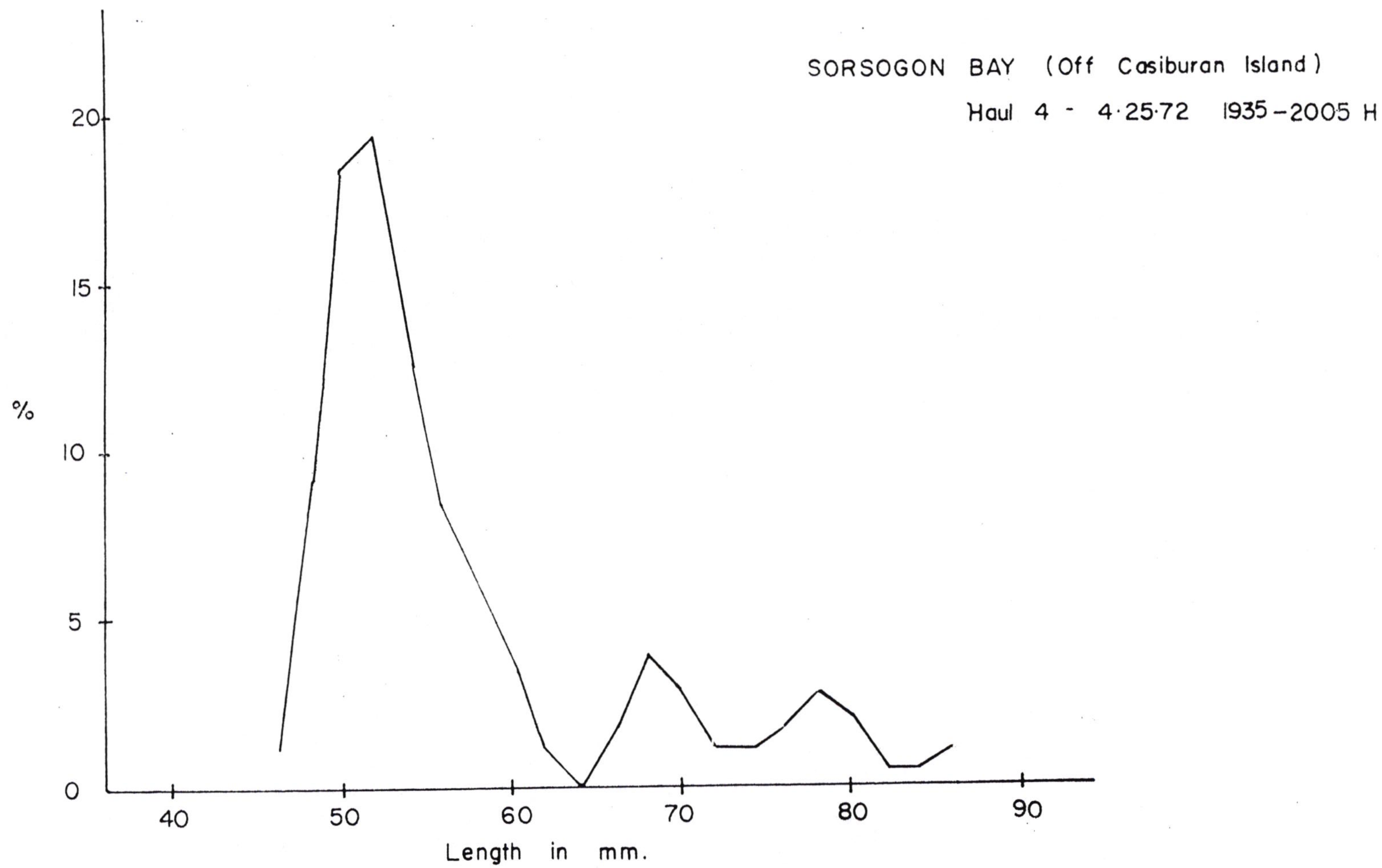

Fig. 15 LENGTH COMPOSITION OF POMADASYS ARGYREUS

In the Casiburan area the slipmouths predominated during the night dragging but the day haul showed that lizardfish (*Saurida tumbil*) or *Kalaso* predominated the catch. Other groups showing predominance were the grunts (*Pomadasys argyreus*) or *agoot*, *Apogon* sp., gobies or *talimusak*, shrimps, and the San Francisco or *Charybdis*.

5. FISH BIOLOGY

Biological investigations on fishes caught during the trawling experiments in Sorsogon Bay involved length and weight measurements and sex and maturity determinations. Fishes which are dominant in the catch were biologically examined.

Length frequency distributions in per cent of the different fish species are represented in Figures 12 to 15.

Leiognathus splendens– Sizes ranged from 26 mm to 96 mm with a mean length of 63 mm off Bucalbucalan and from 46 mm to 92 mm with a mean length of 64 mm off Casiburan Ialand (Fig. 12). Examination of the gonads showed that they were still immature (stages I to III). Smaller fishes with lengths ranging from 16 mm to 30 mm were just past their post-larval stage.

Leiognathus ruconius– Length ranges from 24 mm to 68 mm with a mean length of 48 mm off Bucalbucalan and from 36 mm to 74 mm with a mean length of 48 mm off Casiburan Island (Fig. 13). Immature ones were found in the 30–45 mm group and mature ones are from 50 to 70 mm. Two distinct groups were found in the stock.

Leiognathus bindus – In both areas (Fig. 14) length ranges from 32 mm to 64 mm but their mean lengths differ by 1 mm. All of the stock was immature.

The stock of *Leiognathus* seems to be larger off Casiburan Island than off Bucalbucalan.

Pomadasys argyreus– Larger specimens with a mean length of 85 mm were found off Casiburan Island (Fig. 15) but they were still immature, stages I and II. The smallest specimen measured was 46 mm.

Among the other fishes caught, the ambassids *(Ambassis* sp.) and the theraponids *(Therapon* spp.) were already mature. The rest were small and immature.

The blue crabs, *Neptunus pelagicus,* which were predominantly caught in both areas were gravid. Males were dominant.

6. MARKET SURVEYS, FISHING ACTIVITIES AND INTERVIEWS

The most common fishes observed in the market were *bolinau* (*Stolephorus* spp.), balanyong (*Dussumieria* sp.) *burau (Rastrelliger* sp.), *sapsap* (*Leiognathus* sp.) and *asu–os Sillago* sp.). Large quantities of *kasag* or *alimasag (Neptunus pelagicus)*, different kinds of *pasayan (Penaeus* spp.) and shells were landed daily. *Baloko* (*Atrina* sp,) was abundant. *Bugitis (Venus* sp.), piyong (*Arca* sp.), *punao* (*Circe* sp.), *batotoy* or bloody clan (*Arca* sp.) and *Halaan (Paphia !itterata)* were also abundant and commonly sold.

All these fishes, crabs, shrimps and shells were sold either by piece or by bunch or *tumpok.* Price per bunch or *tumpok* ranged from £ 0.50 to £ 1.00 and the prices of the others depend on the size.

The pelagic fish species like the *balinau* and *burau* were not caught in Sorsogon Bay but in the areas off Magallanes, while some were caught from the Pio Duran area.

Trawl catches were observed to be sold in the fish market. The bigger fishes like *torcillo (Sphyraena jello)*, goatfish or *saramulyete (Upenpides sulfureus)*, *asu–os* or whiting *(Sillago sihama)*, etc. were separated from the main catch. The rest of the catch was composed mainly of very small fishes (considered as trashfishes) which were still being sold in *tumpoks.*

The trashfish was composed mainly of small gobies, grunts, and slipmouths. The gobies were mostly small fishes, while the grunts and slipmouths were the small and immature ones also.

During the survey, fishing activities were also observed and unit counts of gear in operation were noted.

A total of 28 units of fish corrals *(baklad)* was counted. These were observed in the eastern side of the bay, east and west of Sablayan Island and in the southern side of the channel leading out towards Magallanes.

Some baby trawlers *(kaladkad)*, gill netters *(panke)* and crablift net *(bintol)* fishermen were observed operating in the Bay. Some fishermen were observed gathering *baloko* in the shallow areas of the eastern side of Sablayan Island. *Sakag* or push net fishermen were also observed fishing in the mangrove swamps off Juban.

From the surveys and interviews conducted by Bureau of Fisheries extension workers, data and information were gathered from four fishing municipalities around Sorsogon Bay and shown in Table 2. The estimated catch in kilograms per day per year was based from average of 17 actual fishing days per month.

It may be seen that in Casiguran, the average daily catch was some two kilos/fisherman or one kilo per gear. In Juban, it was about one kilogram/day per fisherman gear. In Sorsogon, it was also about one kilogram/day. The catch of the baby trawl does not even allow a kilogram per fisherman. In Castilla, however, it was also one kilogram per gear but about 10 kilos per fisherman in view of the effective use of crab lift nets. This year is however only seasonal. Considering that the area of the bay is 120 sq km the average production was 20 $kg/km^2/day$. This appears to be very low if compared to other fishing areas as Manila Bay or Malampaya Sound.

Likewise, the production of 1 to 2 kg/fisherman is equivalent to some 365 to 730 kg/man/year. The poor average per gear in the country is 700–800 kg/year, although, the better approximate would be some 1000 kilos/year/fisherman. This shows how overfished Sorsogon Bay is. The 545 fishermen who caught some 2,414.5 kg/day averaged only about 4 kg/day.

Table 2 Sorsogon Fishery

Municipality	Number of Fulltime Fishermen	Fishing Gear Used Number	Fishing Gear Used Type	Catch Average (kg/day)	Estimated Total Catch (kg/day)	Catch composition
1. Casiguran Sorsogon	150	46	Gill net	1	46	Halfbeak, mullet, sea catfish, goatfish, common whiting, grunt, *Therapon* and *Caranx*
		16	Scissors net	0.5	8	Shrimps, blue crab and goby
		9	Baklad	0.5	4.5	Blue crab, shrimp, common whiting, flat-fishes, goatfishes
		4	Kitang	1	4	Silver pike eel, sea catfish, grouper
		2	Beach seine	1	2	Blue crab, slipmouth, goby, shrimp, flatfishes and sting ray
		16	Drive-in-net (tuy-tuy)	1	16	Blue crab, shrimp, goby, slipmouth, goatfishes, rays
		4	Bocatot	1	4	Slipmouth, blue crab, and goby
		210	Bintol	1	210	Blue crabs
		1	Liftnet	1.5	1.5	Crevalle, slipmouths, anchovies, hardtail
Total	150	308			296	

Table 2 (cont.)

Municipality	Number of Fulltime Fishermen	Fishing Gear Used		Catch Average (kg/day)	Estimated Total Catch (kg/day)	Catch Composition
		Number	Type			
2. Juban, Sorsogon	30	8	Gill net	1	8	Halfbeak, mullet, sea catfish, goatfish, common whiting, grunt, *Therapon* & *Caranx*
		11	Baklad	1	11	Blue crab, shrimp, common whiting, falt-fishes, goatfishes
		6	Kitang	1	6	Silver pike eel, sea catfish, grouper
		6	Hook and line	1.5	9	Snapper, grouper, silver pike eel, *Talakitok*
		1	Drive-in-net	1	1	Blue crab, shrimp, goby, slipmouth goat-fishes and sting ray
Total	30	32			45	
3. Sorsogon, Sorsogon	285	24	Baby trawl	5	120	Shrimp, slipmouth, goby, blue crab, lizardfish, flatfish, goatfish, *malakapas*, and *Therapon*
		115	Gill net	1	115	Halfbeak, mullet, sea catfish, common whiting, grunt, goatfish, *Therapon*, *Caranx*, and croaker
		31	Bocatot	1	31	Slipmouth, blue croaker
		24	Baklad	0.5	12	Blue crab, shrimp, common whiting, flatfish goatfish, croakers, *Therapon*

Table 2 (cont.)

Municipality	Number of Fulltime Fishermen	Fishing Gear Used		Catch Average (kg/day)	Estimated Total Catch (kg/day)	Catch Composition
		Number	Type			
con't Sorso-gon, Sorso-gon		800	Crab lift (bintol)	1	800	Blue crab
		5	Kitang	1	5	Silver pike eel, sea catfish, grouper
		12	Scissors net	0.5	6	Shrimp, blue crab, goby
		5	Hook and line	1.5	7.5	Silver pike eel, snapper, grouper, grunt
Total	285	1016			1096.5	
4. Castilla, Sorsogon	80	13	Gill net	1	13	Halfbeak, mullet, sea catfish, common whiting, grunt, goatfish, *Therapon*, *Caranx*, and croaker
		920	Crab lift (bintol)	1	920	Blue crab
		2	Beach seine	1	2	Blue crab, slipmouth, goby, shrimp, flatfish
		23	Scissors net	0.5	11.5	Shrimp, blue crab, goby
		9	Kitang	1	9	Silver pike eel, sea catfish, grouper
		3	Lift net	1.5	4.5	Hardtail, crevalle, anchovy, slipmouth
		3	Bocatot	1	3	Slipmouth, blue crab, goby
		10	Hook & Line	1.5	15	Snapper, silver pike eel, grouper
Total	80	983			977	

In view of the above, it is very clear that the bay is biologically overfished and should be regulated. The baby trawl has a great catching power which is destructive to the young fishes in the bay. The trawling experiments shows a catch of from 4 to 16 kg/hour.

Remarks and Recommendations

The hydro–biological observations made during the survey present only the existing conditions at that particular time. The results of the observations were not sufficient to be used as basis for whatever regulatory measures are contemplated to be enforced to conserve the fishery and marine resources in Sorsogon Bay.

The results of the trawling experiments conducted show that small immature fishes are taken aside from the big mature ones. Not all the small fishes are immature. There are small–sized fish species which are naturally small and do not attain further increase in size.

There is a need for a continuous study of the bay to provide more data and information on the changes in conditions in space and time.

Reliable catch statistics are needed for the proper evaluation of the fishery resources.

It is therefore recommended that:

(a) a program of regular hydro–biological observation and study be conducted every three months from one to two years, and

(b) a continuing program on the assessment of fish stocks be carried out in the bay, so that proper management and development of the resources can be implemented.
