Proceedings of the First Workshop on Scientific Results of FORV *Sagar Sampada*

5 - 7 June, 1989 : Cochin

Sponsored by

Department of Ocean Development &
Indian Council of Agricultural Research, New Delhi

Organized by

Central Marine Fisheries Research Institute &
Central Institute of Fisheries Technology, Cochin

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CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
&
CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY
COCHIN

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DIRECTOR
Central Marine Fisheries Research Institute
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Edited by

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Central Marine Fisheries Research Institute
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FOREWORD

This volume contains new information and results gleaned from deeper fisheries surveys of our Exclusive Economic Zone carried out since 1985. These surveys were made with a holistic approach towards understanding the ecological environments of living resources that lie in the sea beyond the 50 m deep belt of traditional fishing. This was made possible by the acquisition in 1984 of a modern fisheries research vessel *Sagar Sampada*, by the Department of Ocean Development and entrusted to the Central Marine Fisheries Research Institute for generating and supporting nationally co-ordinated researches aimed at creating the right kind of knowledge that would in turn, aid planned development of marine living resources on a sustained basis. Some new processing technologies and high speed demersal trawls developed in the wake of these experiences are also described.

In addition to furnishing up-to-date information concerning the fisheries resources of the EEZ, notably of the islands of Andaman & Nicobar and Lakshadweep which are fairly comprehensive, the papers that follow provide a first hand account of the various experiments onboard FORV *Sagar Sampada*. These, it is hoped would not only prove to be a valuable fund of collective national experience to build upon as we expand our endeavours towards greater incisiveness and purpose, but also stimulate thoughtful criticism that may spur truly productive and innovative developments.

Prof. V. K. Gaur,
Secretary,
Department of OceanDevelopment,
Mahasagar Bhavan,
New Delhi - 110 003.

New Delhi,
25 - 10 - 1990.

PREFACE

Eversince the multipurpose Fishery Oceanographic Research Vessel (FORV) *Sagar Sampada* arrived India from Denmark in December, 1984, the Central Marine Fisheries Research Institute, in collaboration with the Central Institute of Fisheries Technology and with the involvement of various other institutions and other user agencies has taken keen steps to put the vessel into full use for the exploration of the offshore and oceanic waters of the EEZ of India including the Andaman and Nicobar Islands, Lakshadweep and the contiguous seas. Vast data and voluminous material have been collected onboard the vessel during every cruise which were analysed and studied at the Institute and by the various user agencies.

Having completed five years of fruitful research by the vessel, it was thought necessary to evaluate the results obtained so far, so as to identify the gaps and needs for the future. The most effective way to achieve this, it was felt, was to present and discuss the results and personal experiences at a common forum and publish the same. With this objective in view, a three day workshop was organised jointly by the CMFRI and the CIFT at Cochin from 5 to 7 June, 1989 sponsored by the Department of Ocean Development and the Indian Council of Agricultural Research. The response to the workshop was so great that 72 scientific papers were presented and discussed by the cruise participants from various institutes and universities.

The content of the present volume is the scientific information gathered onboard the vessel from January, 1985 to December, 1988. The information pertain to physico-chemical properties of sea water, meteorology, primary and secondary production, zooplankton, bacteriology, water pollution, Deep Scattering Layer, epi and mesopelagic and demersal fisheries resources. Aspects of fishing gear technology relevant to the vessel and fish processing technology for non-conventional resources explored by the vessel are also incorporated.

As a result of the surveys, precise information on conventional living resources and their seasonality in the area investigated have been obtained. Large fishable concentrations of threadfin bream, ribbon fish, lizard fish, barracuda, cat fish, mackerel, bull's eye, drift fish, scad, cuttle fish, deep sea prawns and lobsters were discovered beyond the conventional fishing grounds.

The vessel also provided opportunities for testing various fishing gears developed at CIFT which resulted in designing more efficient gears for use onboard *Sagar Sampada*.

Special mention may be made of the extensive surveys made for zooplankton and the studies made on the DSL. These have resulted in assessing the richness of several planktonic groups of our waters in the eastern Arabian Sea and the Bay of Bengal both spatially and seasonally.

I take this opportunity to thank Prof. Gaur, Secretary, Department of Ocean Development and Dr. N. S. Randhawa, former Director General, Indian Council of Agricultural Research for the great support extended to the successful conduct of the workshop and to bring out the proceedings. My thanks are also due to Dr. S.Z. Qasim, Vice-Chancellor, Jamia Milia Islamia University and former Secretary, DOD for his keen interest in *Sagar Sampada* and its programmes. Dr. S.A.H. Abidi, Director, DOD was of great help in dealing with the day-to-day affairs of the vessel for which I am thankful to him.

I also wish to thank the heads of institutions and universities namely the C. I. F. T., Cochin; Madras University, Madras; Annamalai University, Parangipettai; Andhra University, Visakhapatnam; I. I. T., Madras; N. I. O., Goa; Z. S. I., Calcutta; F. S. I., Bombay; Cochin University of S & T, Cochin; N. R. S. A., Hyderabad; C. I. F. E., Bombay; Kerala University, Trivandrum; N. P. O. L., Cochin; Vikram University, Ujjain; Fisheries Department, Lakshadweep; Berhampur University, Berhampur; C. A. R. I., Port Blair; Konkan Krishi Vidyalaya, Ratnagiri; Fisheries College, Mangalore; I. I. T., Bombay; Fisheries College, Cochin; S. A. C., Ahmadabad and Fisheries College, Tuticorin who sent their scientific personnel for participating in the various cruises of the vessel.

Finally I wish to place on record my appreciation for the whole hearted co-operation shown by the scientific and other staff members of CMFRI who are deeply involved in various aspects of conducting the technical programme of *Sagar Sampada* be it on land or at sea.

P. S. B. R. James,
Director,
Central Marine Fisheries
Research Institute.

Cochin - 31,
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Inaugural Session

Shri M. R. Nair, Director, CIFT	-	*Welcome*
Dr. S. N. Dwivedi, Addl. Secretary, Dept. of Ocean Development	-	*Presidential Address*
Dr. S. Z. Qasim, Vice-Chancellor, Jamia Milia Islamia University	-	*Inaugural Address*
Dr. K. Alagarswamy, Director, Central Instituite of Brackishwater Aquaculture	-	*Felicitation*
Dr. K. J. Mathew, CMFRI	-	*Vote of thanks*

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TECHNICAL SESSION I

Sagar Sampada as a National Facility

Chairman	:	Dr. S.N. Dwivedi
Rapporteurs	:	Dr. V.N. Pillai
		Shri M. M. Meiyappan
Key-note address	:	Dr. S.N. Dwivedi

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Environment

Chairman	:	Dr. P.V.R. Nair
Rapporteurs	:	Dr. Anand Parthasarathy
		Shri V.K. Pillai

TECHNICAL SESSION III

Productivity

Chairman	:	Prof. C.V. Kurien
Rapporteurs	:	Shri M.S. Rajagopalan
		Dr. M. Srinivasan

TECHNICAL SESSION IV

Living Resources

Chairman	:	Dr. K. Alagarswami
Rapporteurs	:	Shri. K.V.N. Rao
		Dr. C. Suseelan

TECHNICAL SESSION V

Fishing Technology

Chairman	:	Prof. C.T. Samuel & Shri R. Satyarajan
Rapporteurs	:	Dr. M.D. Varghese
		Shri A.C. Kuttappan

TECHNICAL SESSION VI

Post-Harvest Technology

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Rapporteurs	:	Shri Vasant Shenoy
		Shri Cyriac Mathan

PLENARY SESSION

Chairman	:	Dr. P.S.B.R. James
Rapporteurs	:	Shri M.S. Rajagopalan
		Dr. V.N. Pillai
		Dr. K.J. Mathew
Vote of thanks	:	Dr. K. J. Mathew

Presidential address delivered by Dr. S.N. Dwivedi, Additional Secretary, Department of Ocean Development, New Delhi during the inaugural function of the Workshop

Respected Dr. Qasim, Mr. Nair, Dr. James, Dr. Alagarswamy, Dr. Jenson and Distinguished Colleagues and Friends,

It is a matter of great honour, and privilege to be in this beautiful city which is the capital of fisheries in the country. Cochin has made history in oceanographic and fishery sciences. This is the city where you have been provided generation and generation of leadership and new thought, and what you are really going through today is the result of all that. When you talk of *Sagar Sampada,* we are going from an old age to an absolutely modern age, from the nearshore waters to the distant waters. Today we are talking of the most sophisticated systems in the place of simple systems we had in the past. What we did in the International Indian Ocean Expedition with the help of 41 vessels and what was being done later with the help of a number of smaller crafts, we are now doing with a single vessel. It is this which makes us all feel proud of FORV *Sagar Sampada* and I consider myself extremely fortunate to be associated with this first workshop.

When we got *Sagar Sampada,* it has brought to us many new challenges to the forefront. It was not the work of a single individual but the work of a community of very distinguished scientists in India and abroad. Before *Sagar Sampada* came to India, we had a tradition in marine research for more than 50 years. Previously we were doing this research in the coastal universities. Then we started doing this work in very specialised institutions particularly CMFRI, CIFT etc. Then we looked at the subjects, at the regions and at various matters of fishing. During this time the fisheries has developed considerably and the industry started to have very high expectations from the community of scientists. It was at that time the global attention was focused on the Indian Ocean as a result of which it was estimated that the Indian Ocean could produce about 20 million tonnes of fish which was the same calculated by the Indian scientists from the data they had with them. Later, FAO put the figure at about 17 million tonnes. Then CMFRI and organisations like NIO evolved a figure of 11.4 million tonnes on the basis of their data. Again, this morning you heard about 8 million tonnes as the tertiary production in the Indian EEZ. When we give these figures, the industry will start asking us questions. Then what is our duty, what is our responsibility, what we want to do when we have got such a nice vessel ?

Once it was believed that the west coast of India is more productive that the east coast and that the majority of our fish production came from the west. The research done during the International Indian Ocean Expedition and subsequently by other organisations brought out the fact that it is the Bay of Bengal which is very central and that is where most of our fishing industries are located. But where are our commercial fishing going on? This question leads us to a serious responsibility. In such context where the oceanography and fisheries research are being done by large organisations like Ministry of Food Processing, Ministry of Agriculture, CSIR, ICAR and Universities what is role of a single vessel, Sagar Sampada ? Again, in a large country like ours where there are 350 large fishing vessels in the private sector and a large number of vessels with the Fishery Survey of India and the Integrated Fisheries Project, what should be the real role of *Sagar Sampada?* We have to be very selective in this respect. We will have to develop a national policy in which we would be able to think clearly and independently and focus our research in such a way that would be beneficial to other organizations and fishing industry in particular. How well we have discharge so far, is really a question we must discuss at this workshop, and I am happy to say that we have done well.

When you look at a problem, there are two ways for looking at it. You can always say that the beer glass is half empty but there would be somebody else who would say that the beer glass is half full. I am looking at the positive side and when I look at the results of *Sagar Sampada* , I say we have really done extremely well. When we are saying we have done extremely well we must think of the areas where we have done the work. *Sagar Sampada* being one single vessel has only a catalystic influence. It only tells you the areas, new subjects to look at and also the relationship between oceanographic parameters and fishery parameters. We know that there are seasonal fluctuations, we also know that there are annual fluctuations, and what are the reasons for these fluctuations; that is exactly what we are trying to understand. To understand this, we might look at the productivity, the biomass, and the ocanographic parameters. Our present progress is the result of what has been done by the distinguished scientists in the past; what has been done by all of you in the past, and the models which other people have followed in other parts of the world. You may look at the Scripps Institution of Oceanography for some guidance where they may take it with the Inter-American Tuna Commission. Now the Inter-American Tropical Tuna Commission could make a forecast of what could be the total catch that you are going to get. These are the kind of directions in which we would like to follow. It may take some time for us to achieve this. But with *Sagar Sampada* we should be able to make a beginning in this direction. I certainly feel that when we transform ourselves to modernisation we should understand that with the adoption of modern technology, everything does not take place overnight. It takes time. This is the process through which *Sagar Sampada* has to go. We are asking our scientists who were working with reversing bottles to take to the absolute modern methods of analysis, with the computer system provided onboard and get their analyses done and print out when they come out of the vessels. Perhaps, this might be a very big change when it was not possible for us to do things at the speed at which we wanted. But it is a point of work and all of us in this workshop must work with the help of everybody else around. Something which was taking years for analysis in the traditional expeditions carried out all over the world would only take a few days now ! This is the great facility that *Sagar Sampada* is providing you today.

Sagar Sampada, being a national facility, does not belong to any one single organization.We have an opportunity in which interaction of all the universities and Institutions concerned is possible. Particularly, we would like to invite the industry and their representatives. We would like them to tell us the problems in which they want us to investigate. How best can they participate and make use of this very valuable support or facility that India has ?

While we are talking of this valuable facility, we must think of the small island states in the Indian ocean region. Some of these island states even with much less facilities have done well. We must look at them and learn from them. Probably they have a different kind of resource. Therefore this is an area where the work done by the vessel will not only be useful to India but also to the Indian Ocean region as a whole. Whatever the work you do now will be the only reference available for many more years to come from this part of the world.

It is not that the vessels of the other countries are not fishing or not coming into the Indian ocean for oceanographic research. We have a tradition of a large number of vessels coming from various European countries and working in the Indian Ocean under physical oceanogrpahy or other programmes and also under fishing programmes. But the data available to us from these vessels is rather limited. Now you have opened up entirely a new chapter. When you are opening a new chapter, evidently you are going into an area of difficulty. You are going into the intricate realms of microbiology, pollution, theoretical computer modelling etc. All these are time consuming exercises. Therefore the basic thing that we would really like to do in the workshop is to evaluate what we have done, and what we would like to do in future.

There are atleast, as per the data available, five ecosystems along the Indian coast line. We have not really understood the production cycles and the resons for the variations on the prodution of these areas. We knew that the Arabian Sea and the Bay of Bengal are very different environments. They are closed by land in the north. We also know that there is a layer of low oxygen present throughout the year at deeper levels which surfaces every year with the advent of the monsoon. What implication does it produce every year, and how can we help the industry to use such areas where the fishes get concentrated? These are the questions we must really ask. Besides, we must all see that there are certain traditional areas, like typical taxonomy or descriptive research. These things do not find a place on *Sagar Sampada*. These have to be replaced by something modern.

To decide what exactly *Sagar Sampade* has to do is the responsibility of the Cruise Planning and Programme Priority Committee. We also have other problems. Getting equipments is very easy, but making optimum use of equipments and maintaining them in good condition is a difficult task. This is one aspect which must receive our immediate attention. Again, we have the problem of intercalibration. The data, that you are accumulating today should be comparable with the data that is being collected by other scientists all over the world or atleast in this country or in any other part of the Indian Ocean. At the end you would be able to put it together to evolve a national picture.

From the oceanographic point of view, you would be in a very difficult situation when questions on global warming are being raised. Now we know that there are going to be a lot of changes in oceanographic parameters. How these changes in oceanographic parameters are going to get affected? Let us take the case of the Bay of Bengal, where we know for certain that the number of cyclones, storms and surges have increased for the last few years. Can our vessel give reasonable data on the various kinds of physical and chemical parameters so that we may be able to pool up and workout something? Another interesting thing that has been brought out is the hypothesis that whenever there are storms, surges and cyclones in the Bay of Bengal, it would be followed by a bumper crop of prawns. So far, we have not tested it scientifically. Is it the effect of the churning of the water at the bottom? At what time intervals does it happen and with what intensity? These are the new questions which we should be able to answer. When calamities occur in nature it may also have some positive aspects. When we fight drought and other national hazards in India we should also be able to look for the kind of ecological changes these natural hazards might bring out. We are fortunate to have a reliable vessel as *Sagar Sampada* to experiment and work on such hypothesis in the sea. But in my personal opinion I feel that for such a vast area in the Indian Ocean, *Sagar Sampada*, a single vessel, is insufficient to meet the demand. But we have limitations in finance. Therefore, we should develop programmes as to how best we can use *Sagar Sampada* in collaboration with the vessels of other institutions or from the industry.

Many times industry has said that our marine fish production is stagnating around 1.8 million tonnes. This is very true. It is hightime that we should have some introspection regarding marine production. If you look at Lakshadweep, the fish production in 1974 was around 10,000 tonnes. So was the production in the Maldives. Today Maldives are saying that they are exploiting about 60,000 tonnes. In Lakshadweep it is still around the same figure. Why don't we bring out any changes in the total catch ? What has happened in Maldives to enhance the production? It was the information available on productivity, migration pattern and the oceanographic parameters of the waters that proved helpful in locating the fishery resources in Maldives. Then the fisheries group came and started investigations on fish processing and other things. Can we not really do adopt their methods, and if not why? We must say that we are very fortunate particularly in Cochin where you have got excellent fish processing units. We have got vessels of all grades. We have got an export industry. I think this is the ideal place, and forum for us to meet the other distinguised scientists from all over the country and to discuss and review the work done by *Sagar Sampada* and to evaluate its capabilities to ahieve our aims. As we are fully conscious of the national problems that we face today we must by all means try hard to better the effort to work along with the industry and link the fundamental sciences with the applied sciences. This might require long term research as we have long term perspectives to achieve. So these are the kind of challenges that we have and I think *Sagar Sampada* and this excellent institute, CMFRI, with the support of CIFT, can face these challenges with confidence.

There are many more things that we can plan and do particularly on a day like this when we have Dr. Qasim in our midst who had provided able guidance and leadership in the advancement of marine fisheries of this region from this very city for a number of years and to the country as a whole.

One of the major things that *Sagar Sampada* has achieved is the participation of the younger scientists as research fellows. The older generation has the responsibility to make them as modern as possible and give them the needed facilities, financial support and encouragement. These are some of the new challenges that we are facing and I am sure with the help and blessings of all of you and our distinguished Danida delegates who are watching our progress and whom I would request to give suggestions so that we can do still better, I am sure we will be able to go a long way.

Thank you, gentlemen,

(S. N. Dwivedi)

Address delivered by Dr. S.Z. Qasim, Vice-Chancellor, Jamia Milia Islamia University, New Delhi and former Secretary, Department of Ocean Development, New Delhi while inaugurating the Workshop

Dr. Dwivedi, Mr. M.R. Nair, Dr. Swedrup Jenson, Dr. Alagarswamy, Dr. James, Members of Danida Team here, Ladies and Gentlemen,

I must say once again that it is a great pleasure and honour to be here in this charming great city of Cochin where I spent many many years of my service. I am sorry that we could not make this function on time which was totally beyond our control. As you all know, there is always a fight between the weather and man and the weather always wins. The time will come when man will win the weather, but really I don't know when, may be in 50 years or a 100 years or even more.

When we have a seminar or a workshop of this nature, I remember my earlier years in Cochin, factually 25 years ago. In 1964 when we started work, we used to talk about having better facility, say a ship, for oceanographic work. Although we had a programme for the Indian Ocean Expedition in which many foreign vessels and scientists participated, we did not have any research vessel of our own. Of course, we had a borrowed vessel from the Indian Navy, and one or two vessels more. The *Varuna* was from the then Indo-Norwegian Project and the other, the *Conch*, from the Kerala University. These formed a sort of a fleet for our oceanographic work. The latter two vessels were small and not properly equipped. Yet some oceanographic work was done.

The first vessel built in India exclusively for oceanographic work was *Gaveshini* and she has done a marvellous job. It was not really built in India but was converted here. She is still running and has done more than 200 cruises in the Indian Ocean and in several foreign waters. Then came another very sophisticated vessel, *Sagar Kanya,* built in the Federal Republic of Germany and a few years later came *Sagar Sampada.* I remember, it was in July, 1981 when a small team consisting of 2-3 persons and I went to Europe for chartering an ice breaker to go to Antarctica. We were in Copenhagen for a week and it was at that time that I discussed with the Danish Government about the possibility (of course some talk had started earlier) of getting a ship of this type for India and I must thank one of my very dear friends in Denmark, whom you all know, Dr.Von Hansen who spent many years in Cochin as Curator of the Indian Ocean Biological Centre. He helped us a lot in this negotiation with the Danish Government and it was on 9th of March, 1983 that I, as Secretary, Dept. of Ocean Development, signed the contract in Delhi in South Block for the ship to be built in Haros. Of course, the Danish Ambassador and some members of Danida were also there at that time when the signing ceremony took place. Precisely, after 17 months say in October, 1984 the ship was delivered to us. I was to go to take delivery of the ship, but a very serious tragedy occurred when our Prime Minister, Smt. Indira Gandhi was assassinated and I could not go. However, the ceremony took place in Denmark and the ship sailed after trials and arrived in Bombay where we were all present, and from there she sailed to Cochin and I was here to receive the ship. You must be remembering the wonderful function we had here in Cochin. I remember, it was on 31st December the ship came here and on the Wellington Island the ceremony took place.

Since her arrival the *Sagar Sampada* had been doing fisheries and oceanographic work. She has done, as you have heard, a very large number of cruises in different parts of the Indian Ocean, and collected very valuable information. I must say that a little more than 4 years have passed since we have been using the vessel and this is the right time to discuss what we have done and what we have accomplished during the last four years, and this workshop is indeed very timely.

I am happy that our Danida Team is also here and I would like to express my gratefulness, gratitude and thanks to the Danish Government and to Danida for building this vessel according to our needs, according to our specifications, and then giving it to us on such wonderful terms and conditions including a soft loan, interest free, which is to be paid over a prolonged period and I think it is a very generous gift given by the great country, small but a great country, Denmark, with very high traditions of ship building and seafaring. Now this is the genesis of this vessel, which I thought is very appropriate to tell you on this particular occasion.

Now, coming to the workshop - I have just glanced through the programme which you already got in your folder. I could see that the way the seminar has been divided is indeed well thought out and very appropriate. In the beginning, there is a paper by Dr. James giving *Sagar Sampada* as a national facility. I think this is very important because we have declared atleast these two ships, *Sagar Kanya* and *Sagar Sampada* as national facilities for work. Both are effective for the time, one is the only oceanographic vessel with capabilities of deep sea exploration upto 6,000 m depth and can do a variety of functions. *Sagar Sampada* is smaller but a very beautifully built vessel and can perform different functions. It can do oceanography, it can do fishing, it can do several other jobs including deep sea fishing. So it is a very versatile vessel.

Now this national facility is not only being utilized by the ICAR but also by the CSIR, several other governmental institutions and all those institutions which are present in Cochin. I really don't know the exact number but if you look at the total of those institutions which have been represented and which have participated, it will run to, I think, quite a large number, 24 or so. I think nobody has participated from the Jamia Milia University where I have gone. The Jamia Milia people have a wonderful sense of humour. The day I joined as Vice Chancellor they named me as 'V. Sea'. So they called me only as the Vice Chancellor of the sea. They would very much like to be associated with the vessels programmes and there is a lot of interest in the department of bio-sciences. Universities form a very good training ground of potential oceanographers and marine biologists and I think this would be kept in mind when you plan the future cruises.

Dr. James has included a section on environment. I think this is a very important area because it is not just the fish alone that matters but the environment in which it lives. Today when you go to a fisheries seminar being conducted in any part of the world what they are talking about is diversity which the environment provides in fish abundance. Why is it so, what is the reason behind it and how can we explain the appearance and disappearance of certain shoals of populations in time and space? I think this is a very important area and some explanations could be given whether it is in EEZ or beyond. I think that it would provide very valuable information. Then we will be talking about the resources. Of course, there was a paper from Dr. Mathew just before this inaugural session started, and many interesting calculations have been made on secondary production. You have come to certain figures which many of you have done in the past. I have also been involved in doing it for the Indian Ocean as a whole or a certain part of the Indian Ocean. In CMFRI, Dr. Ramachandran Nair has done it earlier so also Dr. Prasad and others. These are very interesting exercises but I feel that besides this kind of calculation, today one of the simplest and the most useful way of predicting the potential of fish population is studying the fish eggs and larvae.

I can tell you that the overall potential of what is going to be the future of fisheries year by year through clupeoid fishes, anchovies and so on are all one year group and I won't be surprised even if in mackerel you exploit not more than a year and half old age group. I would say that in the north sea where the longevity of the fishes is much longer you begin to exploit the populations in the 3rd or 4th year. The fishes are unable to sustain the large fishing pressure and show the signs of depletion. Here you don't find it so easily because the population breed in the same year and then you can fish the breed potentially. Whether you fish or not, physiologically the fishes are dead after breeding has occurred. This hypothesis, I tried to explain in one or two of my papers, and I don't know whether the fishery biologists have accepted it or not, but this is my way of thinking and in prawns also it is the same story. It is only the 0 and 1 year group which you are exploiting. In 8-9 months these fishes become big enough to be harvested. So the just one year stock after breeding can be fished without much depletion. Over fishing will only happen when you destroy the breeding population to such an extent that they are unable to survive.

Apart from fisheries resources you have the fishing gear in which Mr. M.R. Nair's group has been involved and they have been able to give some interesting modifications in it and with very productive results. Some modifications have given very phenomenal results as far as the fish catches are concerned. Finally there are fish by-products in which the fisheries institutions here are involved say the IFP (Mr. Sathyarajan is here) and several others.

What really happens to the fish caught from the sea off Cochin? Now we get them in Delhi and all over India. So the transportation mechanism and preservation of fish have improved tremendously and in fact in any restaurant in Delhi, you can get prawns, jumbo prawns, lobsters, pomfrets, king fish and so on in their menu cards. They are so expensive but they are there. So it is a success story of our fishing industry that although ours is a tropical warm country, fish can reach all parts of the major consuming centres of the country in fresh condition. So here again this has to be linked with the *Sagar Sampada* programme.

Another very interesting capability which *Sagar Sampada* has and which we have not yet really utilized is that its hull is ice strengthened and can fish in the sea covered with broken ice. The idea was to have the programme of krill fishing in cold water of the southern Antarctic Ocean. It does not have to go alone but can go as a second vessel after an ice breaker has gone. I am sure that time will come when this capability of the ship will also be fully exploited.

Now, lastly about the data of deep sea fishing which *Sagar Sampada* has done. This is the only ship which has done sustained deep sea fishing. There were other vessels earlier like the Polish vessel M.T. *Muraena* and one or two Mexican vessels which came for short period but none of them has done sustained deep sea fishing. This vessel has gathered lot of very interesting and valuable information with regard to the potential and the economics of deep sea areas. Again in this connection it is very desirable, as Dr. Dwivedi has said in his presidential address, that you must involve fishing industry and you know fishing industry really means the president and secretary of the Indian Fisheries Association. They should come and attend your meetings when you do the cruise planning. In case they find something interesting they may be taken on board which would help them to develop better understanding about the economics of deep sea fishing.

With this remarks, I would say again that I am greatly honoured by participating in this very important and very timely workshop on *Sagar Sampada*. I wish you have a kind of stock checking every year or every second year which will be a very important and useful exercise. I am sure that this ship is going to bring many more laurels and credits to the fisheries community and to our country as a whole. With this very optimistic note I perform the pleasant duty of inaugurating this Workshop.

Thank you,

(S.Z. Qasim)

RECOMMENDATIONS

First Workshop on Scientific Results of FORV *Sagar Sampada*, Cochin, 5 - 7 June, 1989

SPONSORED by the Department of Ocean Development, and the Indian Council of Agricultural Research, the First Workshop on the Scientific Results of FORV *Sagar Sampada* was jointly organized by CMFRI and CIFT from 5-7 June, 1989 at Cochin. The workshop was formally inaugurated by Dr. S.Z. Qasim, former Secretary to the Dept. of Ocean Development and now the Vice Chancellor of Jamia Milia Islamia University.

The main objective of the workshop was to focus attention on the scientific contribution of the multipurpose sophisticated research vessel during the first four years since it commenced its cruises in 1985 and to evaluate the results so as to ensure better planning for the future.

The workshop comprised 6 technical sessions viz., (i) *Sagar Sampada* as a national facility, (ii) Enviornment, (iii) Productivity, (iv) Living resources, (v) Fishing technology and (vi) Post harvest technology. In all 72 scientific papers were presented and discussed among the 200 participants to the workshop. The following recommendations emerged from their discussion.

1. The workshop noted with satisfaction the enthusiasm of different user organisations to participate in the cruises of the vessel and utilise this national facility. It is recommended that this facility be extended to more user organisations. The role of the universities in this regard has to be strengthened.

2. Appreciating the presentation made at the workshop by a number of young scientists it was felt necessary to bring more young blood into this work.

3. In order to compare the data of *Sagar Sampada* with the findings of earlier exploratory research surveys, the need for intercalibrating the methodologies of data collection and the functions of different instruments onboard the vessel was stressed to ensure comparability and dependability of the data.

4. The Workshop stressed the need for standardisation of sampling methods employed by different users of this facility. The number of samples in each grid should be uniform.

5. Most papers presented pointed out the generally high level of production of biomass in the eastern Arabian Sea, the shelf region of the Bay of Bengal and in pockets around the island ecosystems. The Workshop stressed the need for intensive follow - up studies based on comprehensive data collected during different seasons than to restrict their observations to one or two cruises.

6. Considering the productivity of the sea around India as a tool for assessing the potential fishery resources, it was recommended that eggs and larval surveys would give a better picture of the fishery resources and then forecasting.

7. The Workshop stressed the need for integrating the oceanography, productivity and fisheries data so that the dynamics of the fishery resources could be better understood. Such a need for interlinking the various data is needed within the Institute and outside.

8. The very objective of the Workshop, it was stressed, should be towards evaluating the scientific contributions of the vessel and its utility for semi-commercial and commercial fishing operations. It was suggested that representatives of the Industry should be given an opportunity to participate in the planning of the cruise programmes and also participation in cruises.

9. Realising the importance of island ecosystems and the urgent need for exploiting the fishery potential around the islands, it was recommended that more intensive work should be carried out to catalyze proper action plans for island development.

10. Considering the strenuous effort put in by the scientists and technicians onboard the vessel for collection of data information, it was pointed out that monetary incentives given to them was very meagre and these should be substantially increased in the form of 'hardship allowance'.

11. It was suggested that at the end of each cruise a preliminary report is brought about as a publication indicating the objectives, area covered, data collected, the participants and achievements in

brief. This would give due credit to the hard work done by the participants onboard and also this would reduce the time lag between the data collection and detailed analysis of the results by experts.

12. The non functioning of certain sophisticated instruments onboard has been pointed out as a constraint and in this context it is recommended that all the systems onboard are maintained and kept operational by permanent technicians onboard, and young scientists are given periodical training in the operation of various systems onboard.

13. The workshop has given an opportunity to evaluate the preliminary results of the cruises of this vessel. Based on this, it is recommended that future planning be undertaken to understand resource specific problems round the year to delineate maximum exploitable levels.

14. Apart from *Sagar Sampada*, other vessels of Govt. of India and ICAR institutes are now engaged in fishery exploitation and it will be worthwhile if a joint programme is undertaken pooling all the vessel facilities and manpower which would quicken the phase of utilizing the resources of EEZ.

15. The scientific programmes of the vessel have been managed so far by CMFRI and CIFT who have borne the brunt of pressure of work on this account. There is immediate need to strengthen the shore management cell at CMFRI and also immediate placement of technicians to maintain the various systems onboard.

16. There should be a steady flow of fishery data from commercially operated large vessels to CMFRI for proper integration and dissemination through the data base at the Institute.

17. Recognising the importance of mesopelagic resources in our EEZ and considering the lack of information on this group, work has to be intensified by sampling intensively the Deep Scattering Layer (DSL).

18. There appears to be a dearth of data on chemical oceanography and trace metals. In this connection it was recommended that adequate samples are collected in each cruise, stored in frozen containers and analysed in centres where facilities are available for this purpose.

19. At present the information on fishery resources is descriptive in nature and these should be quantified through mathematical models to understand the dynamics of various factors responsible for the occurrence of these resources and for forecasting the fishery.

20. As regards sea resources it was pointed out that these are only indicative and the potential of these has to be clearly assessed by FORV *Sagar Sampada* through proper sampling techniques and standardised sampling systems. For this purpose the acoustic system onboard need to be calibrated and utilized. Although designed for deep sea trawling, the vessel is at present having some limitations and these need to be rectified.

21. The scientists should be informed in advance about their participation and responsibilities be clearly indicated. The chief scientists chosen should be a subject matter specialist with reference to the objective of the particular cruise. The participating scientists should be given opportunity to publish their findings.

22. More emphasis should be laid on fishery oriented research. Gearwise estimates of fish catch may be made and its composition be studied.

23. It is suggested that all the scientists who participated in the cruises are invited to future workshops.

24. To avoid shortage of qualified technicians onboard it is suggested that personnel be drawn from CIFNET, IMD, IIT etc.

25. Modalities of disposal of valuable fish caught should be examined.

26. It was suggested that while designing the trawl nets for the vessel, the experience of commercial trawlers should be made use of and also modern methods such as video screening of operation should be employed.

27. It was also recommended that population parameters of unexploited resources be studied so that such information will be useful when the exploitation of these resources takes place.

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TECHNICAL SESSION I

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SHIPBOARD RESEARCH FOR MARINE LIVING RESOURCES — SOME POLICY CONSIDERATIONS

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Fishery Potential

The research on the marine living resources in the Indian Ocean started during the early part of the century in various maritime universities and in some coastal states. Measurements were conducted on primary, secondary and tertiary productivity to understand the total living resource potential of the Indian Ocean. During the International Indian Ocean Expedition, the first estimate of the productivity of the Indian Ocean was made by Dr. Panikker and others. The estimated potential was 20 mt (Million tonnes = mt) of fish. This consisted of 17.0 mt from regular fishing and 3.0 mt. from substistance fishing. Later, FAO estimated the potential of the Indian Ocean around 16.0 mt. Studies based on organic production (Prasad *et al.*) indicated that the potential is 11.0 mt. The National Agriculture Commission estimated that the potential of the EEZ of India is 4.5 mt. These estimates show a very large variation and clearly indicate the necessity of conducting oceanogrphic studies to determine the carbon dioxide budget and production levels at primary, secondary and tertiary trophic levels. Along with these studies, it is also necessary to study the oceanographic parameters, which cause fluctuations in production at different trophic levels, in different regions, in time scale.

Oceanography and Fishery Inter - relation

In the central Indian Ocean, incidence of large scale mortality of fish, and occurrence of red-tide along the west coast of India have been reported. The large scale fluctuations and changes in the ecology of the oceans and movement of the fish stocks are brought about as a result of oceanogrpahic process, air-sea interaction, air-sea and land interphase and wind-induced upwelling. The wind-induced upwelling during the pre-monsoon season (March-May) results in movement of surface waters towards the west cost of India and low oxygen waters rise to the surface. The existence of this large scale upwelling phenomenon has been reported from time to time.

This was also clearly established by M.T. *Muraena* cruises during Indo-Polish survey of the Arabian Sea (1978-'79). But enough data to understand as to how and to what degree the changes in the oceanographic parameters influence the movement of pelagic stocks and bring about changes in the pattern of production and migration of pelagic and semi-pelagic fishes is not well established. Therefore, there is a necessity to conduct extensive oceanographic investigations to understand the regime of the oceans and understand fluctuations in the levels of production in space and time. These are not only common in the Arabian Sea and the Bay of Bengal but also occur in the equatorial region. The occurrence and magnitude of their variations from year to year is not yet well understood. It is with these perspective to understand the manner in which the ecology of ocean influences the living resources, India is operating a sophiscated vessel FORV *Sagar Sampada.*

For the last four decades, oceanographers have been conducting research in the Indian Ocean to understand and predict the changes in primary production which ultimately governs the changes in the fish stocks. The relationship between the primary, secondary and tertiary production and exploitable fish stocks is difficult to determine. This needs very extensive scientific data. Therefore, we are clearly aware that one single vessel like FORV *Sagar Sampada* cannot fulfill these tasks. However, due to the limitations of resources, we are not able to have many more vessels. Therefore, cruises of FORV *Sagar Sampada* should be designed in such a way as to understand relationship between ecological conditions and fluctuations in fish production and migration of fishes.

Problem Oriented Approaches

In India, fisheries are important for meeting protein needs, providing employment and export. The marine fish production is around 1.8 mt. The Fishery Survey of India, which functions under the Ministry of Food Processing Industries, deploys a large number of vessels to survey and study the productivity potential of the EEZ. Similarly, the Integrated Fisheries Project and the Central Institute of Fisheries Nautical and Engineering Training also operate vessels which assist in survey for tuna and other resources. NIO also operates RV *Gaveshini*. In addition to these efforts of the various Government institutions, there are about 350 trawlers which undertake prawn fishing. Number of organisations working in different ministries of GOI are making efforts to exploit marine living resources. Under these circumstances, the task of FORV *Sagar Sampada* becomes very specific. Its programme should be so designed that it plays a problem oriented role, which may unfold the functional relationship between levels of biomass productivity and oceanographic parameters thereby providing rational and reliable tools for assessing productivity under varying conditions and possible identification and manipulation of favourable parameters in a model which may enhance productivity. As far as possible, whilst avoiding large overlaps, some planned overlaps may be built for testing and enhancing reliability of data. Also, ships of other organisations may be used as ships of opportunity to monitor sensitive oceanographic parameters to test models of biomass production.

Catalytic Role and Collaborations with other Agencies and Industry

Keeping in view the large area of the Indian Ocean and the complexity of the tropical oceans, it is necessary that the scientists involved in planning the cruises of the FORV *Sagar Sampada*, work in close collaboration with the user agencies namely the State Government and the fishing industry. At best, FORV *Sagar Sampada* can play a catalytic role and work in areas where our information on living resources are rather limited. The limitation demands that we must undertake extensive scientific debate to delineate regional problems which can be solved with minimum shipborad efforts. The crux is to articulate a minimum set of experiments that will illuminate the dominant processes that exercise a major control. Similarly, we should also prepare metrics of long term problems, like oxygen, nutrient etc. These are time taking programmes and require large number of observations and considerable analysis and long term planning in time series. Therefore, these may also relate to IGBP programmes. With the available information it will be useful to develop a few hypotheses which can be tested. This information may also be useful to the user agencies and the industry. For this purpose, the Department of Ocean Development has constituted a Cruise Planning Committee at the national level which discusses the problems and works out the details of different cruises so that we are able to develop information in new and critical areas. The results achieved so far by FORV *Sagar Sampada* have been described briefly in the Annual Report of the DOD and detailed accounts have been published by CMFRI from time to time.

In the present workshop, it is proposed to present the results of the work done by FORV *Sagar Sampada* and discuss these with the distinguished group of scientists, administrators, policy makers and industrialists. We hope, during this workshop it should be possible to develop broad guidelines to identify problems for future investigations. It is in this context that some problems are mentioned here as indicative examples. These are breeding grounds and migration of commercially important fishes like pomfret, mackerel, tuna and tuna like fishes. List should be examined and enlarged in this workshop.

At this juncture, it is necessary to point out that FORV *Sagar Sampada* plays only a small part as compared to the total national efforts deployed through Ministry of Agriculture, Ministry of Food Processing Industries, CSIR etc.

Ecosystems

However, this vessel has been specially designed to study the multi-disciplinary oceanographic problems which affect the production, growth, migration and congregation of fisheries stocks as influenced by physico-chemical parameters. It can also investigate the deeper waters and distant areas.

The oceanographic investigations conducted from 1965 till date have also spelt out the existence of five ecosystems along the Indian coastline. These are: *The North West Coast* of India off Gujarat where zooplankton biomass production levels in column per m^2 vary between 5 and 10 ml; the *Central West Coast* of India along Bombay covering parts of Maharashtra and Gujarat where the production levels are less than 5 ml/ m^2 (where the pollution in the coastal waters is extremely high); the *South West Coast* of India off Karnataka and Kerala where occurrences of upwelling is a regular annual phenomenon and level of production reach up 30 ml/m^2; the *South East Coast* of India off Tamilnadu and parts of Andhra Pradesh upto Ongole which is characterised by the narrow continental shelf and the *North East Coast* of India off Andhra Pradesh, Orissa and West Bengal where the estuarine influence is very high. This estuarine influence results in very high productivity as a result of which, very high biomass of fish eggs and larvae have been detected at the head of the Bay of Bengal. The influence of estuarine waters and the nutrients also affect the ecology of the fishing grounds in the Bay of Bengal. In this sector, "Sand Heads" are important fishing grounds for commercial catches of prawn and shrimps. It has also been reported that the fluctuations in shrimp catches occur from year to year. The analysis of the data during the last few years also indicates that a few months after the occurrence of cyclones, generally bumper catches of prawn are reported in the Bay of Bengal. However, the time lag between the cyclones and the bumper catch and its localisation is not clearly understood. Similarly, due to the changes in the input of estuarine waters, migration of *Hilsa* stocks is also adversely affected. *Hilsa* aggregates in large numbers near the head of the Bay of Bengal but does not migrate through the Hooghly estuary due to changes in ecological conditions. These are a few indicative problems which influence the overall production of fish and consequently affect the industry by intra-seasonal and annual fluctuations.

Cruise Planning

In the absence of extensive scientific data, industry is not able to make proper estimates of the production cycles and large scale variations in the catches. They even now depend on the vagaries of nature which are brought about by changes in the oceanographic parameters that we propose to examine through the researches to be conducted by FORV *Sagar Sampada*.

This is a very extensive task with multiple variables. We, therefore, urge the scientists, administrators and planners to carefully look into the problems and decide cruise programming so that we may be able to move a step ahead to provide better answers for long term fluctuations for changes in marine living resources. While making this effort, one should clearly understand that the role of FORV *Sagar Sampada* is that of a catalyst and is complimentary to what is being done by the various Central Government organisations and other research institutes which are engaged in the tasks of research and development. We should try our best to discharge this role effectively and help in better understanding of long and short term changes.

Equipment Maintenace

The experience of operating research vessels particularly *Sagar Sampada* has brought out the necessity of improved maintenance and servicing of scientific equipment onboard. Perhaps this can best be done through Shipping Corporation of India which operates this vessel. They can provide specially trained technicians and engineers who can maintain and service essential scientific equipments on the vessel itself. The servicing and maintenance of equipments, apart from ensuring better performance, would also reduce the time spend for repairs etc.

Trial Cruises

Regular testing and checking of equipment and analysis and inter-calibration of oceanographic data logging are essential. These exercises should be done, at regular intervals, desirably every quarter or once in six months. Therefore, it would be useful if TRIAL cruises of one week's duration can be organised with the specific objective of testing the instruments, intercalibration of data and evaluating the project-wise performance.

Priorities

This workshop, critically analysing the work done, should help in sharpening our focus. It should be possible to define the problems, develop programmes of work in given time frame and also discuss priorities. We should also learn from the industry as to how we can share this facility with them and tell us about the problems which they like FORV *Sagar Sampada* to investigate. I hope these brain storming exercises and workshops will be very helpful for the Cruise Planning Committee in their future deliberations.

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SAGAR SAMPADA AS A NATIONAL FACILITY FOR MARINE FISHERIES RESEARCH : WORK DONE AND FUTURE PROSPECTS

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Abstract

The paper gives details on the salient features of the Fishery Oceanographic Research Vessel *Sagar Sampada* owned by the Department of Ocean Development and utilised by 24 different participating agencies. The scientific programme of the vessel is managed by the Central Marine Fisheries Research Institute under the Indian Council of Agricultural Research.

The major research objectives of the vessel in the disciplines of marine fisheries resources, primary and secondary production, oceanography and meteorology are given in detail. The utilisation of the vessel by the various user agencies since January, 1985 is discussed.

The results of work carried out by the vessel during the past four years by effecting 80% coverage of the Indian EEZ at depths beyond 50 m is summarised and given in terms of average catch per unit effort of demersal trawling for a total of seven selected known fishery resources such as threadfin bream, ribbon fish, lizard fish, barracuda, cat fish, Indian mackerel and deep sea lobster which are yet to be exploited commercially by the fishing industry at depths beyond 50 m. The paper also discusses the immense potentiality of another five selected under-exploited deepwater/oceanic resources viz., bull's eye, drift fish, scad, deep sea prawns and cuttle fish.

In what manner the results brought out by *Sagar Sampada* are different from information already brought out on similar resources by other government agencies is also highlighted in the paper. The future programmes of the vessel proposed during the eighth Five Year Plan are discussed in detail.

The paper also briefly summarises the achievements of the vessel in terms of development of fishing gear and post-harvest technology especially for selected under-exploited deep water resources.

The role played by the vessel in manpower development especially in creating the nucleus to build up the future manpower in this highly specialised field is also highlighted in the paper.

Introduction

The 71.5 m OAL multi-purpose Fishery and Oceanographic Research Vessel *Sagar Sampada* was constructed at the Dannebrog Shipyard Limited, Denmark under the Danish Assistance Programme to India and was delivered to the Dept. of Ocean Development, Govt. of India during November, 1984. The Danish International Development Agency (DANIDA) provided the aid for the scientific equipments.

The Central Marine Fisheries Research Institute under the Indian Council of Agricultural Research is carrying out the responsibility of planning, co- ordination and implementation of the scientific programmes of the vessel. The vessel is manned by the Shipping Corporation of India.

Major research objectives

The FORV *Sagar Sampada* has been designed for fisheries and oceanographic research in the Exclusive Economic Zone of India and the contiguous high seas. The vessel is ice strengthened to give support to India's Antarctic scientific programmes by working as far south as 60° S lat. FORV *Sagar Sampada* complements Oceanographic Research Vessel *Sagar Kanya* which is equipped for geoscientific, meteorological, physical and chemical oceanographic work by fulfilling the needs of onboard research on marine living organisms in relation to their environment.

Marine fisheries resources research is the principal function of the vessel. She is equipped for locating fish resources, assessing the extent of their distribution in time and space and quantifying the fish stocks in the column waters and on the sea bottom through the effective use of different types of fishing gear such as bottom trawls, pelagic and midwater trawls and long line with the aid of modern

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underwater acoustics and electronic data processing systems. The data acquired through these integrated methods have a high degree of reliability in estimating the commercial fish stocks and also those which are under-exploited, non-conventional and new to the fishery. Besides, the vessel carries out directed research on spawning population/fishing grounds and also on young fish which are essential for fishery production, conservation and management of resources.

Oceanographic research which forms the integral part of marine fisheries research is the second programme of the operation of the vessel. The physical, chemical and biological factors which influence and control the quality and levels of primary, secondary and tertiary production, life history of fishes and studies on special features such as upwelling, convergence, deep scattering layer and marine pollution are also being investigated. Such wide ranging studies have been made possible onboard this vessel through automatic data acquisition system, water sampling and analysis of different parameters through sophisticated instruments.

Meteorological research forming part of oceanographic research is carried out in the vessel to understand the weather phenomena over the Indian Ocean and the subcontinent particularly the effect of monsoons and tropical cyclones on the water masses.

The Central Institute of Fisheries Technology under the Indian Council of Agricultural Research is entrusted with the responsibility of designing suitable fishing gear for the commercial exploitation of both conventional and nonconventional varieties of fishes, crustaceans and cephalopods from FORV *Sagar Sampada*.

Similarly, product development with special reference to fishery resources caught by *Sagar Sampada*, especially the non-conventional varieties of fishes and other marine life also form some of the significant activities of the vessel.

Performance

The FORV *Sagar Sampada* has completed 58 scientific cruises during the period January, 1985-February, 1989; 27 in the Arabian Sea and 31 in the Bay of Bengal within the Exclusive Economic Zone of the country beyond a depth of 40 m. During the above period the vessel made 10 coverages of the waters around Lakshadweep and Andaman & Nicobar islands based on national priorities. During the 50 months of operation the vessel made representative coverage of almost 80% of the Exclusive Economic Zone of the country covering a total track distance of more than 2.3 lakhs line km, occupying over 1550 stations where meteorological, oceanographic, plankton and fishing data were collected.

Sea truth data collection in relation to studies on marine living resources conducted onboard for a total of around 1,000 days by more than 950 scientists and technical personnel representing 24 different user agencies brought to light some major findings on which further studies are being undertaken for obtaining confirmatory evidence.

Initially between January, 1985 and March, 1988 the vessel undertook an extensive survey of the Exclusive Economic Zone around the sub-continent with fixed stations for hydrography, plankton and fishing. These studies have thrown light on the large fluctuations noticed in the occurrence and abundance of selected deep water fishes and crustaceans. In order to understand the seasonal fluctuations, it was felt that the vessel should concentrate in specific areas for one year period. From April, 1988 onwards the vessel explored specific areas for a 'one-year' period at frequent intervals to study the seasonal fluctuations of various fishery resources which were found in abundance both exploited as well as under-exploited.

For the above purpose the Exclusive Economic Zone of the country was divided into six zones namely the northeast, southeast, northwest, southwest, Lakshadweep and Andaman & Nicobar waters. Taking into consideration the national priorities, the A & N waters were intensively studied during April, 1988 - February, 1989 while covering the northeast coast in alternate cruises. The programme for 1989-'90 envisages coverage of the southeast coast along with A & N area in alternate cruises.

It is proposed to cover the southwest and northwest coasts of the sub-continent in a similar manner with alternate coverages of the Lakshadweep area during the period 1990-'91 and 1991-'92 respectively. Thus by the middle of 1992 it is envisaged to complete the systematic exploration of the EEZ of the country, areawise/seasonwise with the ultimate aim of locating and charting new or virgin fishing grounds for both exploited as well as underexploited varieties of fishes, crustaceans and cephalopods.

Procedure adopted for formulation/implementation of cruise programmes

The draft cruise proposals for FORV *Sagar Sampada* for one year period are prepared by a team of scientists/technical personnel from the Central Marine Fisheries Research Institute in consultation with the members of the working groups for fisheries and oceanography for FORV *Sagar Sampada* and presented at the working groups meeting which is held at CMFRI headquarters annually. The programmes as approved by the working groups are placed before the ICAR Co-ordination Committee under the Chairmanship of Deputy Director General (Fisheries), ICAR for necessary clearance and for placement before the Cruise Planning & Programmes Priorities Committee under the Chairmanship of Secretary, DOD, Govt. of India. The scientific programme of the vessel as approved by the above mentioned 3 committees are implemented by the CMFRI. Periodic reports with regard to progress in the implementation of the approved cruise programmes are sent to the Department of Ocean Development at regular intervals.

During the third phase of the operation of the vessel, it is planned to take up detailed studies on individual fishery resources by way of intensively covering specific areas where higher concentration of the particular resources was found from the earlier cruises. During the third phase, the *Sagar Sampada* would have generated necessary information which can be utilised ultimately for the commercial exploitation of specific resources. This will include already exploited conventional resources in the deeper waters and also those of the non-conventional varieties which are yet to be exploited from the deeper and off shore areas of the Indian Exclusive Economic Zone. During the third phase the results are to be tested through the operation of suitable fishing vessels/ fishing gear for semi-commercial/commercial exploitation of the stocks.

Analysis, processing and dissemination of information collected by the vessel

During every cruise a total of 14 scientists/ technical hands representing the different user agencies are posted onboard for collection of basic data. Two fishing masters and six fishing hands drawn from Central Marine Fisheries Research Institute and Central Institute of Fisheries Technology also participate in each cruise. The data collected in the different disciplines are compiled and submitted to Director, CMFRI by the Chief Scientist of the cruise nominated for the purpose. Sea water/plankton/fish samples are analysed partly onboard and later in the shore laboratories of the respective institution. The plankton as well as fish samples are sorted and subjected to detailed study by specialist scientists at CMFRI. Similarly samples collected for the purpose of conducting processing experiments are also subjected to various tests at the shore laboratory of the Central Institute of Fisheries Technology. The preliminary results of each cruise are compiled in a standard format and brought out in consolidated preliminary reports of 10 cruises each immediately on completion of the cruises.

In order to utilise the data collected onboard to the fullest extent, specific work pertaining to these aspectes are included in the various research projects of the participating agencies which will also ensure detailed studies on individual subject by specialists in the specific discipline.

In order to attempt an evaluation of the results which have accumulated during the first 4 years operation of the vessel, it was decided to conduct a workshop of all concerned scientists and technicians for effecting necessary changes/modifications in the data collection programmes by incorporating the same into the methodology of data collection and also to provide an opportunity for specialist scientist in the various disciplines to sort out some of the problems which they are facing at present and also to suggest ways and means to overcome these difficulties by mutual discussions. A workshop of this kind was organised at Cochin from 5th to 7th June, 1989. Individual specialist scientists were requested to prepare working paper based on results achieved on the basis of analysis and processing of relevant data already collected by them. Selected papers presented at the Workshop will be brought out in the form of a publication for the benefit of policy makers in the government, scientists working in the field elsewhere and also the fishing industry for undertaking commercial ventures on selected resources. Annexure - I gives details of participation by user agencies in the various cruises of FORV *Sagar Sampada* between January, 1985 and February, 1989.

It is worth mentioning in this context that for the first time a large number of young scientists drawn from different agencies could participate in the scientific cruises of a modern fishery oceanographic research vessel and gain experience in the collection of sea truth data under various disciplines. This training component would form the nucleus for the future manpower requirement in the specialist's field. The success of this scheme has been very evident from the participation of large number of scientists and technical personnel in the various cruises.

Fishing results

Bottom trawling operations carried out by the vessel in the various fishing grounds surveyed employing different kinds of bottom trawling gear and expending a total of about 300 effective trawling hours revealed the existence of the following major fishery resources which are available in sufficient quantities for commercial exploitation beyond 40 m depth range.

Exploited Resources Offering Scope for Increased Production

1. **Threadfin bream** (*Nemipterus* sp.): Average CPUE was between 0.65 and 3.5 tonnes per hour of trawling. Comparatively rich grounds were located off Kerala (June, July), off Karnataka (July), Wadge Bank (July, August) and off Gujarat (September-November) upto a maximum depth of 100 m.

2. **Ribbonfish** (*Trichiurus* sp.): Average catch rate varied between 0.9 and 1.9 tonnes per hour of trawling. Rich grounds were located mainly off Gujarat (September-November) upto a maximum depth of 68 m.

3. **Lizard fish** (*Saurida* sp.) : Average CPUE varied between 0.25 and 0.95 tonnes per hour of trawling. Comparatively rich grounds were located mainly off Kerala coast (June) upto a maximum depth of 63 m.

4. **Barracuda** (*Sphyraena* sp.): Average CPUE varied between 0.3 and 4.67 tonnes per hour of trawling. Comparatively rich grounds were located in the Wadge Bank (June-August) and off Maharashtra coast (September, October) upto a maximum depth of 70 m.

5. **Catfish** (*Tachysurus* sp.) : Mean catch rate was 2.4 tonnes per hour of trawling. Comparatively rich grounds were located mainly off Kerala coast upto a maximum depth of 50 m during June.

6. **Indian mackerel** (*Rastrelliger kanagurta*): Average CPUE varied between 1.47 and 2.85 tonnes per hour of trawling. Comparatively rich grounds were located mainly off Orissa coast at a depth of 70 m during October.

7. **Deepsea lobster** (*Puerulus sewelli*): Average CPUE varied between 0.1 and 0.25 tonnes/hour of trawling. Comparatively rich grounds were located mainly in the Quilon Bank off the Kerala coast at depths between 130 and 770 m (December, January).

Under Exploited Deep Water and Oceanic Resources

8. **Bull's eye** (*Priacanthus* sp.): Average CPUE was between 0.8 and 4.9 tonnes per hour of trawling. Comparatively rich grounds were located in the Wadge Bank (August), off Goa (September) and off Andhra Pradesh (September) upto a maximum depth of 120 m.

9. **Drift fish** (*Psenes indicus*): Average CPUE was 7.5 tonnes per hour of trawling. Comparatively rich grounds were located mainly along northeast coast at depths between 62 and 68 m in February.

10. **Scad** (*Decapterus russelli*) : Average CPUE of 6 tonnes per hour of trawling was recorded. Comparatively rich grounds were located mainly along northeast coast at depths between 60 and 70 m in February.

11. **Deepsea prawns** (*Pontocaris* sp., *Parapandalus* sp., *Aristaeus* sp.) : Average CPUE was 0.62 tonnes per hour of trawling. Comparatively rich grounds were located mainly in the Quilon Bank off Kerala coast at depths between 130 and 770 m (December-February).

12. **Cuttlefish** (*Sepia* sp): Mean catch rate was 1 tonne per hour of trawling. Comparatively rich grounds were located off Karnataka coast at a depth of about 200 m (November).

The observations made by FORV *Sagar Sampada* threw light on the immense potentiality of the deeper and oceanic waters beyond 50 m depth, especially the abundance of fishable concentrations of under exploited deep water resources such as bull's eye, driftfish, scad and deepsea prawns. The studies also revealed the existence of fishable concentrations of resources such as threadfin bream, ribbon fish, lizardfish, barracuda, catfish and the Indian mackerel in deeper waters beyond 50 m.

The observations also confirmed the availability of fairly rich grounds for deep sea lobster in the Quilon Bank off Kerala coast at depths between 130 and 770 m during December, January and also for

TABLE 1. *Participation by user agencies in the various cruises of FORV* Sagar Sampada *between January, 1985 and February, 1989*

	Name of user agency	No. of participants
1.	Central Marine Fisheries Research Institute (ICAR)	556
2.	Central Institute of Fisheries Technology (ICAR)	221
3.	Madras University	27
4.	Annamalai University	22
5.	Indian Institute of Technology, Madras	19
6.	National Institute of Oceanography (CSIR)	13
7.	Zoological Survey of India	12
8.	Fishery Survey of India	11
9.	Andhra University	11
10.	Cochin University of Science & Technology	8
11.	National Remote Sensing Agency	8
12.	Central Institute of Fisheries Education (ICAR)	7
13.	Kerala University	7
14.	Naval Physical & Oceanographic Laboratory, Cochin	4
15.	Vikram University	4
16.	Lakshadweep Fisheries Department	4
17.	Berhampur University	3
18.	Central Agricultural Research Institute, Port Blair (ICAR)	2
19.	Konkan Krishi Vidyalaya	2
20.	Fisheries College, Mangalore (UAS)	2
21.	Indian Institute of Technology, Bombay	2
22.	Fisheries College, Cochin (KAU)	2
23.	Space Application Centre	2
24.	Fisheries College, Tuticorin (TNAU)	1
	TOTAL	950

cuttlefish off Karnataka at a depth of about 200 m during November.

DEVELOPMENT OF FISHING GEAR

While attempting to design suitable indigenous fishing gears for the commercial exploitation of the deep sea demersal resources of the Indian EEZ, the vessel introduced the concept of high speed demersal trawling, as the basis of future developmental activities. The Central Institute of Fisheries Technology designed, fabricated and tested three high speed demersal trawls viz., CIFT High Speed Demersal Trawl No. I, No. II and No. III with distinctive features. The performance of the gears was encouraging and record catches of 10, 8 and 12 t/hour respectively for CIFT HSDT I, II and III were obtained from the Wadge Bank and Quilon Bank.

Between June, 1986 and February, 1988, the CIFT HSDT series have caught 142.77 t of fish in 132 hours of trawling resulting in an average catch of 1.1 t/hour. However, the pre-commercial feasibility studies of the HSDT series, landed 111 t in 52 hours with an overall average of 2.1 t/hour.

The record catches were made possible due to the relatively high speed of trawling (3.5 and 4.5 knots/hour). Side by side with the field trials of the HSDT series, combination wire ropes were tested in the actual field operations by rigging the high speed trawls. This has led to the development of a standard combination wire rope comparable with imported wire ropes. The commercial production has been already taken up by M/s Usha Martin Industries, Calcutta paving the way for import substitution.

Where all the imported bobbin trawls failed, the one developed at CIFT has proved a great success in the trial fishing conducted in December, 1987 along the rocky Wadge Bank area of the southwest coast, with a maximum catch of 1.75 t/hour consisting of rock cods and perches.

Considering the cost factor, when each imported demersal trawl of *Sagar Sampada* costs nearly Rs. 1.25 lakhs, the cost of one HSDT developed by CIFT is between Rs. 50,000/- and Rs. 60,000/-.

Development on Post-Harvest Technology

Suitable methods and technologies are being devised for the proper preservation onboard and onshore laboratories of these 12 varieties of fishes caught during the cruises of FORV *Sagar Sampada*, by CIFT and on perfection, these techniques will help the industry to adopt the preservation techniques before they are marketed.

Freezing characteristics of several deepsea species like *Priacanthus* sp., *Pseneopsis* sp., *Elacate* sp., rock cod, oceanic squid and cuttlefish were studied and the frozen shelf-life of different species were estimated as follows:

Pseneopsis sp.	32 weeks
Elacate sp.	9 to 10 months
Priacanthus sp.	12 months

Delayed icing for rock cod from 5 to 10 hours at ambient temperature and frozen had a shelf-life of 17, 15 and 10 months at —22°C and oceanic squids 18-19 months at —22° C.

Till recently trawling operations were undertaken mostly within 50 m depth range in the coastal waters using comparatively smaller vessels except for observations made by a few of the larger vessels of the Fishery Survey of India, Central Institute of Fisheries Nautical & Engineering Training and Integrated Fisheries Project of the Govt. of India. Based on these results the industry also concentrated their effort in a narrow coastal belt mainly for the exploitation of shrimp because of its high export value.

The observations made by FORV *Sagar Sampada* threw light on the immense potentiality of the deeper waters beyond 50m depth. In terms of fishable concentrations, the survey produced formal evidence with regard to availability of a particular resource for fishing in space and time the survey carried out by the vesssel during the last four years could identify areas of fish abundance in the deeper waters especially with respect to a total of 10 major varieties which are yet to be exploited commercially from the deeper waters.

Manpower Development

So far a total of 950 scientists and technical personnel representing 24 different user agencies and Research Fellows and Associates of the DOD received training in the collection and analysis of meteorological, oceanographic, plankton and fishing data out at sea using modern standard equipments.

For the first time a large number of young scientists drawn from different agencies could participate in the scientific cruises of a modern fishery oceanographic research vessel and gain experience in sea truth data collection under various disciplines. This training component would form the nucleus for the future manpower requirements in this specialised field. The success of this scheme is very evident from the participation of large number of scientists and technical personnel and also from the achievements given in the foregoing paragraphs.

Based on the achievements of FORV *Sagar Sampada* during the past 4 years and taking into consideration the future needs of the country along these lines, the Central Marine Fisheries Research Institute has already proposed the acquisition of a new vessel in the same size range as *Sagar Sampada* through the VIII Plan document of the Department of Ocean Development to be in position by the year 2000. Similarly the Institute has also proposed acquisition of 2 numbers of slightly smaller fishery oceanographic vessels (55-65 m OAL) and technical personnel to be employed for specific studies on living resources, development of fishing gear, processing and product development.

TECHNICAL SESSION II

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DIEL VARIATIONS OF HEAT FLUXES ACROSS THE AIR-SEA INTERFACE FROM THE BAY OF PORT BLAIR

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ABSTRACT

The heat fluxes of sensible and latent heat over the Bay of Port Blair in August and September, 1988 based on the surface meteorological data collected over a period of 24 hrs in each month at an interval of 1 hour have been represented on the time scale. The latent heat throughout the 24 hrs of the day was positive during August and the air layer remained below saturation level. During September latent heat transfer was from air to sea (ie. negative) during the period 0700 - 1500 hrs indicating that condensation has taken place. This was supported by the observation of drizzling during the period with saturated condition of the air layer in the latter month. During the day time hours in both months, the relative humidity range was from 70 to 98%. Probably the high water vapour content in the air gets heated up higher than the sea surface. This may be one of the possible reasons for the transfer of sensible heat from air to sea surface during daylight hours. During the rest of the hours of the day the transfer of heat was from sea surface to air in both the months.

The observations of fluctuating parameters viz., sea-surface-temperature, barometric pressure, wind speed and direction over a diel period of 25 hrs were transformed into three cascade waves, ie. the diurnal wave, semi-diurnal wave and quarter diurnal wave which oscillated over the steady value of the respective parameters. The transformation was based on the choice of sixteen ordinates of each of the parameters equidistantly placed in the diel period. The amplitudes of the waves decreased in the order of diurnal, semi-diurnal and quarter diurnal for both air-temperature and sea-surface-temperature. The semi-diurnal wave exceeded the diurnal wave in amplitude in the case of pressure. The amplitude of semi-diurnal wave of wind speed was found higher than that of the diurnal wave in September.

INTRODUCTION

Exchange of latent heat and sensible heat across the air-sea interface is important for the heat balance studies of the atmosphere. Based on climatological parameters of the northern Indian Ocean, the heat fluxes across the sea were observed in the Indian Ocean by a few authors during the IIOE (Ramanadham and Murty, 1970).

MATERIALS AND METHODS

Diurnal observations of meteorological parameters were made at an interval of 1 hr onboard FORV *Sagar Sampada* from the Bay of Port Blair during August and September, 1988.

The parameters observed onboard the vessel were sea surface temperature (SST) (using bucket thermometer), temperature of Dry Bulb and Wet Bulb, barometric pressure and wind directions and speed. During August, the observations were started at 1800 hrs on 11-8-1988 and closed at 2400 hrs on 12-8-1988. During September, the observations were started at 1800 hrs on 29-9-1988 and the observations were wound up at 2400 hrs on 30-9-1988. In both the months, observations were made from the same area when the vessel was anchored.

RESULTS

The parameters of sea surface temperature, barometric pressure and wind speed were analysed for their wave nature by adopting the sixteen ordinate scheme (Murty, 1987) and the dominant wave forms were determined. The sensible heat and latent heat were calculated from the parameters SST, Dry Bulb and Wet Bulb temperatures by adopting the bulk aerodynamic formulae (Hasternath and Peter, 1978).

$$QE = \rho \, Le \, Cd \, (es\text{-}ea)V$$

$$QS = \rho \, CPCD \, (TS\text{-}TQ)V$$

QS - sensible heat transfer between ocean and atmosphere,

QE - latent heat transfer between ocean and atmosphere,

CD - drag coefficient (dimensionless),

CP - specific heat of air at constant pressure,

ea - vapour pressure of air, (10m above the sea-surface),

es - Saturation vapour pressure of air, (10 m above the sea surface),

Lc - latent heat of evaporation at the sea surface,

Ta - temperature of air,

Ts - sea surface temperature,

V - scalar wind speed (m/s),

p - density of air (1.175 kg m^{-3}).

The value of C is taken as 1.4×10^{-3} for low wind speeds (less than 10 m per second) according to Bunker (1976). In the above equation the effect of salinity on the saturation vapour pressure corresponding to SST was considered. The correction factor was as follows:

For salinity 35‰ $e_s = 0.98\, e_{d5}$ at the same temperature, where e_d is the saturated vapour pressure over distilled water (Letestu, 1966). The latent heat and sensible heat variation during the day were also analysed for the wave pattern in them by subjecting that data to the sixteen ordinate scheme referred to above.

The sea surface temperature (Figs. 1 and 2) was maximum at about 1800 hrs and minimum at about 0600 hrs. The diurnal wave was predominant in determining the total value of the SST during both the months. In the case of barometric pressure, (Figs. 3 and 4) the diurnal and semidiurnal waves are effective in determining net values of pressure. In the case of wind speed (Figs. 5 and 6) during August, the diurnal wave was predominant whereas in September the semidiurnal wave was predominant.

During August, in the case of latent heat, the diurnal wave dominated the total variation whereas in September, the diurnal and semidiurnal waves were equally contributing to the total variation. In the case of sensible heat (Figs. 9 and 10), the diurnal and semidiurnal waves were predominant in the latter month in determining the total diel variation of sensible heat. The average values of the sensible heat flux and the latent heat flux during the noon period for August were 36.62 Wm^{-2} and 84.8 Wm^{-2} and the averages for September were found to be -18.2 Wm^{-2} and -20.62 Wm^{-2} respectively. The Bowen's ratio at about noon was found to be about 43% during August and 90% during September indicating that both

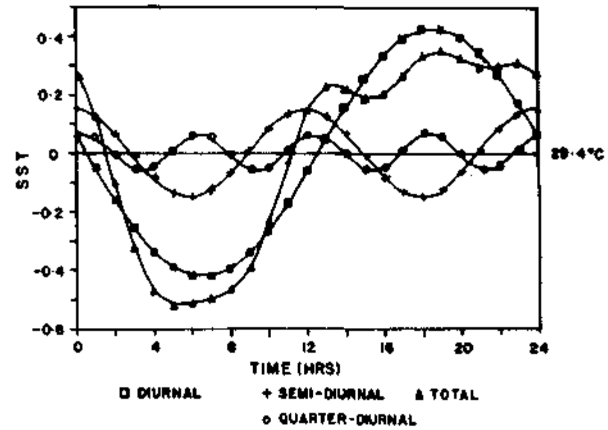

Fig. 1. Diurnal variations of SST during August, 1988.

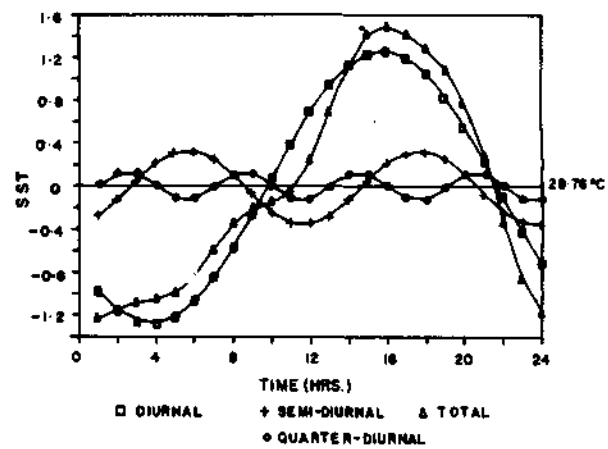

Fig. 2. Diurnal variations of SST during September, 1988.

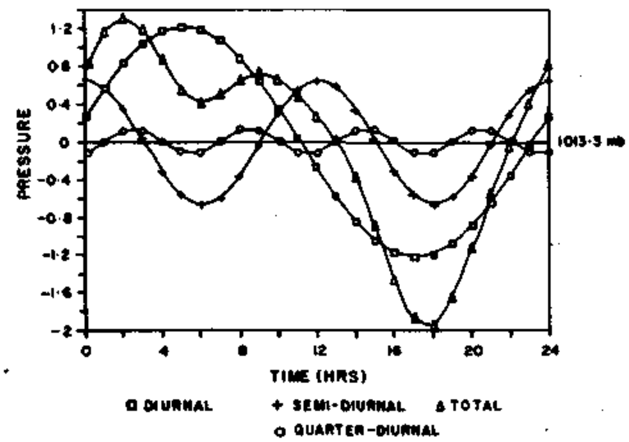

Fig. 3. Diurnal variations of pressure during August, 1988.

sensible heat and latent heat were equally important in the heat exchange from the Bay of Port Blair at least during these months. The sensible heat and latent heat during September were negative during the

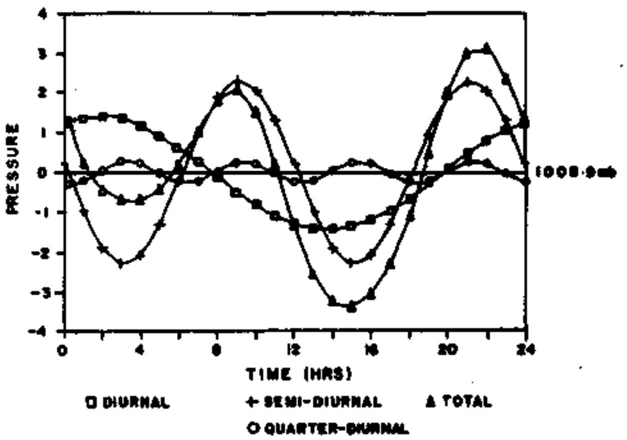

Fig. 4. Diurnal variations of pressure during September, 1988.

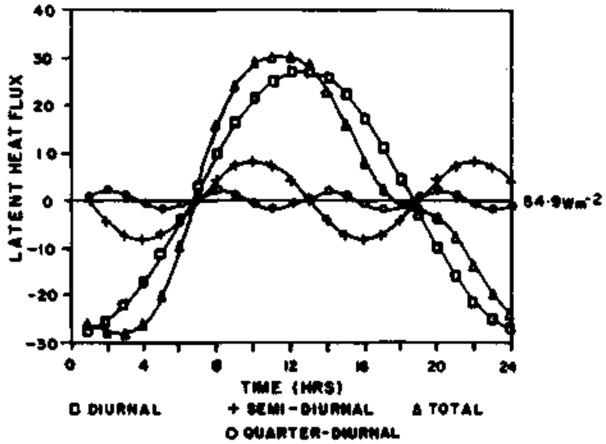

Fig. 7. Diurnal variations of latent-heat flux during August, 1988.

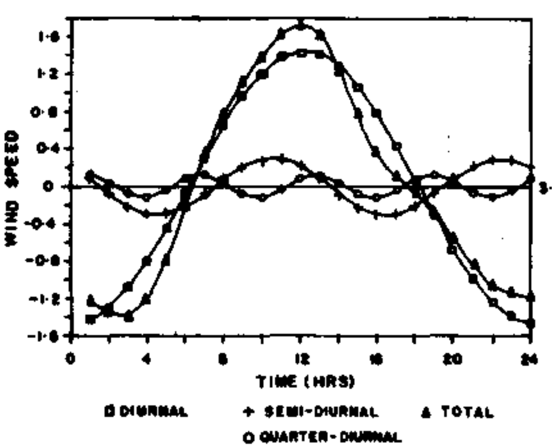

Fig. 5. Diurnal variations of wind speed during August, 1988.

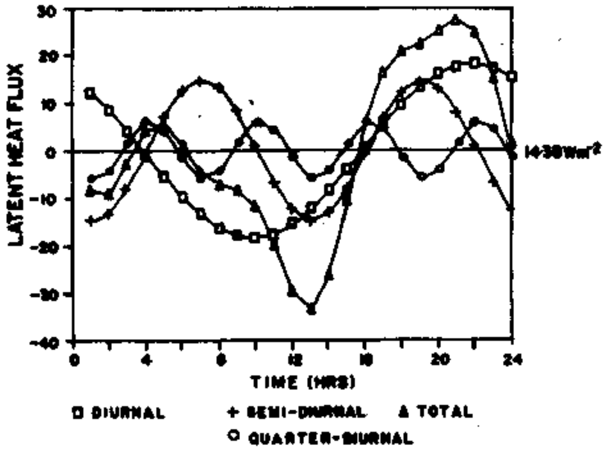

Fig. 8. Diurnal variations of latent-heat flux during September, 1988.

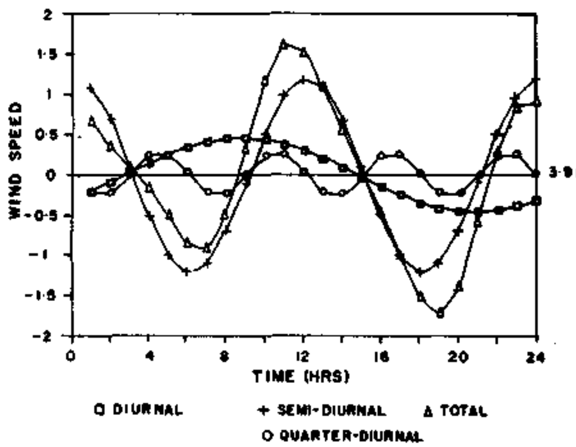

Fig. 6. Diurnal variations of wind speed during September, 1988.

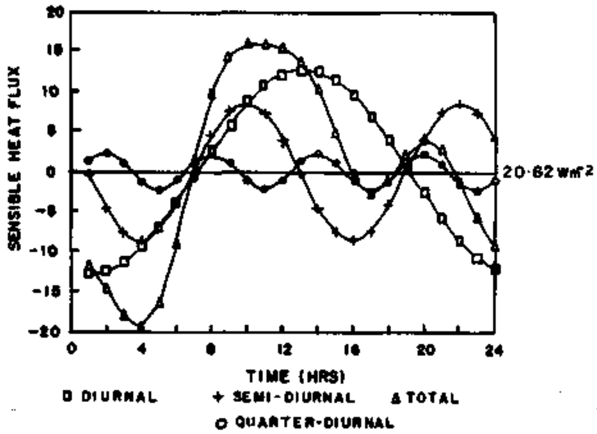

Fig. 9. Diurnal variations of sensible-heat flux during August, 1988.

noon period indicating that the heat flow was from air to sea surface. During this period the reverse of evaporation (condensation) was taking place (Fig. 8). During the same period the sky was overcast with drizzling quite often indicating that the air had reached almost saturation condition.

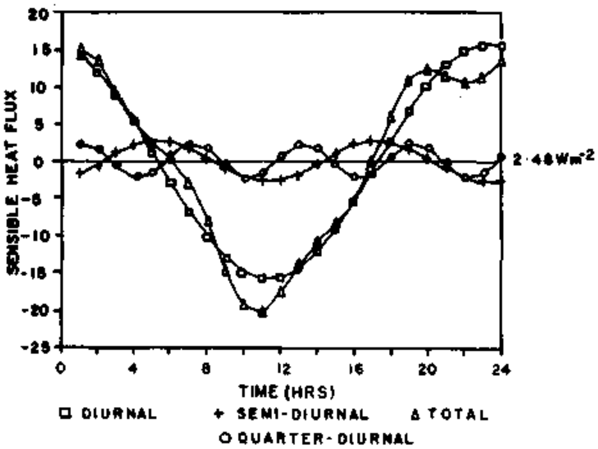

Fig. 10. Diurnal variations of sensible-heat flux during September, 1988.

Summary

The spot observations on air-sea interaction parameters were observed for a diurnal period from the Bay of Port Blair and the analysis indicated the relative importance of latent heat and sensible heat which were exchanged between the sea water and air above it (August and September, 1988). The relative analysis revealed the dominant wave forms in the parameters.

Acknowledgements

The authors are thankful to Mr. M. Srinath and Mr. M. Karthikeyan for their valuable help in computing the data. The first two authors are also thankful to D.O.D for providing fellowships.

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CHEMICAL CHARACTERISTICS OF THE WATERS AROUND ANDAMANS DURING LATE WINTER

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ABSTRACT

Water samples from standard depths (0-500m) around Andamans collected during December, 1988 to January, 1989 were analysed for various hydrographic parameters and nutrients. A study of hydrographic parameters showed that the thickness of the surface mixed layer was less around North Andaman and eastern side of Little Andaman. The distribution of nutrients showed that the surface concentrations of silicate and phosphate were high and comparable to those in other world oceans. However, the deeper values were less. But it is striking to note that the NO_3N concentration in the surface layers (0-50m) was very low and almost undetectable. This is well in accordance with the reported low primary productivity of Andaman waters. The lower inorganic nitrogen concentration in the surface may be due to the slow process of regeneration of nitrogeneous matter and absence of adequate supply of inorganic nitrogen from the deeper layers due to limited mixing.

INTRODUCTION

Compared to the other regions of Indian Ocean, Andaman Sea remains the least explored. The Andaman and Nicobar group of islands located in the southeastern Bay of Bengal between lat. 06° & 14°N and long. 91° & 94°E comprise of 321 islands collectively having an area of 8,293 km². All the islands of this archipelago have, in general, steep slopes and hence oceanic conditions prevail even in the near shore areas. Andaman and Nicobar islands separate the Andaman Sea from the Bay of Bengal and the latter is connected to the former by three main channels viz., (1) The Preparis Channel in the north (2) the Ten Degree Channel in the middle between Car Nicobar and Little Andaman and (3) The Great Channel in the south between Great Nicobar and Sumatra. Besides these, the Strait of Malacca maintains the connection of Pacific Ocean water flowing through the South China Sea to the Bay of Bengal.

The Andaman Sea is known to be rich in marine wealth and is of considerable interest to marine scientists. But very few investigations have been conducted in this area since the pioneering work of Sewell (1928, 1929, 1932). However, certain aspects of its oceanographic characteristics were studied during the International Indian Ocean Expedition and recently by certain other research vessels. During the 56th cruise of FORV *Sagar Sampada*, a survey was conducted around the Andaman Islands. The area covered lay between lat. 09° & 13° N and long. 92° & 94° E (Fig. 1).

MATERIALS AND METHODS

Water samples were collected from standard hydrographic depths (0-500 m) using reversing Nansen Bottles. Temperature was measured by reversing thermometers. Salinity, dissolved oxygen and nutrients were found out using standard analytical methods. (Grasshoff, 1976; Strickland and Parsons, 1968).

RESULTS AND DISCUSSION

Salinity

The surface salinities are in general high. The surface values which varied from 33.22 to 34.58 ‰ showed an increasing trend from south to north on the western side as well as on the eastern side. The salinity - depth profile is not uniform at all stations. At stations 1587, 1590, 1591 and 1593, salinity reached a near maximum value around 50 - 100m. Another feature of importance was the feeble salinity maximum observed in depths around 300m (Ramaraju *et al.*, 1981). The salinity showed a depthwise increasing trend (Fig.2). Different water masses were identified in this region with the help of T-S diagrams. Upto 150m depth three water masses are present; the northern dilute water, a transition water and southern Bay of Bengal water. Among these, the transition water dominated in the Jan. - Feb. period around Andaman Island (Murty *et al.*, 1981).

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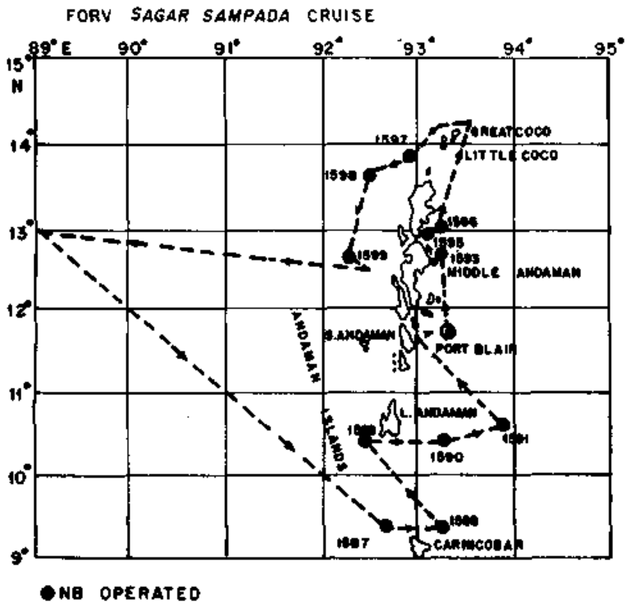

Fig. 1. Cruise Track of Cruise No. 56 of FORV *Sagar Sampada*.

In the absence of a clear picture of the circulation pattern during this season, no convincing conclusions can be arrived at. Besides, the Andaman Sea which has a very uneven bottom topography, receives very large and variable quantities of fresh water and is connected to the South China Sea through Strait of Malacca. Non- homogeneous mixing and incursion of low density water also contribute much towards the observed salinity maxima at various depths for different stations.

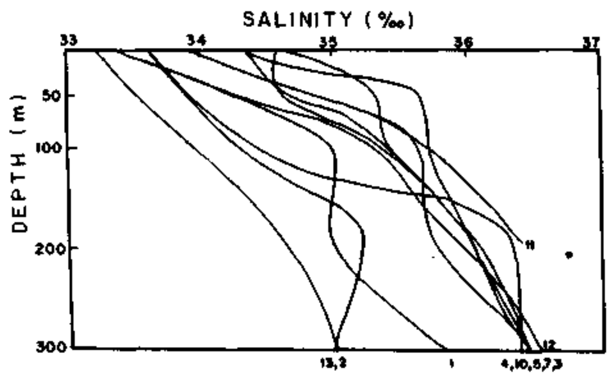

Fig. 2. Distribution of salinity with depth.

Temperature

The sea surface temperature varied from 26.00° to 28.00°C. Both on the eastern side and western side, the temperature showed a northward decreasing trend. Relatively warm surface water was observed at stations south of Little Andamans. These stations are located just above the 10° Channel. Another feature of importance was the occurence of inversions at two stations—Stn. 1595 at 12° 56'N & 93° 05'E and Stn.1599 at 12° 31.5'N & 92° 31.5'E (Fig. 3). At these stations comparatively low surface temperatures were recorded (26.30° and 26.00°C respectively). At Stn.1595 an inversion of 0.40°C occurred well within the surface layer i.e. in the upper 10m itself and then upto 50 m depth an isothermal water column existed. At Stn. 1599, the inversion recorded was 0.50°C in the depth range of 0.50m. These surface layer inversions could occur possibly through differential mixing of Andaman Sea waters with those coming from the adjoining seas. The intense evaporation occurring in this area coupled with the incursion of low density water also contributes to the same condition (Ramaraju *et al*., 1981).

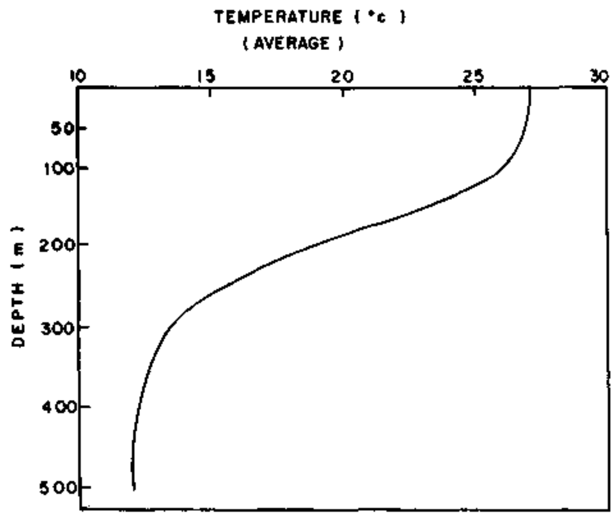

Fig. 3. Distribution of temperature with depth.

Spatial and temporal distribution of nutrients

In oceanic environment, the term nutrient has been applied exclusively to silicon, phosphorous and inorganic nitrogen although most of the major constituents of sea water and a large number of essential trace metals present together with them are also nutrient elements. The present study is confined to the vertical distribution of dissolved silicon, inorganic phosphate and nitrate at selected locations in the waters surrounding Andaman Islands. Rock weathering, decay of organic material and discarded wastes are the major sources of nutrient elements in the sea to which they are carried by land drainage. The geochemical and geophysical processes influence the concentration of nutrients in the sea by addition and removal. The primary agencies for the biological removal of nutrients from sea water are the unicellular algae of phytoplankton.

Silicate

The silicon in solution in sea water exists mainly in the form of silicic acid. The surface concentration of dissolved silicon was in the range 3.86 µg at Si/l to 10.04 µg at Si/l during the present study (Fig. 4). The relatively higher concentration was observed only at one station. These values are comparable to the values reported earlier from this area (Sen Gupta *et al.*, 1981) and to the concentration found in other world oceans (Armstrong, 1965). Though the concentration showed a depth wise increase in general, lesser concentrations were observed for all standard depths other than the surface when compared to the earlier values. The highest concentration recorded for the present cruise was 28.34 µg at Si/l at 500 m depth whereas 50 µg at Si/l was reported by Sen Gupta *et al.* in 1979. But it is found that the concentration of dissolved silicate in solution in the sea varies than that of any other element (Spencer, 1956). The increase in concentration of dissolved silicate with depth is not always regular. River water usually contains higher concentrations of silicic acid than does sea water and hence the dissolved silicon content in coastal regions is higher than that of open ocean surface waters (Stefanson and Richards, 1963). Moreover dinoflagellates are the important primary producers since they are able to thrive in oligotropic tropical waters unlike diatoms (Devassy and Bhatathiri, 1981). The diatoms are the major consumers of silicates. The coastal waters where nutrient values are relatively high, can sustain a richer diatom population. The observed values go well in accordance with the above mentioned factors.

Inorganic phosphate

The concentration of dissolved inorganic phosphate (orthophosphate) in the surface layers of oceans is variable, but over large areas the maximum concentrations are in the range of 0.5 to 1.0 µg at P/l (Sverdrup *et al.*, 1942). The surface values observed for Andaman waters were also within these extremes. (0.47 µg at P/l to 0.68 µg at P/l) (Fig. 5).

Reddy *et al*. (1968) have reported a very high concentration of inorganic phosphate (12 µg at P/l)

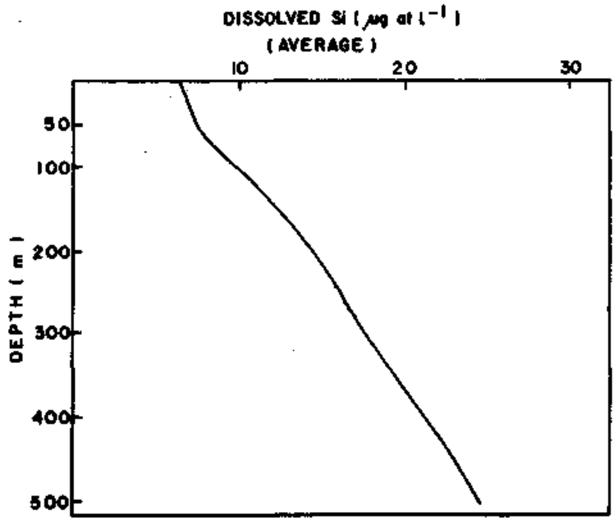

Fig. 4. Distribution of dissolved silicon with depth.

at all depths in the waters around Andaman Islands. Later Sen Gupta *et al.* (1981) reported a maximum of 3 µg at p/l. For this cruise the highest value recorded was 0.98 µg at P/l at 500m depth. The higher concentrations of phosphate in coastal water when compared to offshore waters may be attributed to enrichment by fresh water drainage. Inorganic phosphate is lost from the water column at a considerable rate and regeneration will limit the rate of primary production.

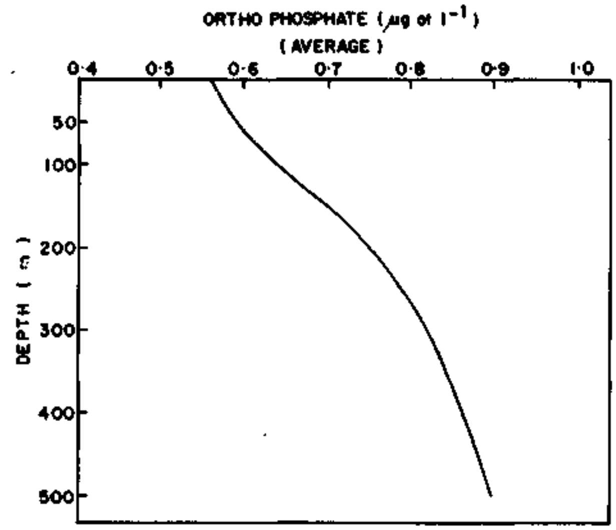

Fig. 5. Distribution of orthophosphate with depth.

Nitrate-N

Nitrate-N is the stable form of combined inorganic nitrogen and the variation in the concentration is mainly due to biological factors (Spencer, 1956). In the upper 50m, the nitrate-N present is almost undetectable (Fig. 6). This matches well with the reported low primary productivity of Andaman waters (Parulekar and Ansari, 1981). It was earlier reported that nitrogen consuming blue green algae (*Trichodesmium thiebautii*) occured at various depths, while *Trichodesmium erythraeum* was found mainly at surface (Devassy and Bhattathiri, 1981). The process of regeneration of nitrogeneous matter is slow and the supply of nitrogen from the deeper layers is almost absent due to lack of mixing on account of steepness of the continental slope. Sharp stratification (Ivanov, 1964) of water is a characteristic feature of the Andaman Sea. The very stable stratification except for shelf region (Massellinikov, 1973) and limited mixing between surface, subsurface and bottom water inhibit the influx of nutrients to the surface (Sen Gupta *et al.*, 1981).

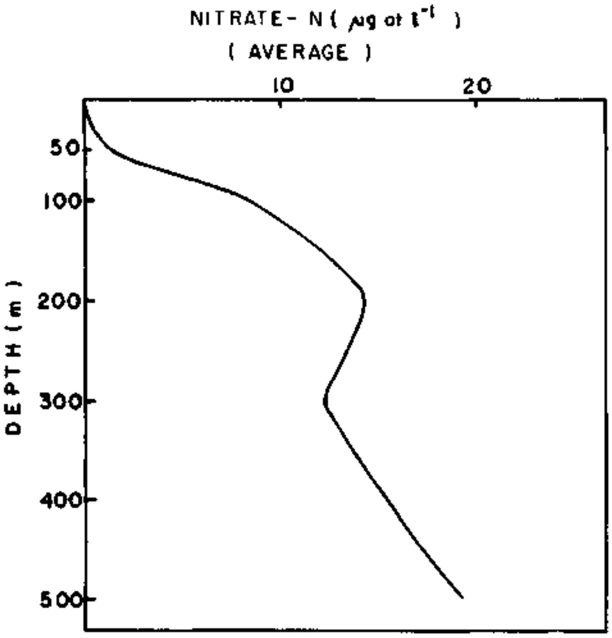

Fig. 6. Distribution of nitrate - N with depth.

CONCLUSIONS

The surface concentration of dissolved silicon is comparable to those reported earlier from this area but deeper values showed a marked deviation and its concentration in coastal regions is higher than that of open ocean surface waters. The dissolved inorganic phosphate also follows the same trend as silicate. The nitrate-N is almost undetectable in the upper layers. The enrichment of nutrients from deeper waters is almost absent possibly due to limited mixing and sharp stratification.

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VERTICAL DISTRIBUTION OF PHOSPHATE, NITRATE AND NITRITE OF LAKSHADWEEP WATERS IN THE ARABIAN SEA

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ABSTRACT

The paper presents the estimation of physico-chemical parameters of seawater samples collected from 28 stations between 07°50' and 13 ° 00' N and between 70°00' and 75°00' E onboard FORV *Sagar Sampada* in February, 1987. Water samples drawn from selected depths of 0, 100, 200, 300, and 500m were analysed for dissolved oxygen and nutrients (phosphate, nitrate and nitrite). In general, lower concentration of nutrients was recorded at surface and 100m depth at all stations. Higher concentrations of nutrient components were encountered at deeper depths with low values of dissolved oxygen. Lowest nutrient values at surface and highest at bottom (500 m) recorded, in microgram-at/l, were PO_4-P: 0.14-7.17; NO_3-NO. 08-27.35 and NO_2-N: Trace - 1.48 except with 1.65 microgram-at/l at 300 m. Probable factors governing the distribution of analysed parameters in Lakshadweep waters are discussed.

INTRODUCTION

Detailed studies dealing with the distribution, cycles, and inter-relationship of the nutrients in the Indian seas have been carried out by many workers viz., Ryther *et al.* (1966), Sankaranarayanan and Reddy (1968), Viswanathan and Ganguly (1968), Reddy and Sankaranarayanan (1968a and 1968b), Sankaranarayanan (1973), Sen Gupta *et al.* (1975, 1976, 1977, 1979), Deuser *et al.* (1978), Devassy *et al.* (1978), Naqvi and Qasim (1983), Sankaranarayanan *et al.* (1983), Sen Gupta and Naqvi (1984) and De and Singbal (1986).

It is understood from the available literature that only limited information is available on the distribution of nutrients in the Lakshadweep Sea. In the present study an attempt has been made to investigate the pattern of distribution of the nutrients such as PO_4, NO_2 & NO_3 in relation to temperature and dissolved oxygen in the Lakshadweep waters based on samples collected onboard FORV *Sagar Sampada.*

MATERIAL AND METHODS

A total of 28 stations covering an area between 08° and 13° N and between 70° and 75°E near to the Lakshadweep Islands were selected and divided into six transects (I to VI) each transect 1° apart covering 4 to 5 stations. Transects and station positions are given in Figure 1.

Water samples were collected by using Rosette sampler from standard depths of 0, 100, 200, 300 and 500m for nutrients estimation. Water samples were analysed immediately after collection onboard the vessel using the Digital Spectrophotometer GS: 5600 (ECIL make) for nutrients following standard methods of Strickland and Parson (1968) for dissolved oxygen. Temperature values were recorded by automatic temperature recorder attached with the rosette sampler. Mean value of each parameter for each transect and each depth was calculated (Tables 1 and 2).

RESULTS AND DISCUSSION

Hydrographic factors

Temperature and dissolved oxygen showed significant variation with depth and little variation among transects.

From the composite average values (Table 1) it was found that waters in southern transects were warmer than that of the northern. Vertical temperature values (Table 2) ranged between 27.9 and 10.20°C with an average of 18.0°C.

Dissolved oxygen

Oxygen concentration (Table 2) ranged from 5.0 to 0.1 ml/l (Ave. 1.5) Vertical distribution of dissolved oxygen showed a sharp decrease from surface down to 200 m and thereafter values remained almost constant. Composite average values with respect to south and north transects revealed that Lakshadweep waters of southern area were

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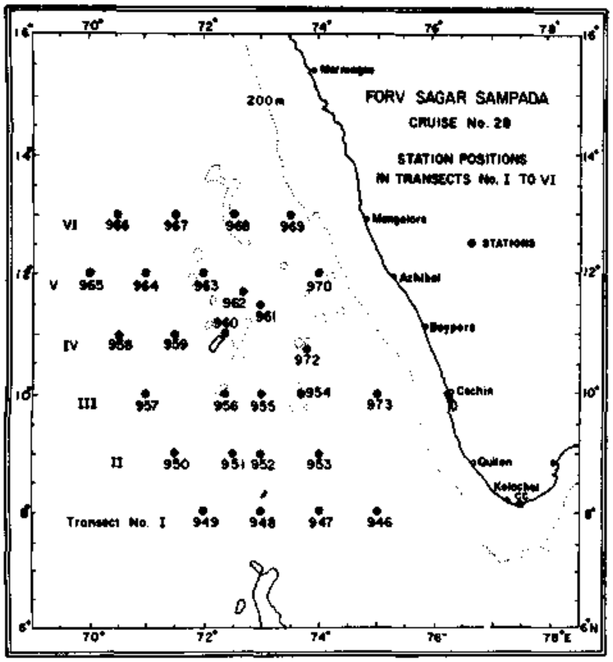

Fig. 1. The positions of stations and transects chosen for the study in the Lakshadweep Sea.

higher in oxygen level than that of the northern region (Table 1).

Nutrient distributions

The possible reasons for the depthwise and regional variation of nutrients content in the Arabian Sea and in Lakshadweep waters particularly have been discussed by Red Field *et al.* (1963), Reddy and Sankaranarayanan(1968 a, 1968 b), Sankaranarayanan (1973), Sen Gupta *et al* . (1975, 1979), Devassy *et al.* (1978) and De and Singbal (1986). It is assumed that the distribution of nutrients and hydrographic parameters in Lakshadweep waters appeared to be more dependent on the dilution, general current pattern and source of origin of water masses.

Phosphate

The lowest and highest values observed were 0.76 µg-at/l at surface and 5.76 µg-at/l at 300 m in transects V and VI respectively. PO_4 values showed an increasing trend from surface to bottom in transects I, IV & V whereas in transects II, III and VI the values increased upto 300 m and then gradually decreased down to 500 m. The observed mean (3.78 µg-at/l)

TABLE 1. *Transectwise mean and composite average values of nutrient and hydrographic parameters of Lakshadweep waters during February, 1987*

Regions		Parameters				
		Phosphate (µg-at/l)	Nitrate (µg-at/l)	Nitrite (µg-at/l)	Temp. (°C)	Dissolved oxygen (ml/l)
Southern region	I	4.11	13.17	0.11	17.6	1.56
	II	3.63	14.28	0.21	18.3	1.74
	III	3.56	11.62	0.14	18.3	1.54
Composite average	(I - III)	3.76	13.02	0.15	18.1	1.61
Northern region	IV	3.76	12.03	0.14	17.9	1.44
	V	3.58	11.08	0.12	18.0	1.60
	VI	4.14	12.68	0.42	15.4	1.36
Composite average	(IV - VI)	3.87	11.93	0.23	17.4	1.47
Range of average values	(I - IV)	0.76 - 5.76	0.57 - 21.66	0.03 - 0.70	27.4 - 10.7	4.30 - 0.40
Mean values		3.78	12.45	0.19	18.0	1.5

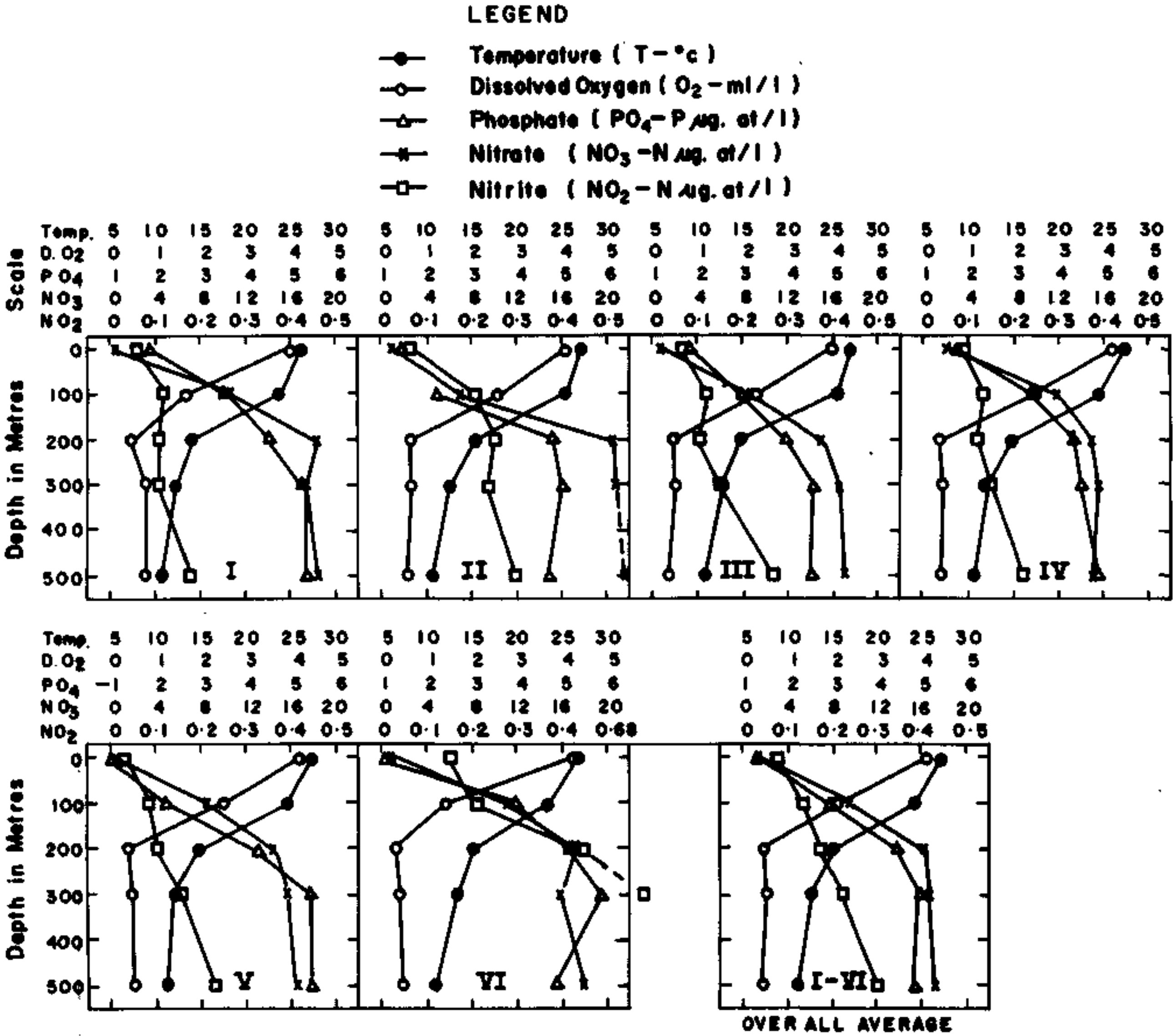

Fig. 2. Depth-wise pattern of distribution of nutrients and hydrographic parameters in the Lakshadweep waters.

was almost similar to those reported earlier by Viswanathan *et al.* (1967) in west coast of northern Indian Ocean and by Sen Gupta *et al.* (1976a and 1979) in the Arabian Sea. Later Devassy *et al.* (1978) reported higher PO_4 range (2.00-13.15 µg-at/l) from oceanic waters in the presence of bloom conditions than those of normal oceanic waters. Composite average values observed were 3.76 and 3.87 µg-at/l in south and north transects respectively. This revealed that PO_4 content was higher in waters of northern transects and hence an increasing trend from south to north was noticed (Fig. 2 and Table 1). High amount of phosphate content in deeper waters may be due to absence of photosynthetic activity. Another reason for depth-wise increase of PO_4 in oceanic conditions may be that due to oxidation of organic matter in intermediate depths, depletion of oxygen takes place with concomitant release and increase of PO_4 (Red Field *et al.*, 1963).

Nitrate

NO_3 content showed an increasing trend with depths in all transects except I & VI where it decreased at 300 m and then increased down to 500 m depth (Fig. 2). Lowest and highest values (Table 2) recorded were 0.57 µg-at/l at surface and 21.66 µg-at/l at 500 m in respect of transects V and II. Composite average values (Table 1) were 13.02 and 11.93

TABLE 2. *Depth-wise analysis for nutrients and hydrographic parameters for Lakshadweep waters during February, 1987*

Depth (m)	Parameters				
	Phosphate (µg-at/l)	Nitrate (µg-at/l)	Nitrite (µg-at/l)	Temp. (°C)	Dissolved oxygen (ml/l)
0	0.76 - 1.87 (1.41)	0.57 - 2.36 (1.00)	0.03 - 0.15 (0.07)	26.3 - 27.4 (27.1)	4.0 - 4.3 (4.1)
100	2.18 - 3.96 (2.98)	7.12 - 11.77 (9.55)	0.08 - 0.22 (0.13)	23.3 - 26.8 (24.2)	1.4 - 2.6 (2.1)
200	4.00 - 5.09 (4.45)	14.26 - 20.56 (16.55)	0.10 - 0.44 (0.17)	14.4 - 15.5 (15.0)	0.3 - 0.7 (0.5)
300	4.47 - 5.78 (5.00)	15.55 - 20.90 (16.95)	0.10 - 0.58 (0.22)	12.3 - 13.0 (12.6)	0.25 - 0.8 (0.5)
500	4.49 - 5.37 (4.90)	15.24 - 21.66 (17.52)	0.17 - 0.70 (0.30)	10.5 - 10.8 (10.8)	0.4 - 0.8 (0.49)
Range (0 - 500)	0.14 - 7.17 (3.78)	0.08 - 27.35 (12.45)	Trace - 1.48 (0.19)	27.9 - 10.2 (18.0)	5.0 - 0.1 (1.5)

µg-at/l in southern and northern transects which revealed a decreasing trend from south to north. Observed average values in the present study were slightly lower than those reported by Sen Gupta *et al.* (1976) for the same depth range along 9° -14° N Lat. in northwestern Indian Ocean. Overall average (12.45 µg-at/l) was also lower (16 µg-at/l) than that reported earlier by Sen Gupta *et al.* (1976a) from northeastern basin of the Arabian Sea. Low NO_3 values may arise first from a high rate of denitrification and secondly due to the net effect of the bio-chemical processes (Deuser *et al.*, 1978).

Nitrite

Figure 2 shows that NO_2 content has an irregular trend of increasing and decreasing with depth in all transects though the values increased gradually from surface to lower layers in transects V & VI. The composite values recorded (0.15 and 0.23 µg-at /l) (Table 1) for south and north transects revealed an increasing trend from south to north. Nitrite values were very low at surface and found to increase gradually with intermediate depths. Observed average values varied from 0.03 to 0.70 µg-at/l with an overall average of 0.19 µg-at/l (Table 1). Sen Gupta *et al.* (1976a) observed a range of 0.38 to 1.56 µg-at/l of NO_2 for the waters from surface to 900 m depth of the eastern Arabian Sea. Sen Gupta *et al.* (1979) found a range of NO_2 values (0.16-0.20 µg-at/l) for the surface layers of the Lakshadweep waters which are comparable to the values of the present study (0.03-0.22). Since the concentrations and differences of nitrite values were of low orders, no special emphasis could be made on the factors governing nitrite content variation. Increase in nitrite content at surface layers results from denitrification as well as by air-sea interaction of exchange of chemical elements. It is interesting to note that below the depth of about 200 m the nitrates were steady whereas nitrite content increased with depth (Fig. 2). The increase of nitrite in the deeper layers (200 m) may be attributed to the presence of bacteria favourable for the denitrification. The release of oxygen in the process of denitrification might have been used by bacteria for their survival, reducing the oxygen content very much (De and Singbal, 1986). The process of denitrification involves the use of NO_3 ions as the next source of energy when all oxygen from the system has been utilized. During this process NO_2 ions are formed as the intermediate product and gaseous nitrogen as the end product.

Conclusions

In general, phosphate and nitrate showed a regular trend of distribution whereas nitrite showed an irregular pattern of distribution with depth. The intensity of their depth-wise increase was in the order as NO_3, PO_4, NO_2. The distribution of PO_4 and NO_2 showed an increasing trend whereas NO_3 indicated a decreasing trend from south to north. The low nutrient, might be related to the denitrification process and diffusion of currents contributing to the nutrient depleted waters. And also high level of nutrients could be resulted from the mineralization of organic material through bacterial oxidation and chemical decomposition.

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DISSOLVED MERCURY LEVELS AND CHLOROPHYLL CONCENTRATIONS IN THE OFFSHORE WATERS OF THE NORTHEAST COAST OF INDIA

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Abstract

Dissolved mercury and total chlorophyll concentrations from the surface waters between 16°00' and 20°30'N (upto 1000 m depth zone) were estimated from the samples collected onboard FORV *Sagar Sampada* during October, 1988. The dissolved mercury levels showed an average value of 1.04 µg/l, ranging from 0.3 to 2.2 µg/l and the total chlorophyll to 0.423mg/m^3 varying from 0.120 to 1.149 mg/m^3. Mercury concentrations in the presently reported areas is within the tolerance limit but lie well above the risk concentration levels. The high levels of mercury observed can be attributed to the discharge from the major rivers adjoining the coast.

Introduction

In recent years reports on hazards of mercury and organomercuric compounds have been appearing in literature. Mercury, a toxic pollutant can enter the coastal environment from industries. The level of mercury in sea water is about 0.2 ppb (Ehrlich, 1975). In the coastal waters subjected to mercury containing waste discharge, mercury content exceeds this level (Higgins and Burns, 1975). In Indian coastal waters high levels of mercury are reported from the coastal waters of Cochin (Balachand and Nambisan, 1986; Alavandi *et al.*, 1989), Thana Creek of Bombay (Zingde and Desai, 1981) and Binge Bay of Karwar (Kureishy *et al.*, 1986). These levels were linked to the discharge of effluents containing mercury into these coastal areas. The status of marine pollution including the mercury levels, around the Indian peninsula has been reviewed by Qasim and Sen Gupta (1980), Qasim *et al.* (1988) and Sanzgiry *et al.* (1988). This communication presents the mercury levels observed in the surface waters between 16°00' and 20°30' N in the northeast coast of India in relation to the standing stock of phytoplankton and mercury level reported earlier from other regions of Indian coasts.

Materials and Methods

Water samples from the surface collected from 14 stations onboard FORV *Sagar Sampada* in October, 1988 formed the material for the study. Station positions are given in Fig. 1. Water samples were collected in polythene containers of 5 l capacity, filtered through glass filters (GF/O.45µ), acidified with 5 ml of conc. HNO_3 and preserved in refrigerator for mercury analysis. The filter papers were used for chlorophyll determination (Parsons *et al.*, 1985) with 90% acetone using UV/VIS spectrophotometer (551S - Perkin - Elmer). The preserved samples were anlaysed for dissolved mercury content by cold vapour atomic adsorption spectrophotometry (Hatch and Ott, 1988) using mercury analyser, MA 5800 A (ECIL). The average percentage recovery of total mercury from water was 84.5% by the procedure followed. The minimum detection limit was 0.2 ng/ml.

Results and Discussion

As shown in Table 1 the maximum level of mercury observed was 2.2 µg/l and the minimum level of 0.3 µg/l with an average value of 1.04 µg/l. Higher levels of mercury were observed at station 9 (1.9 µg/l) and 10 (2.2 µg/l), which are situated in the sea off the mouths of Devi and Kushbhadra rivers. These high levels can possibly be attributed to mercury containing waste discharged into these rivers and finally reaching the marine environment.

A comparative account of mercury concentration in the shelf waters along Indian coast is given in Table 2. From the available data, Binge Bay of Karwar appears to be more polluted than other areas. Dissolved mercury concentrations in the presently reported area is within the tolerance limit (0.1 mg/l, source ISI, 1981), but above the risk concentration levels (0.1 µg/l; Bernard, 1981) and higher than the levels reported by Sanzgiry *et al.* (1988). Comparison of these data may not be of much validity since the area of study and period of sampling vary and obvi-

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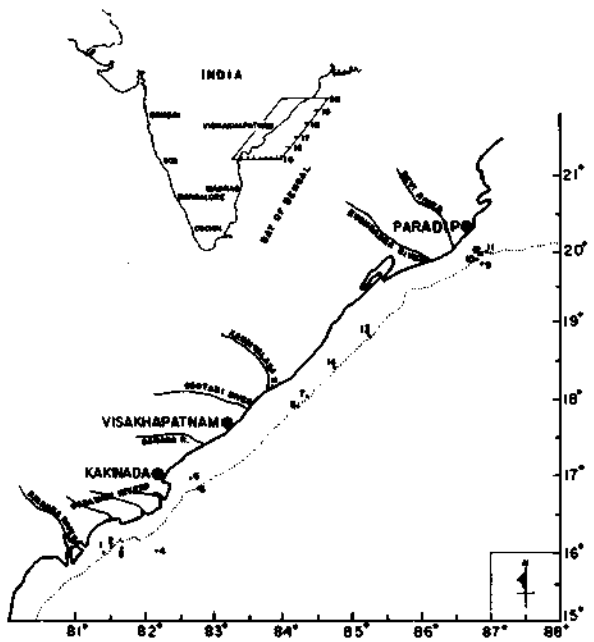

Fig. 1. Study area and the station positions along northeast coast of India.

ously lead to certain amount of discrepancy as the method of mercury analysis followed by various authors differ and also the instrumentation involved.

TABLE 1. *Levels of dissolved mercury and total chlorophyll content from 14 stations of northeast coast of India*

Station No.	Depth at each station (m)	Dissolved mercury levels (μg/l)	Total chlorophylls (mg/m^3)
1	100	1.1	0.398
2	200	1.1	0.361
3	500	0.3	0.411
4	1000	0.3	0.707
5	200	0.8	1.149
6	65	0.5	0.228
7	100	0.4	0.587
8	500	1.1	0.392
9	1000	1.9	0.120
10	500	2.2	0.342
11	200	1.1	0.274
12	900	0.8	0.444
13	65	1.4	0.188
14	150	1.5	0.314

TABLE 2. *Comparative account of mercury concentrations in Indian waters in μg/l*

Areas studied	Mercury levels	Source
Binge Bay, Karwar	17.83	Kureishy *et al.*, 1986
Thane Creek, Bombay	0.247	Zingde & Desai, 1981
Cochin	1.02	Alavandi *et al.*, 1989
Tuticorin	2.04	Gopinathan*
Arabian Sea	0.078	Qasim *et al.*, 1988
Bay of Bengal	0.045	-do-
Indian coasts	0.2	Sanzgiry *et al.*, 1988
Northeast coast of India	1.04	Present authors

*Personal communication from Dr. C. P. Gopinathan, R. C. of C. M. F. R. I., Tuticorin.

Total chlorophyll content from the 14 stations ranges from 0.120 to 1.149 mg/m^3 showing an average of 0.423 mg/m^3 which is parallel to the values reported earlier (Devassy *et al.*, 1983). It is imperative that mercury concentration and the population of phytoplankton and the flora and fauna at large are negatively correlated (Hollibaugh *et al.*, 1980). In our study no strong relationship was observed. Although there is no apparent deleterious effects observed on the biota of the northeast coastal waters during and after the period of study, the results indicate that the mercury levels in this area lie well above the minimum risk concentration and calls for detailed monitoring to curtail the further rise in the level of mercury. Constant monitoring for heavy metal level including mercury is warranted to find out whether these reported levels are accidental or a recurring phenomenon.

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DISTRIBUTION AND BIOCHEMICAL ACTIVITY OF HETEROTROPHIC BACTERIAL POPULATION OFF MADRAS COAST

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ABSTRACT

The quantitative distribution and biochemical avtivity of heterotrophic bacteria capable of multiplying in organic media of Proteinaceous composition from, shelf and slope waters off Madras coast between 11° 30' N and 14° 30' N were studied during March, 1986. The percentage of samples yielding more than 100 X 10^5 / ml colonies was only 12 in number in depth range 0-10 metres. Pigmented bacteria was encountered more in this depth range. Faecal coliform bacteria was not encountered throughout the observations. Total bacterial count varied from 8.6 X 10^5 to 3.08 X 10^7 / ml in spread plate method of isolation. *Pseudomonas, Vibrio, Alcaligenes, Flavobacterium, Cytophaga, Agarobacterium* and *Chromobacterium* formed the predominant flora isolated. Their correlation with environmental parameters like temperature, salinity, oxygen and pH are discussed. The cultures were more proteolytic than amylolytic which indicated the process of organic decomposition and vigorous liberation of plant nutrients in these latitudes.

INTRODUCTION

Marine heterotrophic bacteria play a major role in the decomposition of dissolved organic substances. Their activities and relative abundance reflect the hydrological structure and nutrient levels in the marine environment (Oppenheimer, 1963). Also they form an important constituent of any ecosystem and can be considered as an index for monitoring environmental stress and changes. This paper reports the nature and distribution of the heterotrophic bacteria off Madras coast between 11 ° 30' N and 14° 30' N and 79° 54' E and 80° 24' E in relation to some environmental parameters such as temperature, salinity, dissolved oxygen and pH from the samples collected during Cruise 13A of FORV *Sagar Sampada* during 21st to 24th March, 1986.

MATERIALS AND METHODS

The quantitative and qualitative distribution of heterotrophic bacteria was assessed from water samples collected aseptically in precombusted water bottles from various depths (0 m, 10 m, 20 m, 30 m, 50 m and 75 m) in the shelf waters from six fixed stations (stations 473, 474, 475, 476, 477 and 478) from 21st to 23rd March, 1986 where the depth ranged from 0-91 m. The mid- depth samples from stations 476 and 478 were omitted since these 2 stations were relatively shallow. A rosette sampler was used for collecting water samples. Platings for bacterial enumeration were done within one hour of collection.

The temperature and pH of water samples were recorded and salinity and dissolved oxygen were determined by titration method using standard procedures.

The spread plate method was used throughout since this method has the advantages of a shorter incubation time, higher counts and more uniform colonial size over the streak plate on pour plate method (Buck and Cleverdon, 1961). Aerobic bacterial counts were obtained by plating 0.1 ml of an appropriate sea water dilution of the original sample on sea water Agar medium (10 g Peptone (Difco), 0.1 g Yeast extract (Difco) and 20 g purified Agar in 1000 ml aged sea water). The agar plates were kept in sterilised chamber for 1 hr to dry the surface prior to smear the 0.1 ml water samples over the surface. The plates inoculated were incubated at 20° C for 2 weeks and then colonies formed on the plates were counted according to standard methods. Faecal coliforms (*E. coli*) counts were made by using selective media Tergitol 7 Agar medium by the spread plate method.

Single colonies were picked up at random from each standard plate with 30 - 300 colonies and re-streaked on appropriate agar plates three times before a pure culture was established in agar slants. Standard bacteriological procedures were carried out to determine the bacterial genera and their identifications were accomplished according to Bergy's manual of Determinative Bacteriology by Breed *et al.*

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(1974) and other references (Zobell and Upham, 1944; Simidu and Aiso, 1962; Hayes, 1963; Shewan, 1963; Baumann *et al*., 1972).

Results

Horizontal distribution

The heterotrophic populations in surface water were highest in 5 stations studied and total bacterial count varied from 8.6×10^5 cells ml^{-1} to 3.08×10^7 cells ml^{-1}. The highest counts being usually obtained along the thermocline at 20 to 30 m. The percentage of samples yielding more than 100×10^5/ml colonies was only 12 in numbers in the depth-range of 0-10 m. Pigmented bacteria was encountered more in 0-10 metre depth range. Surface water temperatures at all stations were found to be rather uniform.

Vertical distribution

The temperature, dissolved oxygen and pH decreased while salinity increased with depth in all stations during the observation. Although stratification of the hydrological structure was observed, no definite stratification on the vertical distribution of heterotrophic bacteria was detected. The highest counts were obtained in surface samples in most of the stations except Station 474 where mid-depth samples contained more bacteria than in the surface samples.

The surface water temperature ranged from 28.1 to 28.9°C. The waters below the surface upto 30m showed a gradual decrease and ranged from 27.4 to 27.9°C. The temperature at 50m depth ranged from 24.5 to 27.7°C.

The dissolved oxygen content from surface to about 30 m depth showed uniform values around 4.8 ml/1.

The salinity of the surface waters ranged from 28.5 to 34.9‰. At 50 metres the salinity ranged from 29.4 to 34.8‰.

Determination of bacterial genera

A total number of 46 strains were isolated from all the samples and the strains were assigned to 7 genera including 12 strains of *Pseudomonas*, 10 strains of *Vibrio*, 5 strains of *Alcaligenes*, 7 strains of *Flavobacterium*, 8 strains of *Cytophaga*, 3 strains of *Agarobacterium* and one strain of *Chromobacterium* (Table 1).

A large number of yeasts were also present in the Tergitol 7 Agar plates after 24 - 48 hrs incubation but faecal coliforms (*E. coli*) was not encountered throughout the observation in this selective medium. All the 15 pigmented forms like *Flavobacterium* and *Cytophage* were encountered in the depth range 0-10 metres. An antibiotic producing purple-pigmented *Chromobacterium* was isolated from the sea water sample by using non selective isolation techniques. The culture produces 3 bromine containing metabolites. Anderson *et al.* (1974) showed that these compounds can inhibit the growth of selected human pathogens as well as certain marine bacteria. The organism is maintained in the laboratory for further studies of antibiotic properties.

Table 1. *Number and percentage of identified strains of marine bacteria isolated from off Madras coast*

Bacterial strain	No. of strains	Percentage
Pseudomonas	12	26.0
Vibrio	10	21.7
Alcligenes	5	10.8
Flavobacterium	7	15.2
Cytophaga	8	7.3
Agarobacterium	3	6.5
Chromobacterium	1	2.1

Discussion

The water collected at various depths gave a picture not only of the quantitative distribution of the bacterial flora but also generic composition (Table 1) and biochemical activity (Table 2). The flora consisted of physiologically active organisms exhibiting proteolytic (78. 3%) amylolytic and lipolytic activities. The present pattern of horizontal distribution of bacteria is comparable with those observed in Palk Bay in India (Velankar, 1955), Kamogaway in Japan (Simidu and Aiso, 1962) and Narrangansett Bay in Rhode Island, U.S.A. (Sieburth, 1967).

The actinomycetes and yeasts are known to play important role in degradation. In the present study although no specific attempt was made to enumerate these groups a large number of yeasts were isolated in Tergitol 7 Agar, reflecting their predominance in this area.

Like in other marine environments (Simidu and Aiso, 1962; Liston Colwell, 1963; Shewan, 1963; Simidu *et al*., 1971; Baumamn *et al*., 1972) same types of micro-organisms belonging to the genera *Pseudomonas, Vbrio, Alcaligenes and Flavobacterium* were isolated in Madras coast also. The numbers of each of the taxonomically distinct groups showed the presence of variety of enzymes implicated in degradative processes.

TABLE 2. *Bio-chemical characteristics of 46 marine bacterial strains off Madras coast*

Characteristics	Frequency of occurrence(%)
1. Gram negative	98.0
2. Motility	47.6
3. Pigmented	32.6
4. O/F Dextrose fermentation	
Oxidative	36.8
Fermentative	30.0
No reaction	19.5
5. Proteolytic	78.3
6. Amylolytic	44.5
7. Lipolytic	20.6
8. Nitrate reducers	90.6
9. H_2S producers	12.5
10. Indole producers	—
11. Catalase producers	100.0
12. Sugar fermentation	
Glucose	40.6
Sucrose	35.8
Lactose	Nil
Maltose	55.0
Mannitol	42.6
13. Sensitivity towards Penicillin	
2.5 I.V./Disc.	12.6

Regarding vertical distribution, slight stratification of temperature, salinity, dissolved oxygen and pH is observed in this region. However, no stratification of heterotrophic aerobic bacteria is detected. Due to the relative shallowness of the stations, the mixing effect of water layers is quite evident as indicated by the slight stratification (Table 3) of hydrological parameters and the similar number of bacteria present in different depths. Total counts of bacteria off Madras region are correlated with environmental parameters and none of the correlations are found significant except depth versus temperature (Table 3).

The effect of temperature on micro-organisms is well documented (Ingraham, 1962; Rose, 1967). Most of the marine bacteria in temperate regions grow well at temperatures between 22 and 30°C. It was concluded that the maximum growth temperature for bacteria taken from tropic and temperate waters is only a few degrees above their environmental temperature (Zo Bell, 1962). The temperature never exceeded 28.5°C during the present observation providing sub-optimal temperature for the growth of marine bacteria. Thus correlation analysis in the present investigation indicated that temperature and other parameters have little effect on both horizontal and vertical distribution of heterotrophic aerobic bacteria off Madras region.

The effect of salinity and pH are probably more serious on the bacteria. It is well documented that faecal coliforms and non-marine bacteria die rapidly in water with high salinities and alkaline pH which may be the reason for not encountering faecal coliforms throughout the observation. Since the mortality of coliform and non-marine bacteria is high in sea water (Ketchum *et al.*, 1952; Carlucci and Pra-

TABLE 3. *Mean and std. deviation of different characteristics*

Characteristics	Mean	s.d.	Correlation matrix					
			1	2	3	4	5	6
1. Depth	17.200	14.583	1.000	0.172	0.105	-.266	-.834	-.377
2. pH	8.214	0.006	0.172	1.000	0.170	0.213	-.029	-.124
3. Salinity	31.694	2.326	0.105	0.170	1.000	-.008	0.217	-.085
4. Oxygen	4.814	0.414	-.266	0.213	-.008	1.000	0.226	-.163
5. Temperature	27.823	0.922	-.834	-.029	0.217	0.226	1.000	0.337
6. Total plate count	109.920	45.590	-.377	-.124	-.085	-.163	0.337	1.000

mer, 1969; Carlucci *et al.*, 1961; Jones, 1963) they do not constitute any significant portion of the heterotrophic bacterial population in this marine environment.

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HETEROTROPHIC BACTERIA IN THE SURFACE LAYERS OF OCEANIC WATERS OF THE WADGE BANK REGION

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ABSTRACT

This paper embodies the results of bacteriological investigations carried out in the Wadge Bank region of the Indian Ocean during August, 1985. The aerobic heterotrophic bacterial population of the surface waters (0-100 m) ranged from 1×10^5 / ml to 9.8×10^5 during the peak monsoon season. Bacteria belonged to genera of *Pseudomonas, Aeromonas, Vibrio, Alcaligens* and *Micrococcus*. The isolates were found to be active decomposers of macromolecules. No significant correlation was observed between the bacterial population and the light intensity at various depths.

INTRODUCTION

The heterotrophic micro-organisms play a very important role in the process of mineralization in the sea and also in other environments by virtue of their zymogenous activity (Wood, 1967). Considerable amount of information on the heterotrophic bacteria from the coastal regions and estuaries is available (Kannan and Vasanta, 1986; Vasanta and Kannan, 1987; Alavandi, 1989) whereas the data on the heterotrophic bacteria of offshore waters around the Indian peninsula, even in the Exclusive Economic Zone (EEZ) is limited. This paper is a preliminary report on the qualitative and quantitative aspects of aerobic heterotrophic bacteria in the surface layers of the oceanic waters in the Wadge Bank region of the Indian Ocean where three seas viz., Arabian Sea, Indian Ocean and the Bay of Bengal confluence.

MATERIALS AND METHODS

During the sixth cruise of FORV *Sagar Sampada* in August, 1985, water samples from three stations viz., 138, 139 and 140 from depth 0, 50 m and 100 m were collected with the help of rosette sampler fitted with tefflon coated bottles. Then a portion of water samples was transferred to sterile glass bottles for microbiological analysis. The water samples were inoculated in duplicate immediately onboard the vessel on Zobell's marine agar 2216 (Himedia) by serial dilution and spread plate method. After incubation for 5 days at 28°C the colonies were counted and recorded as total viable count (TVC). Morphologically distinct colonies were isolated and identified upto generic level according to Buchanan and Gibbons, 1974. The isolates were tested for their extracellular enzyme activity viz., of Protease, Amylase and Lipase by conventional methods in order to understand their potential to breakdown the macromolecules. The proteolytic activity of the isolates was tested by inoculating the bacteria on Zobell's marine agar incorporated with 4 per cent nutrient gelatin. After an incubation for 48 hours, the plates were flooded with $HgCl_2$ solution. Positive activity was indicated by a clear zone around the colonies. Amylolytic activity was tested by inoculating the bacteria on Zobell's marine agar incorporated with 2 per cent soluble starch. The plates were flooded with lugol's iodine solution after incubation, and the activity was indicated by a clear zone around the colonies. Similarly bacteria were inoculated onto Zobell's marine agar supplemented with 1% Tween 80, and the formation of a turbid zone around the colonies indicated positive lipolytic activity. The light intensity available at various depths of the ocean was obtained from the Quantameter fitted onboard the vessel and expressed as percentage quanta.

RESULTS AND DISCUSSION

The culturable aerobic heterotrophic bacterial population in the surface layers of the oceanic waters in the Wadge Bank area of the Indian Ocean ranged from 1×10^5 per ml to 9.8×10^5 per ml with an average of 4.7×10^5 per ml (Table 1). The present findings conform with Kriss *et al.* (1960) who reported high heterotrophic bacterial counts from the

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TABLE 1. *Quantitative distribution of heterotrophic bacteria Vs. light intensity*

Stn. No., Depth at Stn., Position, Time of sampling	Depth of Sampling	TVC x 10^5 per ml	Illumination in Quanta %
138	Surface	3.5	98.29
2767 m	50 m	5.3	97.04
4° 59.3' N,77° 29.5'E			
0700 hrs	100 m	3.6	95.96
139	Surface	5.1	-
2483 m	50 m	5.3	-
5° 30' N, 76° 16'E	100 m	9.8	-
2000 hrs			
140	Surface	1.0	97.88
2754 m	50 m	6.4	95.43
6° 00.1'N, 75° E			
0730 hrs	100 m	3.3	94.01

equatorial regions of the oceans of the world including the Indian Ocean. This has been attributed to high organic content of allocthonous origin. It is interesting to note that despite the oligotrophic nature of the oceanic waters, the bacterial population did not show much decline compared to the coastal areas, where the bacterial load is of the order of 10^6 per ml (Alavandi, 1989). High counts of bacteria could be due to the availability of high organic content originating either from phytoplankton (Gundersen, 1976), or dead and decaying fauna, in the form of detritus, or from allocthonous materials. This is substantiated by the highly active nature of the isolates of bacteria in decomposition of macromolecules viz., protein, starch and lipid (Table 3). High zymogenous activity indicates the potential of these bacteria in breaking down organic matter in the oligotrophic marine environment.

TABLE 2. *Zymogenous nature of the genera of bacteria isolated from Wadge Bank oceanic waters*

Genera	No. of isolates tested	Lipase	Amylase	Protease
Vibrio	3	++-	++-	+++
Pseudomonas	2	+-	++	+-
Aeromonas	4	+++-	+++-	++++
Alcaligens	1	-	-	-
Micrococcus	1	-	-	+

Only the genus *Alcaligens* was found to be lacking the extracellular enzymes to degrade the macromolecules among the bacteria found in the Wadge Bank area of the Indian Ocean.

Although the primary productivity and the population of photoautotrophs which are involved in the conversion of inorganic matter into their cellular constituents in the presence of photic energy, a correlation analysis was carried out between the quanta of light available in the subsurface waters and the population of heterotrophic bacteria. A Negative correlation ($r = -0.31$) was observed although not significant. Bacterial abundance and light intensity in the aquatic environment are known to be negatively correlated (Zobell, 1946). The insignificant correlation observed in this study may be attributed to (i) low intensity of light because of cloudy monsoon and (ii) time of sampling (See Table 1).

The population of different genera of bacteria at various depths is given in Table 2. Genus *Aeromonas* appears to occur in large numbers compared to other genera in this region of the Indian Ocean, although *Pseudomonas* is reported to be predominant genus occurring in the marine environment among the culturable bacteria (Zobell, 1946). *Vibrio, Pesudomonas* and *Aeromonas* occurred in all the three locations, whereas *Alcaligens* and *Micrococcus* occurred less frequently.

TABLE 3. *Qualitative distribution of heterotrophic bacteria in the Wadge Bank region*

Depth	Organism	138	139	140
Surface	*Vibrio*	0.020	-	-
	Aeromonas	74.300	88.20	90.000
	Pseudomonas	5.700	9.80	6.000
50 m	*Vibrio*	47.500	5.70	11.100
	Aeromonas	42.500	94.30	85.200
	Pseudomonas	0.004	-	0.002
	Alcaligens	9.400	-	-
100 m	*Vibrio*	27.800	1.02	0.020
	Aeromonas	61.100	96.90	75.800
	Pseudomonas	8.300	-	-
	Micrococcus	-	-	3.030

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FUNGI ISOLATED FROM THE EEZ OF INDIAN COAST

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ABSTRACT

Seventy eight water samples from suface to 1000 m were collected at 15 stations during FORV *Sagar Sampada* Cruise No. 24. From these, 208 yeast isolates were obtained belonging to the genera *Candida, Rhodotorula, Sporobolomyces, Sterigmatomyces, Trichosporon, Cryptococcus, Saccharomyces* and *Debaryomyces*. *Candida* was the dominant genus followed by *Rhodotorula*.

Seventeen yeast isolates were obtained from the benthic sediment samples and in association with euphausiids from eight stations during FORV *Sagar Sampada* Cruise No. 35. They belonged to the genera *Candida, Rhodotorula, Trichosporon* and *Debaryomyces*. Filamentous fungi isolated during the cruise belonged to the genera *Aspergillus, Penicillium, Cladosporium, Fusarium* and *Alternaria*. Here the yeast *Rhodotorula* was dominant and *Aspergillus* amongst filamentous fungi. *C. tropicalis* was found commonly associated with euphausiids.

INTRODUCTION

Occurrence of yeasts in the sea and open ocean has been reported by several workers (Bhat and Kachwalla, 1955; Fell and van Uden, 1963; Kriss *et al.*, 1967). Bhat and Kachwalla (1955) were the first to isolate yeasts from Indian waters. Fell (1967) reported yeasts from Indian ocean. Similarly there have been a few reports on the filamentous fungi from the sea and open ocean (Johnson and Sparrow, 1961; Roth *et al.*, 1964; Willingham and Buck, 1965; Cvetkovic' and Ristanovic', 1980). Fell (1967) reported the occurrence of filamentous fungi while studying the distribution of yeasts in the Indian Ocean. During the last decade too, there had been sporadic reports of yeasts and filamentous fungi from sea water and sediments (Paula *et al.*, 1983; Bruni *et al.*, 1983; Fedorak *et al.*, 1984). There had been reports of yeasts isolated from amphipods (Roth *et al.*, 1962), from copepods (Seki and Fulton, 1969), from shrimps (Phaff *et al.*, 1952) and in association with shrimp (Pagnocca *et al.*, 1989). Till now no systematic study of the fungal flora of the EEZ of the Indian coast has been taken up.

This paper comprises of the results of the two cruises of FORV *Sagar Sampada*, one in the EEZ of the west coast of India in the Arabian Sea (Cruise No.24 in November, 1986) and the other in the EEZ along the east coast of India in the Bay of Bengal in September, 1987. During these two cruises we had tried to investigate the different aspects of marine mycology.

Fungal flora, both filamentous fungi (Prabhakaran and Ranu Gupta - in press) and the yeasts were isolated from the water samples collected from different depths of the water column from 15 stations during Cruise No. 24. From the benthic sediment samples too, both the fungal flora were isolated from eight stations during FORV *Sagar Sampada* Cruise No. 35. Yeasts associated with the zooplankton (euphausiids) were also isolated in the latter cruise.

MATERIALS AND METHODS

The sampling stations of Cruise No. 24 is given in Fig. 1. The water samples were collected from 15 stations at different depths from 0 to 1000 m by the Rosette sampler available onboard the ship. The Rosette bottles were cleaned and rinsed with alcohol (95%) before every operation. Hydrographic parameters such as temperature, salinity, dissolved oxygen and pH of the water were recorded simultaneously. Processing of the samples was started immediately after all the collections were over at each station. 500 ml of each sample was filtered through a millipore filter membrane with 0.45 μm porosity. After filtration, each membrane was placed in a petri plate on nutrient medium containing antibiotic mixture to prevent bacterial growth (van Uden and Fell, 1968). The plates were then incubated at 25±1°C for the samples collected down to 100m depth and 10±1°C for the samples collected below that depth (Jones, 1976) for two weeks when maximum colonies

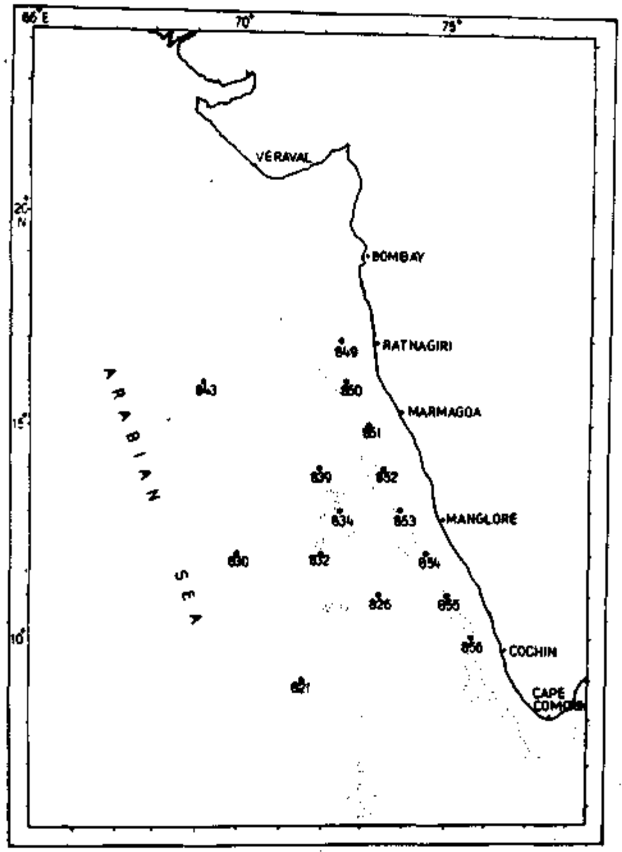

Fig. 1. Map showing location of sampling stations (FORV *Sagar Sampada* cruise No. 24).

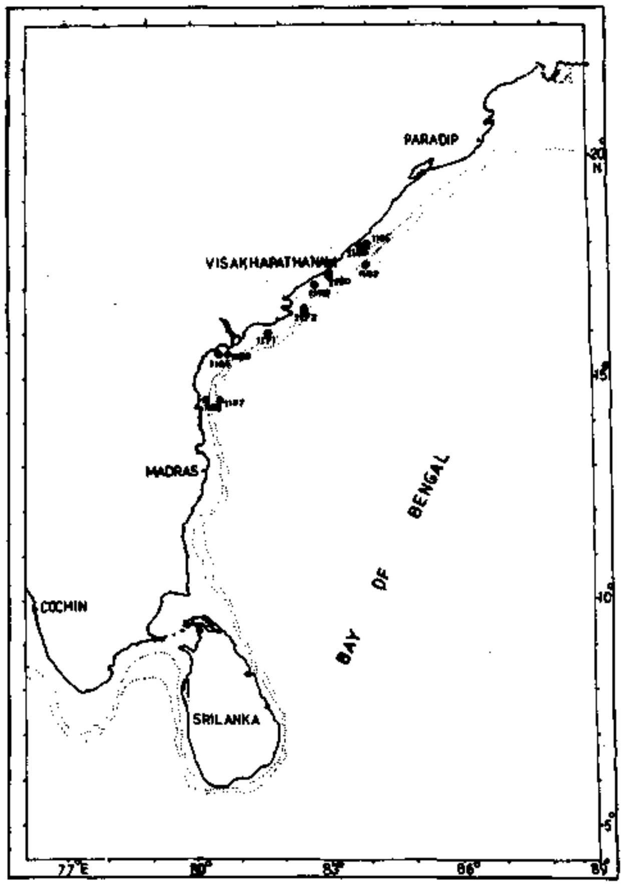

Fig. 2. Map showing location of sampling stations (FORV *Sagar Sampada* cruise No. 35).

showed up. The colony counts were taken through a colony counter.

The track of FORV *Sagar Sampada* cruise No. 35 is given in Fig. 2, showing the sampling stations near the coast from where the benthic sediment samples were collected and also the euphausiid samples from the regular zooplankton hauls. The depth ranged from 32 to 57 m. As the deep sea grab was not available onboard, coastal stations with lesser depths were chosen for sediment collection.

A Van Veen grab was used to collect the sediment samples. The grab was thoroughly cleaned and then wiped with cotton wool soaked in alcohol (95%) before each collection. After every collection the whole lump of the sediment was immediately taken up in a pre sterilized polythene bag. The samples were taken out aseptically inside a sterile chamber from the centre of the lump to avoid any chance of external contamination. One gram of this sediment sample was shaken with 100 ml of sterilized sea water and allowed to stand for 10 minutes to let the particles to settle down. The supernatant was then filtered through 0.45 µm porosity cellulose acetate membrane filter which was placed in a petri plate with nutrient medium containing antibiotic mixture (Van Uden and Fell, 1968). Medium used for the isolation of filamentous fungi was GY-Agar (Johnson and Sparrow, 1961) with 0.01% chloramphenicol to avoid bacterial growth. Triplicate samples were taken from each collection and each membrane was placed in one plate for the yeast isolation and similar process was carried out for the isolation of filamentous fungi. For each set, blank plates were put in triplicate as controls. The plates were incubated at 25±1°C for a week for the yeast and for 3 to 4 days for the filamentous fungi. The colony counts were taken as before.

For each of the eight stations five samples of healthy looking euphausiids were taken from the regular hauls and washed well with sterilized sea water to remove the loosely adhering micro-organisms from them. Then each sample was asepetically planted on nutrient medium with antibiotic mixture (van Uden and Fell, 1968), in petri plates and incubated at 25 ± 1°C for a week. The growth appearing out from the euphausiids on the medium was isolated and identified.

The identification of yeasts was carried out on the basis of detailed cultural, morphological, physiological and biochemical characteristics (Kreger van-Rij, 1984). The identification of filamentous fungi was carried out according to the standard mycological books.

Results and Discussion

Out of the 78 water samples collected, 71 were positive for the presence of yeasts. Table 1 gives the list of yeast species isolated. Table 2 gives the hydrographical parameters and the species of yeasts isolated from different samples at each of the 15 stations. Yeast concentration ranged from 0 to 260 colony forming units (cfu) per litre.

Yeast population was denser down to 100 m depth after which the density decreased. A total of 24 species belonging to eight genera were isolated (Table 1) of which 16 species occurred infrequently. *Candida membranaefaciens* was the dominant yeast species followed by *Rhodotorula rubra.* Bhat and Kachwalla (1955) reported *C. tropicalis* as the most common species of marine yeast from Bombay coastal waters, but for Fell (1967) *C. atmospherica* and *R. rubra* were the ubiquitous species of yeasts in the Indian Ocean.

Most of the yeast species were isolated down to 100 m depth. Exceptions were *R. graminis, Cryptococcus* sp. and *Candida* sp. from 500 m depth at different stations and an isolate of *Candida* sp. even from 1000 m depth.

Of all the yeasts isolated *Sterigmatomyces indicus* was the only obligate marine yeast, while the others were facultatively marine yeasts (Kohlmeyer and Kohlmeyer, 1979). Amongst the eight genera isolated *Debaryomyces* and *Saccharomyces* were the two ascosporogenous ones while all the others asporogenous.

It is obvious from Table 2 that dissolved oxygen and temperature of the collection site had direct influence on the incidence of the yeast species whereas pH and salinity had apparently no effect.

C. albicans, C. parapsilosis, C. atmospherica and St. indicus were found in the temperature range of 20°C to 28°C with high dissolved oxygen. Exception was at st. 834 where *C. albicans* was isolated from

Table 1. *Species of yeasts isolated from the EEZ of west coast of India*

Species
Candida albicans (Robin) Berkhout
C. atmospherica Santa Maria
C. glabrata (Anderson) Meyer et Yarrow
C. guilliermondii (Castellani) Langeron et Guerra
C. membranaefaciens (Lodder et Kreger van-Rij) Wickerham et Burton
C. parapsilosis (Ashford) Langeron et Talice
C. polymorpha Ohara et Nonomura ex Meyer et Ahearn
C. tropicalis (Castellani) Berkhout
C. Vvni (Desmazieres ex Lodder) Van Uden et Buckley
Candida sp.
Cryptococcus laurentii (Kufferath) Skinner
Cryptococcus sp.
Debaryomyces hansenii (Zopf) Lodderet Kreger-Van Rij
Rhodotorula aurantiaca (Saito) Lodder
R. glutinis (Fresenius) Harrison
R. graminis (Di Menna)
R. minuta (Saito) Harrison
R. rubra (Demme) Lodder
Rhodotorulas sp.
Saccharomyces cerevisiae Meyen Ex hansen
Saccharomyces sp.
Sporobolomyces sp.
Sterigmatomyces indicus Fell
Trichosporon sp.

low dissolved oxygen area. Above 24°C and with high oxygen areas yeast species isolated were *C. glabrata, C. polymorpha, C. tropicalis, R. aurantiaca* and *R. minuta.* The versatile yeast species tolerating wide temperature and dissolved oxygen range were *C. guilliermondii, C. membranaefaciens, C. vini, Candida* sp., *Cr. laurentii, Cryptococcus* sp., *D. hansenii, R. glutinis, R. garminis, R.rubra, Rhodotorula* sp. *S. cerevisiae* and *Trichosporon* sp.

Table 3 gives the details of the positions of the stations for the collection of sediment samples and the filamentous fungi isolated during FORV *Sagar Sampada* Cruise No. 35. Table 4 gives the details of the yeast species isolated from the benthic sediment samples during the same cruise. Table 5 gives the details of the yeast species found associated with euphausiids from five out of eight stations. Out of the 40 samples of healthy euphausiids screened, only five samples from five different stations showed positive association with yeast.

In our investigation we find that the yeast density was restricted to the euphotic zone and very few yeast counts were obtained from 500 and 1000m depth of the water column. Fell (1967) too observed that increased density of yeast population was related to the productivity of the region in particular, corresponded with the concentration of the inverte-

TABLE 2. *Species of yeasts isolated from different water samples in the EEZ of west coast of India. (FORV* Sagar Sampada *Cruise No. 24, 16.11.1986 - 4.12.1986)*

Station No.	Position	depth (m)	Temp. (°C)	Salinity (°/₀₀)	Oxygen (ml/l)	pH	Total No. of Cfu/l	Species isolated
1	2	3	4	5	6	7	8	9
821	09° 00'N 71° 30'E	0	27.00	35.1	4.23	8.26	8	*C. albicans* & *C. membranaefaciens*
		10	23.92	35.6	4.15	8.27	18	*C. membranaefaciens* & *C. vini*
		50	20.95	35.4	3.15	8.14	18	*Cryptococcus* sp., *R. minuta* & *Rhodotorula* sp.
		100	15.98	35.7	0.54	7.67	6	*C. quilliermondii* & *S. cerevisiae*
		500	10.05	35.5	0.99	7.57	4	*Candida* sp.
		1000	9.07	35.4	1.23	7.62	0	-
826	11° 00'N 73° 30'E	0	23.50	34.9	4.92	8.26	0	-
		10	23.10	35.1	4.88	8.29	18	*C. quilliermondii* & *St. indicus*
		50	22.20	35.0	0.38	8.21	28	*C. membranaefaciens* & *Cryptococcus* sp.
		100	20.50	35.2	0.26	7.79	30	*C. membranaefaciens*, *Candida* sp. *Cryptococcus* sp. & *R. rubra*
		500	13.50	34.9	0.38	7.59	2	*R. graminis*
		1000	8.50	34.8	0.61	7.58	0	-
830	11° 59' N 70° 03' E	0	27.90	35.8	4.81	8.25	0	-
		10	22.90	36.0	4.61	8.29	158	*Cr. laurentii*, *D. hansenii*, *R. glutinis* & *R. rubra*
		50	19.50	35.4	0.45	7.85	16	*Candida* sp. & *Trichosporon* sp.
		100	16.93	35.8	0.29	7.72	2	*Candida* sp.
		500	13.75	34.9	0.38	7.61	6	*Candida* sp. & *Cryptococcus* sp.
		1000	9.74	34.8	0.62	7.59	4	*Candida* sp.
832	12° 00'N 71° 58'E	0	28.00	34.9	4.91	8.27	58	*C. membranaefaciens*, *Cr. laurentii* & *D. hansenii*
		10	24.62	35.8	4.84	8.26	128	*C. qlabrata*, *Candida* sp., *Cryptococcus* sp. & *S. cerevisiae*

Table 2 contd.

1	2	3	4	5	6	7	8	9
		50	21.15	35.6	0.85	7.92	86	*D. hansenii, R. graminis* & *R. rubra.*
		100	19.05	34.9	0.23	7.73	86	*C. quilliermondii, C. membrane faciens* & *Rhodotorula* sp.
		500	14.35	34.8	0.30	7.51	6	*Candida* sp.
834	13^0 00'N	0	28.30	35.2	4.81	8.23	136	*C. membranaefaciens, Cr. laurentii, D. hansenii* & *St. indicus*
	72^0 30'E	10	26.35	35.3	4.54	8.21	160	*C. tropicalis, D. hansenii, R. graminis, R. rubra, Sporobolomyces* sp. & *St. indicus*
		20	24.95	34.9	3.46	8.20	60	*Cr. laurentii, D. hansenii* & *R. minuta*
		30	22.75	34.8	1.92	8.10	36	*C. albicans* &*St. indicus*
		40	20.70	35.1	1.07	8.10	80	*Cr. laurentii, R. minuta* & *R. rubra*
839	14^0 00'N	0	27.30	35.0	5.08	8.27	81	*C. membranaefaciens, R. glutinis* & *Rhodotorula* sp.
	71^0 57'E	10	26.93	34.8	4.82	8.26	38	*C. polymorpha, D. hansenii, R. minuta* & *R. rubra*
		50	20.35	35.0	0.84	7.98	40	*C. membranaefaciens, R. glutinis, R. graminis* & *R. rubra*
		100	17.36	35.2	0.46	7.73	44	*C. membranaefaciens, Candida* sp. & *Saccharomyces sp.*
		500	11.57	34.9	0.23	7.49	0	-
	15^0 45' N	0	26.10	35.3	5.11	8.23	108	*C. atmospherica, R. rubra* & *St. indicus*
843	69^0 14' E	10	26.52	35.6	4.92	8.22	38	*R. graminis* and *R. minuta*
		50	23.35	35.6	4.54	8.19	32	*C. atmospherica, Cryptococcus* sp. *R. rubra* & *St. indicus*
		100	21.23	35.4	1.46	7.69	42	*C. membranaefaciens, C. vini* & *Candida* sp.
		500	11.98	35.1	0.23	7.48	0	-
849	17° 00' N	0	27.30	34.6	5.03	8.31	118	*C. albicans, C. tropicalis* & *R. rubra*
	72° 31' E	10	26.99	34.5	4.92	8.30	198	*C. albicans, C. troicapalis, D. hansenii* & *R. rubra*

Table 2 Contd.

1	2	3	4	5	6	7	8	9
		20	26.93	34.6	4.85	8.19	134	*C. membranaefaciens, C. parapsilosis, C. vini Cryptococcus* sp., *D. hansenii* & *R. minuta*
		30	27.05	34.3	4.85	8.08	82	*C. membranaefaciens, R. minuta* & *R. rubra*
		70	20.74	34.2	4.69	7.99	30	*C. albicans* & *Candida* sp.
	16° 00'N	0	27.00	35.3	5.30	8.22	228	*C. membranaefaciens, C. tropicalis, D. hansenii* & *R. rubra*
	72° 48' E	10	27.02	35.3	4.99	8.20	260	*C. membranaefaciens, C. tropicalis, D. hansenii* & *R. rubra*
		30	21.96	35.3	4.46	8.10	90	*C. parapsilosis, Candida* sp. & *R. rubra*
		75	19.96	35.1	0.46	8.08	28	*C. quilliermondii, Cryptococcus* sp. & *R. glutinis*
		100	19.87	34.8	0.31	7.89	38	*C. vini* & *R. rubra*
	15° 00'N	0	26.80	35.2	5.12	8.24	98	*C. albicans, C. membranaefaciens, C. tropicalis* & *R. minuta*
	73° 15' E	10	27.08	35.1	5.08	8.19	84	*C. albicans,C. membranaefaciens, C. tropicalis* & *R. minuta*
		30	26.24	35.2	5.07	8.15	56	*C. tropicalis* & *Cryptococcus* sp.
		75	20.95	35.9	0.99	8.11	34	*C. quilliermondii, C. membranaefaciens* & *R. rubra*
		100	19.85	35.9	0.77	7.91	16	*C. membranaefaciens*
852	14° 00N	0	27.42	35.1	4.98	8.20	140	*C. albicans, R. rubra* & *Trichosporon* sp.
	73° 34' E	10	27.35	35.1	4.92	8.16	96	*C. albicans, R. rubra* & *Sporobolomyces* sp.
		30	25.88	35.6	4.46	8.12	84	*C. vini, D. hansenii* & *R. qlutinis*
		50	21.90	35.8	1.23	8.09	24	*Cryptococcus* sp.& *S. cerevisiae*
		75	22.01	35.8	1.07	8.02	26	*C. membranaefaciens* & *Candida* sp.
853	13° 00N	0	26.10	35.1	5.10	8.22	60	*Cryptococcus* sp., *D. hansenii Rhodotorula* sp. & *Saccharomyces* sp.

Table 2 Contd.

1	2	3	4	5	6	7	8	9
	74° 00' E	10	27.39	34.9	4.92	8.21	62	*Cryptococcus* sp., *D. hansenii,* & *S. cerevisiae*
		30	25.08	34.9	4.69	8.16	44	*C. membranaefaciens, Cryptococcus* sp. & *R. rubra*
		75	24.50	35.1	2.99	8.07	50	*C. membranaefaciens* & *Cryptococcus* sp.
		90	23.79	35.1	2.92	8.02	24	*Candida* sp. & *Cryptococcus* sp.
854	12°00N	0	26.92	35.1	5.34	8.26	98	*C. tropicalis, Cryptococcus* sp., *R. minuta* & *Saccharomyces* sp.
	74°36'E	10	27.43	35.1	4.92	8.19	74	*C. parapsilosis, C. tropicalis R. minuta* & *R. rubra*
		30	26.20	34.8	4.61	8.15	84	*C. membranaefaciens, Candida* sp. & *R. minuta*
		50	25.34	35.2	4.54	8.06	48	*Candida* sp., *Cryptococcus* sp. & *Sporobolomyces* sp.
		100	22.27	35.1	2.07	7.96	0	-
855	11°00N	0	27.35	34.9	5.08	8.31	56	*C. albicans, C. parapsilosis, R. rubra* & *Trichosporan* sp.
	75°09'E	10	27.83	34.8	4.85	8.27	144	*C. albicans, C. guilliermondii, C. parapsilosis, C. tropicalis,* & *R. rubra*
		30	25.82	35.0	4.23	8.14	140	*C. membranaefaciens, C. vini Cryptococcus* sp., *R. rubra* & *Saccharomyces* sp.,
		75	23.95	35.3	3.99	8.06	80	*Candida* sp. & *R. rubra*
		100	22.90	35.3	3.76	7.98	20	*R. graminis*
856	10°00'N	0	26.63	35.1	5.23	8.28	38	*C. membranaefaciens, C.tropicalis* & *R. rubra*
	75°40'E	10	26.92	35.0	4.69	8.23	108	*C. membranaefaciens, C. tropicalis, D. hansenii, R. aurantiaca* & *R. rubra*
		30	27.26	34.9	4.08	8.19	100	*C. membranaefaciens, Cryptococcus* sp. & *R. rubra*
		75	26.66	34.8	3.69	8.05	70	*C. membranaefaciens* & *Rhodotorula* sp.
		100	25.34	35.1	3.53	7.99	32	*C. membranaefaciens* & *Candida* sp.

TABLE 3. *Species of filamentous fungi isolated from different sediment samples in the EEZ of east coast of India (FORV Sagar Sampada Cruise No. 35)*

Station No.	Position	depth (m)	Total No. of Cfu/g	Species isolated
1156	14° 30' N 80° 18' E	32	10	*Penicillium* Sp., *Fusarium* sp. and *Aspergillus flavus*
1164	15° 33' N 80° 40' E	50	8	*Aspergillus fumigatus* and *Cladosporium* sp.
1171	16° 00' N 81° 28' E	160		
	Near the st. 16° 05' N 81° 30' E	40	13	*Aspergillus niger, Penicillium chrysogenum, Penicillium* sp. and *Fusarium* sp.
1172	16° 31' N 82° 25' E	34	34	*Aspergillus niger, Penicillium* sp., *Fusarium* sp., *Cladosporium* sp. *C. herbarum* and *Alternaria* sp.
1179	17° 15' N 82° 05' E	46	7	*Aspergillus niger* and *Cladosporium* sp.
1180	17° 25' N 83° 00' E	51	8	*Aspergillus fumigatus* and *Cladosporium* sp.
1185	18° 03' N 84° 04' E	57	9	*Penicillium* sp. and *Cladosporium* sp.
1186	18° 01' N 83° 54' E	40	22	*Aspergillus niger, Aspergillus flavus, Penicillium* sp. and *Fusarium* sp.

brates. Majority of yeasts in ocean are probably saprophytes, for their growth they depend on the available organics after the death of various marine organisms (Fell, 1976). In turn they may be included in the diet of invertebrates as a supplementary source of proteins and vitamins. Our observation of the presence of denser population of yeast in the upper layers (euphotic zone) corroborates Fell's observations.

In view of the above and as is obvious from our results of the cruise more detailed study of the EEZ of India is essential to give a better understanding of the yeast population in relation to their linkage to the productivity of the region and their role in the food chain of the ecosystem.

When we compare the population of yeast and filamentous fungi in the benthic sediment, we find that the filamentous fungi were more in number and variety than the yeasts, but it was reverse in water samples. As deep sea grab was not available onboard we took the sediment samples from the coastal stations. It is obvious that most of the filamentous fungi isolated were from terrigenous origin highly adapted to diverse ecological conditions.

Out of the five positive samples of euphausiid, two showed association with *C. tropicalis*, one with *R. lactosa*, another one with *Trichosporon* sp. One sample showed association with both the yeasts (*R. lactosa* and *C. tropicalis*). The relation between the yeast species and the euphausiid has to be established.

TABLE 4. *Species of yeasts isolated from different sediment samples in the EEZ of east coast of India (FORV* Sagar Sampada *Cruise No. 35)*

Station No.	Position	depth (m)	Total No. of Cfu/g	Species isolated
1156	14° 30' N 80° 18' E	32	18	*Rhodotorula graminis*
1164	15° 33' N 80° 40' E	50	9	*Debaryomyces hansenii & Rhodotorula minuta*
Near the st.1771	16° 05' N 81° 30' E	40	19	*Rhodotorula minuta*
1172	16° 31' N 82° 25' E	34	-	-
1179	17° 15' N 82° 05' E	46	12	*Rhodotorula rubra*
1180	17° 25' N 83° 00' E	51	6	*Rhodotorula minuta & Rhodotorula graminis*
1185	18° 03' N 84° 04' E	57	8	*Rhodotorula minuta , Rhodotural rubra & Candida tropicalis*
1186	18° 01' N 83° 54' E	40	16	*Candida tropicalis*

TABLE 5. *Species of yeasts isolated in association with euphausiids during FORV* Sagar Sampada *Cruise No. 35*

Station No.	Position	Species isolated
1156	14° 30' N 80° 18' E	*Candida tropicalis*
1157	14° 30' N 80° 28' E	*Candida tropicalis*
1165	15° 30' N 80° 46' E	*Rhodotorula lactosa & Candida tropicalis*
1179	17° 15' N 82° 05' E	*Trichosporon* sp.
1182	17° 30' N 84° 00' E	*Rhodotorula lactosa*

Healthy samples were chosen, so that there is less chance of the saprophytic role of the yeasts isolated. As suggested by Pagnocca *et al*. (1989) in the case of shrimp, it could be from the intestinal flora where they are favourably lodged.

During these two cruises we had tried to explore different avenues of marine mycology in the EEZ of Indian coast and the results indicate that a detailed systematic study is needed in this less studied field of biological oceanography.

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TECHNICAL SESSION III

Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5 - 7 *June*, 1989 : 47 - 53 (1990)

PRIMARY PRODUCTIVITY AND PLANKTON ABUNDANCE ALONG THE SHELF AND OCEANIC WATERS OFF SOUTHEAST COAST OF INDIA DURING AUGUST, 1987

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Abstract

The study is based on the hydrobiological data collected on board FORV *Sagar Sampada* from the shelf and oceanic waters of Bay of Bengal between Lat. 10° - 14° N and Long. 80° - 83° E in August, 1987. Mean values of chlorophyll 'a', 'b', 'c' and plant carotenoid pigments in surface water were estimated as 2.180, 0.184, 1.616 and 1.651 mg/m^3 in the shelf and 0.333, 0.088, 0.406 and 0.297 mg/m^3 for the oceanic region respectively while primary productivity experiments (by oxygen method) showed mean values of 146 and 92 mg C/m^3/day respectively in the upper euphotic zone.

Phytoplankton blooms and zooplankton swarms observed in the shallow shelf region between 10°30' and 11°30'N and along the continental shelf edge and adjacent oceanic waters between 12°30' and 13°30'N are reported. Wet volume of plankton biomass (soon after preservation) was found to vary from 0.88-10.6 cc/m^3 of water in the shelf and 0.18-1.77 cc/m^3 in the oceanic region with their mean volume estimated as 3.14 and 0.48 cc/m^3 in the respective regions. The concentration of total suspended matter (dry weight) in the surface layer varied from 1.90 -7.91 mg/l. Contribution of plankton biomass to total suspended matter, their distribution pattern and factors relating to their abundance are discussed.

Introduction

Fertility of the sea is determined by its bioproductivity. Phytoplankton, being the basic food in the marine food-chain, followed by zooplankton play a vital role of significance to our food resources from the sea. Hence, investigation on the distribution and abundance of plankton is necessary to assess the potential fishery resources. James *et al.* (1983) have briefed out the important works on the production and distribution of phytoplankton and zooplankton of the west and east coasts of India in relation to fisheries. Apart from the investigations made during the International Indian Ocean Expedition (IIOE), the information available on phytoplankton and zooplankton productivity of the east coast of India is very much limited, especially from the oceanic waters. The present paper is based on the hydrobiological data collected on board FORV *Sagar Sampada* during cruise 34 along the shelf and oceanic waters of the southeast coast of India in Bay of Bengal during August, 1987.

Material and Methods

The study is based on the collection and analysis of hydrographic and plankton samples, primary productivity experiments, quantitative estimation of phytoplankton pigments and total suspended matter and the observations made at 9 stations from the shelf and 23 from the oceanic waters, commencing from stations 1124 to 1155 (Fig. 1) between Lat. 10°-14° N and Long. 80°-83°E, during 19-28 August, 1987.

Phytoplankton pigments were determined by the method given by Strickland and Parsons (1968) using Perkin-Elmer UV/VIS Spectrophotometer. Primary productivity experiments were conducted at all stations by oxygen (light & dark bottle) technique with uniform artificial light incubation for three hours; and the productivity values thus obtained were extrapolated for 12 hours of the day.

Salinity and dissolved oxygen were estimated for the water samples by the standard titration methods. Wet volume of plankton biomass, collected by Bongo-60 net in oblique hauls, were quantified in cc/m^3 of water, soon after preservation in 5% formalin. Quantitative estimation of total suspended matter in dry weight was made for the surface water samples and expressed in mg/l of water.

Observations and Results

Chlorophyll 'a'

Concentration of chlorophyll ' a ' in surface water varied from 0.734 to 6.305 mg/m^3 in the shelf and 0.035 to 3.201 mg/m^3 in the oceanic region with their mean values as 2.180 and 0.333 mg/m^3 respectively. The stations at which maximum values recorded were 1125 in the shelf and 1151 in the oceanic waters (Fig.1) by the blooming of *Trichodesmium erythraeum* and *Rhizosolenia* sp. respectively. A very prominent low productive zone (<0.100 mg/m^3) was observed in the oceanic realm between 11° and 12°N adjacent to the continental shelf edge (Fig. 2) . Other least productive stations were 1128, 1129,1130 and 1143. In general, the shelf region south of 12° N (south zone) and oceanic region north of 12° latitude (north zone) appeared to be fertile in chlorophyll 'a' pigment.

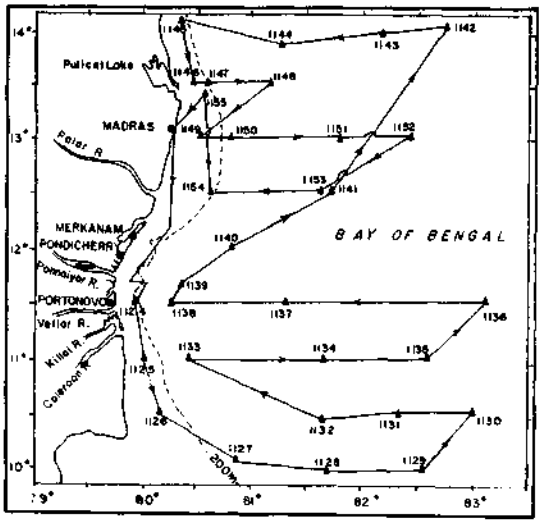

Fig. 1. Map showing station position and cruise route.

Chlorophyll 'b'

Its concentration varied from nil to 0.857 mg/m^3 in the shelf and from nil to 0.610 mg/m^3 in the oceanic region with their mean values as 0.184 and 0.088 mg/m^3 respectively. Maximum values were recorded at stations 1126 in the shelf and 1127 along the slope region in the south zone. In the north zone, higher values of 0.406 and 0.460 mg/m^3 were recorded in the oceanic region at stations 1153 & 1154 respectively. Other than these, all stations in the shelf and oceanic regions had 'b' pigments less than 0.150 mg/m^3 only (Fig. 3). In general, higher concentration of chlorophyll 'b' was found distributed in areas little south of blooming zones of *Trichodesmium* and *Rhizosolenia* (Figs. 2 & 3), indicating watermass of different characteristics from the blooming zone.

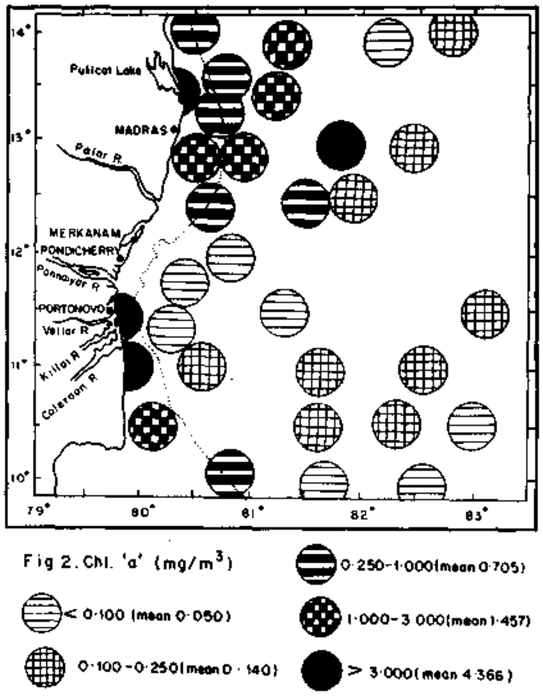

Fig. 2. Distribution of chlorophyll 'a' pigment (mg/m^3).

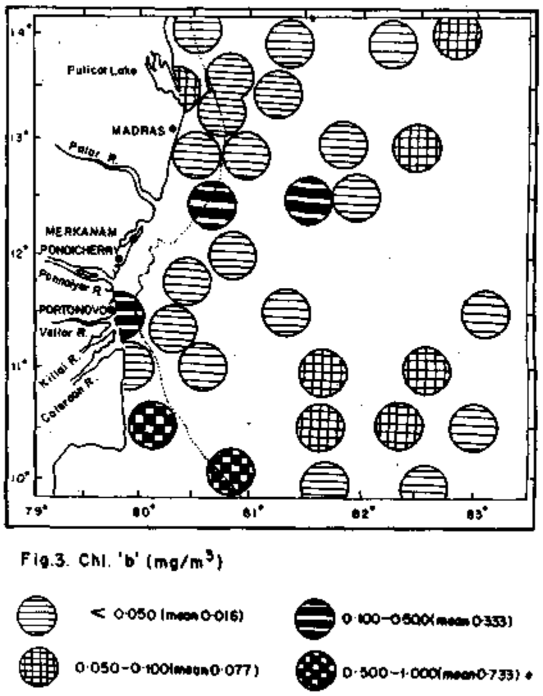

Fig. 3. Distribution of chlorophyll 'b' pigment (mg/m^3).

Chlorophyll 'c'

The distribution pattern of chlorophyll 'c' pigment was found almost similar to that of chlorophyll 'a' except in the level of concentration (Figs. 2 & 4). The values ranged from 0.271 to 3.231 mg/m^3 in the shelf and trace to 1.989 mg/m^3 in the oceanic waters with their mean values as 1.616 and 0.406 mg/m^3 respectively. The stations at which maximum values (>3.000 mg/m^3) recorded were 1125 &1126 in the shelf and at 1151 in the oceanic region. As in the case of chlorophyll 'a', a well demarcated low productive area of chlorophyll 'c' was observed in the same oceanic region between 11° and 12° N (Figs. 2 & 4). The surface water along the continental shelf and slope south of 12° latitude (south zone) was found to be highly fertile with values ranging between 1.921 and 3.231 mg/m^3 with an average of 2.732 mg/m^3, while along the northern shelf zone (north of 12° latitude), the values ranged from 0.271-2.454 with an average of 0.922 mg/m^3 only. The south and north zones of oceanic region recorded mean values of 0. 292 and 0.616 mg/m^3 respectively.

Total chlorophylls

Combined data of chlorophyll 'a', 'b' and 'c' pigments showed the distribution pattern almost similar to that of chlorophyll 'a' and 'c'(Figs. 2, 4 & 5).The total values ranged from 1.041 to 9.425 mg^3 in the shelf region and from trace to 5.233 mg/m^3 in the oceanic region with their mean as 3.980 and 0.781 mg/m^3 and their maximum values recorded at stations 1125 and 1151 in the shelf and oceanic waters respectively. In general, the shelf region south of 12° N latitude proved to be highly fertile with phytoplankton pigments when compared to the shelf and adjacent oceanic waters of north zone and the central oceanic region adjacent to the concave edge of continental shelf between 11° and 12° N proved to be least productive zone in the surveyed sector.

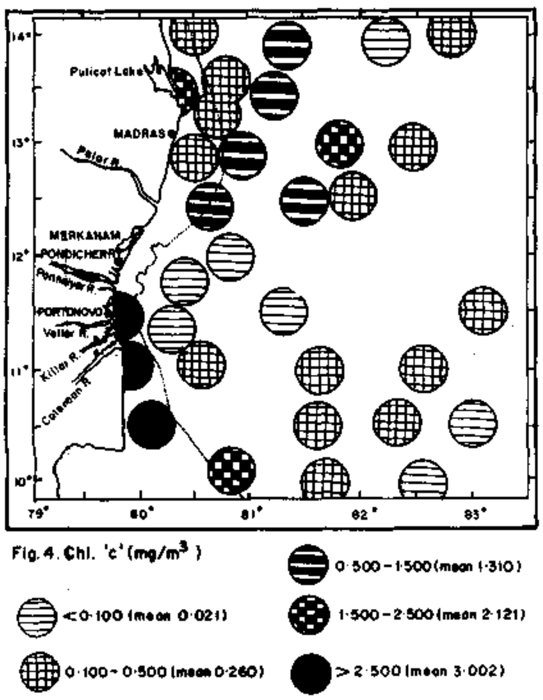

Fig. 4. Distribution of chlorophyll 'c' pigment (mg/m^3).

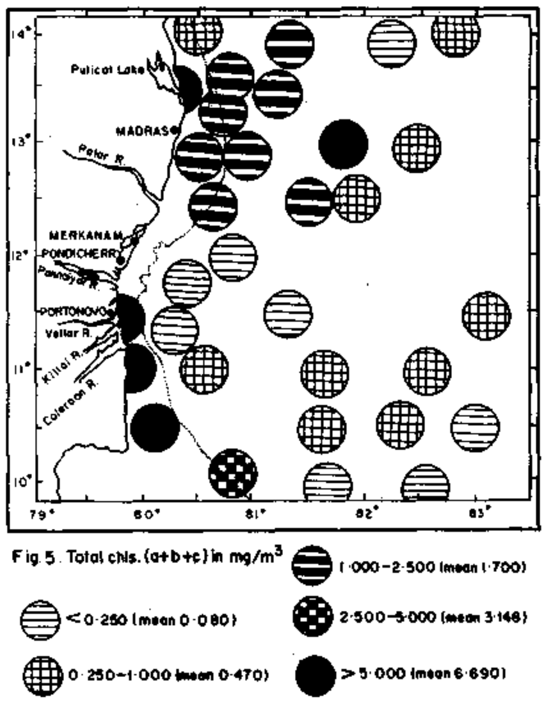

Fig. 5. Distribution of total chlorophylls ('a' + 'b' + 'c') in mg/m^3.

Plant carotenoids

In the shelf waters, the concentration ranged from 0.500 to 4.146 mg/m^3 with a mean of 1.651 mg/m^3 while in the oceanic waters, it varied from 0.010 to 1.769 with an average of 0. 297 mg/m^3. The distribution of plant carotenoids showed the same pattern and trend as in the case of total chlorophylls. The concentration was found more in the blooming areas of *Trichodesmium* and *Rhizosolenia* , showing more affinity towards chlorophyll 'a' and 'c' pigments (Figs. 2-6).

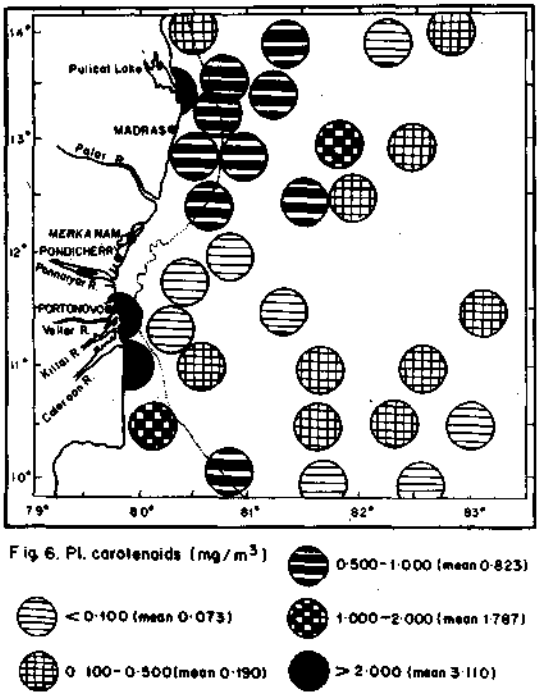

Fig. 6. Distribution of plant carotenoids in mg/m³.

Primary productivity

Along the shelf region, the rate of production per day ranged from 12 to 812 mg C/ m³ with a mean value of 146 mg C/ m³ while in the oceanic euphotic zone the range and mean were 17 - 223 and 92 mg C/m³ respectively.

Relatively higher productivity values were obtained at stations 1125, 1124 and 1146 in the order along the shelf region. The rate of production was found to increase at station 1137 where phytoplankton pigments were found in very low concentration; and the productivity was found low at stations 1153 and 1154 where chlorophyll 'b' concentration was relatively higher. These observations indicated that the rate of production increased in patches and did not show any definite relation with the concentration of phytoplankton pigments (Fig. 7). In general, the northern oceanic zone indicated relatively higher productivity when compared to the south oceanic zone during August, 1987.

Plankton biomass

Wet volume of plankton biomass, determined soon after preservation, was found to vary from 0.88 (stn. 1145) to 10.6 cc/m³ (stn. 1125) in the shelf and from 0.18 (stations 1142, 1152) to 1.77 cc/m³ (stn. 1148) in the oceanic waters, while the mean values were estimated as 3.14 and 0.48 cc/m³ for the respective regions.

Along the southern shelf region, the mean volume was found to be 5.90 cc/m³ while it was 1.63 cc/m³ in the northern shelf region. The biomass volume was found to boost up from 8.83 to 10.6 cc/m³ at stations 1124 and 1125 respectively in the southern shelf region. The northern oceanic zone appeared to be more productive than the oceanic waters of south zone (Fig. 8).

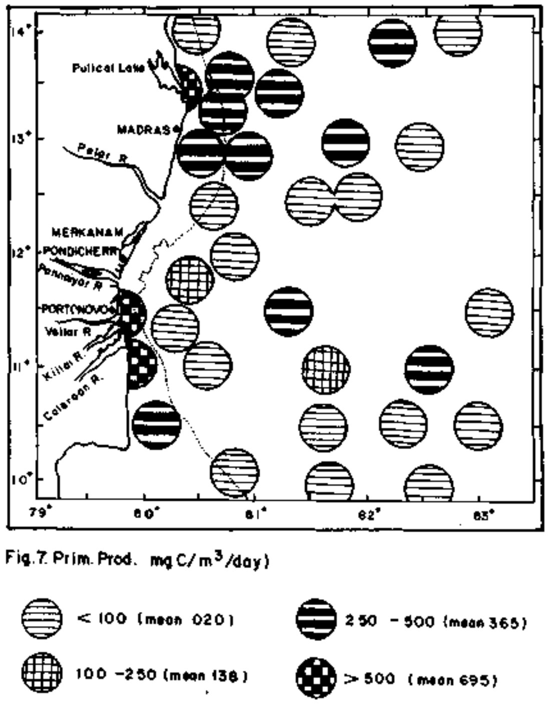

Fig. 7. Primary productivity in mg C/m³/day.

The biomass was dominated by *Trichodesmium, Rhizosolenia, Chaetoceros,* and *Ceratium* among phytoplankton and by copepods, chaetognaths, small medusae and doliolids among zooplankton in the order of abundance. Other groups encountered in the samples were *Planktoniella, Bacteriastrum, Thalassiosira, Thalassionema, Coscinodiscus, Hemidiscus* and *Ditylum* among phytoplankton, and lucifers, polychaetes, euphausiids, decapod larvae, gastropod larvae, fish eggs and larvae and radiolarians among the zooplankton. The rare planktonic branchiostoma was recorded in the oceanic stations 1129, 1131 and 1140 where the depth to bottom varied from 2100 to 3660 m. Leptocephali were found abundant at station 1142.

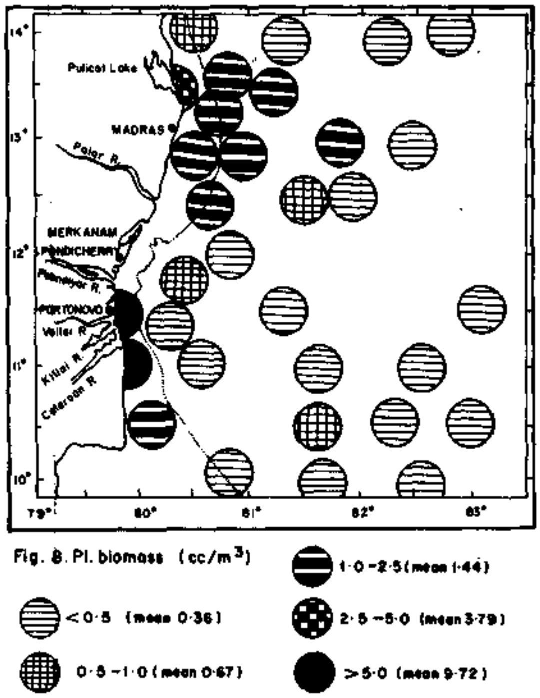

Fig. 8. Distribution of plankton biomass (wet volume in cc/m^3 of water).

Dense blooms of *Trichodesmium erythraeum* observed in the shelf waters between 10°30' and 11°30'N at stations 1124 and 1125 on 19.8.1987 and of *Rhizosolenia* sp. observed during 25-28 August, 1987 in the northern zone between 12°30' and 13°30'N, predominently distributed at stations 1144, 1146, 1148, 1150 and 1151 along the shelf and adjacent oceanic waters, gave an indistinct smell causing severe vomiting sensation to the participants onboard. Apart from this, a very long and broad stretch of natural slick of silvery shining observed in the surface waters off Madras quite parrellel and close to the shelf edge and the route between stations 1154 and 1155 (Fig. 1) on 28.8.1987 was confirmed to be due to *Rhizosolenia* bloom.

Suspended particulate matter

Dry weight of total suspended matter in surface water constituted by plankton biomass and other suspended organic and inorganic inert materials, showed a different trend in distribution pattern when compared to the distribution pattern of phytoplankton pigments and plankton biomass (Figs. 2-6, 8 & 9). The total dry weight varied from 2.35 (stn. 1126) to 7.91 mg/l (stn. 1145) in the continental shelf region and from 1.90 (stn. 1127) to 5.17 mg/l (stn. 1151) in the oceanic region, with their mean values estimated as 5.05 and 3.07 mg/ l for the respective regions. The coastal region north of Pulicat Lake (stn. 1145) showed the highest value (7.91mg/l) with moderate plankton production. In general, the northern zone appeared to be more in total suspended matter (Fig. 9) with an average of 4.58mg/l as against 3.09 mg/l in the south zone.

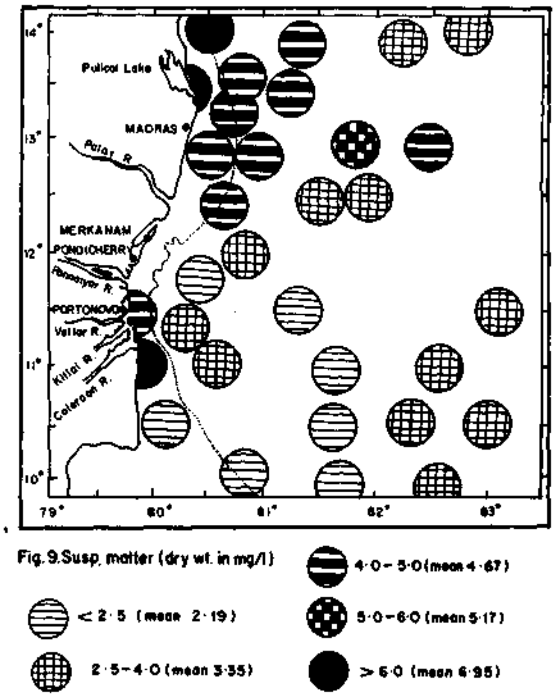

Fig. 9. Distribution of suspended particulate matter (dry weight in mg/l of water).

Hydrography

Surface water had temperature ranging from 27.0 to 29.5°C with its minimum recorded at station 1125 and maximum at 1145. The range in salinity was 34.75 - 36.00‰. Dissolved oxygen varied from 4.17 to 5.31 ml/l with its maximum recorded at stations 1124 and 1125 in the shelf and at 1151 in the oceanic waters indicating the areas of highest primary production. The oceanic waters at station 1137 recorded relatively low oxygen and temperature and higher salinity than the surrounding waters.

Discussion

The results of the present investigation reveal the occurrence of higher concentrations of phytoplankton pigments, plankton biomass and suspended particulate matter in patches along the shelf and adjacent oceanic waters off the southeast coast of India during August, 1987. Subrahmanyan (1960; 1967) has pointed out that on the east coast, maximum primary production occurs during the southwest monsoon months, followed by one or more peaks of prodcution of a lesser magnitude during the northeast monsoon months. Although southwest monsoon rainfall has not much of direct effect along the southeast coast, the surface layers of shelf and adjacent oceanic waters are influenced partly by the outflow of river systems of this coast bringing monsoon waters from interior places of southern India and partly by the drift of the coastal waters from the west coast towards the southeast coast bringing nutrient-rich water to this region resulting in considerable increase in phytoplankton production during this period.

Apart from these, the local mixing up of nutrient-rich deeper water with surface column may also play a significant role in the distribution and abundance of planktonic communities. The very long and broad stretch of natural slick due to the bloom of *Rhizosolenia* sp. observed in the surface water between 12°30' and 13°30'N quite parrellel and close to the shelf edge, with relatively higher salinity recorded in the surface water along its shelf edge and slope and simultaneous abundance of zooplankton communities around this region may be related to such mixing processes during this period. Further, the continuity in the distribution and abundance of *Rhizosolenia* sp. and zooplankon biomass from the oceanic region towards the shelf region off Madras coast (between 12°30' and 13°30'N) indicates the distribution of watermass of same hydrographic characteristics towards the coast.

In this connection, the article by Radhakrishnan *et al.* (1989) on the unusual upwelling-like phenomenon and subsequent congregation of deep water organisms along the north Tamilnadu coast observed during the same period (August- September, 1987) and the observations of Vivekanandan *et al.* (1983) close to this period of 1982 should be of interest. The shoreward drift of upwelled water, from the shelf edge and the adjacent oceanic waters, might be attributed to the observations of Radhakrishnan *et al.* (1989) on the appearance of "Vandal Thanneer" (local name) or turbid water with low temperature (24.5-27.0°C) and low dissolved oxygen (2.37-3.22 ml/l) recorded close to the shore during 26th August to 4th September, 1987 in and around Kovalam Bay near Madras. As per local enquiry, it seems that it is a regular phenomenon every year particularly during August-September period. The wind generated turbulance of water in relation to the topography of the shelf edge of this region (Fig.1) and perhpas the change in pattern and direction of the ocean current system in Bay of Bengal close to August-September period might have significant role in such mixing processes. However, further studies on the hydrodynamics of this region during this period are required to substantiate the actual causes of such phenomenon.

Blooms of phytoplankton and abundance of zooplankton are known to occur generally in the inshore regions while it has been rarely reported from the oceanic waters. Mathew *et al.* (1988) have enlisted in detail the occurrence of phytoplankton blooms at different centres of the east and west coasts of India during the period 1982- '87. However, the present occurrence of blooms o *Rhizozsolenia* sp. from the shelf and oceanic regions off Madras coast and of *Trichodesmium erythraeum* along the shelf region south of Portonovo form the record of this season. Simultaneous abundance of phytoplankton and zooplankton groups along with high dissolved oxygen content in the water indicates that phytoplankton production might be much higher than the grazing level by zooplankton.

Although the distribution of total suspended matter (dry weight) showed a different picture from that of phytoplankton pigments, plankton biomass concentration and primary productivity, it revealed some relation with the abundance of plankton biomass (wet volume) in the regions where the biomass was found abundant. However, the data indicated that the composition of plankton groups in the biomass and distribution of other suspended inert materials brought by the estuarine discharges and by other sources may have significant role in it. The abundance of phytoplankton and zooplankton and the availability of high dissolved oxygen level in the surface waters, along the shelf and adjacent oceanic regions of north zone extending to about 82° E and along the shelf region of the south zone of the surveyed sector indicate the areas of highly productive zones for potential fishery resources close to this season.

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PRIMARY PRODUCTIVITY AND PHYTOPLANKTON PIGMENTS IN THE SOUTHWEST BAY OF BENGAL DURING DECEMBER, 1986

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Abstract

Primary productivity, photosynthetic efficiency, chlorophyll *a* and phaeopigments investigated at 28 stations in the southwest Bay of Bengal during December, 1986 are discussed. The average column productivity values for shelf, slope and offshore regions were 1.01, 1.68 and 0.99 gC/m2/day respectively. Surface productivity was relatively high in shelf waters than at other two regions. Similarly, chlorophyll *a* and phaeopigment values were high in the shelf region. Photosynthetic efficiency showed that the slope region was comparatively more productive.

Introduction

Earlier, several workers have carried out investigations on phytoplankton productivity, chlorophyll and other water characteristics from different regions in Bay of Bengal in relation to the prevailing hydrographical conditions and seasons (Prasad *et al.*, 1970; Krey, 1973; Qasim, 1977, 1978; Radhakrishna, 1978; Radhakrishna *et al.*, 1978; Bhattathiri *et al.*, 1980; Devassy *et al.*, 1983). The present study purports to show results of findings on phytoplankton pigments (chlorophyll *a* and phaeopigments) and productivity at selected locations in the southwest Bay of Bengal carried out in December, 1986 during the cruise of FORV *Sagar Sampada.*

Materials and Methods

Altogether 28 stations (range of depth 36-3, 641 m) located between 80° 00 ' and 82° 30'E and 10° 30' and 14° 30'N on grid pattern, were studied (Fig. 1). Sea water samples were collected from 7 standard depths viz., 0, 10, 20, 30, 50, 75 and 100 m employing a Rosette Sampler. Primary productivity was estimated by 14C technique (Steeman Nielsen, 1952) under simmulated illumination on board for 6-8 hrs and the carbon uptake measured through a liquid scintillation counter (LSS-34, Electronic Corporation of India, Hyderabad) later in the shore laboratory. While chlorophyll *a* and phaeopigments were estimated following the conventional trichromatic method (Strickland and Parsons, 1972 and Parsons *et al.*, 1985), water temperature and salinity were measured with the help of an underwater probe which supplied data onboard. Photosynthetic efficiency was calculated following methods suggested by Copeland and Dorris (1964) and Platt (1969). Based on bathymetry, it was possible to divide the study area into 3 regions namely the shelf region (depth ≤ 200 m) represented by 8 stations (stations 857, 858, 871, 872, 876, 882, 885 and 887), the slope (depth 200-1000m) 2 stations (stations 874 and 886) and the offshore region (depth 1000 m) 18 stations (stations 859, 860, 861, 862, 863, 864, 865, 866, 867, 869, 870, 873, 875, 877, 878, 879, 880 and 881). Table 1 contains data on temperature (°C), salinity‰ chlorophyll *a*, phaeopigments, primary productivity and photosynthetic efficiency (kb%) observed at the individual locations during the investigation.

Results and Discussion

During the study, the overall surface water temperature varied from a minimum of 24.0 (st.857) to a maximum of 27.8° C (st. 872), with a mean of 26.2° C and salinity, between 25.91 (stations 857 and 886) and 32.33‰ (st. 865). Off Cauvery river mouth (st. 872, depth 75 m), surface salinity was appreciably low (28.74‰ compared to waters at 10 m or below where the salinity was uniform (34.33 ‰). During the study, dissolved oxygen content of the surface waters varied between 4.4 (st. 886) and 5.8 mg/l (st. 879), with a mean value of 5.1 mg/l.

The overall chlorophyll *a* varied markedly between different stations and exhibited a general northward increase. The observed values fluctuated from a minimum of 0.04 to a maximum of 0.42 mg/m^3 for surface waters and from 2.65 to 34.07 mg/m^2 for the column (Table 2). Mean surface chlorophyll *a*

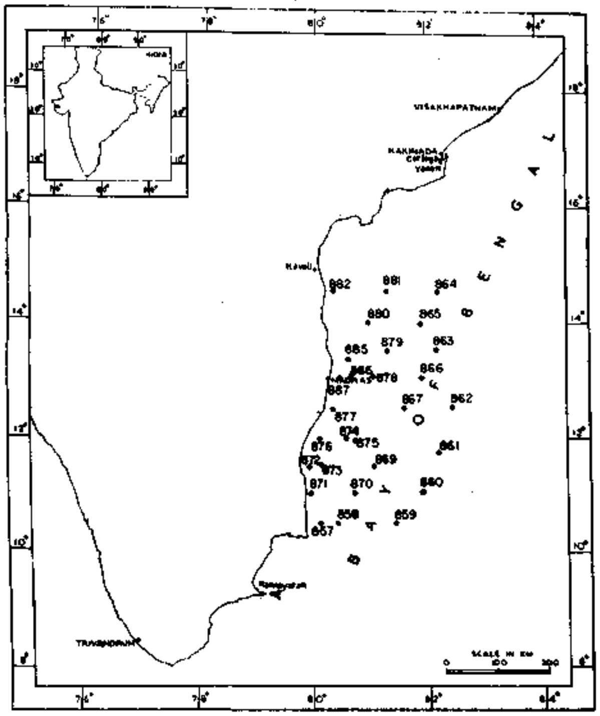

Fig. 1. Forv Sagar Sampada Cruise No. 25 In the Bay of Bengal during December, 1986 : Sampling locations.

values for shelf, slope and offshore regions were 0.222, 0.095 and 0.176 mg/m^3 and for column water 9.18, 9.40 and 14.48 mg/m^2 respectively. Phaeopigment values in the surface waters varied between 0.01 (stations 863, 866, 870 and 873) and 0.19 mg/m^3 (st. 880).

During the study, the overall range of primary productivity for surface waters varied between 3.36 and 52.8 mgC/m^3/day, the average values for shelf, slope and offshore regions being 32.76, 21.96 and 10.8 mgC/m^3/day respectively. Column productivity also varied greatly from a low of 0.294 to a high of 2.040 gC/m^2/day. Mean productivity values for shelf, slope and offshore regions during the study were 1.01, 1.68 and 0.99 gC/m^2/day respectively (Table 2). It may be noted that the slope region was relatively more productive than the other two.

The overall photosynthetic efficiency (kb%) values ranged from a low of 0.002 to a high of 0.024% for surface waters and from 0.06 to 0.46% for the column (Table 1). Mean photosynthetic efficiency values for shelf, slope and offshore regions respectively were 0.01, 0.012 and 0.005 in surface waters and 0.22, 0.38 and 0.24% in the column (Table 2). It is evident that productivity-wise, the slope region is relatively more efficient than the other two regions.

Assimilation index provides information on the carbon fixation per unit chlorophyll *a*. During the present study, the overall assimilation number varied from a low of 28 to a high of 295 for surface waters and from 30 to 320 for column (Table 1). Average assimilation figures for shelf, slope and offshore regions were 160, 230 and 70 in surface waters and 130, 215 and 67 in the column respectively (Table 2).

Based on the findings made in the study, certain conclusions may be drawn. It may be seen that appreciable difference existed in chlorophyll *a*, productivity, photosynthetic efficiency and assimilation values between the shelf and offshore regions. For instance, the mean chlorophyll *a* of surface waters in the shelf region was relatively higher (0.222 mg/m^3) than in the offshore region (0.176 mg/m^3). Similarly, productivity in surface waters in the shelf region was 3 to 4 times higher than offshore. The comparatively high productivity of the shelf region could be attributed to active replenishment of nutrients leading to a high phytoplankton abundance in this area. During the study, it was also noticed that the photosynthetic efficiency of surface waters in the shelf region was relatively high (0.010) than the offshore environment (0.005). Subba Rao (1981) observed that off Waltair photosynthetic efficiency in the coastal waters was high (0.59) during March-April period when there was a rich bloom of phytoplankton coinciding with seasonal upwelling. Similarly, the assimilation index of the shelf waters (mean 160) was greater than the offshore region (mean 70). The comparatively high assimilation numbers in the shelf region could be due to the possible involvement of other accessory pigments in the primary production. Pant *et al.* (1976) and Bhattathiri and Devassy (1977) found that nanoplankton played a significant role by contributing 40-100% of the overall primary production in the nearshore waters. Similar observations were made by Radhakrishna *et al.* (1978) in the inshore waters in Arabian Sea. The low assimilation index (mean 70) in the offshore waters observed in the present study could be due to the simultaneous release of extracellular products during photosynthesis described as responsible by Pant *et al*. (1976) and Bhattathiri and Devassy (1977).

In column waters, considerable differences were noticed between the shelf and offshore regions in chlorophyll *a* values, primary productivity and assimilation numbers. For instance, the mean

TABLE 1. *Temperature, salinity, chlorophyll a, phaeo pigments, primary productivity and photosynthetic efficiency (Kb) at different stations in the south-west Bay of Bengal during December, 1986 (FORV* Sagar Sampada, *Cruise No. 25)*

Sl. No.	St. No.	Depth (m)	Lat. (N)	Long. (E)	Date	Surface						Column		
						Temp. (°C)	Sal. (°/₀₀)	Chl. *a* (mg/m³)	Phae. pig. (mg/m³)	Prim. prod. (mgC/m³/day)	Kb (%)	Chl. *a* (mg/m²)	Prim. prod. (gC/m²/day)	Kb (%)
1.	857	50	10°30′	80°10′	17.12.86	24.0	31.43	0.15	0.09	30.84	0.014	12.75	0.540	0.12
2.	858	200	10°30′	80°30′	17.12.86	25.0	31.43	0.14	0.03	22.32	0.010	17.83	1.975	0.44
3.	859	3641	10°30′	81°30′	18.12.86	26.2	31.43	0.07	0.02	7.44	0.003	11.48	0.699	0.15
4.	860	3602	11°00′	82°00′	18.12.86	25.0	30.53	0.43	0.12	13.92	0.006	17.60	1.791	0.40
5.	861	3512	11°45′	82°15′	18.12.86	26.5	32.33	0.18	0.02	5.04	0.002	10.55	0.590	0.13
6.	862	3423	12°30′	82°30′	19.12.86	25.8	32.33	0.18	0.02	–	–	14.97	–	–
7.	863	3370	13°30′	82°15′	19.12.86	25.7	30.53	0.04	0.01	–	–	19.65	–	–
8.	864	3225	14°30′	82°15′	20.12.86	26.0	31.43	0.09	0.02	–	–	18.37	–	–
9.	865	3320	14°00′	82°00′	20.12.86	26.2	32.33	0.12	0.02	3.36	0.002	15.27	0.826	0.18
10.	866	3447	13°00′	82°00′	20.12.86	26.0	30.53	0.04	0.01	–	–	14.10	–	–
11.	867	3478	12°30′	81°40′	20.12.86	25.5	32.33	0.19	0.05	6.20	0.003	14.20	0.719	0.16
12.	869	2700	11°30′	81°10′	21.12.86	27.0	30.53	0.35	0.09	–	–	19.10	–	–
13.	870	2261	11°00′	80°45′	21.12.86	26.5	31.43	0.06	0.01	–	–	7.35	–	–
14.	871	75	11°00′	80°00′	21.12.86	27.5	31.43	0.29	0.09	14.40	0.006	5.60	0.294	0.06
15.	872	75	11°30′	80°00′	22.12.86	27.8	28.74	0.28	0.12	14.40	0.006	0.90	0.686	0.14
16.	873	1232	11°30′	80°15′	22.12.86	24.5	31.43	0.06	0.01	–	–	6.05	–	–
17.	874	798	12°00′	80°40′	22.12.86	26.5	31.43	0.09	0.03	19.44	0.009	5.25	1.563	0.35
18.	875	2867	12°00′	80°45′	22.12.86	26.2	31.43	0.09	0.03	13.44	0.006	34.07	1.442	0.32
19.	876	39	12°00′	80°10′	22.12.86	27.5	30.52	0.13	0.08	38.40	0.018	2.65	0.528	0.12
20.	877	1200	12°30′	80°20′	23.12.86	27.0	32.32	0.17	0.12	–	–	8.50	–	–
21.	878	3390	13°00′	81°00′	23.12.86	26.5	30.50	0.10	0.02	14.64	0.007	10.55	1.363	0.30
22.	879	3289	13°30′	81°20′	23.12.86	25.5	30.53	0.10	0.02	7.68	0.004	12.78	0.320	0.07
23.	880	2972	14°00′	81°00′	24.12.86	25.5	31.43	0.36	0.19	10.08	0.005	16.00	1.606	0.36
24.	881	2937	14°30′	81°20′	24.12.86	27.0	31.43	0.26	0.12	26.64	0.012	10.10	0.490	0.10
25.	882	48	14°30′	80°20′	24.12.86	27.0	31.43	0.29	0.13	52.80	0.024	–	–	–
26.	885	50	13°20′	80°40′	25.12.86	26.5	25.91	0.29	0.12	38.40	0.010	–	–	–
27.	886	293	13°00′	80°45′	25.12.86	27.0	25.91	0.10	0.04	24.42	0.011	12.75	1.810	0.40
28.	887	75	13°00′	80°20′	25.12.86	26.5	25.91	0.21	0.10	50.40	0.023	6.40	2.040	0.46
					Minimum	24.0	25.91	0.04	0.01	3.36	0.002	2.65	0.294	0.06
					Maximum	27.8	32.33	0.42	0.19	52.80	0.024	34.07	2.040	0.46
					Mean	26.2	30.68	0.17	0.05	20.71	0.010	12.84	1.071	0.24

TABLE 2. *Chlorophyll* a, *primary productivity, photosynthetic efficiency (Kb) and assimilation index in Bay of Bengal in December, 1986 (values represent ranges and in parenthesis the mean)*

	Surface				Column			
	Chl. a (mg/m³)	Primary productivity (mgC/m³/hr)	Kb (%)	A. N.	Chl. *a* (mg/m²)	Primary productivity (gC/m²/day)	Kb (%)	A. N.
Shelf	0.13 - 0.29 (0.222)	1.20 - 4.40 (2.73)	0.006 - 0.024 (0.010)	49 - 295 (160)	2.65 - 17.83 (9.18)	0.294 - 2.040 (1.01)	0.12 - 0.46 (0.22)	40 - 320 (130)
Slope	0.09 - 0.10 (0.095)	1.61 - 2.04 (1.83)	0.009 - 0.013 (0.012)	216 - 245 (230)	5.25 - 12.75 (9.4)	1.564 - 1.810 (1.68)	0.35 - 0.40 (0.38)	140 - 290 (215)
Offshore	0.04 - 0.42 (0.176)	0.28 - 2.20 (0.90)	0.002 - 0.012 (0.005)	28 - 149 (70)	6.05 - 34.07 (14.48)	0.49 - 1.792 (0.99)	0.07 - 0.40 (0.24)	30 - 160 (67)
Entire	0.170	2.071	0.01	130	12.84	1.071	0.24	137

chlorophyll *a* was appreciably low (9.18 mg/m^2) in column waters in the shelf region than offshore (14.48 mg/m^2) (Table 2). Similarly, there was a marked difference in the mean assimilation indices, the values being almost twice in the shelf region (130) than offshore column (67). The low chlorophyll and high assimilation indices observed in the shelf region during the study were suggestive of rapid turn over rates in productivity in this area. However, there was no such difference in the overall column productivity of the shelf (mean 1.01gC/m^2/day) and offshore areas (0.99 gC/m^2/day), as well as in photosynthetic efficiency values (Table 2).

It is noteworthy that in the slope region, the photosynthetic efficiency and assimilation indices were comparatively higher than the shelf and offshore areas. For instance, the mean photosynthetic efficiency values for surface and column waters in the slope regions were comparatively greater being 0.012 and 0.38 respectively. Similarly, the assimilation indices for both surface (mean 230) and column waters (mean 215) were higher. Radhakrishna *et al.* (1978) observed that along the east coast, waters in the slope regions remained comparatively more productive than shelf and offshore regions which they attributed to the narrow nature of the slope in the Bay of Bengal.

Finally, spatial gradients in chlorophyll *a*, phytoplankton productivity and its efficiency observed during the study exhibited appreciable differences in the shelf, slope and offshore regions. This could possibly be due to variations in depth, currents prevailing in the area, sinking of water masses or other ocean phenomena such as convergence and divergence mentioned by Bhattathiri and Devassy (1977).

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STUDIES ON ZOOPLANKTON BIOMASS AND SECONDARY AND TERTIARY PRODUCTION OF THE EEZ OF INDIA

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ABSTRACT

The zooplankton collected from 1,113 stations occupied in the EEZ of India and contiguous seas during the cruises 1-44 of FORV *Sagar Sampada* during 1985-'88 has been analysed for spatial distribution, monthly and seasonal abundance and diurnal variations. The data obtained have been used for estimating the biomass and secondary production on a half degree square basis and fish production for every one degree square in the EEZ.

In general it has been found that the waters off the west coast were more productive. Pockets of very high density of over 1,000 cc of zooplankton per 1,000 m^3 of water were observed off Cochin and Mangalore. Fairly high density areas were frequently encountered all along the shelf area off the west coast especially the Wadge Bank area, the Gulf of Mannar, off Cochin, Mangalore, Goa and along the Gujarat coast. In the oceanic area of the eastern Arabian Sea also high desity areas were frequently met with. Off the east coast, high density areas were noticed north of Mardas and off Kakinada. East of Andamans and around Nicobar Island, there were restricted areas of zooplankton abundance.

The average density of zooplankton in the entire area investigated has been estimated to be 88.33 cc per 1000m^3 of water. The average zooplankton biomass in the entire shelf area of both the coasts of India and the Andaman and Nicobar Islands has been estimated to be 164.04 cc against a biomass value of 54.75 cc for the entire oceanic areas. A consideration of the biomass in the shelf and oceanic areas separately for the two coasts showed that the shelf area of the west coast with 200.25 cc accounted for the maximum followed by the shelf area of the east coast including the Andaman and Nicobar Islands with only 92.25 cc. In the oceanic area also the biomass almost doubled in the eastern Arabian Sea (67.66 cc) than in the Bay of Bengal (36.65 cc). A further estimate of the biomass during the three seasons indicated that in the shelf area the average values for the premonsoon, monsoon and postmonsoon were 101.05, 216.85 and 132.51 c c respectively. The same in the oceanic areas was found to be 45.03, 72.89 and 49.37 cc respectively thus indicating a two fold increase in the shelf region during the pre and postmonsoons and a three fold increase during the monsoon season. While the day samples yielded a quantity of 83.44 cc, the night samples made up 95.99 cc.

A half degree wise production at the secondary level was worked out and it was found that the values ranged between 0.5 and 20.92 gC/m^2/year. From the values of secondary production, the fish production was worked out for the total area under study and for the EEZ. Accordingly it was seen that the fish production in the Indian EEZ could be 7.46 million tonnes with split values of 4.78 mt for the west coast, 1.32 mt for the east coast and 1.37 mt for the Andaman and Nicobar Seas.

INTRODUCTION

The history of zooplankton investigation in the Indian Ocean dates back to 1857 when the ship *Novara* engaged 52 stations along 40°S eastward upto 80°E meridian, along 85° E meridian northwards upto Madras and eastward upto Sumatra. Afterwards several expeditions have visited some or the other parts of the Indian Ocean and made plankton sampling. However, these collections were mainly used for faunistic studies. The first major attempt to study the quantiative distribution and abundance of zooplankton of the Indian Ocean was by the International Indian Ocean Expedition (1960-'65) during which ships of several countries participated. Eventhough the studies gave a general picture about the quantitative distribution and abundance of zooplankton (Prasad, 1968, 1969; Rao, 1973), due to inadequacy of samples the results obtained were not very conclusive. Nor was it possible to make any seasonal studies. Except for a few locations, especially in the northern parts of the Indian Ocean, the number of samples available for a 5° area was less than 10.

Apart from the IIOE, many other intensive but localised surveys for zooplankton have been carried out subsequently. RV *Varuna* investigated the shelf and oceanic waters of the southwest coast of India (Ramamirtham and David Raj, 1981); RV *Rastrelliger* and RV *Sardinella* of the erst-while Pelagic Fisheries Project, Government of India made detailed but restricted studies in the shelf waters between Ratnagiri and Tuticorin (Anon., 1973, 1976;

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Menon and George, 1977). Recently the National Institute of Oceanography has come out with an Atlas (Supria *et al.*, 1988) which gives the zooplankton biomass of the EEZ based on a mere 464 samples collected during 1976-'80 by RV *Gaveshini.*

All the above studies point to the inadequacy of coverage or insufficiency of samples for arriving at proper conclusions with regard to distribution and abundance of zooplankton in space and time. In view of this, an attempt is made here to study the total zooplankton biomass and the secondary production of the eastern Arabian Sea, the Bay of Bengal and the Andaman & Nicobar Seas. Using the secondary production data obtained during the present studies an attempt has also been made to work out the tertiary production in the area investigated. The present study is one step ahead of the earlier investigations rather than a continuation, for the reason that the areas covered are far wider and the frequency of sampling much better.

Material and Methods

The material which formed the basis of the study was collected onboard FORV *Sagar Sampada* from the Indian EEZ and contiguous seas during the period 1985-'88. The gear used was Bongo -60 net with a mesh size of 0.33 mm. Hauls were made from 150 m to surface in oblique manner with the ship in motion at 2 knots speed. A precaliberated flow meter was used in most cases and hence the data on biomass as well as individual zooplankton groups could be quantified. The plankton was preserved in 5% formaldehyde solution. In the laboratory the total volume was determined by displacement method. After removing the macroplankton, a minimum of 5 cc of zooplankton was sorted out into different groups and enumerated. The biomass as well as individual groups were estimated for 1000 m^3 of water.

For the purpose of comparisons, the area under investigation was divided into four latitudinal regions namely, Region-1: 04°30'N to 10°N; Region-2 : 10°N to 15°N; Region-3: 15°N to 20°N, region-4 : 20°N to 23°N. The area west of 77°30'E was considered as eastern Arabian Sea and that east of it as Bay of Bengal. The shelf area mentioned in the paper is the area within the continental shelf and that beyond it is called as oceanic area. The three seasons recognized in the paper are premonsoon from February to May, monsoon from June to September and postmonsoon from October to January. The samples collected between 0600 and 1800 hrs have been considered as day samples and those collected between 1800 and 0600 hrs as night samples. A total of 1113 zooplankton samples collected during cruises 1-44 have been analysed for the present study. For obtaining finer details of quantitative distribution in space, biomass values have been worked out for every half-degree square area against 5° square followed for the IIOE data. For this purpose the number of stations occupied in each half-degree square were considered together and the data obtained were pooled together. The estimates for secondary and tertiary production were made following the method by Cushing (1973) and later modified by Dalal and Parulekar (1986). All the data were analysed in a computer.

Results and Discussion

Coverage and frequency of sampling

Figure 1 Shows the area covered by the *Sagar Sampada* for zooplankton sampling and the frequency of sampling in each half degree square. Off both the coasts and the Andaman and Nicobar seas, sampling was not strictly confined to the EEZ but the neighbouring areas were also covered. This was especially so in the case of Bay of Bengal which was almost entirely covered though less intensively. The coverage was more intensive off the southwest coast. However, adequate sampling has been done in other areas also including the Andaman and Nicobar seas. Incidently it is to be mentioned that this is the first time a study is made on zooplakton of the Indain EEZ making use of such enormous data.

Spatial distribution

For drawing the isolines of biomass density in space, the values were broadly categorised into five to represent the ranges between 1 cc and more than 500 cc per 1000 m ^{3} of water. The results obtained are depicted in Fig. 2. In general the waters off the west coast was more productive. There itself the shelf area was highly productive. Pockets of very high density of zooplankton were observed off Cochin (1,228.32 cc/ 1000 m^3 at 09°00'N 76°19'E) and off Mangalore (1,968. 25 and 1,527.51 cc/1000m^3 at 10° 30'N 75° 40' E and 10°30'N 75° 30'E respectively). High-density areas were rather frequently encountered all along the shelf off the west coast especially in the Wadge Bank area, the Gulf of Mannar, off Cochin, Mangalore, Goa and along the Gujarat coast (Fig. 2). In the oceanic waters also

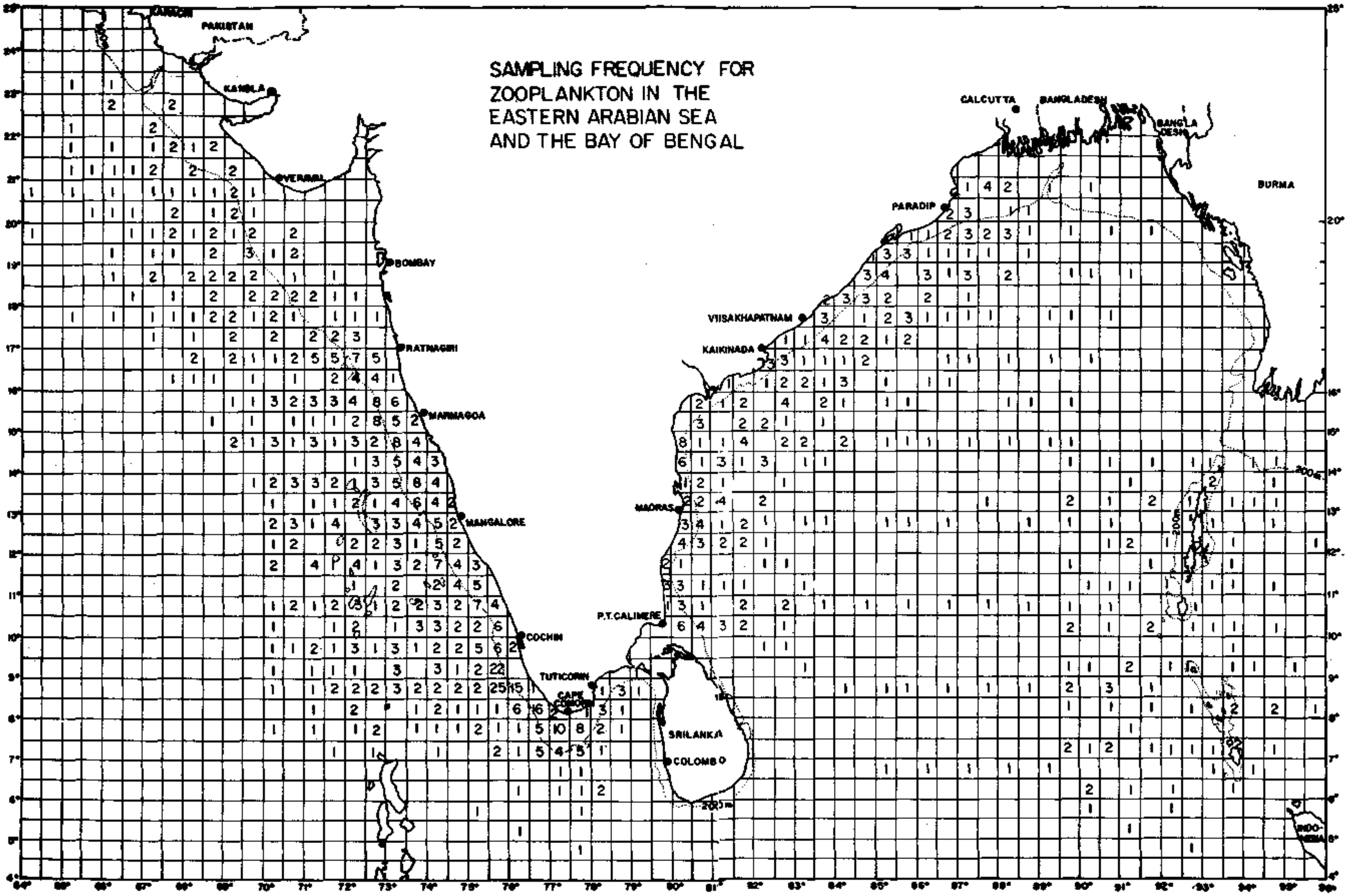

Fig. 1. Sampling frequency for zooplankton in each half degree square.

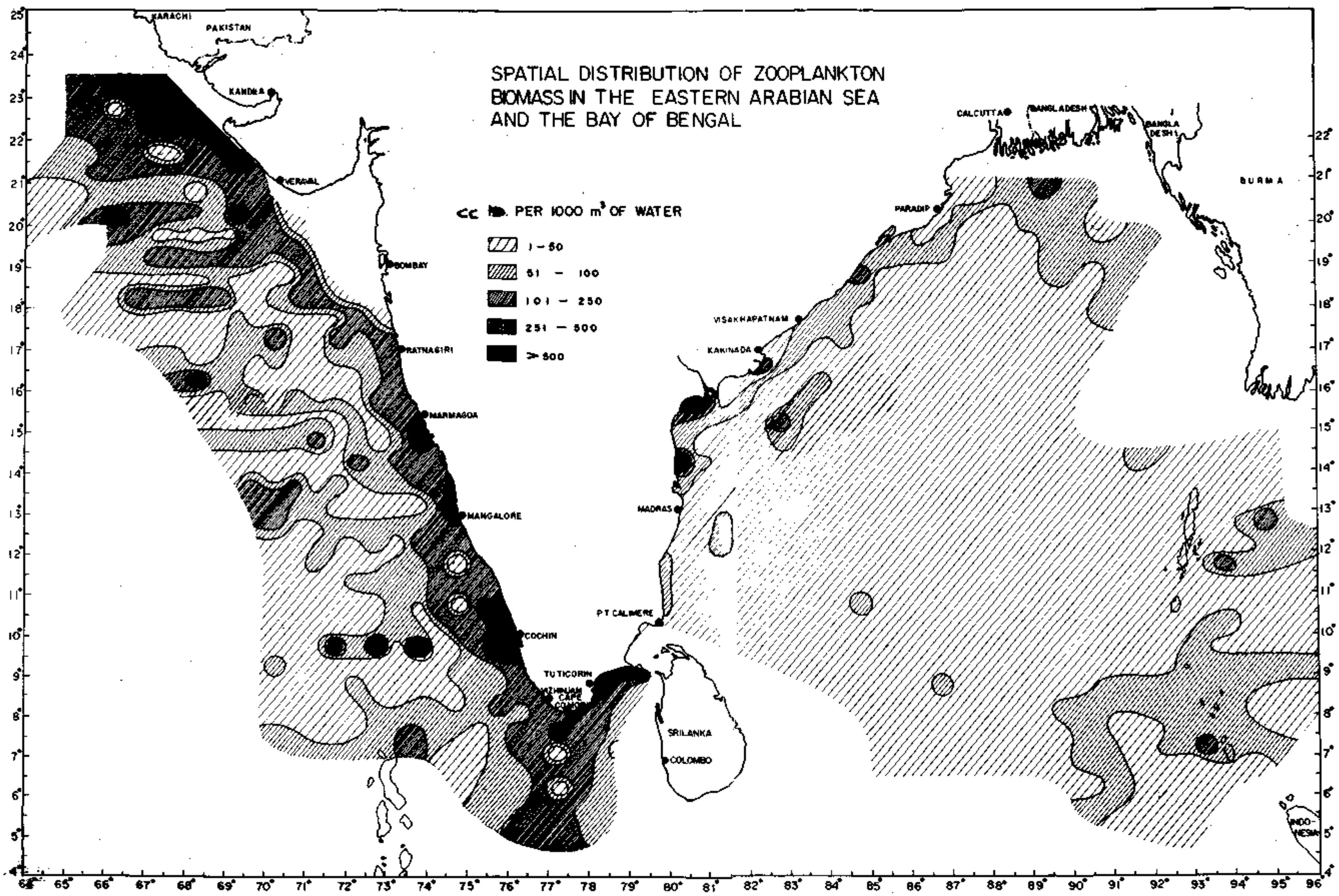

Fig. 2. Spatial distribution of zooplankton biomass.

high-density areas were frequently met with in the eastern Arabian Sea. In a recent atlas made for the zooplankton of the EEZ of India, Supria *et al.* (1988) have shown highly productive areas off Veraval, Bombay , Goa, Mangalore and Kanyakumari, and this is in conformity with the present investigations.

The zooplankton biomass was rather sparse in the Bay of Bengal, where in the oceanic waters, the density was below 50 cc/1000 m^3 . However , around Nicobar Islands the production ranged between 51 and 100 cc. East of Andaman also there were restricted areas of abundance. In the shelf waters off the east coast the rate of zooplankton production was relatively better than in the oceanic area. Localised high-density areas were noticed north of Madras and off Kakinada. On the whole, moderate to low production appears to be the general trend in the shelf area of the east coast.

The biomass values obtained for the EEZ and the neighbouring waters have made it possible to work out some generalised figures for the overall average density of zooplankton for the different water areas on a broader basis. Thus the average density of zooplankton in the entire area has been estimated to be 88.33 c c per 1000 $m^3$of water. The area was further divided into shelf and oceanic areas and the average values obtained for the respective areas were 164.04 and 54.75 cc per 1000 m^3 of water which indicated that the shelf waters were three-times more productive. A consideration of the biomass in the shelf and oceanic regions separately for the two coasts showed that the shelf area of the west coast with 200.25 cc was the maximum productive, followed by the shelf area of the east coast with only 92.25 cc. In the oceanic area also the biomass of the west coast (67.66 cc), was almost double than that of the east coast (36.65 cc).

A further estimate of the biomass during the three seasons indicated that in the shelf area the average values for premonsoon, monsoon and postmonsoon were 101.05, 216.85 and 132.51 cc respectively. The same in the oceanic areas were found to be 45.03, 72.89 and 49.37 cc respectively. While the average density of zooplankton during day time was 83.44 cc the same in the night was 95.99 cc.

Monthly variation in abundance

Figure 3 shows the monthly variation of plankton in the study area. The general trend observed was that the period from June to December was highly productive with the maximum during August when the average monthly biomass reached 182 cc per 1000 m^3 of water. This was followed by September during which month the average value obtained was 116.70 cc. The least value of 28.72 cc was obtained in May. The monthly values when categorised into three seasons, it was found that the monsoon season (June-September) accounted for the maximum biomass of 121.96 cc followed by the postmonsoon season (October - January) with 77.63 cc and the premonsoon (February-May) with the least value of 54.405 cc. Rao (1973) who worked on the Indian Ocean zooplankton also found the July-September period to be the maximum productive season.

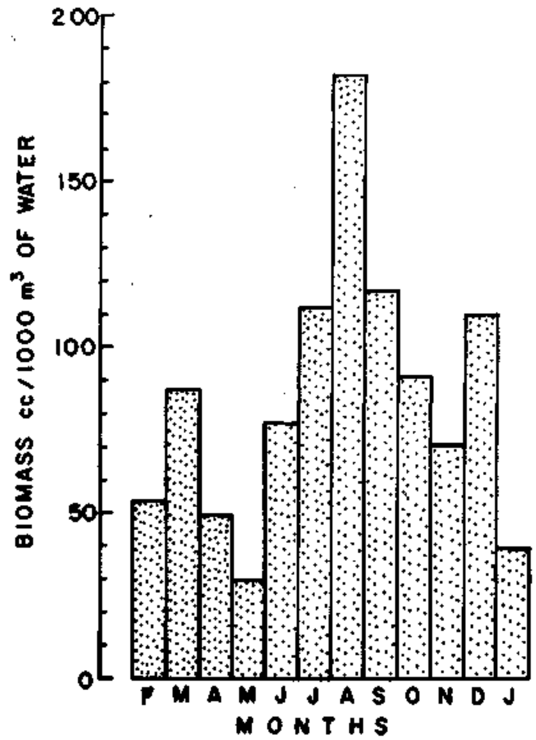

Fig. 3. Monthly abundace of zooplankton biomass in the area studied.

A further attempt was made to understand the variations in monthly abundance in the eastern Arabian Sea and the Bay of Bengal separately (Fig. 4). On the whole about 60 to 80% of the plankton was obtained from the west coast. However, during January, February and April the biomass off the east coast was found to be relatively more than that off the west coast. Off the west coast, the maximum biomass value (average 133.00cc) was found from June to September followed by the October to December period (average 100. 02 cc).

Off the east coast the period of maximum production was from July to October (average 86.29 cc). The results obtained for the west coast is in agreement with the earlier findings for the whole Arabian Sea and for localised areas. Thus Prasad (1969) recorded the maximum production during the southwest monsoon. Same was the observation made by Menon and George (1977) and Ramamirtham and David Raj (1981) in the shelf waters of the southwest coast of India.

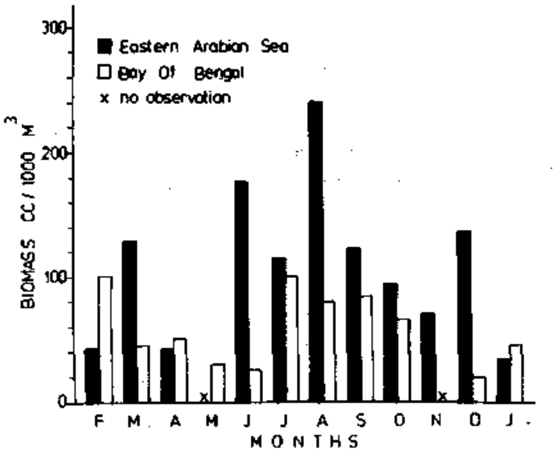

Fig. 4. Monthly abundance of zooplankton biomass in the eastern Arabian Sea and the Bay of Bengal.

A comparison between biomass values obtained for the shelf and oceanic areas for the total area investigated was made and the results are presented in Fig. 5. As could be expected the shelf was found to be far more productive than the oceanic areas and the increase was of the order of 60 to 80%. Regarding the month to month variation, it was found that in the shelf area while the period from June to October appeard to be very rich in plankton, in the oceanic area the corresponding period was from July to December.

Latitudinal abundance

The whole area investigated was divided into four latitudinal grids i.e., upto 10°N, 10-15°N, 15-20°N and above 20°N. In general it was found that in the eastern Arabian Sea, the zooplankton biomass gradually increased form south to north with the exception in the 3rd latitudinal region which recorded the maximum of 83 cc per 1000m³ of water (Fig. 6). In the Bay of Bengal, on the other hand, region-1 (southernmost) was the maximum productive which itself was less than the least productive

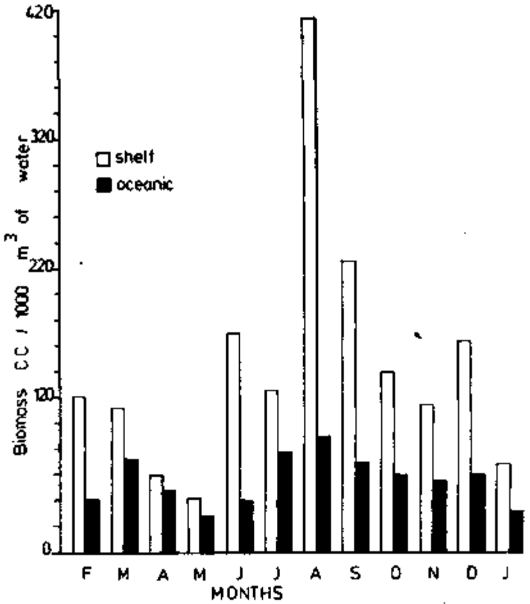

Fig. 5. Monthly abundance of zooplankton biomass in the shelf and oceanic waters of the area investigated.

region in the eastern Arabian Sea. The 2nd region in the Bay of Bengal with 36.9 cc was the least productive in the whole area investigated. The biomass value in this latitudinal region was equal to only 22% of the corresponding region off the west coast.

A much more detailed study was carried out for the zooplankton abundance during the three major seasons in the four latitudinal regions separately for the two major sea areas and the results are given in Fig. 7. Off the west coast while in regions 1 and 2 the maximum abundance was during the monsoon season, in the 3rd and 4th regions the same was during the premonsoon season. The sequence from maximum to minimum production in the former two regions was monsoon, postmonsoon and premonsoon, and off the east coast the sequence was premonsoon , monsoon and postmonsoon.

Another study carried out was the abundance in the shelf and oceanic areas off the two coasts separately during the three major seasons and the results are depicted in Fig. 8. It was found that each subsector presented different pattern of abundance seasonally.

Off the west coast in the first and second regions the sequence of abundance from high to low in both shelf and oceanic areas was monsoon,

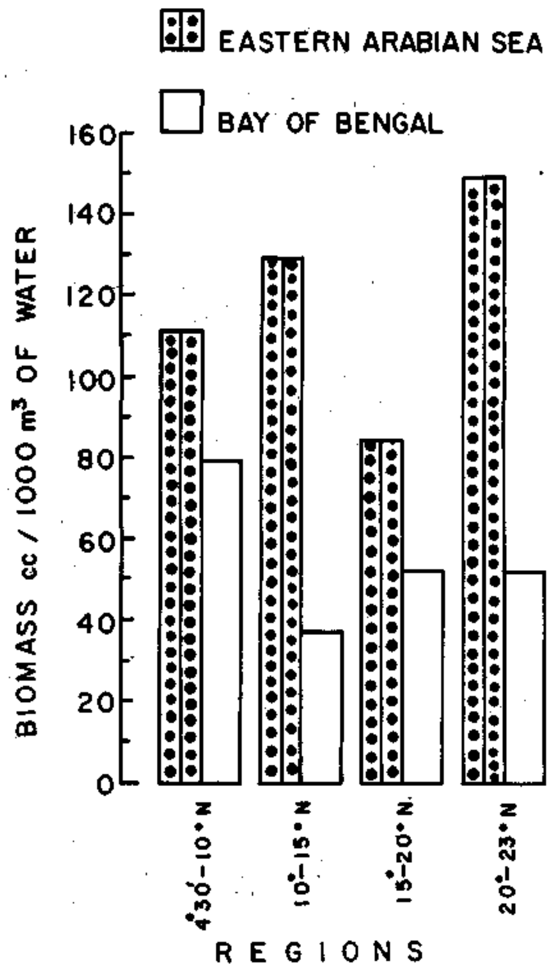

Fig. 6. Latitudinal abundance of zooplankton biomass in the eastern Arabian Sea and the Bay of Bengal

postmonsoon and premonsoon. In the 3rd region a different picture was obtained for the shelf area in the sense that there was no sequential increase or decrease through the three seasons. The maximum

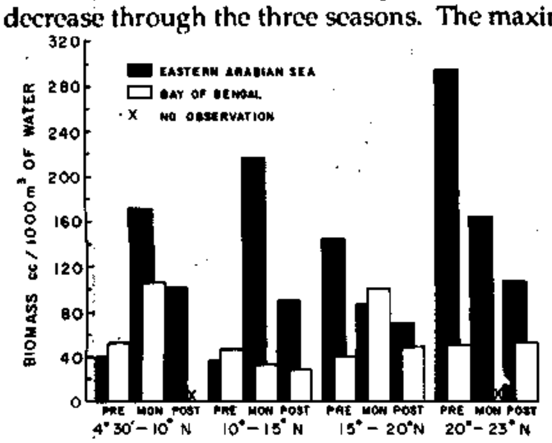

Fig. 7. Seasonal variations in the latitudinal abundance of zooplankton biomass in the eastern Arabian Sea and the Bay of Bengal.

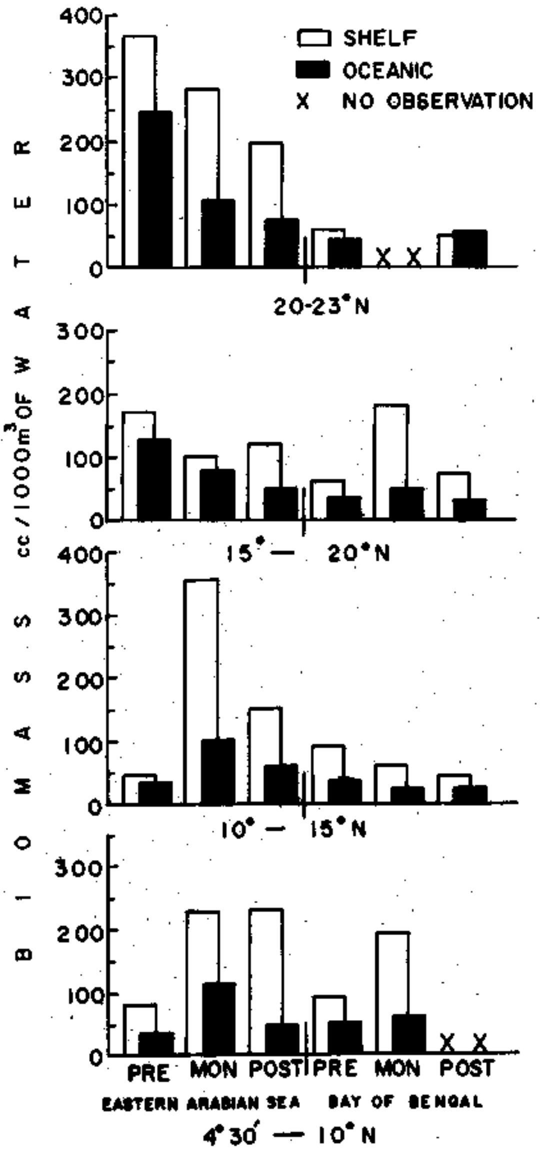

Fig. 8. Seasonal variations in the latitudinal abundance of zooplankton biomass in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

biomass in the shelf area was observed during the premonsoon. During the monsoon season, a drastic reduction was seen only to make a marginal increase during the postmonsoon season. In the oceanic area of this region the maximum production was during the premonsoon period which amounted to about 50% of the total annual biomass. In the 4th region also the premonsoon production was the highest in the shelf and oceanic areas.

Off the east coast also the different areas did not present uniform pictures. Due to lack of data, a comparison was not possible for the first and last latitudinal regions. In the second region, the sequence was premonsoon, monsoon and postmonsoon in both the shelf and oceanic areas. Same was the pattern observed in the oceanic waters of the thrid region. In the shelf area of this region monsoon yelded the maximum biomass followed by postmonsoon and premonsoon.

Day- night abundance

The total of 1,113 samples considered for the study were put under day or night categories and the results obtained are presented in Fig. 9. Almost in all months the night samples contianed more quantities of zooplankton. The maximum night abundance was in September and the percentage of increase was 79.07%. July accounted for an equal representation in day and night samples. During February and March the day samples contained slightly more zooplankton and the increase was by 12.81 and 5.98% respectively.

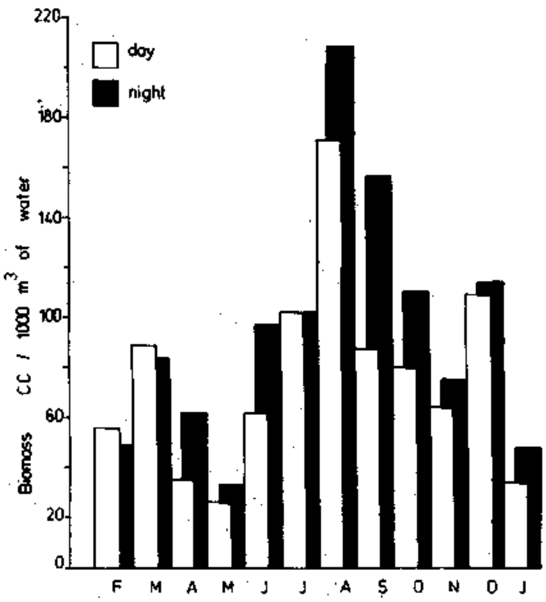

Fig. 9. Monthly diurnal variations in the abundace of zooplankton biomass.

Estimated production at secondary and tertiary levels

Having examined the finer aspects of geographic distribution and seasonal, regional and diurnal abundance of the zooplankton in the study area, it was sought to understand the quantum of production at the secondary and teritary levels. The rate of secondary production for every half degree area was estimated following the method of Cushing (1973) which was subsequently revised by Dalal and Parulekar (1986). The vlaues obtained are plotted as grams carbon per m^2 / year in Fig. 10.

The average secondary production in every half degree square of the area under investigation ranged between 0.5 and 20. 92 $gC/m^2/year$. As expected, the west coast accounted for the maximum production. There, again, the shelf area was the most productive. The very high values of secondary production obtained from the northern Arabian Sea was mainly due to the abundant occurrence of the highly gelatinous macroplankton like salps, doliolids and medusae. In the Andaman and Nicobar waters, most of the values obtained were below 5 $gC/m^2/year$. Off the east coast most of the higher values obtained were towards the outlet of River Ganga. The far oceanic waters of the Bay of Bengal recorded relatively low secondary production.

From the values of secondary production, the fish production for the area under study and for the EEZ was worked out following the method of Cushing (1973) assuming that the tertiary production is equal to 10% of the secondary production. Accordingly, it was found that the entire area investigated accounts for a total fish production of 7.91 million tonnes. Out of this, the eastern Arabian Sea, Bay of Bengal and the Andaman and Nicobar waters have a share of 5.14, 1.38 and 1.39 million tonnes of fish respecitvely.

A separate estimate was made for the EEZ alone (Fig.11) and it was found that the EEZ of the west coast has a total fish stock of 4.78 million tonnes. The fish stock of the EEZ of the east coast and the Andaman and Nicobar seas worked out to be 1.32 and 1.37 million tonnes respectively. The fish production for the entire EEZ is estimated at 7.46 million tonnes.

If explotiation at 50% level of the total stock is envisaged, it could be seen that the Indian EEZ can yield upto 3.74 million tonnes of fish against the present yield of 1.6 million tonnes. Out of the potential yield, the share of the respective sea areas could be: west coast 2.39 mt, east coast 0.66 mt and Andaman and Nicobar seas 0.69 mt. If consdiered at the present level of explotiation, while an increase in exploiation by 100 % could be effected for the west coast, only 50 % increase may be contemplated

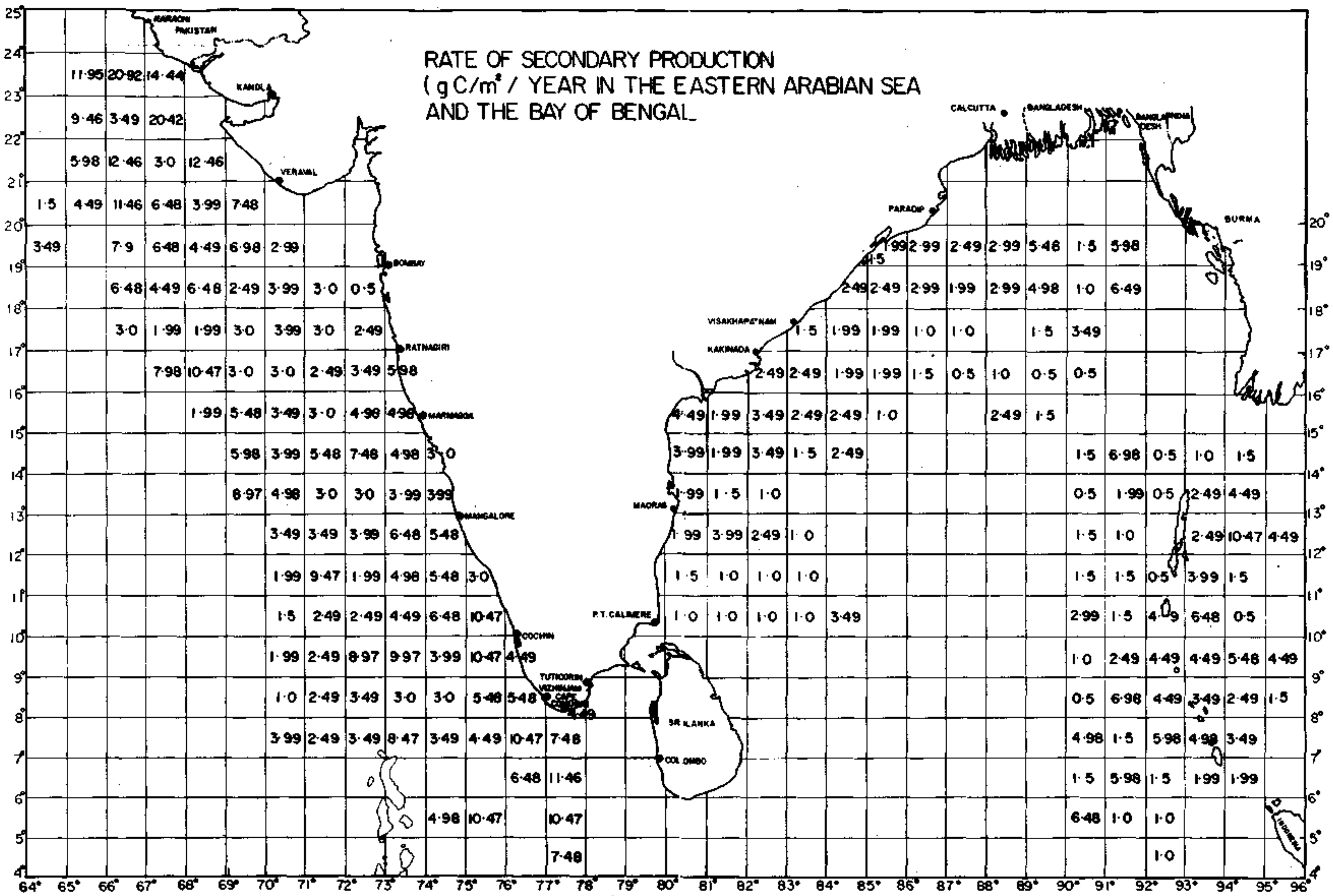

Fig. 10. Rate of secondary production in the EEZ of India.

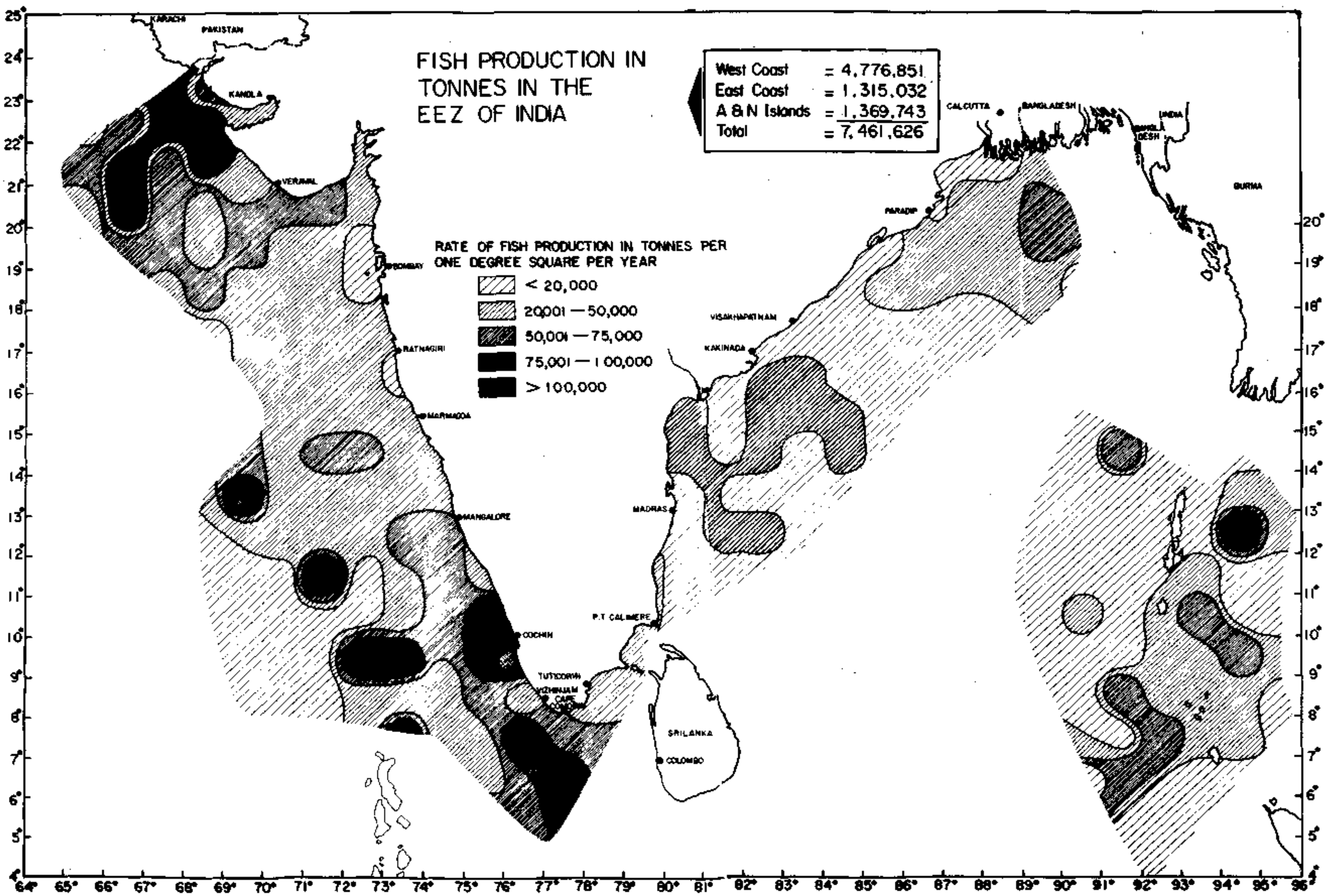

Fig. 11. Rate of fish production in the EEZ of India.

for the east coast. Since exact fish catch statistics are not available for the Andaman and Nicobar islands, the percentage of expected enhancemnt in fish catch cannot be visualised.

In this context it may be remembered that the coastal areas upto 50 m depth along both the coasts of India are being exploited intensively. Therefore any attempt in further exploitation may be planned beyond the 50 m depth zone. The FORV *Sagar Sampada* has located several rich grounds for both conventional and non-conventional fish resources on our EEZ beyond the presently exploited areas.

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STUDIES ON THE DISTRIBUTION OF RECENT PLANKTONIC FORAMINIFERA IN THE ARABIAN SEA AND THE BAY OF BENGAL

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Abstract

Observations on the distribution of Recent planktonic Foraminifera in the waters of the continental shelf and the adjacent oceanic waters and the Andaman and Nicobar Islands between 4°30'N and 23°N lat. made during 1985-'88 are presented and discussed.

Of the 1,086 stations sampled 281 contained planktonic Foraminifera. The abundance of the planktonic Foraminifera was greater in the Bay of Bengal than that in the eastern Arabian Sea. In the eastern Arabian Sea the continental shelf off Bombay and Ratnagiri and the oceanic waters off the Wadge Bank area off Cape Comorin were rich in planktonic Foraminifera. In the Bay of Bengal the concentration was high in the shelf waters of Tuticorin and off the Point Calimere - Nagapattinam coast. However, the population density of 35,135/1000 m^3 encountered in a half a degree square in the oceanic region off Pondicherry was the highest in the seas around India.

While the monthly maximum occurred simultaneously, in the shelf and oceanic regions of the eastern Arabian Sea in December, in the Bay of Bengal the abundance recorded in February was the highest hardly differing from that observed in June. The planktonic Foraminifera of the shelf region constituted 54 and 68% respectively in the eastern Arabian Sea and the Bay of Bengal.

The foraminiferal content of the continental shelf between 10°N and 15°N lat. recorded during the premonsoon season in the eastern Arabian Sea and Bay of Bengal and in the oceanic region between 15°N and 20°N lat. in the eastern Arabian Sea during the same season was very high. Whereas in the oceanic waters of the Bay of Bengal between 10°N and 15°N lat. the maximum occurred during the monsoon season.

The difference between the samples collected during day time and at night in the foraminiferal abundance was marginal. However, the day samples contained more Foraminifera in June and the night samples in February. The samples collected during day time from the continental shelf were comparatively rich in planktonic Foraminifera. Little difference occurred in the foraminiferal content of the day and night samples from the oceanic waters.

Introduction

The number of species of planktonic Foraminifera inhabiting the world oceans are less than the benthic species but are far more useful to man than the latter in the study of palaeoecology and palaeoclimatology and as indicators of water masses, upwelling, regions of high productivity and pollution.

Murray (1897) pioneered studies on the distribution of planktonic Foraminifera. Phleger (1954) compiled the methods of study involving living planktonic Foraminifera and their distribution. Berger (1969) summarised the information on ecology and distribution of the planktonic Foraminifera of the world oceans. Be (1977) reviewed the ecological, zoogeographical and taxonomic aspects of the Recent planktonic Foraminifera. Jijung (1985) evaluated the information on this group from the eastern Arabian Sea. However, according to Phleger (1954), Berger (1969) and Rao *et al.*, (1989) work on the Recent planktonic Foraminifera from plankton tows is meagre when compared to the wealth of information already available on this group settled into sediments of the world oceans a long time ago.

Therefore, the primary objective of the present paper that incorporates observations made during 1985-'88 utilising the sampling facilities available on board FORV *Sagar Sampada* is to study the distribution of the Recent planktonic Foraminifera and the seasonal and diurnal variations in their abundance on the eastern Arabian Sea and the Bay of Bengal between 4°30'N and 23°N lat. and 65°E and 96°E long.

Material and Methods

Out of the 1,086 samples of zooplankton collected by oblique hauls from an average depth of 150 m to the surface using the twin Bongo 60 net (mesh aperature 0.33 mm) fitted with a calibrated flow meter, 331 are from the continental shelf and the rest 755 are from the oceanic waters and 281 samples contained planktonic Foraminifera.

Aliquots were analysed whenever the biomass determined by displacement volume exceeded 5 ml. The average number of specimens present in 1000 m^3 of water per half a degree square area was estimated.

The area between 4° 30'N and 23°N lat. divided into four regions viz. (1) 4°30'N - 10°N lat., (2) 10°N - 15°N lat., (3) 15°N - 20°N lat. and (4) 20°N - 23°N lat. and these regions are compared. The combined faunal content of the continental shelf on either side of the Indian subcontinent is compared with that of the contiguous oceanic waters. The shelf region of the eastern Arabian Sea or the Bay of Bengal is compared with the respective contiguous oceanic region. Monthly, seasonal and day-night variations in those regions are also compared. Besides, three seasons namely, premonsoon from February to May, monsoon from June to August and postmonsoon from September to January in the following year are identified for the purpose of comparison of the variations between the seasons.

Observations

Spatial distribution of planktonic Foraminifera in the seas around India

The distribution of the stations from which the samples are collected are shown in Fig. 1. The concentration was very high in the shelf waters off Ratnagiri and Bombay, off Cape Comorin and the Wadge Bank area, off Tuticorin and off the Point Calimere - Nagapattinam coast. However, the mean density of planktonic Foraminifera observed in a half a degree square area in the oceanic region off Pondicherry, was the highest (35,135/1000 m^3) recorded during 1985-'88.

Region-wise distribution in the eastern Arabian Sea and the Bay of Bengal

The standing crop of planktonic Foraminifera varied from 1,392 to 67,952 specimen/1000 m^3 in the eastern Arabian Sea and from 4,488 to 2,43,156/1000 m^3 in the Bay of Bengal.

In the Arabian Sea between latitudes 4°30'N and 10°N and 15°N and 20°N, the mean concentration of Foraminifera was high (382 - 450/1000 m^3) when compared to that recorded in the latitudes between 10°N and 15°N or the sparse distribution in the region north of 20°N (Fig. 2). On the contrary, in the Bay of Bengal, the mean concentration observed between latitudes 10°N and 15°N (1,474/1000 m^3) was the highest and was far less north of 15°N.

Monthly variations of Foraminifera in the seas around India

Figure 3 shows that the foraminiferal abundance attained maximum at least once every season as observed in February in the premonsoon and in December in the postmonsoon varying slightly from the yearly maximum (total number of specimens: 1,24,542, mean : 1, 946/1000 m^3) recorded in the southwest monsoon in June. The foraminiferal content which remained steady during March-April increased considerably in May. After the steep fall observed in July following the yearly maximum in June, the increase in the abundance observed in August was remarkable.

Monthly mean abundance in the eastern Arabian Sea and the Bay of Bengal

The total number of specimens per 1000 m^3 in the eastern Arabian Sea varied from 136 to 82,321 and in the Bay of Bengal from 212 to 1,21, 265.

In the Arabian Sea the monthly mean abundance varied widely from a few numbers recorded in September to more than a thousand in December (2-1,176/1000 m^3). In the Bay of Bengal, the decrease in abundance observed during February - April from 4,546 to 50 and during August -October from 1,385 to 16 as well as the increase during April - June from 50 to 2,887 and during October - January from 16 to 383 were gradual (Fig. 4).

Monthly distribution in the shelf and oceanic waters of the seas around India

The standing crop of these organisms ranged from 37 to 64,253 in the shelf waters and in the oceanic waters from 8,33 to 79,507/1000 m^3.

The foraminiferal abundance in the shelf waters exceeded that recorded in the adjacent oceanic waters except during March - May, in November and January (Fig. 5). The mean concentration was the highest in February in the shelf (4,943/1000 m^3) and in June in the oceanic region (1,228/1000 m^3).

During the premonsoon season the density of Foraminifera observed in the continental shelf was nearly four times greater than that recorded in the

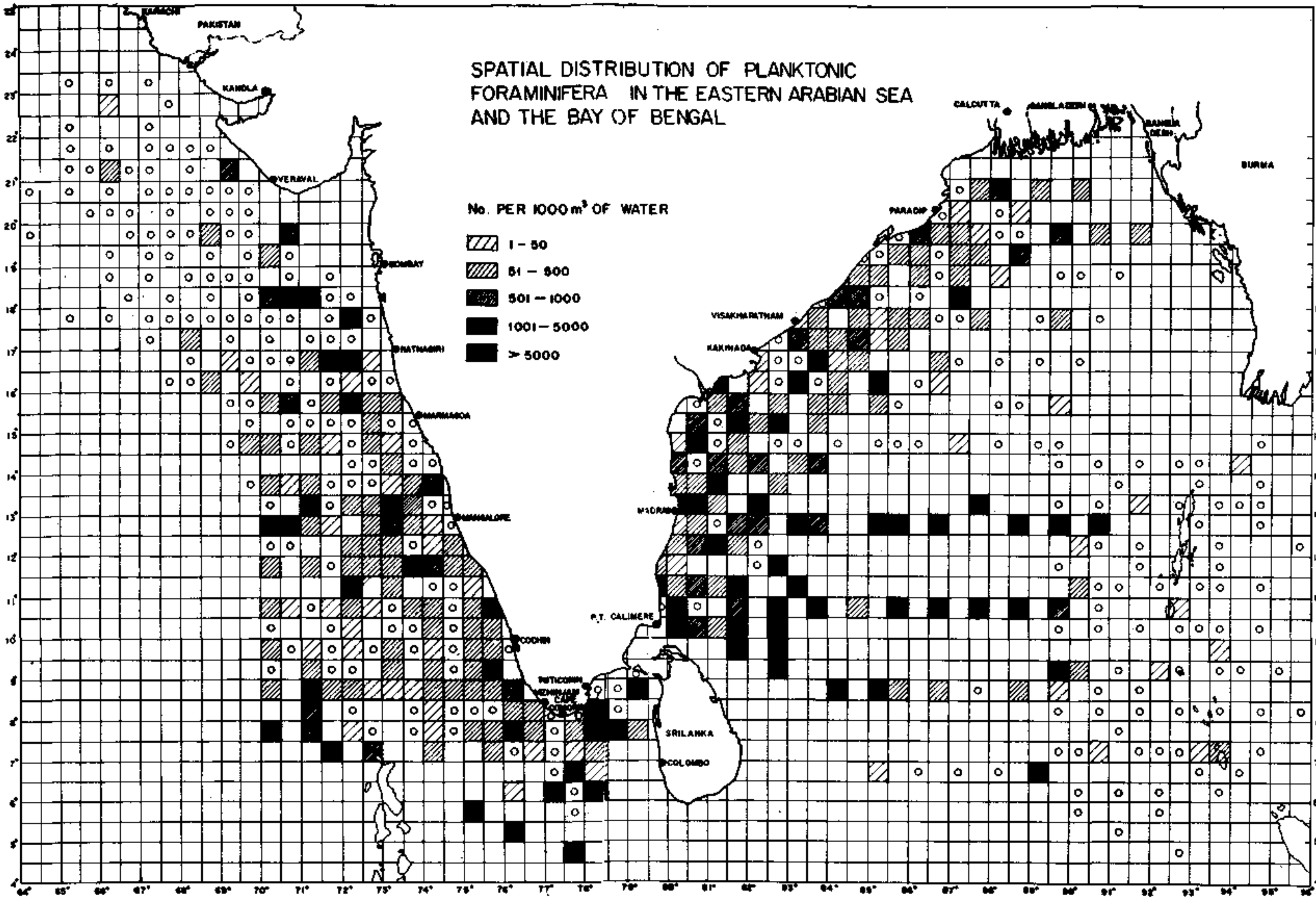

Fig. 1. Spatial distribution of planktonic Foraminifera in the seas around India.

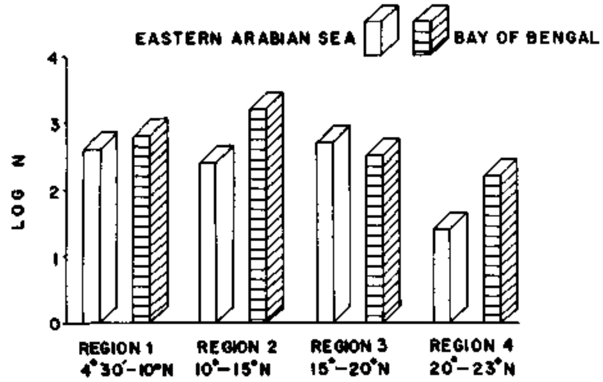

Fig. 2. Region-wise distribution of planktonic Foraminifera in the eastern Arabian Sea and the Bay of Bengal.

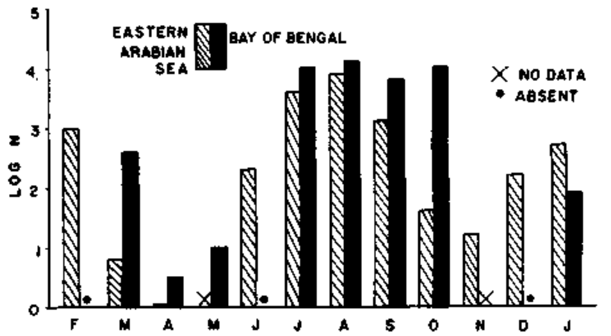

Fig. 4. The monthly variation in the anundace of plancktonic Foraminifera in the eastern Arabian Sea and the Bay of Bengal.

oceanic area (Fig. 6). But this difference in the abundance between the shelf and the adjacent areas was greatly reduced during the monsoon season and disappeared altogether in the postmonsoon season.

Monthly variations in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

In the eastern Arabian Sea the standing crop of planktonic Foraminifera in the shelf ranged from 42 to 40,807 and from 51 to 41,514 specimens/1000 m^3 in the oceanic areas.

Figure 7 shows that the average concentration observed in the shelf was the highest (1,974/1000 m^3) in December and was the lowest in March. Besides, the foraminiferal abundance observed in February and August was noticeably high. In the adjacent oceanic areas Foraminifera showed an increasing trend from February to April and more conspicuously from September to December.

In the Bay of Bengal the total number of specimens observed in 1000 m^3 of water varied from 37 to 55,170 in the shelf and from 2,267 to 76,272 in the oceanic area.

The variations in the shelf and adjacent oceanic regions were similar from February to June and again from August to December. However, the mean concentration in the shelf and oceanic waters recorded in June was the highest (11,248 and 2,007/1000m^3 respectively).

Region-wise seasonal distribution in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

The planktonic Foraminifera present in the oceanic area formed 46.4% of the total observed in the eastern ArabianSea (Fig. 8a).

Foraminifera were absent in the waters of the continental shelf except between 10°N and 15° N lat. during the premonsoon and north of 15°N lat. in the premonsoon and the monsoon seasons. It may be

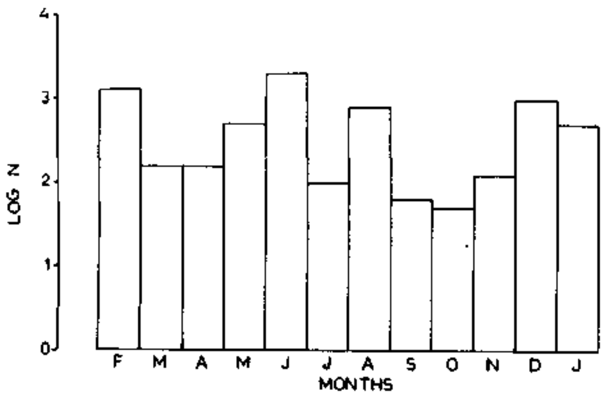

Fig. 3. The monthly variations in the abundace of planktonic Foraminifera in the seas around India.

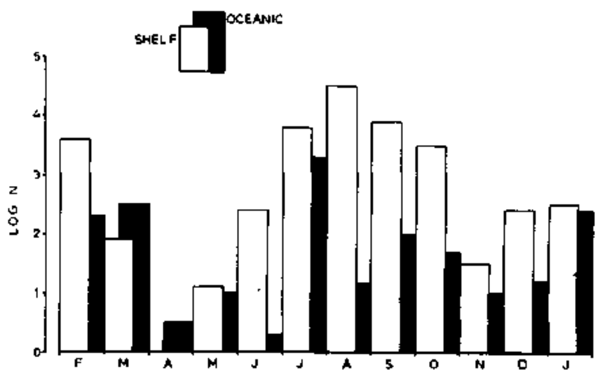

Fig. 5. The monthly variations in the abundace of planktonic Foraminifera in the shelf and oceanic areas of the seas around India.

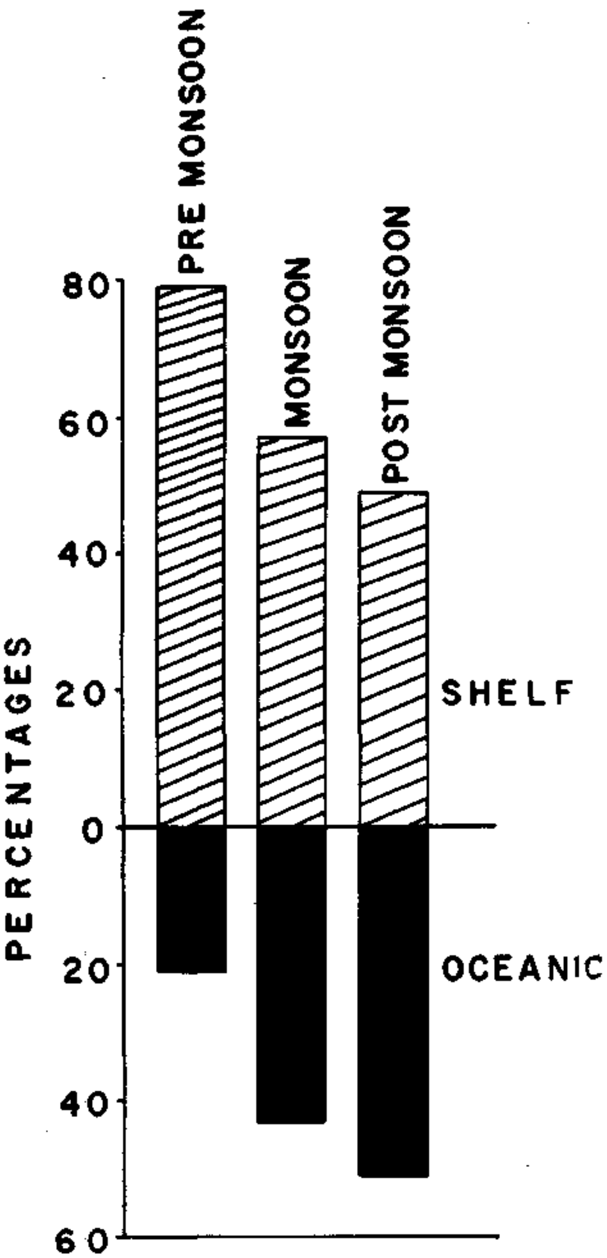

Fig. 6. Seasonal variations of planktonic Foraminifera in the shelf and oceanic waters of the seas around India.

seen that the planktonic Foraminifera were almost equally abundant in the oceanic area, between 4°30'N and 15°N lat. in all the three seasons. Whereas, between 15°N and 20°N lat. this group was abundant during the premonsoon and postmonsoon seasons, but recorded a perceptible decrease in the monsoon season.

Foraminifera occurring in the oceanic waters formed 31.6% of the total observed in the Bay of Bengal (Fig. 8b).

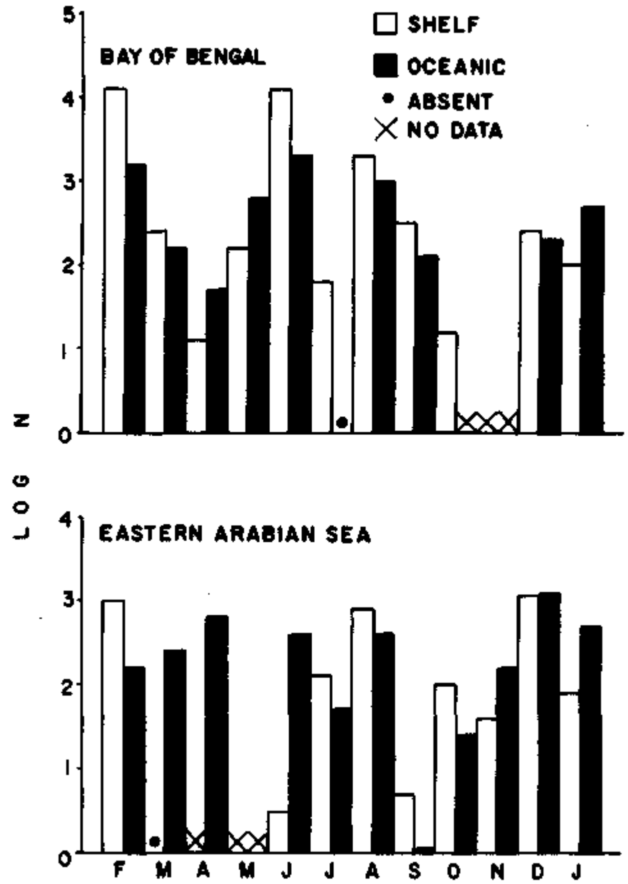

Fig. 7. The monthly variation in the abundace of planktonic Foraminifera in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

Forminifera were absent during the premonsoon in the shelf between latitudes 4°30'N and 10°N. The foraminiferal abundance in the shelf waters between 10°N and 15°N lat. during the premonsoon was the highest (Total number : 55,240, mean : 3,946/1000 m^3) and that recorded in the postmonsoon season was the lowest, but in the oceanic area this group showed conspicuous increase during the monsoon season. The seasonal variations in the shelf between15° and 20°N lat. were almost similar to those recorded between 10°N and 15°N lat., but in the oceanic area the abundance decreased considerably in the monsoon season.

Monthly variations in abundance during day and at night

During May and September, Foraminifera were equally abundant in the samples collected during day as well as at night (Fig. 9). The day samples contained slightly more Foraminifera during

March, June, August, November and December but comparatively much less than the night samples during July and October.

Foraminifera were equally abundant in the day and night samples during the postmonsoon season (Fig. 10). However, the formainiferal content of the night samples was much more than that of the day samples during the premonsoon season and much less in the monsoon season.

Monthly variations in the shelf and oceanic waters during day and at night

The foraminifera observed in April and June in the shelf exclusively belonged to the day samples (Fig. 11) as these were absent in the former month in the night samples and formed a mere 2% in the latter month. Increased abundance of Foraminifera was observed in the night samples in February, March, July and October and in the day samples from April to June, November and December.

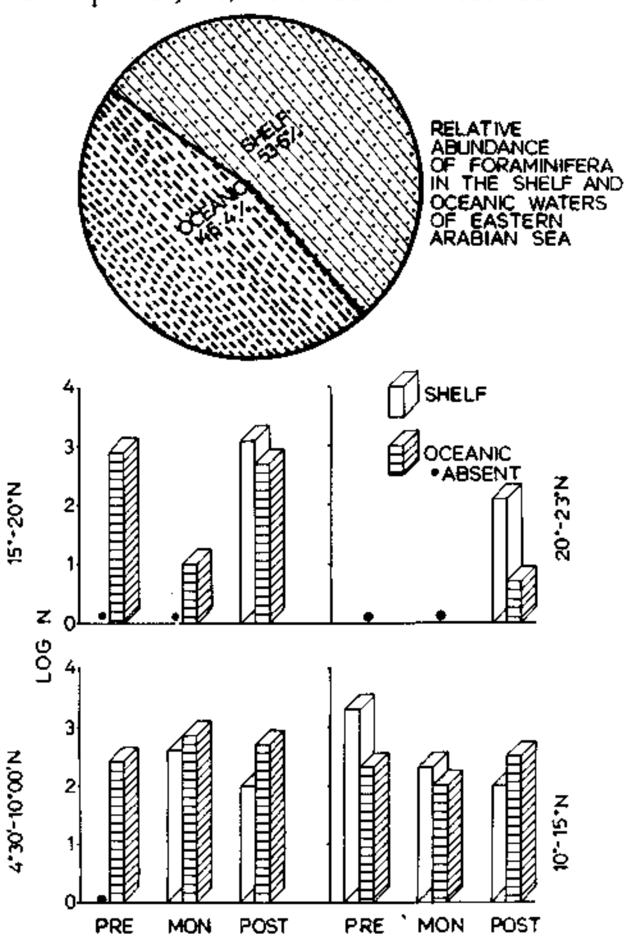

Fig. 8a. Region-wise seasonal distribution of planktonic Foraminifera in the shelf and oceanic waters of the eastern Arabian Sea.

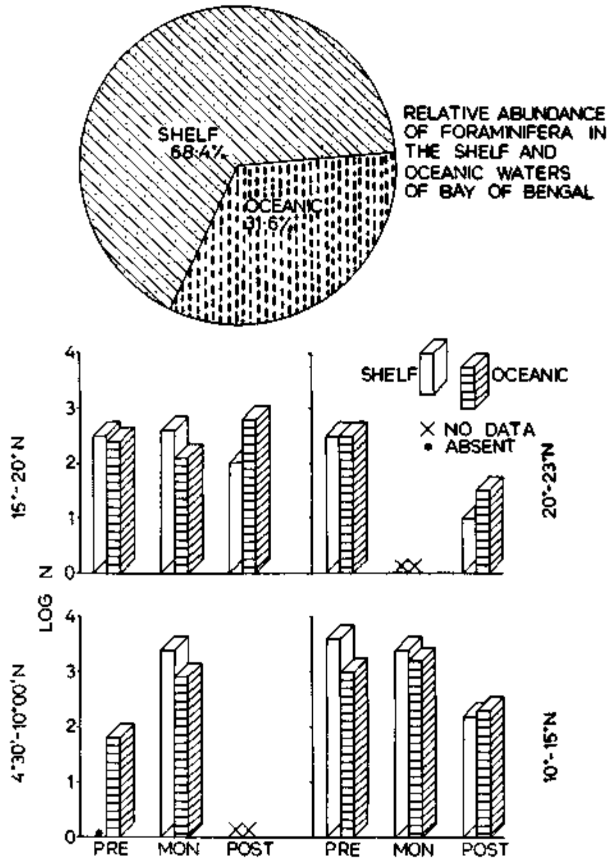

Fig. 8b. Region-wise seasonal distribution of planktonic Foraminifera in the shelf and oceanic waters of the Bay of Bengal.

In the oceanic region, the density of Foraminifera observed in the day samples during February - March was more than 75%. It also formed more than 50% during June, August, October and November. In the night samples this group formed more than 50% during April-May, July, September and December - January.

During the premonsoon season 90% of the Foraminifera was present in the samples collected during night in the shelf waters. But a greater portion of this pelagic fauna was present in the day samples during the monsoon and postmonsoon seasons (Fig. 12).

In the oceanic waters, the foraminiferal abundance of the day samples was slightly more than that of the night samples during the premonsoon and monsoon seasons whereas it was considerably higher in the night samples during the postmonsoon season.

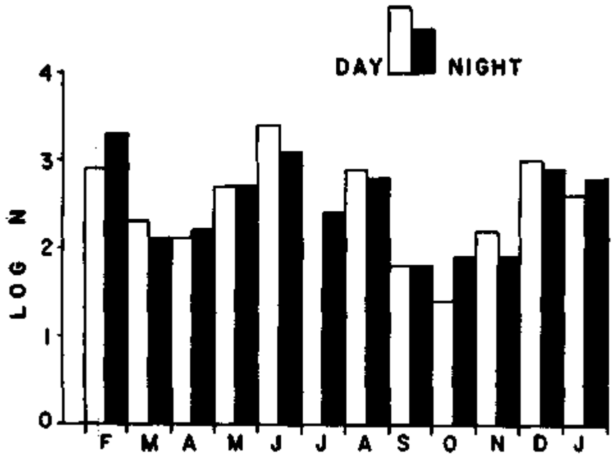

Fig. 9. The monthly variation in the abundace of planktonic Foraminifera during day and at night in the seas around India.

Discussion

Observations made during 1985-'88 in the seas around India show that the Recent planktonic Foraminifera were more abundandant in the Bay of Bengal than in the eastern Arabian Sea (Fig.1).

In the eastern Arabian Sea, the increased abundance of this pelagic fauna was observed in the region off Bombay where, according to Rao (1972) the fertility of the area is enhanced by the mixing of Antarctic water with the Red Sea water, Indian equatorial water and the Indian central water found along the west coast of India. The region next in abundance in the Arabian Sea is the Wadge Bank area off Cape Comorin which was found to be one of the most productive coastal areas in the world where three seas meet with the distinct pattern of water currents, and enrichment of the water column in the euphotic zone by upwelling in the SW monsoon (Rao *et al.,* 1988). The other areas where the abundance of Foraminifera was conspicuous (mean number 1,001 - 5,000/1000 m^3) are those off Angria Bank, Vengurla, Mangalore and Calicut. All these regions along the west coast of India come under the influence of upwelling leading to replenishment of nutrients and subsequent high production of plankton and fish during the SW monsoon or early postmonsoon (Prasad, 1969). According to Jijung (1985) the living planktonic Foraminifera is more abundant at 0 to 10 m depth of the euphotic

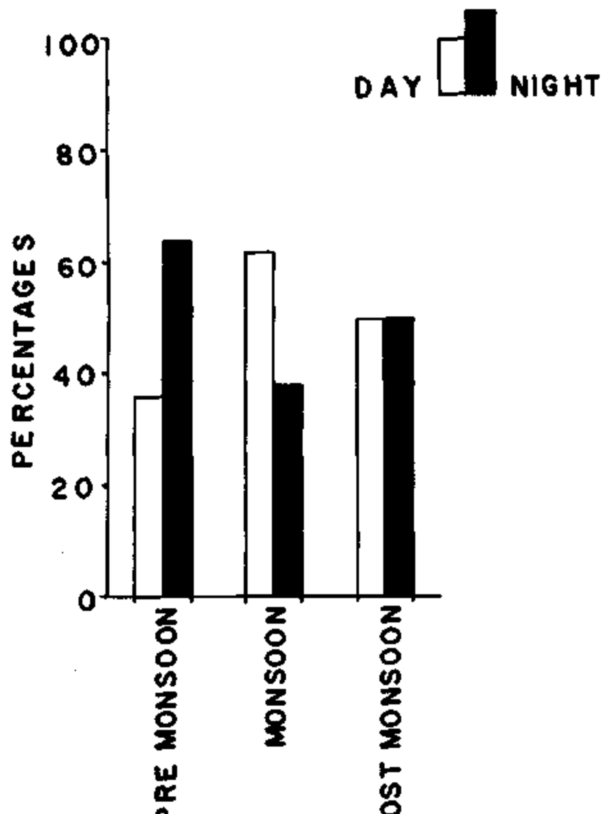

Fig. 10. Seasonal variations of planktonic Foraminifera during day and at night in the seas around India.

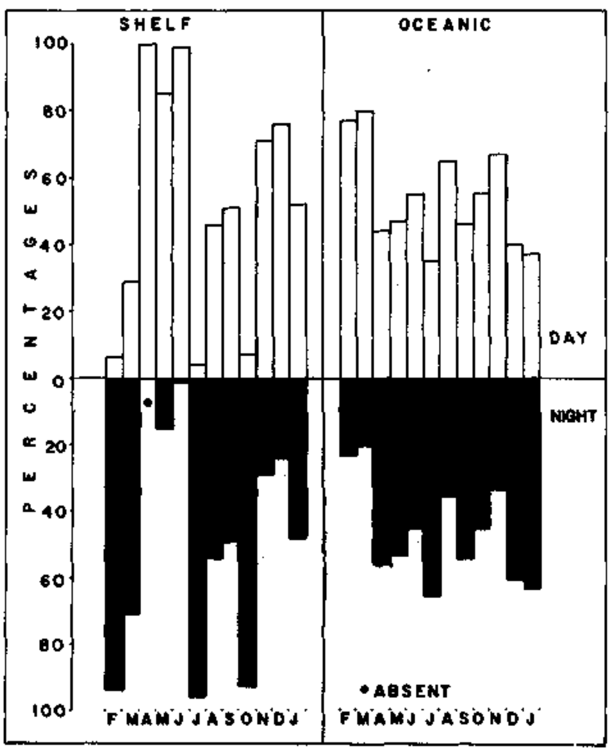

Fig. 11. The monthly variations in the abundance of planktonic Foraminifera in the shelf and oceanic waters during day and at night in the seas around India.

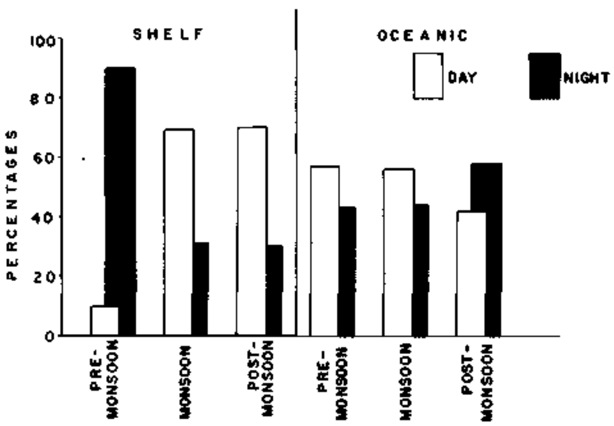

Fig. 12. Seasonal variations of planktonic Foraminifera in the shelf and oceanic waters during day and at night in the seas around India.

zone in the eastern Arabian Sea and the variations in the abundance appear to be governed by upwelling events which may vary seasonally and spatially.

The areas where high concentration of planktonic Foraminifera was observed in the Bay of Bengal are in the shelf waters off Tuticorin, Gulf of Mannar, off Point Calimere and Porto Novo (Fig. 1). Incursion of nutrient rich Antarctic bottom water in the Gulf of Mannar was already reported by Sewell (1932). The oceanic regions between Pondicherry and Madras, and those off Andhra coast are also rich in the living planktonic Foraminifera. A mean concentration of 15,965 specimens/1000 m^3 was encountered both in the shelf region off Tuticorin and Porto Novo and the highest population density (35,135 specimens/1000 m^3) observed in this study was found in the oceanic waters between Pondicherry and Madras. According to Murray (1897) the planktonic Foraminifera are highly abundant in the regions of open ocean with strong surface currents. Berger (1969) reported that surface water with high nutrient content generally support largest populations of planktonic Foraminifera. Upwelling is prevalent off Madras and Visakhapatnam during premonsoon and monsoon periods (Murty and Varadachari, 1968) but is predominant off Vishakahapatnam (Rao *et al.* 1986) during the same period. Upwelling is also reported in the coastal areas of the north western Bay enriching the surface waters (Sankaranarayanan and Reddy, 1968). According to Rao *et al*. (1989) high standing crops of planktonic foraminiferal abundance is connected with and dependent on upwelling.

The population density of this pelagic fauna in the eastern Arabian Sea was the highest in the region between 15°N and 20°N lat. and the abundance observed in the region from 4°30'N to 15°N lat. was conspicuous (Fig. 2). On the other hand, in the Bay of Bengal, between 4°30'N and 20°N lat. the concentration was fairly good and that observed between 10°N and 15° N lat. was the highest. According to Jijung (1985) provinces or zonations occur in the eastern Arabian Sea and latitudinal variation can be a major factor in controlling the distribution of planktonic Foraminifera in such wide ranging faunal zonations or provinces apart from the other important factors such as temperature and salinity. Be and Tolderlund (1971) remarked that the latitudinal distribution and abundance of planktonic Foraminifera are temperature dependent.

The abundance of living Foraminifera was maximum in December in the eastern Arabian Sea and in February in the Bay of Bengal (Fig. 4). It may be seen that in the eastern Arabian Sea 53.6% of this group occurred in the shelf and the rest in the oceanic waters. In the Bay of Bengal, the foraminiferal abundance from the shelf waters accounted for 68.4% of the total (Fig. 8b). It is reported that the increase in the living planktonic foraminifera manifests towards the outer shelf and slope (Setty, 1978).

Seasonal variations of foraminiferal abundance in the four regions show that in the eastern Arabian Sea the population density was high in the shelf waters between 10°N and 15°N lat. and in the oceanic waters between 15°N and 20°N lat. during the premonsoon season (Fig. 8a). On the other hand, in the Bay of Bengal, high concentration of this pelagic fauna was encountered in the shelf waters between 10°N and 15°N lat. during the premonsoon season and in the oceanic waters during the monsoon season (Fig. 8b). Latitudinal distribution of planktonic Foraminifera in the eastern Arabian Sea and the Bay of Bengal and the impact of seasonal upwelling on their abundance has already been discussed elsewhere in this account.

The number of stations sampled during day for this study was 659 and at night was 427. Monthly variations in the abundance show that the foraminiferal content was the highest in the day samples in June and in the night samples in February (Fig. 9). In general, the variations in monthly abundance of planktonic Foraminifera collected during day and at night was marginal. However, Fig. 11 shows that the concentration of this pelagic fauna in the shelf was distinctly higher in the day time than at night whereas in the oceanic regions though the day samples were more abundant in living Foraminifera than the night samples the difference was not as conspicuous as observed in the shelf. High concentrations of planktonic Foraminifera in plankton tows made during the day time than at night were reported by Be and Hamlin (1967), Berger (1969) and Rao *et al.* (1988). According to Berger (1969), diurnal variations appear to be the strongest for small forms of shallow water Foraminifera in fertile regions.

Acknowledgements

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STUDIES ON THE QUANTITATIVE DISTRIBUTION OF CHAETOGNATHA FROM THE INDIAN SEAS COLLECTED DURING THE CRUISES 1 - 44 OF FORV *SAGAR SAMPADA*

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Abstract

Chaetognatha from 1,159 zooplankton samples, collected during the cruises 1-44 of FORV *Sagar Sampada*, from equator to 24°N and 64° to 96° E between 11-2-1985 and 27-3-1988, were studied and their quantitative distribution and variation in day and night samples are reported and discussed.

Introduction

Chaetognaths constitute one of the major components of the marine zooplankton and play a vital role in the food cycle. Substantial work has been carried out on the distribution of chaetognaths of the west coast of India (Lele and Gae, 1936; John, 1937; George, 1952; Nair, 1967, 1972, 1974, 1975; Nair and Rao, 1973 a, b; Nair *et al.*, 1981 a,b; Silas and Srinivasan, 1968, 1969, 1970; Srinivasan, 1972 a, b, 1976, 1979, 1988a, b and 1989). Recently Srinivasan (1987) reported the distribution of chaetognaths from the northern Arabian Sea, bordering the Arabian countries, Pakistan and India and described a new genus and new species of Chaetognatha (Srinivasan, 1988b). However, only a few publications are there on the chaetognaths from the east coast of India (John, 1933; Subramaniam, 1940; Rao, 1958 a, b, 1966; Rao and Ganapati, 1958; Rao and Kelly, 1962 a, b; Sudarsan, 1961; Srinivasan, 1977, 1980, 1987 b, Srinivasan and Krishnan, 1985 and Nair *et al.*, 1981 b). However, a comprehensive account based on regular intensive sampling, on the distribution of Chaetognatha covering the Indian coasts, Lakshadweep Sea, seas around Andaman and Nicobar Islands and the Indian Ocean north of equator is lacking. This is mainly due to the lack of material.

The availability of chaetognaths sorted from the plankton samples collected by several participants in the cruises of FORV *Sagar Sampada*, has given the author a good opportunity to analyse and report the distribution of chaetognaths of the eastern Arabian Sea and the Bay of Bengal.

Material and Methods

Material for this study has been obtained from the zooplankton samples collected at 1,159 stations located between 0° and 24° N and 64° and 96° E, during the 44 cruises of FORV *Sagar Sampada* between 11-2-1985 and 27-3-1988. Among these 1,159 samples, 696 (60%) were collected during the day time and the remaining 463 (40%) were collected during the night time (Fig. 1). Most of the samples were collected with 60 cm Bongo net, with a mesh size of 0.33 mm from 150 to 0 m, as open oblique hauls. In the shelf areas, where the depth was less than 150 m, the samples were collected from five metres above the sea bottom to surface. The samples were preserved in 5% neutralised formaldehyde solution. The displacement volume of the samples was determined. The chaetognaths from the whole sample were sorted out, when the volume was less than 5 ml and if the volume of the sample was more than 5 ml, aliquot samples, not less than 5 ml were taken and the chaetognaths were sorted out, counted and total number for the whole sample was calculated. As a flow meter was attached to the net, the quantity of the volume of the water filtered and the number of specimens present in the filtered water were known. So the number of specimens in the quantity of water filtered was standardised for 1000 m^3 of water filtered for all the samples.

As 1,159 stations were occupied within 0° and 24° N and 64° and 96° E, it was not possible to locate all the stations in the map for reporting the distribution of chaetognaths. So to get a vivid picture of distribution, the total area of operation involved during the 44 cruises was divided into 2° squares. The latitudes between 0° and 24°N were divided into 12, two degree grids as A to L and the longitudes 64° to 96° E were divided into 16, two degree grids as 1 to 16. A total of 106 two degree squares could be plotted in the total area of operation. The total number of chaetognaths from all the samples collected from the stations located in each 2° squares were totalled and the average was taken to represent that 2° square for the purpose of chaetognath distribution.

Then the average number of chaetognaths for the day and night samples from the stations occupied in each 2° square was taken and percentages for the day and night samples were calculated and plotted in a pie diagram.

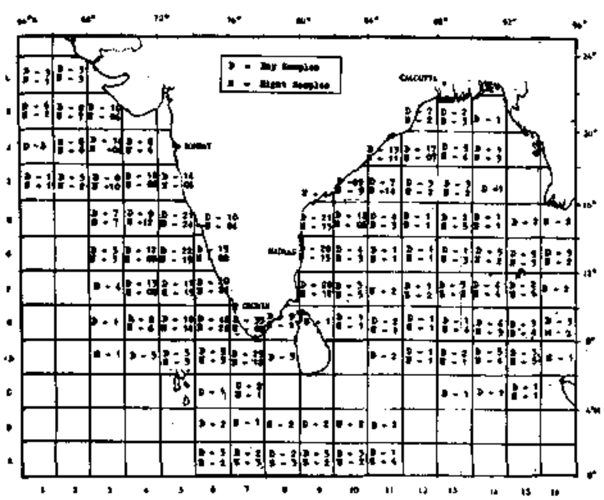

Fig. 1. Number of day and night samples from each 2° square.

Discussion

The distribution of chaetognaths shown in the map (Fig. 2) clearly points out that the density of the chaetognath population was more along the west coast of India and along the southernmost part of the east coast of India upto Point Calimere. Further, the density of the population was very rich between Cochin and Mangalore coasts and near the Kandla coast. The density of the chaetognath population along the east coast of India as a whole was moderate and the density of the population between Madras and Andhra Pradesh coast and between Paradip and Bangla Desh coast was high than the remaining areas of the east coast of India.

Along the west coast of India, the chaetognath population density decreases from the shelf to offshore region, whereas along the east coast, the population density increases from shelf to offshore region and it was thick around the Andaman and Nicobar Islands (Fig. 2). This may be due to the fact that there is free mixing of waters between the Indian Ocean and Pacific Ocean. During the northeast monsoon the water flows from the Pacific Ocean into the Bay of Bengal through the Malacca Straits and during the southwest monsoon, the reverse happens, resulting in the flow of water from the Bay of Bengal into the Pacific Ocean, through the same passage.

Overall chaetognath distribution from the seas around India, shows that the density of the population was more along the west coast of India, than the east coast. This may be due to the fact that the process of upwelling that occurs along the west coast, helps in enriching the nutrient contents of the surface waters and this ultimately increases the primary and secondary production.

It is a known fact that the general fishery is good along the west coast of India, than the east coast. So the presence of high density of chaetognath population along the west coast of India, shows that these carnivorous organism, which mainly feed on other smaller organisms like copepods, siphonophores, medusa, euphausiids, fish eggs and larvae, etc. may play a key role in the food cycle and ultimately help in the increase of fish production as these are fed by bigger carnivorous forms and fishes.

The average number of chaetognaths from the night and day samples in each 2° square was calcu-

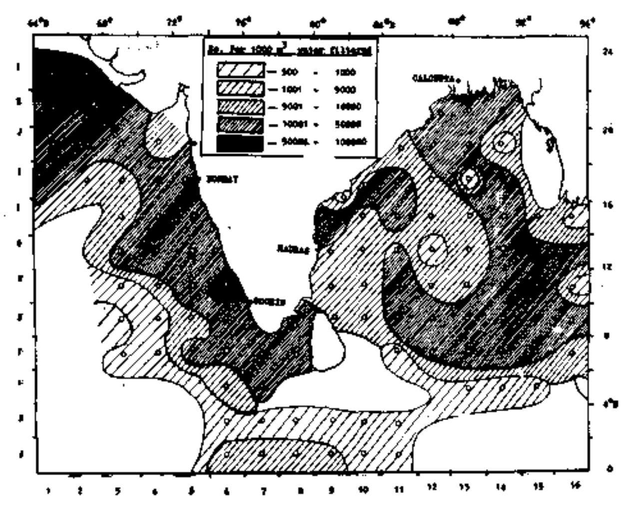

Fig. 2. Population densities of chaetognaths in the Arabian Sea, Bay of Bengal and Indian Ocean north of equator.

lated and is shown in Fig. 3 in the pie diagram. Significant difference was not noticed between the samples collected during day and night. In some squares, the percentage of chaetognath population was more in the samples collected during the day time and in others the reverse happened. Among the total number of chaetognaths, 48% of the specimens was from the samples collected during the day time and remaining 52% was from the night samples. Eventhough there was no significant difference in the chaetognath population between the samples collected during day and night, a slight increase in the population was noticed in the samples collected during the night time.

Further studies on he distribution of the individual species of chaetognaths present in the samples and their seasonal fluctutation in abundance are in progress.

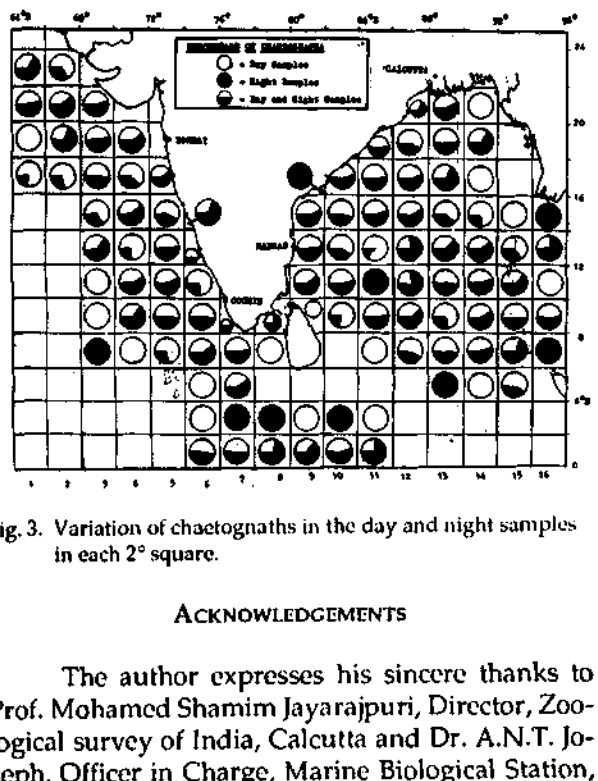

Fig. 3. Variation of chaetognaths in the day and night samples in each 2° square.

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The author expresses his sincere thanks to Prof. Mohamed Shamim Jayarajpuri, Director, Zoological survey of India, Calcutta and Dr. A.N.T. Joseph, Officer in Charge, Marine Biological Station, Madras for the facilities provided. He is extremely indebted to Dr. P.S.B.R. James, Director, Central Marine Fisheries Research Institute, Cochin, for giving an opportunity to study the chaetognaths collected during the cruises of FORV *Sagar Sampada*. His thanks are also due to Dr. K.J.Mathew, Central Marine Fisheries Research Institute, Cochin for providing necessary information for undertaking this study; to Shri P. Dhandapani, Scientist 'D', Marine Biological Station, Madras for the critical suggestions and to Shri S. Anand, for the help rendered in preparing the distribution charts and maps.

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STUDIES ON THE DISTRIBUTION OF CLADOCERA IN THE EASTERN ARABIAN SEA AND THE BAY OF BENGAL

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Abstract

Observations on the distribution and abundance of Cladocera in the continental shelf and the oceanic part of the eastern Arabian Sea and the Bay of Bengal between 4°30'N and 23°N lat. were made during 1985 - '88. Out of the 1,086 samples 159 contained cladocera.

The cladoceran abundance was high in a few places on the continental shelf and was poor in the adjacent oceanic region. The cladoceran concentration of 2,45,899/1000 m³ encountered in a half degree square in the shelf off Cochin was the highest with those of the Wadge Bank off Cape Comorin and the shelf off Karwar taking the second and third places respectively, in the order of abundance. In the Bay of Bengal the population density recorded off Paradip was more than that observed off Madras.

The population abundance observed was comparatively high during July-September in the Arabian Sea and during July-October in the Bay of Bengal and was maximum in August. In the eastern Arabian Sea the concentration of Cladocera in the shelf and the oceanic region was the highest respectively in August and in July. Whereas in the Bay of Bengal the increased abundance in the shelf occurred during July - October and in the oceanic region during March. The Cladocera occurring in the shelf constituted 95.3% and 98.8% respectively in the Arabian Sea and the Bay of Bengal.

In the eastern Arabian Sea the concentration of Cladocera was high between 4°30'N and 10°N lat. during the premonsoon and monsoon seasons and was conspicuously higher in the shelf between 10°Nand 15°N lat. during the monsoon season. In the Bay of Bengal, the cladoceran density recorded during the monsoon season was the highest in the shelf between 4°30'N and 10°N lat. In the region north of 20°N lat. the cladoceran population was conspicuous and that observed in the oceanic waters during the postmonsoon was the maximum.

The cladoceran concentration in stations sampled during day time far exceeded that at night except during August in the shelf and March - April and August in the oceanic region.

Introduction

Marine cladocera are mainly neritic and form a major proportion of the coastal zooplankton often far exceeding the copepods in abundance. Several workers (Madhupratap, 1981; Suseelan *et al.,* 1985; Naomi, 1986) have attributed greater significance to the abundance of Cladocera in the coastal waters as a prey item of the economically important planktivorous fishes of India. Despite its numerically superior abundance during certain seasons and its importance to the pelagic fisheries, a comprehensive account on the distribution, biology and ecology of cladocera of the seas around India is yet to be compiled. Madhupratap (1981) summarised the available information on this group from the coastal and estuarine waters of the southwest coast of India. Della Croce and Venugopal (1972) studied the distribution of cladocera in the Indian Ocean based on 552 samples of the IIOE. Onbe (1985) compiled the distribution and abundance of cladoceran populations in the world oceans. Turner (1984) Paffenhoffer and Orcutt (1986) and Jagger *et al.* (1988) described the feeding habits and ecology of the marine cladocera. The present paper based on observations made during 1985-'88 describes the distribution, seasonal and diurnal fluctuations in the abundance of cladocera of the shelf and oceanic areas of the eastern Arabian Sea and the Bay of Bengal.

Material and Methods

Out of the 1,086 samples of zooplankton collected by oblique hauls from an average depth of 150 m to the surface using a twin Bongo 60 net (mesh aperture 0.33 mm) fitted with a calibrated flow meter, 331 are from the continental shelf and the rest 755 from the oceanic waters, and 159 samples contained cladocera.

Aliquots were analysed whenever the biomass determined by displacement volume exceeded 5 ml. The average number of specimens present in 1000 m³ of water filtered per half a degree square area was estimated.

The area between 4°30'N and 23°N lat. is divided into four regions viz. (1) 4°30'N - 10°N lat., (2) 10°N - 15°N lat., (3) 15°N - 20°N lat. and (4) 20°N - 23°N lat. and these regions are compared. The combined faunal content of the continental shelf on either side of the Indian subcontinent is compared with that of the contiguous oceanic water. The shelf region of the eastern Arabian Sea or the Bay of Bengal is compared with the respective adjacent oceanic region. Monthly, seasonal and day-night variations in those regions are also compared. Besides, three seasons namely, premonsoon from February to May, monsoon from June to August and postmonsoon from September to January, in the following year are identified for the purpose of comparison of the variations between the seasons.

Observations

Spatial distribution of cladocera in the seas around India

Figure. 1 shows that the cladocera were abundant in a few places on the continental shelf such as the Wadge Bank region (average number of specimens per half a degree square ranging from 5,455 to 1,43,012/1000 m^3) off Cape Comorin and Vizhinjam (9,261-68,252/1000 m^3), off Cochin (2,45,899/1000 m^3) and Karwar (20,573/1000 m^3) in the eastern Arabian Sea and off Tuticorin (20,433 - 60,544/1000 m^3), and the Coromandal coast (24,483 / 1000 m^3) and the region off Paradip (8,870 - 32,793/1000 m^3) in the Bay of Bengal. In the shelf waters off Quilon and the oceanic areas off Veraval, Krishnapatnam, Machilipatnam and Kakinada, the concentration encountered was between 1,001 and 5,000/1000 m^3 . In the Andaman Sea cladoceran abundance was poor.

Region-wise distribution in the eastern Arabian Sea and the Bay of Bengal

The total number of specimens/1000m^3 varied from 2,371 to 5,78,107 in the eastern Arabian Sea and from 44,844 to 6,55,767/1000 m^3 in the Bay of Bengal.

The mean abundance in the eastern Arabian Sea was the highest (2,665/1000 m^3) in the region between 4°30'N and 15°N lat. while it was poor in the region north of 15°N lat. (Fig. 2). On the other hand, in the Bay of Bengal the mean concentration was the highest (7,538/1000 m^3) in the regions between 4°30'N and 10°N lat., and 20°N and 23°N lat. while it was low in the region between 10°N and 20°N lat. but not as low as it was observed in the Arabian Sea.

Monthly variations in the seas around India

Figure 3 shows that the cladoceran concentration that increased during the latter part of the postmonsoon months, December and January, continued to be high in February in the succeeding premonsoon season. However, the tendency to increase not only weakened but also reversed in March to severely reduce the abundance in April. The abundance observed in May was slightly more than that of April but increased further till July and recorded the maximum in August. The decline in the cladoceran content registered in September and October was considerable but less drastic than the one which followed in November.

Monthly abundance in the eastern Arabian Sea and the Bay of Bengal

The total number varied from 12 to 2,92,571 in the Arabian sea and from 8 to 1,68,872/1000 m^3 in the Bay of Bengal.

The mean concentration observed in the Arabian Sea was more during July - September while it was more during July - October in the Bay of Bengal. The abundance of Cladocera both in the Arabian Sea and the Bay of Bengal was the lowest simultaneously in April. In the Bay of Bengal, cladocera were absent during February, June and December.

Monthly variations in the shelf and oceanic areas of the seas around India

The standing crop of the group varied from 143 to 10,74,776/1000 m^3 in the shelf waters and from 71 to 17,156/1000 m^3 in the oceanic waters.

The average abundance observed in the shelf remained higher than that recorded in the adjacent oceanic waters except in March and was the highest (30,708/1000 m^3) in August in the shelf while it was more in July (2,176/1000 m^3) in the oceanic waters (Fig. 5). Figure 6 shows the seasonal abundance in the shelf and oceanic waters. The Cladocera observed in the latter region formed 10% or less of the total during the different seasons while the rest was from the shelf. The density of Cladocera in the oceanic waters during the premonsoon was almost the same as that occurred in the postmonsoon but it decreased drastically forming a mere 2% during the monsoon season. The cladoceran abundance showed a moderate increase in the shelf waters during the monsoon over those recorded in the pre- and postmonsoon seasons.

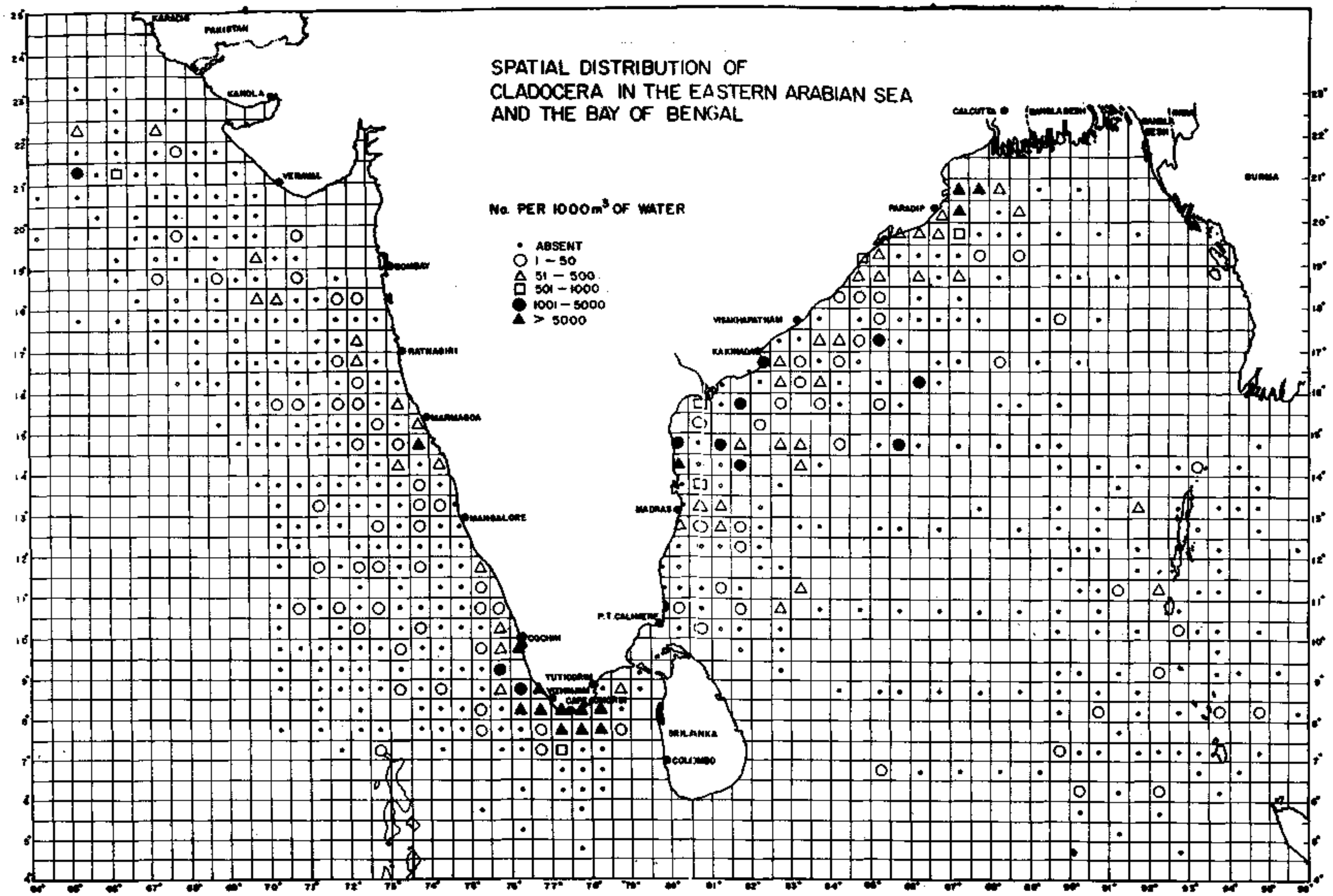


Fig. 1. Spatial distribution of Cladocera in the seas around India.

Monthly variations in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

In the Arabian Sea the total number of specimens / 1000 m^3 varied from the 435 to 5,71,450 in

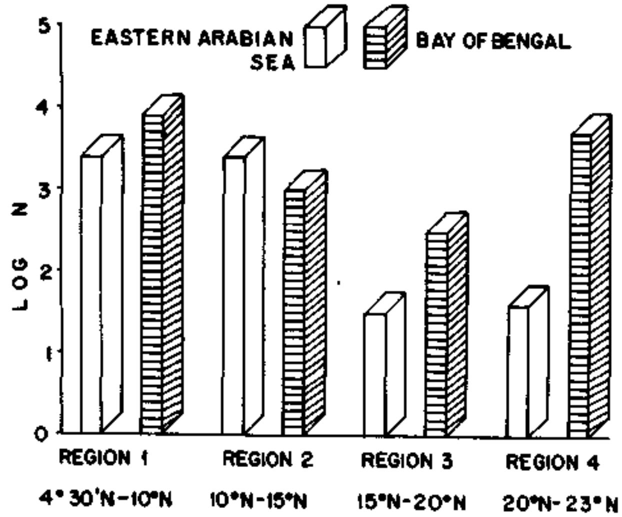


Fig. 2. Region-wise distribution of Cladocera in the eastern Arabian Sea and the Bay of Bengal.

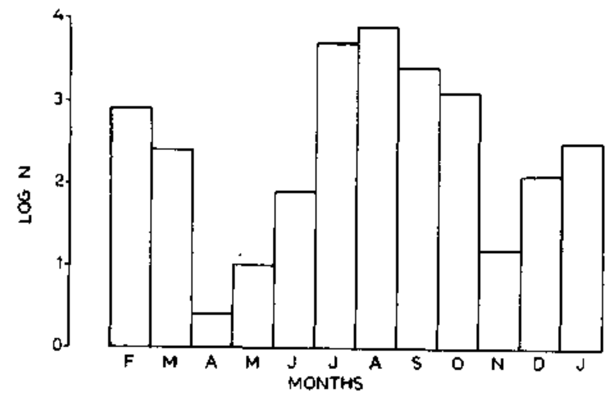


Fig. 3. The monthly variations in the abundance of Cladocera in the seas around India.

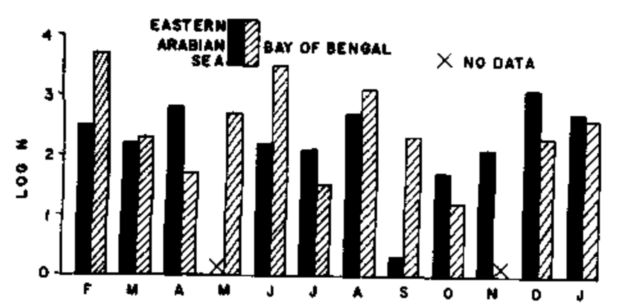


Fig. 4. The monthly variation in the abundance of Cladocera in the eastern Arabia Sea and the Bay of Bengal.

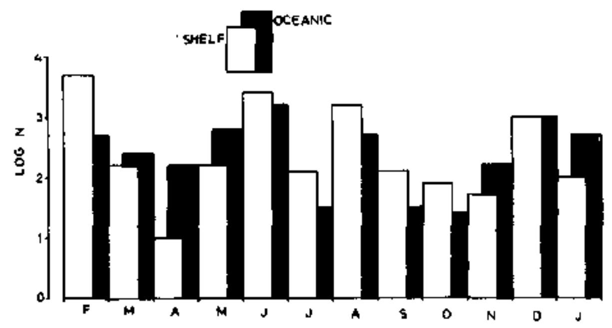


Fig. 5. The monthly variations in the abundance of cladocera in the shelf and oceanic areas of the seas around India.

the shelf and from 12 to 56,428 in the oceanic regions.

Figure 7 shows that the average concentration observed was high in the shelf waters of the Arabian Sea in February (5,554/1000 m^3), from July to September (3,809 to 40, 818/1000 m^3), in January (3,349/1000 m^3) and in the oceanic region only during July (3,527/1000 m^3). Cladocera were absent in the shelf during March and in the adjacent oceanic area during April, August and September.

In the Bay of Bengal the standing crop of Cladocera varied from 143 to 5,03,326 in the shelf and from 8 to 16,959/1000 m^3 in the oceanic areas but they were absent simultaneously in the shelf

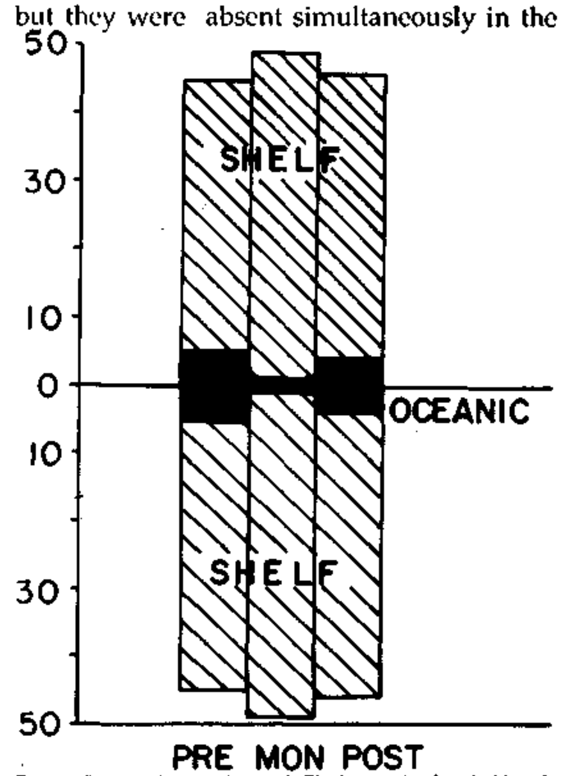


Fig. 6. Seasonal variations of Cladocera in the shelf and oceanic waters of the seas around India.

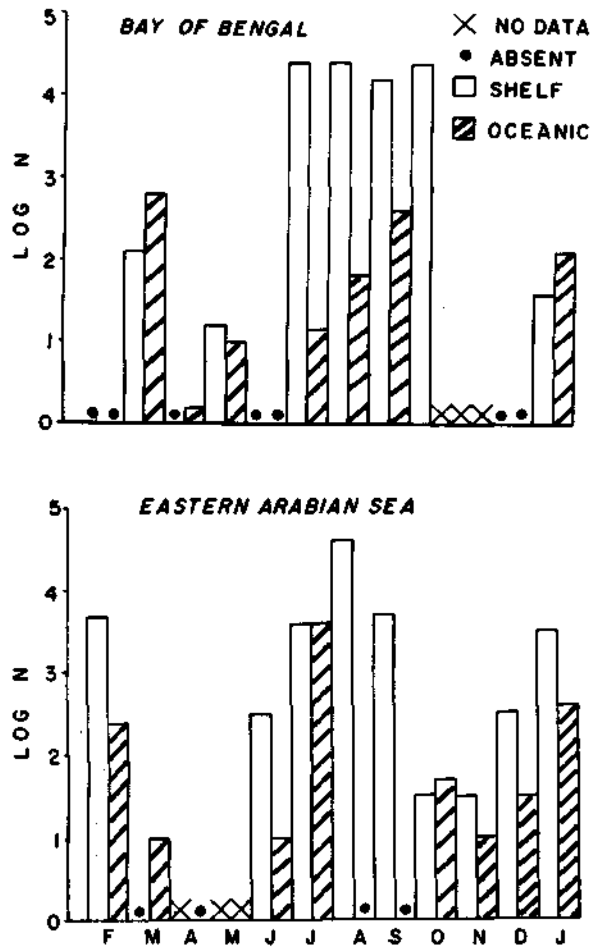


Fig. 7. The monthly variations in the anundance o f Cladocera in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

and oceanic waters in February, June and December and once in the shelf waters alone during April.

The mean cladoceran density observed was high in the shelf waters of the Bay of Bengal (10,924-23, 968/1000 m^3) during July - October and in the adjacent oceanic area during March (565/1000 m^3) and September (421/1000 m^3).

Region -wise seasonal distribution in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

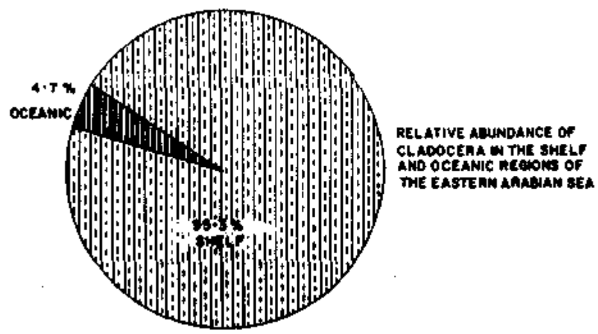
In the eastern Arabian Sea a greater portion of Cladocera forming as much as 95.3% occurred in the continental shelf and the rest 4.7% was found in the oceanic area (Fig. 8 a).

In the eastern Arabian Sea the continental shelf corresponding to the region between latitude 4°30'N and 10°N was rich in Cladocera during the premonsoon and monsoon seasons whereas, in the adjacent oceanic area of the same region, the increase recorded in the monsoon was conspicuous.

Between latitudes 10°N and 15°N the cladoceran abundance observed in the shelf during the monsoon season was impressive and the concentration was the highest (total number : 5,75,441 and mean number : 13,382/1000 m^3) recorded from the Arabian Sea during 1985-'88.

In the Bay of Bengal, 92.8% of Cladocera occurred in the shelf waters and the rest in the oceanic area (Fig. 8b).

Between latitudes 4°30'N and 10°N the abundace observed in the monsoon season in the shelf waters was the highest recorded (Total number : 6,55,314; and mean number : 40,957 / 1000 m^3)



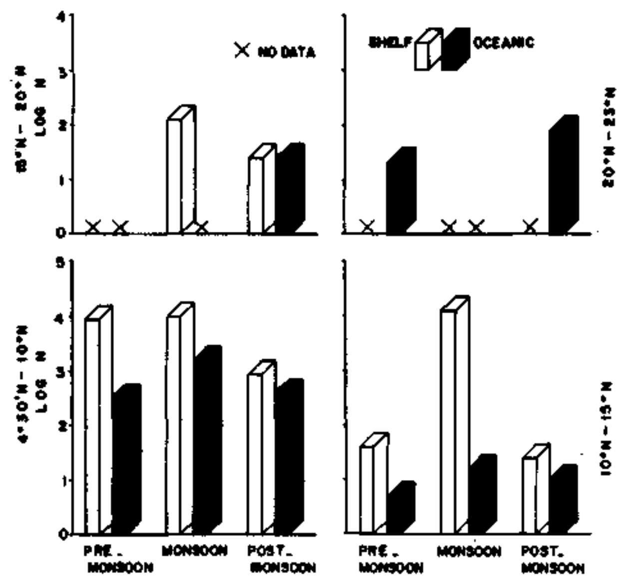


Fig. 8a. Region-wise seasonal distribution of Cladocera in the shelf and oceanic waters of the eastern Arabian Sea.

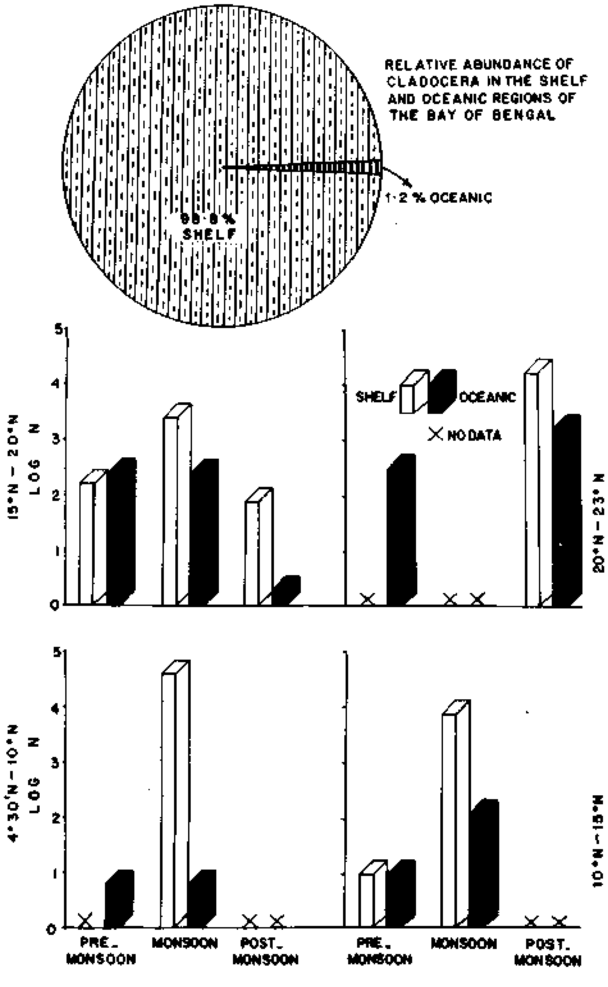


Fig. 8b. Region-wise seasonal distribution of Cladocera in the shelf and oceanic waters of the Bay of Bengal.

during this study. The density of Cladocera observed in the monsoon season between latitudes 10°N and 20°N and in the region north of 20°N recorded in the postmonsoon season was high. Besides, the concentration recorded in the postmonsoon season in the oceanic area north of 20°N was comparatively more than those recorded in other parts of the Bay of Bengal during the season.

Monthly variations in abundance during day and at night in the seas around India

Figure 9 shows that the cladoceran content of the stations sampled during the day time and those at night differed markedly. The night samples were richer in March, April and August but the day samples contained more Cladocera during the remaining months, except in November when Cladocera were equally abundant in the day as well as the night samples.

Though the difference in the cladoceran content of the day and night samples could hardly be discernible during the monsoon season, the contrast during the postmonsoon was immense with Cladocera of the night samples forming a mere 5% (Fig.

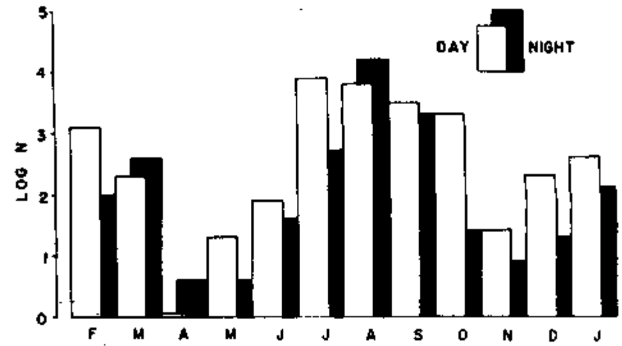


Fig. 9. The monthly variations in the abundance of Cladocera during day and at night in the seas around India.

10). On the other hand, during the premonsoon, the Cladocera of the night samples formed 20%.

Monthly variations in the shelf and oceanic waters during day and at night

Cladoceran component of the day samples from the continental shelf was higher; constituting more than 50% except in August, than that of the night samples, or the day/night samples from the oceanic part of the eastern Arabian Sea/Bay of Bengal (Fig. 11). The day samples from the oceanic region were richer in Cladocera than the night

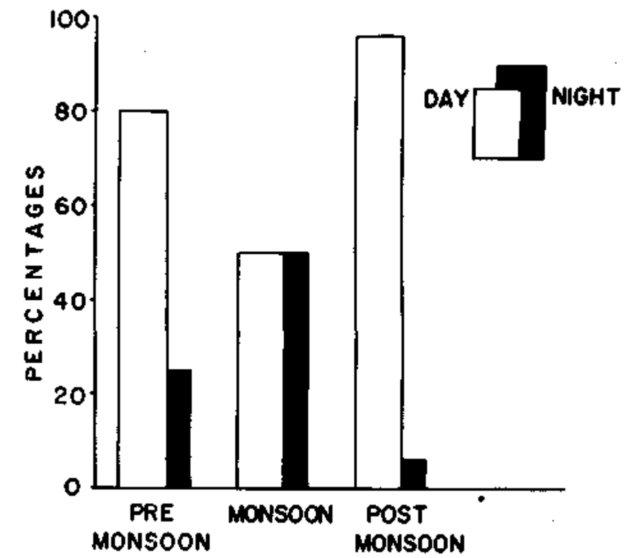


Fig. 10. Seasonal variations of Cladocera during day and at night in the seas around India.

samples of the shelf as well as the oceanic region and in the latter region except during March - April and August. However, the night samples from the samples from the oceanic region contained a significant percentage of the Cladocera except in May.

In the shelf waters the cladoceran content of the night samples of the premonsoon season was nil and that of the postmonsoon season was less than 5%. But during the monsoon season the concentration in the night samples exceeded that recorded in the day samples (Fig. 12).

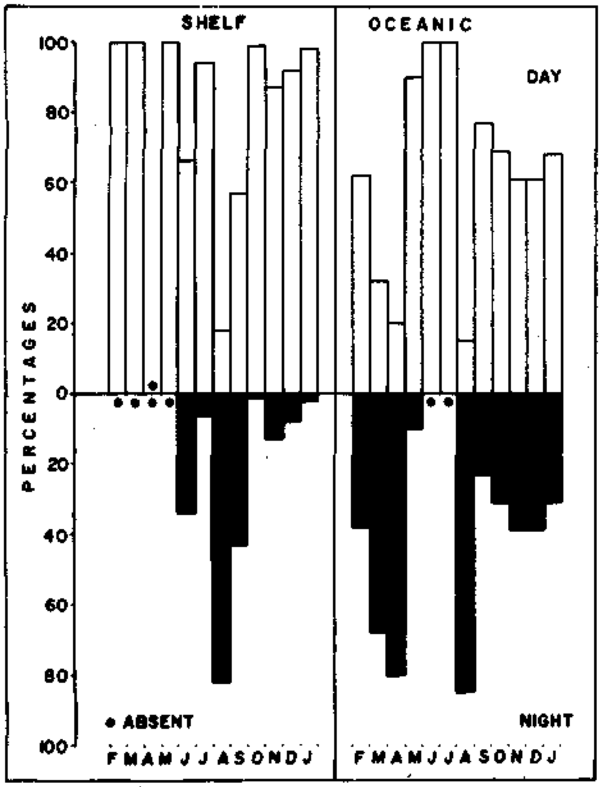


Fig. 11. The monthly variations in the abundance of cladocera in the shelf and oceanic waters during day and at night in the seas around India.

In the oceanic waters during the premonsoon season the cladoceran content of the night samples nearly equalled that of the day samples. In the monsoon season Cladocera were present almost exclusively in the day samples. Whereas, in the postmonsoon season Cladocera were more in the samples collected during the day than those at night.

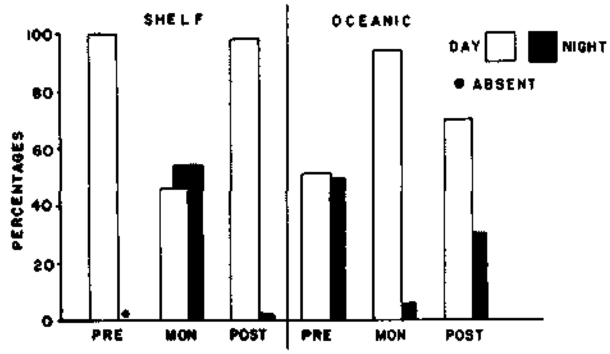


Fig. 12. Seasonal variations of Cladocera in the shelf and oceanic waters during day and at night in the seas around India.

Discussion

The distribution of cladocera between 4°30'N and 23°N lat. and 65°E and 96°E long. shows that the regions between 4°30'N and 15°N lat. on the continental shelf of both the eastern Arabiann Sea and the Bay of Bengal are more densely populated than the rest of the continental shelf as well as the entire adjacent oceanic areas (Fig. 2). It may be seen that the cladoceran abundance occurred in the coastal waters known for high biological productivity and adjacent to major fish landing centres. The concentration of Cladocera estimated in a half a degree square off Cochin (Fig.1) was the highest (2,45,899/ $1000m^3$). It also shows that the Cladocera abounded in the Wadge Bank area off Cape Comorin and the coastal waters of Vizhinjam and Karwar and off Tuticorin, Coromondel coast and Paradip. The increased abundance and seasonal fluctuations of these planktonic crustaceans in the waters of the Wadge Bank, off Tuticorin, Coromondel coast and Paradip are reported for the first time. According to Paffenhofer (1983) cladocerans occur in high concentrations in the nearshore upwelling regions.

Figure 2 shows that in the eastern Arabian Sea the Cladocera were abundant on the continental shelf in the region between 4°30'N and 15°N lat. where, between 5°N and 10°N lat. according to Warren *et al.* (1966) upwelling was particularly intense in the southwest monsoon season and between 7°N and 16°N lat. where prevalence of upwelling was reported by Panikkar and Jayaraman (1966) during the southwest and early postmonsoon seasons. In the Bay of Bengal also the Cladocera were abundant where upwelling and enrichment of nutrients are reported to occur in regions between Madras and Vishakhapatnam during the pre- and postmonsoon periods (Murty and Varadachari, 1968) and in the coastal waters of north western Bay of Bengal (Sankaranarayanan and Reddy, 1968). The cladoceran abundance observed off Veraval was though lower in intensity than those described earlier in this account occurred in a region enriched by the incursion of nutrient rich Persian Gulf waters (Rao *et al.*, 1979). It may also be seen that the cladoceran populations are concentrated in certain areas on the continental shelf forming 95.3 and 98.8% of the total observed respectively in the eastern Arabian Sea and the Bay of Bengal (Fig. 8a and 8b).

All these appear to indicate an explosive rate of reporduction owing to parthenogenesis (Onbe, 1977; 1985) occurs on the continental shelf in the monsoon season at the time of upwelling. It may be mentioned here that the upwelled water is characterized by low temperature, high salinity and high density as it ascends and spreads along the continental shelf. Perhaps the resting cladoceran eggs in the sediments are borne towards the surface where at moderately high temperature the eggs hatch causing the explosion in the population of the Cladocera (swarms) which eclipses the other components of the coastal zooplankton. The occurrence of such swarms frequently during the monsoon and early postmonsoon in the coastal waters off Karwar (Naomi, 1986), off Cochin (Naomi and Mathew MS, and off Vizhinjam (Rani Mary *et al.*, 1981) have been reported earlier. Such swarms off Cochin were sometimes associated with the blooms of *Fragilaria oceanica* (Naomi and Mathew MS) or with those of *Trichodesmium* and pteropods (Sakthivel and Haridas, 1974).

The cladoceran abundance observed in the eastern Arabian Sea was high during February and July - September and in the Bay of Bengal during July - October (Fig. 4). While the concentration observed in the shelf region of both the eastern Arabian Sea and the Bay of Bengal was the highest in August, that of the contiguous oceanic areas attained maximum in July in the former and March in the latter.

Figures 8a and 8b show that Cladocera were abundant during the premonsoon and monsoon seasons between 4 °30'N and 15°N lat. in the eastern Arabian Sea as reported earlier by Madhupratap (1981) along the southwest coast of India but the concentration in the shelf together with that of the adjacent oceanic waters observed during the monsoon season was the highest. On the other hand, in the Bay of Bengal the cladocera were abundant in the monsoon and postmonsoon seasons. The concentration of Cladocera was high in the shelf between 4°30'N and 10°N lat. in the monsoon season, and in the shelf and oceanic waters of the region north of 20°N lat. in the postmonsoon season.

The cladoceran content was more in the samples collected in the day time than those sampled in the night except in March and August (Fig. 9). The number of stations sampled in the day time and in the night was respectively 659 and 427. The total number of specimens observed in the day samples was 13,59,840 and in the night samples it was 6,98,579 with a mean of 2,063 and 1,636/1000 m^3 respectively. According to Onbe (1977) the pattern of diurnal migrations performed by *Penilia avirostris* of Sididae is far less distinct than the other members of Polyphemidae and Podonidae which aggregated densely at the surface during day but migrated downwards to the intermediate layers at night leaving the surface sparse. Bosch and Taylor (1973) felt that the inactivity of these pelagic crustaceans might make them sink to the deeper layers at night.

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The authors are grateful to Dr. P.S.B.R. James, Director, C.M.F.R.I., Cochin for his guidance and constant encouragement. They are also thankful to Dr. K. S. Scariah, and Mr. P. P. Pavithran of this Institute for processing the data. All the help rendered by Mr. Abdul Nizar is acknowledged.

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HETEROGENEITY IN THE DISTRIBUTION PATTERN OF PELAGIC COPEPODS COLLECTED ONBOARD FORV *SAGAR SAMPADA* IN THE INDIAN EEZ

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Abstract

Areal and seasonal average distribution pattern of pelagic copepods in selected sectors of the Indian EEZ limited within Lat. 07°-23°N; Long. 64°-78°E (eastern Arabian Sea); Lat. 10°-21°N; Long.80°-89°E (NW Bay of Bengal), and Lat. 06°-17°N; Long. 89°-95°E (Andaman Sea), collected during the period 1985-'88 were investigated and results presented. Spatio-temporal coverage of samples, which is relatively equidistributed over seasons (monsoon-53%, inter-monsoon-47%) facilitated synthesis of data to assess seasonality in the copepod distribution in these areas.

Results of synoptic studies in the above lines indicate that in this monsoon dominated regime, occurrence and abundance of pelagic copepods are related largely to the environmental stability. The turbulent environmental conditions prevailing during the monsoons considerably influence their availiability to the secondary level of marine food chain.

Analysis of the pattern of diurnal numerical distribution of pelagic copepods in relation to microplankton biomass revealed positive correlation with b (slope) values recorded at 1.048 for night samples and 1.689 for day samples indicating a passive relationship. Significance of mapping of Potential Richness (Rp) to locate productive fishing grounds in the Indian EEZ is discussed in this communication.

Introduction

A series of publications are available on the taxonomy, distribution and ecology of pelagic copepods of the EEZ of India and contiguous seas, of which salient ones are the UNESCO/IIOE reprints (1965 - '72), publications based on R. V. *Varuna* zooplankton analyses (1972 -), UNDP/FAO progress Reports 1-18 (1971-'76), papers presented at the symposia held at Kiel (1971), Cochin (1971) and Goa (1976) and those published in various journals. Pattern of synoptic distribution of pelagic copepods in the neretic and oceanic areas, and around insular realms of Indian seas has also been studied in the past (Pillai, 1974; Thompson, 1978; Goswamy, 1979; Madhupratap *et al*., 1981). The research cruises of FORV *Sagar Sampada* during 1985-'88 have covered about 80% of the Indian EEZ area at depths beyond 50 m, and the seasonal coverage of zooplankton sampling facilitates analysis of the synoptic and spatio-temporal distribution pattern of copepods in this area.

The present report embodies the results of synoptic studies on the areal (1° square area) and temporal (seasons) distribution pattern and abundance of pelagic copepods in three geographical areas of the Indian EEZ, viz., Arabian Sea, Bay of Bengal and Andaman Sea. In the absence of available information on the physico-chemical properties of the environment to corroborate the heterogeneity of copepod distribution, the magnitude of influence of surface circulation on the concentration of copepods, both areal and seasonal was attempted. Diel variation in the numerical distribution of copepods related to microplankton biomass has been studied, and 'biomass ratio' estimated for assessing potential richness (R_p) based on available data in the present study.

Material and Methods

Numerical data on copepods were based on the analyses of zooplankton samples collected from 1139 stations occupied in the Indian EEZ and contiguous seas during the research cruises 1-44 of FORV *Sagar Sampada* in 1985-'88 period. Details of zooplankton sampling and gear(s) employed are dealt with elsewhere (Mathew *et al*., 1990).

Taxonomic list of 93 species of copepods presented is based on the examination of copepod materials from 257 stations during cruises 1 to 10 of *Sagar Sampada*.

Numerical distribution of copepods was computed for 1° square area. The pattern of seasonal coverage of 1° squares within the area 04°-24°N; 64°-96°E indicates that during the premonsoon, mon-

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soon and postmonsoon seasons effecive coverage rates were 34%, 39% and 27% respectively. Hence, month-wise distribution patterns of copepods for 1° square areas were estimated, and mean density as *density indices* (d_1=No./1000 m^3) during the above three seasons were presented for the three geographical areas viz., Arabian Sea, Bay of Bengal and Andaman Sea in a series of maps.

The pattern of surface circulation, and zones of divergence in the Arabian Sea and Bay of Bengal used in the present study were restructured based on published accounts on the subject.

Of the total, 681 stations were occupied during the day and 458 stations during night time. Temporal relationship of 'copepod-microplankton biomass' was studied by cluster analysis method (Haebland and Streta, 1973). Due to the partial coverage of the examination of copepod materials, estimate of the 'Potential Richness' (R_p) (Grandperrin, 1975) of these regions was limited to studying the biomass ratio only.

Numerical occurrence of more than 75 Nos. of copepods/m^3 is considered as high concentration throughout the text.

Distribution pattern of pelagic copepods

A total of 93 species of pelagic copepods belonging to calanoids (76), cyclopoids (13) and harpacticoids (4) were identified to occur in different degrees of concentrations in the samples collected from 257 stations during cruises 1-10 of *Sagar Sampada* (Table-1).

TABLE 1. *List if copepod species idenitifed (Cruises 1 to 10)*

CALANOIDS

F. Calanidae

1. *Canthocalanus pauper* (Giesbrecht)
2. *Nannocalanus minor* (Claus)
*3. *Undinula vulgaris* (Dana)
*4. *U. darwinii* (Lubbock)

F. Eucalanidae

*5. *Eucalanus crassus* Giesbrecht
6. *E. subcrassus* Giesbrecht
7. *E. mucronatus* Giesbrecht
8. *E. pseudattenuatus* Sewell
*9. *E. monachus* Giesbrecht

F. Rhincalanidae

10. *Rhincalanus cornutus* Dana
11. *R. nasutus* Dana

F. Pseudocalanidae

12. *Calocalanus pavo* (Dana)
13. *Clausocalanus arcuicornis* (Dana)

F. Paracalanidae

*14. *Paracalanus parvus* (Claus)
15. *P. aculeatus* Giesbrecht
*16. *Acrocalanus gracilis* Giesbrecht
17. *A. monachus* Giesbrecht
18. *A. gibber* Giesbrecht
19. *A. longicornis* Giesbrecht

F. Euchaetidae

20. *Euchaeta marine* (Prestandria)
21. *E. concinna* Dana
22. *E. wolfendini* A. Scott

F. Aetididae

23. *Aetideus giesbrechtii* Sewell

F. Scolecithricidae

*24. *Scolecithrix danae* (Lubbock)

F. Temoridae

25. *Temora turbinata* (Dana)
*26. *T. discaudata* Giesbrecht

F. Pseudodiaptomidae

27. *Psedodiaptomus serricaudatus* (T. Scott)

F. Centropagidae

*28. *Centropages furcatus* (Dana)
*29. *C. orsinii* Giesbrecht
30. *C. alcockii* Sewell
31. *C. trispinosus* Sewell
*32. *C. tenuiremis* Thompson and Scott
*33. *C. dorsispinatus* Thompson and Scott
34. *C. gracilis* (Dana)
35. *C. calaninus* (Dana)

F. Metridiidae

36. *Pleromamma xiphias* (Giesbrecht)
*37. *P.indica* Giesbrecht
38. *P. abdominalis* (Lubbock)

F. Lucicutiidae

39. *Lucicutia flavicornis* (Claus)
*40. *L. ovalis*

F. Augaptilidae

*41. *Haloptilus longicornis* (Claus)

F. Arietellidae

*42. *Metacalanus aurivillii* Cleve

F. Candaciidae

*43. *Candacia brady* A. Scott
*44. *C. pachydactyle* (Dana)
45. *C. discaudata* A. Scott
46. *C. aethiopica* (Dana)
47. *C. curta* (Dana)
*48. *C. catula* (Giesbrecht)
*49. *Paracandacia truncata* (Dana)
50. *P. bispinosa* (Claus)

F. Pontellidae

*51. *Calanopia elliptica* (Dana)
*52. *C. minor* A. Scott
53. *C. thompsoni* A. Scott
*54. *Labidocera acuta* (Dana)
*55. *L. pectinata* Thompson and Scott
56. *L. kroyeri* (Brady)
*57. *L. detruncata* (Dana)
58. *L. euchaeta* Giesbrecht
59. *L. acutifrons* (Dana)
*60. *L. minuta* Giesbrecht
61. *Pontella danae* Giesbrecht
62. *P. securifer* Brady
*63. *P. fera* Dana
64. *P. ansersoni* Sewell
65. *P. spinipes* Giesbrecht
66. *Pontellopsis villosa* Brady
67. *P. scotti* Sewell
68. *P. regalis* (Dana)
69. *P. herdmani* Thompson and Scott
70. *Pontellina plumata* Dana

F. Acartiidae

*71. *Acartia spinicauda* Giesbrecht
*72. *A. danae* Giesbrecht
*73. *A. negligens* Dana
74. *A. erythraea* Giesbrecht

F. Tortanidae

75. *Tortanus barbatus* (Brady)
*76. *T. forcipatus* Giesbrecht

CYCLOPOIDS

F. Oithonidae

*77. *Oithona plumifera* Baird
*78. *O. nana* Giesbrecht
79. *O. linearis* Giesbrecht
80. *O. robusta* Giesbrecht

F. Oncaeidae

81. *Oncaea venusta* Philippi
82. *O. conifera* Giesbrecht

F. Corycaeidae

83. *Corycaeus gibbulus* Giesbrecht
84. *C. speciosus* Dana
85. *C. catus* F. Dahl

F. Sapphirinidae

86. *Sapphirina metallina* Dana
87. *S. opalina* Dana
*88. *Copilia mirabilis* Dana
89. *C. vitrea* (Haeckel)

HAPRACTICOIDS

F. Longipediidae

90. *Longipedia scotti* (Sars)

F. Ectinosomidae

91. *Microsetella rosea* (Dana)

F. Macrosetellidae

92. *Macrosetella gracilis* (Dana)
93. *Miracia efferata* Dana

Species with popiulation density > $50/m^3$ are marked by *

Arabian Sea

During the *premonsoon* season, area of high concetration of copepods (> $100/m^3$) was recorded off Bombay in the sector 17°-23°N and 67°-72°E in the offshore waters. Copepods were less numerous in the central and southern parts of eastern Arabian Sea. Their concentration was relatively high during the *monsoon* season in the area off south and south-west coast of India (04°-12°N; 74°-78°E) while in the offshore waters their distribution was patchy. Wide-spread distribution of copepods was recorded during the *postmonsoon* season along the outer shelf and oceanic waters off the west coast of India with two areas of concentration located between (i) 17°-24°N; 65°-71°E and (ii) 07°-16°N; 73°-78°E in the eastern Arabian Sea (Fig. 1 a-c).

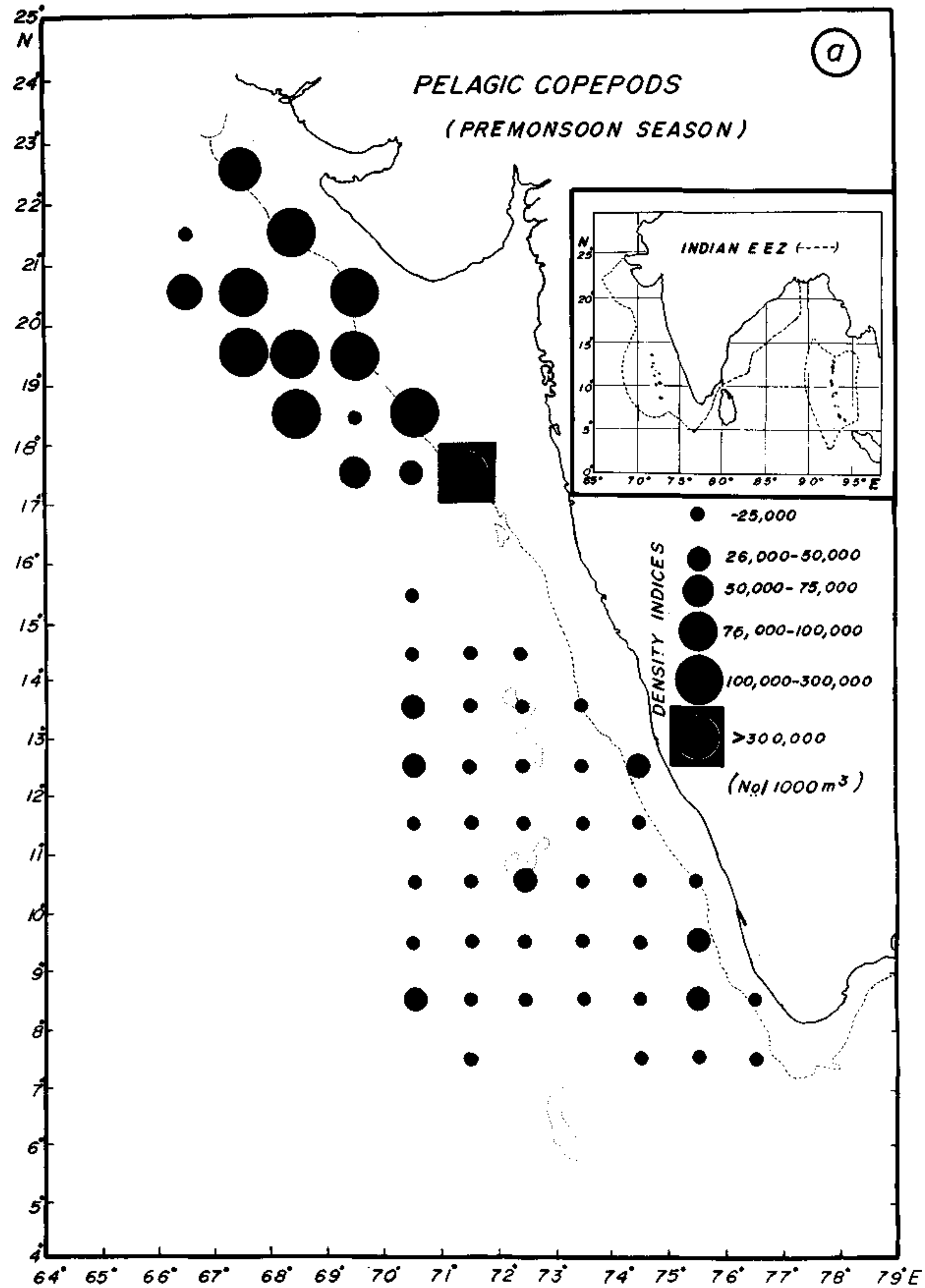

Fig. 1 a. Areal distribution pattern of pelagic copepods during premonsoon season in the Arabian Sea. Density indices (d_i) are indicated.

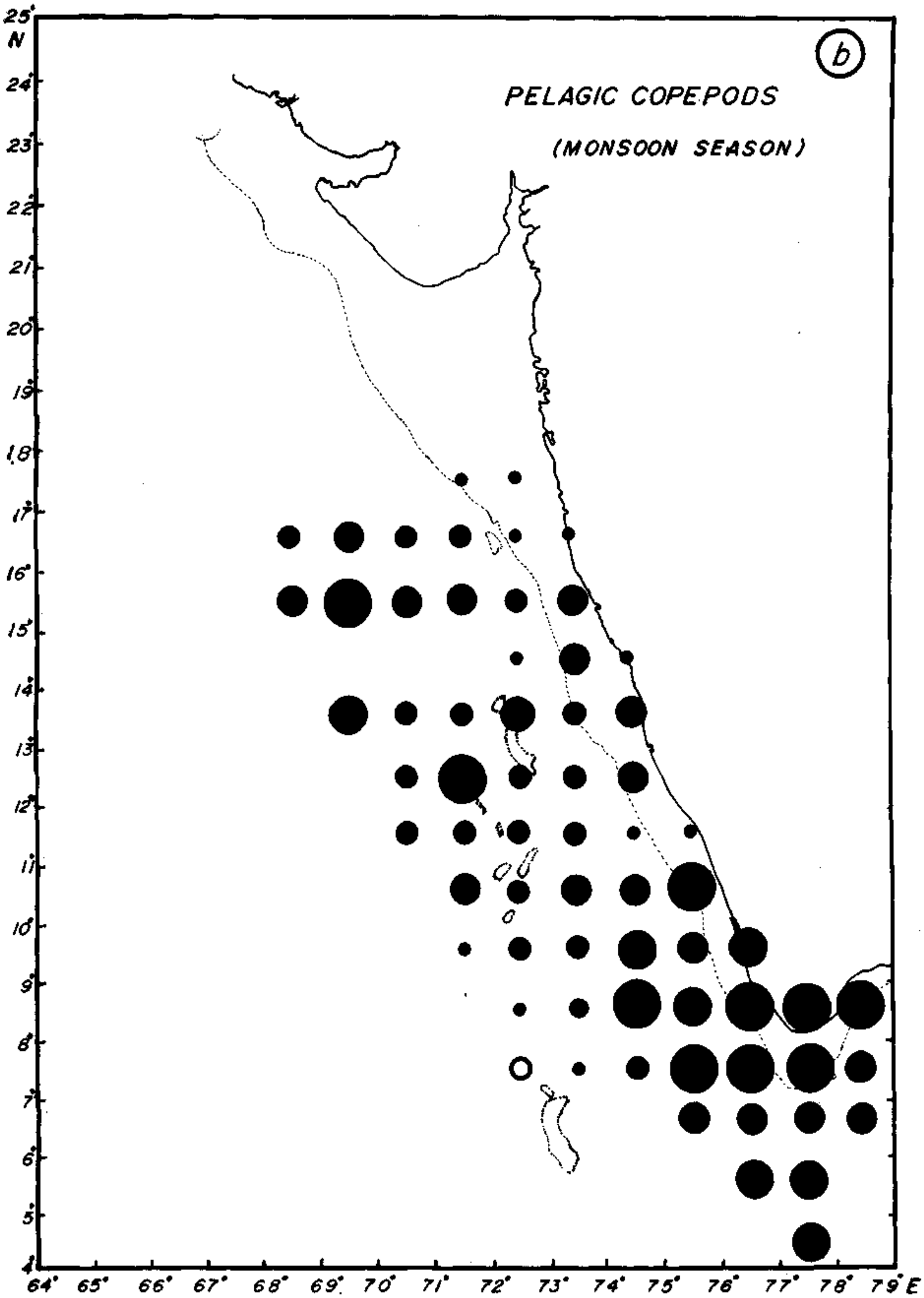

Fig. 1 b. Areal distribution pattern of pelagic copepods during monsoon season in the Arabian Sea.

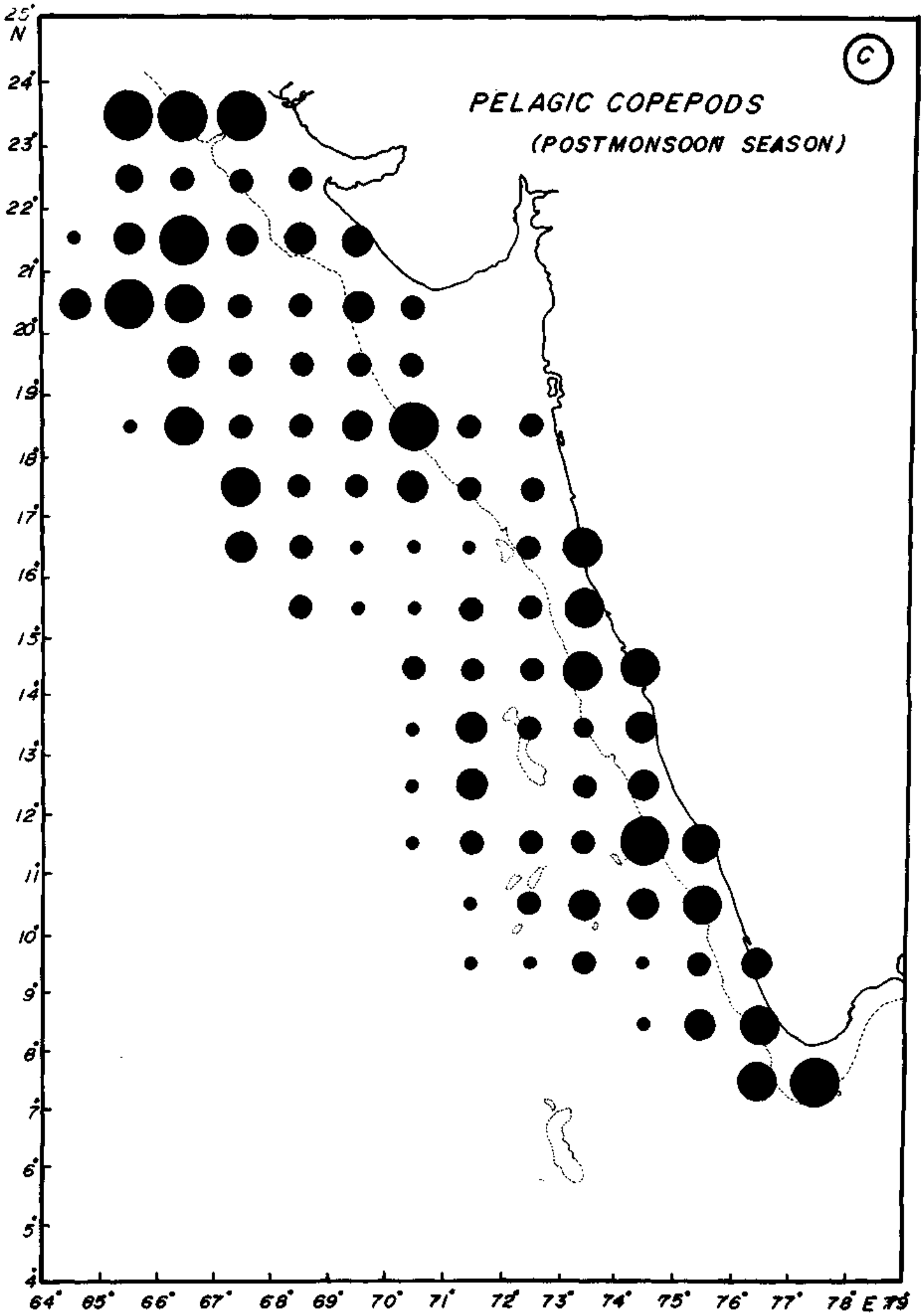

Fig. 1 c. Areal distribution pattern of pelagic copepods during postmonsoon season in the Arabian Sea.

Bay of Bengal

Copepod data are mainly available from the area 80°-89°E along the western Bay of Bengal.

During the *premonsoon* season, relatively high numerical values of copepods were recorded from the area 11°-18°N; 80°-86°E. They were widespread along the east coast of India during the *monsoon* season, and they were concentrated in the southeastern coast of India (08°-14°N; 79°-82°E.), a contiguous pattern of that observed in the southwest coast during the monsoon season. During *postmonsoon* season, copepods were widely distributed along the western Bay, and relatively high concentraion was recorded in the area close to southeast coast (13°-20°N; 80-88°E) (Fig. 1 *d-f*).

Andaman Sea

Relatively high concentraion of copepods was recorded mainly along the southeastern part of Andaman and Nicobar Islands (06°-11°N; 91°-93°E) during the *premonsoon* season. During *monsoon*, copepods were more concentrated along the west coast of Nicobar Islands in the area 08°-11°N; 94°-96°E. No data is available from the Andaman Sea during the postmonsoon period.

An executive summary of the spatial and temporal abundance and numerical concentraion of copepods in these areas observed during the present study is given in Table 2.

Circulation of surface waters

The pattern of sea surface circulation in the northern Indian Ocean area has been restructured based on published information and the same presented for four seasons viz., NE monsoon, transition, SW monsoon and postmonsoon periods in Fig. 2. The pattern described below is mingled with subjectivity, but these were made use of in conjunction with literature on the topic in the present study (Gallaher, 1966; Varadachari and Sharma, 1967; Darbyshire, 1967; Pillai, 1974; Krey and Barbanard, 1976 and Marcille, 1985). A brief summary of the pattern of circulation studied by streamline technique (Varadachari and Sharma, 1967), which also permitted rapid survey of the major features during the course of an year is presented below.

During early phase of the NE monsoon period, the coastal currents are southerly and the flow is predominantly westerly. With the onset of NE monsoon, in the Arabian Sea, the coastal currents are oriented towards north and northeast while from the oceanic area components of east flowing currents join the coastal currents flowing north and northwest, and the resultant flow is north-north-west. In the Bay of Bengal, the westerly flow was observed along the east coast of India with anticyclonic convergence. March-April represent the spring transition period during which the clock-wise circulation in the Arabian Sea and Bay of Bengl strengthens, with a northerly component on the western side of the seas, and a southerly component on the east.

During the SW monsoon period, the surface currents in the northern Indian Ocean are essentially driven by the SW monsoon, and the flow is accordingly easterly over the equatorial region. It is essentially the SW monsoon current which flows during the entire period clockwise, south and southeasterly.

TABLE 2. *Seasonality in the distribution pattern of copepods*

		Arabian Sea	Bay of Bengal	Andaman Sea
Premonsoon	:	17° - 23°N; 67° - 72°E (NE)	12° - 18°N; 80° - 86°E (CW)	06° - 11°N; 91° - 93°E (SE)
Monsoon	:	04° - 12°N; 74° - 78°E (SE)	08° - 13°N; 79° - 82°E (SW)	08° - 11°N; 94° - 96°E (SW)
Postmonsoon	:	17° - 23°N; 65° - 71°E (NE)	13° - 20°N; 80° - 88°E	No sampling
		07 -16°N; 73° - 78°E (SE)	-	-

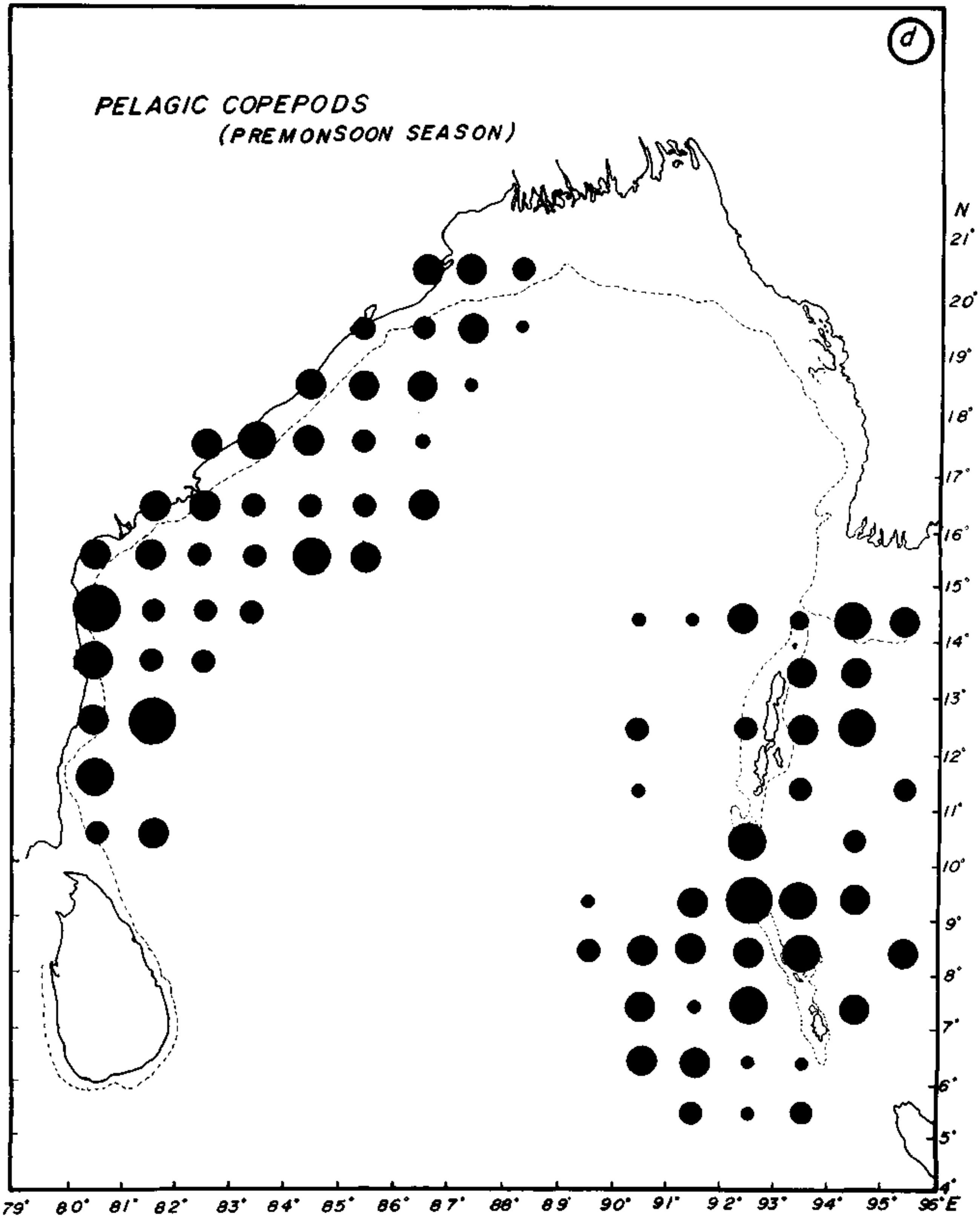

Fig. 1 d. Areal distribution pattern of pelagic copepods during premonsoon season in the Bay of Bengal.

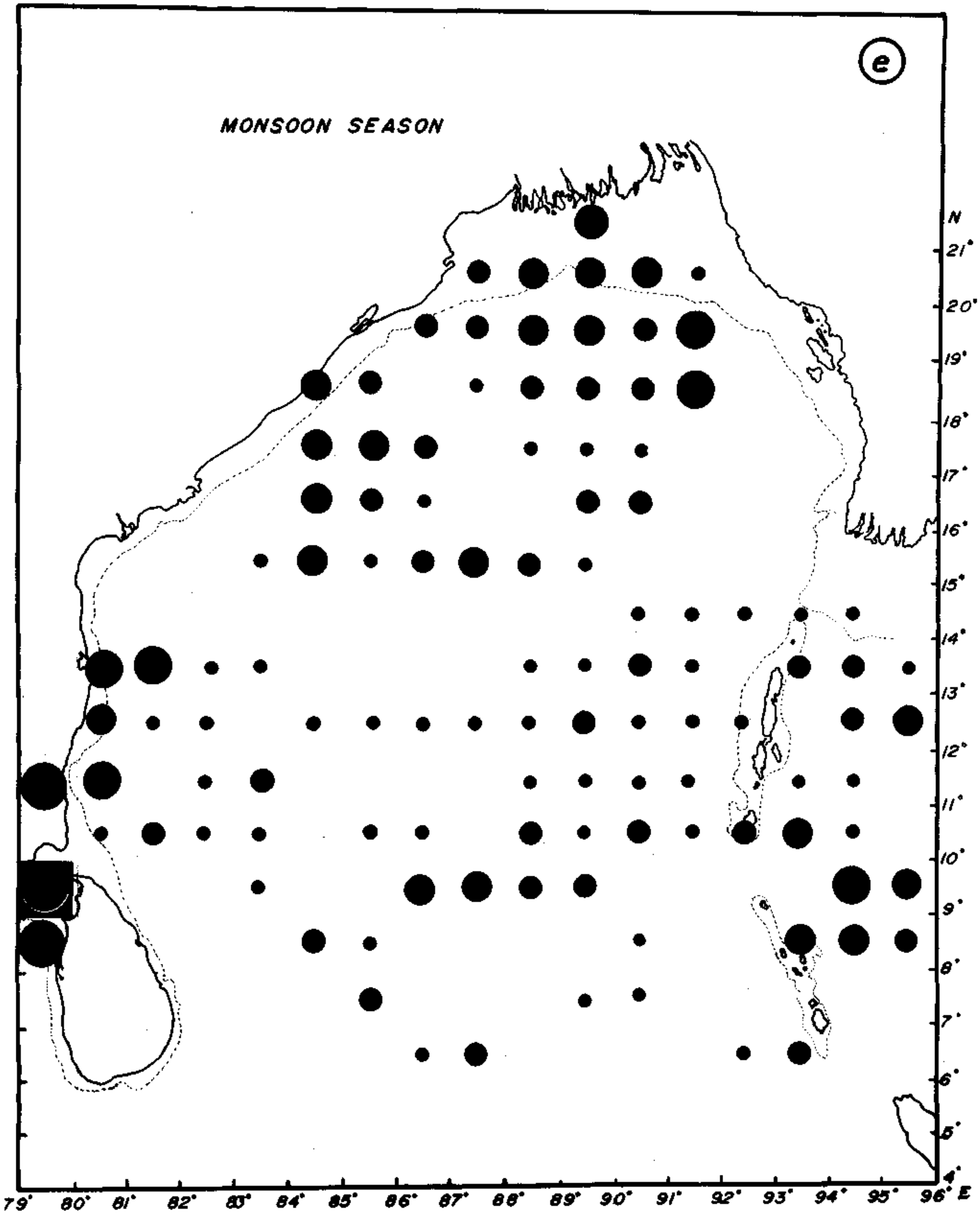

Fig. 1 e. Areal distribution pattern of pelagic copepods during monsoon season in the Bay of Bengal & Andaman Sea.

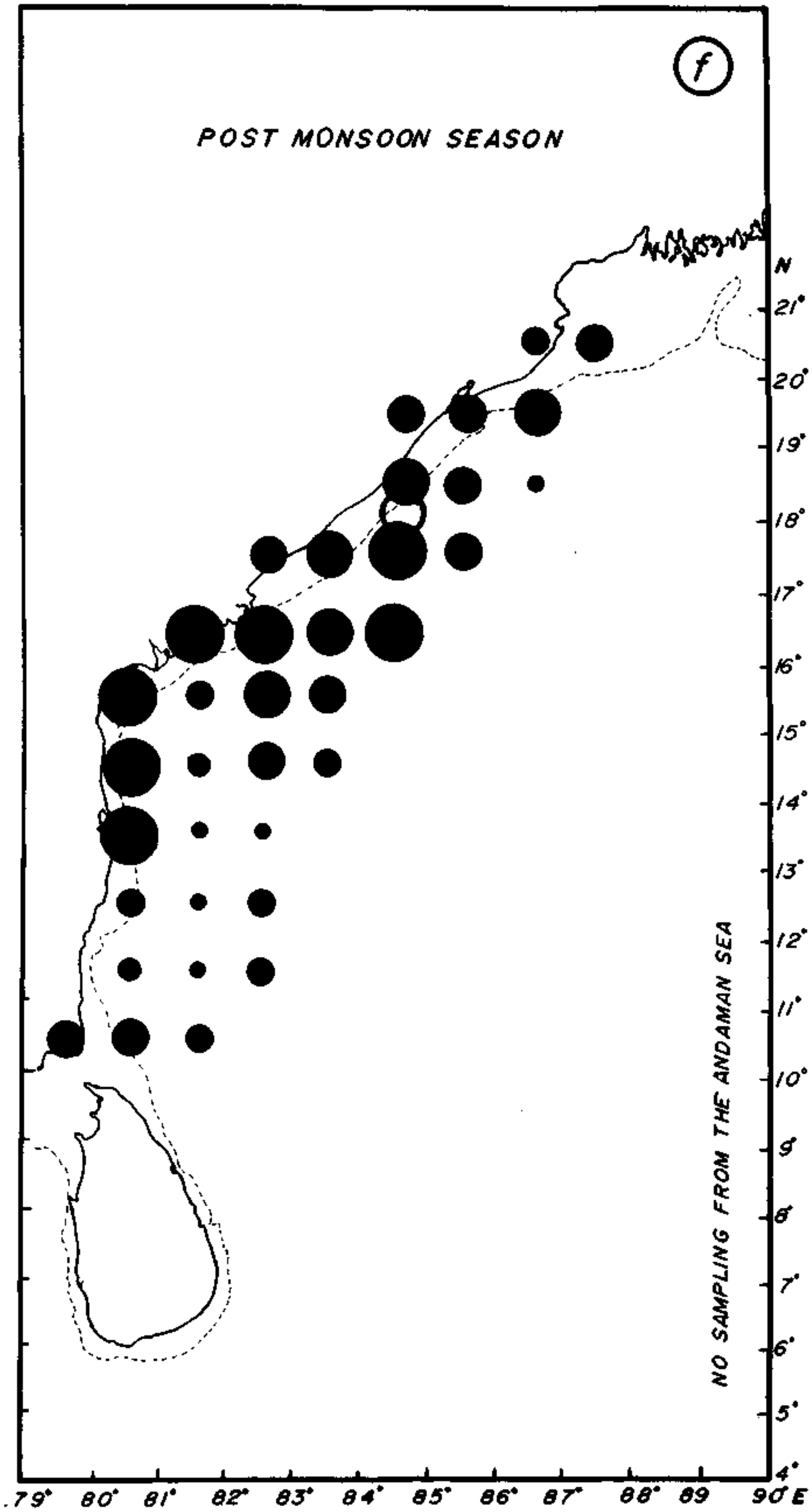

Fig. 1 f. Areal distribution pattern of pelagic copepods during postmonsoon season in the Bay of Bengal & Andaman Sea.

In the open parts of the northern equatorial region, the current is oriented towards east.

September-October period (postmonsoon) represents the transition period between the SW and NE monsoons. The effect of SW monsoon disappears in the Bay of Bengal, while it still prevails over the Arabian Sea and equatorial regions. In the Bay of Bengal, the surface flow is predominantly southerly on the western side and northerly along the eastern side. In the Arabian Sea, definite changes in the

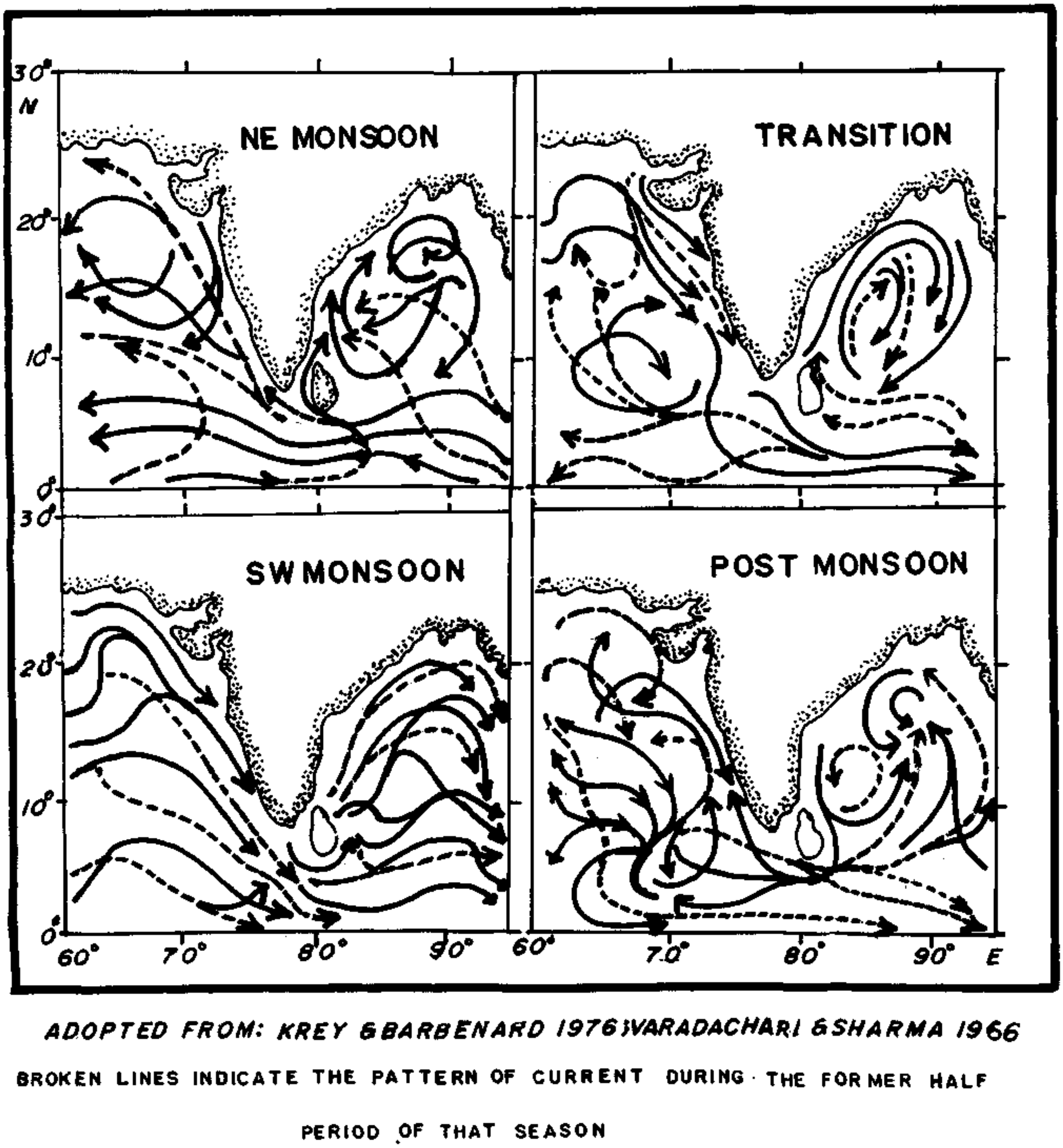

Fig. 2. Surface circulation pattern in the Arabian Sea and Bay of Bengal. Adopted from: Krey and Barbanard, 1976; Varadachary and Sharma, 1966. Broken lines indicate the pattern of current during the former half of that period.

pattern of flow is discernible, and the resultant flow is mainly towards east and onshore.

Based on the pattern of surface flow and direction, broad areas which are indicative of divergence zones near the surface of the sea are considered for Arabian Sea and Bay of Bengal.

TABLE 3. *Areas indicative of divergence in the Arabian Sea and Bay of Bengal during different seasons*

Seasons		Arabian Sea	Bay of Bengal
Premonsoon	:	North-eastern area	North-eastern & western areas
Monsoon	:	Southern & western areas	Southern & central areas
Postmonsoon	:	Central & western areas	Central & southern areas

Diel variation in copepod distribution

An attempt has been made to assess the quantitative relationship between numerical abundance of copepods with the differential distribution pattern of microplankters during day and night. Data for 458 night stations and 681 day stations were separated into 42 latitudinal clusters each (Haebland and Streta, 1973). Regression analyses indicate that the relationship is positive, and the *b* values recorded were 1.048 and 1.689 for night and day samples respectively (Fig. 3). From the level of slope (*b*) it is evident that the relationship is passive eventhough the biomass of microplankters was relatively high in the night samples when compared to that of the day samples.

DISCUSSION

A striking feature of the distribution of pelagic copepods in the zooplankton samples studied is the

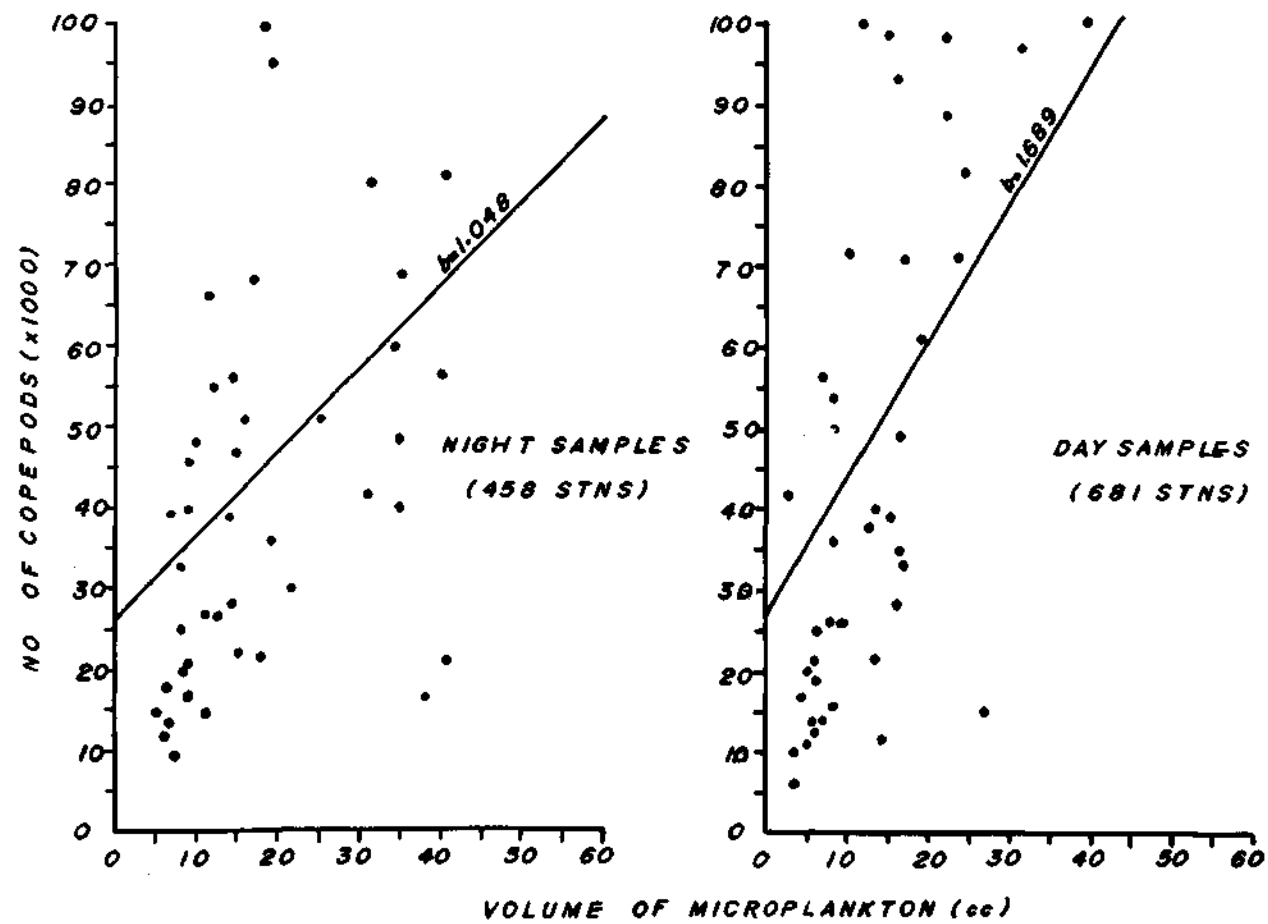

Fig. 3. Diel variation in copepod distribution.

heterogeneity in their abundance in space and time. High density of copepods was recorded in the slope water off the central west coast during premonsoon season (368 Nos./m^3), and from the inshore area of the southeast coast of India during the monsoon period (412 Nos./m^3) (Fig.1). Goswamy (1979) has recorded a value of 516 copepods/m^3 from the neretic area off Cochin during March-April, and Madhupratap *et al.* (1981) observed maximum concentration of 72 copepods/m^3 in the Andaman Sea during February in the zooplankton samples collected during the research cruises of R/V *Gaveshini*. Pillai (1974) recorded a maximum number of 657 copepods/m^3 off southwest coast of India collected by RV *Varuna* during SW monsoon season. Since gears used for zooplankton collections in these studies are different, no attempt has been made to compare the numerical distribiution pattern of copepods.

Another feature observed during the course of study was the seasonality in their concentration. The seasonal shift in their abundance is evident from the summary presented in Table 2. In the Arabian Sea, high concentration of copepods was recorded off the NW coast of India during the premonsoon season (inclusive of NE monsoon period), in the inshore area of SW coast during the monsoon season and they were uniformly widespread in the NW and SW coasts during the postmonsoon season. A similar pattern of areal shift in their concentration was observed along western Bay of Bengal also. During the course of synoptic ecological studies on pelagic copepods along the west coast of India and from the Lakshadweep Sea, seasonality in the abundance of calanoid copepods in the inshore-offshore areas and in different latitudes has been recorded earlier (Pillai, 1974).

According to Murty (1989), the entire west coast, particularly the SW coast and northern half of east coast experience upwelling in different degrees during the southwest monsoon period (summer), and upwelling is generated off Bomaby region during winter under the influence of the offshore winds of the northeast monsoon. As stated earlier (Table 3), most of the areas indicative of divergence, which also reveal upwelling, are located more or less at the similar regions described by Murty (1989). The synchronism of areal concentration of copepods during different seasons with that of the upwelling phenomena in these areas, as observed during the present sudy is noteworthy. However, the "time lag" involved in the trophic cycle during the event of *nutrient enrichment-primary production-herbivores* (copepods) *production* is one of the factors which does not warrant any conclusion regarding the interrelationship involved in the above pattern of concentraion of copepods.

The different distribution patterns shown in Fig. 1 *a-h* may be fitted more easily into a continuous series rather than separate entities. Investigations carried out during the past on the hydrological features of the Arabian Sea and Bay of Bengal indicate that during the period of upwelling, the euphotic zone of the pelagic environment is characterised by low temperature and high salinity in addition to other prevailing and altered physico-chemical properties. If these conditions, which are minimal for population growth are applicable to copepod distribution, one would expect areal decline of this taxa in the above areas. But, the spatial concentration of pelagic copepods in the Arabian Sea and Bay of Bengal, as presented in Table 2 during NE monsoon period, monsoon (SW monsoon) period and postmonsoon period suggest that the surface circulation pattern exerts more influence on their distribution and abundance than the other factors. Large-scale incursion of equatorial water northward along the shelf and slope areas of the west coast of India during the NE monsoon period, the clock-wise circulation pattern observed during the SW monsoon period and the transitional nature of surface flow during the postmonsoon period are presumed to be causative factors for the heterogeneity in the copepod distribution, especially the seasonal oscillation in concentration and subsequent stabilised pattern observed during the present study.

Pillai (1974) described three groups of pelagic copepods viz., *oceanic neretic* and *intermediate* based on the spatial extent of distribution of different species. Variation in their areal distribution pattern during the NE, SW and inter-monsoon periods has been ascribed by him as due to the spatial influx of 'labelled' species, and incursion of oceanic waters over neretic area and vice- versa effected by the surface circulation coupled with the immigration-emmigration phenomena of copepods in the neretic oceanic sectors. In the present study, 93 species of copepods were identified from the samples (Cruises 1-10) of which four species belong to "neretic indicators" and ten species " oceanic indicators". However, future studies on the species-wise distribution pattern of copepods in the zooplankton samples collected by *Sagar Sampda* from the entire area of

Indian EEZ would throw more light on the above assumption.

Assessment of the *potential richness* (R_p) of a region is based on the relationship between plankton biomass, size-specificty of 'forage groups' (for micronecton) and their areal availability and diel periodicity (Grandperrin, 1975). Based on the limited samples, the biomass ratio has been estimated as ranging between 0.10 and 0.12 in the area bounded by 05°-24°N; 65°-76°E and 10°-13°N; 77°-86°E (eastern Arabian Sea and western Bay of Bengal) during February-December, 1985. In-depth study on the entire zooplankton samples is a pre-requisite for mapping of Rp of the shelf and oceanic regions of the Indian EEZ.

Acknowledgement

The author is grateful to Dr.P.S.B.R. James, Director, CMFR Institute for assigning the topic and alloting copepods for study and for the encouragement extended.

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ON THE QUANTITATIVE ABUNDANCE OF MYSIDACEA COLLECTED FROM THE EASTERN ARABIAN SEA AND THE BAY OF BENGAL

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Abstract

The members of the order Mysidacea formed one of the major components in the zooplankton collected from the upper 150m of the Indian EEZ and contiguous seas during the cruises of FORV *Sagar Sampada* undertaken from 1985 to '88. Their average abundance in the area investigated has been estimated to be 364 per 1000 m^3 of water. Areas of very high density with more than 10,000 individuals were found at certain localities in the eastern Arabian Sea namely southwest of Cape Comorin in the oceanic area, north of Cochin within the continental shelf and southwest of Veraval, again, in the oceanic water. As in the case of several other zooplankton, a significant difference in abundance was observed between shelf and oceanic waters, the shelf contributing almost double the quantity of mysids. The eastern Arabian Sea with an average density of 430 mysids was comparatively more populated than the Bay of Bengal. A definite seasonal variattion was noticed for both the sea areas. Off the west coast the southwest monsoon with 775 mysids accounted for the maximum whereas off the east coast the pre-monsoon season with 421 specimens yielded the maximum number. The maximum density in the eastern Arabian Sea was experienced south of 15°N during the southwest monsoon. In the Bay of Bengal the maximum population was observed north of latitude 15°N and it was during the pre-monsoon. The mysids were found to exhibit strong vertical diurnal migration. There was an increase of mysids by 74.11% in the night samples over the day samples.

Introduction

Animals belonging to the order Mysidacea (Crustacea) form a major constituent in the zooplankton especially in the continental shelf area, and form an important forage for higher pelagic organisms. In view of this, considerable attention has been given to the study of this group both qualitatively and quantitatively the world over. Eventhough the Mysidacea has been studied in some detail for its quantitative geographical distribution and aubndance in some of the world oceans (reviewed by Mauchline, 1980), the same of the Indian Ocean has been least investigated and this is especially so for the Indian seas. The earliest works on Mysidacea of the India seas are those of Wood-Mason and Alcock (1891 a, 1891 b) based on collections made onboard *Investigator*. Since then sporadic works have been carried out in some part or the other of the Indian coasts; all being faunistic studies. It was in the sixties when some major studies were carried out on mysids of the Indian Ocean especially that of the Arabian Sea and the Bay of Bengal based on samples collected during the International Indian Ocean Expedition (Pillai, 1964, 1965, 1973). The major thrust in these studies was, again, on taxonomy and occurrence, with very little or no information on quantitative distribution and abundance, ecology etc. The only work dealing with some aspects of ecology and distribution of Mysidacea of the Arabian Sea and the Bay of Bengal is that of Pillai (1973). However, he has made no attempt on the quantitative abundance in space and time of the total mysids or of the species. This being the stae of affairs, it was felt necessary to have precise information on various aspecs of distribution and abundance of mysids as a group. The enormous data collected onboard FORV *Sagar Sampada* from 1985 to 1988 have facilitated such a study for the EEZ of India and the adjacent seas.

The material and methods used in the present study have been detailed in the paper dealing with the zooplankton biomass by Mathew *et al.* (1990) given elsewhere in this volume. The quantitative estimates have been made as number per 1000 m^3 of water.

Results and Discussion

Quantitative abundance

The average abundance of mysids in the entire area investigated has been estimated to be 364 per 1000 m^3 of water. While they occurred at a rate of 430 in the eastern Arabian Sea, only 265 were present in the Bay of Bengal which was equal to 62 and 38% respectively. A significant difference in abundance was noticed between shelf and oceanic areas, the shelf having almost double the population of the oceanic areas. However, when a coastwise consideration was made, it was found that the eastern Arabian Sea was comparatively more populated, with mysids at the rate of 430 per 1000 m^3 of water. A definite variation over seasons was discernible in both the sea areas. But the seasons of abundance were not the same in the two sea areas. Off the west coast the southwest monsoon season with 775 mysids accounted for the maximum whereas off the east coast the pre-monsoon season with 421 specimens yielded the maximum. In the Bay of Bengal the least occurrence of 95 per 1000 m^3 was during the southwest monsoon season. The mysids were found to exhibit strong vertical migration. There was an increase by 74.11% in the night samples over the day samples. Whereas their average occurrence during the day was only 282, the same during the night was 491 per 1000 m^3 of water.

Spatial distribution

The mysids enjoyed a wide spread distribution in the area investigated (Fig. 1). In certain localities their density was over 10,000. However, in most of the areas, either in the shelf or the oceanic, their population size was not as large as some other crustacean zooplankters like copepods, euphausiids, ostracods or amphipods. With regard to population density, the eastern Arabian Sea was better than the Bay of Bengal. Areas of very high density with more than 10,000 individuals per 1000 m^3 of water were found at 3 localised ares in the eatern Arabian Sea namely southwest of Cape Comorin in the oceanic area, north of cochin within the continental shelf and southwest of Veraval, again in the oceanic waters.

In the Bay of Bengal, areas of moderate ocurence between 1,000 and 5,000 were found located east of Andaman Islands and in some places in the shelf and nearby oceanic areas off the east coast (Fig. 1).

Monthly variations

Excepting November, December and January, the group was well represented in all the other months. High abundance was observed during March, August, September and October (Fig. 2). The maximum monthly abundance of 1,132 individuals which was equal to 28.42% of the total mysids obtained was noticed in August. From August to November there was a declining trend with least in November when only 0.21% of the toal mysids was present. It was interesting to note that almost the same trend in abudance was maintained from March to July when the monthly percentage was around five. The picture of abundance becomes more clearer when an examination is made on the seasonal distribution off the east and west coasts. Three major seasons namely pre-monsoon (February-May), monsoon (June-September) and post-monsoon (October - January) were identified based on the southwest monsoon which has a profound influence on the two sea areas.

It has been found that off the west coast, about 65% of the mysids obtained was in the monsoon season, the pre-monsoon and post-monsoon having 16.58% and 18.83% respectively. The picture was quite different off the east coast, where the pre-monsoon accounted for 62.65% of mysids, the monsoon having the least of 14.14% and the post-monsoon 23.21%. The result indicates that while the breeding period of mysids is during the southwest monsoon season off the west coast, it is further advanced in the Bay of Bengal.

A further consideration was made on the monthly abundance off both the coasts separately (Fig. 3). In the eastern Arabian Sea, the period from June to September accounted for 81% of the total mysids obtained from this sea area. August alone contributed 43% of the total mysids taken from here. November with 0.2% and April with 1.7% were the months of least occurrence.

On the other hand, in the Bay of Bengal, the maximum share of 57.31% was taken during February (Fig. 3). The period of abundance was from February to May during which 78% of the total mysids obtained from this sea area was collected. August and December with 1.61 and 1.35% respectively, were the lean months for mysids in the Bay of Bengal. The monthly variations in this group indicate that sudden outbursts in populations is possible within a short period.

Monthly distribution in the shelf and oceanic waters

An analysis was made to understand the variations in abudance of mysids in the shelf and oceanic waters of the entire area of investigation (Fig. 4). It was understood that on the average, the density was almost double in the shelf areas. The period of abundance in the shelf and oceanic areas has been found to be different. Thus in the shelf area, February was the month of population outbreak when about

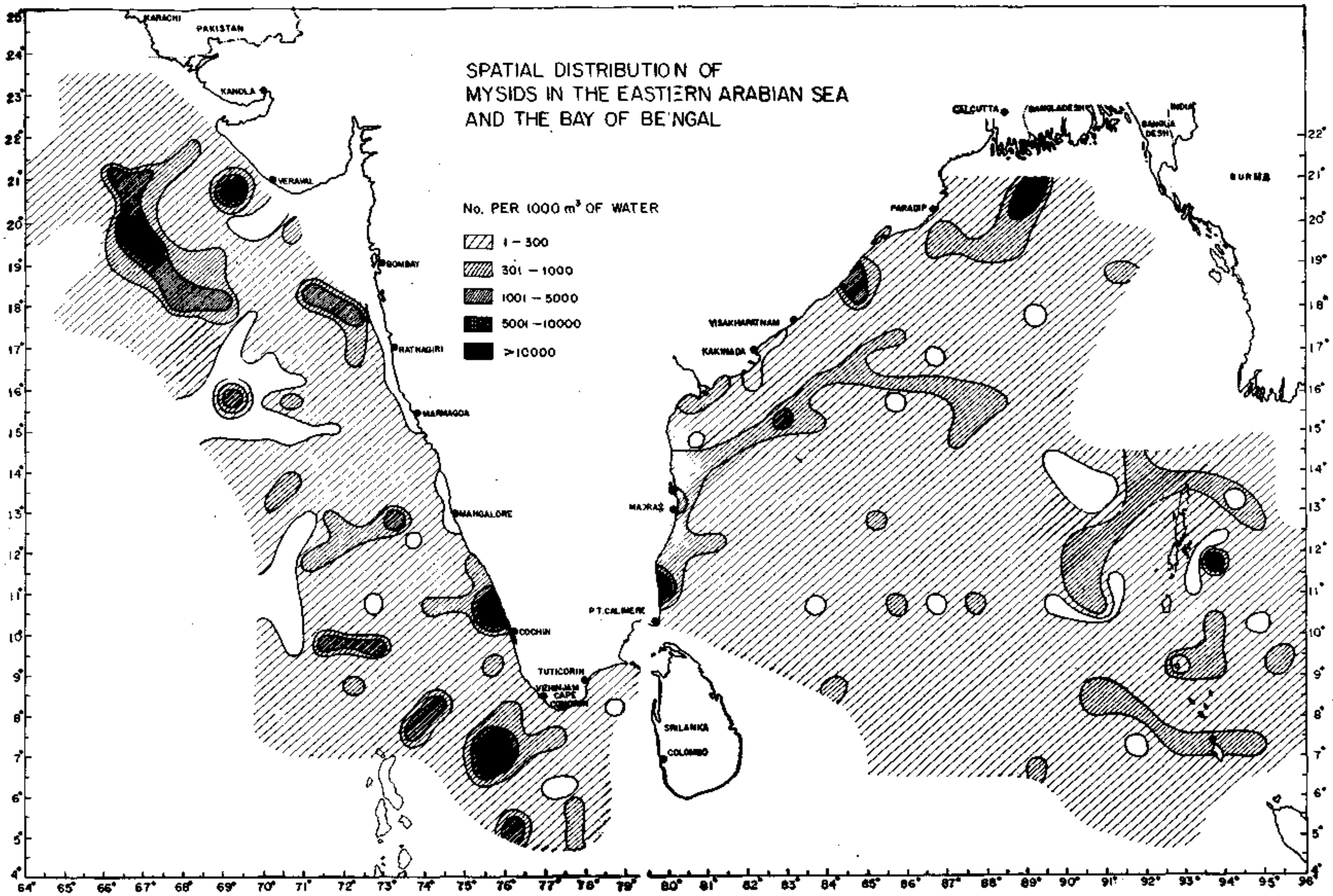

Fig. 1. Spatial distribution of Mysidacea in the EEZ of India and adjacent seas.

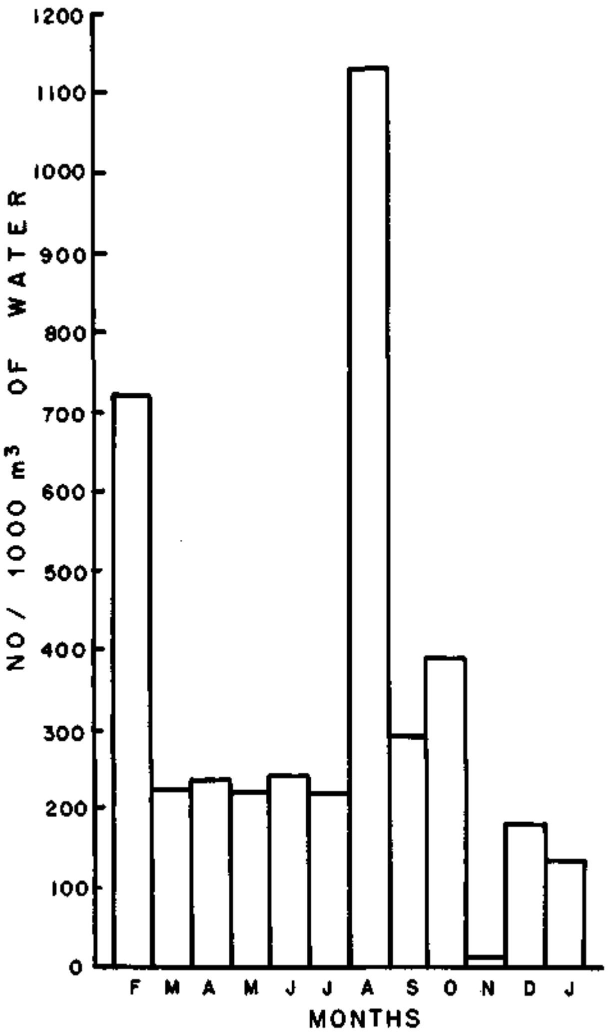

Fig. 2. Monthly abundance of Mysidacea in the area investigated.

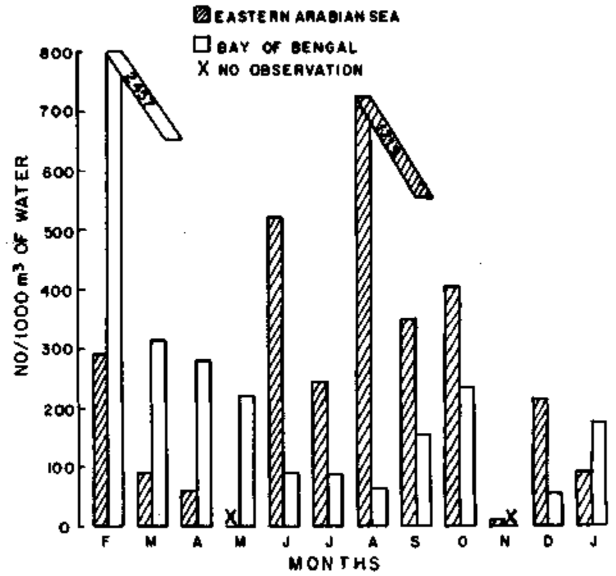

Fig. 3. Monthly abundance of Mysidacea in the eastern Arabian Sea and the Bay of Bengal.

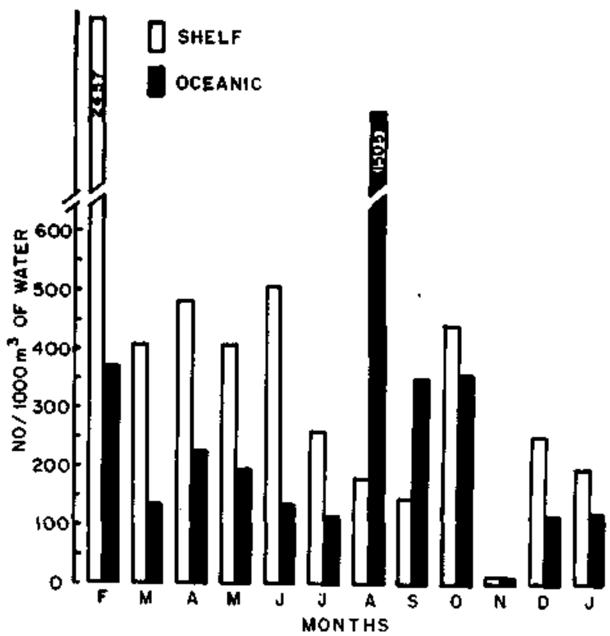

Fig. 4. Monthly abundance of Mysidacea in the shelf and oceanic waters.

43% of the total mysids taken in all the months was collected. Afterwards upto June the density of mysids in the shelf area remained around 8% and thereafter a gradual decline was observed and came down to the least value of 0.17% in November. On the contrary, the poulation outburst in the oceanic areas occurred in August with about 42%. In the subsequent two months the density was considerably reduced and the percentage contribution of the mysids was around 9. However, as in the case of shelf area, the month of least availability in the oceanic waters was November when only 0.22% was present.

Latitudinal abundance off the west and east coasts

Off the west coast, the first region which is the southernmost had the maximum quanitity of 43.14% of mysids, the 2nd and 3rd regions having about 10 and 18% only respectively. A slight improvement towards 28% was noticed in the 4th region. In the Bay of Begnal the southernmost region has the least of 14%. The other 3 regions had an almost equal portion of mysids being around 30% (Fig. 5).

A much more detailed analysis was made for understanding the microlevel distribution of mysids (Fig. 6). In regions I and II in the eastern Arabian Sea,

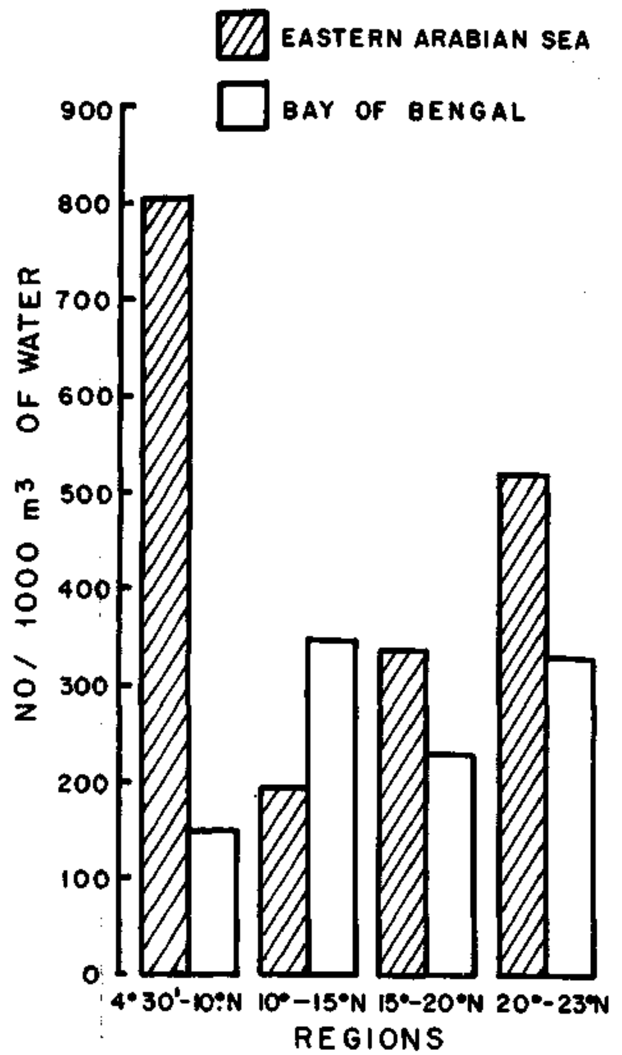

Fig. 5. Latitudinal abundance of Mysidacea in the eastern Arabian Sea and the Bay of Bengal.

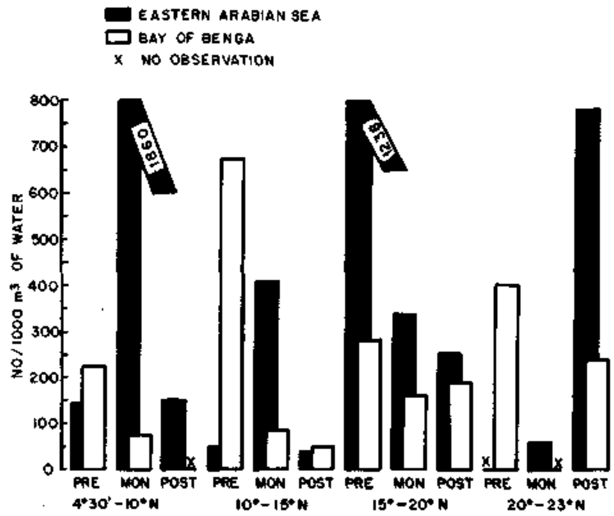

Fig. 6. Seasonal abundance of Mysidacea in the various latitudinal zones of the eastern Arabian Sea and the Bay of Bengal.

the monsoon season accounted for the maximum mysids which was 86 and 82% respectively of the total for the 3 seasons. The pre-monsoon and post-monsoon almost equally shared the rest of the population. In region III while the mysids dominated during the pre-monsoon with 68%, in region IV the post-monsoon had the maximum with 93%.

Contrary to the above finding, in the Bay of Bengal, the first two regions had a pre-monsoon dominance of mysids with 76 and 83% each. As in the eastern Arabian Sea, a pre-monsoon dominance was noticed in the 3rd region with 45% of mysids. Comparable data was not available for the 4th region.

Latitudinal seasonal distibution in the shelf and oceanic areas off the west and east coasts

A study of the seasonal abundance in the shelf and oceanic waters of the respective sea areas in the various latitudinal regions revealed the following facts (Fig. 7). In the first place it is to be mentioned that a consistent nature of variations between the shelf and oceanic waters was not noticeable during the various seasons, in that, while the shelf had the dominance of mysids in certain seasons, it was the oceanic area which accounted for the maximum in certain other seasons. Thus it could be seen that there was an unprecedented increase of the population of the order of 3,121 equal to 92% in the oceanic area of region-I in the eastern Arabian Sea during the monsoon. Another oceanic dominance to the extent of 1,769 per 1000 m^3 was noticed in the 3rd region, but it was during the monsoon season. The only instance when the shelf had a fairly large population was in the nothernmost region and the same was during the post-monsoon season.

In the Bay of Bengal the pre-monsoon season had a clear dominance of mysids in 2nd, 3rd and 4th regions with maximum of 2,349 individuals per 1000 m^3 of water in the 2nd regions (Fig. 7). During the other seasons mostly the oceanic areas of the various regions had relatively more mysids.

Day-night variations

Another study made on this group was on the diurnal variations in abudance. As in the case of

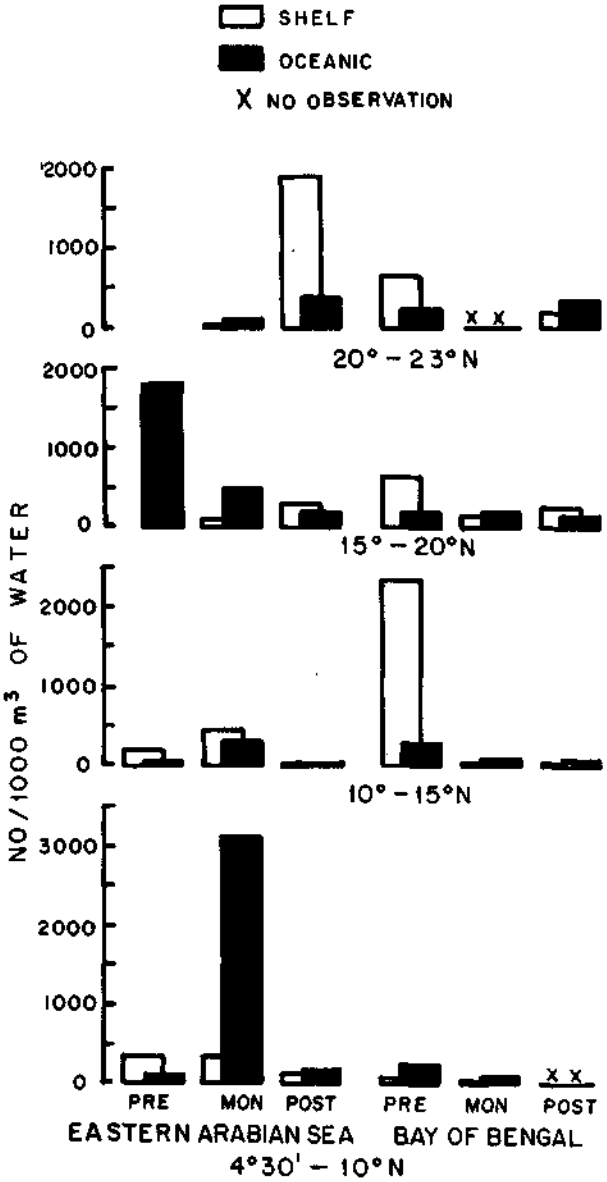

Fig. 7. Seasonal abundance of Mysidacea in the various latitudinal zones of the eastern Arabian Sea and the Bay of bengal.

other zooplankters, the mysids also showed considerable difference in the day and night samples. On the whole, while 62% of the total mysids was present in the night samples, only 38% was present in the day samples which indicates strong diurnal vertical migration.

The day-night abundance during different months revealed some significant results and the same are given in Fig. 8. The night samples accounted for around 90% of mysids during June and

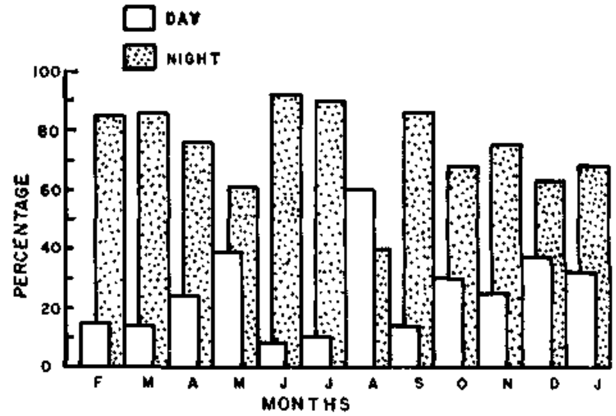

Fig. 8. Monthly day-night variations in the abundance of Mysidacea.

July. All other months except August had a night time abundance which came to the tune of 63 to 86%. Interestingly enough the August had a day time abundance which came to 60%.

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The authors are thankful to Dr. P.S.B.R. James, Director, Central Marine Fisheries Research Institute for his keen interest in this work and to Dr. K.S.Scariah and Shri. P.P. Pavithran for the help received in the computer analysis of the data.

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PRELIMINARY STUDIES ON PLANKTONIC AMPHIPODS COLLECTED BY FORV *SAGAR SAMPADA*

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Abstract

Studies on the occurrence of amphipods of the EEZ of India and adjoining seas were carried out. The samples which were used for this purpose were collected by Bongo-60 net during the cruises 1-44 of the FORV *Sagar Sampada* (1985-1988). It was found that while amphipods at an average rate of 2,278/1000m³ occured in the shelf waters off the west coast, only 1,501/1000m³ occurred in the same area off the east coast. On the other hand in the oceanic region the numerical abundance was relatively low being 1,014/1000m³ off the west coast and 925/1000m³ off the east coast indicating that the amphipods were abundant in the shelf waters of the west coast than other regions. The overall average density for the area investigated showed 1,291/1000m³. Regarding the day-night abundance of amphipods in the area investigated, there was not much of variation. The coastwise study of day-night abundance revealed that night collections were more in the eastern Arabian Sea and certain regions of the Bay of Bengal. The seasonwise study showed always maximum during pre-monsoon except the first region off east coast but there was no regular pattern in the eastern Arabian Sea. A regionwise abundance in the various latitudinal sectors was also noticed. The northern region above 20°N off west coast i. e. 4th region, contributed more amphipods than the other latitudinal regions off the west and east coasts.

Introduction

The planktonic amphipods, comprised mostly of Hyperiidea are generally oceanic although some species occur in coastal waters. Many of them are holoplanktonic enjoying a global distribution (Pillai, 1986). The amphipods form an important food for many fishes and invertebrates (Nair, 1972). The distribution of amphipods in the Indian Ocean was studied earlier by some workers (Jossi, 1972; Nair *et al.*, 1973). Nair *et al.* (1973) noted that Somali and Arabian coasts had average to good density comparable to that of the Bay of Bengal where high concentration was noted towards northern part of the Bay and highest concentration in the northern part of the Arabian Sea. In the present paper an attempt is made to study the spatial, latitudinal and seasonal distribution, and day-night variations of amphipods for a period from 1985 to '88 in the EEZ and adjoining seas of India.

Materials and Methods

The material and methods have been given in the paper dealing with zooplankton biomass by Mathew *et al.* (1990) in the present volume.

Observations

Numerical abundance of amphipods

Numerical differences in shelf and oceanic areas were evident in both the coasts. An average of 2,278 amphipods per 1000 m³ was present in the shelf areas of the west coast whereas 1,014/1000 m³ was seen in the oceanic areas of the same coast. Similar observation was made for the east coast where the amphipods averaged 1,501 in the shelf area and 925 in the oceanic areas.

The overall average density for the area investigated showed 1,291/1000 m³. Average density of amphipods in the shelf area of both the coasts was 2,000/1000 m³ of water and in the oceanic area an average of 976 was recorded (Fig. 1). Average day time abundance in the area investigated was 1,274 and that of night was 1,317. Highest percentage of day time abundance was seen during the months of February, July and August. The night time abundance was more during April, June, September and October (Fig. 2).

Seasonal difference in the density distribution of amphipods existed in both the coasts. Apparently more amphipods (2,740-2,012) were caught during cruises made in August and September in the west coast than in the east coast. In the east coast maximum was recorded in the month of February with 5,611.

Spatial distribution (Fig. 3)

The distribution of amphipods off west and east coasts showed numerically very high concen-

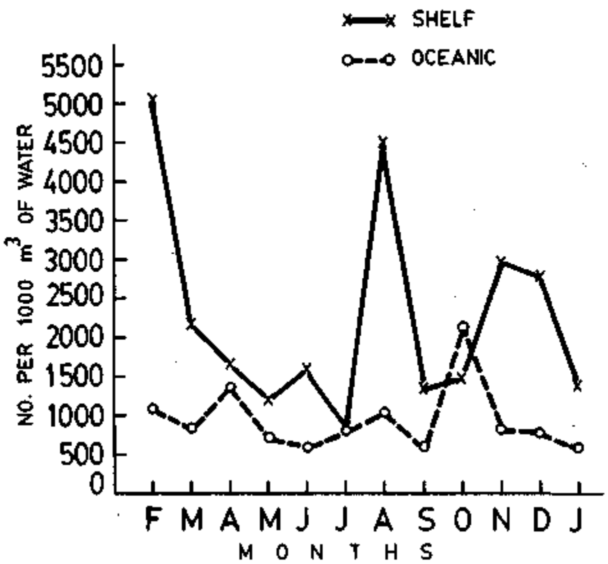

Fig. 1. Distibution of amphipods in the shelf and oceanic areas investigated.

traion in specific locations. A population density of 5,000 specimens per 1000 m³ of water and above has been recorded off Kandla, between off Bombay and off Kandla, Mangalore and Wadge Bank area of south of peninsular India, and off Paradip, Madras, Gulf of Mannar off east coast and Andaman and Nicobar Islands.

The density distribution in the range of 2,001-5,000 has been recorded along the southwest coast of India, off Ratnagiri and northern part of the eastern Arabian Sea. Similar density distribution in the east coast was recorded off Madras, off Paradip between

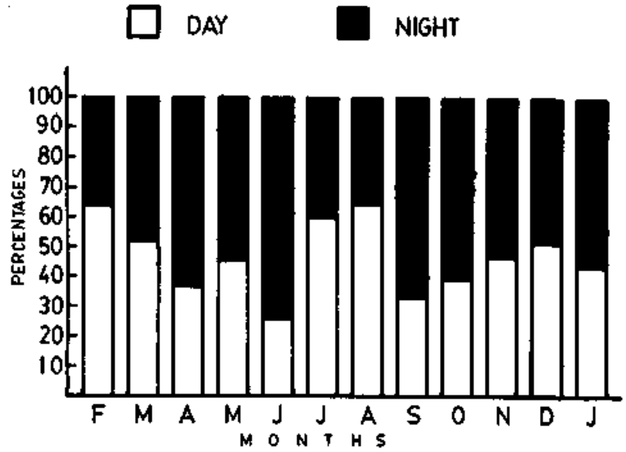

Fig. 2. Day and night variations of amphipods in the area investigated.

Visakhapatnam and Kakinada and near Andaman and Nicobar Islands.

A still lower density ranging between 1,001-2,000 and between 501—1,000 has been represented uniformly off the west and east coasts.

The lowest density distribution of amphipods in the range of 1-500 has been recorded more frequently off east coast than off west coast.

Coastwise, regionwise density distribution (Fig. 4)

For the sake of convenience of study, both the coasts were divided into 4 latitudinal regions as region 1 (5°N-10°N), region 2 (10°N-15°N), region 3 (15°N-20°N) and region 4 (above 20°N).

Off the west coast, the region 4 showed a maximum of 3,098/1000 m³ followed by the region 1 with 1781, region 2 with 1,128 and region 3 with 990/1000 m³ of water.

Off the east coast, the region above 20°N i.e., 4th region showed a maximum density distribution of 1,202 followed by region 2 with 1,101 and regions 1 and 3 with 1,092 and 1,023 of amphipods per 100 m³ of water respectively.

Coastwise, regionwise, shelf & oceanic distribution (Fig. 5)

The density maximum of amphipods for shelf region off west coast between 5°N-10°N (region 1) was at the magnitude of 3,739 followed by the region 4 with 2,429, region 3 with 2,004 and region 2 with 1,250/1000 m³ showed the least.

The oceanic region off west coast showed population density of amphipods with a maximum of 3,372/1000 m³ in the region four, 834 in the region one, 682 in the 2nd region and 853 in the 3rd region.

The shelf region off east coast showed a maximum density of 1,996 in the region between 5°N-10°N (1st region) followed by 1,773, 1,169 & 1,252 of amphipods in the 2nd, 3rd & 4th regions respectively.

The oceanic region off east coast on the other hand showed a density of 1,139/1000 m³ in the region above 20°N (4th region) followed by 9,64, 899 and 872 per 1000 m³ in the 3rd, 2nd and Ist regions respectively.

Coastwise, regionwise seasonal abundance (Fig.6)

Various regions off west coast showed the population density distribution of amphipods in the

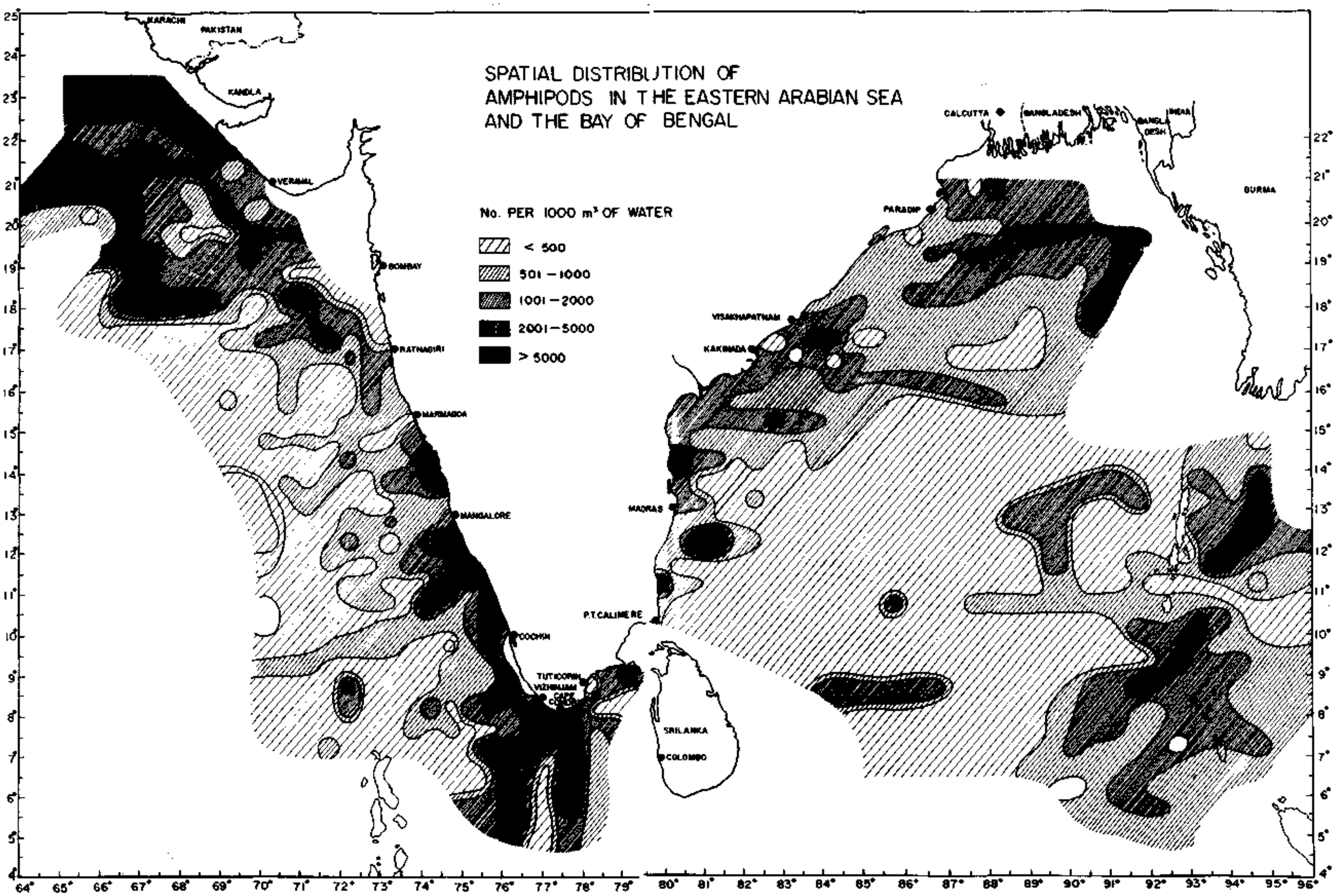

Fig. 3. Spatial distribution of amphipods.

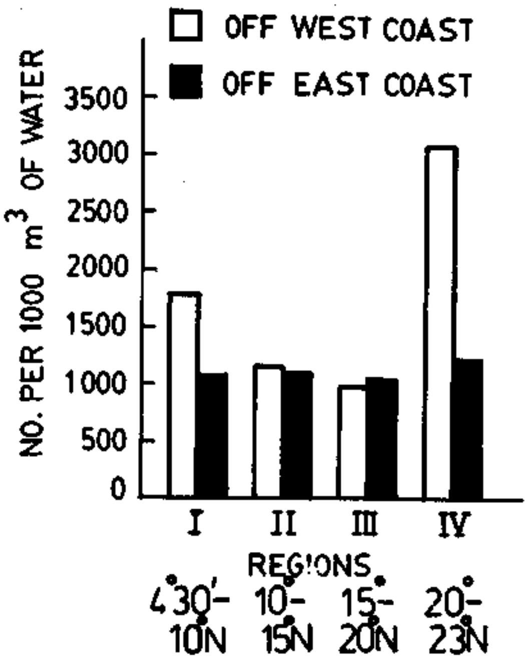

Fig. 4. Coastwise, regionwise density distribution of amphipods.

following manner during premonsoon, monsoon and postmonsoon seasons. The 1st region between 5°N-10°N had a density at the rate of 483/1000m³, 3,155/1000m³, and 1,240/1000m³ during premonsoon, monsoon and post monsoon seasons. The respective figures for the 2nd, 3rd and 4th regions were 470, 1,167 & 1,364; 2,413, 619 & 1,124 and 2,857 1,590 & 3, 542 during the above said seasons in order.

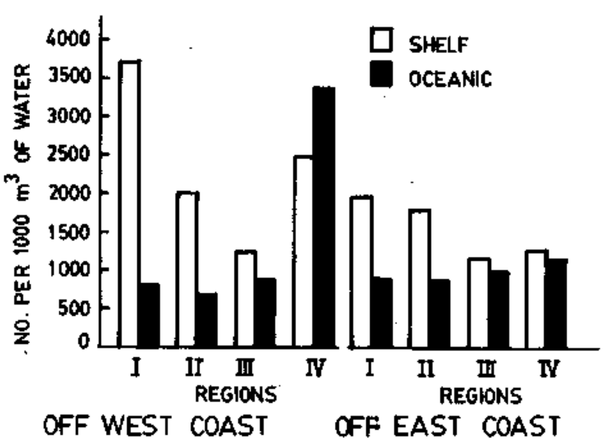

Fig. 5. Coastwise, regionwise shelf and oceanic distribution of amphipods.

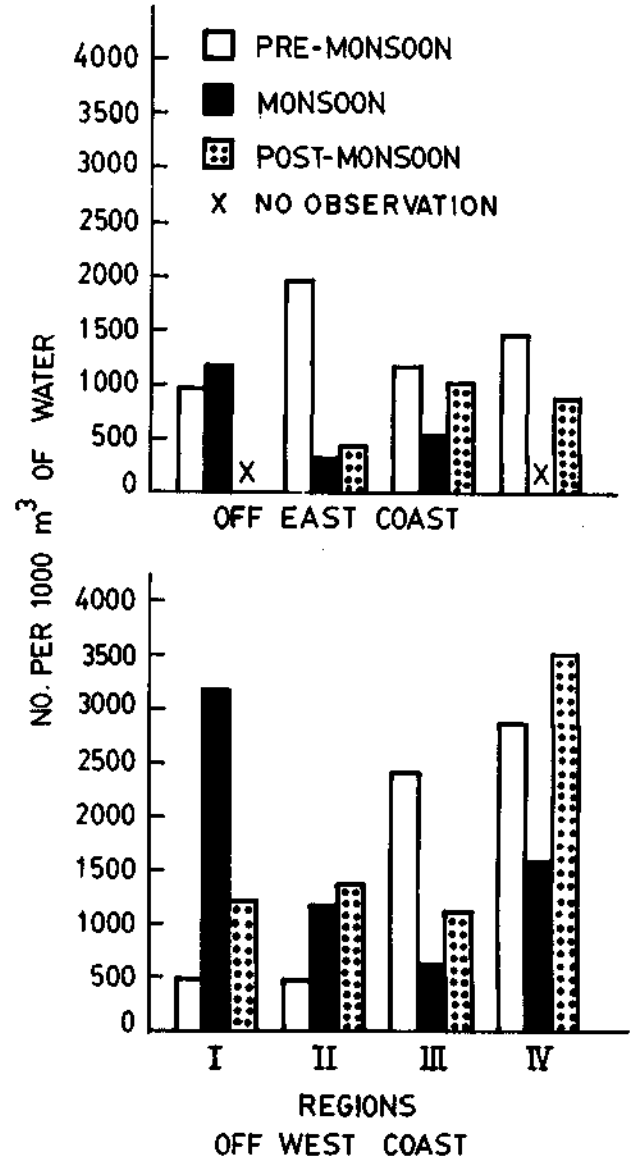

Fig. 6. Coastwise, regiowise seasonal abundance of amphipods.

The different regions off east coast had a density of amphipods at the rate of 988 & 1,198 during premonsoon and monsoon in region 1; 1,986, 330 and 440 amphipods per 1000 m³ during premonsoon, monsoon and postmonsoon in region 2; 1,169, 534 and 1,043 during premonsoon, monsoon and postmonsoon in region 3 and 1,457, 882 during premonsoon and postmonsoon seasons in region 4.

Coastwise, regionwise, day and night abundance (Fig. 7)

The collection during day off the west coast showed a density distribution maximum of amphipods in the region above 20°N i.e., 4th region with 2,901. The amphipods in region 3 was least with 746. In 2nd and 1st regions it showed 1,047 and 1,932 of amphipods per 1000 m³ respectively.

The density maximum for night collection was recorded in region 4 with 3,470 of amphipods. The regions 1,2 & 3 showed the numbers 1,451, 1,223 and 1,334 respectively.

The collection during day off east coast showed a maximum of 1,215 in the region 1, and 1,123, 935 & 1,127 were noted in region 2, 3 & 4 respectively.

The night collections off east coast showed a maximum of 1,379 in the 4th region. The regions 1, 2 & 3 showed 890, 1,067 and 1,157 amhipods per 1000 m³ of water respectively.

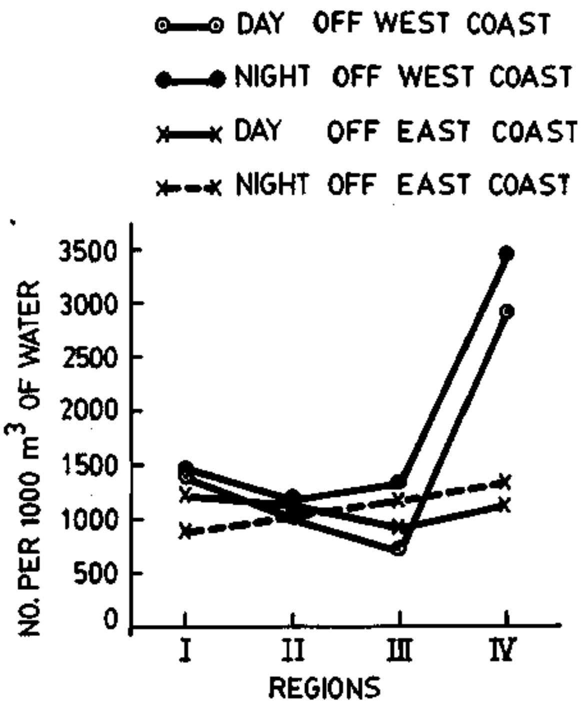

Fig. 7. Coastwise, regionwise day and night abundance of amphipods.

Discussion

The study during the period of 1985-'88 revealed that the northern part of the eastern Arabian Sea with 44% had the maximum concentraion of amphipods. Similar was the situation in the Bay of Bengal. Among the coasts, about 57% of amphipods was contributed by the west coast. Similar observations were made by Nair *et al.* (1973,. The present observations showed that the central part of the eastern Arabian Sea had the least abundance of amphipods. A comparison of the shelf and oceanic areas revealed that amphipods had a numerical abundance in the shelf areas than in the oceanic areas. There was no regular pattern of distribution of amphipods during various seasons in the eastern Arabian Sea but in the Bay of Bengal except in the southernmost part, all other regions showed a maximum during the premonsoon season. Regarding day-night abundance, night collections showed more off the west coast and in certain regions in the Bay of Bengal.

Acknowledgement

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DISTRIBUTION OF EUPHAUSIACEA IN SPACE AND TIME IN THE INDIAN EEZ AND CONTIGUOUS SEAS

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Abstract

The Euphausiacea collected from 1,086 stations during the cruises 1-44 of FORV *Sagar Sampada* in the eastern Arabian Sea and the Bay of Bengal from 1985-'88 were studied for their spatial, seasonal and day and night abundance. The average density of euphausiids in the entire area investigated was estimated to be 3,214 per 1000 m³ of water. With regard to spatial distribution, areas of maximum density of over 20,000 per 1000 m³ were observed in the shelf areas off Cochin and the far oceanic areas off Gujarat, off and south of Marmagoa, off Cochin and off Cape Comorin. In the Bay of Bengal, high population density was observed around Nicobar Islands and east of Andamans. On the whole more euphausiids were present in the eastern Arabian Sea (3,680/1000 m³) than in the Bay of Bengal (2,517/1000 m³). Separate estimates made for the entire continenetal shelf and the oceanic areas showed that while the shelf had a density of 4,824 euphausiids, the oceanic area had a concentration of only 2,507 per 1000 m³ of water. The observed percentage of increase for the eastern Arabian Sea over the Bay of Bengal worked out to 92.42. When an attempt was made to understand the seasonal variation, it was found that off the west coast, more number of euphausiids was present (the rate being 5,272/1000 m³) during the southwest monsoon season. Least abundance of 2,505 was noticed during the premonsoon season. The postmonsoon abundance was estimated to be 2,776. The number of individuals obtained off the east coast during the three seasons was of low magnitude than off the west coast. Off the east coast while 2,437 euphausiids per 1000 m³ were present during the premonsoon, the number collected during the monsoon and postmonsoon seasons were 3,384 and 1,434 respectively. The day time abundance of euphausiids in the upper 150 m of water column was at a rate of 2,282 while the same during the night was 4,651, thus indicating 103.81% of increase in the night samples. As far as the latitudinal abundance of euphausiids was concenrned, it was found that the region above 20°N was the most productive in both the eastern Arabian Sea and the Bay of Bengal. Further microlevel analysis of distribution in the various latitudes during different seasons were carried out for the shelf and oceanic areas separately for the two sea areas and the results obtained are also presented in the paper.

Introduction

The euphausiids form an important constitutent of the zooplankton in the epipelagic, mesopelagic and bathypelagic zones of the marine environement. By virtue of their great importance in the marine food chains, considerable attention has been paid to the study of this group of planktonic crustaceans. Being larger in size than many of the zooplankton organisms, sometimes their biomass may surpass any other single groups in the plankton. A good amount of work on taxonomy, distribution, ecology and biology of euphausiids has been carried out the world over. But the euphausiid fauna of the Indian Ocean, especially that of the Indian seas is less investigated. Although several expeditions which visited Indian Ocean have made studies on euphausiids, all except the 'Discovery' (1932, 1937, 1950-'51) and the IIOE (1959-'65) did only faunistic surverys. However, the 'Discovery' reports did not pertain to the Indian seas.

The first major work on the euphausiids of the Indian Ocean in general was by Gopalakrishnan and Brinton (1969) based on IIOE data. They dealt with the quantitative geographical distribution and seasonal abundance of total euphausiids. However, the inadequacy of samples was a great constraint of this study. Weighmann (1970) dealt with the euphausiids of the Arabian Sea during the northeast monsoon. Ponomareva (1972) also studied the quantitative distribution of total equpausiids of the Indian Ocean. In 1973 Brinton and Gopalakrishnan made a study on the quantitative distribution of euphausiids of the Indian Ocean based on IIOE material.

Ponomareva (1975) carried out investigations on the vertical and quantitative distribution of Indian Ocean euphausiids based on 2,390 plankton samples. Mathew (1980, 1985) studied the quantitative spatial abundance and ecology of euphausiids in general and of various species of the southwest coast of India. All the above studies point to the fact that they were either highly generalised spatially with inadequate samples or restricted to certain areas so that realistic informaion could not be obtained over a fairly wider area. So far there is no single study on euphausiids of the EEZ of India based on intensive sampling. The present study is expected to give a comprehensive idea about various aspects of euphausiid distribution in the EEZ and contiguous seas. A total of 1,087 zooplankton samples have been analysed for this purpose which is the largest number ever used for such a study in the area concerned. The material and methods, the area covered and the frequency of sampling for this study have been dealt with in detail in another paper by Mathew *et al.* (1990) which deals with the zooplankton biomass elsewhere in this volume. For all consideration the number of euphasiids (total) per 1000 m^3 of water has been made use of.

Results and Discussion

Total euphausiid biomass

First of all it was let to understand the average biomass of euphausiids, numerically, in the entire area of investigation and the same has been estimated to be 3,214 individuals per 1000 m^3 of water. This is a remarkable figure and is comparable to what is present in any other sea area in the world except the Antarctic waters where the Krill occurs in huge quanitities or in the north Pacific where *E. pacifica* occurs in very large numbers. When a further estimte was made for the eastern Arabian Sea and the Bay of Bengal separately, it was found that 3,680 euphausiids per 1000 m^3 of water were present in the former sea area while the latter claimed only 2,517. This clearly indicates the fertility and richness of the eastern Arabian Sea. Mathew (1980) who studied the density of euphausiids in the shelf waters of the southwest coast of India obtained an average of 1,981 individuals only per 1000 m^3 of water for the area. The reason for the significant difference between the two estimates is the oceanic nature of the euphausiids which could not be collected in good quantities from a number of shallow water stations covered in the study of Mathew (1980). Separate estimates made for the entire continental shelf and the oceanic areas showed that while the shelf had a density of 4,824 euphausiids, the oceanic area had a concentration of only 2,507 per 1000 m^3 of water. The average euphausiid abundance in the shelf and oceanic waters of both the coasts when worked out separately was found that the shelf of the west coast had 5,326 individuals while the corresponding area of the east coast had a density of 4,821 only. While the oceanic area of the west coast accounted for 2,907 individuals, that of the east coast had only 2,449 individuals per 1000 m^3 of water.

Distribution in space

As seen from Fig. 1, the euphausiids have a large population in the eastern Arabian Sea and the Bay of Bengal. Of the two sea areas, the former is rich in euphausiids with number of euphausiids exceeding 20,000 per 1000 m^3 of water in certain areas. Areas of maximum density were observed in the shelf areas off Cochin, and the far oceanic areas off the coast of Gujarat, off and south of Marmagoa, off Cochin and off Cape Comorin. In the Bay of Bengal, high population density was observed around Nicobar Islands and east of Andamans. In most part of oceanic areas of the Bay of Bengal, the population density ranged between 1 and 5,000. High density patches above 10,000 per 1000 m^3 of water were found to occur here and there in the shelf as well as oceanic areas Fig. 1.

Monthly variations in abundance

A great deal of variations in the monthly occurrence were observed (Fig. 2). High abundance was noticed during the August-November period, with the maximum density of 6,843 individuals during September. This four month period accounted for 50% of the total euphausiids caught. The period of maximum abundance which could be the active breeding period coincides with the latter half of the southwest monsoon and former half of the postmonsoon period. The January-February peiod accounted for the least abundance when the density of occurrece was around 1,600 only.

The whole data when consolidated into three seasons i.e., premonsoon, monsoon and postmonsoon, it was found that in general the monsoon season with 46% of euphausiids was the most productive, the premonsoon and postmonsoon sharing almost the same quantity equal to around 27%. (The classification is based on the southwest monsoon which is the major monsoon affecting both the Arabian Sea and the Bay of Bengal).

When the seasonal abundance was considered for the two sea areas separately, it was found that off the west coast more numbers of euphausiids were present (the rate being 5,272/1000 m^3) during the southwest monsoon. The postmonsoon abun-

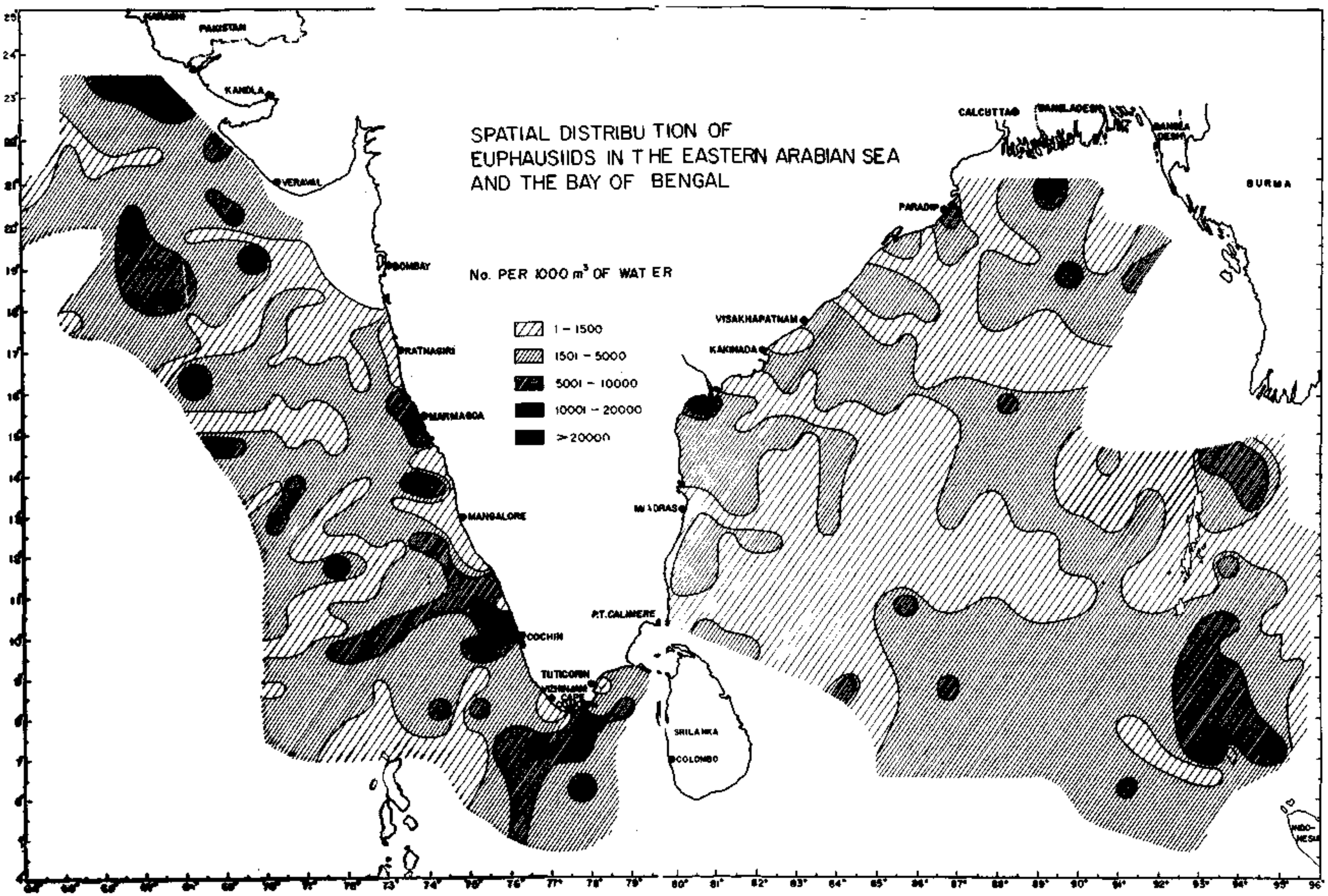

Fig. 1. Spatial distribution of Euphausiacea in the EEZ of India and adjacent seas.

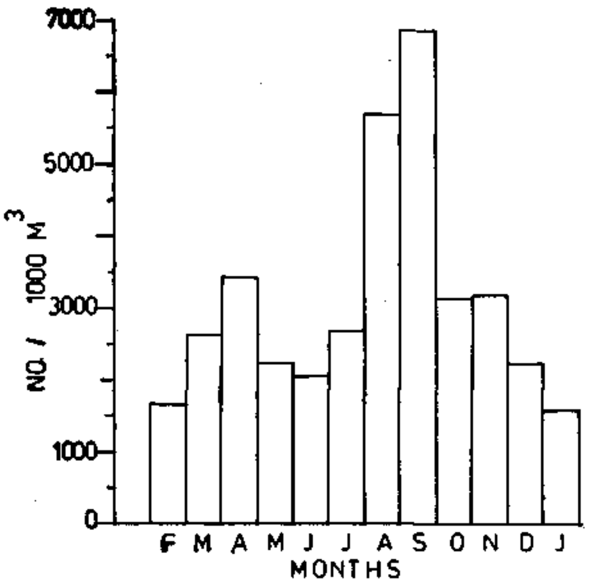

Fig. 2. Monthly abundance of Euphausiacea in the area investigated.

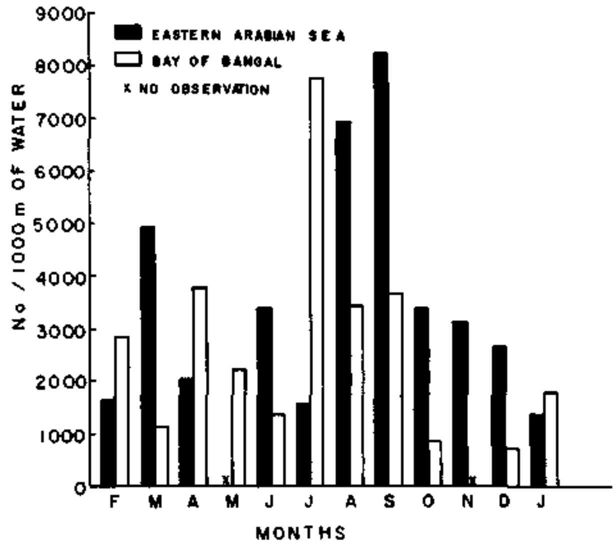

Fig. 3. Monthly abundance of Euphausiacea in the eastern Arabian Sean and the Bay of Bengal.

dance was estimated to be 2,776. The least abundance of 2,505 was noticed during the premonsoon season. The seasonal trend was almost the same in Bay of Bengal. However, the number of individuals obtained off the east coast during the three seasons was of low magnitude than off the west coast. Off the east coast while 2,437 euphausiids per 1000 m^3 were present during the premonsoon, the numbers collected during the monsoon and postmonsoon seasons were 3,384 and 1,434 respectively.

Monthly distribution off the west and east coasts

Fig. 3 shows the monthly abundance of euphausiids in the eastern Arabian Sea and the Bay of Bengal separately. Generally speaking the density was maximum during the August-September months in the eastern Arabian Sea. October also contributed some sizable quantity from whence it was a gradual reduction upto February. March-June period exhibited large fluctuations in population size.

In the Bay of Bengal, July accounted for the maximum abundance while August and September had moderate quantities. The months from October-November contributed the least. As in the case of the eastern Arabian Sea, the period from February to June experienced great fluctuations in population.

Monthly distribution in shelf and oceanic areas

The shelf area accounted for the maximum number of euphausiids. The average density in the shelf area was found to be 4,824 per 1000 m^3 of water whereas it was only 2,507 in the oceanic water, the rate of decrease being 92%. The trend in abundance in the shelf and oceanic areas during different months was almost the same as is seen in Fig. 4. The increase or decrease in each month reflected almost the same way in the shelf and oceanic waters.

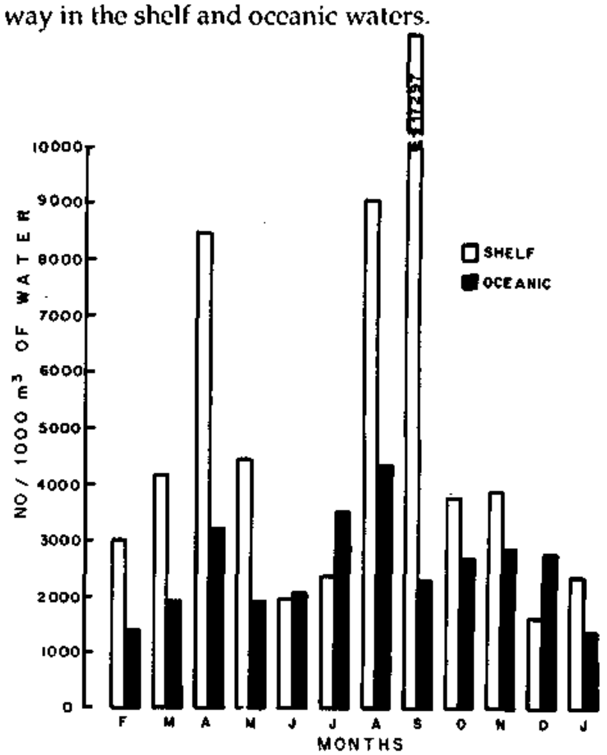

Fig. 4. Monthly abundance of Euphausiacea in the shelf and oceanic waters.

Coast-wise, latitudinal distribution

Another study made was the latitudinal abundance in the two sea areas separately (The way in which four latitudinal regions are identified is given in another paper by Mathew *et al.* (1990) which deals with zooplankton biomass in this volume). In the eastern Arabian Sea (Fig. 5) the 2nd and 4th regions yielded the maximum quantity of euphausiids whereas in the Bay of Bengal the Ist and 4th regions contributed the maximum. Thus the 4th region (the northern most region) in the two sea areas proved to be the best sea area for the euphausiids.

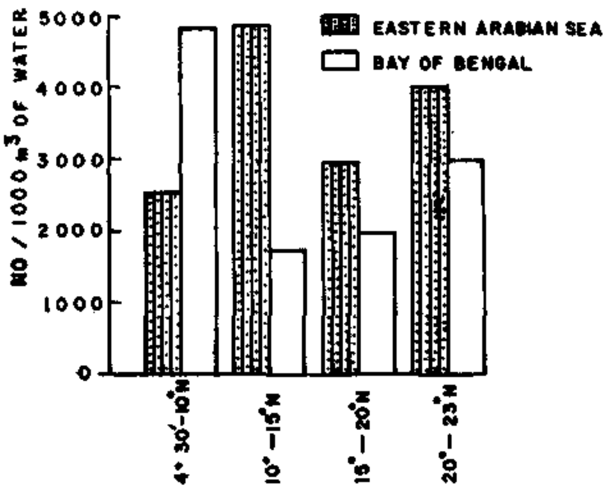

Fig. 5. Latitudinal abundance of Euphausiacea in the variouslatuitudinal regions of the eastern Arabian Sea and the Bay of Bengal.

Coast-wise, region-wise seasonal distribution

Further it was sought to understand the region wise seasonal variations in distribution in the eastern Arabian Sea and Bay of Bengal separately (Fig. 6). Off the west coast in regions I and II, the southwest monsoon accounted for the maximum abundance, being 51 and 68% respectively of the total (values standardised to 1000 m³ of water) of 3 seasons. This was followed by the postmonsoon and premonsoon. In the 3rd and 4th regions of this sea area, premonsoon sharing 58 and 49% respectively happened to be the most favourable period. The monsoon and postmonsoon seasons each contributed only 21 - 33% of euphausiids only.

In the Bay of Bengal there was no comparable data for all the seasons in the first and fourth regions. In the second region, unlike off the west coast, the premonsoon was rich in euphausiids (50% of the 3

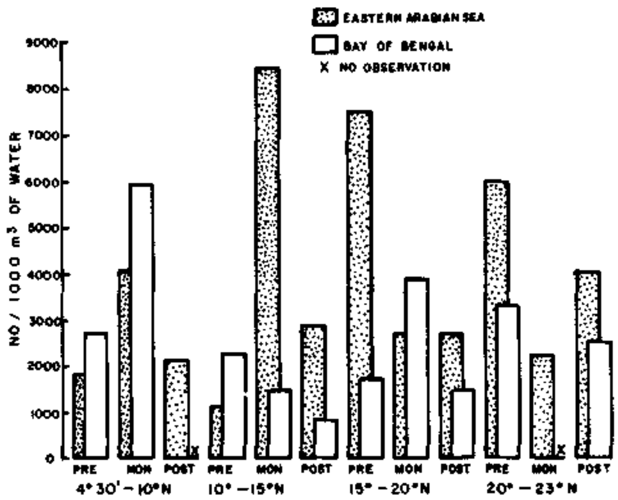

Fig. 6. Seasonal abundance of Euphausiacea in the valous latitudinal regions of the eastern Arabian Sea and the Bay of Bengal.

seasons) followed by monsoon and postmonsoon with 32 and 18% respectively. In the third region, the monsoon season with about 55% of euphausiids stood first. The premonsoon and postmonsoon with little more than 20% was almost equally rich.

Coast-wise, shelf and oceanic, region-wise seasonal distribution

Fig. 7 presents the region-wise seasonal abundance in the two sea areas in the shelf and oceanic waters. In the eastern Arabian Sea, the 1st region generally contributed less euphausiids. There was not much of a difference between the shelf and oceanic areas in this region with euphausiid numbers falling around 4,000 per 1000 m³ of water. In both shelf and oceanic areas in this region, the abundance was during monsoon when 64% was the rule in the oceanic area and 49% in the shelf.

In the Bay of Bengal the shelf water with 61% of euphausiids during premonsoon proved to be the best. In the oceanic water also the euphausiids were comparatively more during the premonsoon but the overall quantity was less than in the shelf area.

Unlike in the first two regions, off the west coast, the euphusiids abundance in the shelf and oceanic area of the 3rd region was during the premonsoon. While 76% of the total euphausiids (based on standardised values) of the 3 seasons occurred during the premonsoon in the shelf waters, only 43% occurred in the oceanic waters during the same season.

In the Bay of Bengal also the southwest monsoon period accounted for the maximum euphausiids in both shelf and oceanic areas. However, there was great difference in the abundance, being of the order of 68% in the shelf and 47% in the oceanic area.

In the 4th region the magnitude of difference in euphausiid population between seasons in the shelf as well as oceanic areas was less. While premonsoon had a density of the order of 53% in the shelf area, the oceanic waters had it at 38.76% only.

With monsoon data absent, the shelf waters in the 4th region of Bay of Bengal accounted for more euphausiids during the premonsoon (80%) while in the oceanic waters the postmonsoon claimed the maximum (75%).

An analysis of the above results clearly indicates that irrespective of the seasons, maximum fluctuations in the population density is found in the shelf area where the environmental conditions vary drastically according to seasons than in the oceanic area where the same conditions do not fluctuate considerably. Another interesting fact revealed was that in the eastern Arabian Sea the euphausiids migrated southwards as season advanced from premonsoon to southwest monsoon. There was no such migration indicated in the Bay of Bengal.

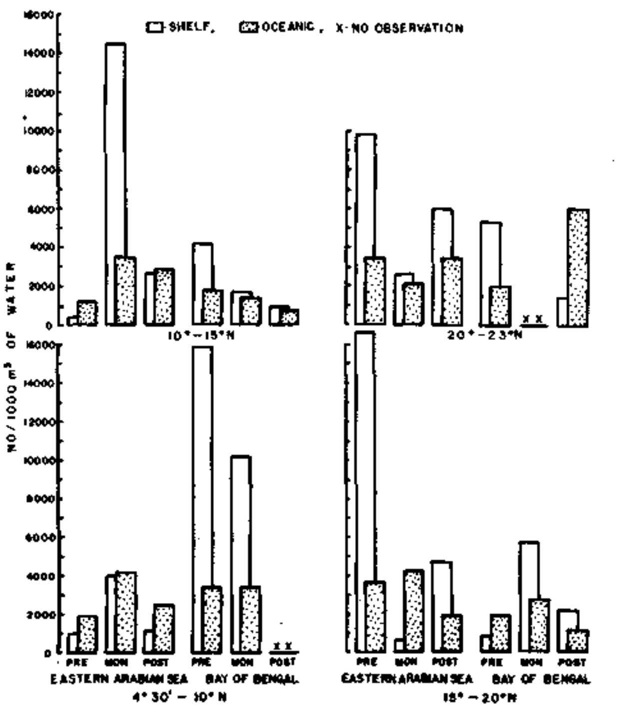

Fig. 7. Seasonal abundance of Euphausiacea in the shelf and oceanic waters in the different latitudinal regions of the eastern Arabian Sea and the Bay of Bengal.

Day - night abundance

As in the case of other diurnally vertically migrating zooplankton, there was a pronounced day-night difference in the abundance of euphausiids also and the results of the study emerged are presented in Fig. 8. A more than cent per cent increase in abundance was noticed in the night samples. While the rate of occurrence was 2,284 per 1000 m^3 of water in the day samples, the same in the night samples was 4,651. A monthwise consideration for the day-night abundance showed that in almost all the months, more than 60% of euphausiids were found in the night samples. The maximum night abundance was noticed in September when the thermocline remains far down. In July when the thermocline used to be in the upper layers of the water column, more euphausiids were taken during the day time, suggesting that the euphausiids were reluctant enough to swim up or down in the water column penetrating the strong thermocline. In June also the night time abundance was not that much pronounced.

In summing up it may be stated that the euphausiids form a major portion of the plankton in the eastern Arabian Sea and the Bay of Bengal. They are more abundant in the former sea area. Seasonally, the monsoon proved to be the best season followed by postmonsoon and then premonsoon and this throws some light on their breeding season. This finding is in agreement with the results made earlier on this planktonic group in the shelf water along the

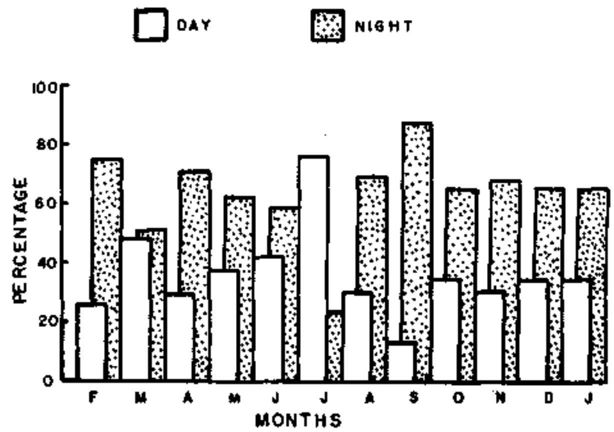

Fig. 8. Monthly day-night variations in the abundance of Euphausiacea.

southwest coast (Mathew, 1980). Considerable differences in abundance were noticed between shelf and oceanic areas with dramatic fluctuations in the shelf waters. And finally, large scale abundance was found in the night samples especially after the southwest monsoon period.

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STUDIES ON THE DISTRIBUTION AND ABUNDANCE OF THE GENUS *LUCIFER* COLLECTED DURING THE CRUISES OF FORV *SAGAR SAMPDA*

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Abstract

Distribution and numercial abundance of the genus *Lucifer* in the eastern Arabian Sea and the Bay of Bengal between 4° 30'N and 23° N latitudes are discussed based on 1086 zooplankton collections from 44 cruises of FORV *Sagar Sampada.* Lucifers were present in 99% of the samples, forming a major component of the planktonic decapods with an abundance of 2,499 per 1000 m^3 of water for the entire region. The average abundance of lucifers was 2,591(number per 1000m^3 of water) for the Arabian Sea and 2,361 for the Bay of Bengal. The density in the shelf area (5,105) was higher than that in the oceanic waters (1,357). The concentration of lucifers observed in the region between 4° 30 'N to 10° N was the highest for the entire region of study; 3,996 for the Arabian Sea and 3,503 for the Bay of Bengal. The number in the shelf area of the Bay of Bengal was the highest (6,461) followed by that recorded in the eastern Arabian Sea (4,382). Their abundance in the oceanic regions was 892 and 1,700 respectively. The highest concentration half-degree wise was observed in the shelf region off Andhra coast (58,524). The numerical abundance of lucifers was almost 64% of the total during the monsoon season. However, their abundance was more during the premonsoon season in the Arabian Sea beyond 15° N latitude. The density of lucifers collected during night time was only marginally higher than that in the day time in the eastern Arabian Sea and the Bay of Bengal but considerably high in the shelf region at night during the premonsoon season.

Introduction

The species of the genus *Lucifer* (Macrura, Penaeidea, Sergestidae) are warm water epiplanktonic shrimps restricted to Atlantic, Indo-West Pacific and Eastern Tropical Pacific oceans. Of the seven recognized species in the genus *Lucifer,* five are found widespread in the coastal waters of India (Omori, 1977).

Extensive literature available on the seasonal occurrence of *Lucifer* spp. are from the nearshore waters and estuaries of India. Quantitative studies on *Lucifer* spp. encompassing large areas of the Indian waters have been attempted recently from the cruises of RV *Gaveshini.* Works of Paulinose *et al*. (1987) in the Arabian Sea, Nair *et al.* (1981) and Paulinose *et al.* (1988) in the Bay of Bengal and Madhupratap *et al.* (1981) in the Andaman Sea have wider coverage. However, there is a lacuna in the knowledge of the seasonal distribution and abundance of this genus in the seas around India, particularly the oceanic areas of the Indian subcontinent.

The role of *Lucifer* spp. in the zooplankton community is considerable as they play a significant role in the food web of the warm neritic waters, often becoming a major component in the diets of shore fishes and large shrimps (Omori, 1974). The spatial and seasonal distribution of *Lucifer* spp. has great relevance to the fisheries of the region since they have been shown as a good indicator of the presence of a core pelagic fishing ground (Huang, 1987).

Materials and Methods

The studies were based on 1086 plankton samples collected since January 1985 to March 1988 in the area within 4°30'N, to 23°N lat. and 75°E to 95°E long. by oblique tows from 150 m to surface using a Bongo - 60 net (mesh aperture 0.33 mm), equipped with a calibrated flow meter. The average No. / 1000 m^3 per half a degree square pooled for 1985 - '88 was taken as the index of abundace wih reference to area and time.

The faunal content of the eastern Arabian Sea (65° to 77°30'E long.) is compared with that of the Bay of Bengal (77° 30' to 95°E long.). Latutudinal variations of the fauna between region I (from 4°30'N to 10°N lat.), region II (10°N to 15°N lat.), region III (15° to 20°N lat.) and region IV (beyond

20°N upto23°N lat.) in the eastern Arabian Sea and the Bay of Bengal are compared. The shelf region of the eastern Arabian Sea or the Bay of Bengal is compared with the respective oceanic region. Premonsoon (Feb. -May), Monsoon (June -Sept.) and postmonsoon (Oct. - Jan.) were the periods identified for comparing the variations between seasons. Samples collected from 0600 to 1800 hrs were taken as day samples and 1800 to 0600 hrs as night samples for studying the day - night variations in distribution.

Observations

Geographical distribution

Lucifers were found distributed extensively all along the Indian coasts with pockets of high abundance along the east coast and off the southwest coast (Fig.1). Along the northeast coast, lucifers were present in dense patches off Andhra and Orissa. The highest concentration in a half-degree square (58,524) was observed between 15° N and 16° N latitudes. Patches of fairly high concentrations were obsereved at the head of the Bay, from Puri to Visakhapatnam with a central core of very high concentration (> 30,000), off Kakinada, in the oceanic region off Madras and in the neritic waters from Pondicherry to Point Calimere. High concentration (28,000) was seen around the peninsular curve including the Gulf of Mannar and the Wadge Bank down to 6° N latitude. The high density area continued and extended along the shelf upto 13° N latitude on the west coast, with a dense patch from Calicut to Mangalore. Pockets of very high densities (23,000-46,000) were present in the oceanic waters off Vizhinjam-Alleppey, between 8° N and 9°30' N latitudes. In the eastern Arabian Sea, apart from pockets of fairly high concentrations observed in the oceanic regions south of Minicoy (8,000), off Mangalore, off Goa and a patch extending along the 200 m depth contour from Bombay to Dwakraka (19° to 22°N lat.), the distribution was only in moderate numbers (1,001-5,000). In the central Bay of Bengal lucifers were sparse (<1000) but they were present in moderate numbers in the seas around Andaman and Nicobar Islands. A pocket of high concentration was observed to the west of Great Nicobar (12,000) and another one of fairly high concentration to the east of South Andamans (5,829).

Numerical abundance

Lucifers were present in 99% of the samples with an average density of 2,499. Not much variation in densities was observed between the eastern Arabian Sea (2,591) and the Bay of Bengal (2,361).

The monthly density distribution for the total area surveyed (Fig. 2) and for the eastern Arabian Sea and the Bay of Bengal (Fig. 3) showed a similarity in the distribution pattern. The major period of abundance was around the monsoon with the peak in June in the Arabian Sea and in October in the Bay of Bengal subsequently falling in November and December respectively. Relatively steady numbers were noticed from December to May.

Lucifers were found distributed in higher concentration on the shelf throughout the year (Fig. 4). The major concentration was found along the shelf region in the Bay of Bengal (6,461). The neritic waters in the eastern Arabian Sea had a density of 4,382. However, while the oceanic waters in the Bay of Bengal had very poor density (892), the oceanic waters in the Arabian Sea supported a moderate population (1,700) (Fig. 5).

A very large population of Lucifers was found to be maintained between 4°30'N and 10°N latitudes in the west (3,996) and the east coasts (3,503) while the abundance for the rest of the regions varied between 1,300 and 2,300.

Lucifers were distributed in high abundance in the shelf waters of the Bay of Bengal during the southwest monsoon season with the peak between 15°N and 20°N latitudes. In the Arabian Sea the monsoon abundance extended from 4°30'N to 15°N latitudes beyond which high abundance was noticed during the premonsoon months. In this region during the southwest monsoon lucifers were observed in more concentrations in the oceanic waters than in the shelf waters.

The density of lucifers in samples collected during night time was more than those collected in the day time. However, this variation was not signficant (Fig. 8). The density of lucifers during night and day varied relatively little in the oceanic region but varied considerably in the continental shelf (Fig. 9). In the shelf waters the genus was more abundant in the night samples during the premonsoon season (73%) and monsoon (57%) but during the post monsoon season they were more abundant in the samples collected during day time (63%).

Discussion

Lucifers were present in more stable numbers

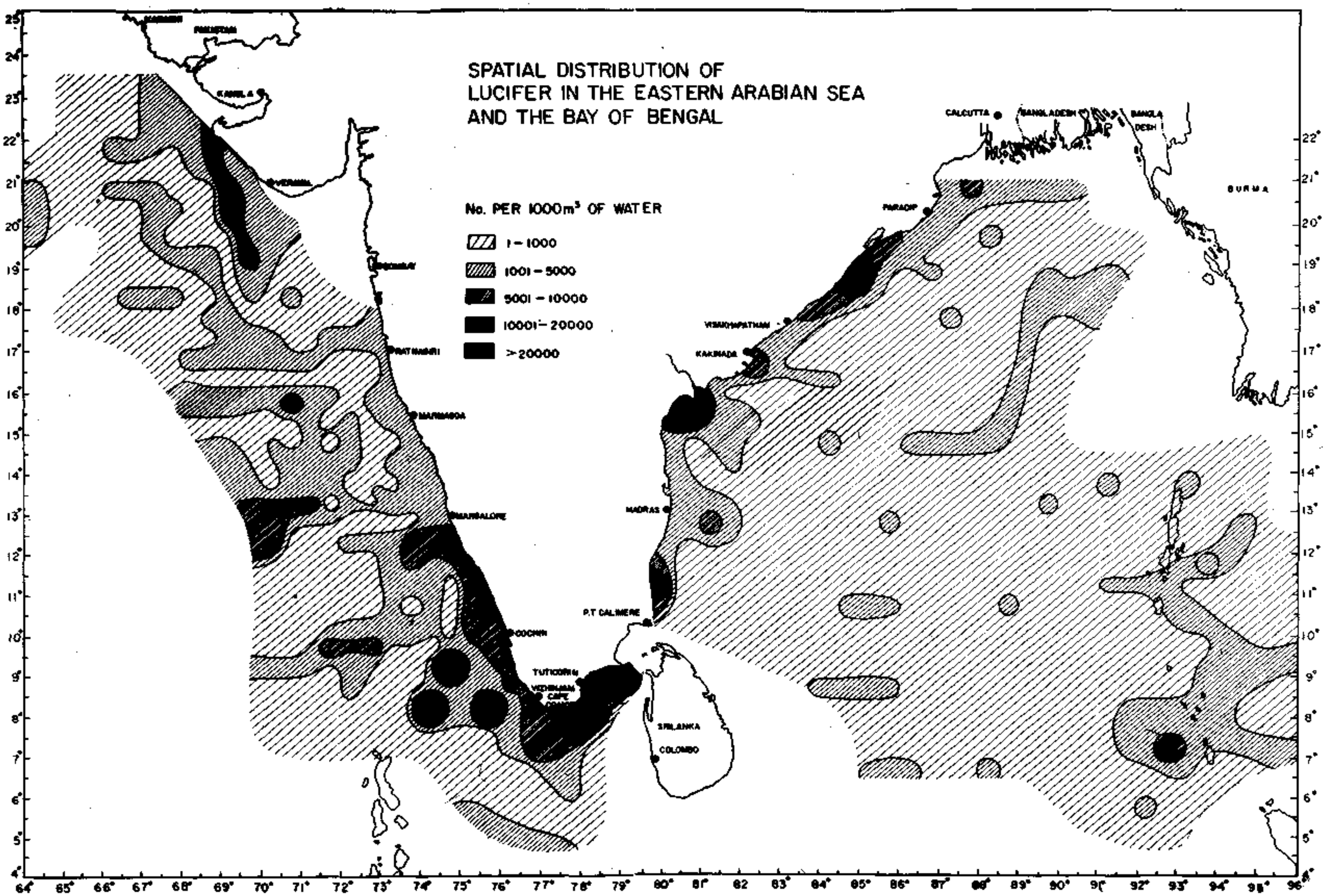

Fig. 1. Spatial distribution of lucifers in the eastern Arabian Sea and the Bay of Bengal.

throughout the year than any other zooplankton group, forming numerically the major component of the planktonic decapods as observed by Menon and Paulinose (1973).

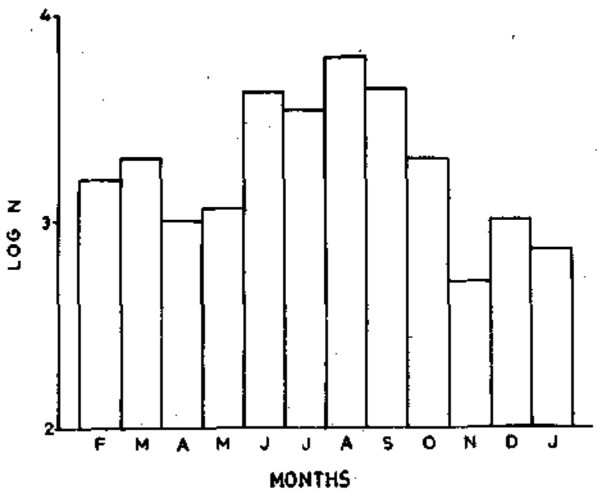

Fig. 2. Monthly variations of lucifers in the seas around India.

The monsoon cycles have been found to play a significant role in the abundance of lucifers in the Bay of Bengal as a whole and in the Arabian Sea upto 15°N latitude beyond which the impact of seasonal cycle was not significant. In the Bay of Bengal this is in agreement with the observations of Menon (1933), Prasad (1954, 1958) Krishnamurthy (1961), Marichamy and Siraimeetan (1979) from the Gulf of Mannar-Palk Bay region andof Sarkar *et al.* (1986) around 21°N latitude. Ganapati and Ramanamurthy (1975) have reported that the major peak of the developmental stages of lucifers off Visakhapatnam was during February-June and that of adults in November. RV *Gaveshini* cruises in the western Bay of Bengal (Achuthankutty *et al.*, 1980; Nair *et al.* 1981 and Paulinose *et al.*, 1988) also confirm large aggregation of lucifers in the coastal waters of the Bay of Bengal during the monsoons. Madhupratap *et al.*, (1981) have reported lucifers as the major group of planktonic decapod around Andaman and Nicobar Islands. Goswami (1983) found lucifers forming 9% of the zooplankton around Lakshadweep. Along the southwest coast in the nearshore waters Menon (1945), George (1953), Mukundan (1967) and George and Paulinose (1973) have reported lucifers to be common throughout the year. Naomi and Mathew (1989 M. S.) found lucifers more abundant during the southwest monsoon off Cochin. The present observations along the northwest coast of India are in agreement with those of Nair *et al.*, (1980), Achuthankutty *et al.* (1981) and Naomi (1986) who have reported lucifers to be more abundant during the premonsoon months (March-April).

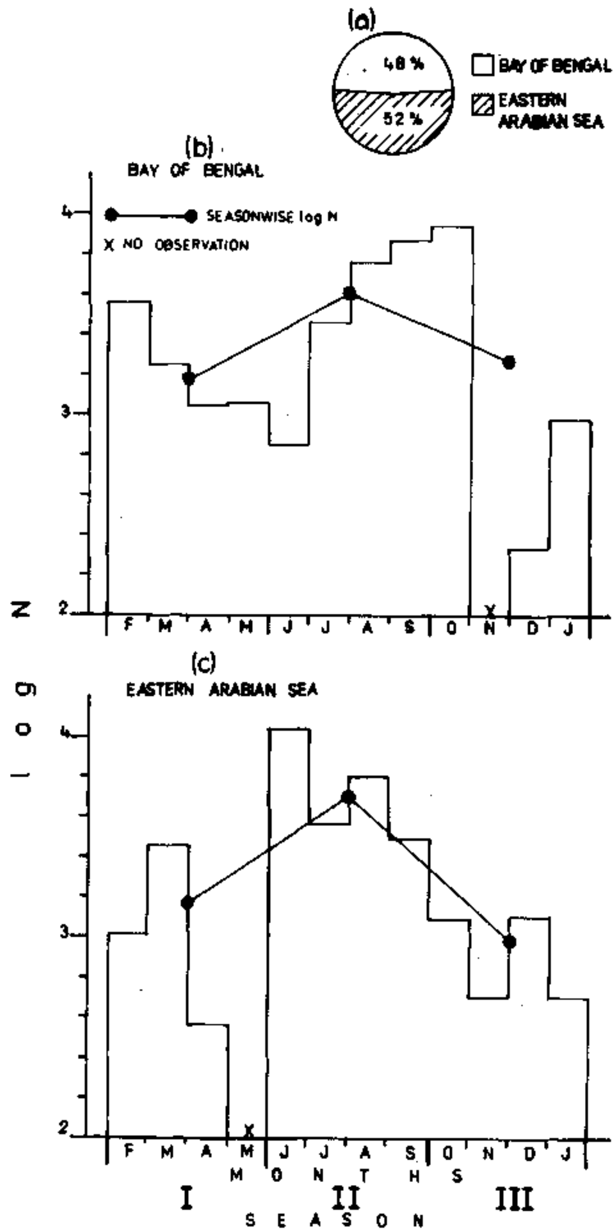

Fig. 3. Abundance of lucifers in the eastern Arabian Sea and the Bay of Bengal (a) Relative abundace. Monthly and seasonal variations in (b) the Bay of Bengal and (c) the eastern Arabian Sea.

All the areas of abundance of lucifers in the shelf along the southwest coast and at localised areas along the east coast (off Madras, Visakhapatanam and Orissa) and around the Andamans

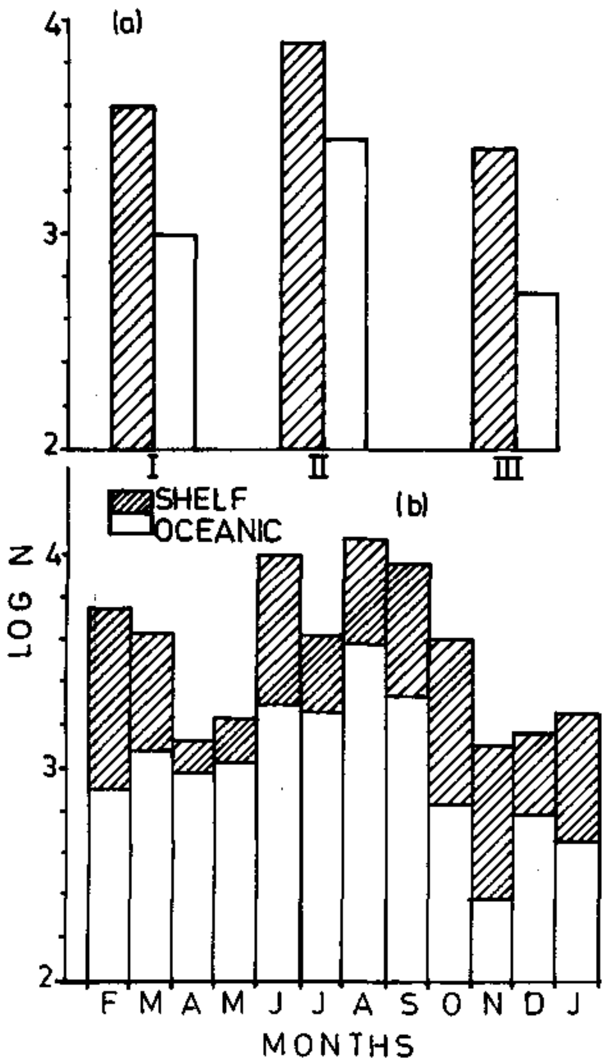

Fig. 4. Seasonal (a) and monthly (b) variations in the relative abundance of lucifers in the shelf and oceanic waters of the seas around India.

appear to be areas where strong upwelling followed by increased production at the primary and secondary levels is reported (Panikkar and Rao, 1973; Subramanyan, 1973; Menon and George, 1977 and Qasim 1977).

The abundance of lucifers was found to decrease with the increasing distance from the coast as indicated by Omori (1974). Their abundance in the oceanic waters of the Arabian Sea was greater than that in the Bay of Bengal but very patchy, containing some of the richest and some of the least abundant areas. The same feature, characteristic of the Arabian Sea is indicated by Ryther and Menzel (1965) who have reported areas of extremely dense plankton blooms which vary in size from 100 yards or less to several miles in diameter and often sharply delineated by extremely clear and unproductive water. Nair *et al.* (1980) found lucifers to be a main component of the Zooplankton during March-April as a result of the enrichment caused by the *Trichodesmium* bloom. In the Bay of Bengal the column productivity in the central areas is reported to be low (Qasim, 1977) and this could be a reason for the very sparse and even distribution of lucifers in the oceanic waters of the Bay.

The present study also revelas that lucifers in the neritic waters of the Bay are 16% more than that of the Arabian Sea. The surface production in the coastal waters in the Bay of Bengal per unit area is reported to be greater than that of Arabian Sea (Qasim, 1977). The concentration of epiplanktonic shrimps is particularly great in waters where the bottom slopes steeply close to the shore and strong upwelling is frequently observed (Omori, 1974). Hence it is logical to conclude that lucifers aggregate in the areas of narrow and steep continental slope of the east coast where intense upwelling, followed

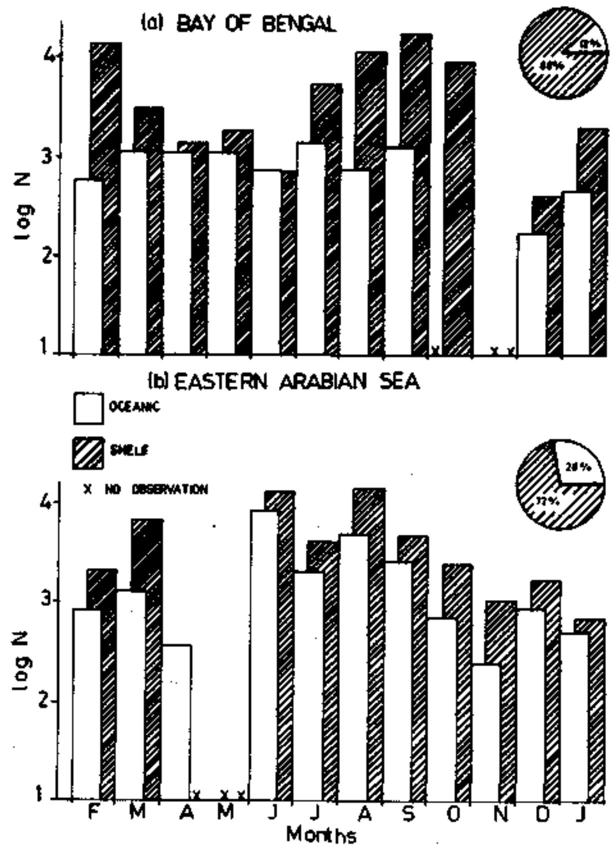

Fig. 5. Monthly variations and the relative abundance of lucifers in the shelf and oceanic waters of the Bay of Bengal (a) and eastern Arabian Sea (b).

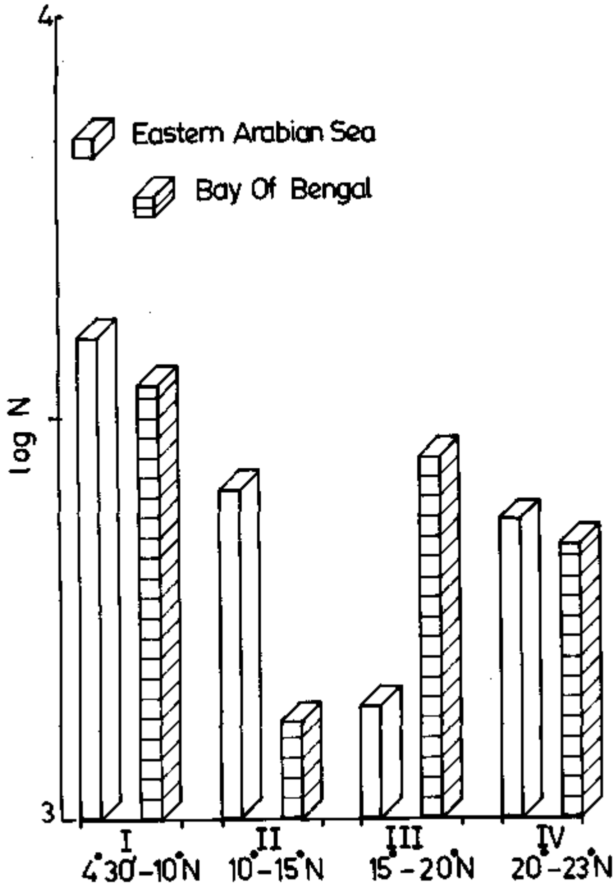

Fig. 6. Regionwise distribution in the abundace of lucifers in the eastern Arabian Sea and the Bay of Bengal.

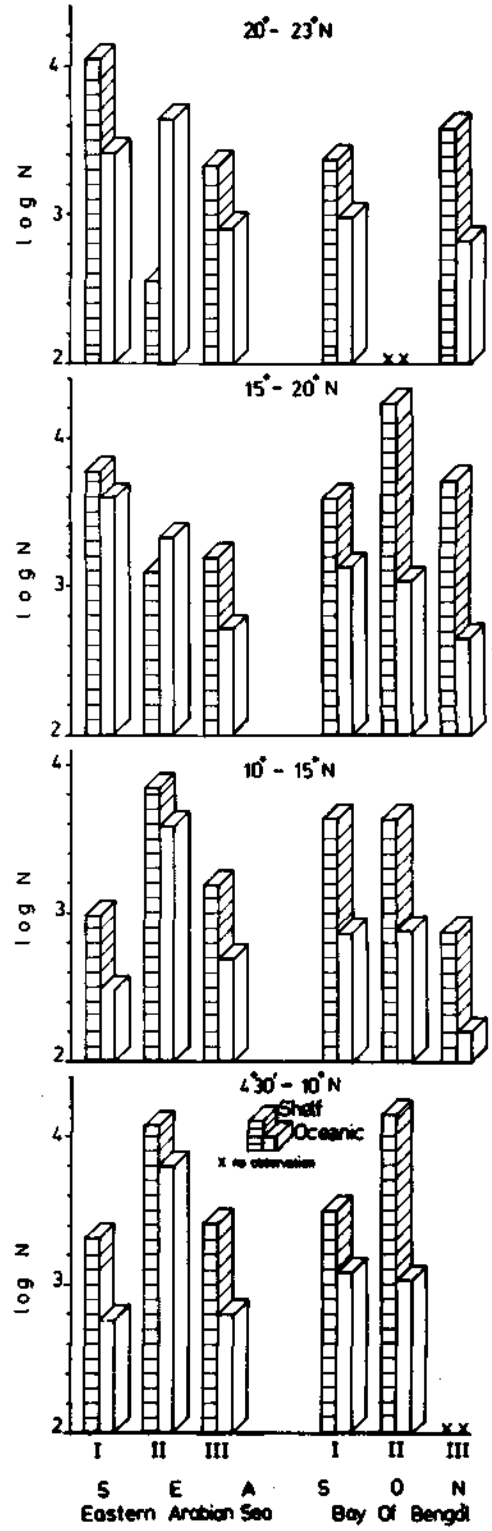

Fig. 7. Regionwise seasonal abundance of lucifers in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

by very high surface productivity, is reported. Swarms of lucifer around the peninsular curve during the southwest monsoon is probably related to precipitation and direction of the monsoon winds. Furthermore there is less upwelling south of Quilon and the oxygen rich surface layer is much deeper with better environmental condition (Anon., 1976).

In this study diurnal migration of lucifers was not significant, as the main part of the population is in the upper 150-metre layer both at day and night intimately associated with the productive zones where they eat (Omori, 1974). Apart from food supply, light intensity and temperature are regarded as important factors in the vertical distribution of a neritic genus like *Lucifer* (Raymont, 1983). This may be the reason for their lesser abundance in the samples during day time in the premonsoon season when the light intensity is more than during the monsoon and postmonsoon seasons.

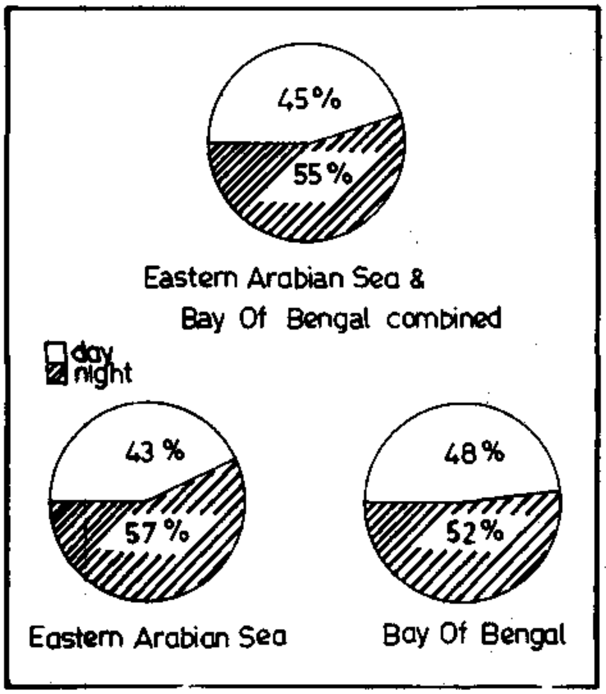

Fig. 8. Variations in the abundance of lucifers during day and night.

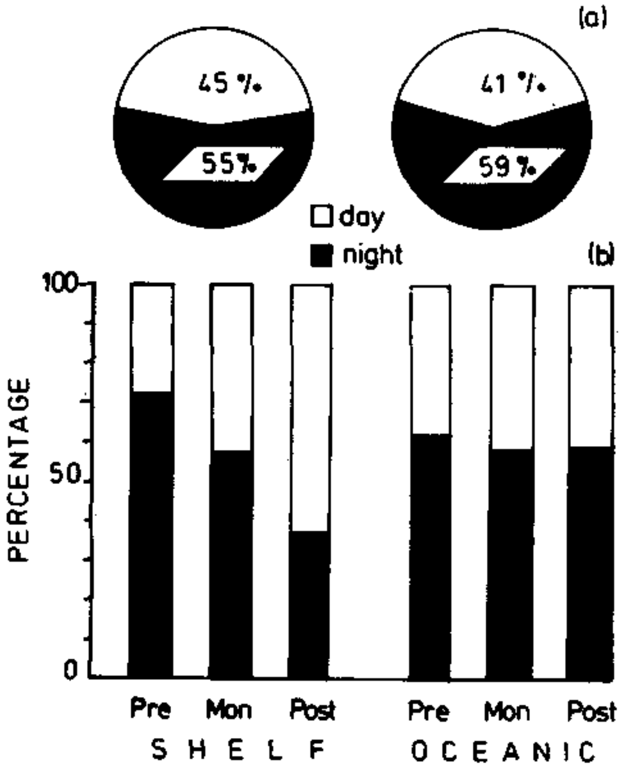

Fig. 9. Day - Night variation in the abundance of lucifers in the shelf and oceanic waters: (a) in the seas around India, (b) seasonal variations.

Lucifer spp. are reported to be very common in the diets of pelagic fishes (Prasad, 1954; Rao, 1962; Nath, 1966; Kagwade, 1967; Sreenivasan, 1979). Huang *et al.* (1987) found the variatons in abundance of lucifers and the catch of *Decapterus maruadsi* similar in the Taiwan waters.

The pattern of distribution and abundance of *Lucifer* reported in this study agrees with the distribution of young fish of several pealgic species reported by the investigations of the UNDP/FAO Pelagic Fishery Project along the west coast of India (Anon., 1975) and also with the areas of high abundance of the fishery resoruces of the Indian EEZ (George *et al.*, 1977). Since lucifers play a signifciant role as food of fish and shrimps in their nursery grounds (Omori, 1974) it seems that the abundance of *Lucifer* spp. may serve as an indicator of these nursery grounds.

Acknowledgements

We are thankful to Dr. P. S. B. R. James, Director, CMFRI for his keen interest shown in this work. Our thanks are also due to Dr. K. S. Scariah and Shri. P. P Pavithran for the help rendered in the computer analysis of the data and to Shri. M. A. Nizar for the various help rendered.

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OBSERVATIONS ON ZOOPLANKTON BIOMASS IN RELATION TO THERMOCLINE IN LAKSHADWEEP AREA

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Abstract

Based on a survey conducted in February, 1987 in the oceanic waters around Lakshadweep Islands by FORV *Sagar Sampada*, zooplankton abundance from 28 stations was correlated with the top-depth of thermocline and its intensity. Thermocline was generally found to be around the depth of 75m. Interesting results found are (i) the animal congregations generally occur at the thermal front, (ii) the less the depth of thermocline, the more would be the plankton biomass, (iii) the amount of plankton collected by the net is inversely related to the intensity of thermocline and (iv) in the present study the net collection of plankton was determined by the thermocline depth since the Bongo net was lowered to a limited depth only.

Introduction

Very little information is seen from the published work on the effect and influence of physical characteristics of water masses on the secondary production from oceanic waters around Lakshadweep. Some of the recent publications on zooplankton from Lakshadweep area are by Goswami (1973, 1979, 1983), Madhupratap *et al.* (1977), Tranter and George (1972) and Rengarajan (1983) and on water quality and water masses by Jayaraman *et al.* (1960), Patil and Ramamirtham (1963), Murty (1965, 1981), Silas (1972) and Rengarajan (1983). Hence an attempt has been made to study the influence of thermocline on zooplankton biomass during the day and night in the oceanic waters of Lakshadweep and the results are presented in this account.

Material and Methods

The oceanic area between 08° and 13° N and 70° and 75°E around Lakshadweep Islands, in transects more or less parallel to latitudes, was surveyed during February, 1987 by FORV *Sagar Sampada* (Cruise No. 28). In all, 28 stations; 11 during day time and the rest at night, were covered in 6 transects, each 1° apart (Fig.1). Zooplankton collections were made by Bongo net from about 150 m to the surface as oblique hauls. The vertical profile of temperature was recorded by a bathythermograph. Samples were preserved in 5% formalin before displacement volume for total biomass was taken.

The bottom depth at each station was more than 1000 m except at stations 954, 960 and 968 where the depth was between 300 and 500 m. However, the depth of each station was more than sufficient for studying the vertical spread of thermocline. An attempt was, therefore, made to understand the behavioural pattern of zooplankters with respect to the thermocline location and its intensity.

As the net is not a closing type and the vessel makes a circle at the station dragging the net, it gives only the total abundance of zooplankton in the entire column of water swept by the mouth of the net. Due to water current and the movement of the vessel, the net used to make a slant which did not give a correct quantity of water filtered to assess the zooplankton biomass in the vertical column of water at the station.

Results and Discussion

The displacement volume of zooplankton is plotted stationwise in Fig. 2 and the stations are arranged as per increasing latitude position of the transect and in the order of increased distance of the stations from the coast off the mainland in each transect. The stations numbered 949, 961 and 965, were not considered, as samples were either spoiled or not collected. The zooplankton abundance computed as per the formula supplied by CMFRI, ranged from 4.36 ml/1000 m^3 at station 958 to 108.93 ml/1000 m^3 at station 968. Fig. 2 indicates that there is no systematic relationship of zooplankton abun-

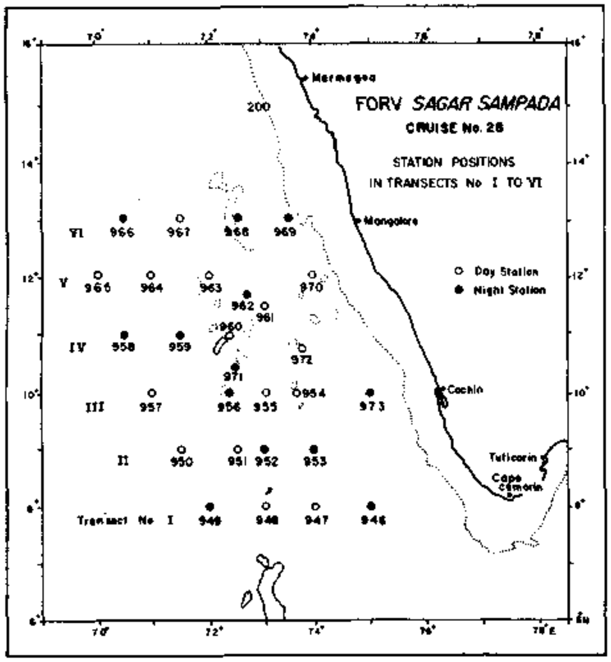

Fig. 1. Station positions and Cruise (No. 28) track of FORV *Sagar Sampada* to Lakshadweep in February, 1987.

dance with the change of either latitude or distance from the mainland. However, the night collection per haul was more than twice to that during day (29.28 ml/1000 m³ during night, 12.90 ml/1000 m³ during day per haul). In fact, the day time collection per haul was only 44% of that of the night time collection.

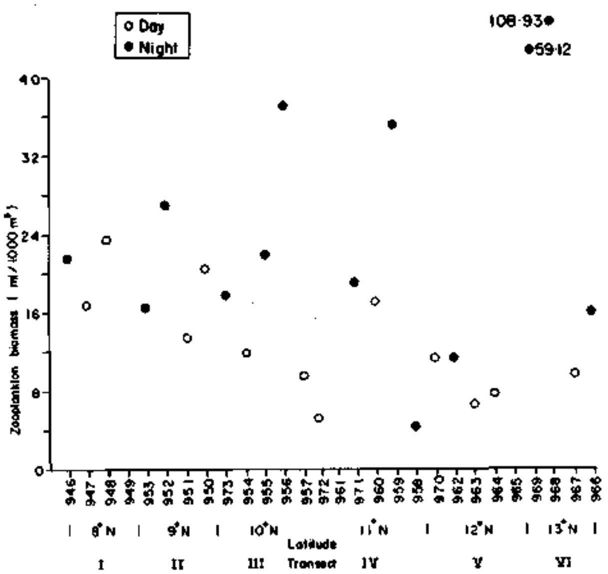

Fig. 2. Zooplankton biomass distribution over the six transects.

The first five highest or maximum zooplankton collections are from night stations only. The highest zooplankton biomass among the day stations was 23.41 ml/1000 m³ from station 948.

The day time observations of zooplankton abundance were analysed in relation to thermocline condition both in its intensity and depth. On an average, the depth of thermocline was found to be 75 m. The waters above the thermocline are warmer than the waters below the thermocline. Therefore, the thermocline may be treated, in a broad sense, as a thermal front where animal congregations generally occur. Fish congregations are known to be associated with frontal regions (Taivo Laevastu and Ilmo Hela, 1970; Cushing, 1982).

If the thermocline is much shallow, say less than 75 m and the plankton net is sent far below the thermocline say about 150 m, there is every chance of getting more plankters as the amount of water filtered through the thermal front is also more. Therefore, the less the depth of thermocline, the more would be the plankton collection. The same inverse relation of plankton with depth of thermocline is expressed in Fig. 3.

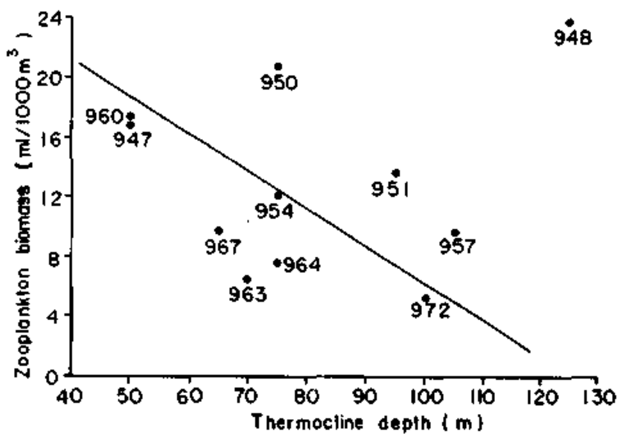

Fig. 3. Variation in zooplankton biomass in relation to the depth of thermocline.

Stable layers of water impede vertical movement of plankters. Stability of water within the thermocline layer depends upon the thermocline intensity. The more the intensity of thermocline, the more is the stability leading to less vertical movement of plankton and therefore the zooplankton collections in such condition would be poorer. The plankton collection by the net is, thus inversely related with the intensity of thermocline (Fig. 4). It is therefore concluded that the efficiency of the Bongo net towards collection of plankton is to give improved collections with less depth of thermocline and with less intensity of thermocline as revealed by Figs. 3 and 4.

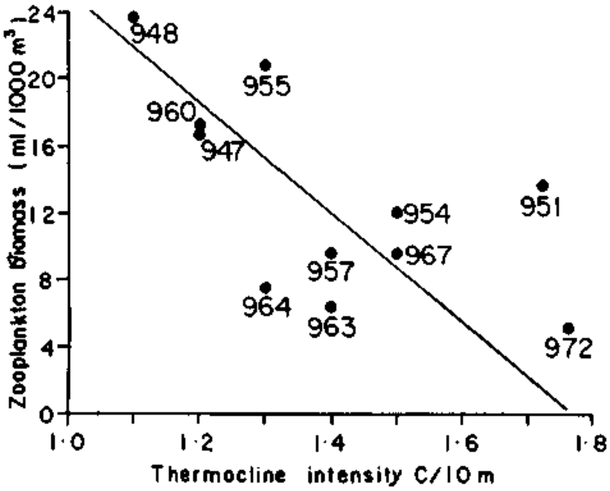

Fig. 4. Variation of zooplankton biomas in relation to the intensity of thermocline.

Conclusions

The above results which were based on the concept that thermocline be treated as a "front" and the congregation of plankton and fishes are associated with such fronts, deserve further investigation in a detailed manner by using a plankton net with closing mechanism and depth indicating unit to obtain the descrete level of distribution of plankton. Large pooled up information of plankton thus obtained and the details of thermocline formation and intensity and fish catch data may lead to quantitative determination of the influence of thermocline on the abundance of fish stocks in the sea. This in turn leads to better forecasting the availability of pelagic fishes before shooting the net.

Acknowledgement

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ON THE COLLECTIONS OF PHYLLOSOMA LARVAE BY ISAACS-KIDD MIDWATER TRAWL FROM THE WEST COAST OF INDIA

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Abstract

The operations of Isaacs-Kidd Midwater Trawl from February, '85 to January, '86 along the west coast of India have indicated the regular occurrence of phyllosoma larvae belonging to palinurid and scyllarid lobsters. The average number of larvae caught per haul varied from 2 to 8, though a single haul contained a maximum of 92. The night collections were richer than that of day. The depth-wise operation has shown that greater numbers were taken from 10-200 m zone. Dispersal of larvae of different species in relation to oceanographical conditions is discussed.

Introduction

Among the reports available on the occurrence of phyllosoma larvae of palinurid, synaxid and scyllarid lobsters in the coastal waters of India, systematics of larvae have been dealt with by Prasad and Thampi (1957, 1959a, 1960a and 1968), Prasad *et al.* (1975), Thampi and George (1975) and Sarasu (1985). The seasonal availability of phyllosoma larvae in the plankton samples is reported by Alikunhi (1948), Bal and Pradhan (1952), Chacko (1950), George (1953), Menon (1945) and Prasad (1954), while information on the hatching of eggs, description of larvae and larval rearing under laboratory conditions are given by Deshmukh (1968), Mohamed, Rao and Suseelan (1971), Prasad and Tampi (1959b and 1960b) and Sankolli and Shenoy (1973). The present study deals with the occurrence and distribution of phyllosoma larvae in the Exclusive Economic Zone of the west coast of India, based on the materials obtained from the operation of Isaacs-Kidd Midwater Trawl on board FORV *Sagar Sampada.*

Material and Methods

The larvae obtained from the area lying between latitudes 7° to 23° N and longitudes 67° to 78° E were considered for the present study. The phyllosoma larvae were collected in 30-minute horizontal haul by Isaacs-Kidd Midwater Trawl (IKMT) made during the cruises 1, 3A, 3B, 6, 7, 8, 9, 10 and 11. The depth of operation of the gear varied from 10 to 500 m. The total number of larvae for each haul came from the entire sample analysed. To study the seasonal abundance, the number of larvae from each haul were pooled together on month-wise basis, irrespective of the cruises and the average number per haul per month was worked out based on the total number of hauls made in each month. For depth-wise distributional study, larvae were grouped into different depth zones starting from 0 to 500 m at 50 m interval. To identify the larvae and fixing up of stages' the keys and salient characters given by Prasad *et al.* (1975) and Tampi and George (1975) were followed.

Observations

Larval abundance

The location of stations from where the phyllosoma larvae obtained is marked in Fig. 1. The details of total number of hauls made and group-wise number of larvae caught are given in Fig. 2. Totally 280 hauls were made, of which, 108 hauls contained larvae. Out of these 108 hauls, 56 were made during the day time and the rest 52 during the night. Altogether 456 larvae were caught, of which, 168 belonged to palinurid, 1 to synaxid and 287 to scyllarid lobsters. In the case of palinurids, maximum number of larvae were obtained during March-April, October, December, '85 and January, '86. Whereas the scyllarid larvae were more in number during August and December, '85. A single larva of synaxid lobster was caught in December '85. Though the average number (combined figure for all these three groups) per haul varied from 2 to 8, the maximum of 8 was recorded in August and December,

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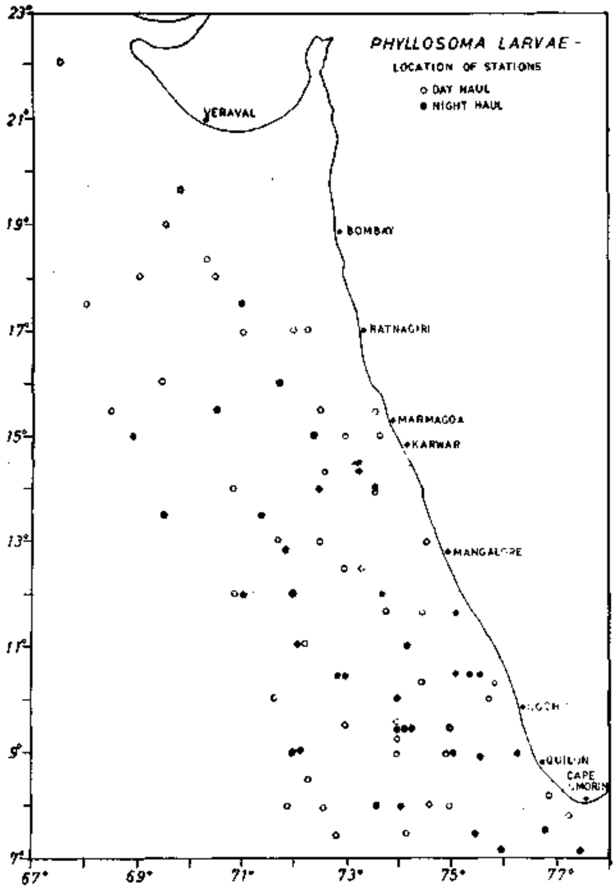

Fig. 1. Map showing the location of stations.

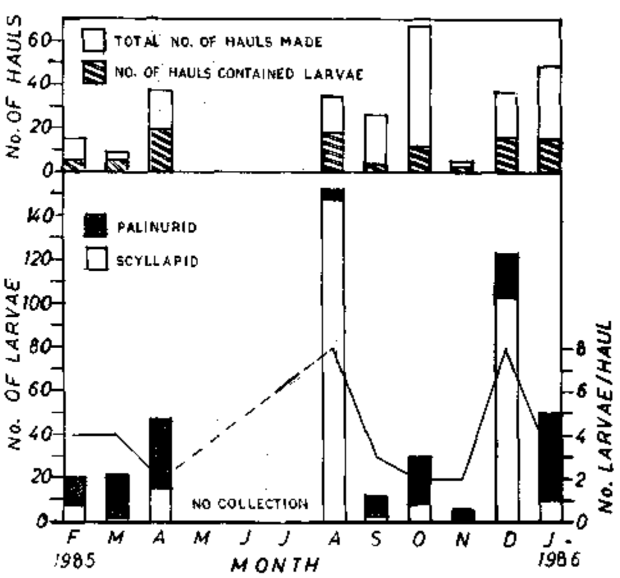

Fig. 2. Abundance of phyllosoma larvae during February, 1985 to January, 1986.

'85. However, a single haul from Cruise 10 contained 92 larvae (2 palinurid, 1 synaxid and 89 scyllarid) in December, '85. Inspite of the gap in the collection of larvae during the three months (May to July, '85), the phyllosomae were present in all other months in the study area. This could be due to the lengthy larval life and dispersal of larvae to distant waters.

To study the diurnal variations, the total number of palinurid and scyllarid larvae caught during day and night hauls during February, '85 to January '86 are marked in Fig. 3. In the case of palinurid larvae, greater numbers were caught during the night hauls in February-April, '85 and again in January, '86. In other months, fairly good representation was made in the day time hauls. For the scyllarid larvae, day time hauls yielded more number during February, April, August and December, '85 and January, '86 and the night hauls during August and December, '85. In general, night hauls were

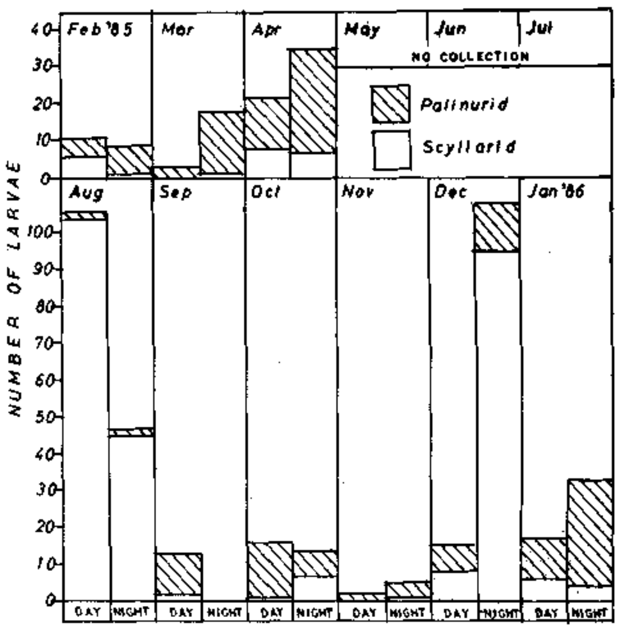

Fig. 3. Diurnal variation in the collection of palinurid and scyllarid lobster larvae.

richer than that of day for both palinurid and scyllarid larvae.

The data on the depth-wise operation of IKMT was available only to the cruises 3B, 6, 7, 8, 9A, 10 and 11. Based on these data, the larvae obtained from different depth zones are summarized in Table 1.

It is seen that though more hauls were made upto 100 m depth, the number per haul was 2.8 at 0-

TABLE 1. *Depth-wise distribution of phyllosoma larvae*

Depth zone	No. of hauls made	Number of larvae: Palinurid	Scyllarid	Total	No. of larvae per haul
0-50	56	24	131	155	2.8
51-100	10	78	83	161	16.1
101-150	2	35	44	89	44.5
151-200	1	20	14	34	34.0
201-250	1	1	8	9	9.0
251-300	4	5	2	7	1.4
301-350	3	2	1	3	1.0
351-400	2	1	1	2	1.0
401-450	2	2	0	2	1.0
451-500	1	0	3	3	3.0

50 m and 16.1 at 51-100m. In the case of other depth zones, the number of hauls taken ranged from 1 to 4. However, the number of larvae per haul ranged from a minimum of 1 to a maximum of 44. Thus, greater number of larvae were hauled up from a depth of 51 to 200 m.

Species composition:

The palinurid larvae belonged to 4 genera, namely, *Panulirus, Puerulus, Palinustus* and *Linuparus,* while those of *Scyllarus* and *Thenus* represented scyllarid larvae. Among the palinurid larvae, *Panulirus homarus* accounted for 47.4% by number, followed by *P. versicolor* (33.3%), *P. penicillatus* (5.1%), *P. sewelli* (4.5%), *P. polyphagus* (2.8%), *P. longipes* (2.8%), *L. trigonus* (1.7%), *P. mossambicus* (1.2%), *P. ornatus* (0.6%) and *P. angulatus* (0.6%). In scyllarid larvae, *S. martensii* formed 80.3%, followed by *S. rugosus* (12.7%), *S. batei* (4.7%), *S. cultifer* (1.0%), *Scyllarus* sp.1 (1.0%) and *T. orientalis* (0.3%). The single larva of synaxid lobster belonged to *Palinurellus wienckii.*

TABLE 2. *Stage-wise occurrence of phyllosoma larvae*

Species	Stages: I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
P. homarus	—	2	1	11	6	29	13	10	7	5	—	—
P. versicolor	—	—	—	4	—	6	11	8	10	20	—	—
P. penicillatus	—	—	—	—	—	—	2	3	1	1	—	2
P. polyphagus	—	—	—	—	1	3	—	1	—	—	—	—
P. ornatus	—	—	—	—	—	1	—	—	—	—	—	—
P. longipes	—	—	—	—	—	—	1	2	—	2	—	—
P. sewelli	—	3	1	—	1	—	1	1	—	1	—	—
P. angulatus	—	—	—	—	—	—	—	1	—	—	—	—
P. mossamibicus	—	—	—	—	—	—	—	—	—	2	—	—
L. trigonus	— — — — — — — — — — —					3	nos ?	— — — — — — — — — —				
P. wieneckii	—	—	—	1	—	—	—	—	—	—	—	—
S. martensii	—	6	8	28	17	68	17	54	42	3	—	—
S. rugosus	1	1	4	5	—	2	1	4	5	3	6	6
S. batei	1	2	3	4	—	1	—	—	1	2	—	—
S. cultifer	—	1	1	—	—	1	—	—	—	—	—	—
Scyllarus sp.1	—	—	—	—	—	—	—	—	—	—	—	3
T. orientalis	—	—	—	1	—	—	—	—	—	—	—	—

Larval stages

The number of larvae caught in each stage for the species studied are given in Table 2.

Species like *P. homarus, P. sewelli, S. martensii* and *S. batei* had more number of early stages (I to VI), while more number of advanced stages (VII to XII) were present in *P. versicolor, P. penicillatus, P. longipes, S. rugosus* and *Scyllarus* sp. 1. Some of the larval stages of *P. sewelli, P. angulatus, P. mossambicus* and *L. trigonus* were caught for the first time from the wild. The description of these larvae will be published elsewhere.

Dispersal of larvae

Based on the location of the stations, the distance from the nearest shore was calculated. The number of palinurid and scyllarid larvae in different stages were plotted against the distance and the details are shown in Table 3. It is seen that majority of larvae of both the groups were caught within 200 km distance from the shore. The advanced stages were found mostly closer to the shore (up to 100 km), indicating the possible return to inshore waters for settling at the bottom after metamorphosing into postlarval stages. The earlier larval stages were found in considerable numbers in the nearshore waters and a very few of them in the distant waters, even upto 600 km from the shore.

Discussion

The present observation on phyllosoma larvae collected by IKMT along the west coast of India has indicated their occurrence throughout the year. Among the larvae, those belonged to scyllarid dominated, as observed by Berry (1974) in the South African waters. Moreover, the swarming of scyllarid larvae (92 number) netted in a single haul had added up the numerical abundance. The peak occurrence of larvae was recorded during October-April, which is in agreement with the collection of earlier phyllosoma larvae during November-March by Bal and Pradhan (1952), George (1953) and Menon (1945) from the coastal waters of the west coast of India.

The observations by Johnson (1960) Chittleborough and Thomas (1969) and Rimmer and Philips (1979) have shown that the night hauls contained more phyllosoma larvae than that of the day due to the ascending movement during the night and descending movement during the day. The present collection of more larvae during the night could be due to such diurnal movement of larvae. The depthwise collection of larvae in the present study has indicated the capture of maximum number of larvae in 51-200 m depth zone. Whereas the observation by Prasad (1978) has shown the maximum concentration of larvae between 50 and 100 m depth.

The dominance of larvae of *P. homarus* among palinurids and *S. martensii* among scyllarids in the present study could be due to greater adult population in the coastal waters and high fecundity and protracted breeding season (at least in the case of *P. homarus*), as suggested by Prasad and Tampi (1965). The data on dispersal of larvae in the inshore and offshore waters has indicated the presence of advanced stages in the waters upto 200 km distance from the shore, which could be due to return to nearshore waters before the settlement at the bottom. The occurrence of early stages in the distant waters (upto 600 km) could be due to the movement off shore rather than inshore, as pointed out by Rimmer (1980) for phyllosoma larvae.

The dominance of larvae of *P. homarus* in the present material has already been mentioned. George (1967) who studied the biology of the species has reported the peak breeding season as November-March along the Kanyakumari coast. According to Murty (1965), the current flows northward during November to February and southward during March-September along the southwest coast of India. It is quite possible that the larvae of *P. homarus* liberated during November-March and carried away by northerly flowing currents return to the original habitat of the adult by southerly currents, as more larvae of the species were obtained in the southern part of the west coast. A detailed study on the biological aspects of different species of lobsters and intensive collection of larvae may throw more light on the dynamics involved in the abundance and dispersal of larvae in space and time.

Acknowledgements

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TABLE 3. *Dispersal of palinurid (P) and Scyllarid (S) larval stages in the inshore and offshore waters*

Distance from the shore (km)	I		II		III		IV		V		VI		VII		VIII		IX		X		XI		XII		Total	
	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S
Up to 50	—	1	—	2	—	8	3	10	1	6	3	37	3	15	5	29	3	20	6	2	—	1	—	—	24	131
51-100	—	—	1	—	1	—	2	8	2	2	7	21	12	8	12	18	15	20	26	4	—	2	—	—	78	83
101-150	—	—	—	1	—	3	7	4	5	9	6	14	8	2	3	4	3	2	3	3	—	2	—	—	35	44
151-200	—	—	—	2	—	1	4	2	—	—	10	2	3	2	1	3	1	2	1	—	—	—	—	—	20	14
201-250	—	—	—	1	—	—	—	2	—	—	1	4	—	—	—	1	—	—	—	—	—	—	—	—	1	8
251-300	—	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—	2	—	—	—	—	5	2
301-350	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	1	—	—	2	1
351-400	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	1	1
401-450	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2	0
451-500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0
501-550	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	1	—	—	0	3
551-600	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0

Assistant in assisting in the analysis of the samples

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THE PHYLLOSOMA LARVAE FROM ANDAMAN AND NICOBAR WATERS

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Abstract

The Isaacs-Kidd Midwater Trawl, Bongo net and pelagic trawl collections from Andaman and Nicobar waters during April, 1986 contained 80 palinurid, 15 synaxid and 70 scyllarid lobster larvae. Night hauls were better than that of day time operations. The depth-wise hauls from Isaacs-Kidd Midwater Trawl has indicated that greater number of palinurid larvae came from 26-50 m deep and that of scyllarid from 76-100 m. Among the palinurids, larvae belonging to *Panulirus homarus* and *P. Penicillatus* dominated, while larvae of *Scyllarus martensii* and *S. rugosus* were more in number. Some of the larval stages of *Puerulus sewelli*, *P. angulatus* and *Palinustus mossambicus* are described in detail.

Introduction

The occurrence of commercially important lobsters, namely, *Panulirus homarus* (Linnaeus), *P. ornatus* (Fabricius), *P. versicolor* (Latreeille), *P. penicillatus* (Olivier), *P. longipes* (A. Milne-Edwards), *Puerulus angulatus* (Bate), *P. sewelli* Ramadan, *Linuparus trigonus* (Von Siebold) and *Thenus orientalis* (Lund) in the waters around Andaman and Nicobar Islands, is reported by Balss (1925), Chekunova (1973), Menon (1976), Premkumar and Daniel (1980) and Shanmugham and Kathirvel (1983). However, no biological information is available on these species, except the remarks on the deep water lobster *P. sewelli* by Chekunova (1973) and the record of a few larvae of *P. penicillatus*, *Scyllarus cultifer* and *S. rugosus* from this region by Tampi and George (1975). The present account provides more information on the phyllosoma larvae obtained during the fourteenth cruise of FORV *Sagar Sampada*.

Materials Examined

The phyllosoma larvae were collected from a wider area lying between Lat. 5° to 15°N and Long. 90° to 95°E in the eastern part of Bay of Bengal and the western part of Andaman Sea during 1st to 23rd April, 1986. The larvae were obtained from the operation of Isaacs-Kidd Midwater Trawl (IKMT - 30 minutes horizontal haul), pelagic trawl (PTR -1 hour horizontal haul), and Bongo net (15 minutes oblique haul). The depth of operation for IKMT was 33 to 125 m, while it was 50 to 100 m and 150 to 0 m for PTR and Bongo net respectively. The position of station from where the larvae were obtained and the number of larvae caught either in a single gear or more gears are marked in Fig. 1. The total number of larvae from IKMT and PTR hauls came from the entire sample analysed and those of Bongo net were the estimated number raised from the sub-sample to the total volume of each plankton sample.

Observations

Numerical abundance

The number of larvae obtained in different gears are given in Table 1.

Among the three gears, the maximum number of larvae came from IKMT, followed by Bongo net and the least in PTR, which could have been due to the varying mesh of the net. In the combined figures for three gears, the palinurid larvae dominated (48.5%), followed by scyllarids (42.4%) and synaxid (9.1%).

Diurnal variations

The phyllosoma larvae caught during the day and night hours in the three gears are given in Table 2.

It has been observed that night hauls yielded more larvae than that of day times. A maximum catch rate of 7.4 larvae/haul was recorded in the night hauls, whereas only 4.5 larvae/haul was seen in day time. Among the three groups of larvae, those of palinurids were more in number in the night time IKMT and Bongo net collections. However, maximum number of scyllarids came from the day time IKMT hauls. These larvae appeared to congregate in the upper columnar waters during night times.

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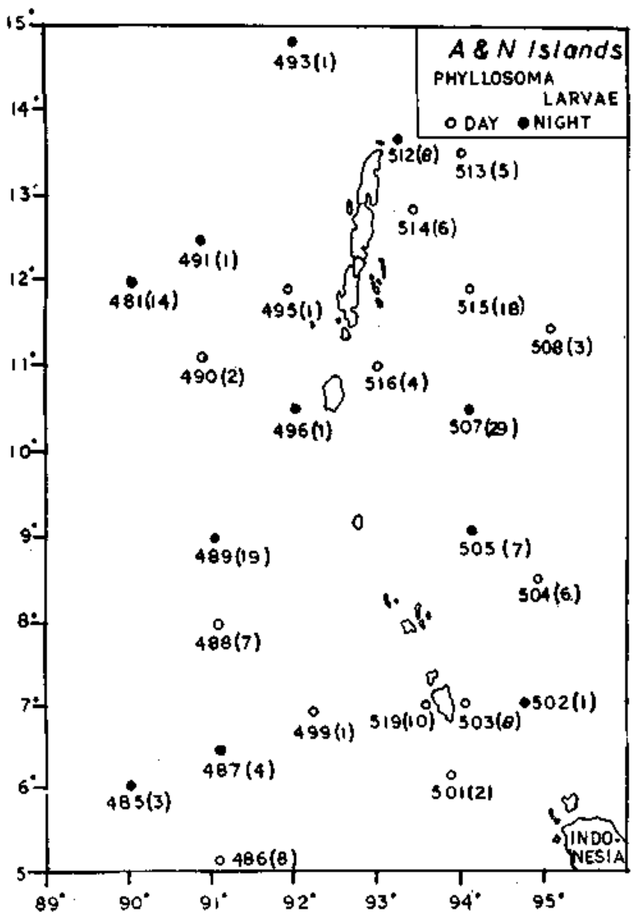

Fig. 1. Map showing the location of stations and numerical occurrence (in brackets) of phyllosoma larvae.

Depth-wise distribution

Among the three gears studied, the IKMT alone was operated from different depths, ranging from 26 to 125 m. The larvae caught from different depths are summaried in Table 3.

Among the different depth zones, both day and night hauls from 26 to 75 m yielded greater number of larvae (5.4 to 9.0 per haul) than those from 76 to 125 m (1.0 to 4.0 per haul) indicating the concentration of larvae in the upper layer of the water mass.

Dispersal of larvae

Depending upon the location of stations, the distance from the nearer shore was calculated and plotted against the number of larvae caught in different stages in Fig. 2. It has been observed that early stages (I to VI) were caught in considerable number beyond 150 km and were recorded upto 450 km from the shore whereas, the advanced stages (VII to XII) were found in more number upto 300 km distance.

Species composition

In the IKMT collections, *Panulirus homarus* was the dominant species (47.1% by number), followed by *P. penicillatus* (33.3)%), *Puerulus angulatus* (5.9%), *Palinustus mossambicus* (5.9%), *P. sewelli* (3.9%), *P. versicolor* (1.9%) and *P. longipes* (1.9%). The synaxid larvae were represented by *Palinurellus wienckii*. In the case of scyllarids, *Scyllarus martensii* formed 32.8%, followed by *S. rugosus* (25.4%), *S. batei* (19.4%), *Scyllarus* sp. 1 (17.9%) and *S. cultifer* (4.5%). In the Bongo net collections, only palinurid and synaxid larvae were present, of which, *P. homarus* dominated (34.1%). The other larvae included were *P. wienckii* (26.3%), *P. versicolor* (13.2%), *P. sewelli* (13.2%) *and* *Panulirus* sp. (13.2%). Among the four larvae caught in the PTR, 3 belonged to *Scyllarus* sp. 1 and 1 to *P. Penicillatus*.

Description of larvae

Some of the stages of *Puerulus sewelli*, *P. angulatus* and *Palinustus mossambicus* which were not known earlier are briefly described here. Two larvae

TABLE 1. *Gear-wise number of phyllosoma larvae*

Gear	Total No. of hauls made	No. of positive hauls	Number of larvae			
			Palinurid	Synaxid	Scyllarid	Total
IKMT	40	23	51	5	67	123
PTR	31	3	1	—	3	4
Bongo	40	6	28	10	—	38
Total			80	15	70	165
% by number			(48.5)	(9.1)	(42.4)	

TABLE 2. *Number of phyllosoma larvae in day and night collections*

Gear	Day Time						Night Time					
	No. of	Number of larvae					No. of	Number of larvae				
	hauls	P.	Sy.	Sc.	Total	No./ haul	hauls	P.	Sy.	Sc.	Total	No./haul
IKMT	12	18	2	34	54	4.5	11	33	3	33	69	6.2
PTR	3	1	—	3	4	1.3	—	—	No operation—			—
Bongo	1	—	1	—	1	1.0	5	28	9	—	37	7.4

P. = Palinurid; Sy. = Synaxid; Sc. = Scyllarid

TABLE 3. *Depth-wise distribution of phyllosoma larave in the IKMT collections*

Depth range (m)	No. of hauls made		No. of larvae caught		Number/haul	
	Day	Night	Day	Night	Day	Night
26 - 50	1	5	6	27	6.0	5.4
51 - 75	4	4	23	36	5.7	9.0
76 - 100	4	1	14	1	3.5	1.0
101 - 125	4	—	16	—	4.0	—

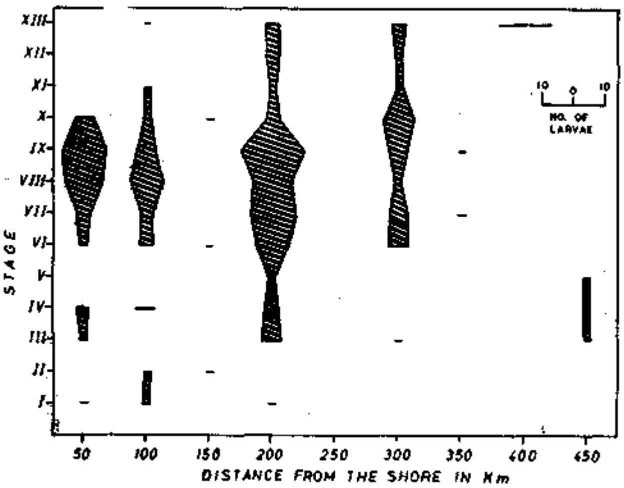

Fig. 2. Dispersal of phyllosoma larvae in the inshore and offshore waters.

of *P. sewelli* measuring 15.5 and 15.8 mm in total length were obtained from Station No. 515 by IKMT collection. In both the specimens, cephalic shield overlapped the thorax including the coxa of fifth walking legs. First and second antenna was 5 and 7 segmented. The first maxilliped was bilobed, while the exopod of second maxilliped was 2- segmented and setose. Considering the size and development of characters, these two larvae were placed in stage IX. Among the three specimens of *P. angulatus* obtained from station No. 519 by IKMT, the one measuring 10.0 mm in TL belonged to stage VIII, while the other two were in VII. The notable developments in stage VIII were 4- segmented antenna 1, 5-segmented antenna 2, cephalic shield overlapping 5th abdominal segment and pleopod long and biramous. First maxiliped bilobed, exopod of second maxilliped long and setose and fifth leg uniramous. All the three specimens of *Palinustus mossambicus* came from PTR hauls made at stations 481 and 504. These specimens were larger in size measuring 33.0, 36.0 and 51.0 mm in TL. The first two belonged to stage X and the largest to stage XII. The most striking character of these larvae was the presence of one outer and one inner spine at the distal part of third segment of second antenna.

GENERAL REMARKS

The present collection of phyllosoma larvae from the eastern part of Bay of Bengal and western part of Andaman Sea around Andaman and Nicobar Islands has indicated the dominance of larvae of *Panulirus homarus* among the palinurids and those of *Scyllarus martensii* among scyllarids, which might have been due to the presence of larger adult population of these two species in the region, as suggested by Prasad and Tampi (1965). Though the adults of *P. wienckii, P. mossambicus, S. martensii* and *S. batei* are not recorded so far from this area, the collection of their larvae indicates their availability in these oceanic islands.

Among the 165 larvae collected, 80 belonged to palinurids. Such dominance of palinurids over the other groups is reported by Prasad *et al.* (1975) from the Indian Ocean. The greater abundance of larvae in the IKMT hauls made during the night in the depth range of 26 to 75 m has indicated the resultant of the upward migration, as observed in the earlier studies on the distribution of phyllosoma larvae (Johnson, 1960; Saisho, 1966; Chittleborough and Thomas, 1969; Prasad, 1978; Rimmer and Phillips, 1979). Moreover, Prasad (1978) has opined that the concentration of larvae in the upper 100 m zone is related to the distribution of pycnocline values. The record of early larval stages in the distant waters and those of advanced stages in the nearshore waters (see Fig. 2) suggests the possible emigration and immigration of larval forms through the offshore/onshore currents. However, more oceanographical data is required to confirm this view.

The larval stages of *P. sewelli, P. angulatus* and *P. mossambicus* described here have shown the salient characters noted for early stages of respective species by Tampi and George (1975) and Prasad *et al.* (1975).

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LARVAE OF *AMPHIONIDES REYNAUDII* (H. MILNE EDWARDS) CRUSTACEA: (EUCARIDA) FROM THE ARABIAN SEA

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Abstract

Larvae of *Amphionides reynaudii* (H. Milne Edwards) Crustacea: Eucarida are pelagic with transparent flattened carapace and elongated thoracic appendages similar to phyllosoma larvae of Scyllaridae but differing from them in the absence of a constriction in the cephalothorax. Larvae of *A. reynaudii* were present in the plankton collected at 20 stations during cruise 11 (26th December, 1985 to January, 1986) by FORV *Sagar Sampada* in the Arabian Sea. Sixty five larvae were collected and they ranged from 3.0 mm to 19.0 in length. The different stages and their distribution are presented here.

Introduction

Gurney (1936) reported the occurrence of about a hundred specimens of *Amphion* and one of *Amphionides* from the plankton collection of *Discovery* Expedition. Heegard (1969) examined 5,108 specimens collected by various *Dana* and other Danish Expeditions sponsored by Calrlsberg Foundation and allotted them all to one species *Amphion reynaudii* H. Milne Edwards distributed throughout the tropical and the subtropical oceans. He described the full developmental cycle of *Amphion* from larvae to adult but not sexually mature male or female.

Williamson (1973) studying the specimens collected by the International Indian Ocean Expedition and by R.R.S. *Discovery,* changed the family and generic name respectively into Amphionididae and *Amphionides* Zimmer since the generic name *Amphion* H. Milne Edwards was preoccupied when first proposed. He suggested the erection of a new order Amphionidacea along with Euphausiacea and Decapoda under Eucarida. Williamson (1973) also described the sexual differentiation in the larvae and the unique form of thoracic brood pouch in female. Further, Williamson (1973) stated that comparatively four specimens were taken in either the Arabian Sea or the Bay of Bengal. The present paper reports the occurrence of *A. reynaudii* larvae from the Arabian Sea.

Material

Forty four plankton samples collected at different stations during cruise 11 (26th December, 1985 to 17th January, 1986) of FORV *Sagar Sampada* in the Arabian Sea were examined for *Amphionides* larvae.

Results

Sagar Sampada material of *A. reynaudii* consisted of sixtyfive specimens and they were taken at twenty stations in the Arabian Sea extending from 8°00N to 17°00N and from 70°00E to 75° 00E. Particulars about them are given in Table 1 and Figure 1.

Table 1. Amphionides reynaudii *from the southwest coast of India*

Station	Date	Time (hrs)	Position Lat. °N	Position Long. °E	No. of specimens	Length range (mm)
326	28-12-'85	0500	17°00'	70°00'	1	0.0-6.0
327	28-12-'85	0800	16°00'	70°00'	3	5.5-7.5
329	29-12-'85	1145	16°10'	71°50'	2	6.0-7.0
330	29-12-'85	1700	16°00'	72°40'	1	0.0-5.5
332	30-12-'85	0615	15°00'	72°40'	2	6.5-7.5
338	02-01-'86	1715	11°00'	70°00'	2	9.0-19.0
342	04-01-'86	0720	08°00'	71°00'	3	6.5-8.5

Table 1. Contd.

Station	Date	Time (hrs)	Position Lat. °N	Position Long. °E	No. of specimens	Length range (mm)
344	05-1-'86	0600	10°00'	71°00'	1	0.0-3.3
345	05-1-'86	1500	11°00'	71°01'	1	0.0-8.0
348	06-1-'86	1930	14°00'	70°50'	1	0.0-7.0
355	09-1-'86	1500	11°00'	73°00'	6	3.1-7.5
357	10-1-'86	1000	13°00'	72°30'	7	3.3-6.5
358	10-1-'86	1500	14°00'	72°30'	5	5.5-6.0
360	11-1-'86	1430	13°00'	73°20'	7	3.0-6.5
361	12-1-'86	0015	12°00'	74°00'	2	4.2-8.2
362	12-1-'86	0915	11°00'	74°00'	6	3.3-5.8
363	12-1-'86	2000	10°00'	73°59'	1	0.0-3.3
364	13-1-'86	0575	09°00'	74°00'	5	3.3-8.0
370	15-1-'86	0800	08°00'	75°00'	6	4.5-6.5
372	16-1-'86	0130	10°00'	75°00'	3	4.0-5.5

Larvae of Amphionidae are pelagic with transparent flattened carapace and elongated thoracic appendages similar to phyllosoma larvae of Scyllaridae but differing from them in the absence of a constriction in the Cephalothorax. In morphology the specimens agree well with the description, given by Heegard (1969). Small rostral and postrostral spines are distinctly seen in all the specimens. Orbital spines are also present. The carapace is very much flattened. The abdomen has no spines. The telson is narrow becoming pointed and with spines the in early stages. Most of them (stage III to VI) have the last one of the four legs. Similar to the observation made by Williamson (1973), in the later stages, 19.0 mm specimens which had robust antennular peduncles showed uniramous 8th thoracic appendages and the 1st pleopod had short endopods as well as exopods.

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DISTRIBUTION AND ABUNDANCE OF STOMATOPOD LARVAE IN THE EEZ OF INDIA

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Abstract

The distribution pattern and abundance of the stomatopod larvae in the EEZ of India are reported based on the collections of the FORV *Sagar Sampada* for a period of 4 years from 1985-'88 during her voyages covering a number of stations both in the Bay of Bengal and the Arabian Sea. The results indicate that the stomatopod larvae are widely distributed in the Indian seas though, they are absent in some of the stations. The station-wise abundance of the stomatopod larvae in different depths are also discussed in detail.

Introduction

Our knowledge of the Indian Ocean stomatopods stems mainly from the monograph of Kemp (1913). He reported 97 species/varieties of stomatopods from the Indo-Pacific region and 54 from the seas around India. Other important contributions on adult stomatopods from Indian waters include the works of Kemp and Chopra (1921), Gravely (1927) and Copra (1934).

The information from the Indian seas on the larval stomatopods is scanty. Alikunhi (1950, 1965) studied the larval development in some species of stomatopods from Madras region. Shanbhogue (1975) studied the common stomatopod larvae occurring in the seas around India. The present paper deals with the distribution and abundance of stomatopod larvae in the EEZ of India.

Material and Methods

The present report is based on the larvae collected during 44 cruises of FORV *Sagar Sampada* for a period of 4 years from 1985 to 1988. Bongo - 60 net was used for collection of samples with a depth of haul upto 150 metres. The number of larvae collected in each station was computed as number of larvae/1000 m^3 of water. Although 1,293 stations were selected for the study of distribution of stomatopod larvae, they were present only in 1,200 stations.

Results and Discussion

The quantity of larvae (No./1000 m^3) varied between 3 and 3,347 at different localities in the EEZ. The average density of larvae in the shelf areas was more than in oceanic waters. In the SE region the quantity of larvae varied between 4 and 3,347 with an average of 129.12 (Table 1). In SW region the larval number ranged from 4 to 3,190 with an average number of 135.44, whereas in NE region it varied between 4 and 2,415 with an average number of 274.5 and between 4 and 944 in NW region. Table 1 shows the seasonal abundance of stomatopod larvae in different regions of EEZ of India. In 1985 the density of larvae during June and July was 44.25 and 141.28. In 1986 the density of larvae during February, March, June and July was higher compared to other months. In 1987, January, October and November recorded higher density of larvae compared to other months.

In India though more than 50% of the stomatopod landings come from SW coast (Sukumaran, 1987) the average density of stomatopod larvae was highest in NE region (274.5). The spawning season of *Oratosquilla nepa* along Karnataka coast is from March to June (Sukumaran, 1987) and the maximum density of larvae in this region was recorded during June. Since no information is available on the spawning season, and stomatopod abundance from other regions, it is difficult to compare the larval abundance with spawning season and landings of

TABLE 1. *Average monthly abundance of stomatopod larvae (No./1000 m^3) during 1985 - '88*

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1985	-	-	-	-	-	44.25	141.28	-	-	-	-	9.33
1986	20.86	278.23	292.21	45.13	92.63	227.93	323.79	84.55	159.96	46.27	49.43	38.50
1987	354.58	21.30	-	28.25	70.00	-	94.53	96.90	114.59	519.33	-	200.56
1988	13.09	100.25	190.22	-	-	-	-	-	-	-	-	-

Average number of stomatopod larvae (No. /1000 m^3) in different regions

S.W	N.W	S.E	N.E
135.44	87.63	129.12	274.50

adult stomatopods. However, higher density of larvae in NE region may be due to the current pattern which influence the distribution and dispersal of larvae.

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DISTRIBUTION AND ABUNDANCE OF PTEROPOD AND HETEROPOD MOLLUSCS IN THE EEZ AND ADJOINING WATERS OF INDIA

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Abstract

The pteropod and heteropod molluscs formed an important constituent in the zooplankton of the EEZ of India and the adjacent areas. Between them the pteropods dominated numerically over the heteropods in all situations. The average density of pteropods in the area investigated was 734 (expressed as number per 1000 m^3 of water) and heteropods was 335. Both the groups were more in the eastern Arabian Sea than in the Bay of Bengal. However, the difference in the rate of occurrence in the two sea areas was more pronounced in the case of heteropods, being 46.56% against 21.35% for the other group. Both the groups were relatively more in the shelf waters, the increase over the oceanic area being more than one and a half times for the pteropods which sometimes exhibited some kind of population explosion in the shelf waters. For the heteropods the incease in the shelf area was of the order of 87.88%. The pteropods had a trimonthly abundance, say, during February, May, August and November. November and December were the favourable months for the heteropods. A seasonal variation was not very significant for both the groups. However, pteropods were comparatively more during the premonsoon season off the west coast (826) and the east coast (729). With regard to heteropods, while an increase (449) was noticed in postmonsoon season in the eastern Arabian Sea, in the Bay of Bengal the increase was during the premonsoon period (373). In the eastern Arabian Sea there appeared to be a gradual reduction in population of both the groups from south to the north. However, in the Bay of Bengal the situation prevailed was exactly the opposite. The observed reduction in population was effected through the various seasons starting from premonsoon through monsoon to the postmonsoon. A population outburst was noticed for pteropods in the shelf waters of the southernmost latitudinal region of the eastern Arabian Sea during the permonsoon. In the same region off the east coast a similar phenomenon occurred during the monsoon season. The day-night variations in the two groups was striking in that both had an overall increase by 27% in the night samples. There was considerable difference in regard to diurnal variations during different months for pteropods and heteropods.

Introduction

Pteropods and heteropods are two groups of pelagic marie gastropod molluscs found abundantly in the zooplankton. The former is a sub-order belonging to the Sub-class Euthyneura, Order Ophisthobranchiata. The latter comes as a section of Suborder Taenioglossa which belongs to the Sub-class Streptoneura and Order Aspidobranchiata. These two groups from the Indian Ocean have been studied in the past from the taxonomic point of view (Ref: various expeditions which visited the Indian Ocean). Some studies have been made in the Indian Ocean on the spatial distribution and quantitative abundance of some species of pteropods and heteropods. Sakthivel (1969) made a preliminary study on the distribution and relative abundance of euthecosomatous pteropods in general and the seasonal variation of species of the genus *Limacina*. The seasonal and diurnal variations and also the spatial abundance of *L. inflata* was studied, again, by Sakthivel (1973a). The biogeographical change in the latitudinal boundary of a species of pteropod was also investigated by him (Sakthivel, 1973b). Aravindakshan (1969) has given a preliminary report on the geographical distribution of some species of heteropods of the Indian Ocean. Later he (Aravindakshan, 1973) made a study on the distribution and ecology of one species of pterotrachea. Another study made by him was on the distribution of the species of the family Pterotracheidae in the Indian Ocean (Aravindakshan, 1977).

The above studies being highly generalised for the Indian Ocean as a whole and supported by relatively less number of samples, they cannot be considered conclusive. For the geographical distribution, the average values for 5° squares only were worked out which again tell upon the inadequacy of samples. The present study pertaining mainly to the EEZ of india based on a relatively large number of samples has permitted a microlevel analysis of the spatial distribution on a half-degree basis and of other aspects of abundance.

The material and methods have been detailed in the paper dealing with the zooplankton biomass given elswhere in this volume (Mathew *et al.*,1990) The unit biomass is always expressed as number per 1000 m³ of water.

Results and Discussion

While sorting zooplankton collected onboard FORV *sagar sampada* it was found that the planktonic gastropods formed a major constituent. Among them the pteropods and heteropods had a major share quatitatively and hence were taken up for a common consideration to facilitate a rather comparative study. Some species of the pteropods are known for their swarming habit in the shelf waters during some months when the food is plentiful. In view of this, the pteropods were considered separately from the heteropods.

In all the situations the pteropods surpassed the heteropods in number. Thus while the pteropods had an average density of 734 in the entire area of study, the heteropods had an average concentration of 335 only. The former group occurred at a rate of 790 in the eastern Arabian Sea and at a rate of 651 in the Bay of Bengal. The heteropods also had a dominance off the west coast with 384 individuals against 262 in the Bay of Bengal.

The abundance of pteropods in the continental shelf waters was the most striking. While they were present at a rate of 1,292 in the shelf waters, the oceanic area had them at a rate of 489 only. Such abundance in the shelf waters could be due to the swarming of pteropods in certain months. Such a difference in abundance was not noticed with the heteropods whose density in the two sea areas was 496 and 264 respectively. Both the groups exhibited difference in the diurnal occurrence also, being more in night samples. An interesting point noted was that the percentage of increase in night samples was exactly the same for both the groups (27%) which may suggest their equal ability to perform diurnal vertical migration.

Distribution in space

The pteropods had a cosmopolitan distribution in the area investigated, of course, in varying densities and this is shown in Fig. 1. Very high-density areas where the number of pteropods exceeded 5,000 per 1000 m³ of water were found off Ratnagiri, Kanyakumari, Madras and south of Calcutta. High-density areas where the range was between 2,000 and 5,001 occurred off Paradeep, around Andamans, north of Cochin, in the Lakshadweep seas and southwest of Veraval.

The spatial distribution of heteropods is presented in Fig.2. They also enjoyed a universal distribution but in smaller quantities. Area of maximum density exceeding 5,000 was observed north of Cochin in the shelf waters, besides other pockets in the shelf and oceanic areas as seen from Fig. 2.

Monthly variations

In the case of pteropods, November accounted for the maximum abundance with 1,541 which can be considered a swarm (Fig. 3). The least abundance was in October with 328 specimens. On the whole the April-October period was comparatively less productive with the exception of May and August. It was interesting to note that from February onwards, once in every three months there was an unusual increase in population.

With regard to heteropods also, November accounted for the maximum abundance with 752 specimens. December also had a proportionately high density. Any significant variation in other months was not noticed (Fig. 4). September with 186 individuals represented the month of least abundance.

On a consideration of the coastwise monthly abundance of the two groups, it was found that in most of the months the pteropods occurred in greater numbers in the eastern Arabian Sea (Fig. 5). In the Bay of Bengal they were relatively more abundant in April, August and January. Off the west coast, while November with 1,541 pteropods stood first, off the east coast it was August which yielded the maximum number, of course, of a low magnitude (992). In regard to heteropods also, abundance in the Bay of Bengal was noticed in February, April and October (Fig. 6). In the eastern Arabian Sea they had the greatest abundance in June.

Seasonal variations

A further consideration of the abundance on the basis of three seasons, viz., premonsoon (February - may), monsoon (June - September) and postmonsoon (October - January) in the two sea areas separately, revealed that no significant difference was observed in the case of pteropods during the three seasons either in the eastern Arabian Sea or in the Bay of Bengal. The differences between the seasons of maximum and minimum abundance were 46 in the former sea area and 209 in the latter. As far as the heteropods also are concerned, there was no

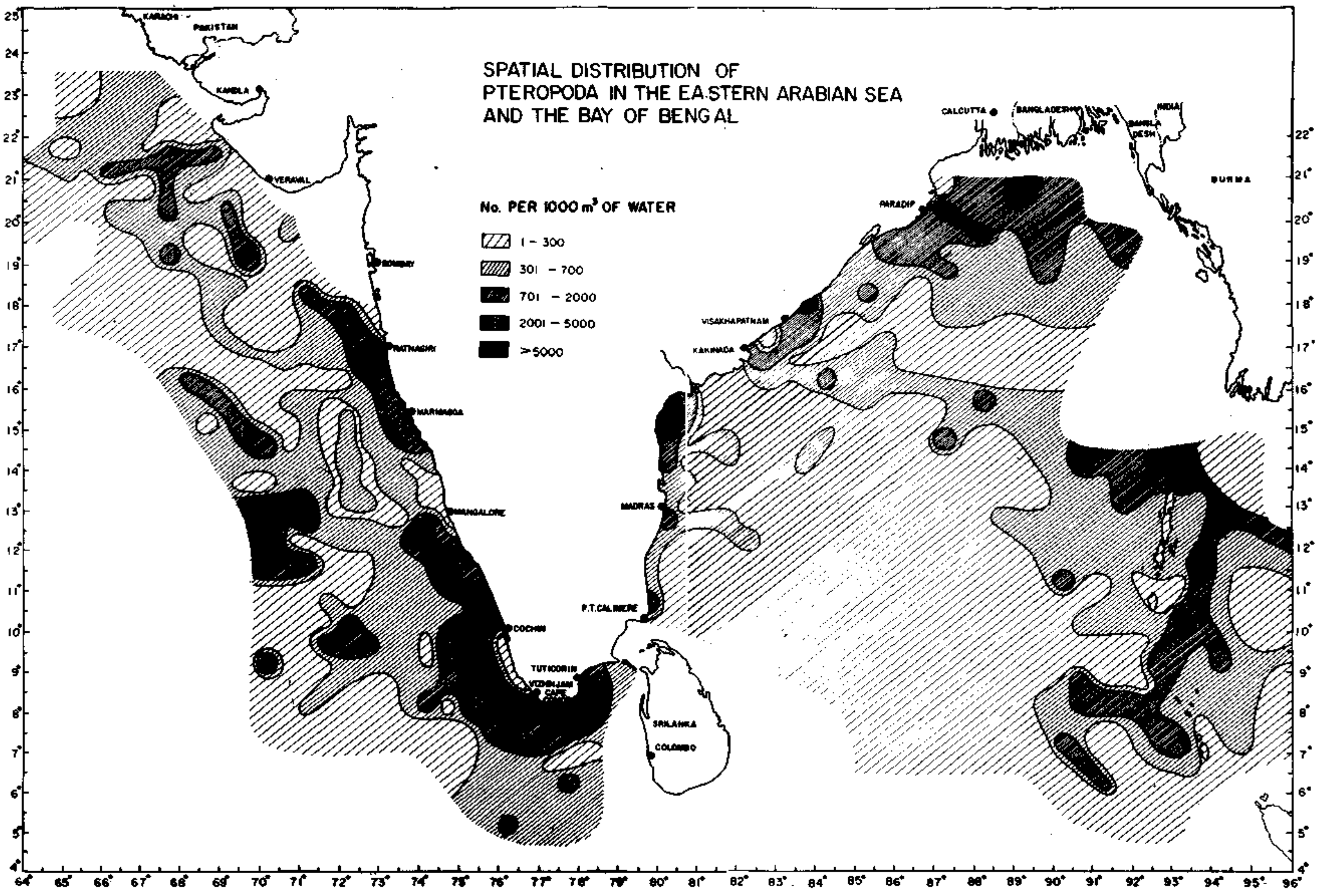

Fig. 1. Spatial distribution Pterpoda in the EEZ of India and adjacent seas.

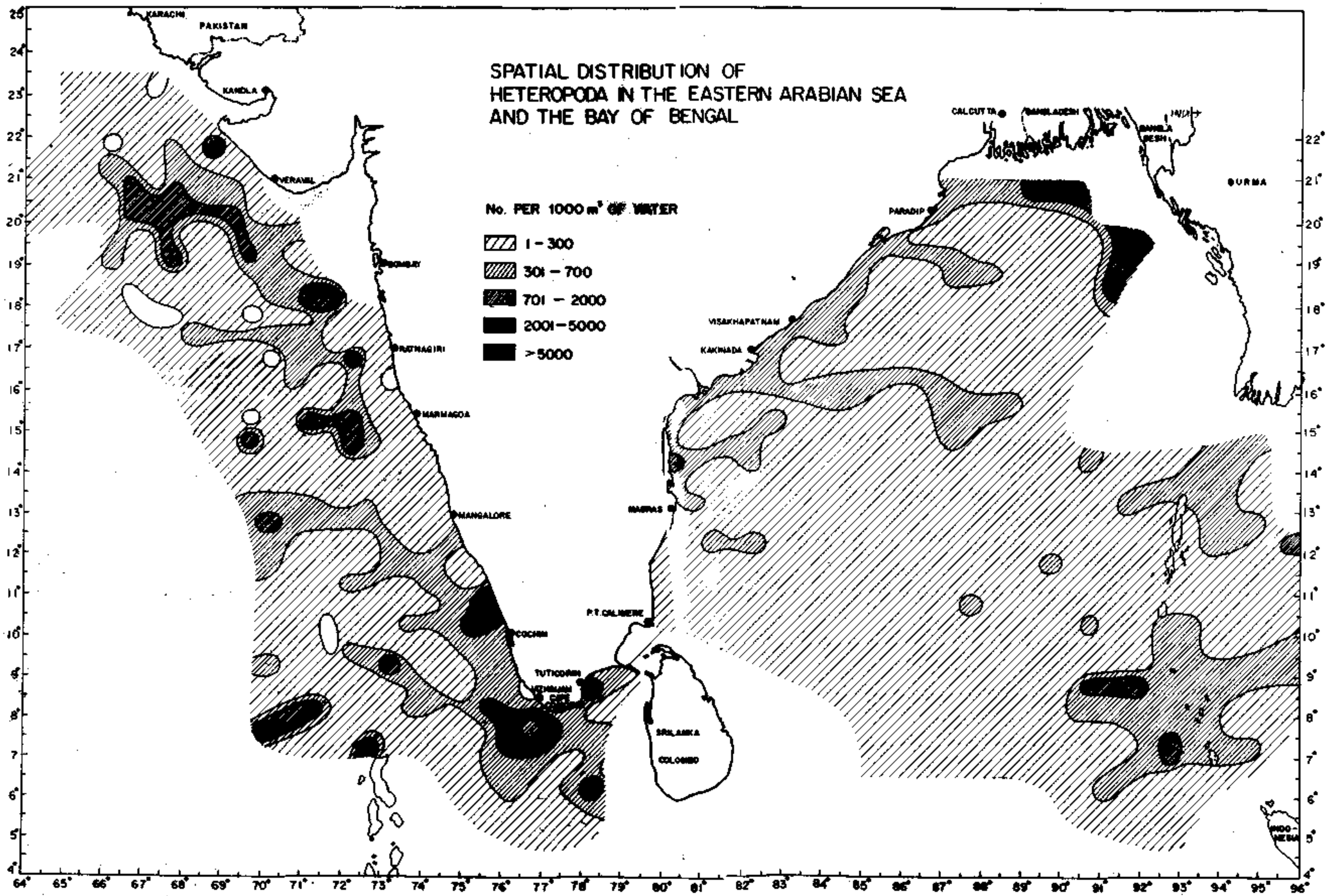

Fig. 2. Spatial distribution of Heteropoda in the EEZ of India and adjacent seas.

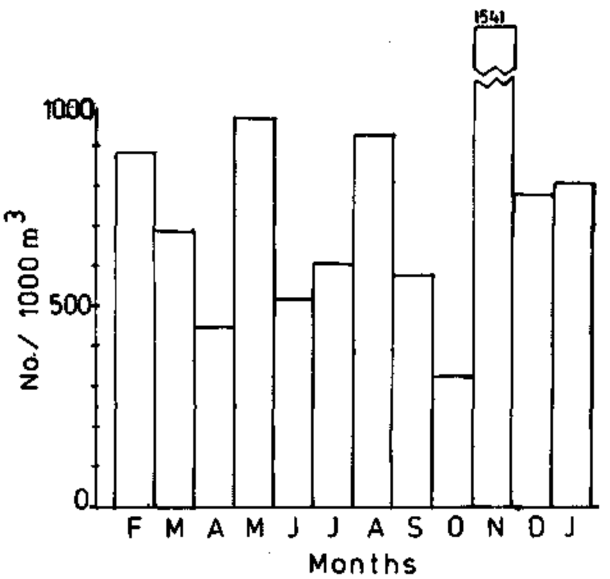

Fig. 3. Monthly abundance of Pteropoda in the area investigated.

substantial seasonal difference off the west and east coasts.

Monthly distribution in the shelf and oceanic areas

As seen from Figs. 7 and 8, the pteropods and heteropods were more abundantly present in the shelf area than the oceanic. When the shelf area contribiuted pteropods at the rate of 1,292, the share of the oceanic area was only 489. Its maximum density in the shelf was observed during March, June and December. An interesting point noted was that some kind of population outbursts occurred in the shelf waters in these months during which the density went up sharply from 1,091 in may to 4, 454 in June and from 380 in November to 4,824 in December. However, similar outbursts in population never

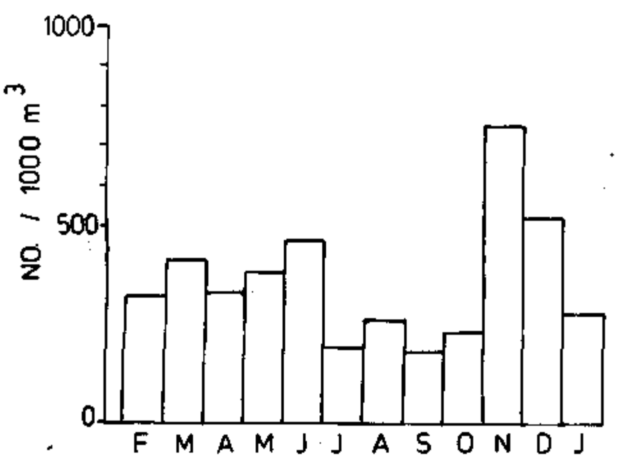

Fig. 4. Monthly abundance of Heteropoda in the area investigated.

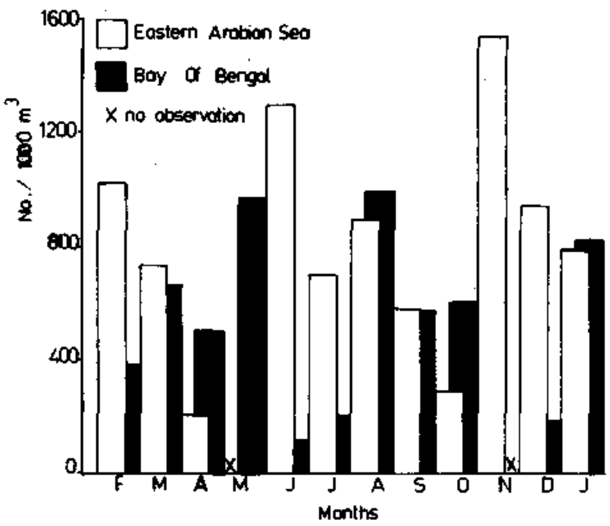

Fig. 5. Monthly abundance of Pteropoda in the eastern Arabian Sea and the Bay of Bengal.

occurred in the oceanic waters even though ups and downs in population size took place in different months.

In the case of heteropods, a sudden increase in population took place in December only, of course, in a moderate way (Fig. 8). In the oceanic areas vast variations were not noticed in different months.

Coast-wise latitudinal abundance

With regard to both the groups there was a gradual reduction in population from the southern to the northern latitudes in the eastern Arabian Sea (Figs. 9 & 10). While in the southernmost region 1,126 specimens of pteropods were taken, the contribution of the northernmost region was at a rate of 390 specimens only. Similarly the heteropods from a maximum of 496 in the southern latitudinal region

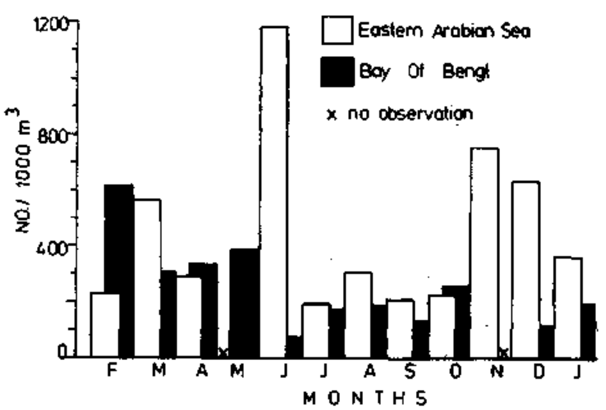

Fig. 6. Monthly abundance of Heteropoda in the eastern Arabian Sea and the Bay of Bengal.

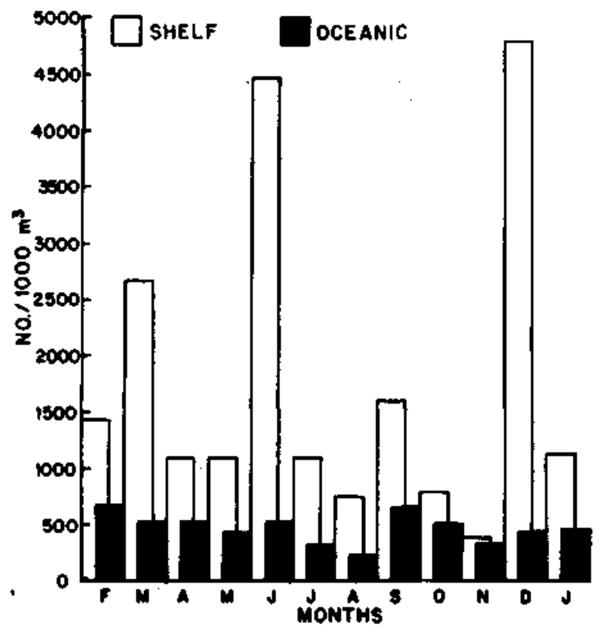

Fig 7. Monthly abundance of Pteropoda in the shelf and oceanic waters.

thinned down to 355 in the northernmost region.

In the Bay of Bengal the situation was almost the opposite: the two groups were more in the northern latitudes (Figs. 9 & 10).

Latitudinal seasonal abundance off the two coasts

Figs. 11 and 12 show the seasonal variations of pteropods and heteropods in the four latitudinal regions in the eastern Arabian Sea and the Bay of Bengal. In all the latitudinal regions, the density of pteropods during different seasons was almost diametrically opposite in the two sea areas (Fig. 11). While in the southernmost region in the eastern Arabian Sea there was a gradual reduction in population from the premonsoon through monsoon to

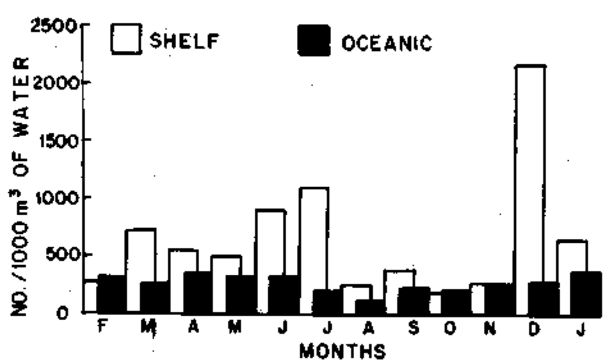

Fig. 8. Monthly abundance of Heteropoda in the shelf and oceanic waters.

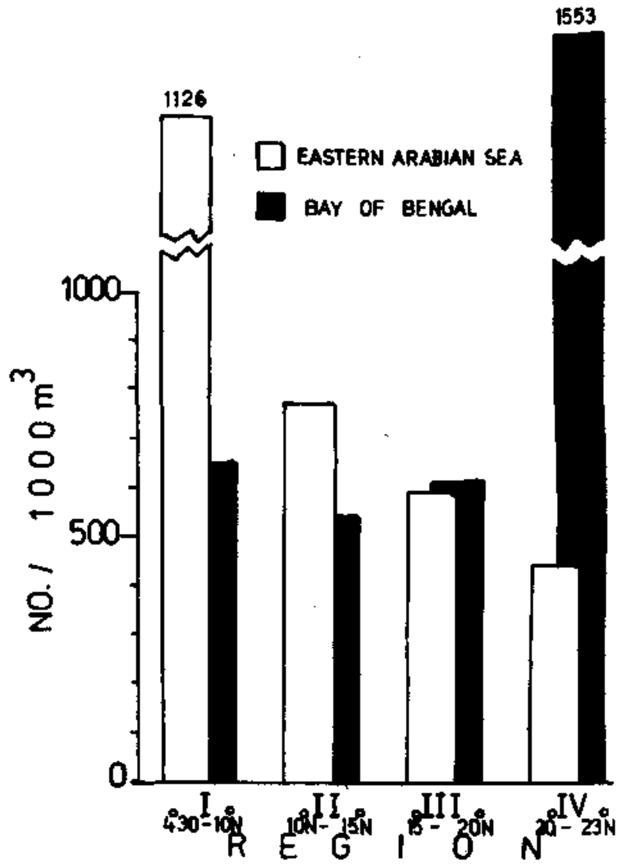

Fig. 9. Latitudinal abundance of Pteropoda in the eastern Arabian Sea and the Bay of Bengal.

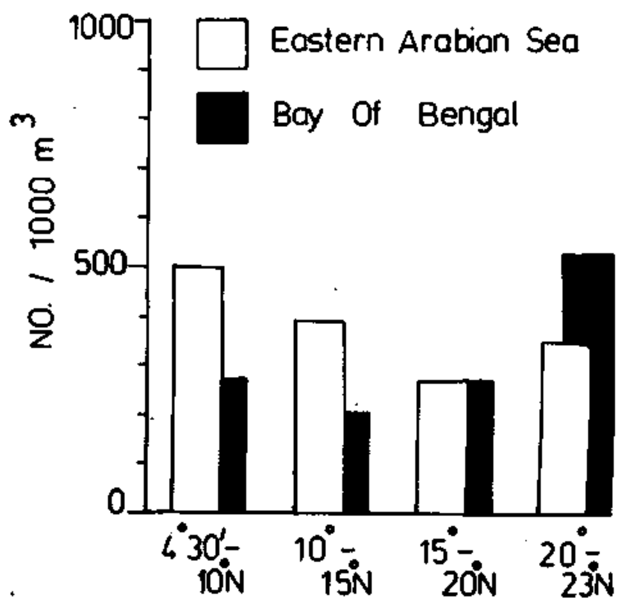

Fig. 10. Latitudinal abundance of Heteropoda in the eastern Arabian Sea and the Bay of Bengal.

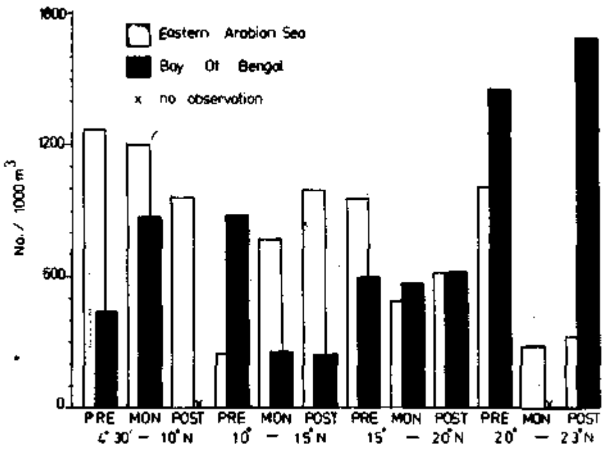

Fig. 11. Seasonal abundance of Pteropoda in the various latitudinal regions of the eastern Arabian Sea nd the Bay of Bengal.

postmonsoon, in the Bay of Bengal in the same region an increasing trend was noticed from premonsoon onwards. In the second region the density was the least during premonsoon in the eastern Arabian Sea, which gradually increased to the postmonsoon season. At the same time in the Bay of Bengal the pteropod population decreased from a premonsoon maximum to a postmonsoon minimum. Almost the same was the trend in the third and fourth regions also.

In the case of heteropods, the trend of variation of populations in the various latitudinal regions of the two sea areas during different seasons was noticed in an opposite way in the two southern latitudinal regions (Fig. 12). In the third and the fourth regions of the eastern Arabian Sea and the Bay of Bengal, the seasonal fluctuations followed the same trend, either increasing or decreasing.

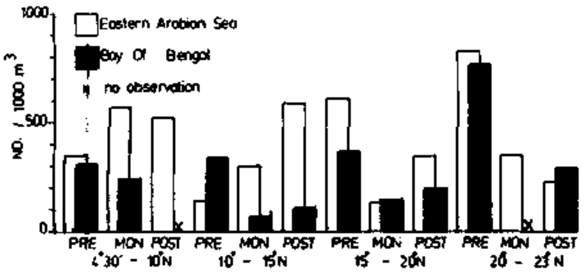

Fig. 12. Seasonal abundance of Heteropoda in the various latitudinal regions of the eastern Arabian Sea and the Bay of Bengal.

Abundance in the shelf and oceanic waters of the four latitudinal regions of the west and east coasts during different seasons

A still finer analysis of the data was made to understand the variations in the abundance in the shelf and oceanic areas of the various latitudinal regions in the two sea areas and the results obtained are given in Fig. 13 for pteropods and in Fig.14 for heteropods. One significant observation made was that the pteropods experienced an explosion of the population in the shelf waters of the southernmost latitudinal region of the eastern Arabian Sea during the premonsoon. Off the east coast three such population explosions occurred in the shelf waters but of comparatively less intensity during the monsoon in the first latitudinal region and during the premonsoon in the second and the fourth regions. In general the populations of pteropods were significantly more in all the regions in the shelf water.

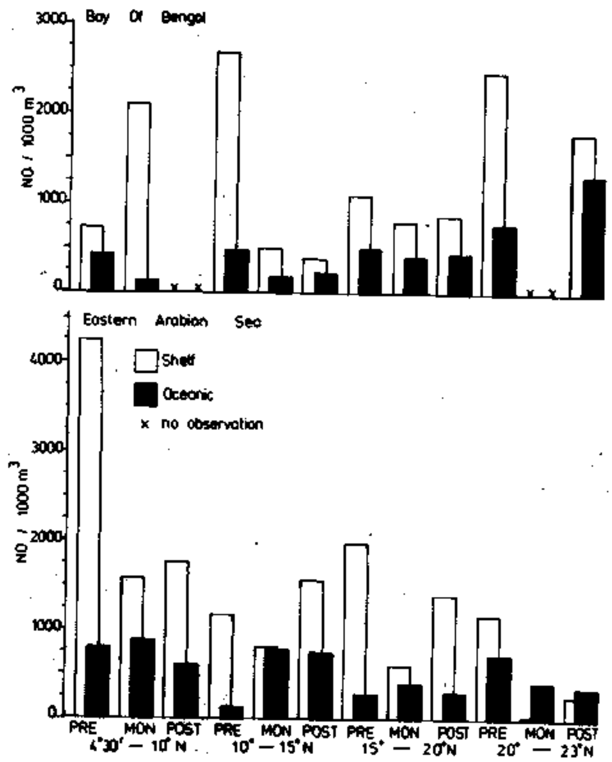

Fig. 13. Seasonal abundance of Pteropoda in the shelf and oceanic waters in the different latitudinal regions of the eastern Arabian Sea and the Bay of Bengal.

With regard to heteropods also population density was more in almost all latitudinal regions and seasons in the shelf waters but population outbreaks were not as intense as in pteropods. However, very high numbers were noticed in the shelf waters of the northernmost region in the two sea areas (Fig. 14).

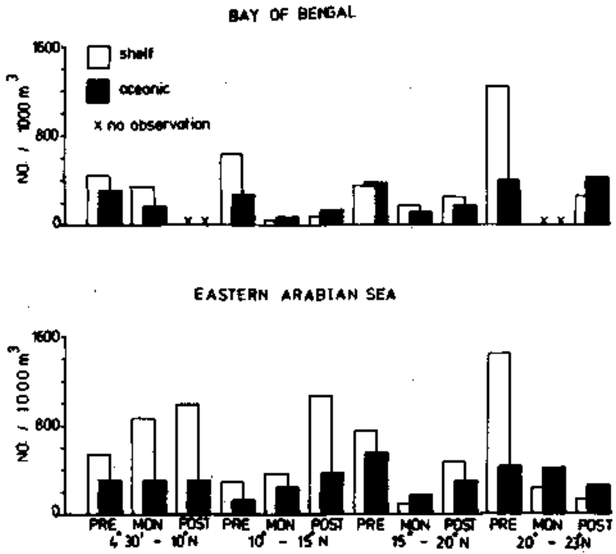

Fig. 14. Seasonal abundance of Heteropoda in the shelf and oceanic waters in the different latitudinal regions of the eastern Arabian Sea and the Bay of Bengal.

Day -night abundance

There was a clear difference in the day-night occurrence of both pteropods and heteropods (Figs. 15 & 16) with more numbers in the night samples. The overall increase in the night samples amounted to about 27%. When considered on a monthly basis it was found that in February, March and August, the

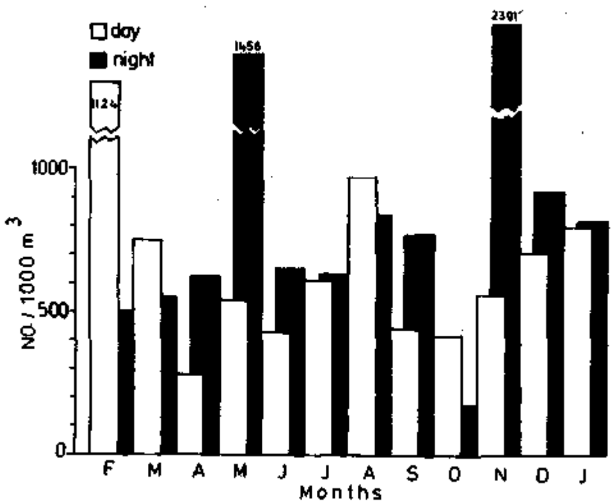

Fig. 15. Monthly day - night variations in the abundance of Pteropda.

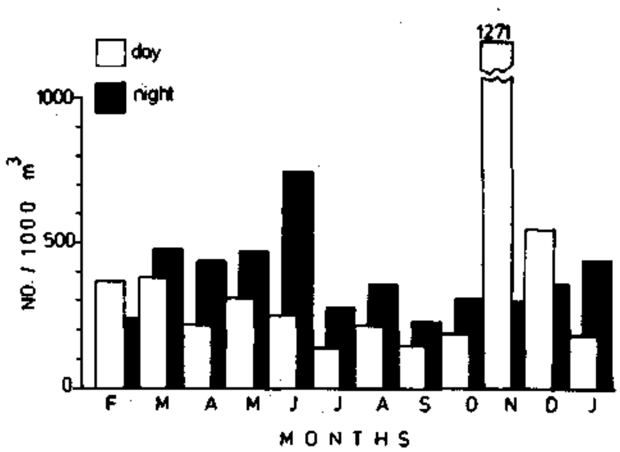

Fig. 16. Monthly day - night variations in the abundance of Heteropda.

day samples had relatively more pteropods. The diurnal variation was least noticed in June for this group. The night time abundance was phenomenal in May and November when 3-5 times increase was observed.

When compared to pteropods, the monthly diurnal variations among heteropods were not very striking except in June and November. In the former month, more than 100% increase was noticed in the day samples. The other months which exhibited a day time abundance though of low magnitudes were February and December. In general the monsoon months had more number of heteropods in the night samples.

Acknowledgements

We are thankful to Dr. P.S.B.R. James, Director, CMFRI for his keen interest shown in this work. Our thanks are also due to Dr. K. S. Scariah and Shri P.P Pavithran for the help rendered in the computer analysis of the data.

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STUDIES ON THE OCCURRENCE AND ABUNDANCE OF PLANKTONIC GASTROPODS OTHER THAN PETROPODS AND HETEROPODS FROM THE EEZ OF INDIA AND ADJOINING SEAS

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ABSTRACT

The observations made during 1985- '88 between 4°30'N and 23° N lat. and 65°E and 96° E long. in the eastern Arabian Sea and the Bay of Bengal on the distribution and abundance of planktonic gastropods, other than pteropods and heteropods, at 1,086 stations sampled by FORV *Sagar Sampada* during her cruises 1-44 showed that they were present in 83% of the samples at an average density of 877 (number per 1000 m³). Their population density in the eastern Arabian Sea (1,137) was more than double that in the Bay of Bengal (489) and was distinictly higher in the shelf (1,059) than in the oceanic waters (797). The concentration of pelagic gastropods observed between 14° N and 20° N lat. in the eastern Arabian Sea was high, and that (1,65,349) encountered in a half degree square in the oceanic region off Karwar was the highest. The abundance was comparatively high from September to December in the eastern Arabian Sea and from February to March and during August in the Bay of Bengal. A comparison of the planktonic gastropod content in the samples collected during day with those taken at night showed that they were more abundant in the latter (1,290) than in the former (609) with an increase of 8% and 233% respectively in the shelf and oceanic waters.

INTRODUCTION

Marine gastropods, the largest and the most successful of all molluscs, have a thriving fishery in the seas around India and are much valued, for their ornamental shells, in religious rituals, in indigenous medicine, for the manufacture of lime and for the meat used as bait and to a very limited extent as food. The developmental stages of these benthic gastropods as well as a few isolated holoplanktonic gastropod genera other than pteropods and heterpods form occasionally a significant part of the plankton of the warm tropical seas around India. These planktonic gastropods were found to be an important food item for the planktivorous fishes (Rao, 1962; Kagwade, 1967; Desai, 1971).

Natarajan (1957) reviewed the information on the eggs and larvae of marine gastropods from the world oceans and studied the breeding season and larval development for 32 species of prosobranchs from the Palk Bay and the Gulf of Mannar. Prasad (1954), Mahadevan and Nayar (1966) and Siraimeetan and Marichamy (1988) studied the seasonal occurrence of gastropod larvae in the Gulf of Mannar. Achuthankutty *et al.* (1980) estimated the numerical abundance of this planktonic fauna from 47 stations in the western Bay of Bengal. In the eastern Arabian Sea, the seasonal occurrence of planktonic gastropods from the inshore waters of Karwar (Naomi, 1986), Calicut (Mukundan,1967), Colachel (Suseelan *et al.*, 1985) and Vizhinjam (Rani Mary *et al.*, 1981) has been reported. Distribution map of meroplanktonic Gastropoda (IOBC, 1971) based on 1,548 samples from the Indian Ocean is the only available work with a wide coverage on the seasonal and spatial variations.

The planktonic gastropods other than the holoplanktonic pteropods and heteropods can be said to be the least studied component of the zooplankton compared to the wealth of information available on the distribution of adult gastropods along the Indian coasts (Jones, 1970; Rao, 1973; Nayar and Mahadevan, 1973; Nayar *et al.*, 1985; Sundaram, 1974; James, 1988; Devaraj and Ravichandran, 1988). The present study based on material from 1,086 stations collected by FORV *Sagar Sampada* in the shelf and oceanic waters of the eastern Arabian Sea, the Bay of Bengal and the Andaman Sea was undertaken to highlight the salient features of the spatial and temporal distribution of planktonic gastropods other than pteropods and heteropods.

MATERIALS AND METHODS

The studies were based on 1086 plankton samples collected since January, 1985 to March ,1988 in the area within 4° 30' N to 23° N lat. and 75°E to 95°E long. by oblique tows from 150 m to surface using a Bongo- 60 net (mesh aperture 0.33 mm), equipped with a calibrated flow meter. The average No. /1000 m^3 per half a degree square pooled for 1985 - '88 was taken as the index of abundance with reference to area and time.

The faunal content of the eastern Arabian Sea (65° to 77° 30' E long.) is compared with that of the Bay of Bengal (77° 30' to 95° E long.). Latitudinal variations of the fauna between region I (from 4° 30' N to 10° N lat.), region II (10° N to 15° N lat.), region III (15° to 20° N lat.) and region IV (beyond 20° N upto 23° N lat.) in the eastern Arabian Sea and Bay of Bengal are compared. The Shelf region of the eastern Arabian Sea or the Bay of Bengal is compared with the respective oceanic region. Premonsoon (Feb. - May), Monsoon (June - Sept.) and postmonsoon (Oct. - Jan.) were the periods identified for comparing the variations between seasons. Samples collected from 0600 to 1800 hrs were taken as day samples and 1800 to 0600 hrs as night samples for studying the day - night variations in distribution.

Observations

Spatial distribution

The planktonic gastropods were present in 83% of the samples with an average density of 877 from the seas around India.

The fauna was found distributed as patches of varying densities over the area investigated with the greatest concentrations in the northern half of the eastern Arabian Sea between 14°N and 20°N latitude (Fig. 1). The mean concentration of this pelagic fauna encountered in a half degree area in the oceanic waters of Karwar was the highest (1,65,349). Their abundance was observed to range between 33,254- 59,487 in the high density pocket observed off Bombay. The group occurred in a continuous stretch from Karwar to Cape Comorin along the outer shelf spilling over to the adjacent oceanic waters with dense pockets off Mangalore, Calicut, Cochin, Alleppey and Vizhinjam-Cape Cormorin extending down to 5°N lat. A patch of fairly high density was observed in the region between 8°30'N and 11°N lat. around Lakshadweep.

In the Bay of Bengal, the density (11,356) observed at the head of the Bay was the highest. A similar dense area was observed off Tuticorin (10,703) and comparatively high production occurred in the waters of the Gulf of Mannar. Fairly high density pockets were also encountered at the mouths of River Krishna (5,884) and Cauvery (2,191). Except for a narrow belt of moderate concentration off Andhra and Orissa coasts and a few isolated patches in the oceanic waters, their density was of low order in the central Bay.

In the Andaman Sea, moderate abundance of planktonic gastropods was observed with pockets of denser areas (2,500-2,800) between 9°N and 10°30'N lat. and to the west of the Great Nicobar Island.

Regionwise distribution in the eastern Arabian Sea and the Bay of Bengal

The population density of planktonic gastropods was higher in the four latitudinal regions of the eastern Arabian Sea than the corresponding regions of the Bay of Bengal (Fig. 2) with the maximum variation in their densities observed between 15°N and 20°N latitudes (1,731 and 501 respectively).

In the eastern Arabian Sea it is highly significant that a progressive increase in the number of planktonic gastropods was observed from the southern (mean density of 759 and 882 in the region from 4°30'N to 10°N lat. and from 10°N to 15°N lat. respectively) to the northern latitudes (mean density of 1,423 in the region from 20°N to 23°N lat.) with the major concentration confined between 15°N and 20°N latitudes (1,731).

In the Bay of Bengal the highest concentration of planktonic gastropods was observed in the northernmost region beyond 20°N lat. (1,171). A drastic reduction in their population density was observed south of 20°N lat. (501 in the region from 20°N to 15°N lat. and 323 in the region from 15° to 10°N lat). However, their abundance between 10°N and 4°30'N lat. (554) was highest than those of the regions between 20°N and 10°N latitudes.

Monthly variations in the seas around India

The monthly variations in abundance for the total area surveyed showed that the fauna was present throughout the year in the seas around India (Fig. 3). From the lowest number (171) observed in July, their abundance increased steadily from August to reach the maximum number (4,580) in November. Their abundance was moderate from January (515) to May (493).

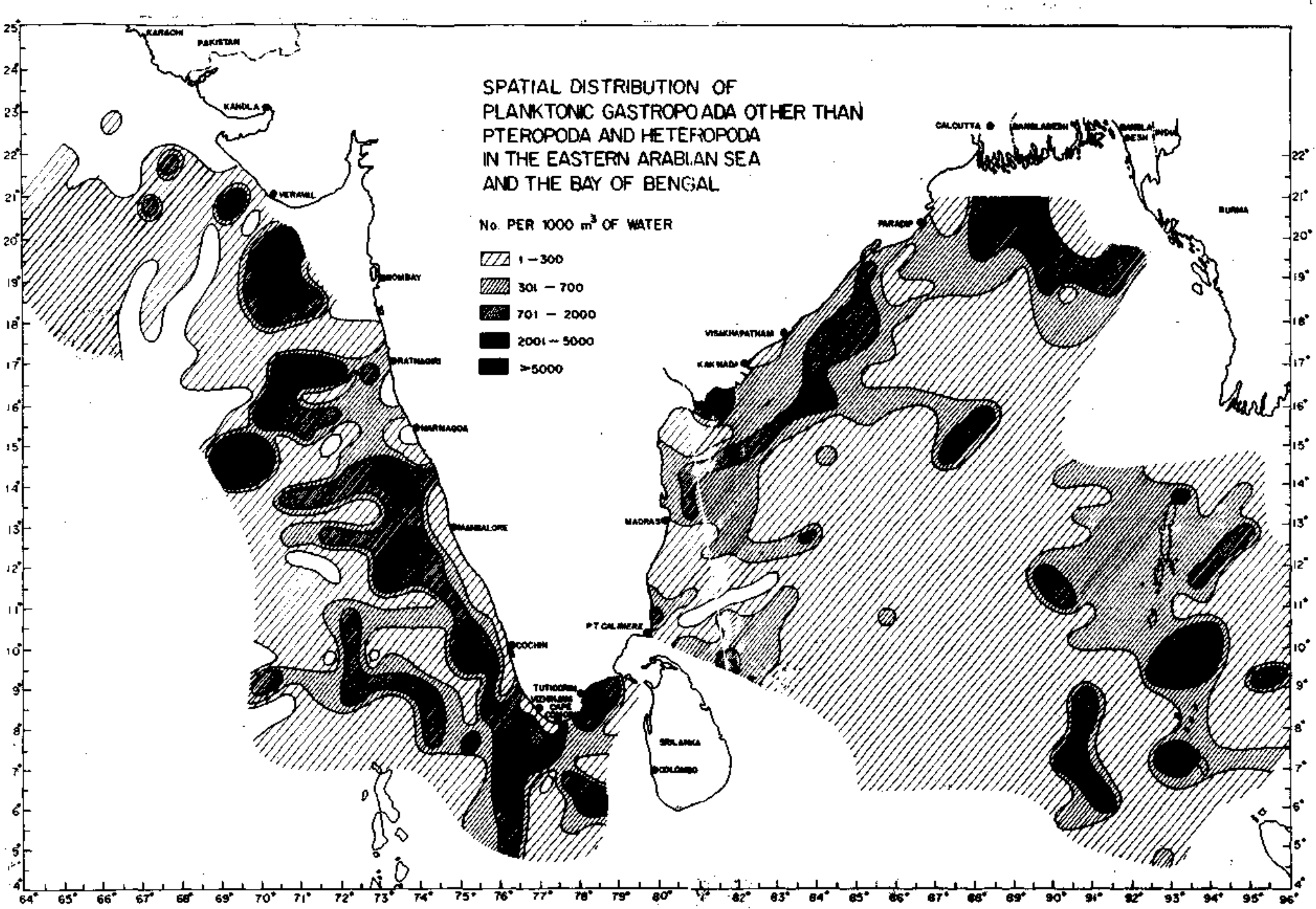

Fig. 1. Spatial distribution of planktonic Gastropoda other than Pteropoda and Heteropoda in the eastern Arabian Sea and the Bay of Bengal.

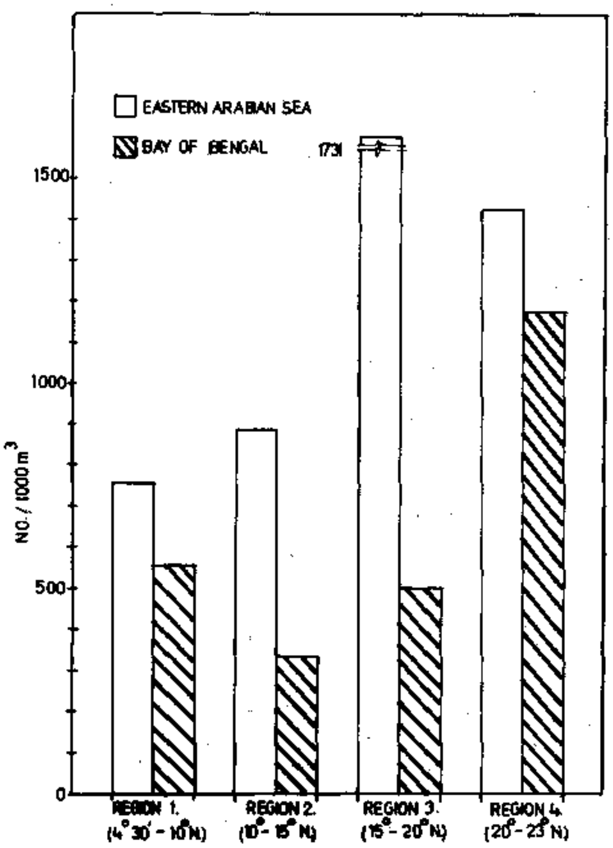

Fig. 2. Regionwise distribution in the abundace of planktonic gastropods other than pteropods and heteropods in the eastern Arabian Sea and the Bay of Bengal.

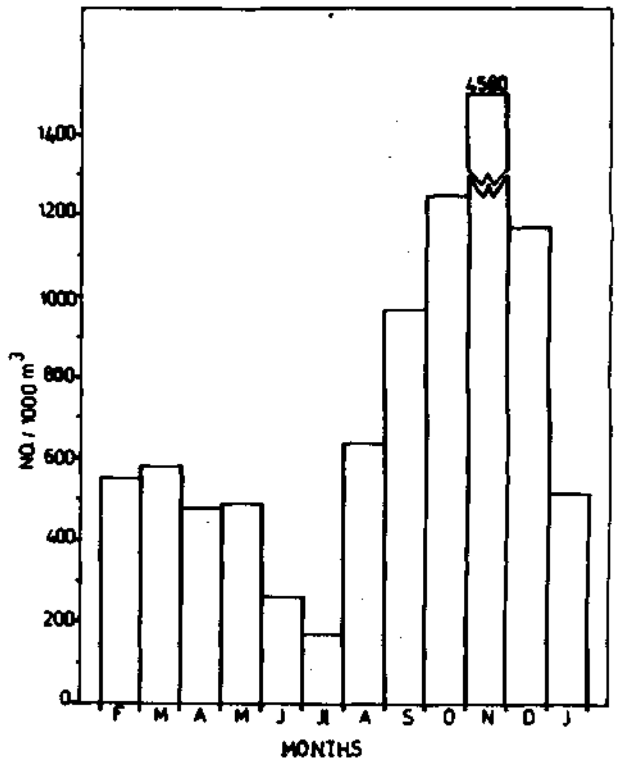

Fig. 3. Monthly variations in the abundace of planktonic gastropods other than pteropods and heteropods in the seas around India.

Monthly variations in the eastern Arabian Sea and the Bay of Bengal

The density of planktonic gastropods was observed to be 40% more in the eastern Arabian Sea than in the Bay of Bengal, (Fig. 4) with an average concentration of 1,137 and 489 respectively.

In the eastern Arabian Sea the numerical abundance of gastropods which showed a steady increase from September reached the maximum in Novemebr while in the Bay of Bengal the primary peak noticed in March was followed by a secondary peak in August. The least abundance of the group was observed in April in the eastern Arabian Sea and in June in the Bay of Bengal.

It was observed that in the eastern Arabian Sea the abundance of planktonic gastropods started to increase as the intensity of the southwest monsoon decreased and attained the maximum during the postmonsoon season. In the Bay of Bengal, their concentration which was observed to increase as the intensity of the northeast monsoon decreased reached the maximum soon afterwads. The increased abundance observed in August was just after the peak of the southwest monsoon.

Monthly variations in the shelf and oceanic areas of the seas around India

Planktonic gastropods were found to be more abundant in the shelf (1059) than in the oceanic waters (797) with a 14% increase in their density in the shelf over that of the oceanic waters (Fig. 5).

It may be seen that in the shelf waters the increase in their abundance from August reached the maximum in October (2,549) whereas in the oceanic waters an unprecedented population outburst (5,769) occurred in November in contrast to their sparse distribution (< 574) observed during the rest of the months.

In the shelf as well as the oceanic waters, the abundance of planktonic gastropods was the maximum during the postmonsoon season while a lowering of their number was evident during the monsoon season.

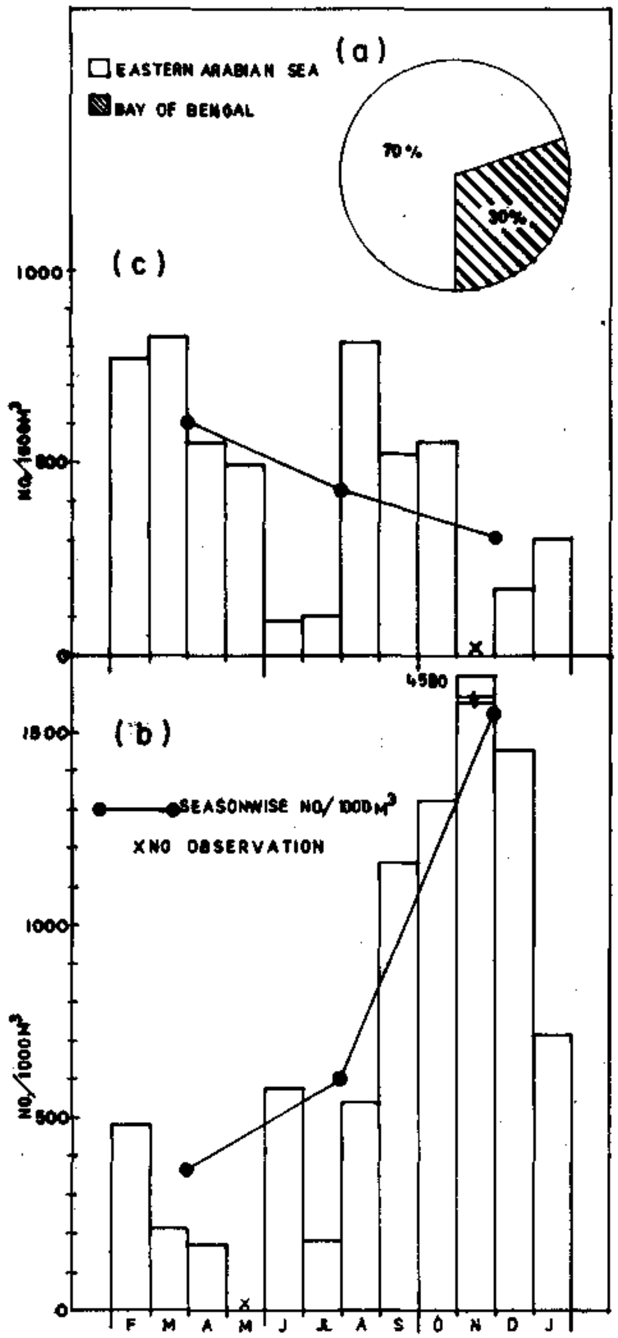

Fig. 4. Abundance of planktonic gastropods other than pteropods and heteropods in the eastern Arabian Sea and Bay of Bengal (a) Relative abundace, Monthly and seasonal variations in (b) the eastern Arabian Sea and (c) the Bay of Bengal.

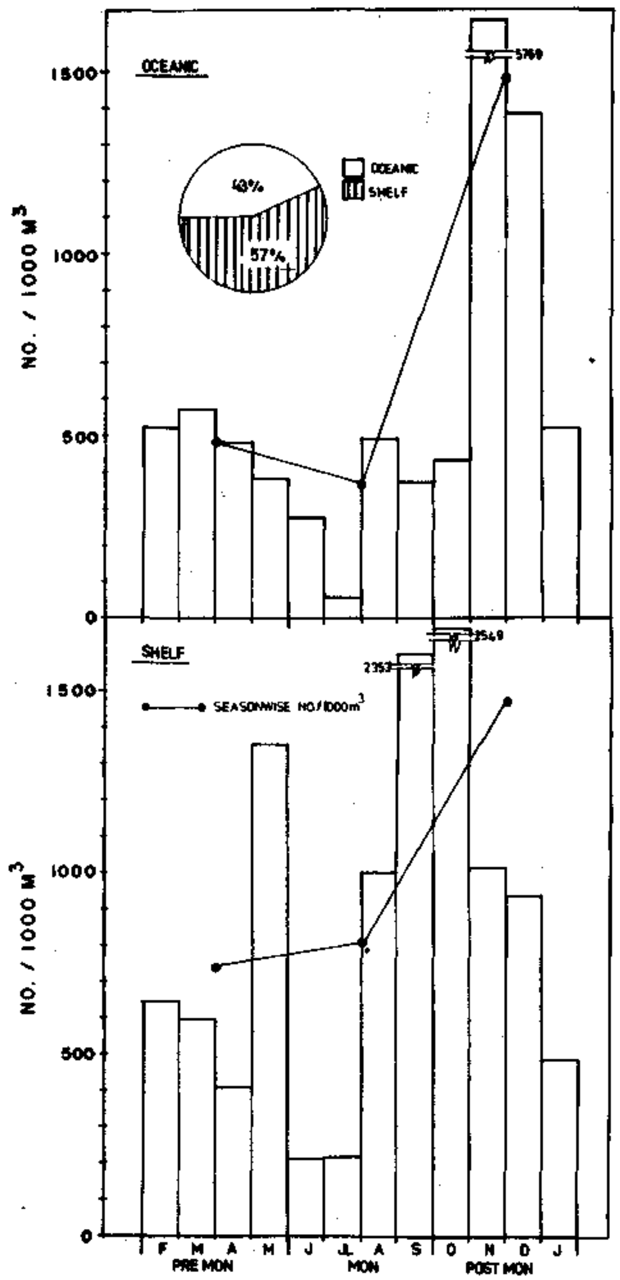

Fig. 5. Monthly and seasonal variations in the abundance of planktonic gastropods other than pteropods and heteropods in the shelf and oceanic waters of the seas around India.

Montly variation in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

In the eastern Arabian Sea greater abundance of the pelagic fauna occurred during September (3,636) - October (3,267) in the shelf waters (Fig. 6). A population outburst of the group occurred in Novemebr (5,770) in the oceanic waters, where increase in abundnace was also observed during December and June. For the remaining part of the year there was not much vairation in their concentration between the shelf and the oceanic waters.

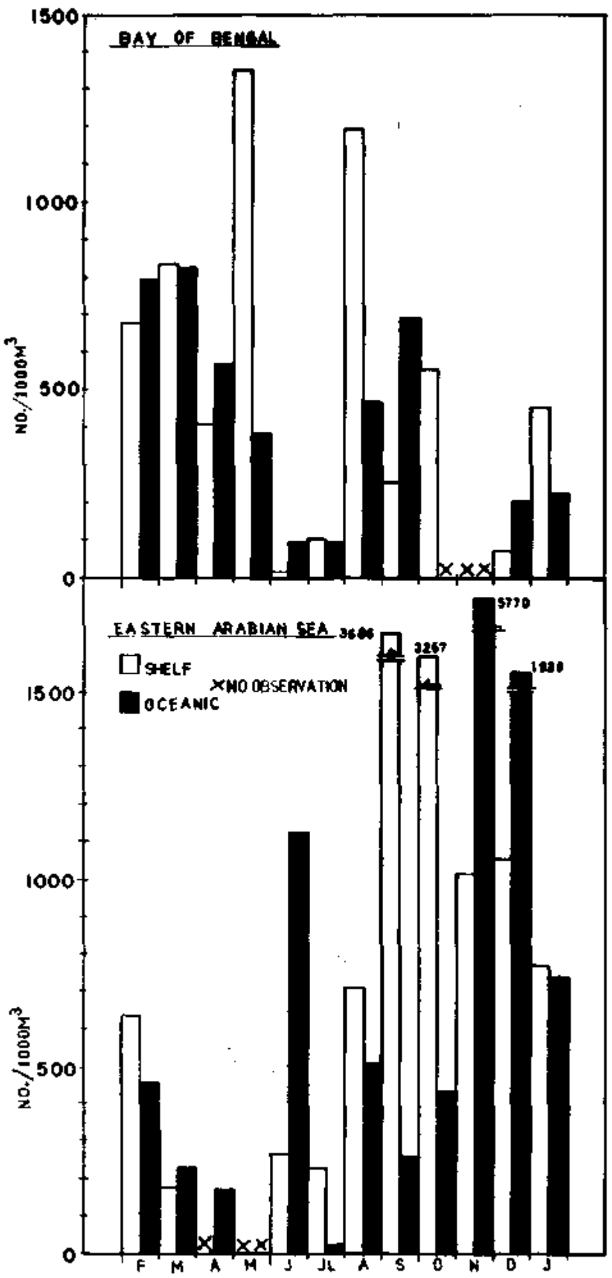

Fig. 6. Monthly variations in the abundace of planktonic gastropods other than pteropods and heteropods in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

In the Bay of Bengal, variations in the abundance of planktonic gastropods between the shelf and the oceanic waters were discernible only during May and August when their concentration fluctuated between 1,352 and 384, and 1,196 and 467 respectively.

Latitudewise seaonal distribution in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

A comparison of the population densities of planktonic gastropods between the shelf and oceanic waters in the eastern Arabian Sea (mean number 1,268 and 1,072 respectively) and the Bay of Bengal (mean number 667 and 426 respectively) showed that they were 18.3% more in the shelf than in the oceanic waters in the eastern Arabian Sea whereas in the Bay of Bengal their concentration was 56.6% more in the shelf than in the adjacent oceanic waters (Fig. 7). In the eastern Arabian Sea, variation in the density of the fauna between the shelf and the oceanic waters increased from south to north and was found most significant beyond 20°N lat., where the density of the fauna was 90% more in the shelf waters than the adjacent oceanic waters whereas in the Bay of Bengal this variation was considerable only in the region between 4°30'N and 10°N lat. where the shelf fauna was 70% more than the oceanic fauna.

In the eastern Arabian Sea, throughout the four latitudinal regions, the planktonic gastropods observed in lesser abundance during the premonsoon season, increased during the monsoon season to reach the maximum during the postmonsoon season. During the premonsoon season, the abundance of the fauna was found to decrease from the south to the north in the four latitudinal regions (mean number of 1,096, 892, 193 and 105 respectively observed in the shelf together with the adjacent oceanic waters). Their abundance in the shelf was higher than that of the oceanic waters in the four latitudinal regions. During the monsoon season, eventhough there was a shift in the increased abundance from the shelf to the oceanic waters between 4°30'N and 15°N lat., an increasing trend in abundance in the four latitudinal regions from the south to the north was evident (mean number of 912, 963, 2,160 and 1,794 respectively in the shelf together with the adjacent oceanic waters), the highest concentration confined in the region between 15°N and 20°N latitudes in the shelf waters (1,987). The increase in abundance from south to north was most significant during the postmonsoon season when the density of planktonic gastropods observed in the shelf together with the adjacent oceanic waters between 4°30'N and 10°N lat. 2,565 increased to 3,288 between 10°N and 15°N lat. and to 3,928 between 15° and 20°N lat. reaching the

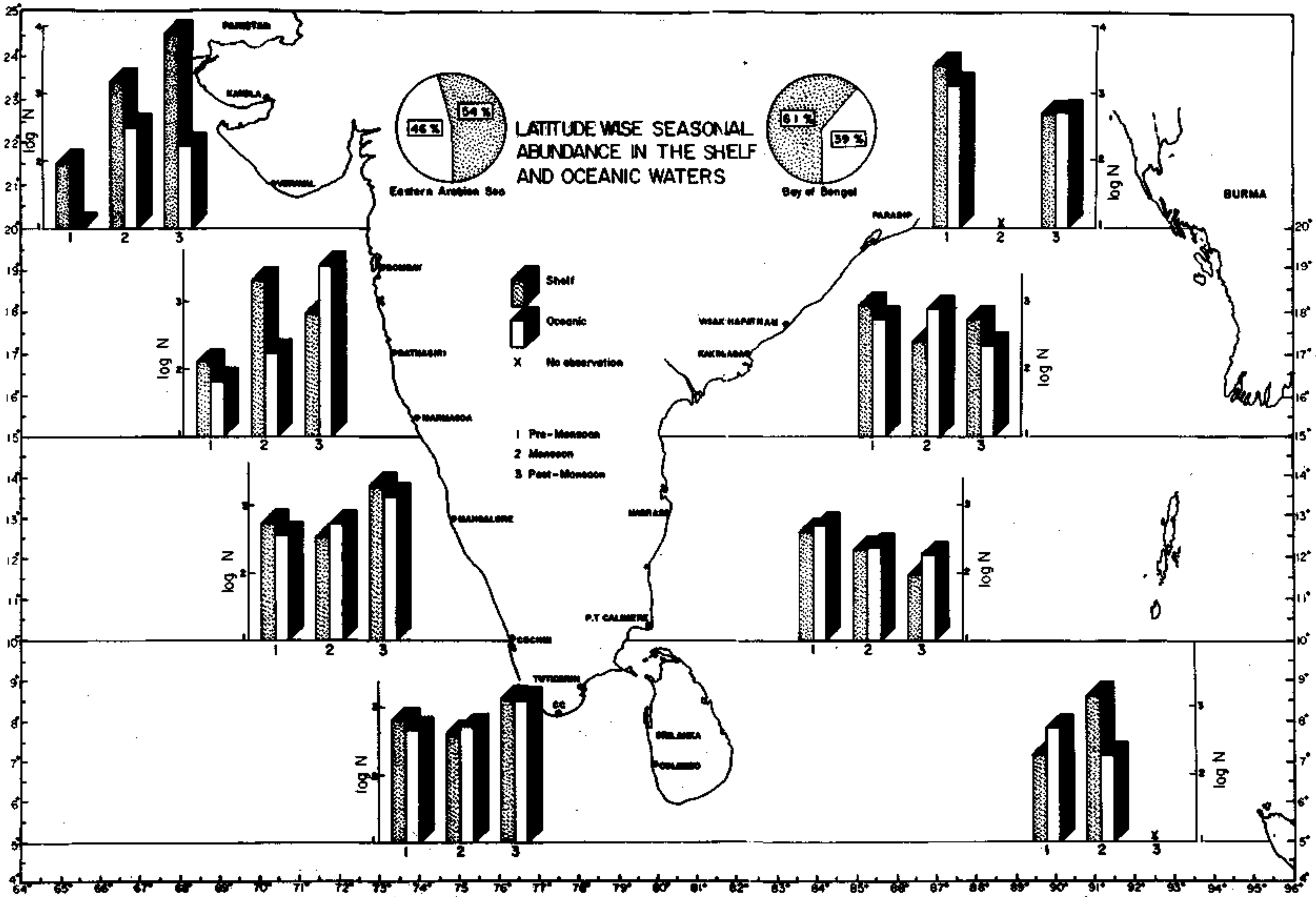

Fig. 7. Latitudewise seasonal abundance of planktonic gastropods other than pteropods and heteropods in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

maximum of 7,614 beyond 20°N lat. During the postmonsoon season the fauna was found more in the shelf than in the oceanic waters in the three latitudinal regions other than the region between 15°N and 20°N lat., where the concentration encountered was more in the oceanic than in the adjacent shelf waters.

In the Bay of Bengal, planktonic gastropods was observed in high abundance during the premonsoon season in the latitudinal regions above 10°N increasing from the south to the north (895 and 1,408 in the shelf together with the adjacent oceanic waters between 10°-15°N and 15°-20°N lat. respectively) with the maximum concentration above 20°N lat. (3,683). While the abundance of the fauna was found moderate during the monsoon season between 20°N-15°N lat. and 15°N - 10°N lat. (1,030 and 459 respectively), their concentrations in these regions (755 and 272 respectively) as well as in the region above 20°N lat. (972) was considerably reduced during the postmonsoon season, the least numbers being observed in the shelf waters between 15°N and 10°N lat. (91). In the region between 10°N and 4°30'N lat. the abundance of planktonic gastropods was found high during the monsoon season (1,587) than the premonsoon season (667) with higher concentrations in the shelf (1,397) than the adjacent oceanic waters (190).

Day - night variations in abundance

The number of stations sampled for this study in the area investigated during the day time was 659 and in the night 427. The mean number of planktonic gastropods observed in the day samples was 609 and in the night samples 1,290 (32 and 68 % respectively) thereby showing an increase of 112 % in their density at night than during day (Fig. 8 a). In the eastern Arabian Sea, the number of stations sampled during day and night were 392 and 258 with a mean concentration of 761 and 1,743 respectively (30 and 70 %) therey showing an increase of 129 % in their abundance during night than during day (Fig. 8 b). In the Bay of Bengal, the mean number of planktonic gastropods observed from 267 samples during day was 361 and from 169 samples at night was 693 (34 and 66 % respectively) thus showing a 92 % increase in their occurrence in the night samples than the samples collected during day time (Fig. 8 c).

Monthly variations in the area investigated showed that the planktonic gastropod content of the night samples was higher than that of the day samples in all the months except September (Fig. 9a). The maximum day-night variation was observed during November when 82.7% of the total gastropods was present in the samples collected during night time.

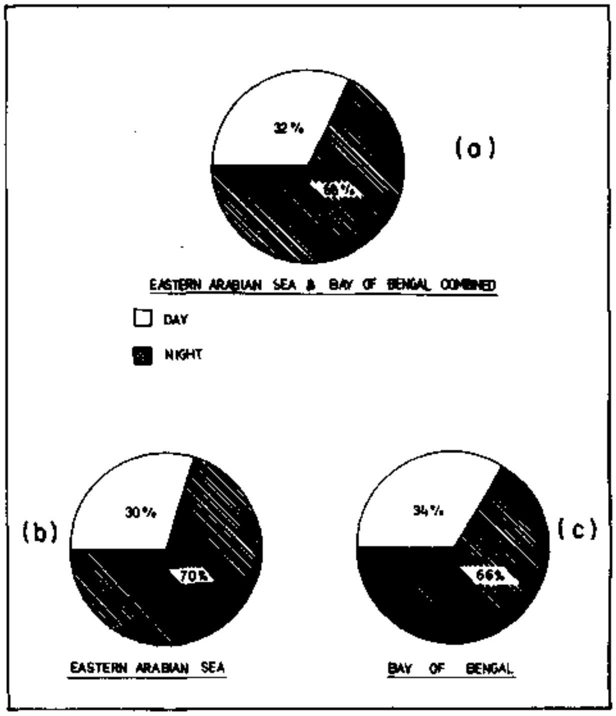

Fig. 8. Variations in the abundance of planktonic gastropods other than pteropods and heteropods during day and night.

While a marginal increase in abundance in the day samples was observed than that in the night samples (550 and 529 respectively) during the monsoon season (Fig. 9 b) their abundance in the samples at night was higher than at day during the post-monsoon (2,478 and 848 respectively) and the premonsoon (753 and 375 respectively) seasons.

The concentration of planktonic gastropods collected during day and at night from the oceanic waters in the seas around India (mean number of 408 and 1,358 from 446 and 309 stations sampled during day and night respectively) showed an increase of 233 % in their density at night than during day whereas in the shelf waters (mean number of 1,113 and 1,029 from 118 night and 213 day stations sampled respectively) the increase in the abundance at night was only 8 % more than that during the day (Fig. 10 a).

The variation in monthly abundance of planktonic gastropods collected during day and night in

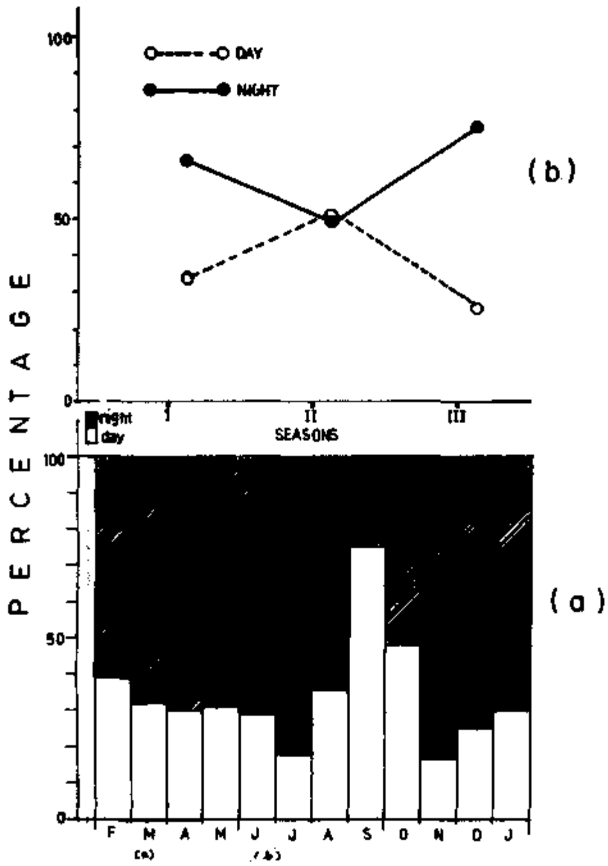

Fig. 9. Monthly and seasonal variations during day and night in the abundance of planktonic gastropods other than pteropods and heteropods in the area investigated.

the shelf and oceanic waters (Fig. 10 b) shows that the concentration of these animals collected during the night time was markedly higher in the oceanic waters from September to January with the maximum variation observed in December (mean number of 3,039 and 360 in the day and night samples respectively) and in the shelf waters from March to August and in Novermber with considerable variation observed in May (2,381 and 322) as well as in November (1,813 and 214). Their abundance in the samples collected in the day was more than that at night during September and December (98 % and 57 % of the total resepctively) in the shelf waters and in July (66 % of the total) in the oceanic waters.

Seasonal variation in the abundance of planktonic gastropods during day and at night in the shelf and oceanic waters of the seas around India (Fig. 10c) shows that the concentration of these organisms far exceeded in the night time than at day during the premonsoon and postmonsoon seasons. While the concentration of the fauna was distinctly higher in the night time than at day in the shelf waters during the premonsoon season, (1,451 and 363) the difference was not as conspicuous as duirng the postmonsoon season in the oceanic waters (2,880 and 533). During the monsoon, higher concentration was observed in the samples collected in the day time (904) than at night (634) from the shelf whereas in the oceanic region their abundance in the samples of the night time (465) showed marginal increase than those of the day (302).

Discussion

Estimates of the numerical abundance of planktonic gastropods from the seas around India

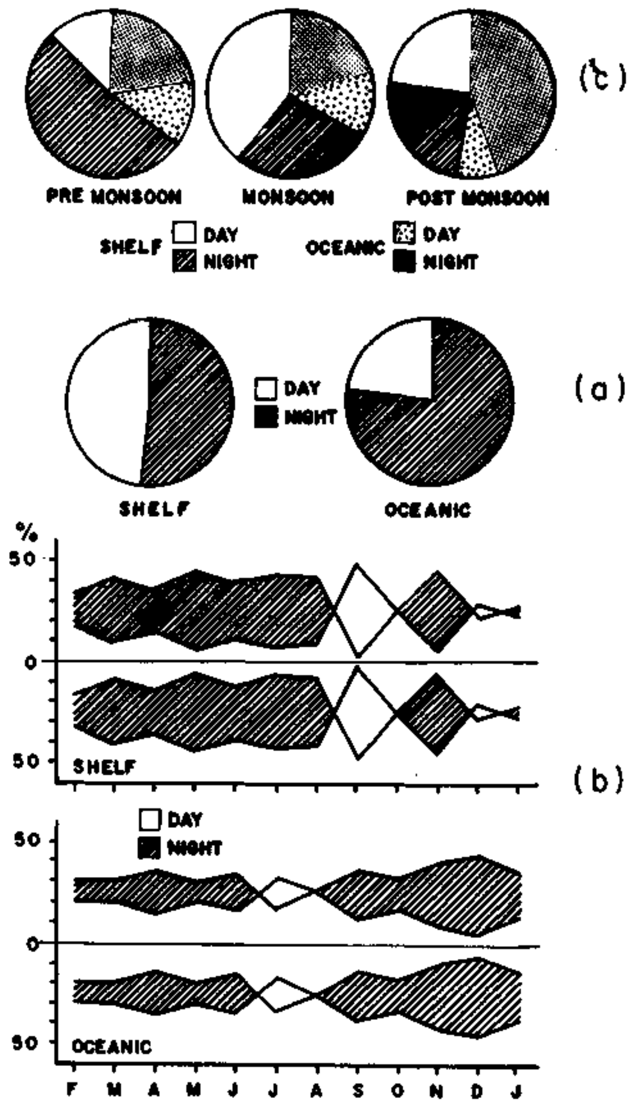

Fig. 10. Day - night abundance of planktonic gastropods other than pteropods and heteropods in the shelf and oceanic waters a) In the seas around India b) Monthly variations c) Seasonal variations.

show considerable patchiness in the faunal distribution (Fig. 1), in conformity with earlier reports (IOBC, 1971; Panikkar and Rao, 1973). The present study shows that the population density of planktonic gastropods was distinctly higher in the eastern Arabian Sea than in the Bay of Bengal with the maximum abundance occurring between 14°N and 20°N latitudes. Though the abundance of this pelagic fauna was reported to be high along the whole of the southwest coast of India (Rao, 1973) during the present investigations they were found to be concentrated more along the outer shelf and the adjacent oceanic waters (Fig. 1), whereas in the Bay of Bengal , the density of these larvae was very high in the shelf waters between 20°N and 21°N latitude and in the Gulf of Mannar waters. It was moderately high at the river mouths of Krishna and Cauvery and also in small pockets around the Andaman Sea. Dense occurrence of planktonic gastropods had been reported in the Gulf of Mannar (Prasad, 1954), at the head of the Bay (Rao, 1973) and between Pondicherry and Point Calimere (Achuthankutty *et al.*, 1980).

Planktonic gastropods were found throughout the year in the seas around India, with definite seasonal fluctuations in abundance (Fig. 2). The marine gastropods are known to have a protracted breeding period in the warm seas (Raymont, 1983) with specific period of intense activity (Natarajan, 1957; Mahadevan and Nayar, 1966; Rajagopal *et al.*, 1981).

In the eastern Arabian Sea, the planktonic gastropods flourished during September - December with the peak abundance occurring in November but were in small numbers during March- April and July (Fig. 4). In general, gastropod larvae were less abundant in the premonsoon season throughout the four latitudinal regions but the shelf always contianed more of these organisms particularly in the region between 4°30'N and 10°N lat. (Fig. 7). During the monsoon season, the population density of the group increased more both in the shelf and the contiguous oceanic areas and the concentration observed was the highest in the former between 15°N and 20°N lat. The overall abundance of the pelagic fauna reached the maximum during the postmonsoon season especially in the shelf waters around 20°N lat. and the oceanic area between 15°N and 20° N lat. was also densely populated during the same season. Reports on the seasonal abundance of the larval gastropods in the coastal waters of the eastern Arabian Sea indicate that the fauna abound in the waters off Calicut during the summer months (Mukundan , 1967), off Trivandrum from December to April (Prased, 1954), off Vizhinjam during February, August and November (Rani Mary *et al.*, 1981), off Colachel in March and December (Suseelan *et al.*, 1985) and off Karwar during March, May and December (Naomi , 1986).

In the Bay of Bengal, planktonic gastropods occurred in large number during February- March and August and the least was observed during June-July and December (Fig. 4c). Figure 7 shows that while the concentration north of 10°N lat. was the highest in the shelf waters during the premonsoon season (February - May) with the maximum concentration occurring beyond 20°N lat., the abundance was high during the monsoon season (June - September) in the region south of 10°N lat. In the Gulf of Mannar, Prasad (1954) reported the occurrence of gastropod larvae throughout the year with two peak spawning seasons, one in March-April and the other around August. Natarajan (1957) observed peak breeding for most of the groups during January-March and July- August . In the same region, Siraimeetan and Marichamy (1988) observed that the larval gastropods exhibited two distinct modes; the first during Feburary- April and the second during September- December and that in certain years the fauna was prominent during June -July also.

The present studies reveal that the density of planktonic gastropods is rather low during the warmest months as well as at the peak of the monsoons in the eastern Arabian Sea and the Bay of Bengal . However, soon after the peak of the monsoon, the lowering of salinity probably triggers spawning in many species of gastropods with the result that the spawned products were found in increased abundance during the latter half of the monsoon to reach the peak abundance noticed during the postmonsoon season. The dominance of veligers during the period of low salinity had been reported off Goa by Goswami and Selvakumar (1977).

The regions remarkable for the dense concentration of the gastropod larvae as observed in the eastern Arabian Sea, Andaman Sea and in the western Bay of Bengal excluding the northern Bay beyond the Godavari river mouth are well known for their rich fishing grounds of the adult gastropods (Jones, 1970; Rao, 1973; Nayar and Mahadevan, 1973; Nayar *et al.*, 1985; Sundaram, 1974; Devaraj and Ravichandran, 1988; James, 1988). Planktonic gastropods are reported to be feeding mainly on microalgae (Richter, 1987). Areas of higher concentrations of planktonic gastropods in the seas around India are also regions enriched by upwelling or land drainage followed by high phytoplankton productivity as reported for the high abundance of euthecosomatous gastropods in the Indian Ocean by Sakthivel (1969).

Qasim (1977) observed that the Arabian Sea is far more productive than the Bay of Bengal and that the regions of maximum primary production are along the southwest coast of India. In the eastern Arabian Sea, upwelling starts in May, continue through the southwest monsoon and reach the peak in August/September (Anon., 1976). The standing crop of phytoplankton is reported to be high along the coast off Trivandrum from January onwards and the maximum is attained in May, and at Calicut and further north it is during July- August (Subrahmanyan, 1973). Sukhanova (1962 a, b) recorded regions of fairly high concentrations of phytoplankton between 15° and 19°N lat. and 70°-75°E long. during the north east monsoon and Zernova and Ivanov (1964) reported rich phytoplankton in the northwest Indian Ocean north of 12°N lat. during October - December.

At different centres of north western Bay, upwelling had been reported to occur during January - June (La Fond, 1954; Varadachari and Sharma , 1967; Sankaranarayanan and Reddy, 1968) and the maximum standing crop of phytoplankton during February - April (Ganapati and Murty, 1955; Ganapati and Subba Rao, 1958) whereas in the southern part of the Bay of Bengal, phytoplankters are rich during the southwest monsoon, about 2 - 2.5 times more than that of the northeast monsoon (Sukhanova, 1964). Nair *et al.*, (1973) observed higher values of primary production in the inshore waters of the Gulf of Mannar and the palk Bay region during June - July.

It is observed that the seasonal fluctuations in the abundance of planktonic gastropods (Fig. 7) clearly follow the primary maxima of the phytoplankton production, which is reported to move from north (in February) to south (in June) direction along the east coast and from south (in January) to north (in September) along the west coast (Nair and Gopinathan, 1981).

The larval gastropods were found to be more abundant in the shelf waters than in the oceanic waters (Fig. 5). Thorson (1940) is of the opinion that the pelagic development of the prosobranchs of the world oceans is restricted to the shelf and it was found to be the highest in the shelf areas of the tropics. Mahadevan and Nayar (1974) attributed great significance to the presence of a large amount of food materials and calcium content in the surrounding waters for the growth of chank larvae. The increased concentration of planktonic gastropods in the continental shelf may be due to the increased productivity of the shelf as already discussed.

It may be seen that an unprecedented population outburst occurred in the oceanic waters during November- December (Fig. 5 a & b) in the eastern Arabian Sea. Legendre and Demers (1984) suggested that the zooplankton maxima need not be the result of *in situ* grazing and growth but can be due to physical transport and behavioural aggregation. Menon and George (1977) reported that along the west coast of India, north of Kasaragod (12°30'N), the biological cycle is influenced not only by upwelling alone but also due to the influence of the environmental regime in the northern Arabian Sea, particularly the current system. Investigations of the Pelagic Fishery Project indicated the existence of a convergence zone, where the heavier Arabian Sea water sinks below the north flowing low salinity equatorial surface water during the early part of the northeast monsoon. The position and intensity of the convergence zone showed large variations from year to year and was located in 1974 between Karwar and Ratnagiri (Anon., 1976). Thorson (1950) was of the view that many tropical macroplanktonic species have long planktonic life and refers (Thorson, 1961) to certain gastropods of which the larvae grow into relatively large veligers with greatly hypertrophied lobes that appears to be truly adapted for trans - oceanic passage. Natarajan (1957) has observed in the Gulf of Mannar many gastropod veligers with well developed velum and having a long planktonic phase. Mileikovskiy (1966), Scheltema (1968) and Scheltema and Williams (1983) have reported meroplanktonic larvae of many gastropod spp. transported over long distances by currents. It seems logical to conclude that the presence of very high density pockets of planktonic gastropods observed in the eastern Arabian Sea between 14°N and 20°N latitudes may be due to transport by currents, further leading to a mechanical concentration in the convergence zones as suggested by Vinogradov and Voronina (1962).

The planktonic gastropod content in the samples collected at night far exceeded that of the day time in the eastern Arabian Sea and in the Bay of Bengal (Fig. 8). Monthly variations showed that this pelagic fauna was abundant throughout the year in the night samples except in September and the maximum encountered at night was in November (Fig. 9). The day- night variation in the abundance was marginal in the shelf waters but was conspicuous in the oceanic area (Fig. 10 a). Though the figure shows only a marginal variation in the shelf waters, Fig. 10 c shows that during the premonsoon season their abundance at night was distinctly higher than in the day. In the oceanic region the gastropod content in the night samples was higher than that of the day almost all through the year and a remarkable increase was observed during the postmonsoon season with the maximum occurring in December (Figs. 10 b & c).

The distinct variations in the abundance of the samples collected during day and at night indicate that the planktonic gastropods undergo vertical migration and aviod surface layers during day time. It is highly significant that the only variation noticed in this vertical migration was during September in the shelf waters when a greater percentage of these organisms was present in the day samples. Gastropod veligers being voracious phytoplankton feeders, their ascend at night may be for feeding on phytoplankton generally most abundant at 75 m (Humphrey and Kerr, 1969). The very high surface productivity in the shelf waters during September may be the reason for the higher concentration of the fauna in the day time.

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QUALITATIVE AND QUANTITATIVE DISTRIBUTION OF PLANKTONIC CEPHALOPODS IN THE EXCLUSIVE ECONOMIC ZONE OF THE WEST COAST OF INDIA

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ABSTRACT

The cephalopod larvae and juveniles in plankton samples collected during the first 10 cruises of FORV *Sagar Sampada* off the west coast of India from February to December, 1985 have been studied for their qualitative and quantitative distribution. The samples were obtained in Bongo net operations carried out in an extensive area covering Lat. 4° to 23° N and Long. 65° to 77° E. Out of the total 258 stations sampled, cephalopods were obtained in 110 stations in varying numbers. The estimated number of cephalopods per haul ranged between 1 and 112. Of the total number of hauls in which cephalopods obtained, 51% occurred in night hauls and the rest in day hauls. The density per haul during night was 22, whereas it was 13 in day haul. Cephalopods belonging to families Sepiolidae, Sepiidae, Enoploteuthidae, Onychoteuthidae, Ommastrephidae, Cranchiidae and Octopodidae were the important components. Among the identified cephalopods, larvae and juveniles of Ommastrephid squids were by far more abundant and occurred more frequently. The occurrence, distribution and abundance of different species of cephalopods in the study area in relation to oceanographic conditions are discussed.

INTRODUCTION

Cephalopods, comprising of cuttlefish, squid and octopus, are one of the important seafood items. They are in great demand in export trade because of their delicacy and nutritive value. Recently Silas *et al.* (1986) have reviewed the studies carried out so far on this group in the Indian Ocean and stressed the need for further studies on the ecology of larval, juvenile and adult phases of neritic and oceanic species of cephalopods. Silas (1968) observed the quantitative and qualitative abundance and distribution of neritic and oceanic planktonic cephalopods off west coast of India. Much emphasis has been given to the studies pertaining to the quantitative aspects of planktonic cephalopods (Silas, 1969; Sakthivel and Aravindakshan, 1971; Aravindakshan and Sakthivel, 1973 and Meiyappan *et al.*, 1989). In the present paper, the results of quantitative and qualitative analysis of planktonic cephalopods obtained in the Bongo net during the cruises of FORV *Sagar Sampada* along the west coast from February to December, 1985 are presented.

MATERIAL AND METHODS

The planktonic cephalopods were sorted out from the zooplankton samples collected in 10 minutes oblique hauls by Bongo 60 net in a depth range of 150 - 0 m. The description of the net and details of operation have been described elsewhere. Totally 258 hauls were made during the cruise No. 1, 2, 3A, 3C, 5, 6 to 9, 9A and 10 in the area lying between latitudes 04° 59'N and 23° 30'N and longitudes 65° 10'E and 77° 30'E. Based on the aliquote sample drawn from each haul, the qualitative and quantitative data on major planktonic groups were estimated including cephalopods. The number of cephalopods contained in each fractional sample was raised to the total volume. The pooled data were used for the seasonal and distributional studies . Since it is obvious that the identification of larvae and juvenile cephalopods is difficult, specimens were identified generally upto family and wherever possible upto genus and species level. The measurements (in mm) of the specimens mentioned in the text denote the Dorsal Mantle Length (DML) and Total Length (TL).

OBSERVATIONS

Cruise- wise abundance

The details of cruise-wise hauls and number of cephalopods obtained are given in Fig. 1. Totally 258 hauls were made, of which, 110 hauls (42.6%) contained cephalopods. The total number of cephalopods amounted to 1758, the greater number (> 100) came from the cruise No. 2, 3A, 3B, 6, 7, 9 and 10, while the number per haul varied from 0 to 65

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in other cruises. The number per haul varied from 1 to 34. The abundance of cephalopods per haul showed a direct relationship on the total number of cephalopods in a particular cruise.

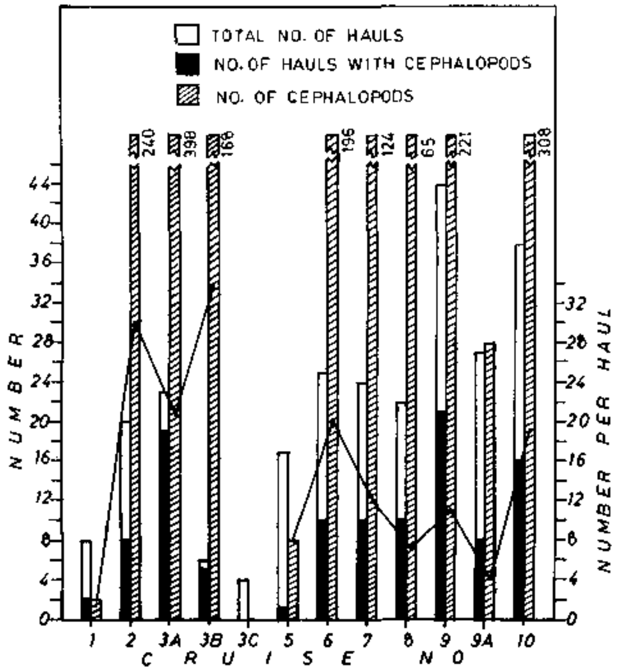

Fig. 1. Cruise-wise abundance of planktonic cephalopods.

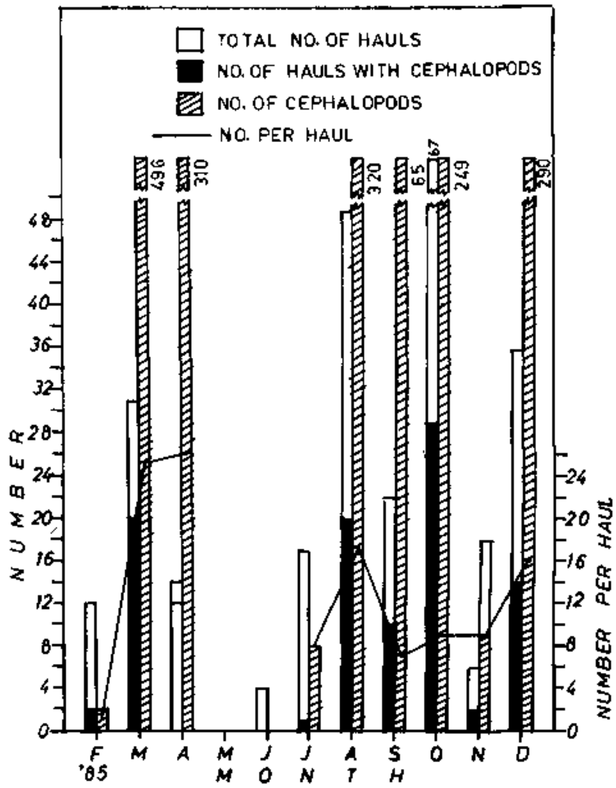

Fig. 2. Month-wise abundance of planktonic cephalopods.

Month-wise abundance

The month-wise abundance of cephalopods during February to December '85 is indicated in Fig. 2. In the months of March, April and August to December, 33 to 86% of hauls contained cephalopods, while the meagre number (6 to 17%) came in February and July. There was no operation of Bongo net during May in the study area. The four hauls made in June did not yield any cephalopods. The number of cephalopods per haul during the period ranged from 1 to 26. The greater number of 6 to 26 per haul were obtained during March, April, August and December, whereas 7 to 9 per haul were caught during July, September, October and November. In February, it was only one number per haul. The record of maximum number during March, April, August and December indicates the peak abundance of cephalopods during the pre and post monsoon periods along the west coast of India.

Diurnal variation

The details of number of cephalopods caught per haul during the day and night hauls are given in Fig. 3. Total number of hauls made during day and night hours amounted to 67 and 43 respectively. The number per haul during day varied from 4 to 24, whereas it was 1 to 14 in the night hauls. The day hauls were found richer during March, April, August and December. In the case of the night hauls, the highest rate of 14 per haul was obtained in October. In the other months the number per haul ranged from 1 to 6. Generally, the number per haul was more in the dark hours (average ; 20 per haul) than that of the day (13/haul) for the whole period.

Composition of planktonic cephalopods

The present collection consisted of both neritic and oceanic cephalopods belonging to 11 families, namely, Sepiidae, Sepiolidae, Loliginidae, Enoploteuthidae, Octopoteuthidae, Ommastrephidae, Cranchiidae, Onychoteuthidae, Gonatidae, Brachioteuthidae, and Octopodidae. The family-wise contribution of cephalopods is indicated in Fig. 4. Among the eleven families, those belonged to Ommastrephidae shared 50.1% by number, followed by Enoploteuthidae (15. 9%), Çranchiidae (9.9%), Loliginidae (6.3%), Octopodidae (4.1%), Sepiolidae (3.7%), Onychoteuthidae (3.5%), Gonatidae (0.8%), Sepiidae (0.5%), Octopoteuthidae (0. 3%) and Bra-

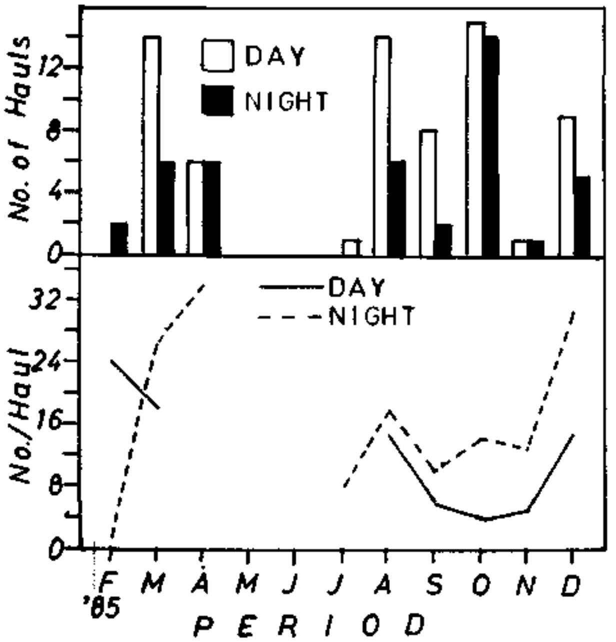

Fig. 3. Diurnal variations in the abundance of planktonic cephalopods.

chioteuthidae (0.3%). The cephalopod fragments constituted 4.6%.

Seasonal abundance of different families

The family-wise number per haul obtained in

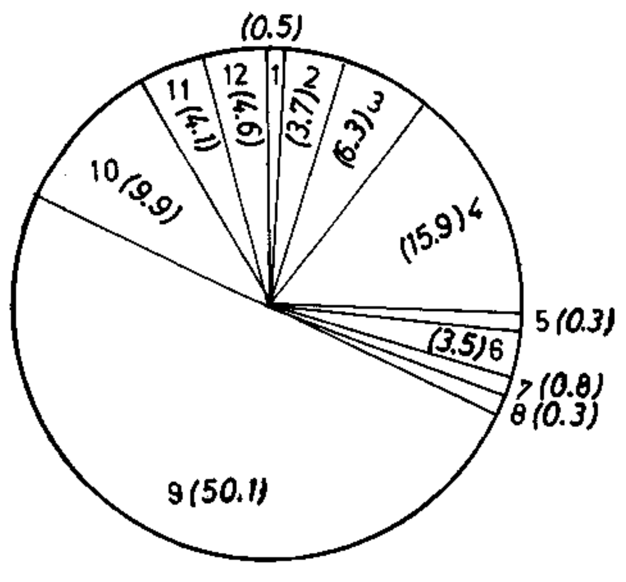

Fig. 4. Family-wise composition of planktonic cephalopods. 1. Sepiidae, 2. Sepiolidae, 3. Loliginidae, 4. Enoploteuthidae, 5. Octopoteuthidae, 6. Onychoteuthidae, 7. Gonatidae, 8. Brachioteuthidae, 9. Ommastrephidae, 10. Cranchidae, 11. Octopodidae 12. Unidentifiable fragments of cephalopods

the day and night hauls during the period February to December, '85 is given in Fig. 5.

Sepiidae : Only 8 numbers were taken in a single day haul in February.

Sepiolidae : Caught during February, March and August; day hauls with a minimum of 8 in August and a maximum of 48 in March and a single night haul in February with only one number.

Loliginidae : Represented in March, April, July, August, October and December; day hauls in March, April, August and December yielded 6 to 24 and night hauls in July with 8 and in October with 3.

Enoploteuthidae : Members of this family occurred in February- March and August to October and December; day hauls with 3 to 12 and night hauls with 5 to 11.

Octopoteuthidae : Represented in a single day haul (4 number) in August.

Onychoteuthidae : Present during February, March, September, October and December; day hauls with 1 in February, 2 in March, 4 each in September, October and December and night hauls with 8 in October and December and 10 in February.

Gonatidae : Represented in the day hauls (4 each) in August, September and October.

Brachioteuthidae : Present only in a day haul (6 number) in March.

Ommastrephidae : Well represented in March, April and August to December; day hauls with 4 (October) to 20 (March) and in other months 5 to 15 and night hauls with 1 (February) to 38 (April) and in other months 6 to 22.

Cranchiidae : Caught in March, April, August, September and December; day hauls during April, August and December with 2 to 9 and night hauls ranging 6 in December to 8 in March-April.

Octopodidae : Members of this family represented in March, April, August, October and December; day hauls ranging from 3 in October to a maximum of 19 in August; and night hauls ranging from 2 in October to 36 in August.

Distribution of different families

Since the present observation is confined to a short period i. e. February to April and July to December, '85, the occurrence of specimens of

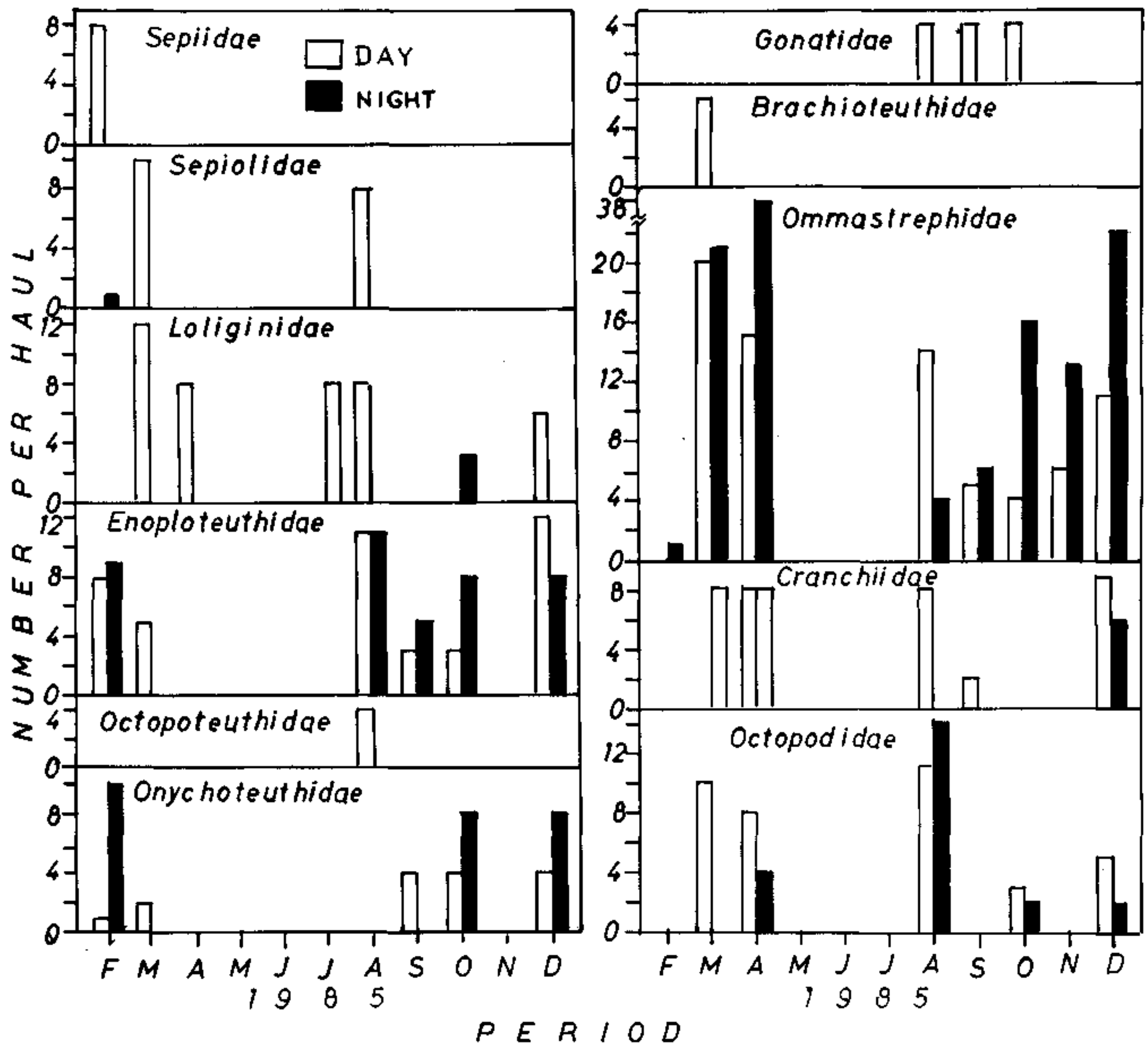

Fig. 5. Seasonal abundance or plaktonic cephalopods.

different families in the study area is indicated briefly in the following account based on the area of operation of the Bongo net.

Sepiidae : This family was represented in a single day haul in the oceanic waters southwest of Veraval.

Sepiolidae : Members of this family were obtained only in day hauls in the neritic and oceanic waters in the stations located south of Veraval and oceanic waters of northwest of Mangalore.

Loliginidae : The loliginids were obtained in both day and night hauls from the Wadge Bank. The day hauls taken northwest of Veraval, Lakshadweep Sea and off Cochin also yielded specimens. A single night haul off Mangalore also contained specimens.

Enoploteuthidae : Among the enoploteuthids, three genera, namely, *Abralia*, *Abraliopsis* and *Enoploteuthis* were represented. The species belonging to *Abralia* were obtained from the oceanic waters of the Wadge Bank in the south to Veraval in the north in both day and the night hauls. Among the specimens examined, 2 were found belonging to

Abralia andamanica , of which, one was taken in the day haul and the other in the night, off Mangalore. Those belonged to *Abraliopsis* were obtained in the day hauls off Verával, Goa, Mangalore and Cochin. *A. gilchristii* was caught off Veraval in a day haul. Specimens belonging to *Enoploteuthis* were drawn from the oceanic waters of Kandla, Mangalore, Cochin and Cape Comorin in the day hauls and off Kandla, Veraval, Bombay and Lakshadweep islands in the night hauls. The maximum number occurred in the area south of Cape Comorin in the day hauls.

Octopoteuthidae : Specimens of *Octopoteuthis* were obtained from a station west of Cape Comorin in a single day haul.

Onychoteuthidae : A single genus *Onychoteuthis* was represented. They were obtained from west and northwest of Veraval and from the neritic waters off Vizhinjam in the day hauls. The samples obtained in the night hauls came from Veraval, Cochin and southwest of Cape Comorin. *O.banksii* was represented in a day haul taken southwest of Lakshadweep Islands.

Gonatidae : *Gonatus* sp. was obtained only in the day hauls taken off southwest of Kandla, west of Karwar and southwest of Cape Comorin.

Brachioteuthidae : The members of this family occurred in a single haul off Quilon.

Ommastrephidae : Most of the specimens belonging to this family were in early and advanced rhynchoteuthis, while a few of them were identified up to the genera, namely *Simplectoteuthis* and *Ommastrephes*. Most of the rhynchoteuthis specimens were obtained off Veraval, Bombay, Ratnagiri, Goa, Trivandrum and Cape Comorin in the day collections. The night hauls taken off Veraval and Cochin were found rich in number. A few numbers belonging to *Ommastrephes* were obtained off Trivandrum, while those of *Simplectoteuthis* were taken in the oceanic waters off Trivandrum and Cape Comorin. The members of this family were comparatively richer in the night hauls. The overall size range for rynchoteuthis larvae was 0.7 to 5.5 mm in DML and 1.3 to 1.6 mm in DML for the genus *Simplectoteuthis*. Majority of rhynchoteuthids were in the size range of 1 to 2 mm in DML. Although majority of the specimens were caught from the oceanic waters, a few were from the neritic waters.

Cranchiidae : Specimens belonging to the genera *Cranchia*, *Sandalops* and *Taonius* were present, of which, the first one dominated by number. Those belonged to *Cranchia* were obtained off Veraval, Ratnagiri, Cochin, Trivandrum and Cape Comorin, while that of *Sandalops* were caught off Cape Comorin. The specimens belonging to *Taonius* were caught off Cochin. Greater number of specimens of *Cranchia* were taken by the day hauls. The size recorded for *Cranchia*, *Sandalops* and *Taonius* was 7.3 mm, 11.4 mm and 11.0 mm in DML respectively.

Octopodidae : Specimens belonging to the genera *Octopus* and*Eledone* were represented. Those belonged to *Octopus* were caught off Veraval, Ratnagiri, Goa, Cochin, Trivandrum and Cape Comorin, while that of *Eledone* were obtained from a single station off Veraval. The size range for *Octopus* was 1.1 to 2.0 mm and 1.5 mm in DML for *Eledone*.

Discussion

The present study on the planktonic cephalopods collected by Bongo 60 net along the west coast of India has indicated their seasonal abundance and distribution in the areas. Greater abundance of planktonic cephalopods was noticed during the pre and postmonsoon months, which agreed with the earlier observations by Silas (1968) and Aravindakshan and Sakthivel (1973). Among the day and night hauls, the number per haul was more (29/haul) in the dark hours than that of the day (13/haul), which confirmed the remarks by Silas (1968), who reported a greater representation of cephalopods in the Isaacs-Kidd Midwater Trawl collections taken during the night.

Among the eleven families represented in the present collection, those belong to Ommastrephidae formed 50.1% by number, followed by Enoploteuthidae (15.9%). However, Silas (1968) recorded those belonged to Enoploteuthidae as the dominant group from the west coast of India. Filippova (1968) has listed the members of the family Ommastrephidae as one of the commonest inhabitants of the Indian Ocean.

The present study also has indicated the dominance of planktonic cephalopods belonging to the families, namely, Enoploteuthidae, Onychoteuthidae and Ommastrephidae in the night hauls and Sepiidae, Sepiolidae, Loliginidae, Cranchiidae and Octopodidae in the day hauls. According to Clarke (1966) and Clarke and Lu (1974, 1975) the abundance of planktonic cephalopods in the columnar water is related to species-specific. The present study has some limitations, since the materials on hand did not contain a complete series of stages in most of the families examined. Such lacunae can be overcome if additional materials are obtained in other suitable gears which could probably collect all the stages of planktonic cephalopods as done by Okutani and McGowan (1969), Young (1972) and Roper and Young (1975), who have described the complete stages of many of the families of planktonic cephalopods.

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Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5-7 *June*, 1989: 185 - 189 (1990)

PRELIMINARY STUDIES OF THE DISTRIBUTION AND ABUNDANCE OF PLANKTONIC CEPHALOPODS IN THE INDIAN EXCLUSIVE ECONOMIC ZONE AND ADJACENT SEAS

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Abstract

Abundance and distribution of planktonic cephalopods collected from the operation of Bongo net in the west coast of India including the Lakshadweep Sea, east coast, Andaman and Nicobar Islands and the Central Equatorial waters have been studied. Relatively greater abundance of cephalopods was noticed on the west coast and Andaman and Nicobar Islands. Their occurrence was more prominant in March - June and August- December on the West coast, and March-September on the east coast. Generally the night hauls were richer than those taken during day. There was not much difference in the relative abundance of planktonic cephalopods in the neritic and oceanic waters except on the west coast where the neritic waters are slightly richer.

Introduction

Early juveniles of most of the cephalopods are pelagic, irrespective of the different niches occupied by their adults. This coloumnar habitat of juvenile cephalopods is reflected in their occurrence in the plankton and midwater trawl collections made from the coastal and oceanic waters of the seas around the world. Important observations on the occurence of planktonic cephalopods are from the Atlantic Ocean (Issel, 1908; Pfeffer, 1912; Clarke, 1966; Clarke and Lu, 1974 and 1975; Lu and Clarke, 1975 a and 1975 b; Roper and Lu, 1978), the Pacific Ocean (Allan, 1945; Okutani and McGowan, 1969; Young, 1972) and the Indian Ocean (Silas, 1968 and 1969; Sakthivel and Aravindakshan, 1971; Aravindakshan and Sakthivel, 1973). The study on these organisms is of great interest as they form the forage to predatory fishes like tunas, mammals such as toothed whales, seals and marine birds (Roper et al., 1984). The present study is based on the planktonic cephalopods taken in Bongo net onboard FORV Sagar Sampada during February 1985 to March 1988.

Data Base

The numerical data considered here pertain to the Bongo net samples taken during the Cruise 1 to 44. The area covered includes the west coast of India (6° to 23°N), the east coast (6° to 21°N), Andaman and Nicobar Islands (5° to 15°N) and the Central Equatroial Region of the Indian Ocean (0° to 3°N and 0° to 3°S). The duration of each haul was 10 minutes, towed in all oblique direction from a depth of 150 m to the surface. The volume of zooplankton obtained in each haul was determined by displacement method and an aliquote sample was examined for major plankton constituents. The number of cephalopods in each fraction was raised to the total volume to determine the total number present in each haul. The data from different cruises were pooled together to study the seasonal and spatial distribution. The hauls made during 0600 to 1800 hours were considered as day hauls and the rest as the night hauls. The number per haul has been taken as an index of abundance.

Observations

Regionwise occurrence

The number of hauls made in different regions and the catch of cephalopods are given in Table 1. For the four regions combined, viz., west coast, east coast, Andaman and Nicobar Islands and the Central Equatroial Region, a total of 1129 hauls were made, of which 595 hauls (52.7%) contained cephalopods. Of 677 hauls made off the west coast, 293 hauls (43.3%) yielded cephalopods, amounting to 3276 numbers with an average of 11 per haul. Along the east coast, though the number of hauls were less (316 only), the hauls containing cephalopods were 194 (61.6%), yielding 1105; the number per haul being 6. In the Andaman and Nicobar Islands and the Central Equatroial Region, the

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TABLE 1. *Region -wise distribution of planktonic cephalopods*

Region	Total number of hauls	Hauls with cephalopods	Number of cephalopods	Number/haul
West coast	677	293	3,276	11
East coast	316	194	1,105	6
Andaman and Nicobar Islands	95	72	813	11
Central Equatorial Region	41	36	264	7
All regions	1,129	595	5,458	9

percentage of hauls with cephalopods was 75.8 and 87.8 with the average number of 11and 7 respectively.

Seasonal abundance

The number of cephalopods obtained per haul in the four regions for different months are given in Fig. 1.

West coast

The number per haul varied from 1 to 26 in 1985, 1 to 52 in 1986, 3 to 8 in 1987 and 3 to 8 in 1988. A number of 5 cephalopods and more per haul was recorded in March- April and August to December, 1985, June and October, 1986, July to December, 1987 and February, 1988.

East coast

The collections made in June and July, 1985 yielded 3 and 5 cephalopod per haul, while those made during February, March, May, June and December, 1986 contained 3 to 9 per haul. In 1987 also, the collections were made intermittently and the number per haul ranged from 2 to 6. The single cruise made during March, 1988 has yielded 8 per haul.

Andaman and Nicobar Islands

The collections were made during April, 1986 and again during April and May, 1987. The number

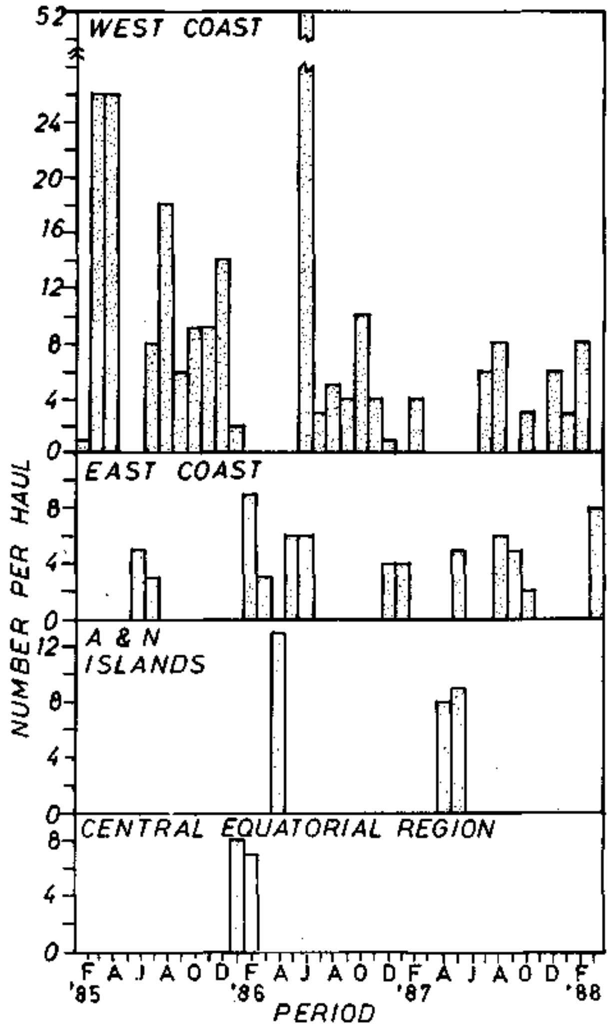

Fig. 1. Seasonal distribution of planktonic cephalopods in different regions.

per haul was 13 in April, 1986, 8 in April and 9 in May, 1987.

Central Equatorial Region

The plankton hauls were confined to January and February, 1986, when the number per haul was 7 and 8 respectively.

Diel variations

The number of cephalopods obtained in each haul from the four regions during day and night in different months are given in Fig. 2. On the west coast, the night hauls made in 1985 yielded 10 to 34 cephalopods as against 4 to 23 in the day hauls; the maximum number of 34 cephalopods was obtained in a night haul in December, 1985. In 1986, the number per haul in the night collections varied from

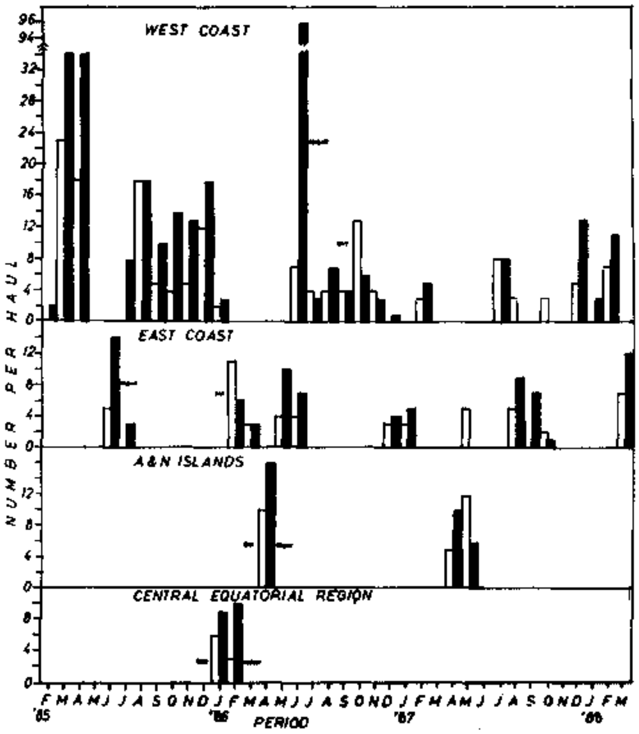

Fig. 2. Diurnal variations in the abundance of planktonic cephalopods.

3 to 96, and in the case of day hauls from 0 to 13; the peak abundance of 96 per haul came in June. In 1987, the night hauls yielded 0 to 13 per haul, whereas the day hauls contained 3 to 8. In 1988, samples were obtained in January and February and the night hauls yielded 3 and 11, and the day hauls 2 and 7. On the east coast the maximum number per day haul came in June, 1985 (5), February, 1986 (11), May (5) and August, 1987 (5) and March, 1988 (7). But the night hauls were better, netting 14 per haul in June, 1985, 10 in May, 1986, 5 in January, 9 in August, 1987 and 12 in March, 1988. In the Andaman and Nicobar islands, maximum number of 10 to 12 was observed in the day hauls and 8 to 15 in the night hauls during April ,1986 and April-May, 1987. In the Central Equatorial Region also a similar trend was noticed: 3 to 6 in the day and 9 to 10 in the night hauls in January- February, 1987. In general, the trend observed was that the night collections were found richer than those obtained during the day, indicating the upward movement of cephalopods in the dark hours.

Abundance in neritic and oceanic waters

The index of planktonic cephalopods (number per haul) in the waters upto 200 m (neritic) and beyond 200 m depth (oceanic) in the four regions is given in Fig. 3. On the west coast, the neritic waters lying between Latitutdes 4° to 12°N and 19° to 22° N yielded larger number of cephalopods (11 to 64/haul) than in the areas lying in between. In the oceanic waters also a similar trend was observed, where the greater number per haul ranged from 8 to 27. On the east coast, the hauls from neritic waters contained 0 to 13 per haul, while the oceanic waters along the entire east coast yielded 3 to 9 per haul. In the case of Andaman and Nicobar Islands, greater number of hauls were taken from the oceanic waters where the number per haul ranged from 4 to 13. In the oceanic Central Equatroial Region, the number per haul ranged from 5 to 12. In general, it appears that the occurrence of planktonic cephalopods is more or less uniform in both neritic and oceanic waters, except on the west coast where the abundance is slightly more in the neritic waters.

Discussion

The present study on the planktonic cephalopods taken in Bongo net operated onboard FORV *Sagar Sampada* indicates that this group is well rep-

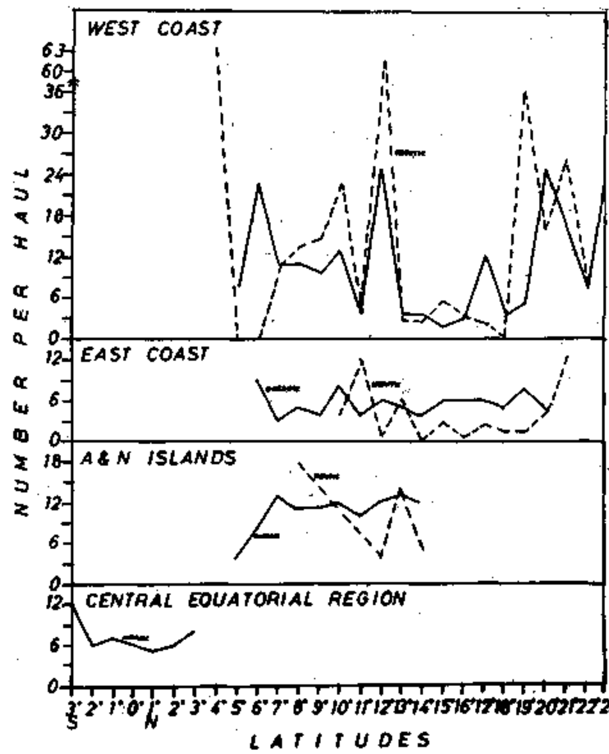

Fig. 3. Relative abundance ot planktonic cephalopods in the neritic and oceanic waters.

resented in the Indian Exclusive Economic Zone and the Central Equatorial Region of the Indian Ocean. Among the four areas studied, the greater abundance of cephalopods (6 to 52 per haul) was noticed on the west coast and Andaman and Nicobar Islands. Aravindakshan and Sakthivel (1973) have indicated that the northwest coast, Central Equatorial Region, east coast and the Bay of Bengal including Andamans from where 10 to 80 per haul was recorded in the plankton collections, are rich nurseries for cephalopods. Silas (1968) also recorded 1 to 13 per haul in the Indian Ocean Standard Net from the southwest coast of India.

In the present collections, the peak abundance was noticed during March-June and August-December on the west coast and March to September on the east coast, which is in agreement with the observations by Silas (1968) and Aravindakshan and Sakthivel (1973). Moreover, Aravindakshan and Sakthivel (1973) have indicated January-March and July- August as the peak periods for the occurrence of cephalopods in the equatroial waters of the Indian Ocean. Though the present observations in the Central Equatorial Region have been limited to January-February, good number of cephalopods (7 to 8 per haul) were obtained.

In regard to the day-night variation in abundance of planktonic cephalopods, the night hauls were found richer. It is known that oceanic cephalopods undergo diel vertical migrations, abounding in 400- 1000 m during the day and in the uppermost 200 m during the night (Roper *et al.*, 1984). Silas (1968) has recorded almost equal representation of cephalopods in the plankton collections made during the day and night from the neritic waters but greater numbers during the night hauls from the oceanic waters of the west coast of India. In the present study, though there was not much variation in the abundance of cephalopods in the neritic and oceanic waters except for the west coast, the night collections in general were richer than the day collections corroborating the theory of diel vertical migration.

Clarke (1966) and Clarke and Lu (1974, 1975) have indicated that the abundance of cephalopods in the columnar waters is species-specific. The qualitative analysis of cephalopods collected by Bongo net operations during the cruises 1 to 10 of FORV *Sagar Sampada* (Sarvesan and Meiyappan, 1989) has indicated a greater abundance of cephalopods belonging to the families Enoploteuthidae, Onychoteuthidae and Ommastrephidae in the night hours, and Sepiidae, Sepiolidae, Loliginidae, Cranchiidae and Octopodidae in the day hours. Further qualitative analysis of samples obtained during the subsequent cruises will throw more light on the seasonal and spatial distribution of cephalopods belonging to different families.

ACKNOWLEDGEMENTS

The authors are thankful toDr.P. S. B. R.James, Director, Central Marine Fishereis Research Institute, Cochin, for suggesting the problem and guidance, and to Dr. K. J. Mathew, Scientist, for making the necessary data available. The help rendered by Shri M. Kathirvel, Scientist is gratefully acknowledged.

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TORNARIA LARVA FROM THE ARABIAN SEA

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Abstract

Plankton samples collected at different stations during Cruise No.11 (26th December, 1985 to 17th January, 1986) by FORV *Sagar Sampada* in the Arabian Sea were examined for tornaria larvae and the same were found in plankton collections from three stations (369, 370 and 372) only. Five specimens occurred at station 372 while thirty five and fifty specimens were found respectively in the plankton collections made at stations 369 and 370. All of them belonged to krohn stage and to one type.

Introduction

Tornaria larva, the planktonic larva of some species of Enteropneusta, was first discovered by Johannes Muller in 1850. Stiasny-Wijnhoff and Stiasny (1927), evaluating the published accounts, reported the occurrence of 14 species of tornaria. Tornaria larvae from the Bay of Bengal have been studied by Menon (1904), Devanesan and Varadarajan (1940) and Rao (1955, 1962). The present study reports the occurrence of tornaria larva in the Arabian Sea.

Material

Forty four plankton samples collected at different stations during Cruise No.11 (26th December to 17th January, 1986) of FORV *Sagar Sampada* in the Arabian Sea were examined for tornaria.

Results

Out of forty four plankton samples examined, tornaria larvae were present in the plankton of three stations only and particulars about them are given below.

Station	Date	Time (hrs)	Lat. (N)	Long. (E)	Surface Temp.°C	No. of Tornaria
369	15-1-'86	0800	08°	74°	24.2	35
370	15-1-'86	1715	08°	75°	25.2	50
372	16-1-'86	0130	10°	75°	26.2	5

Most of the tornaria larvae were found to be damaged in varying degrees due to overcrowding with other plankters and also showed artifacts from their preservation. Larval identification was made following the description by Trewavas (1931).

All the tornaria larvae obtained were fairly large and their length ranged from 3 to 4 mm. They belonged to the krohn stage of a single species.

Discussion

Tentaculate tornaria are limited to the genus *Ptychodera*. Tornaria larva collected from the Arabian Sea resembled *Tornaria chierchiai*, the larva of Indo-Pacific *Ptychodera flava* Eschacholtz. Scheltema (1987) reported that *Tornaria chierchiai*, was found in surface waters throughout the tropical Indian Ocean and in the western and central tropical Pacific but not east of 140° W within the east Pacific Barrier. Scheltema (1987) examined samples from 46 locations in the Indian Ocean between 5° N and 5° S latitude and found that *T. chierchiai* was present at 22% of the stations, the same frequency at which they occurred in the central and west pacific. In the present study the tornaria larvae resembling *T. chierchiai* were found at three stations between 8° and 10° N off the southwest coast of India. The present finding has extended the northward distribution limit of tornaria larvae in the Indian Ocean upto 10° N. Studies by Strathmann and Bonar (1976) and Hadfield (1978) showed that the larva of *Ptychodera flava* adapted for long periods of planktonic life (3.5 to 9 months) which permits them distribution over wide geographic areas. Scheltema (1987) further reported that the common occurrence of *Ptychodera flava* throughout the central Pacific and Indian Ocean supports the hypothesis that its larvae (i.e. *T. chierchiai*) are widely dispersed and able to colonize new areas and maintain genetic continuity between spatially separated populations both along extensive coastlines and widely scattered oceanic islands.

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ON SOME FISH EGGS AND LARVAE FROM THE ANDAMAN AND NICOBAR SEAS

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Abstract

Information on fish eggs and larvae occurring around the Andaman and Nicobar islands is meagre. A knowledge of the same will be very useful in the proper development of marine fisheries in the islands. This report describes some of the common eggs and larvae occurring around the Andaman and Nicobar islands based on material collected by FORV *Sagar Sampada* from the area in June-July, 1988. Fish larvae were found to be invariably more when compared to eggs in all the stations. Eggs and larvae belonging to the families Muraenidae, Ophichthidae, Clupeidae, Engraulidae, Chirocentridae, Synodontidae, Myctophidae, Bregmacerotidae, Exocoetidae, Hemiramphidae, Oreosomatidae, Platycephalidae, Malacanthidae, Carangidae, Pomacentridae, Cirrhitidae, Owstonidae, Uranoscopidae, Gempylidae, Bothidae, Triacanthidae and Balistidae were encountered in the present observation. The eggs and larvae encountered and identified are described herein.

Introduction

Observations on the geographical distribution and abundance of the fish eggs and larvae have been carried out since the inception of marine research. However, there is paucity of information on the early life history of marine fishes and even the available observations are published in scattered journals. Perhaps only ten per cent of marine fishes have hitherto been studied for their early life history (Smith, 1974). The first step for a comprehensive knowledge on the taxonomy and biology of any organism is the accurate identification and description, not only based on adult characters but also early developmental stages. Studies on the early life history of fishes from tropical Indian waters, in general, and particularly from Andaman and Nicobar islands are scanty. The present investigation is an attempt to identify and describe the eggs and larvae of some fin fishes that contribute to the marine fisheries of Andaman and Nicobar waters. This study also attempts to elucidate the breeding periodicities of fishes migrating from sea to ocean and viçe versa, and the dynamic, physico-chemical changes of the environment influencing their migration and spawning.

Materials and Methods

The materials for the present study consisted of 19 samples of ichthyoplankton collected from 19 stations around Andaman and Nicobar islands between 11th June and 5th July, 1988, while participating in the 48th cruise of FORV *Sagar Sampada* by the senior author (M.M). Stations 1-12 are located in the waters around Andaman Islands while the remaining stations are located around Nicobar Islands. The station details are given in Table 1. The icthyoplankton samples were collected by Bongo-60 net of 0.33 mm mesh size. The net was hauled obliquely from about 150 m to the surface wherever depth to bottom exceeded 150 m and from 5m above bottom to surface at other places. The samples were preserved in 5% formaldehyde solution. The eggs and larvae were identified following Jones (1950).

Results and Discussion

The ichthyoplankton of Andaman and Nicobar waters indicated the relative abundance of larvae over that of the eggs, invariably at all stations. Fin fish eggs belonging to 5 genera and larvae belonging to 20 genera have been identified. Eggs of *Amblygaster leiogaster* (Delsman, 1926; John, 1951) were encountered at stations 2, 3, 5, 13 and 14, whereas eggs of *Uranoscopus scaber* (Dekhink, 1973), were observed at stations 1, 2, 3, 4, 12, 13, and 14. Eggs of *Ophichthus* sp. (Ganapati and Raju, 1960) and *Saurus* sp. (Venkataramanujam, 1975), were collected at stations 1, 2, 4, 5, 6, 9 and 12, while the eggs of *Hemiramphus* sp. (Vijayaraghavan, 1957), were observed at stations 1, 2, 9, 11 and 14. Post larvae of *Bregmaceros mcClellandi* (Venkataramanujam, 1975), *Chirocentrus dorab*

TABLE 1. *Station details and occurrence of larvae*

St No.	Date	Time (hra)	Position Lat.(N)	Position Long. (E)	Depth to bottom (m)	Bongo net hauling depth (m)	Occurrence of rare larvae 1	2	3	4	5	6	7	8	9	10	11
1.	16.06.88	0530	14°29'	91°32'	2000	150-0	+	-	-	-	-	-	-	-	-	-	-
2.	16.06.88	0530	14°30	92°15'	3000	150-0	+	-	-	-	-	-	+	-	-	-	-
3.	17.06.88	0545	13°39'	91°04'	2900	150-0	-	-	-	-	-	-	+	-	-	+	-
4.	17.06.88	1900	12°39'	91°43'	3000	150-0	-	-	-	-	-	-	-	-	-	+	-
5.	18.06.88	1500	11°33'	91°71'	1000	100-0	-	-	-	-	-	-	-	-	-	-	-
6.	18.06.88	1500	10°31'	92°08'	450	150-0	-	-	-	-	-	-	-	-	-	-	-
7.	19.06.88	0900	10°31'	93°30'	2700	150-0	-	-	-	-	-	-	-	-	-	+	-
8.	19.06.88	1330	11°36'	94°09'	2000	150-0	-	-	-	+	-	-	-	-	-	-	-
9.	20.06.88	0530	11°32'	94°58'	2988	150-0	-	-	-	+	-	-	-	-	+	-	-
10.	20.06.88	1600	12°31'	94°55'	1500	100-0	-	-	-	-	-	-	-	-	-	-	-
11.	21.06.88	0545	13°40'	93°59'	1545	25-0	-	-	-	-	-	-	-	-	-	+	-
12.	21.06.88	1900	13°10'	93°01'	150	50-0	-	-	-	-	-	-	-	-	+	-	+
13.	27.06.88	1330	9°30'	93°30'	2500	150-0	-	-	-	-	-	+	-	-	-	-	-
14.	27.06.88	2030	9°24'	94°50'	3200	30-0	-	-	-	-	-	-	-	+	-	-	-
15.	28.06.88	0600	8°24'	94°50'	3000	150-0	-	+	-	-	-	-	-	-	+	-	-
16.	28.06.88	1700	7°29'	94°08'	915	50-0	-	-	-	-	-	-	-	+	-	-	-
17.	29.06.88	0600	6°48'	93°57'	98	50-0	-	-	+	-	-	-	-	-	-	-	-
18.	29.06.88	1430	7°45'	93°45'	840	150-0	-	-	-	-	+	-	-	-	-	-	-
19.	30.06.88	0400	9°00'	93'24'	1720	50-0	-	-	-	-	-	-	-	-	-	-	-

+ = present ; - = absent; 1.*Nealotus tripes*, 2. *Family : Owstonidae*, 3. *Cirrhitichthys aprihus*, 4. *Engyprosopon grandisquama*, 5. *Balistoides viridescens*, 6. *Neocyttus* sp., 7. *Abudefduf biocellatus*, 8. *Myctophum phengodes*, 9. *Alectis indicus*, 10. *Hemiramphus lutkei*, 11. *Branchiostegus japonicus*.

(Delsman, 1926), *Exocoetus volitans* (Venkataramanujam, 1975), *Saurida* sp. (Koteswaramma, 1984), *Platycephalus* sp. (Koteswaramma, 1984), *Stolephorus heterolobus* (Koteswarama, 1984), *Anadontostoma chacunda* (Thangaraja, 1982), *Triacanthus brevirostris* (Venkataramanujam, 1975) and leptocephalus stage of *Muraena* sp. (Koteswaramma, 1984) collected invariably from all stations, have already been described. However, the post larvae of *Nealotus tripes, Cirrhitichthys aprihus, Hemiramphus lutkei, Engyprosopon grandisquama, Balistoides viridescens, Alectis indicus, Neocyttus* sp., *Abudefduf biocellatus, Branchiostegus japonicus, Myctophum phengodes* and two larvae belonging to the family Owstonidae have been identified and described in detail in the present study. These larvae are being reported for the first time from Indian waters.

Description of Larvae

Family : Gempylidae

Nealotus tripes (Fig. 1)

Ten post-larvae of *Nealotus tripes,* belonging to the family Gempylidae were obtained from stations 1 and 2. The specimens varied from 7.7 to 10.7 mm in total length and the eye diameter ranged from 0.9 to 1.0 mm. Tip of snout is sharply pointed; dorsal profile of head changes from smoothly convex to nearly straight; trunk attenuates markedly and head length and body depth decrease distinctly relative to body size; all spines of fins and head tend to regress with growth; 2 spines of anal fin bear spinnules on lateral edges; body becomes covered by melanophores which spread from tail; dorsal with XX spines and 20-21 soft rays; anal with II spines and 18-19 soft rays; pectoral fin slightly developed. Spines of pelvics are the longest relative to body size at this stage; caudal is slightly forked.

Family : Owstonidae (Fig. 2)

Two post- larvae of the family Owstonidae were collected from station 15. The specimens varied from 6 to 7 mm in total length and the eye diameter ranged from 0.35 to 0.4 mm; body elongated and compressed; dorsal fin with 20-22 rays and anal fin with 14-15 rays; caudal is elongate. 7-8 pre-anal and 15-17 post-anal myotomes are present.

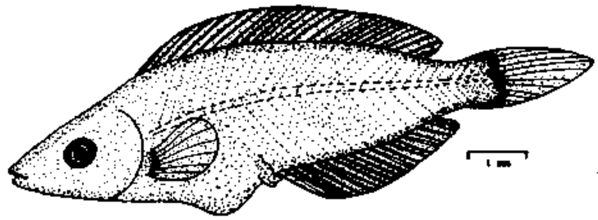

Fig. 2. Post larva of Fam : Owstonidae.

Family : Cirrhitidae

Cirrhitichthys aprihus (Fig. 3)

Ten post-larvae of *Cirrhitichthys aprihus* belonging to the family Cirrhitidae (Hawk fishes) were obtained from station 17. These specimens varied from 6.1 to 6.6 mm in total length and the eye diameter ranged from 0.4 to 0.5 mm; dorsal fin with X spines and 10-13 soft rays and anal fin with III spines and 12 soft rays. In the dorsal fin the second spine is elongated. Pelvic fin has 6 soft rays; the second ray is elongated. The caudal fin is truncate. The Hawk fishes are usually small and richly coloured, inhabiting the rocky and coral habitats. They have many features in common with the scorpaenids.

Family : Bothidae

Engyprosopon grandisquama (Fig. 4)

Five post-larvae of *Engyprosopon grandisquama* belonging to the family Bothidae were obtained

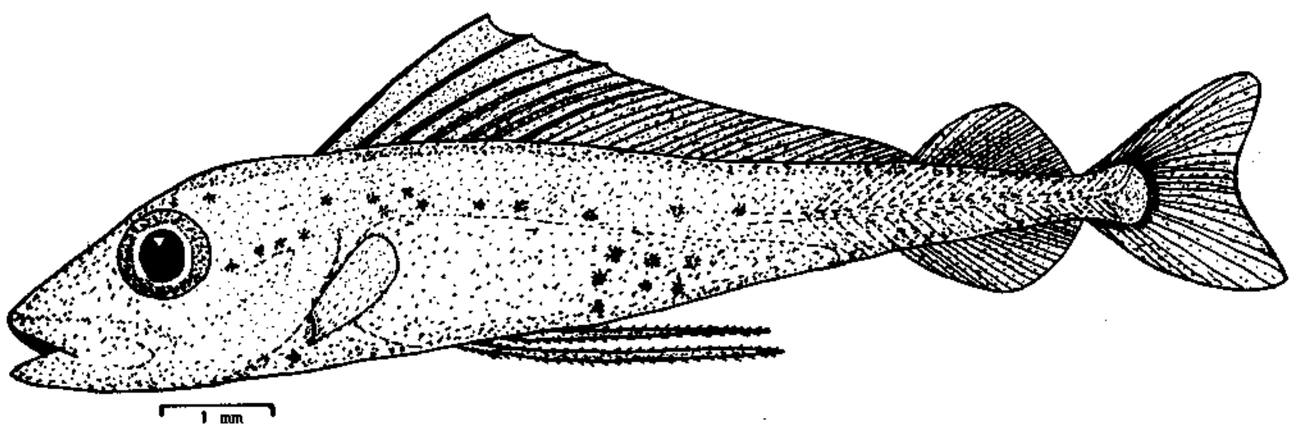

Fig. 1. Post larva of *Nealotus tripes*.

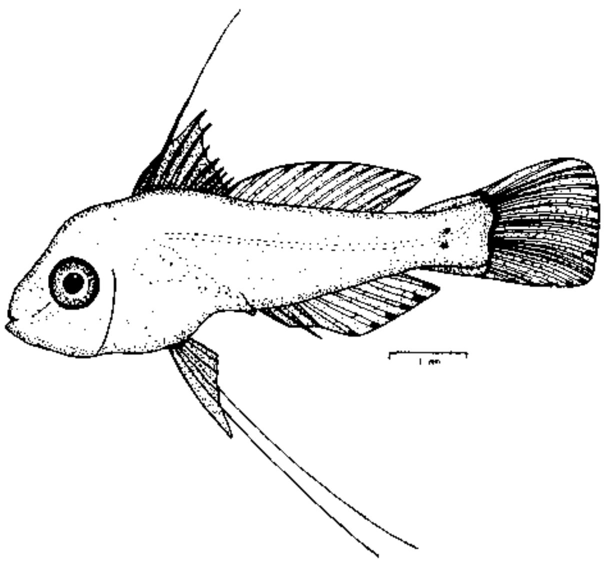

Fig. 3. Post larva of *Cirrhitichthys aprihus*

from stations 8 and 9. Such post larvae have already been collected and identified by earlier workers (Ozawa, 1986). The specimens varied from 4.59 to 5.41 mm in total length and the eye diameter ranged from 0.28 to 0.33 mm. The dorsal fin had 79-85 rays and the anal showed 59-64 rays. These post larvae had 11-12 pre- anal and 21-22 post-anal myotomes.

Family : Balistidae

Balistoides viridescens (Fig. 5)

Two post-larvae of *Balistoides viridescens* belonging to the family Balistidae (Leather jackets) were obtained from station 18. These larvae varied from 4.1 to 4.9 mm in total length and the eye diameter ranged from 0.6 to 0.7 mm. The dorsal fin had III spines and 21-22 rays while anal fin had 22 rays. The pelvic fin was not developed at this larval stage. The body was usually compressed; head and

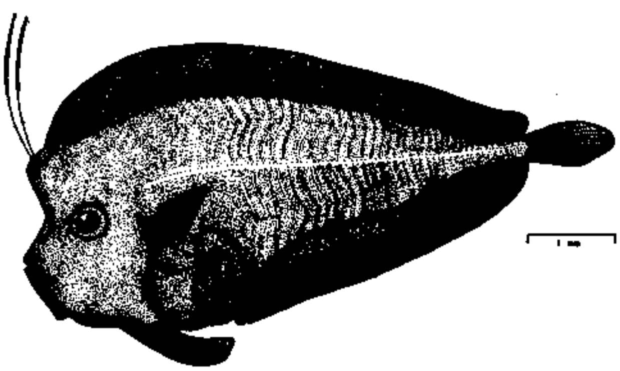

Fig. 4. Post larva of *Engyprosopon grandisquama*.

body in the adult fish, usually covered with scales. But in the larval stages the entire body was covered by minute spines. The pectoral rays were simple. These larvae are popularly called as Trigger fish. The 1-st spine had a deep V-shaped furrow along most of its hind surface. The 2-nd spine is wedge shaped, fitting into the groove of the 1-st, when the first is fully erect and the 2-nd is pushed home. Both lie flat in a deep furrow along the back. Hence the name 'trigger'.

Family : Oreosomatidae

Neocyttus sp. (Fig. 6)

Three post-larvae of *Neocyttus* sp. belonging to the family Oreosomatidae were obtained from station 13. These specimens varied from 5.0 to 5.4

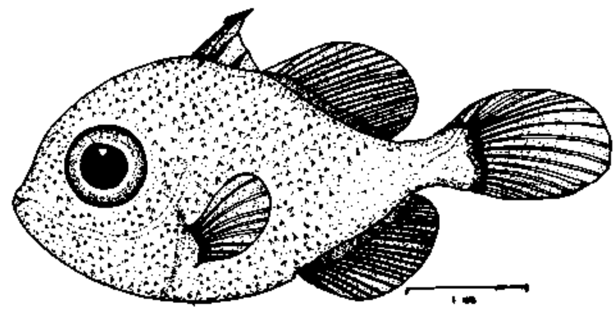

Fig. 5. Post larva of *Balistoides viridescens*.

mm in total length and the eye diameter ranged from 0.4 to 0.5 mm. The body was very deep and compressed; mouth upturned and protractile. Conical scutes present on parts of the body; dorsal fin had VI spines and 33-35 soft rays; anal fin with III spines and 30-33 soft rays; plevic fin with two long spines and 5 rays.

Family : Pomacentridae

Abudefduf biocellatus (Fig. 7)

Two post-larvae of *Abudefduf biocellatus* belonging to the family Pomacentridae (Damsel fish) were obtained from stations 2 and 3. These specimens varied from 7.5 to 8.2 mm in total length and the eye diameter ranged from 0.6 to 0.8 mm. The body was moderately elongated; caudal slightly forked; dorsal fin with XI-XII spines and 16 rays and anal with II spines and 15 rays.

Family : Myctophidae

Myctophum phengodes (Fig. 8)

Five post-larvae of *Myctophum phengodes* be-

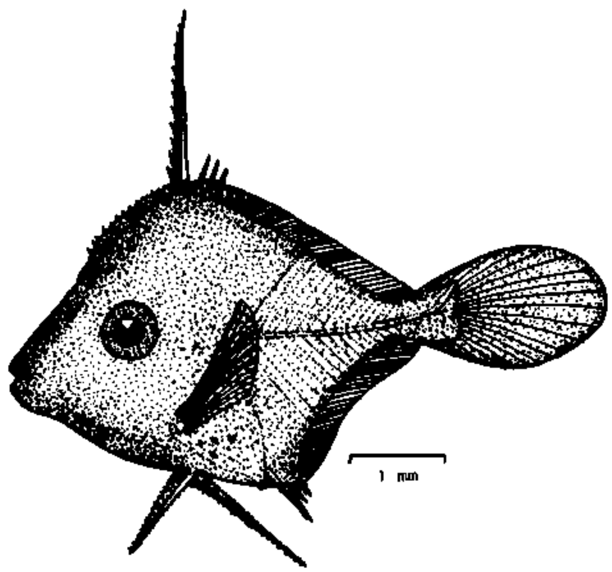

Fig. 6. Post larva of *Neocyttus* sp.

longing to the family Myctophidae (lantern fishes) were obtained from stations 14 and 16. The speci-

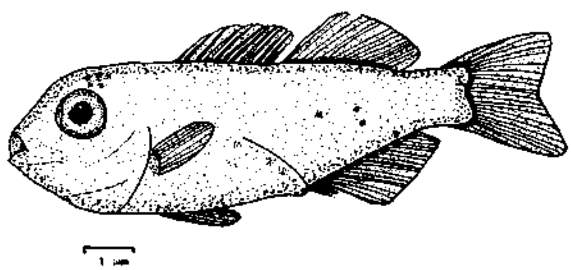

Fig. 7. Post larva of *abudefduf biocellatus*.

mens varied from 9 to 14 mm in total length and the eye diameter ranged from 0.5 to 0.7 mm, the dorsal fin had 12-13 rays and the anal with 19-22 rays; caudal deeply forked; 35 photophores scattered all over the body of this larvae. The photophores were helpful in the identification of these larvae.

Family : Hemiramphidae

Hemiramphus lutkei (Fig. 9)

Eight post-larvae of *Hemiramphus lutkei* belonging to the family Hemiramphidae were obtained from stations 9, 12 and 15. These specimens varied from 12.5 to 16.5 mm in total length and the eye diameter ranged from 0.7 to 0.9 mm. These larvae are slender and elongate. The lower jaw is highly extended than upper jaw. Dorsal fin has 14 soft rays and anal 13 soft rays. Caudal is bifurcate, pigmentations are of the following pattern. On the dorsal side of the upper jaw and the anterior region of the eyes stellate pigments are seen, just behind the cranial region there is a group of stellate pigments dorsolaterally. Myotomes are not clearly visible. *Hemiramphus* sp. has been described by Delsman (1924) from Java waters, whereas *Hemiramphus far* has been studied by Vijayaraghavan (1957) from Madras waters. But the post-larvae of *Hemiramphus lutkei* have not been studied and described by earlier workers. The present post-larvae of *H. lutkei* were collected, identified and described from Andaman and Nicobar waters for the first time in India.

Family : Carangidae

Alcetis indicus (Fig. 10)

The post-larvae of *A. indicus* were obtained from stations 3, 4, 7 and 12. These specimens varied from 8.3 to 9.5 mm in total length; body deep and very compressed; dorsal fin with VI short spines followed by I spine and 18 to 20 soft rays; anal fin with II spines followed by I spine and 15-17 soft rays; caudal slightly forked. Punctate chromatophores scattered all over the body, pectoral and pelvic fins well developed. Identification of the present material is based on meristic counts. So far

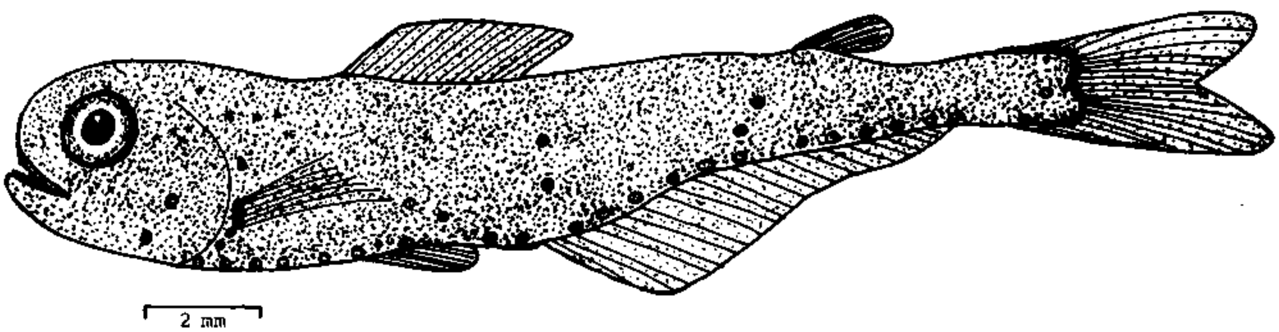

Fig. 8. Post larva of *Myctophum phengodes*.

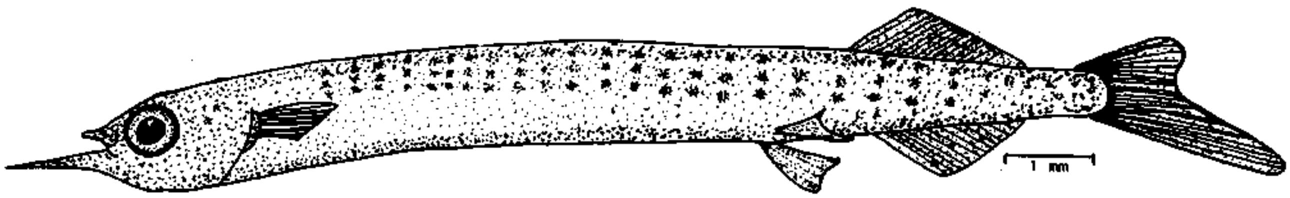

Fig. 9. Post larva of *Hemiramphus lutkei.*

no description of this type is available in this area and the present advanced post-larvae of *A. indicus* are being reported for the first time from Indian waters.

Family : Malacanthidae

Branchiostegus japonicus (Fig. 11)

Three post-larvae of *B. japonicus* were ob-

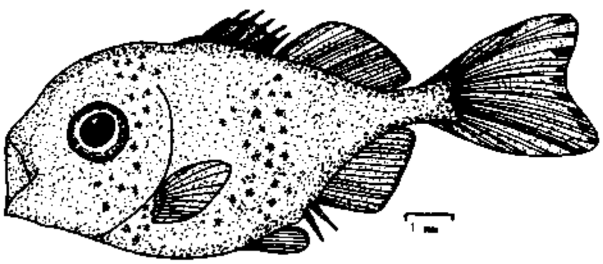

Fig. 10. Post larva of *Alectis indicus.*

tained from station 12. These specimens varied from 6 to 6.5 mm in total length and the eye diameter ranged from 0.5 to 0.6 mm. Body elongate with large head. Mouth large with a few strong canines. A single dorsal fin with VII spines and 13 to 15 soft rays; anal has II spine with 13-14 rays; pelvic has VI spines, of this, the 3rd dorsal spine is very long and serrated; four opercular spines are also present. In this post larvae the myotomes are not clearly visible. Caudal slightly rounded. Pigments are present all over the body. These larvae are being reported for the first time from Indian waters.

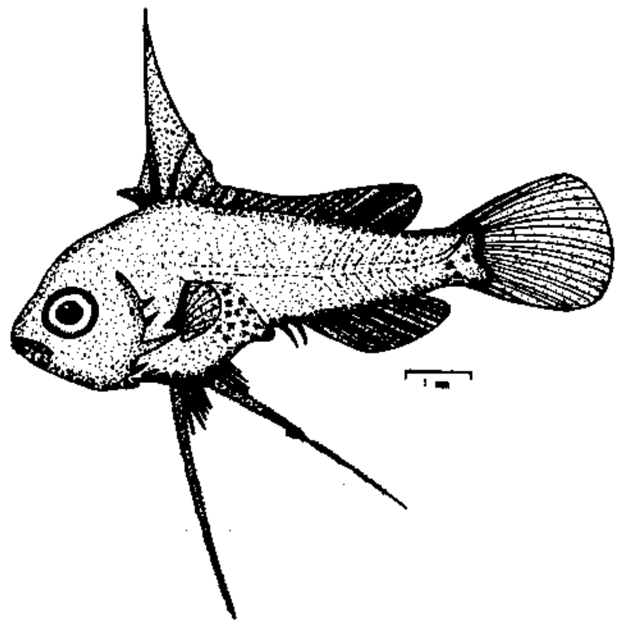

Fig. 11. Post larva of *Branchiostegus japonicus.*

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The authors wish to thank prof. A. Subramaniyan, Director, C.A.S. in Marine Biology for encouragement and for providing the facilities. They also wish to record their sincere thanks to Dr. P.S.B.R. James, Director, CMFRI, Cochin for according the necessary permission to participate the FORV *Sagar Sampada* Cruise No. 48. The first author (M.M.) is grateful to the UGC for financial assistance.

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TECHNICAL SESSION IV

Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5 - 7 *June*, 1989 : 201 - 213 (1990)

FISHABLE CONCENTRATIONS OF FISHES AND CRUSTACEANS IN THE OFFSHORE AND DEEP SEA AREAS OF THE INDIAN EXCLUSIVE ECONOMIC ZONE BASED ON OBSERVATIONS MADE ONBOARD FORV *SAGAR SAMPADA*

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Abstract

Bottom trawling data of FORV *Sagar Sampada* pertaining to a total of 350 fishing hauls with a duration of 330 effective trawling hours for depths beyond 40 m was utilized in the present study. Abundance of selected fishery resources such as threadfin bream, bull's eye, drift fish, lizard fish, ribbon fish, cat fish, barracudas, mackerel, deep sea prawns and deep sea lobster in the offshore and deep sea waters of the Indian EEZ in space and time is indicated. Comparatively high fishable concentrations of threadfin bream was observed at depths beyond 50 m in the fishing squares 8/76 (average CPUE from 650 to 2,610 kg during June-July), 7/76, (1,067 to 3,540 kg during July-August), 11/75 (8,180 kg during September-December), 13/73 (2,500 kg during June-August),15/73 (1,400 kg during June-August), 20/70 (2,400 kg during September-December) and 22/68 (1,260 kg during September-December). Good concentrations of bull's eye were found along southwest coast in fishing squares 7/76 (4,900 kg in August), 15/73 (1,500 kg in September) on the central west coast and in 14/80 and 16/81 (800 to 1,200 kg in September) along northeast coast. For drift fish higher concentrations were found at 19/85 along northeast coast between 62 and 68 m (CPUE 8,000 kg during February). Higher concentrations of lizard fish were observed at 8/76 and 9/75 along southwest coast (250 to 750 kg during June). For ribbon fish good fishing grounds were observed in fishing squares 20/70 and 22/68 along northwest coast (900 kg in September to 1,900 kg in November). Comparatively higher concentrations of cat fish were observed in the fishing square 10/75 along southwest coast at a depth of 50 m (2,400 kg in June). Fishable concentrations of barracudas were observed all along the west coast and northeast coast at a depth of 50 m (300 kg in October and 5,670 kg in August). Mackerel was found in good concentrations along northeast coast between 70 and 85 m in fishing squares 19/86 and 20/87 (1,470 to 2,850 kg during October). Comparatively good fishing grounds for deep sea prawns at depths between 130 and 770 m in fishing square 8/75 were located (620 kg during December-January and 2,200 kg during February). Deep sea lobster was found in good concentrations between 200 and 400 m in the fishing square 8/75 (250 kg in February).

The comparatively high CPUE of the above mentioned fishery resources based on averages worked out for specific fishing areas and seasons is discussed to indicate the possibilities of commercial exploitation of some of these resources which are yet to be exploited on a commercial scale from the offshore and deep sea areas of the Indian EEZ.

Introduction

Till recently trawling operations were mostly undertaken within the coastal waters upto a depth of 50 m in the Indian Exclusive Economic Zone using comparatively smaller commercial/research/exploratory and experimental survey vessels except for observations made by a few of the larger vessels of the Fishery Survey of India, Integrated Fisheries Project (erstwhile Indo-Norwegian Project) and erstwhile UNDP/FAO Pelagic Fisheries Project. Based on the results of smaller vessels the fishing industry also concentrated their efforts within the narrow coastal belt mainly for the exploitation of shrimp which fetched high export value.

Investigations made by Alcock (1901, 1906), Hornel (1916), Gravely (1929), Sundera Raj (1939, 1942), John (1948, 1959), Sivalingam (1957, 1969), Kurien (1965), Mendiz (1965), Menon and Joseph (1969), Silas (1969), Oommen and Remoey (1971), Pillai and Ramachandran (1972), Perumal *et al.* (1972), Mohamed and Suseelan (1973), Rao and George (1973), Tholasilingam *et al.* (1973), Oommen (1974, 1980, 1985), Oommen and Philip (1976), George *et al.* (1977), Joseph (1984, 1986), Ninan (1984), Philip *et al.* (1984), James (1986, 1987), Pillai and Sathiarajan (1986) etc. have contributed to our knowledge regarding the occurrence and relative abundance of both demersal and pelagic fishery resources around the sub continent.

The Department of Ocean Development, Government of India acquired a 71.5 m OAL modern sophisticated Fishery Oceanographic Research Vessel, *Sagar Sampada* in December, 1984. The scientific management of the vessel was entrusted with

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the Central Marine Fisheries Research Institute under the Indian Council of Agricultural Research. The vessel started regular scientific cruises in January, 1985.

During the period January, 1985 to December, 1988, the vessel conducted bottom trawling operations (representative coverage) in almost 80% of a total of 2 million km² area of the Indian EEZ (Fig.1). For convenience sake the entire EEZ is divided into fishing squares depicting 1° lat./long. squares each representing an area of about 12,373 km². Trawling operations carried out by the vessel in different fishing grounds employing different kinds of trawling gear expending a total of more than 300 effective trawling hours confirmed the distribution and relative abundance of 7 major already exploited fish resources offering scope for increased production from deeper waters and another 5 under-exploited deep water and oceanic resources.

Data and Methods

The 71.5 m OAL vessel is essentially a stern trawler with capability for trawling upto a depth of 1000 m. There are two main trawl winches each to take 3,200 m of 22 mm dia. wire rope with a pulling

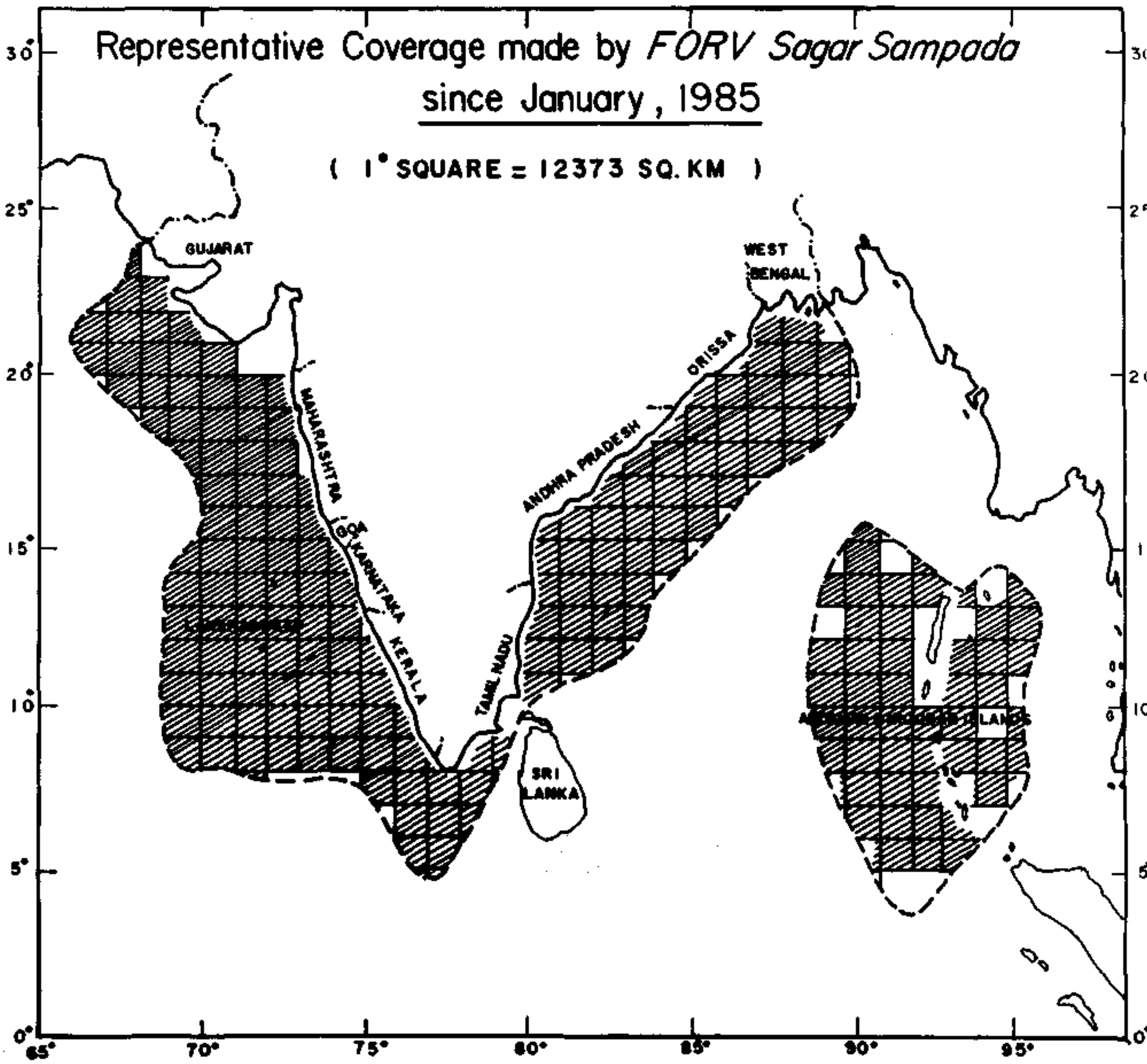

Fig. 1. Representative coverage made by FORV *Sagar Sampada* since January, 1985.

TABLE 1. *Details of bottom trawling gear and accessories operated on board FORV* Sagar Sampada *during the period Jan., '85-Feb., '89*

Sl. No.	Specifications of gear	Trawl doors	Measured vertical opening (centre)
A.	*Imported fishing gear received along with the vessel*		
1.	G.C.V. *Chalut* 400 X 100 mm 80 m = 77 m excluding selve edge - 2 panel with 3 bridles	perfect - V Trawl doors model economy 750 kg each and Perfect -V 2,000 kg each model green-land	Upto 7 m
2.	Star model 500 X 100 mm 100 m = 97 m excluding selve edge - 2 panel - 2 bridles	- do -	- do -
3.	Large Granton 400 x 70 mm 56 m = 54 m excluding selve edge - 2 panel, 2 bridles	- do -	- do -
B.	*Indigenous fishing gear designed and fabricated by Central Institute of Fisheries Technology*		
1.	High speed Demersal Trawl - I	- do -	-
2.	High Speed Demersal Trawl - II	- do -	-
3.	High Speed Demersal Trawl - III	- do -	-

capacity of 30 tonnes. The vessel is fitted up with an auto trawl system which will electrically control shooting, trawling and hauling from the fishing bridge, in addition to manual control from the deck.

The major types of bottom trawls used onboard are given in Table 1. While arriving at averages, special care was taken to see that results obtained from operating the same type of gear alone were considered for calculation of averages.

Bottom trawling operations were undertaken at random on the basis of echo sounder/fish finder recordings indicating the bathymetric profile, type of sea bottom and also the availability of fishable concentration of fishes and other marine life. Depth of operation of the gear was decided on the basis of the above observations. Normally the gear was dragged for a minimum of one hour duration. The details with regard to shooting, duration of fishing, hauling and also the quantity as well as quality of the catch (species wise) were recorded in the fishing log maintained by the Fishing Master. The catch was sorted and analysed immediately after the operation in the wet fish laboratory onboard. Length-frequency measurements as well as collection of specimens/organs for biological studies were done immediately and a representative sample was preserved for further detailed study at the shore laboratory.

Fishing operations onboard were conducted by a team of 2 experienced fishing masters and 6 fishing hands drawn from Central Marine Fisheries Research Institute and Central Institute of Fisheries Technology under the supervision of fishing gear scientists from the latter. Samples were brought to the shore in the frozen condition or preserved in formalin for specific studies. Simultaneous hydrographic, phytoplankton/zooplankton and samples with IKMT were also collected at each fishing station as well as all the fixed hydrographic stations during each cruise to attempt correlation studies.

DISCUSSION

A. *Major exploited resources offering scope for increased production*

The major exploited resources offering scope for increased production from depths beyond 50 m are threadfin bream (*Nemipterus* sp.) ribbon fish (*Trichiurus* sp.), lizard fish (*Saurida* sp.), barracudas (*Sphyraena* sp.), cat fish (*Tachysurus* sp.), Indian mackerel (*Rastrelliger kanagurta*) and deep sea lobster (*Puerulus sewelli*).

1. *Threadfin bream:* The potential yield of perches within the Indian EEZ is estimated to be about 2,50,000 tonnes while the present yield of threadfin bream is only around 39,829 t. They are mainly concentrated along the southwest, centralwest and northwest coasts. Following are the areas (fishing squares) where threadfin bream were

available in fishable concentrations. (CPUE: 500 kg and above/hr of trawling) (Fig. 2)

7/76,77	16/72, 81, 82
8/76	17/72, 82, 83
9/75, 76	18/71, 84
11/74, 75, 79, 80	19/70, 84, 85, 86, 87, 88
12/74, 80	20/69, 70, 87
13/73, 74, 80, 94	21/69
14/73, 94	22/68
15/73, 80	23/67

Along the southwest coast, threadfin bream is mainly concentrated in fishing squares 7/76 (CPUE 5-10 t/hr), 8/76, 9/75, 13/73 and 15/73 (CPUE 1-5 t/hr), during June, July and August. Along the central and northwest coasts CPUE of 5-10 t/hr of trawling was obtained in fishing square 11/75 and 1-5 t in fishing squares 20/69, 20/70 and 22/68 during September, October, November and December. At all other fishing squares listed located along the west and east coasts, the CPUE was between 500 kg and 1 t/hr of trawling.

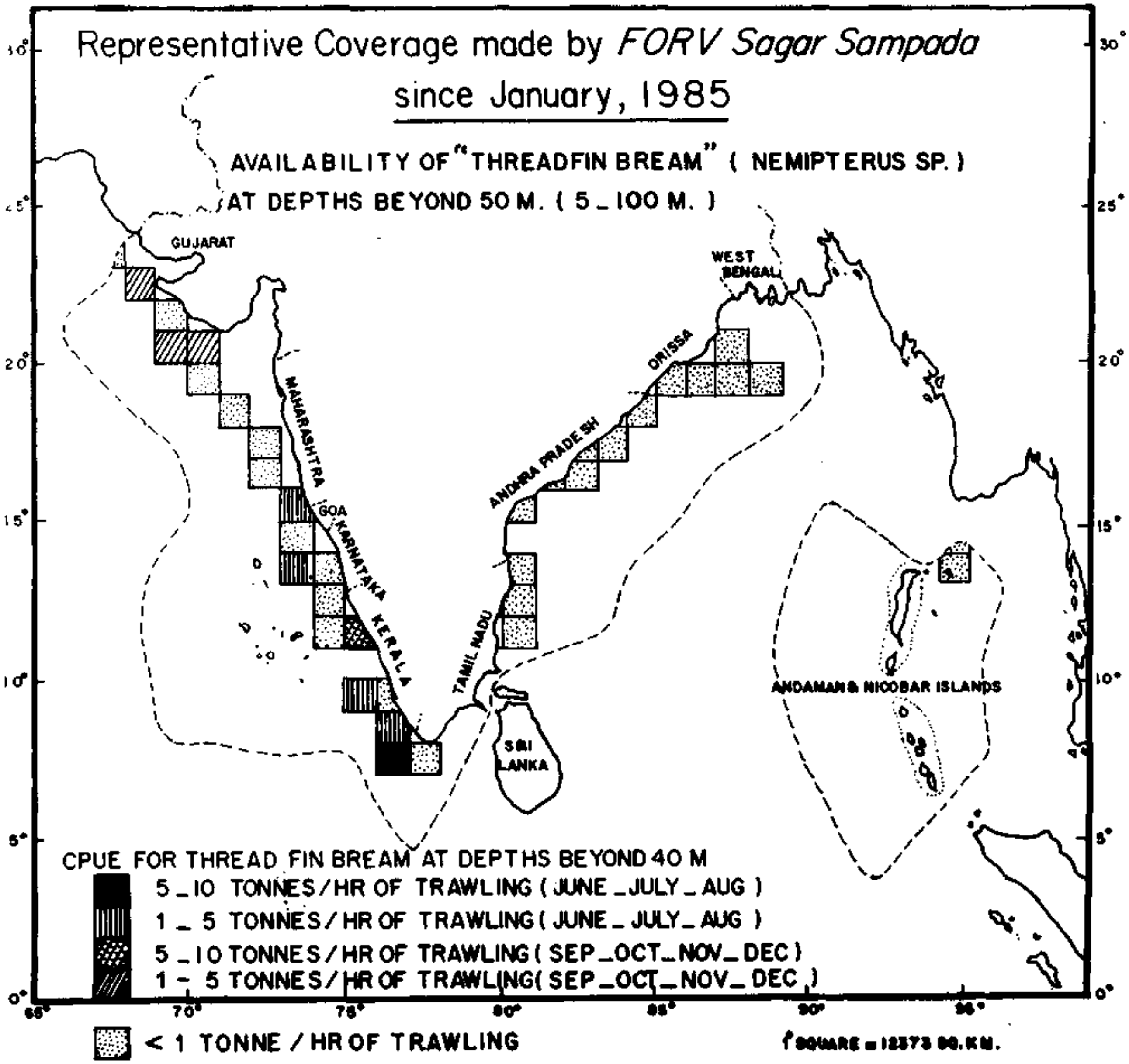

Fig. 2. Availability of Threadfin bream (*Nemipterus* sp.) at depths beyond 50 m (5-100 m).

2. *Ribbon fish:* The potential yield for ribbon fish in the EEZ of India is estimated to be around 2,70,000 t and the present yield is only 82,484 t. They are mainly found concentrated along the northwest, centralwest coast, southwest and northeast coasts. Following are the fishing squares where ribbon fish was found available in fishable concentrations (CPUE 500 kg & above (Fig.3).

8/75, 76	19/70, 88
10/75	20/70, 71, 87
15/73	21/69, 70
17/72, 83	22/68

Large concentration of ribbon fish was found along the northwest coast mainly in fishing squares 20/70 and 22/68 with CPUE varying between 900 kg and 1,900 kg/hr of trawling.

3. *Lizard fish:* The present total annual landings of lizard fish is only around 16,933 t. Large concentration of this fish was mainly found along the southwest coast during June, eventhough they were found all along the west coast and also along the northeast coast in fishable concentrations. (CPUE : 100 to 250 kg/hr).

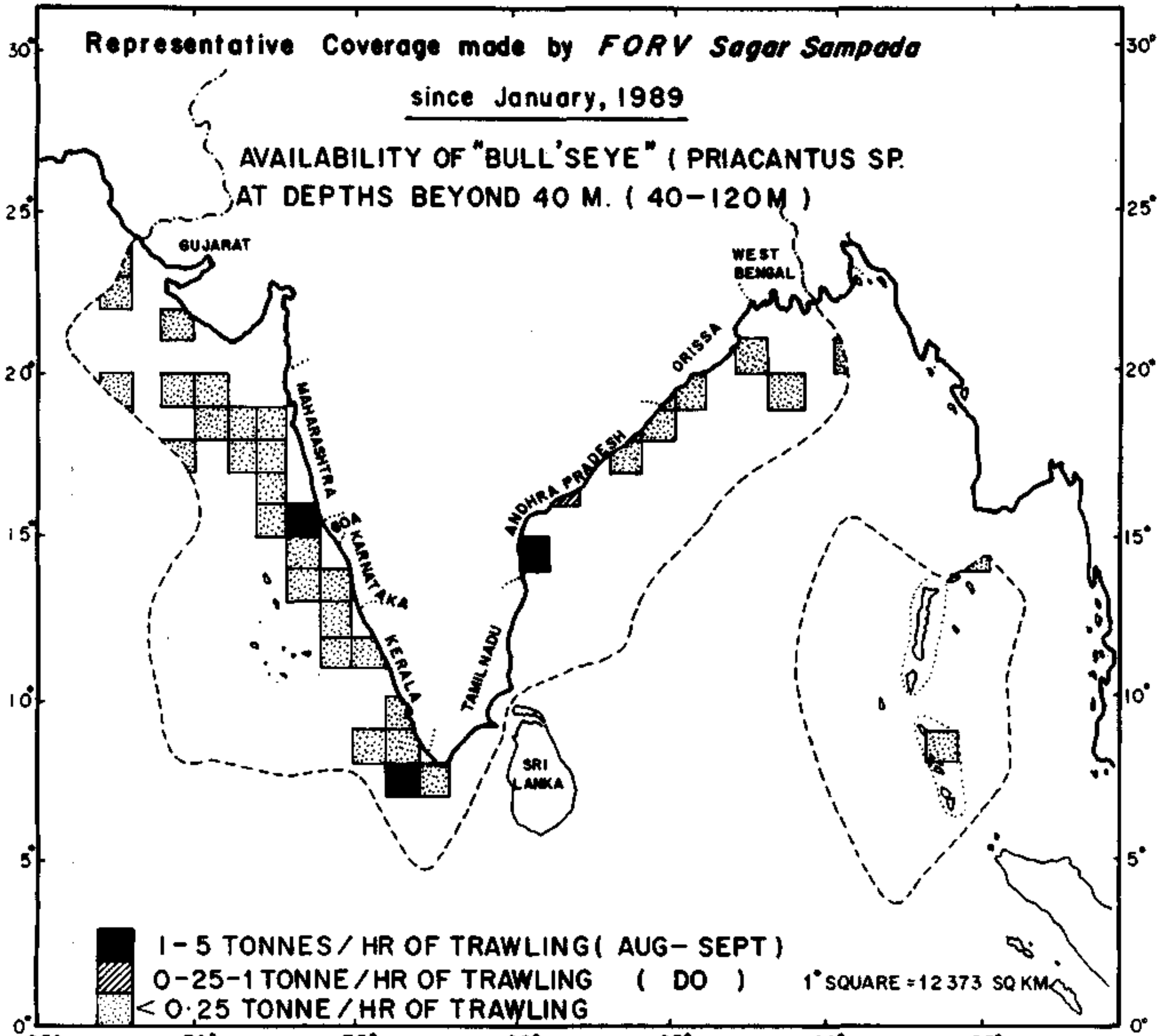

Fig. 3. Availability of Bull's eye (*Priacanthus* sp.) at depths beyond 40 m (40-120 m).

Following are the fishing squares where lizard fish was found available in fishable concentrations (Fig. 4).

7/77	15/73
8/75, 76	16/72, 82
9/75, 76	17/83
10/75	18/71, 84
11/74, 75	19/70, 84, 85, 87, 88
12/74, 80	20/69, 70, 71, 86, 87
13/73, 74, 93, 94	21/69, 70
14/73, 94	23/67

Large concentration of Lizard fish was found along the southwest coast mainly in fishing squares 8/76 and 9/75 with the CPUE varying between 250 to 950 kg/hr of trawling in June.

4. *Barracuda*: Barracudas were found distributed all along the east coast, in the Wadge Bank area and also at selected fishing squares along the west coast. One to five t/hr of trawling was obtained in fishing squares 7/77, 8/78 and 16/81 during June-

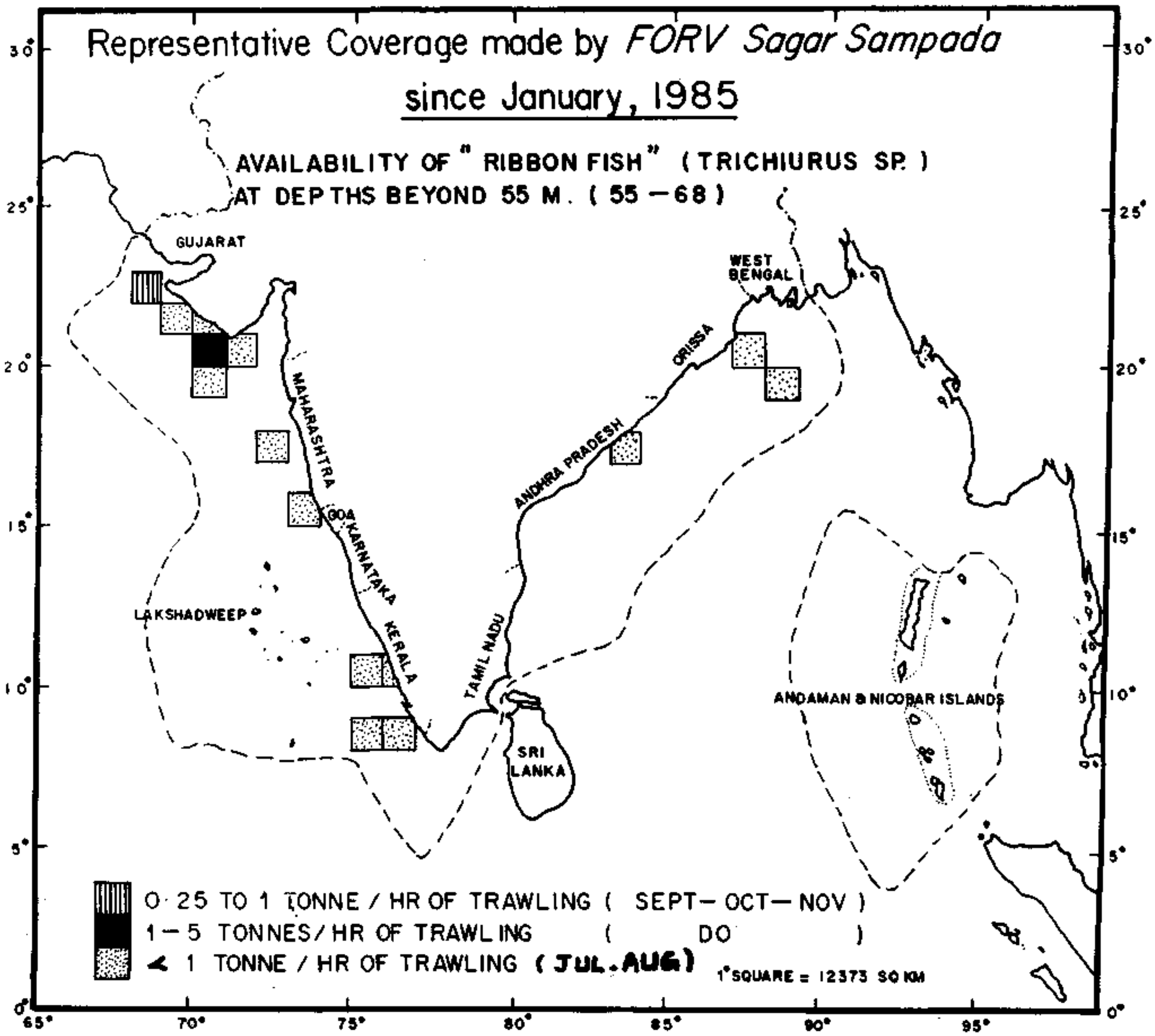

Fig. 4. Availability of Ribbon fish (*Trichiurus* sp.) at depths beyond 55 m (55-68 m).

October. Values between 300 kg and 1 t/hr of trawling was obtained from 18/72 during the same period. The various fishing squares where fishable concentration of barracuda was obtained (above 300 kg/hr of trawling) are listed below. (Fig. 5).

7/77	15/80
8/78	16/81
11/75, 79, 81	17/83
12/80	18/72, 84
13/73, 80	19/85, 86, 88
14/73	

5. *Catfish:* The potential yield for cat fish (*Tachysurus* sp.) in the Indian EEZ is estimated to be around 3,10,000 t out of which only 44,709 t is being exploited at present. They are found mainly distributed along the southwest, centralwest and northeast coasts with higher concentrations (CPUE 1-5 tonnes per hour of trawling) in fishing square 10/75 in June. At all other fishing squares the fish was found in lesser concentrations (CPUE less than 1 t/hr) mainly during June and part of July. The fishing squares where fishable concentrations were found are listed below (Fig. 6).

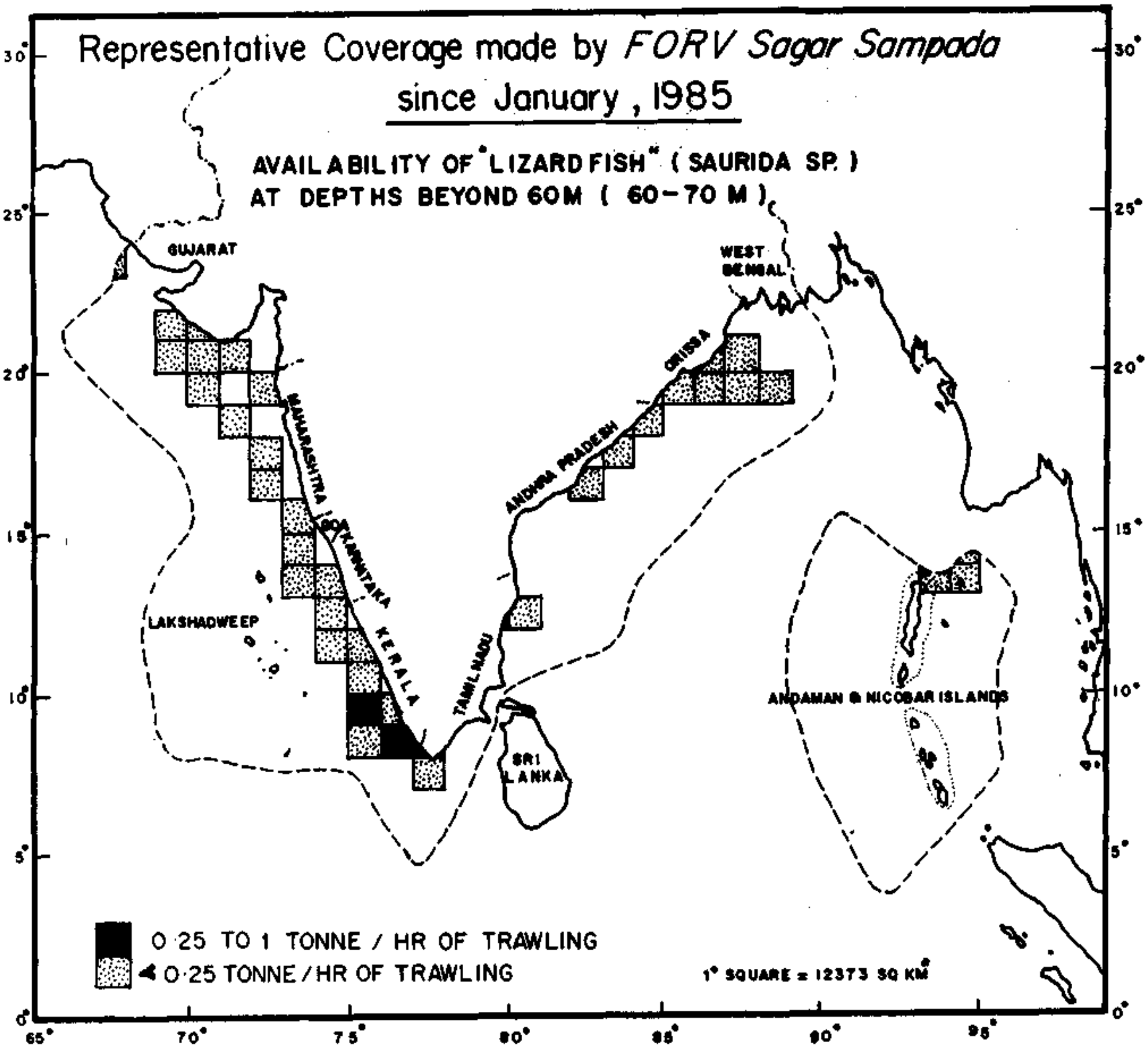

Fig. 5. Availability of Lizard fish (*Saurida* sp.) at depths beyond 60 m (60-70 m).

7/77	15/73
9/76	17/72
10/75	18/84
11/75, 13/73,74	19/72, 85, 86
14/73	20/87

6. *Indian mackerel*: By the acoustic and exploratory surveys conducted by the erstwhile Pelagic Fisheries Project along the southwest coast and Gulf of Mannar, the average annual biomass of mackerel has been estimated as 0.27 million tonnes. Definite indications of large stocks of mackerel in the depth zone of 50-200 m have also come from the recent surveys along the east and west coasts of India (Joseph, 1984 and Ninan *et al.* 1984). The surveys conducted by *Sagar Sampada* confirmed the availability of fishable concentrations of mackerel at depths between 70 and 85 m mainly along the northeast coast and also at selected fishing squares located along the centraleast coast, Wadge Bank and the centralwest coast. Highest concentrations (CPUE 1-5 t/hr) were found in fishing squares 19/86 and 20/87 off Orissa coast during October. Fishing squares with minimum CPUE of 300 kg/hr are listed below (Fig. 7).

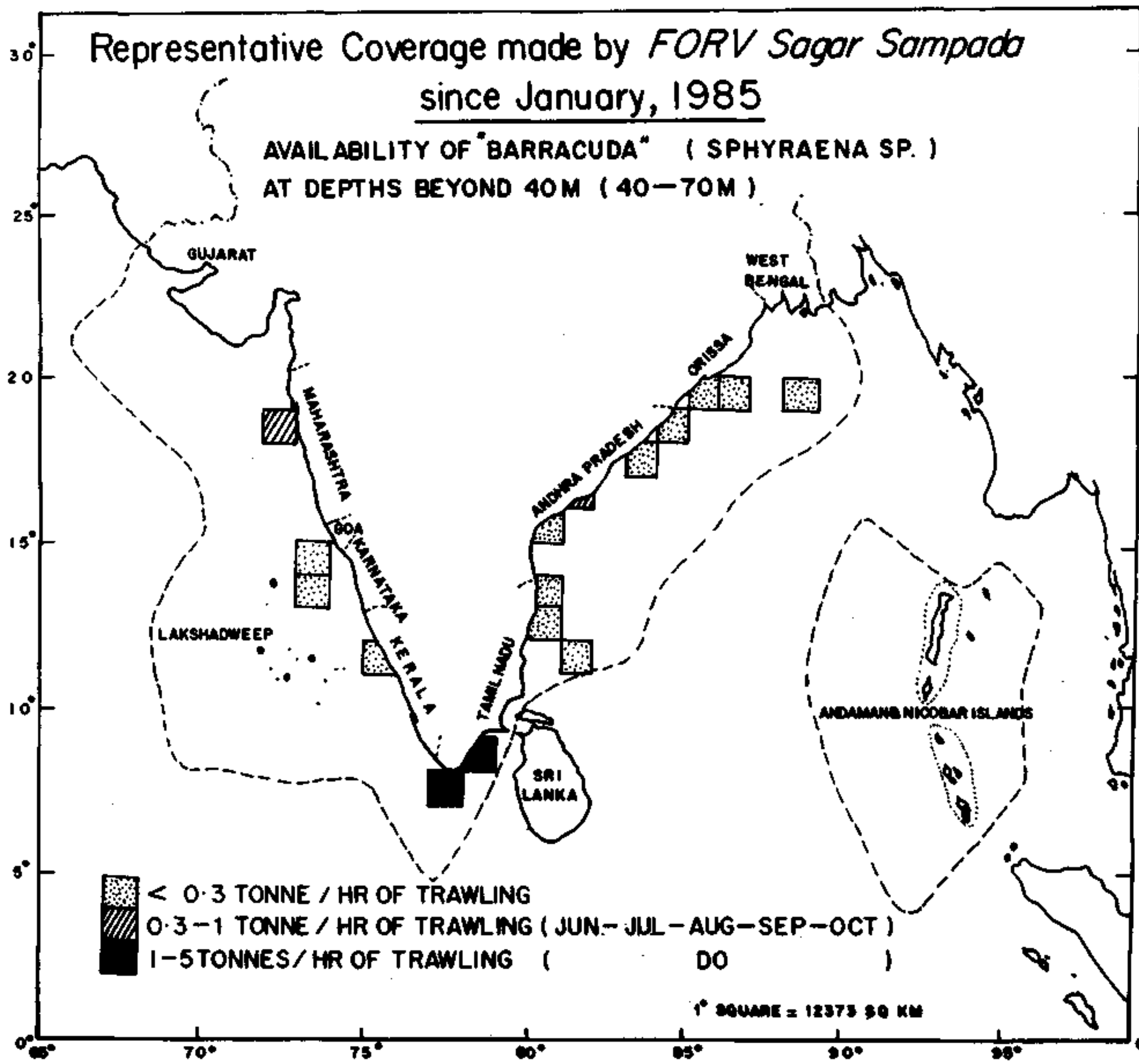

Fig. 6. Availability of Barracuda (*Sphyraena* sp.) at depths beyond 40 m (40-70 m).

7/77	16/72
8/78	17/72, 83
11/79	18/84
12/74	19/85, 86
13/80	20/86, 87

7. *Deep sea lobster*: The sustainable potential for deep sea lobster has been estimated at 8,000 t for southwest coast and 1,200 t for southeast coast out of which hardly 4% is exploited at present. Fishable concentrations of deep sea lobster were found only at a total of 3 fishing squares located off the Kerala coast at depths between 200 and 400 m with maximum abundance between 180 and 270 m during February. The following are the fishing squares where fishable concentrations of deep sea lobster was found (Fig. 8).

8/75	(CPUE 125 kg to 250 kg/hr)
8/76	(CPUE below 125 kg)
9/75	(-do-)

B. ***Under-exploited deep water and oceanic resources***

Oommen (1985) has estimated the standing stock of deep sea fishes along the southwest coast

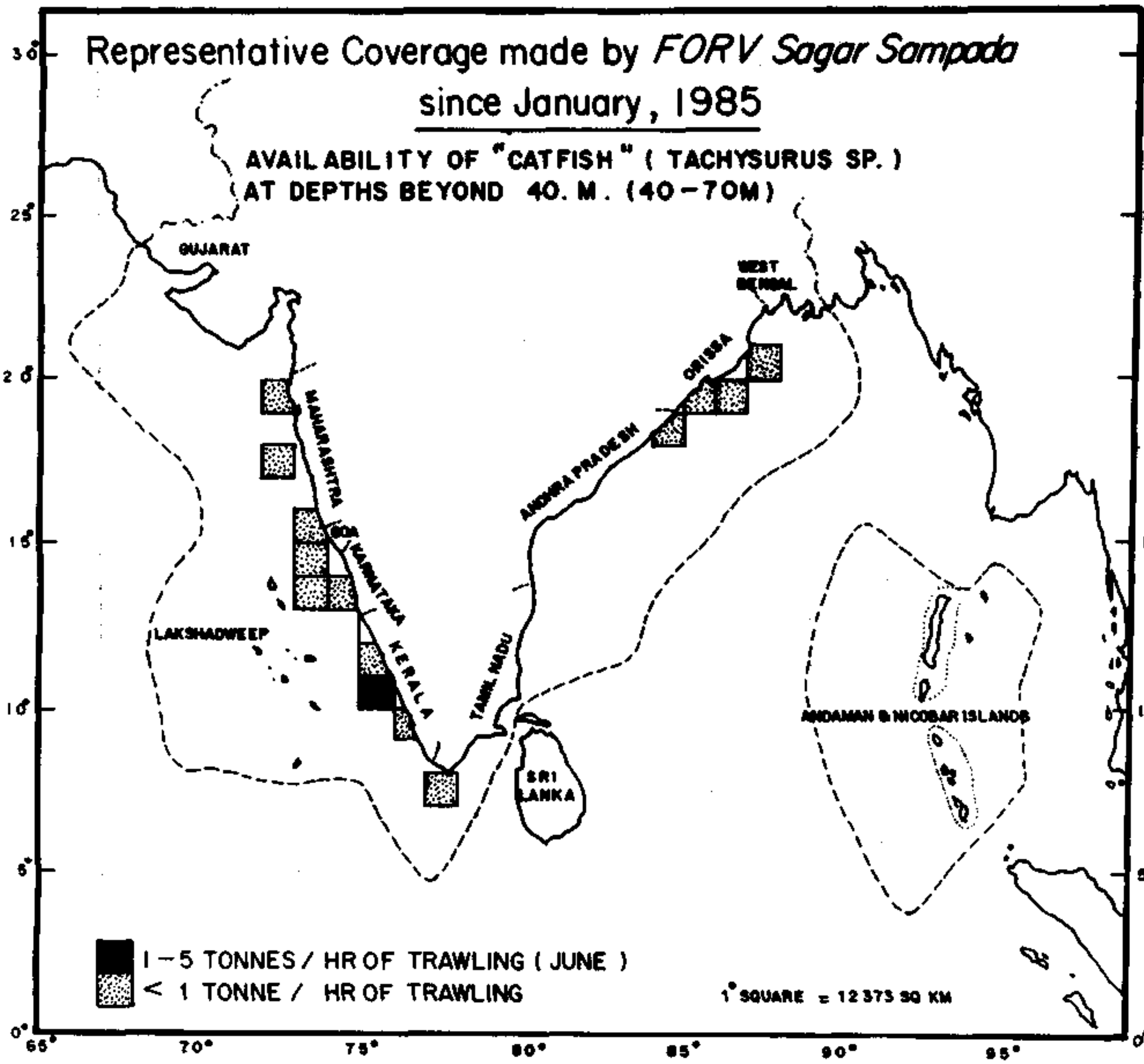

Fig. 7. Availability of Cat fish (*Tachysurus* sp.) at depths beyond 40 m (40-70 m).

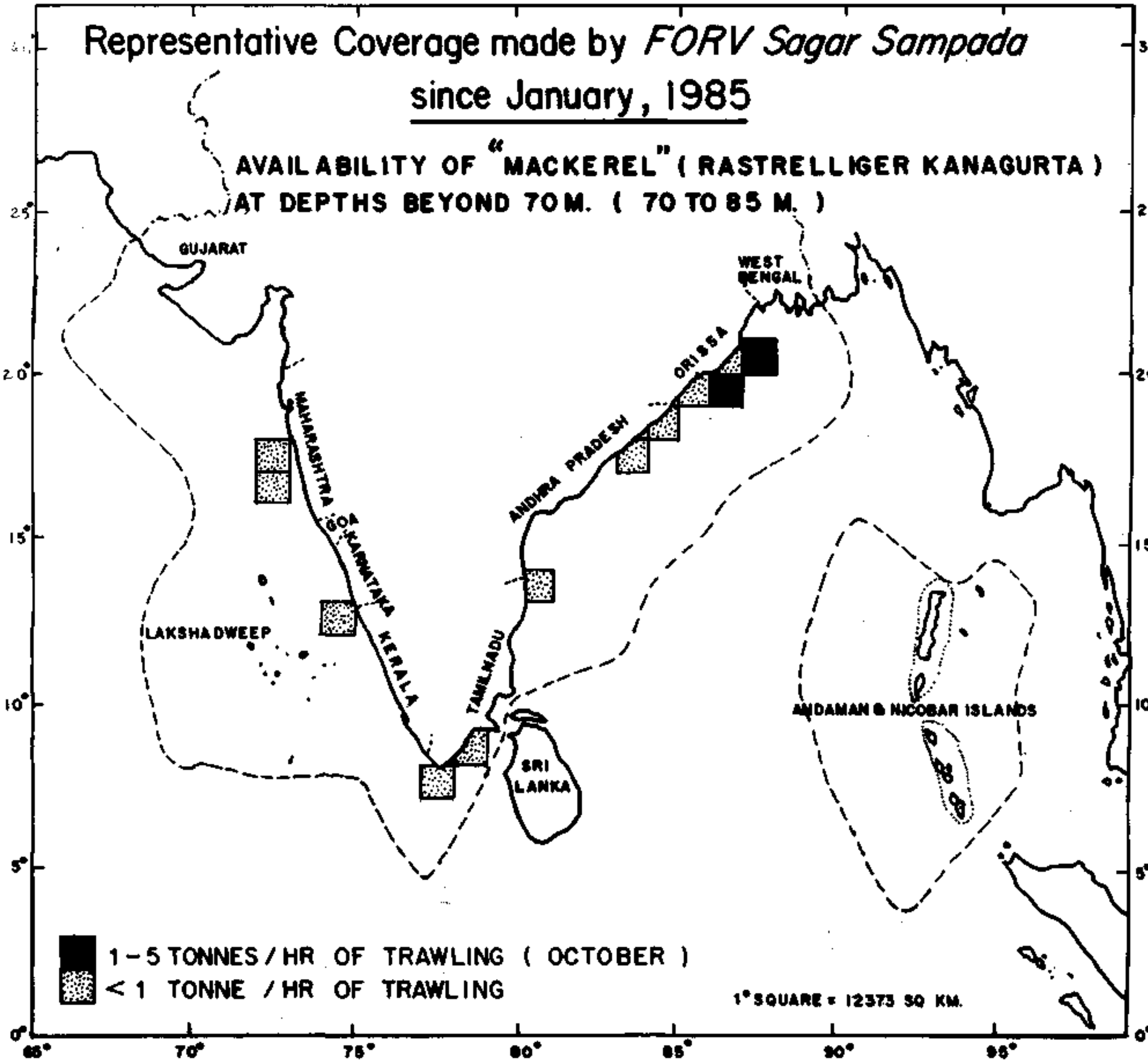

Fig. 8. Availability of Mackerel (*Rastrelliger kanagurta*) at depths beyond 70 m (70-85 m).

(lat. 7° to 13°N) as 8,136 t. Out of this hardly 4 to 5% is being exploited at present.

1. *Bull's eye*: Average CPUE obtained was between 800 kg and 4.9 t/hr of trawling. Comparatively rich grounds were located in the Wadge Bank (August), off Goa (September) and off Andhra Pradesh (September). Maximum CPUE was found at a depth of 120 m. The fishing squares where fishable concentrations of bull's eye were observed (CPUE above 250 kg/hr of trawling) are listed below: (Fig. 9).

7/76, 77	15/72, 73
8/75, 76, 93	16/72
9/76	17/69, 71, 72, 83
11/74, 75	18/70, 71, 72, 84
12/74	23/67
13/73, 74	20/87, 90
14/73, 80, 94	21/69
19/67, 69, 70, 85, 88	22/67

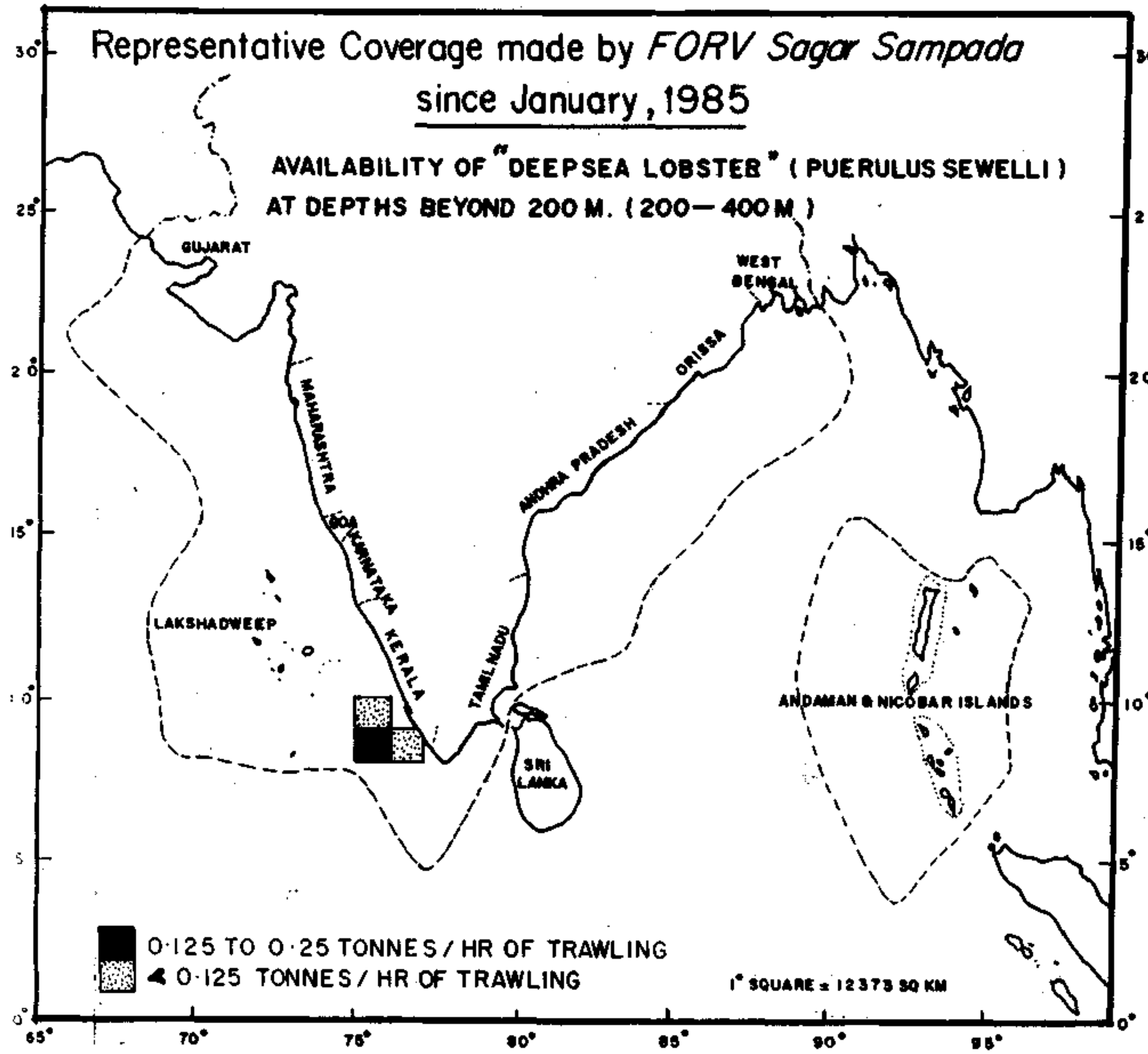

Fig. 9. Availability of deepsea lobster (*Puerulus sewelli*) at depths beyond 200 m (200-400 m).

2. *Drift fish : Psenes indicus*, popularly known as Indian drift fish is another deep water resource found all along the east and west coasts. Fishable concentrations of this fish with CPUE exceeding 1 t/hr of trawling were mainly found along the northeast coast at depths between 62 and 68 m in February. Highest concentrations were found off the Orissa coast in the fishing squares 19/86 and 20/87 with maximum CPUE of 7.5 t/hr in February.

3. *Scad* : Comparatively rich grounds were found mainly along the northeast coast in fishing squares 19/86 and 20/87 off the Orissa coast with a maximum CPUE of 6 t/hr in February.

4. *Deep sea prawns*: The potential yield of deep sea prawns within the Indian EEZ is estimated to be about 3,000 t and the present landings are hardly 5% of the potential yield. *Sagar Sampada* came across fishable concentrations of deep sea prawns (*Potocaris* sp., *Parapandalus* and *Aristaeus* sp.) mainly along the southwest, centralwest and centraleast coasts between depths of 130 and 770 m. Comparatively rich grounds were located mainly in the Quilon Bank off Kerala coast during December-February. Fishable concentration of deep sea prawns with CPUE above 250 kg/hr were found at the following fishing grounds:

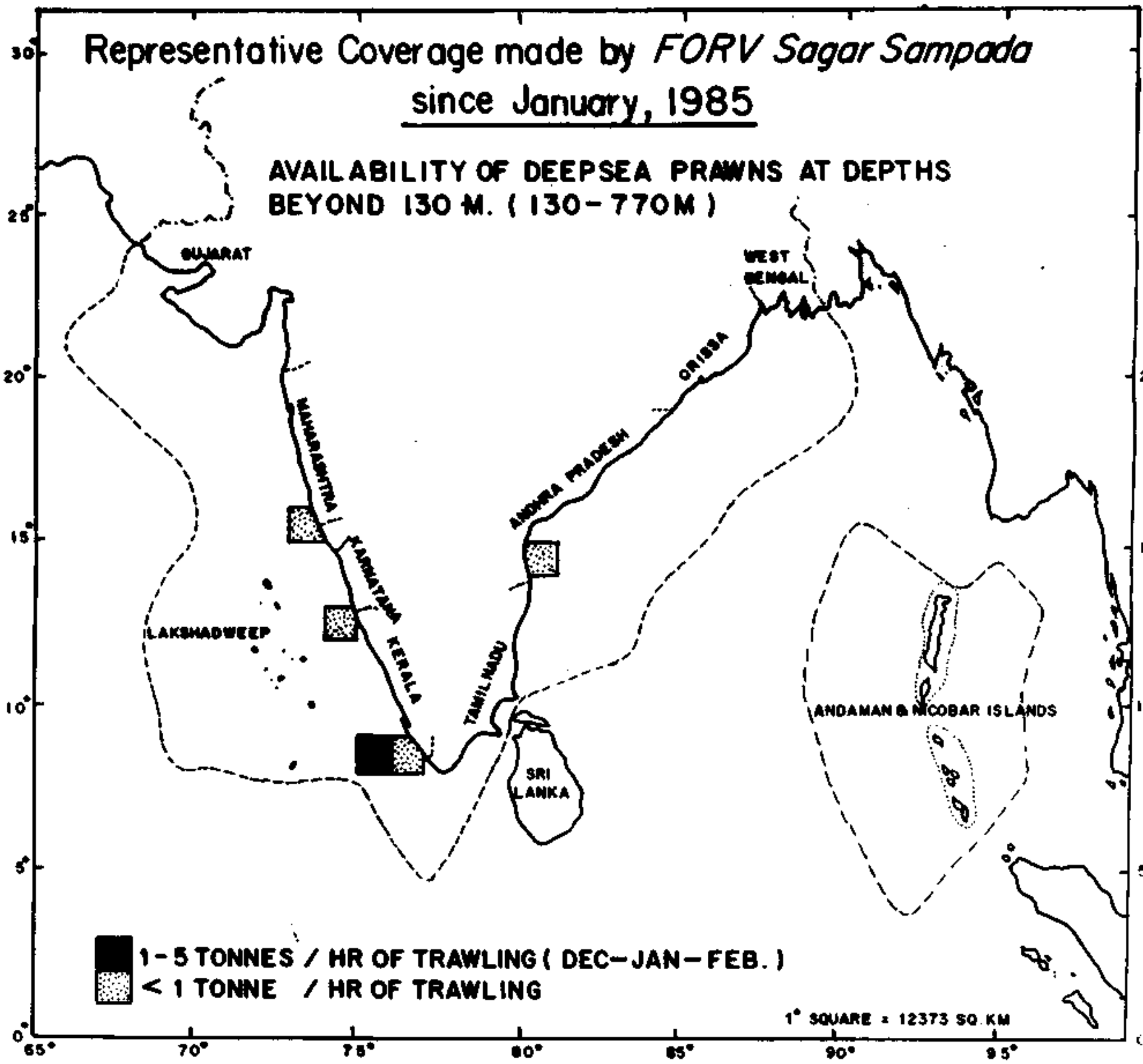

Fig. 10. Availability of deep sea prawns at depths beyond 130 m (130-770 m).

8/75	(CPUE 1 to 5 t/hr)
8/76	(CPUE less than 1 t/hr)
12/74	-do-
14/80	-do-
15/73	-do-

Conclusion

Fishing operations conducted by FORV *Sagar Sampada* threw light on the immense potentiality of the deeper and oceanic waters beyond 50 m depth especially the abundance of fishable concentrations of exploited resources such as threadfin bream, ribbon fish, lizard fish, barracuda, cat fish, Indian mackerel and deep sea lobster beyond the presently exploited zone and also under-exploited deep water resources such as bull's eye, drift fish, scad and deep sea prawns within the Indian EEZ. The observations confirmed the existence of fairly rich grounds for deep sea lobster in the Quilon Bank off Kerala coast.

Based on the above results which threw light on the relative abundance of selected deep water fishery resources in time and space, the fishing industry could venture into the deeper waters by introducing suitable craft and gear for a commercial exploitation of these resources.

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OBSERVATIONS ON THE DEMERSAL FISHERY RESOURCES OF THE COASTAL AND DEEP SEA AREAS OF THE EXCLUSIVE ECONOMIC ZONE OF INDIA

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Abstract

This paper deals with the results obtained in cruises 1 to 49 undertaken by FORV *Sagar Sampada* during the period 1985-'88. Fishery resources obtained from the south, central and north zones along the west and east coasts and from the Andaman-Nicobar Archipelago were analysed in estimating the yield. While southwest zone had the maximum yield, central-east zone had lesser concentration of fishes. Nemipterids formed the dominant group along both the west and east coasts. Depth-wise, 151-398 m depth range had the maximum catch along the west coast, contributed mainly by the deeper waters of the southwest zone. Along the east coast and Andaman-Nicobar Archipelago, 51-100 m depth range yielded the maximum catch. Species composition of the catch, indicated the occurrence of unconventional forms like *Psenopsis* spp. *Trichiurus auriga, Chlorophthalmus agassizi, Neoepinnula orientalis* and *Cubiceps* spp. in addition to the conventional forms especially in the deeper waters of the southwest zone. Relative abundance of major species and their productive areas are also indicated.

Introduction

Since the declaration of 2.02 million sq. km area as the Exclusive Economic Zone of India, in 1976, there has been a growing awareness to augment marine fish production in the country. Thus, by increasing the fishing effort in number and efficiency, and by consecutive exploratory surveys, the fish production which had been at a stagnant level of 1.4 to 1.5 m. tonnes in 1981-'83, could register an increase to 1.7 m.t in 1984 (Sudarsan and Somavanshi, 1988). Nevertheless, the industry has to go a long way in attaining the potential yield of 4.5 m.t.

The demersal fishery resources of the EEZ of India have been estimated to be 1.1 m.t. as against the current yield of 0.34 m.t. (James *et al.*, 1986). While exploratory surveys conducted by organisations like Fishery Survey of India and Central Institute of Fisheries Nautical and Engineering Training can catalyse exploitation, serious thoughts have to be made as to how to tap the unexploited areas beyond 50 m depth. The Central Marine Fisheries Research Institute, Cochin, had been making pioneering attempts in this line using the Fisheries Oceanographic Research Vessel (FORV) *Sagar Sampada* since 1985. The present paper deals with the data collected by this vessel in the spatial distribution and species composition of the various demersal fishes of the coastal and deep sea areas along the EEZ of India during the period 1985-'88.

Material and Methods

The material for the present study was collected onboard FORV *Sagar Sampada.* During the cruises 1-49, the fish samples obtained in Chalute Bottom Trawl, High Speed Demersal Trawl (HSDT-III), Granten Bobbin Trawl and High Life Queen's Trawl were analysed.

In analysing the catch details, stations covered within the latitudes 6°-10°, 10°-16° and 16°-22°N were included under south, central and north zones respectively. Longitudinally, areas within 64°-77° 30' E and 77° 30-89° 00'E were included in the west and east coasts respectively. Cruises undertaken in the Andaman-Nicobar Archipelago were analysed separately.

Depth-wise distribution and abundance of the resource were assessed after grouping the stations covered in each cruise/zone into 4 depth zones of less than 50 m, 51-100 m, 101-150 m and more than 150 m to the maximum depth operated in each zone. Catch per unit effort was estimated against the total number of hours operated in each zone.

Results

A. Exploitation

Fishery in different zones (Table -1)

West coast: In the southwest zone (Lat. 04°00'-

10°00'N, Long. 64°00 -77°30'E) where a total of 110 stations were covered, the total catch amounted to 96.186 tonnes at an effort of 104 hrs 35 min the catch/hr being 919.71 kg. The depth of operation ranged from 35-398 m.

In the centralwest zone (Lat.10°00' - 16°00'N, Long. 64°00'- 77°30'E) the total catch was 36.923 t expending an effort of 62 hrs 40 min at 65 stations. The catch/hr was 589.2 kg and gear depth ranged from 30-250 m.

In the northwest zone (Lat. 16°00'N Long. 64°00' - 77°30'E) covering 46 stations with an effort of 45 hrs, the total catch amounted to 23.222 t with a catch/hr of 5160.5 kg. The depth of operation ranged from 26 - 235 m.

West coast taken as whole, had a total catch of 156.33 t, the catch/hr being 736.54 kg at a total effort of 212 hrs 15 min.

East coast : Southeast zone (Lat. 04°00' - 10°00'N; Long. 77°30'-89°00'E) with 13 stations covered at an effort of 11 hr yielded a total catch of 24.562 t with a catch rate of 2,232.3 kg/hr. The depth of operation varied from 26-631 m.

In the central-east zone (Lat. 10°00' - 16°00'N; Long. 77°30' - 89°00'E), the total catch from 32 stations at an effort 31 hrs amounted to 6.087 t, with a catch/hr of 196.37 kg. Gear depth ranged from 23-168 m.

In the northeast zone (Lat. 16°00' - 22°00'N; Long: 77°30' - 89°00' E) the total catch was 23.971 t. From the 77 stations covered at a total effort of 76 hrs, the catch rate was 315.41 kg. Gear depth ranged from 27-260 m.

East coast taken as a whole had a total catch of 54.620 tonnes at an effort of 118 hrs, the catch rate being 462. 884 kg/hr.

Andaman-Nicobar Archipelago : (Lat. 6° 00'-15°00' N; Long. 92°00'95°00'E) : The total catch from the islands amounted to 2.966 t at an effort of 12 hrs covered in 18 stations, the catch/hr being 234.122 kg. The depth of operation ranged from 34-142 m.

The total catch in the west coast, east coast and Andaman Nicobar Archipelago amounted to 213.917 t, at a total effort of 342 hrs 15 min the catch per hour being 625 kg.

Fishery in different depths

West coast (Table - 1) : Along the southwest zone, depth range of 151-398 m had the maximum catch with a catch/hr of 1,283 kg (Total catch: 56.122 t). The next catch in abundance was from 51-100 m depth range with a catch/hr of 794.5 kg (total catch: 33.57 t). With catch/hr of 525.63 kg, less than 50 m depth range brought a total catch of 3.986 t. Depth range of 101-150 m yielded the least catch of 2.51 t, the catch/hr being 223 kg.

In the central west zone, the maximum catch of 27.314 t was obtained from 51-100 m depth range with a catch/hr of 815.4 kg. Shallow waters of less than 50 m range had the next total catch of 5.331 t the catch/hr being 477.43 kg. From the depth range of 101-150 m, the yield amounted to 3.1 t with a catch rate of 277.64 kg/hr. Deeper waters of 151-250 m range with a total catch of 1.223 t and catch rate of 175 kg/hr yielded the least from the zone.

In the northwest zone, 51-100 m depth range had the maximum catch amounting to 18.76 t with a catch/hr of 625 kg. In the shallow waters of less than 50 m depth range, the total catch amounted to 3.977 t, with a catch/hr of 568.11 kg. In the deeper waters, catch was negligible.

West coast taken as a whole, the highest catch was obtained from 151-398 m depth range with a catch/hr of 1,069 kg/hr (total catch: 57,464 t). The next abundant concentration with a catch rate of 753 kg/hr (total catch : 79.64 t) was in depth range of 51-100 m. Shallow waters of less than 50 m depth had a catch rate of 520 kg/hr (total 13.3 t). Depth range of 101-150 m had the lowest catch with a catch rate of 217.8 kg/hr (total catch : 5.934 t).

East coast (Table 1) : In the southeast zone, depth range of 51-100 m had a dense population with a catch rate of 4,500 kg/hr (total catch 16.5 t). Shallow waters less than 50 m depth range with a catch rate of 1,256 kg also had good concentration of fishes (total catch : 8.1 t). Catch in other depths was negligible.

Centraleast zone generally with a poor catch had a catch rate of 231 kg/hr and 180 kg/hr in 51-100 m and less than 50 m depth range respectively while other depths had negligible catch.

In the Northeast zone also 51-100 m range had a catch rate of 430 kg/hr (total catch 12-795 t) followed by less than 50 m range where the catch rate was 263 kg/hr (total catch : 9.009 t) with very little catch from other depths.

East coast taken as a whole had the shelf

TABLE 1 *Catch details of coastal and deeep sea demersal fishery resources along the EEZ of India during 1985- '89*

Zones/ Position range	No. of stns	Depth range (m) / Catch details														
		50			51-100			101-150			>151			Total		
		Catch (t)	Effort (hrs/ min)	C/E (kg)	Catch (t)	Effort (hrs/ min)	C/E (kg)	Catch (t)	Effort (hrs/ min)	C/E (kg)	Catch (t)	Effort (hrs/ min)	C/E (kg)	Catch (t)	Effort (hrs/ min)	C/E (kg)
A. *West coast* 04° South west 04° - 10° N 64 - 77.30'E	110	3.986	7/35	525.626	33.569	42/15	794.548	2.508	11/15	222.933	56.122	43/45	1,282.794	96.186	104/35	919.706
Central west 10° -16°N 64° -77°. 30 'E	65	5.331	11/10	477.430	27.314	33/30	815.358	3.054	11/-	277.639	1.223	7/-	174.67	36.923	62/40	589.189
Northwest 16° -22°N 64° -77°. 30E	46	3.976	7/-	568.11	18.754	30/-	652.152	0.372	5/-	74.314	0.119	3/-	39.8	23.222	45/-	516.05
Total	221	13.293	25/35	519.626	79.638	105/45	753.085	5.934	27/15	217.746	57.464	55/45	1,069.104	156.331	212/15	736.540
B. *East Coast*																
Southeast 04° - 10°N 77° . 30 '-89°E	13	8.056	6/25	1,255.575	16.500	3/40	4500.00	--	--	--	0.005	1/-	5.00	24.562	11/-	2,232.29
Centraleast 10° -16°N 77°. 30 '-89°E	32	3.239	18/-	179.998	2.772	12/-	231.04	-	-	-	0.075	1/-	75.00	6.087	31/-	196.37
Northeast 16° -22°N 77°30 .-89°E	77	9.009	34/15	263.051	12.795	29/45	430.09	0.390	3/-	130-13	1.776	9/-	197.37	23.971	76/-	315.41
Total	122	20.306	58/40	346.126	32.067	45/25	706.07	0.390	3/-	130.13	1.856	11/-	168.75	54,620	118/-	462.884
C. *Andman-Nicobar Archipelago* 06°-15°N 92°-95°E	18	0.577	2/30	230.92	2.370	8/30	258.584	0.018	1/-	17.90	-	-	-	2.966	12/-	234.122
Grand total	361	34.177	86/45	393.933	114.077	160/20	711.499	6.342	31/15	202.94	59.32	64/45	916.15	213.917	342/15	625.030

waters of 51-100 m range densely populated with a catch/hr of 706 kg (total catch: 32 t) while still shallow waters of less than 50 m range had a catch rate of 346 kg/hr (total catch: 20.3 t).

Andaman Nicobar Archipelago (Table 1) : In this region, depth ranges of 51-100 m and less than 50 m had comparatively good concentration of fishes, the catch rate being 259 kg/hr (total catch: 0.6 t) respectively.

B. Species composition

West coast vis-a-vis-east coast (Table 2)

It is discernible that, nemipterids represented by *N. japonicus, N. delagoae,* and *N. bleekeri* formed the dominant group along both west and east coasts contributing to about 28.43 and 26.71% of the total catch respectively. In addition, *Trichiurus* spp. (*T. lepturus, T. haumala, T. auriga)* forming 7.73% carangids (*Decapterus russelli, D. macrosoma, Megalaspis cordyla, Atule mate, Carangoides malabaricus)* forming 3%, *Psenopsis* spp. forming 11%, and *Chlorophthalmus* spp., forming 10.4% were the dominant groups occurring along the west coast. Besides, perches (*Priacanthus* spp, *Lutjanus* spp., *Epinephelus* spp. , *Lethrinus* spp) , *Upeneus* spp., *Psettodes erumei* and sciaenids were also encountered from the west coast.

Along the east coast, *Sphyraena* spp. (*S. obtusata, S. barracuda, S. jello)* forming 8.9% and carangids (*Caranx ferdue, Decapterus dayi* and *Megalaspis cordyla)* forming 8.4% were the major groups realised in addition to nemipterids (26.71%). Minor groups encountered along the east coast were silverbellies, *Pentaprion longimanus, Psenes indicus, Rastrelliger kanagurta* and deep sea fishes.

Species composition (zone wise) (Tables 3-9, Fig.1)

Along the southwest zone, (Table 3, Fig. 4) the dominant groups were *Psenopsis* spp. (17.45%), *Nemipterus* spp. (16.6%), and *Chlorophthalmus* sp. (16.85%). While *Nemipterus* spp. formed the bulk of the catch (61%) in the centralwest zone (Table 4) followed by *Priacanthus* spp. (11.5%), northwest zone was mainly represented by *Nemipterus* spp. (25.7%) and *Trichiurus* spp. (25.2%) (Table 5). Southeast zone (Table 6) had *Nemipterus* spp. contributing to 52.4% of the total catch followed by *Sphyraena* spp. (14.4%). Perches represented by *Priacanthus* spp., and *Lethrinus* sp. constituted about 33% of the catch in the centraleast zone (Table 7).

Along the northeast zone (Table 8) *R. kanagurta* (20.32%), *Priacanthus* spp. (11.6%) and carangids (11%) were the major groups encountered.

In the Andaman-Nicobar Archipelago, silverbellies (30%), carangids (17.2%) and perches (16%) were the dominant groups in the catches (Table 2 & 9, Fig.1).

Abundance of major species - depth wise (Tables 3 - 9, Fig.1)

Psenopsis spp. which formed the most dominant group caught from the southwest zone was abundant in 151-398 m depth range with a catch rate of 383.54 kg/hr (30%). *Chlorophthalmus* spp. and *Cubiceps* spp. with catch rates of 370 kg/hr (29%) and 76.2 kg/hr (6%) respectively also formed good catches from these deeper waters (Table 3). *Nemipterus* sp. and *Priacanthus* spp. with a catch rate of 359 kg/hr (45%) and 136 kg/hr (17%) respectively were abundant in 51-100 m depth area. In the shallower waters of 0-50 m depth range, *Sphyraena* spp. yielded a catch rate of 158 kg/hr (30%). In the centralwest zone, nemipterids with a catch rate of 602 kg/hr (74%) was abundant in 51-100 m depth range (Table 4, Fig.1).

Northwest zone (Table 5) with *Trichiurus* spp. abundant in less than 50 m and 51-100 m depth range, the catch rate was 240 kg/hr (42.3%) and 139 kg/hr (22.24%) respectively.

Along the east coast, the southeast zone (Table 6) with fish catches exclusively from the coastal waters had dense population of nemipterids in the 51-100 m depth area with a catch rate of 3509 kg/hr (78%). However, along the less than 50 m depth area, *Sphyraena* spp. (551.84 kg/hr), carangids (130.4 kg/hr) and perches such as *Epinephelus* spp. (101 kg/hr) *Lethrinus* sp. (37 kg/hr) and *Lutjanus* spp. (7 kg/hr) and balistids (61 kg/hr) were the major groups encountered. Catches in other depths were negligible.

In the centraleast zone (Table 7), generally with lesser catches, *Priacanthus* spp. with a catch rate of 102 kg/hr (44%) was the dominant group caught only in 51-100 m depth range.

In the northeast zone (Table 8) having more catches from the coastal waters, 51-100 m depth range had *R. knagurta* (159 kg/hr, 37%) and carangids (67 kg/hr, 15.65%) as the dominant groups.

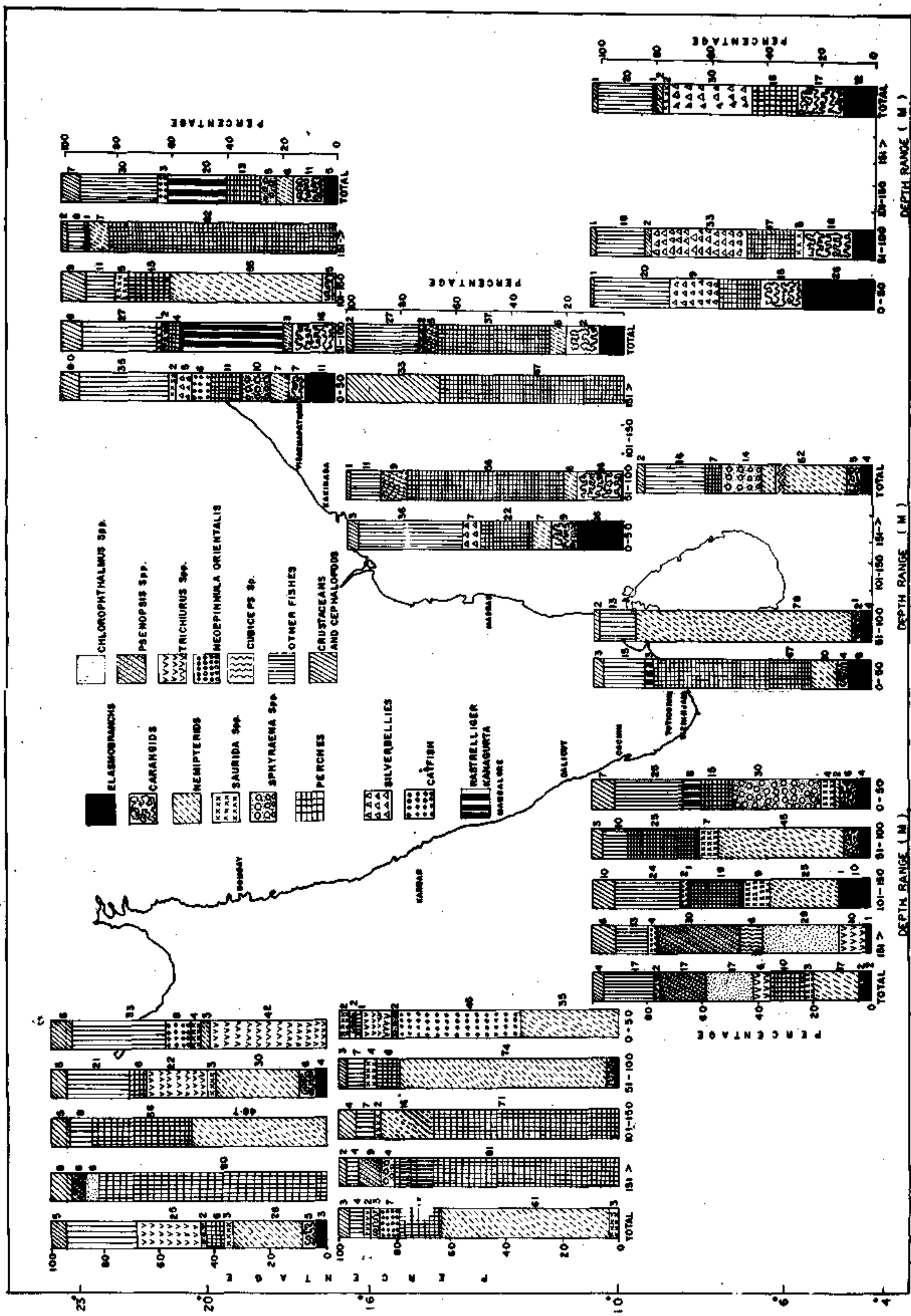

Fig. 1. Depthwise species composition of major fishery resources from the various zones of the EEZ of India. (Figures given on the right side indicate percentage of each group).

TABLE 2. *Percentage composition of various groups of coastal and deep sea demersal fishery resources along west and east coasts of India*

Area:	West coast	East coast	Andaman & Nicobar Archipelago
Effort (hrs/min):	212 hrs/ 15 min	118 hrs	12hrs/40 min
Composition	%	%	%
Shark	0.80	1.81	2.46
Skates	0.17	1.01	0.06
Rays	0.66	2.17	9.22
Carangids	2.89	8.39	17.20
Nemipterids	28.43	26.71	1.56
Saurida spp.	3.12	0.96	2.22
Upeneus spp.	0.97	1.97	1.88
Sphyraena spp.	1.28	8.85	0.68
Priacanthus spp.	6.98	7.55	0.39
Epinephelus spp.	0.73	2.25	3.24
Lethrinus spp.	0.78	1.44	7.21
Lutjanus spp.	1.25	0.28	5.90
Lutianus spp.	0.14	0.74	-
Other perches	0.45	0.66	-
Scieanids	0.84	1.26	-
Silverbellies	0.004	1.42	29.65
Mackerel	0.23	9.38	0.47
Cat fish	2.01	1.47	-
Flat fish	0.63	0.11	-
Trichiurus spp.	6.17	0.53	1.01
T. auriga	1.56	1.00	
Chlorophthalmus spp.	10.37	-	-
Cubiceps spp.	2.14	-	-
Neoepinnula spp.	1.29	-	-
Pseneopsis spp.	10.89	0.46	-
Psenes indicus	0.21	4.96	3.04
Psenes spp.	0.12	-	-
Pipe fish	2.31	-	-
Deep sea fish	0.96	2.26	-
Other fishes	6.74	9.16	12.72
Crustaceans & cephalopods	4.39	4.25	1.08

TABLE 3. *Species composition of coastal and deep sea demersal fishery resources along the EEZ of India (south/west zone)*

Depth range (m) : Effort (hrs/min) : Composition	< 50 7/35 C/E (kg)	51-100 42/15 C/E (kg)	101-150 11/15 C/E (kg)	> 150 43/45 C/E (kg)	Total 104/35 C/E (kg)	%
Sharks	-	13.950	1.69	9.23	9.68	1.05
Skates	-	3.716	8.00	0.23	2.46	0.27
Rays	21.098	2.367	12.89	-	3.87	0.42
Carangids	31.385	34.195	2.40	0.07	22.18	2.41
Nemipterus spp.	11.208	359.137	54.73	1.21	152.29	16.56
Saurida spp.	21.026	53.846	19.91	3.54	29.94	2.93
Upeneus spp.	38.242	4.426	-	-	4-56	0.56
Sphyraena spp.	158.242	1.437	-	-	12.05	1.31
Priacanthus spp.	1.319	136.178	18.13	6.72	59.87	6.50
Epinephelus spp.	47.736	3.818	1.16	9.80	9.05	0.98
Lethrinus spp.	13.846	25.728	0.71	-	11.47	1.25
Lutjanus spp.	9.231	19.136	-	0.23	8.49	0.92
Lutianus spp.	3.297	4.793	-	-	2.18	0.24
Other perches	2.638	10.059	22.49	-	6.67	0.73
Psenes indicus	7.912	2.106	-	3.28	2.80	0.30
Psenes spp.	-	-	-	4.31	1.80	0.19
Silverbellies	0.659	0.040	-	-	0.07	0.007
Cat fishes	1.583	-	-	-	0.11	0.01
Flat fishes	-	0.876	0.44	0.62	0.66	0.07
Pentaprion spp.	15.824	4.733	-	-	3.06	0.33
R. kanagurta	55.305	0.012	-	-	2.87	0.31
Trichiurus spp.	-	0.663	-	71.37	30.13	3.28
T. auriga	-	-	-	55.59	23.26	2.53
Chlorophthalmus spp.	-	0.260	1.87	369.75	154.98	16.85
Cubiceps spp.	-	-	1.69	76.20	37.06	3.48
Pseneopsis spp.	-	-	-	383.54	160.44	17.45
Neoepinnula spp.	-	-	4-89	45.00	19.35	2.10
Fistularia villosa	30.329	2.982	-	6.58	6.16	0.67
Scolopsis spp.	-	-	15.29	-	1.14	0.18
Deep sea fish	-	-	-	0.57	4.43	1.56
Pipe fishes	-	-	-	82.56	34.54	3.76
Other fishes	34.286	64.561	35.29	56.16	55.06	6.07
Crustaceans & cephalopods	36.923	31.147	21.33	62.69	43.78	4.76
Total	526.626	794.532	222.91	1282.78	919.69	

TABLE 4. *Species composition of coastal and deep sea demersal fishery resources along the EEZ of India (Centralwest zone)*

Depth range (m) :	< 50	51-100	101-150	> 151	Total	%
Effort (hrs/min) :	11/10	33/30	11/0	7/0	62/40	
Composition	C/E (kg)	C/E (kg)	C/E (kg)	C/E (kg)	C/E (kg)	
Sharks	-	-	-	-	-	-
Skates	-	-	-	-	-	-
Rays	-	4.84	-	-	2.59	0.44
Carangids	7.46	26.72	0.96	1.94	15.94	2.71
Nemipterus spp.	166.57	602.38	45.58	-	359.70	61.05
Saurida spp.	8.96	34.11	4.20	-	20.57	3.49
Upeneus spp.	-	10.49	0.18	0.21	5.66	0.96
Sphyraena spp.	9.67	5.82	0.05	7.86	5.72	0.97
Priacanthus spp.	0.19	58.34	146.00	95.71	67.54	11.46
Epinephelus spp.	2.69	5.45	1.59	-	3.67	0.62
Lethrinus spp.	-	-	0.20	-	0.04	0.006
Lutjanus spp.	1.79	1.13	48.30	45.09	14.44	2.45
R. kanagurta	0.27	1.25	...	-	0.72	0.12
Trichiurus spp.	56.64	0.30	-	0.07	10.26	1.74
Sciaenids	0.09	4.93	-	-	2.65	0.45
Pomfrets	4.48	-	-	-	0.80	0.14
Catfish	215.37	8.24	2.06	-	43.14	7.32
Flat fish	-	0.12	-	0.04	0.06	0.01
Lactarius sp.	-	1.49	-	-	0.80	0.14
Pomadasys spp.	-	0.12	-	-	0.86	0.01
Chlorophthalmus spp.	-	-	-	0.29	0.03	0.005
Pseneopsis spp.	-	0.45	10.91	15.56	3.89	0.66
Other fishes	1.58	22.13	6.37	4.99	13.79	2.34
Crustaceans & cephalopods	1.98	27.04	11.21	2.90	17.10	2.90
Total	477.43	815.34	277.60	174.68	589.18	

In Andaman-Nicobar Archipelago (Table 9), where coastal waters alone yielded catches, silverbellies (91 kg/hr, 33%), carangids (50 kg/hr, 17.5%) and perches (17%) were mainly caught from the 51-100 m depth area.

Productive areas in different zones(Fig. 2a-c, 3a-d)

In determining the productive areas, average catch rate in each sub area was categorized based on the relative abundance of the fishes. In the southwest zone (Fig. 2a) sub areas such as 7-76/6F, 7-77/

TABLE 5. *Species composition of coastal and deep sea demersal fishery resources along the EEZ of India (northwest zone)*

Depth range (m) :	<50	51-100	101-150	> 150	Total	%
Effort (hrs/min) :	7/0	30/0	5/0	3/0	45/0	
Composition	C/E (kg)	C/E (kg)	C/E (kg)	C/E (kg)	C/E (kg)	
Sharks	1.20	7.68	-	-	5.31	1.03
Skates	-	0.47	-	-	0.31	0.06
Rays	-	15.26	-	-	0.18	1.97
Carangids	2.57	39.37	0.24	-	26.67	5.17
Nemipterus spp.	14.43	189.61	36.16	-	132.67	25.71
Saurida spp.	21.43	21.00	-	-	17.33	3.36
Upeneus spp.	64.43	8.00	-	-	15.36	2.98
Sphyraena spp.	-	13.00	-	-	8.67	1.68
Priacanthus spp.	-	9.44	21.20	8.67	9.23	1.78
Epinephelus spp.	-	21.60	7.60	-	15.26	2.96
Lethrinus spp.	-	9.42	-	-	0.28	0.05
Lutjanus spp.	1.00	3.00	-	23.00	3.69	0.71
Lutianus spp.	-	-	-	-	-	-
Other perches	-	-	-	-	-	-
Psenes indicus	-	1.13	-	-	0.76	0.15
Silverbellies	-	-	-	-	-	-
Cat fishes	45.86	3.62	-	-	09.55	1.85
Flat fishes	0.24	30.39	-	-	20.30	3.93
Sciaenids	70.43	21.75	-	-	25.46	4.93
R. kanagurta	0.29	0.33	-	-	0.27	0.05
Trichiurus spp.	240.03	139.02	0.78	-	130.10	25.21
Chlorophthalmus spp.	-	-	-	2.30	0.15	0.03
Pseneopsis spp.	-	-	-	2.23	0.15	0.03
Pomadasys hasta	0.02	0.03	-	-	0.03	0.005
Polynemus spp.	-	6.13	-	-	4.10	0.80
Dussumieria spp.	-	0.83	-	-	0.56	0.11
Lactarius sp.	21.43	0.23	-	-	3.49	0.67
Diagramma spp.	-	-	-	-	-	-
Pomfrets	2.29	-	-	-	0.36	0.07
Other fishes	49.59	60.86	4.79	-	48.82	9.46
Crustaceans & cephalopods	32.77	31.95	3.54	3.47	27.02	5.24
Total	568.02	625.15	74.31	39.8	516.03	

TABLE 6. *Species composition of coastal and deep sea demersal fishery resources along the EEZ of India (southeast zone)*

Depth range (m) : Effort (hrs/min) : Catch details :	< 50 6/25 C/E (kg)	51-100 3/40 C/E (kg)	101-150 C/E (kg)	> 150 1/100 C/E (kg)	Total 11/05 C/E (kg)	%
Sharks	105.19	-	-	-	61.36	2.75
Rays	48.62	20.45	-	-	35.18	1.58
Carangids	130.41	102.27	-	-	110.09	4.94
Nemipterus spp.	0.47	3,508.63	-	-	1,169.81	52.39
Saurida spp.	4.36	46.36	-	-	18.00	0.81
Upeneus spp.	13.66	-	-	-	7.97	0.36
Sphyraena spp.	551.84	-	-	-	321.90	14.42
Priacanthus spp.	-	19.09	-	-	6.36	0.28
Epinephelus spp.	100.75	83.18	-	-	86.45	3.87
Lethrinus spp.	37.34	-	-	-	21.78	0.97
Lutjanus spp.	6.67	-	-	-	3.89	0.17
Lutianus spp.	19.48	23.18	-	-	19.09	0.85
Other perches	5.45	69.54	-	-	26.36	1.18
Psenes indicus	7.79	95.45	-	-	36.36	1.63
Silverbellies	6.23	-	-	-	3.36	0.16
Cat fish	10.44	-	-	-	0.09	0.22
R. kanagurta	33.81	-	-	-	19.72	0.88
Trichiurus spp.	0.16	-	-	-	0.09	0.004
Fistularia villosa	0.05	-	-	-	0.03	-
Diagramma spp.	23.38	54.55	-	-	31.81	1.42
Scombromorous spp.	7.79	-	-	-	4.55	0.20
Sarda orientalis	1.56	-	-	-	0.91	0.04
Deep sea fish	-	-	-	-	110.00	4.93
Balistids	60.55	-	-	-	35.32	1.58
Other fishes	39.90	92.82	-	5.0	54.64	2.45
Crustaceans & cephalopods	39.65	54.55	-	-	41.31	1.85
Total	1255.58	4,500.00	-	5.0	2,232.87	

5B, 6C; 8-75/4E, 5D, 5E, 6E; 8-76/3E had catches above 2,000 kg/hr. Sub areas 7-77/2A, 4A; 8-75/6D, 6F and 9-75/3F yielded a catch ranging from 1,001-2,000 kg/hr. Catches within the range of 751-1,000 kg/hr were obtained from sub-areas at 8-76/4B, 8-77/IB and 9-75/IF while stations at 7-76/4A, 7-77/2A, 6A, 8-76/IF, 5A, and 9-76/1A yielded a catch rate of 501-750 kg/hr.

In the centralwest zone (Fig. 2b), sub-areas such as 10-75/6D; 11-75/3B and 4A had a catch rate of above 2,000 kg/hr, while those at 14-73/SE, 3F; 15-73/2A, 5B, 6A had catch between 1,001-2,000 kg/hr. Sub-areas such as 11-75/3A and 13-74/3B; yielded a catch rate of 751-2,000 kg/hr and those at

TABLE 7. *Species composition of coastal and deep sea demersal fishery resources along the EEZ of India (central east zone)*

Depth range (m) : Effort (hrs/min) : Composition	< 50 18/0 C/E (kg)	51-100 12/0 C/E (kg)	101-150 C/E (kg)	> 150 1/0 C/E (kg)	Total 31/0 C/E (kg)	%
Sharks	10.61	0.75	-	-	6.45	3.28
Skates	3.17	-	-	-	0.10	0.05
Rays	18.33	-	-	-	10.65	5.42
Carangids	16.77	37.48	-	-	24.24	12.35
Nemipterus spp.	12.29	11.42	-	-	11.55	5.86
Saurida spp.	1.04	1.92	-	-	1.35	0.69
Upeneus spp.	4.34	2.79	-	-	3.60	1.83
Sphyreana pp.	5.82	2.29	-	-	4.27	2.17
Priacanthus spp.	-	102.42	-	50.00	41.26	21.00
Epinephelus spp.	4.39	10.87	-	-	6.76	3.44
Lethrinus spp.	25.00	7.66	-	-	17.48	8.90
Lutjanus spp.	1.28	5.22	-	-	2.76	1.41
Lutianus spp.	0.28	3.43	-	-	1.49	0.76
Other perches	3.47	-	-	-	2.00	1.03
Psenes indicus	-	0.50	-	-	0.19	0.093
Silverbellies	11.69	0.25	-	-	6.88	3.51
Cat fish	0.69	-	-	-	0.40	0.21
Flat fish	0.53	0.13	-	-	0.35	0.18
R. kanagurta	1.90	0.12	-	-	1.15	0.59
Pentaprion spp.	24.62	2.08	-	-	15.10	7.69
Sciaenids	12.29	-	-	-	7.13	3.63
Pomadasys hasta	0.61	1.29	-	-	0.85	0.44
Scombromorous spp.	0.76	0.43	-	-	0.61	0.31
Diagramma spp.	1.66	2.00	-	-	1.74	0.89
Dussumieria spp.	1.33	-	-	-	0.77	0.39
Psenopsis spp.	-	20.83	-	-	8.06	4.50
Mullets	1.09	-	-	-	0.63	0.32
Other fishes	14.16	14.57	-	-	13.86	7.06
Crustaceans & cephalopods	4.89	2.56	-	25.00	4.65	2.36
Total	179.99	231.04	-	75.00	196.37	

TABLE 8. *Species composition of coastal and deep sea demersal fishery resources along the EEZ of India (northeast zone)*

Depth range (m) :	< - 50	51-100	101-150	>150	Total	%
Effort (hrs/min) :	35/15	29/45	3/0	9/0	76/0	
Composition	C/E (kg)	C/E (kg)	C/E (kg)	C/E (kg)	C/E (kg)	
Sharks	1.61	2.00	-	-	1.51	0.48
Skates	14.86	1.31	-	-	7.21	2.28
Rays	12.25	1.65	-	-	6.16	1.95
Carangids	16.97	67.30	6.78	2.19	34.52	10.94
Nemipterus spp.	18.79	12.75	71.49	13.81	17.91	5.68
Saurida spp.	3.87	4.43	6.77	-	3.75	1.18
Upeneus spp.	27.39	7.39	-	-	15.24	4.83
Sphyraena spp.	16.11	10.97	-	-	11.55	3.66
Priacanthus spp.	23.77	14.73	19.68	162.37	36.49	11.57
Epinephelus spp.	0.06	2.25	-	-	0.91	0.29
Lethrinus spp.	-	0.17	-	-	0.07	0.02
Lutjanus spp.	-	0.81	-	-	0.32	0.10
Lutianus spp.	4.15	0.20	-	-	1.95	0.62
Pomadasys hasta	2.14	6.18	-	-	3.39	1.07
Pentaprion spp.	5.81	3.29	-	-	3.91	1.24
Sciaenids	10.62	2.79	5.60	0.10	6.11	1.94
R. kanagurta	3.92	159.18	-	-	64.08	20.32
Silverbellies	13.47	2.05	-	-	6.87	2.18
Catfish	15.96	5.97	-	-	9.53	3.02
Flatfish	0.18	1.49	0.33	-	0.67	0.21
Trichiurus spp.	3.18	6.02	-	-	3.79	1.20
Psenes indicus	14.75	59.29	1.23	3.57	30.33	9.62
Pomfrets	6.10	10.64	-	-	6.91	2.19
Scombromorous spp.	1.27	0.49	-	-	0.76	0.24
Chirocentrus spp.	0.79	0.20	-	-	0.44	0.14
Polynemus spp.	-	0.81	-	0.60	0.07	0.02
Other fishes	26.19	11.54	7.03	11.73	17.98	5.70
Crustceans & cephalopods	18.84	34.17	11.16	2.99	22.66	7.18
Total	263.05	430.09	130.13	197.37	315.40	

TABLE 9. *Species composition of coastal and deep sea demersal fishery resources along the Andaman Nicobar Archipelago*

Depth range (m) : Effort (hrs/min) : Composition	< - 50 2/30 C/E (kg)	51-100 8/30 C/E (kg)	101-150 1/0 C/E (kg)	> 150 C/E (kg)	Total 12/0 C/E (kg)	%
Sharks	16.00	3.88	-	-	6.08	2.46
Skates	-	60.00	-	-	0.15	0.06
Rays	44.40	19.00	-	-	22.78	9.20
Carangids	21.34	49.64	-	-	42.50	17.20
Nemipterus spp.	-	5.16	2.50	-	0.04	1.56
Saurida spp.	-	7.74	-	-	5.48	2.20
Upeneus spp.	15.20	1.97	-	-	4.65	1.88
Sphyraena pp.	-	2.36	2.00	-	1.67	0.68
Priacanthus spp.	-	1.15	-	-	0.98	0.40
Epinephelus spp.	15.20	6.84	-	-	8.01	3.24
Lethrinus spp.	17.40	20.04	-	-	17.83	7.21
Lutjanus spp.	1.76	20.07	-	-	14.59	5.90
Lutianus spp.	-	-	-	-	-	-
Psenes indicus	-	-	-	-	-	-
Psenes spp.	-	10.59	-	-	7.50	3.04
Silverbellies	43.60	90.58	-	-	73.25	29.65
Catfish	-	-	-	-	-	-
R. kanagurta	1.60	1.18	-	-	1.16	0.47
Pentaprion spp.	5.60	1.88	-	-	2.50	1.01
Trichiurus spp.	-	3.53	-	-	2.50	1.01
Pomadasys hasta	-	0.59	-	-	0.42	0.17
Plectorhyhchus spp.	-	0.78	-	-	0.55	0.22
Pristipomoides spp.	-	5.47	-	-	3.87	1.57
Monotaxis spp.	-	2.67	-	-	1.89	0.76
Other fishes	33.36	20.34	10.15	-	22.20	8.98
Crustaceans & cephalopods	1.20	3.02	3.25	-	2.66	1.07
Total	230.92	27.80	17.9	-	247.08	

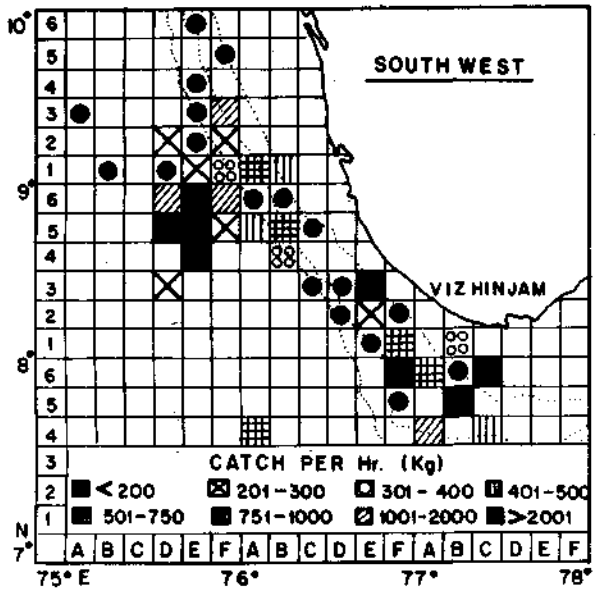

Fig. 2a. Quantitative distribution of Total fish in the southwest zone.

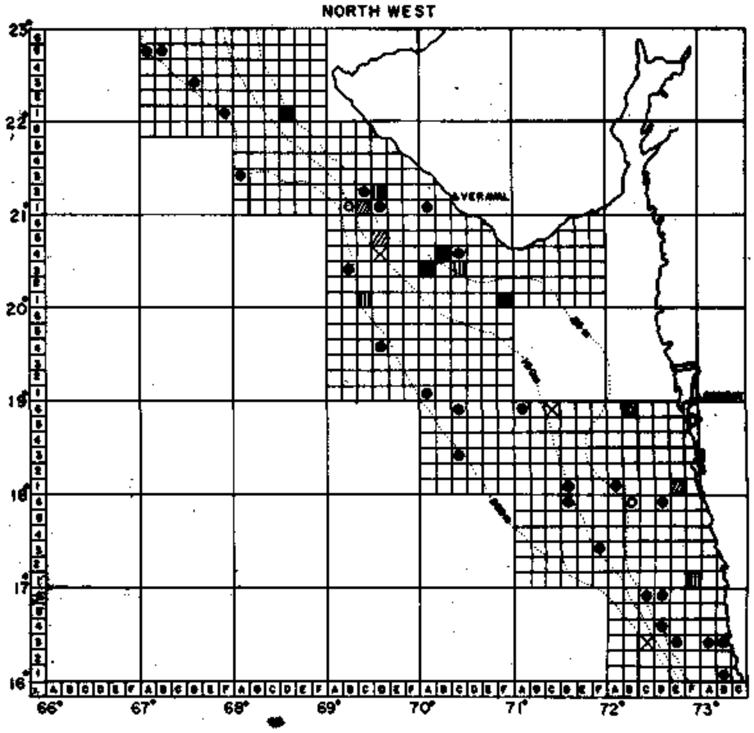

Fig. 2c. Quantitative distribution of total fish in the northwest zone. (For fish density see Fig. 2a).

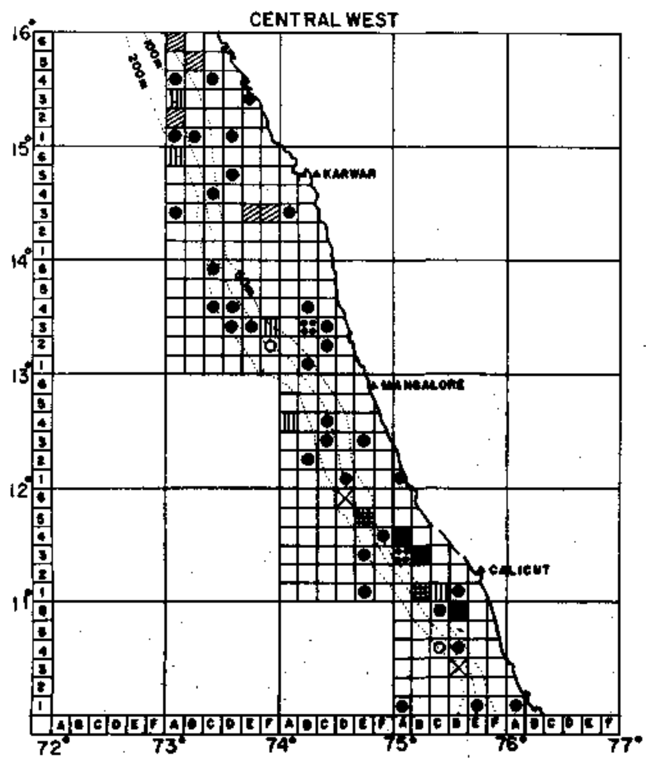

Fig. 2b. Quantitative distribution of total fish in the centralwest zone. (For fish density see Fig. 2a.

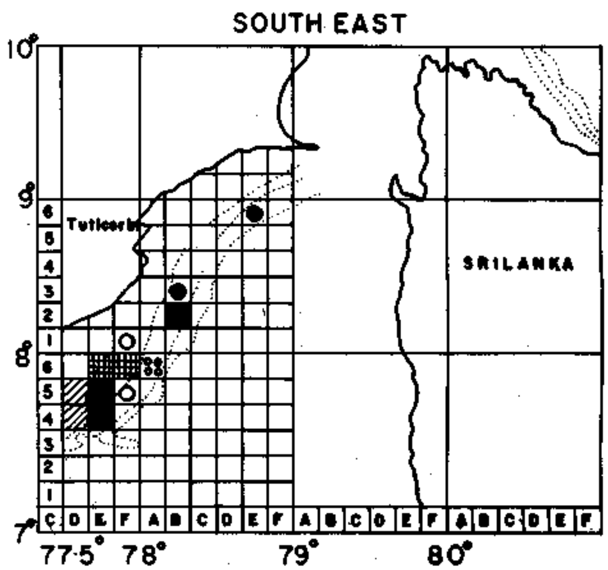

Fig. 3a. Quantitative distribution of total fish in the southeast zone. (For fish density see Fig. 2a).

11-75/1B, 11-74/5E had a catch rate of 501-750 kg/hr.

Along the northwest zone (Fig. 2c) sub-areas such as 20-70/3A, 4B and 22-68/1D yielded catches above 2,000 kg/hr while those at 18-72/1E, 6A, 20-69/50 and 21-69/1C had a catch rate of 1001-2,000 kg/hr.

In the southern zone of east coast (Fig. 3a) sub-areas such as 7-77/4E, 5E and 8-78/2B were found densely populated (catch rates above 2,000 kg/hr). Sub areas at 7-77/4D, 5D, had a catch rate of 1,001-2,000 kg/hr while those at 7-77/6E and 6F had catch rate of 501-750 kg/hr.

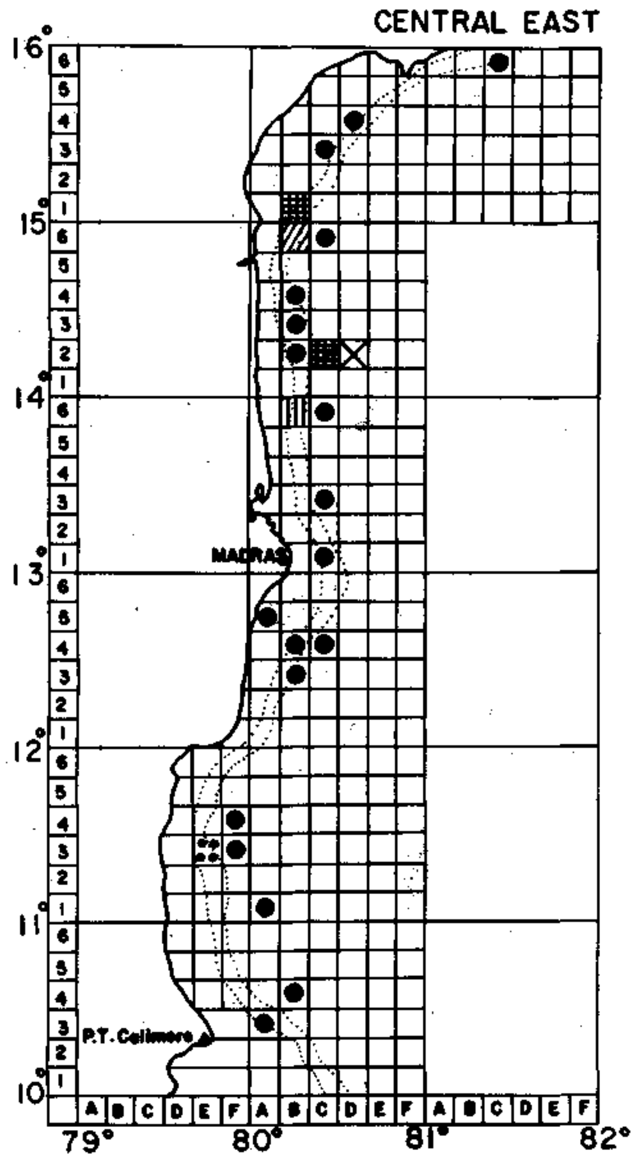

Fig. 3b. Quantitative distribution of total fish in the centraleast zone, (For fish density see Fig. 2a).

In the centraleast zone, (Fig. 3b) sub-areas such as 14-80/6B had a catch rate of 1,001-2,000 kg/hr while at 11-79/3E the catch was between 751-1,000 kg/hr. Sub-areas such as 14-80/2C and 15-80/1B had catches ranging from 501-750 kg/hr.

Along the northeast zone, (Fig. 3c) sub-areas like 19-86/5D, 20-87/3D yielded catch rate above 2,000 kg/hr. Sub areas like 16-81/1C had a catch range between 1,001-2,000 kg/hr while those at 16-82/3C had catch ranging between 501-750 kg/hr.

In the Andaman-Nicobar Archipelago (Fig. 3d) generally with less catch, sub-areas at 13-91/1D alone yielded a catch between 1,002-2,000 kg/hr.

Discussion

Based on the studies made on the nutrient concentration, chlorophyll and biomass estimation, it has already been established that Arabian Sea is more productive than Bay of Bengal. Primary productivity studies along the seas around India had shown that west coast had average value of 1.19 g C/m^2/day while in the east coast it is only 0.63 g C/m^2/day (Nair *et al.*, 1973). Trawl surveys conducted using R.V. *Anton Brunn* at different stations in the Arabian Sea and Bay of Bengal during 1963 had shown that west coast is about 2.5 times more productive than the east coast (Pruter, 1964). In the present study this view is further substantiated where the catch/hr along the entire west coast is 736.54 kg/hr in contrast to 463 kg/hr for the east coast. Discussing the various reasons which cause low productivity in the east coast such as narrow continental shelf, lack of upwelling and large number of rivers emptying their organic material in the land itself, Reghu Prasad (1969) quoting Panicker and Jayaram opines that a thorough understanding of the various factors is essential for finding a satisfactory solution to the major problem in the difference in fish production along the east and west coasts of India.

A closer evaluation of the species wise catch composition in different depths and the relative abundance of the major species in the productive areas reveal certain noteworthy features. Along the southwest zone, sub-areas of 8-76/3E, 8-75/4E, 7-77/4A, 5B in the depth range of 51-100 m were found to be promising fishing grounds for nemipterids and *Priacanthus* spp. Along the

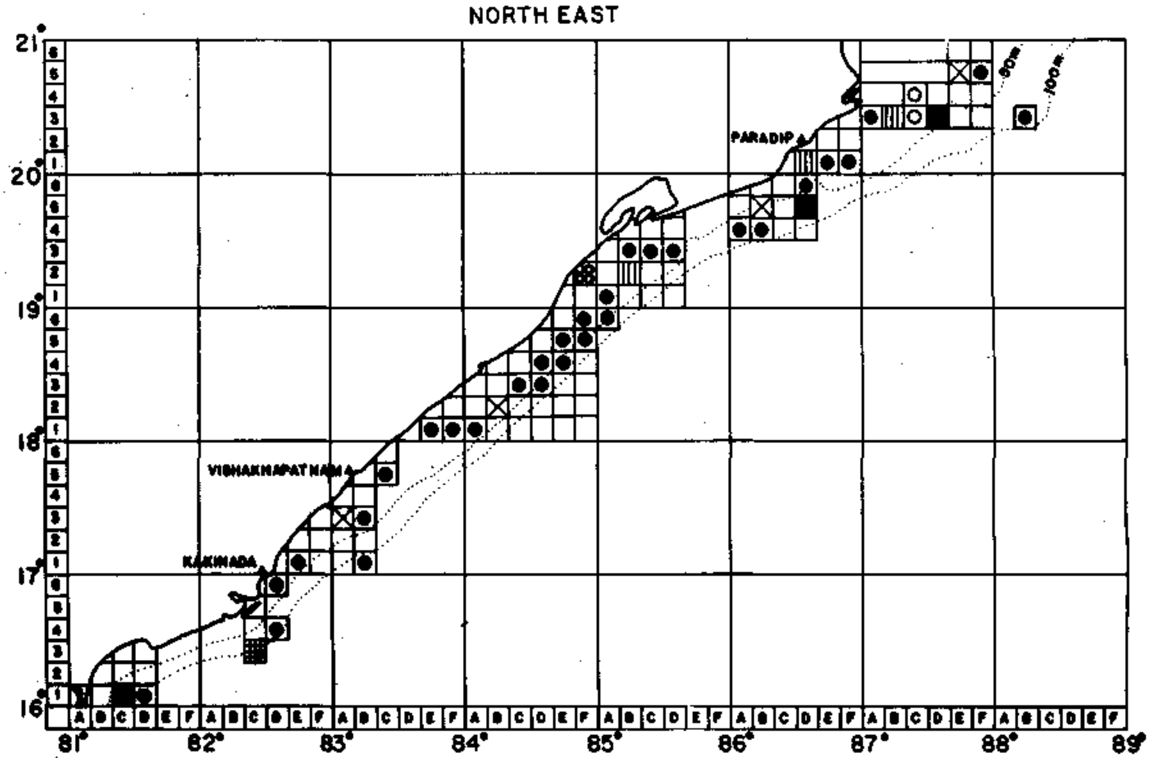

Fig. 3c. Quantitive distribution of total fish in the north east zone.

centralwest zone, sub-areas such as 10-75/6D; 11-75/3E, 3B, 4A in the shallow coastal waters were found densely populated with catfish, nemipterids and *Trichiurus* spp. While northwest zone had nemipterids and carangids in shelf waters at 21-68/1D sub area, with a catch rate upto 4,500 kg/hr, southeast zone with rich Wadge Bank area at 7-77/4E, 5E indicated dense population of nemipterids. While perches and carangids were located at 51-100 m depth range of 11-79/3E sub-area of centraleast zone, *R. kanagurta* and carangids formed the major representatives from the above depths at 16-81/1C and 19-86/5D sub areas of northwest zone. Andaman-Nicobar Archipelago, however, was sparsely populated by fishes.

While the shelf waters indicated dense congregation of a number of coastal species, the neritic waters in the depth range 151-398 m revealed promising potential for deep sea fishes like *Psenopsis* spp., *Chlorophthalmus* spp., *Priacanthus* sp., *Cubiceps* spp., *Neoepinnula* spp. and *T.auriga* especially in the sub areas of 8-75/4E, 5D, 6D in the south west zone. These fishes forming about 43% of the total fish caught from this area substantiate earlier observations emphasizing their potential stock in the deeper waters (Silas, 1969; Mohamed and Suseelan, 1973; Tholasilingam, *et al.*, 1973; Ommen, 1980,1985). Nevertheless simultaneous with attempts to exploit them, measures are also to be taken to popularise the market acceptability of these non-conventional forms. Studies made hitherto on the proximate composition of the species like *Priacanthus* spp. and *Chlorophtahlmus agassizi* have shown that they are rich in protein and fat content of 17.5% and 5.08% in the former and 14.4% and 2.8% in the latter respectively (Philip *et al.*, 1984). It is needless to say that other deep sea fishes should also be studied in this line and attempts to popularise them as food fishes are to be made.

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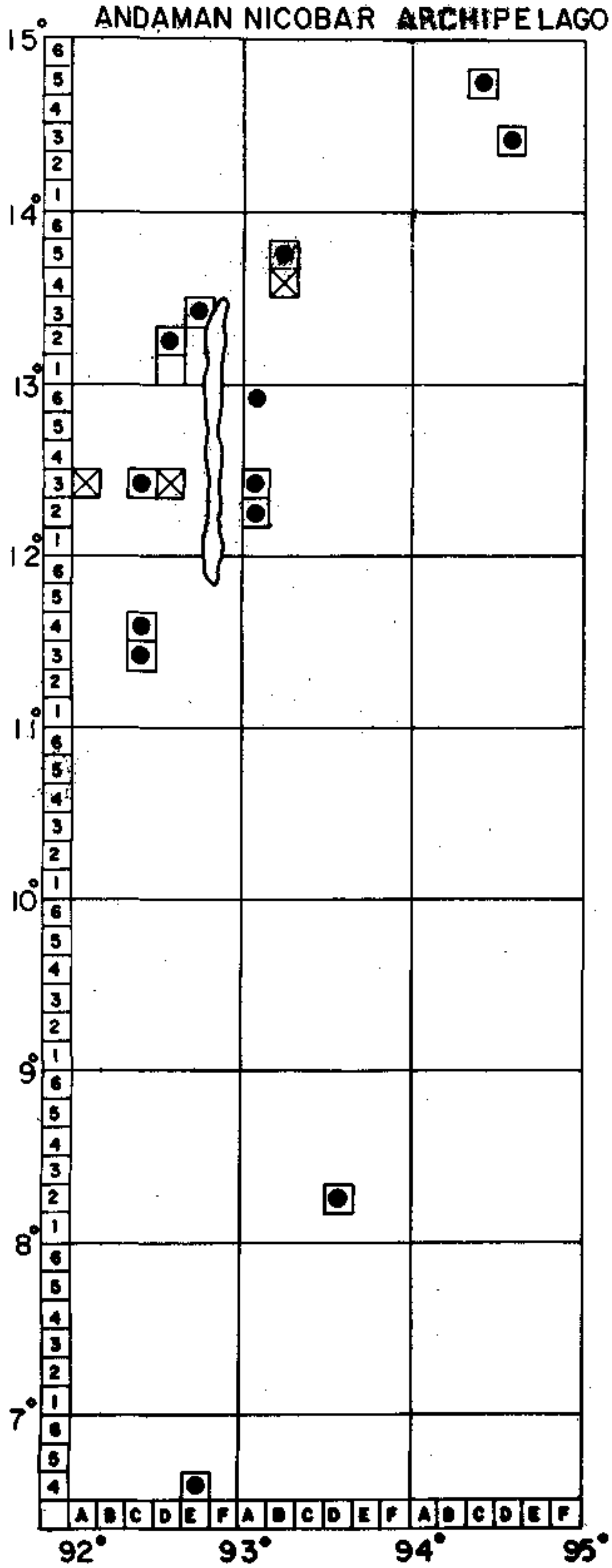

Fig. 3d. Quatitative distribution of total fish in the Andaman-Nicobar Archipelago (For fish density See Fig 2a)

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STUDIES ON THE DISTRIBUTION AND ABUNDANCE OF BULL'S EYE (*PRIACANTHUS* SPP.) IN THE EEZ OF INDIA

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Abstract

Bull's eye is one of the important constituents of the fishes available on the outer shelf in the EEZ of India. The fishery and oceanographic survey conducted by FORV *Sagar Sampada* during 1985-'87 period in her cruises 1-30 showed that the bull's eye *Priacanthus* spp., occurred in 62 out of 182 stations where bottom trawl was operated. It formed 40% of the total catch. The catch rate varied from 0.3 to 4,905 kg. The resource is available from 20 - 262 m depths. The depthwise catch rate was 184.5 kg in 0- 100 m, 249.4 kg in 100-200 m and 25.0 kg in depth more than 200 m. The present paper gives the distribution and abundance of this species in different latitudes and depth zones in the EEZ.

Introduction

Eversince the declaration of the EEZ , with a total exploitable area of 2.02 million km^2, there was a growing awareness among scientists and fishery managers for a better and rational exploitation for full utilisation of the fish resource potential, which is far in excess of the present annual marine fish landings. With this objective, resource surveys were conducted in the neritic and oceanic waters by different government agencies such as the erstwhile Pelagic Fisheries Project, Fishery Survey of India etc. George *et al.* (1977) estimated the potential yield from the Indian EEZ as 4.47 million tonnes, when the annual average yield was only 1.16 million tonnes (1980-'84 period). The earlier surveys by the Pelagic Fisheries Project unfolded various concentration pockets, seasonal migratory behaviours and potential resources of some of the commercially important pelagic fishes along the southwest coast of India. The Fishery Survey of India also made attempts to survey the Indian EEZ.

The present survey by FORV *Sagar Sampada* in the Indian EEZ is aimed at charting out exploited, under -exploited and unexploited regions and also to locate virgin fishing grounds of conventional and non-conventional resources. It is also envisaged to estimate the resource potentials of commercially important and non-conventional fishery resources during different seasons and at various bathymetric realms.

A study on the availability, abundance, geographical and seasonal migrations of one of the important demersal non-conventional resources, the Bull's eye or Big eye (*Priacanthus* spp.) which commonly occurred in the course of the survey by FORV *Sagar Sampada,* was taken up . The earlier investigations on the Bull's eye were by Joseph (1984, 1986), Joseph and John (1986), Sivaprakasam (1986), John and Sudarsan (1988), Vijayakumaran and Philip (1988), Sulochanan and John (1988), Vijayakumaran and Nayak (1988, 1989 a), Gopalakrishnan *et al.* (1988) and Biradar (1989). The present paper deals with the geographical and bathymertric distribution and abundance of Bull's eye based on data collected by FORV *Sagar Sampada* in her cruises 1-30, during February , 1985 to June, 1987.

Material and Method

The catch and effort data of bottom trawl and pelagic trawl operated from FORV *Sagar Sampada* along the Indian EEZ during her cruises, 1-30 (February, 1985 to June, 1987), covering 499 fishing stations were utilised for the study. The trawling was conducted for a duration of one hour at each of the bottom and pelagic trawl stations. The bottom trawl was operated at 182 stations and the pelagic trawl at 317 stations. Out of 499 trawling stations there was fish catch at 110 stations (22.2%) whereas Bull's eye was obtained from 74 stations (15%): 62 bottom trawl and 12 pelagic trawl operations. Total catch, species composition etc. were recorded at each fishing station. Random samples were collected from each haul for biological investigations on length-frequency, sex, maturity, food etc. Standing stock was estimated using the swept area method of Gulland (1971).

Results

Distribution of Bull's eye in the Indian EEZ

The bottom and pelagic trawling surveys conducted by FORV *Sagar sampada* revealed that *Priacanthus* spp. was one of the important non-conventional resources distributed all along the shelf and upper slope regions of the EEZ. The study further indicated the possibility of this resource being migratory both in the horizontal and vertical directions. The bathymetric distribution showed that the resource is available along the shelf at 20-262 m depth. The pelagic trawl caught Bull's eye from an oceanic station with bottom depth of 3,719 m (16°00'N 69°00'E) while trawling at a depth of 60m.

Geographical yield and abundance

Bull's eye is widely distributed all along the areas surveyed with particular abundance on the west coast. The highest catch of 4,905.5 kg was recorded at station No. 143 (07°59'4"N and 76°51' 5"E) during night by bottom trawl. The next important density pocket was at station No. 706 (15°30'N 73°03'E), with a yield per hour of 1,500 kg in bottom trawl. The average catch rate (kg/hour) along the west coast was 193 kg whereas on the east coast it was 59.8 kg. Regionwise abundance showed that the northwest coast had a catch rate of 159.9 kg and the southwest produced 219.7 kg; and the north east and the southeast regions were less productive with 116.6 kg and 3 kg respectively.

High density pockets were located off southwest of Kanyakumari in the Wadge Bank area at 74 m depth and off Marmagoa along the shelf at 120 m depth with a catch rate of 4,905.5 kg and 1,500 kg per hour, respectively. The next dense grounds (200-500 kg) were south of Kanyakumari in the Wadge Bank area, northwest of Mangalore along the shelf, southwest of Marmagoa and off Veraval on the west coast. Areas which produced Bull's eye at the rate of 100-200 kg per hour were off Marmagoa and in the head of Bay of Bengal off Paradip in the shelf region. The areas along the shelf and outer shelf regions off Quilon, south of Marmagoa, Calicut, and Kandla on the west coast produced 50-100 kg per hour. Less dense regions with 0-50 kg per hour were located along the west coast in the shallow regions of the shelf (Fig.1). The stationwise abundance of *Priacanthus* spp. in the EEZ with more than 25 kg per hour is given in Table 1.

Stations 705 (13°30'N 73°E) and 706 (15°30' N 73°03'E) yielded exclusively *Priacanthus* spp. in the bottom trawl operations during day with catch rate of 600 and 1,500 kg/hour respectively. The areas which yielded more than 80% of *Priacanthus* spp. in total catch were stations 21, 162, 167, 532 and 638.

Bathymetric yield and abundance

The depthwise abundance in the EEZ showed that the depth zone 0-100 m was rich for Bull's eye with an average rate of 184.5 kg, whereas the depth zone 100-200 m produced the highest mean catch rate of 249.4 kg per hour. The depths more than 200 m produced only 25 kg/hour. Bull's eye commonly occurred in high concentrations in the shelf region upto 200 m. In all-fish total catch, *Priacanthus* spp. formed 80.5% upto 100 m, 83.6% in 100-200 m and only 20.4% in 200 m and more. The depthwise abundance of *Priacanthus* spp. along the Indian EEZ is given in Fig. 2.

Off the northwest coast, the highest catch rate (419.8 kg) was recorded from the depth zone 100 - 200 m and the shallow zone upto 100 m produced only 61 kg per hour. This resource formed 93.2% of the total fish catch from the 100-200 m depth zone. On the southwest coast the bathymetric zone of upto 100 m yielded Bull's eye at the rate of 318.6 kg per hour, whereas the 100-200 m zone and above 200 m produced 56.9 kg per hour and 25.6 kg per hour respectively. The percentage composition of Bull's eye in total fish yield was 42.5 and 35% in the regions upto100 and 100-200 m respectively. The resource abundance of the west coast of India in general showed that 268.6 kg per hour was recorded from 100-200 m depth zone and 200.3 kg per hour from upto100 m zone. As high as 84% of total fish catch by bottom trawl from the depth zone 100-200 m was composed of Bull's eye.

The bathymetric abundance along the northeast coast showed that upto 100 m zone produced Bull's eye at the rate of 165.4 kg per hour with a percentage yield of 80 in total fish catch. On the other hand, the 100 - 200 m depth zone produced only 18.9 kg per hour. On the southeast coast, Bull's eye was recorded in the shallow waters with a poor catch rate of 3 kg per hour. The shallow waters of upto 100m on the east coast as a whole yielded the resource at 68 kg per hour, with a share of 47.4% in total fish production of the depth zone.

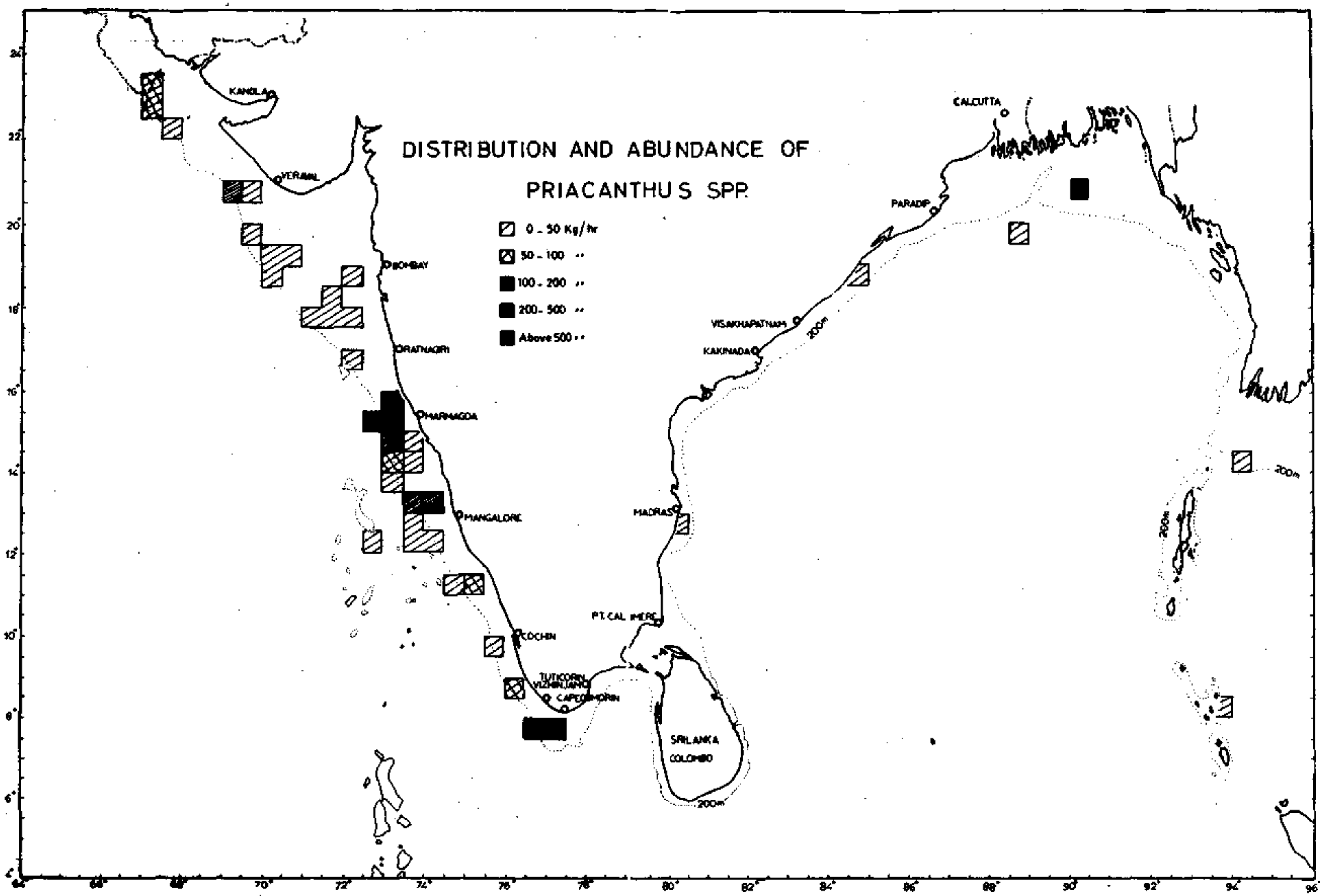

Fig.1. Distribution and abundance of *Pricanthus* spp. in the Indian EEZ.

TABLE 1. *Stationwise abundance of* Priacanthus *spp. in the Indian E. E. Z. (catch per hour of less than 25 kg not included)*

Gear: Bottom Trawl

St. No.	Position		Catch/ hour (kg)	Depth of station (m)
	Latitude (N)	Longitude (E)		
143	07° 59'	76° 52'	4905.5	74
706	15° 13'	73° 03'	1500.0	120
728 A	15° 00'	72° 58'	750.0	161
705	15° 30'	73° 10'	600.0	81
728	15° 00'	72° 58'	422.4	161
805	13° 08'	74° 03'	382.5	80
142	07° 47'	77° 14'	380.9	57
532	20° 57'	90° 30'	219.0	88
797	15° 00'	73° 18'	214.4	104
620	11° 28'	75° 02'	200.0	52
802	13° 30'	73° 50'	198.9	94
30	15° 24'	73° 06'	120.9	100
218	23° 30'	67° 00'	100.0	92
777	22° 53'	67° 00'	100.0	104
691	07° 30'	77° 30'	90.0	90
21	14° 28'	73° 10'	83.5	220
608	08° 49'	76° 18'	75.0	58
167	12° 05'	72° 31'	49.7	80
638	15° 00'	72° 02'	40.8	188
935	19° 30'	88° 50'	39.8	70
721	14° 00'	73° 30'	36.8	108
320	20° 42'	69° 35'	36.5	80
37	18° 30'	70° 26'	31.1	79
616	12° 30'	74° 24'	25.9	109

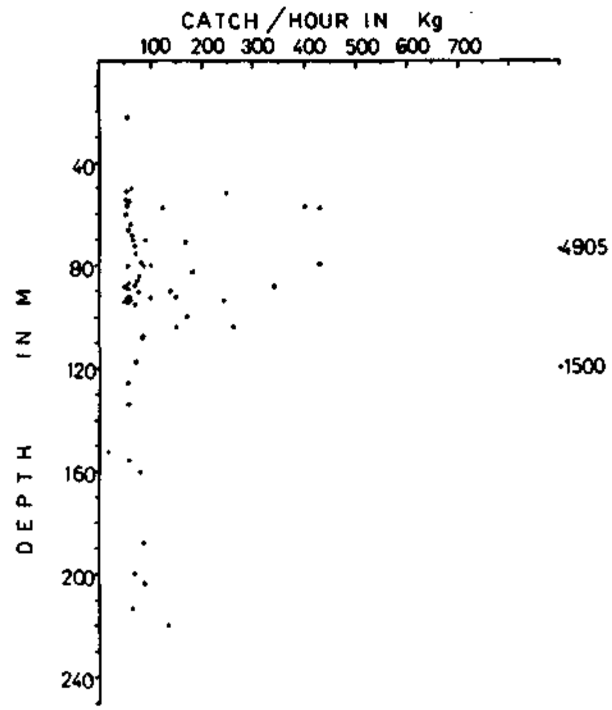

Fig. 2. Bathymetric abundance of *Priacanthus* spp. in the Indian EEZ.

Seasonal abundance

Since the present coverage along the Indian EEZ is not sufficient enough to arrive at a conclusion on the seasonality of the distribution of Bull's eye in different geographical regions, only a general trend of their seasonal availability is given in this report. Along the west coast, Bull's eye was abundant during July-November with the peak abundance in August. On the southwest coast in particular, this resource was abundant during August, whereas, in the northwest it was in September. As there was only very little coverage on the east coast, no trend of seasonal abundance was evident.

Pelagic trawling results

Bull's eye was caught by pelagic trawl net from 12 stations (2501-3719 m) along the slope and oceanic waters. The net was trawled in the depth strata of 100 to 50 m along the slope and the resultant total fish yield varied from 0.1 to 120 kg. The Bull's eye catch ranged from 0.5 to 100% of the total fish taken by the gear. The highest production of 84 kg per hour (70% in the total fish catch) was recorded from station 750 (17° 58' N 69° 00'E, depth: 3373 m) from 60 m depth. Station 746 (18° 00' N 68° 30' E, depth: 3443 m) and 757 (19° 00' N 67° 00' E, depth : 3260 m) were also rich in Bull's eye with production rates of 50 and 30 kg per hour respectively. Invariably high catch of the fish by pelagic trawl was obtained in night trawling, possibly indicating the vertical ascend of this resource during night into the column waters in search of food in the rich DSL.

Species composition

The species encountered in the catches from the EEZ were *Priacanthus hamrur*, *P. tayneus*, *P. blochii*, and *P. macrocanthus*. Biological study on the most dominant species, *P. hamrur* showed that the size range in the bottom trawl catches was 12-34 cm and with maturity stages II to IV domianting during September- November. They feed on demersal fishes and prawns. During night they voraciously feed on pelagic shrimp, *Leptochela*. These shrimps formed an important component of the DSL exhibiting vertical migration.

Standing stock

The biomass of Bull's eye in the regions surveyed is estimated to be around 3.95 lakh tonnes. Region-wise biomass estimate showed that the southwest coast is the richest ground with 2.9 lakh tonnes and the north west coast has only 0.86 lakh tonnes. The east coast is less productive with a standing biomass of 0.18 lakh tonnes. The potential yield from the Indian EEZ is estimated around 0.79 lakh tonnes, following the equation for MSY of Sparre (1988) or 1.95 lakh tonnes by following Gulland (1979).

Discussion

Bull's eye is a widely distributed potentially rich deep water fish resource recorded from shallow shelf to 3719 m in oceanic waters. Joseph (1984, 1986) recorded Bull's eye along north Kerala and Karnataka coasts with peak occurrence in 100-150 m depth during April-June, (average catch rate of 72.8 kg) forming 11.3% in the total fish yield; an average catch rate of 32 kg was recorded from 90-250 m depth from the Gulf of Mannar and the Wadge Bank. On the Andhra coast an average catch rate of 60 kg was recorded from depth zone 120-200 m, forming 5% in total fish yield. This resource "migrate across the shelf and parallel to the shelf, probably depending on cold water current". The Fishery Survey of India surveys indicate rich grounds for Bull's eye in the Gulf Mannar (Somavanshi and Bhar, 1984) and off Andhra Pradesh in 14°-18° N upto 500 m depth (Ninan *et al., 1984)* . Sulochanan and John (1988) reported high concentration of Bull's eye from deeper regions of the shelf off Kerala during May - October, contributing as high as 34.7% to the total fish catches from 50 - 100 m depth.

The present survey by FORV *Sagar Sampada* unfolds some density pockets of Bull's eye along the southwest coast within 07° 00' - 15° 00' N and 72° 30' - 70° 00' E, sometimes, the entire catch being composed of Bull's eye. This observation agrees well with that of Joseph (1986) based on FSI survey, but with a higher concentration in the current observations.

Vijayakumaran and Naik (1988 a) found that *Priacanthus* spp. is abundant in depth zone upto 100 m in latitudes 11° - 12° N along the west coast and 100 - 200 m in latitude 13° N. They reported a south ward shallow water migration in pre-monsoon for breeding and return towards northwest in post-monsoon. The present study with regard to three different depth zones, upto 100 m, 100- 200 m and above 200 m showed that the zone upto 100 m is more productive (318.64 kg/hr) along the south-west coast, whereas in the northwest, the 100- 200 m depth zone was rich with about 420 kg/hr. On the east coast the shallow region upto 100 m yielded 68 kg per hour.

Biradar (1988) found that the resource is abundant in the depth zone 50 - 100 m within 15° N and 22° N latitudes and estimated the biomass of the region as 0.88 lakh tonnes and John and Sudarsan (1988) estimated the biomass as 0.65 lakh tonnes. The present estimate from the same region is about 0.86 lakh tonnes. The biomass estimate for the Indian EEZ is 3.95 lakh tonnes; whereas John and Sudarsan (1988) found it as 1.17 lakh tonnes. As the resource being virgin and unexploited, the MSY may be calculated by using the formula 0.5 X B_0 (Gulland, 1971) which resulted in 1.95 lakh tonnes or by the formula of Sparre (1988) which gives the MSY value at 0.79 lakh tonnes.

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STUDIES ON THE THREADFIN BREAM AND THE LIZARD FISH RESOURCES IN THE EXCLUSIVE ECONOMIC ZONE OF INDIA BASED ON THE DEMERSAL TRAWLING OPERATIONS OF FORV *SAGAR SAMPADA*

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Abstract

The present paper deals with the distribution and abundance of the threadfin bream and the lizardfish resources available for exploitation in the Exclusive Economic Zone of India based on the demersal trawling operations of FORV *Sagar Sampada* during her cruises 1-55. The area surveyed was divided into the northwest, southwest, northeast, southeast, Wadge Bank & Gulf of Mannar and the Andaman & Nicobar Islands and the stock abundance was computed for each latitude zone. Threadfin breams occurred at 39.0% and lizardfishes at 31.7% of the total 387 trawling stations covered during 1985-'88. Threadfin breams predominated in the trawling operations in thet Wadge Bank and the southwest coast forming 34.6 and 44.3% of the total trawl catch respectively. Along the east coast the resource is poor compared to the west coast. The peak abundance of the resource was in 41-80 m depth in the southwest and in 61-80 m depth in the northwest forming significant percentage of the demersal resources. Along the east coast the relative abundance was higher in depths of 80-150 m. The threadfin bream resource was constituted mainly by *Nemipterus japonicus* and *N. mesoprion* along with small quantities of *N. bleekeri. N. metopias* occurred in the northeast and the Andaman & Nicobar region. Lizard fishes constituted 3.7 and 4.6% of the total demersal fish resource in the southwest and northwest region respectively. It was relatively more abundant in the northeast forming 0.6%, whereas in the southeast it formed only 0.4% of the total trawl catch. Along the west coast, the relative abundance of the resource was generally high in 41-60 m depth. The resource was composed mainly of *Saurida tumbil* and *S. undosquamis* along with small quantities of *S. longimana*. The paper also deals with biological characteristics like size distribution, gonadial condition etc. of the main constituent species.

Introduction

The annual potential yield of marine fish resources of the Indian EEZ estimated from primary productivity studies, exploratory surveys etc., ranges from 2.3 to 8.5 million tonnes (Jones and Banerjee, 1973; Silas, 1969; George *et al.*, 1971; Joseph, 1987). Exploratory trawling has indicated that along the west coast, threadfin bream formed significant percentage beyond the limit of the conventional trawling grounds along 8° to 13°N and 14° to 23°N (Silas *et al.*, 1976; Joseph *et al.*, 1987; Sudarsan *et al.*, 1988). Lizard fishes also form significant percentage of the demersal resources in deeper waters along certain latitude zones. So in the present paper an attempt is made to bring together the knowledge gained so far from the trawling operations of FORV *Sagar Sampada* on the distribution and abundance of threadfin breams and lizard fishes in the Exclusive Economic Zone of India. The vessel made 387 hauls during the bottom fish coverage. Threadfin breams occurred at 39% and lizard fishes 31.7% of the total trawling stations covered.

Material and Methods

For analysis of the data, the area surveyed was divided into the northwest, southwest, northeast, southeast, Wadge Bank & Gulf of Mannar and the Andaman & Nicobar islands. The area was further divided into 1° squares and the stock density was calculated. The stock size by depth was computed at 20 m depth interval upto 100 m depth and thereafter the depth ranges followed were 101-150 m, 151-200 m, 201-300 m, for each latitude zone. The depth-wise species composition and size distribution of the dominant species of threadfin breams and lizard fishes were determined for each latitude zone.

Results

Threadfin breams

Area-wise abundance

The area- wise abundance and distribution of threadfin breams along the coasts of India is given in Fig.1.

TABLE 1. *Depth-wise distribution of threadfin breams (kg/hr) at different latitudes along the coast of India*

Latitudes	Depth range (m)							
	21-40	41-60	61-80	81-100	101-150	151-200	201-300	Average
Southwestcoast								
8-9°N	0	382.1	231.7	0	6.5	63.0	5.3	98.4
		(66.6)	(49.4)		(3.3)	(22.5)	(8.6)	(26.9)
10-11°N	7.5	617.0	1254.3	200.0	9.0	1.0	0	298.4
	(0.9)	(57.6)	(73.1)	(40.1)	(1.5)	(0.5)		(42.7)
12-13°N	6.2	0	59.5	113.2	8.1	0	0	26.7
	(79.4)		(23.7)	(83.8)	(9.6)			(16.4)
14°N	0	1800.0	1100.0	0	0	0	0	488.3
	(89.9)	(43.9)						(62.2)
Average	3.4	699.7	661.3	78.3	5.9	21.3	1.3	210.1
	(1.2)	(71.5)	(53.6)	(41.7)	(24.8)	(12.6)	(0.6)	(44.3)
Northwest coast								
15-16°N	0	5.8	3.3	118.8	59.5	0	0	26.8
		(19.1)	(1.5)	(21.1)	(76.7)	-	-	(13.4)
17-18°N	0.5	-	5.4	27.3	-	-	-	11.1
	(0.1)		(0.9)	(19.7)				(2.6)
19-20°N	-	-	481.7	9.9	-	-	-	245.8
			(40.2)		(5.1)			(35.3)
21-22°N	0	51.5	691.0	-	0	-	-	185.6
		(7.1)	(27.1)					(25.6)
23°N	-	-	16.0	-	-	-	-	16.0
			(8.0)					(8.0)
Average	0.2	28.6	295.3	43.0	29.7	0	0	56.6
	(0.1)	(11.4)	(31.1)	(14.4)	(50.6)			(17.3)
Wadge Bank								
7-8°N	0	199.7	1608.1	945.3	396.0	-	-	629.8
		(19.7)	(61.3)	(55.9)	(66.0)			(34.6)
Southeast coast								
10-11°N	1.6	43.5	0	-	-	-	-	15.0
	(1.2)	(11.5)						(8.2)
12-13°N	0	9.2	9	36.7	3	-	-	11.6
		(9.0)	(5.8)	(68.4)				(11.9)
14°N	3	31.5	0	2.0	-	0	-	9.1
	(5.3)	(7.0)		(3.0)				(4.9)
Average	1.5	28.1	4.5	19.4	3	0	-	11.3
	(1.7)	(9.0)	(2.9)	(32.3)				(8.2)

Table 1. *Contd*

Latitudes	Depth range (m)							
	21-40	41-60	61-80	81-100	101-150	151-200	201-300	average
Northeast coast								
15-16°N	2.1	2.1	0	5	0	0.3	-	1.6
	(0.2)	(1.5)		(0.5)		(0.6)		(0.4)
17-18°N	20.0	5.1	0.2	47.5	10.7	0	125	29.8
	(13.6)	(5.3)	(0.1)	(15.5)	(8.7)		(7.4)	(8.2)
19-20°N	1.7	4.4	10.7	13.2	-	0	-	6.0
	(0.7)	(1.5)	(0.4)	(7.1)				(1.0)
Average	7.9	3.9	3.6	21.9	5.4	0.1	125	23.9
	(1.6)	(2.2)	(0.3)	(4.4)	(8.7)	(0.4)	(7.4)	(4.2)
Andaman & Nicobar								
6-7°N	-	0	-	-	-	-	-	0
8-9°N	-	-	0	-	-	-	-	0
10-11°N	-	-	-	2.5	-	-	-	2.5
				(7.5)				(7.5)
12-13°N	0	0	1.3	3.0	0.3	-	-	0.9
			(0.3)	(0.5)	(0.6)			(0.3)
14°N	0	-	0	14.0	-	-	-	4.6
				(42.4)				(12.6)
Average	0	0	0.4	6.5	0.3	-	-	1.4
			(0.2)	(2.2)	(0.6)			(0.8)

yielded very high catch rates while in October-December the peak catch rates occurred in 61-80 m depth. In the Wadge Bank area high catch rates were obtained at 41-100 m depth during July-September. In the east coast no significant and marked seasonal variation in the abundance of the resource was noticed. However, the catch rates were found to be comparatively higher in 81-100 m depth during January-March and 41-60 m during July-September in the southeast and in 21-40 and 101-150 m during April-June in the northeast coast.

Species composition

The analysis of the species composition of threadfin breams in different depth ranges indicated that along the southwest coast the dominant species was *N. japonicus* upto a depth of 60 m, with *N. mesoprion* predominating in 61-80, 81-100 and 101-150 m depths (Table 3). In the northwest, *N. japonicus* formed the main constituent in 41-60 and 81-100 m depths while *N. mesoprion* accounted for the major part of the catch in 21-40, 61-80 and 101-150 m depth zones. *N. bleekeri* formed **41.4%** of the threadfin bream catch at 21-40 m depth zone along 17-18°N.

In the southeast and northeast coasts *N. japonicus* formed the dominant species in 21-40 and 41-60 m depth ranges. *N. mesoprion* dominated the catch in 61-80 m and deeper depth zones.

Size distribution of dominant species

Nemipterus mesoprion

The length-frequency distribution of *N. meso-*

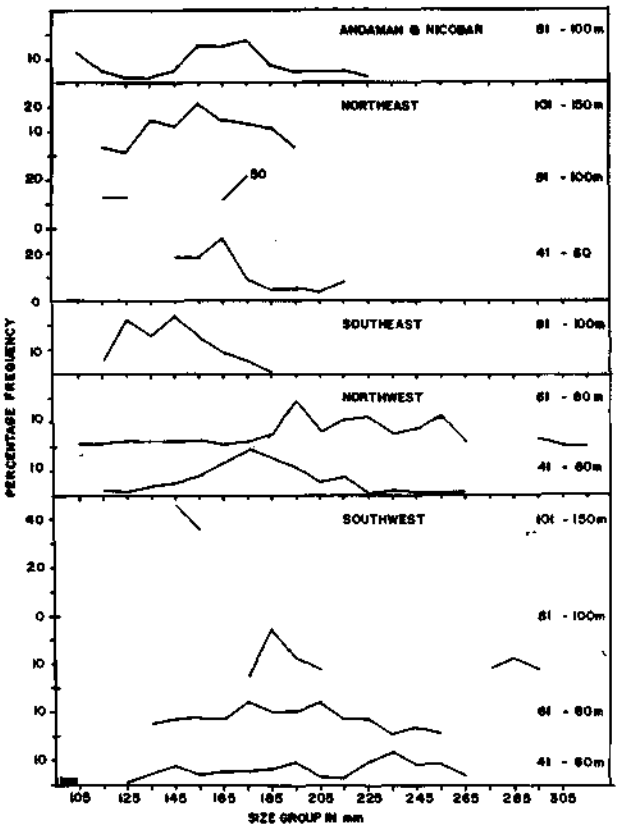

Fig. 3. Size frequency distribution of *N. japonicus* in percentage in different depth zones along the coasts of India.

along 15°-16°N and 19°-20°N, in 81-100 m depth range along 17°-18°N and in 41-60m depth range along 21°-22°N. The average catch rate for the area was the maximum in 61-80 m depth zone (41.7 kg/hr) followed by 41-60 m (38.2 kg/hr) and 81-100 m (25.8 kg/hr).

In the Wadge Bank area the highest catch rate was recorded from 101-150 m depth range (102.0 kg/hr) showing a decreasing trend with decrease in depth.

In the southeast coast, the lizard fish resource was poor along most of the latitudes, the highest catch rate recorded being only 3.3 kg/hr in the 81-100 m depth range along 12°-13°N. The highest average catch rate for the area was in the 81-100 m depth ránge (1.6 kg/hr) followed by 21-40 and 41-60 m depth ranges.

In the northeast coast the potential yield was found to be higher in 81-100 m depth range along 15°-16°N. Along 17°-18°N latitude zone, the catch rates were the highest at 21-40 m depth zone while along 19°-20°N the maximum catch rate occurred at 61-80 m depth zone. The average catch rate for the area was the highest at the depth range of 21-40 m, showing a decreasing trend upto 61-80 m depth, after which it showed a slight increasing trend. In the Andaman-Nicobar area the most productive depth range for the lizard fishes was found to be 61-80 and 81-100 m depth ranges.

Seasonal variation

The depth wise seasonal distribution of lizard fishes showed that along the southwest coast the resource was the maximum in 41-60 and 61-80 m depth ranges during April-June closely followed by July-September. In October-December the peak abundance was observed at 101-150 m. In the northwest the abundance of the resource in the shallower waters was the highest during October-December. In the Wadge Bank area, the peak catch rates at shallower depths were during April-June and July-September. In the southeast in the inshore areas no seasonal fluctuations in the abundance of the resource could be observed, while in the northeast the catch rates were comparatively higher at 21-40 m depth in January-March and at 41-60 m depth in April-June and October-December.

Species composition

The analysis of the species composition of lizard fishes in different depth zones showed that in the southwest coast *Saurida tumbil* was the dominant species in 41-60 m depth range and above along all latitudes (Table 8). In the northwest coast and the Wadge Bank area also the same trend of dominance of *S. tumbil* was noticed except in 41-60 m depth, where *S. undosquamis* predominated. In the northeast *S. tumbil* predominated in 21-40 and 41-60 m depth ranges with *S. undosquamis* forming the major constituent in all higher depth ranges. *S.longimanus* occurred at 61-80 m depth zone along 19°-20°N. In the Andaman-Nicobar area along the northern latitudes, *S. tumbil* was the predominant species in all depth ranges.

Size distribution of dominant species

Saurida tumbil

The length- frequency distribution of *S. tumbil* in the different depth ranges along the coast is given in Fig. 5. In the southwest the modal values were at 265 mm in 21-40 m, at 355 mm in 41-60 m, at 265 and 295 mm in 61-80 m, at 285 mm in 81-100

TABLE 5. *Depth-wise sex ratio and percentage of differnt maturity stages of females of* N. japonicus *along the coasts of India*

		Depth range (m)							
		41 - 60		61 - 80		81 - 100		101 - 150	
		M	F	M	F	M	F	M	F
Southwest coast									
Sex ratio		45.1	54.9	30.0	70.0	48.1	51.9	50.0	50.0
Stages	I	8.9		-		-		-	
	II	25.0		14.2	-			66.6	-
	III - IV	19.6		85.8		28.6		33.4	
	V - VI	-		-		64.3		-	-
	VII	46.5		-		7.1		-	
Northwest coast									
Sex ratio		65.9	34.1	52.7	47.3	50.0	50.0	-	-
Stages	I	31.2		-				-	
	II	56.3		6.9		-		-	
	III - IV	12.5		93.1		100.0		-	
	V - VI	-		-		-		-	
	VII	-		-		-		-	
Southeast coast									
Sex ratio		5.8	94.2	-	-	50.6	49.4	-	-
Satges	I	-		-		29.7		-	
	II	43.7		-		29.7		-	
	III - IV	56.3		-		35.1		-	
	V - VI	-		-		5.5		-	
	VII	-		-		-		-	
Northeast coast									
Sex ratio		48.3	51.7	-	-	-	-	-	-
Stages	I	2.2		-		-		-	
	II	8.8		-		-		-	
	III - IV	75.7		-		-		-	
	V - VI	13.3		-		-		-	
	VII	6.6		-		-			

m and at 175 mm in 101-150 m. In the northwest in 81-100 m depth range the dominant modes were observed at 325 and 345 mm. In the Wadge Bank area, the dominant modes were at 225 and 245 mm in 41-60 m and at 135, 175 and 215 mm in 81-100 m depth zones. In the northeast, the modes were seen at 165 mm in 21-40 m and at 165 and 225 mm in 41-60 m. In the Andaman-Nicobar area the modal sizes were at 235 and 255 mm in the depth range 81-100 m.

The sex ratio and percentage of different maturity stages of the females of *S. tumbil* in various depth ranges along the coast is given in Table 9. In the southwest, specimens in all stages of maturity including spent ones occurred in 41-60 m depth, while preponderance of stage II fish was noticed in 81-100 m depth. In the northwest, stages III - IV and V-VI predominated in 41-60, 61-80 and 81-100 m depth zones. In the southeast, in 81-100 m depth fish in stage III-IV of maturity formed 61.2%. In the northeast, fishes from stage II to VI occurred in 41-60 m, while stage II and III-IV fishes formed the major constituent in 61-80 m depth.

DISCUSSION

Tholasilingam *et al.* (1973) observed a dominance of *N. japonicus* in the catch from intermediate depths along the Kerala coast. The survey conducted by M.T. *Muraena* indicated that the fish is taken in reasonably good quantities in all depth ranges in the northwest coast of India (Bapat *et al.,* 1982). The studies by Sudarsan *et al.* (1988) indicated that nemipterids formed the highest percentage (21-25%) along 8° to 13°N and in 150-200 m and estimated the potential yield of nemipterids at 0.88 lakh tonnes in the west coast and 0.09 lakh tonnes in the Wadge Bank.

The present studies have shown that thread-

TABLE 6. *Depth-wise distribution of lizardfishes (kg/hr) at different latitudes along the coasts of India*

Latitudes	Depth range (m)							
	21-40	41-60	61-80	81-100	101-150	151-200	201-300	Average
Southwest coast								
8-9° N	0 (10.0)	57.5 (28.2)	132.5 (5.4)	3.3 (7.1)	14.1 (0.9)	2.5 (2.3)	14.3 (8.8)	32.0
10-11°N	0	77.5 (7.2)	24.1 (1.4)	35.0 (7.0)	6.3 (1.0)	0	0	20.4 (2.9)
12-13°N	0	0	9.2 (3.6)	1.8 (1.3)	0	0	0	1.6 (0.9)
14°N	0	100.0 (4.9)	0	10.0 (17.5)	0	–	0	18.3 (2.3)
Average	0	58.7 (6.0)	41.4 (3.4)	12.5 (6.7)	5.1 (2.1)	0.8 (0.5)	3.5 (1.5)	17.4 (3.7)
Northwest coast								
15-16°N	0	1.4 (4.6)	25.5 (11.7)	5.1 (1.0)	0	0	0	4.5 (2.3)
17-18°N	0	–	0	52.1 (37.5)	–	–	–	17.4 (4.1)
19-20°N	-	-	124.3 (10.4)	36.1 (18.7)	–	–	–	80.2 (11.5)
21-22°N	0	75.0 (10.3)	17.5 (0.7)	-	0	-	-	23.1 (3.2)
23°N	-	-	10.0 (5.0)	-	-	-	-	10.0 (5.0)
Average	0	38.2 (15.2)	41.7 (4.4)	25.8 (8.6)	0	0	0	15.1 (4.6)
Wadge Bank								
7-8°N	0	27.2 (2.7)	37.5 (1.4)	53.3 (3.2)	102.0 (17.0)	-	0	29.7 (1.6)
Southeast coast								
10-11°N	0	0	0	-	-	-	-	0
12-13°N	0	0.6 (0.6)	0	3.3 (6.2)	0	-	-	0.8 (0.8
14 °N	3.0 (5.2)	0	-	0	-	0	-	(0.8) (0.4)
Average	1.0 (1.1)	0.2 (0.1)	0	1.6 (2.6)	0	0	-	0.5 (0.4)
Northeast coast								
15-16°N	0.5 (0.1)	3.0 (2.1)	0	5.0 (0.5)	0	0	-	1.4 (0.3)
17-18°N	18.3 (12.4)	5.0 (5.2)	1.3 (0.6)	9.5 (3.1)	10.1 (16.0)	0	0	6.35 (1.7)
19-20°N	2.6 (1.0)	5.4 (1.8)	7.3 (2.5)	1.6 (0.9)	-	0	-	3.4 (0.6)
Average	7.1 (1.5)	4.5 (2.5)	2.9 (0.6)	5.4 (8.8)	3.4 (12.8)	0	0	3.3 (0.6)
Andaman & Nicobar								
6-7°N	- (1.9)	2.0	-	-	-	-	- (1.9)	2.0
8-9°N	-	-	0	-	-	-	-	0
10-11°N	-	-	-	1.0 (3.0)	-	-	-	1.0 (3.0)
12-13°N	0	0	5.0 (1.2)	2.3 (0.4)	0	-	-	1.5 (0.5)
14°N	0	-	0	26.0 (78.7)	-	-	-	8.6 (23.5)
Average	0	1.0 (0.5)	1.7 (1.0)	9.8 (3.3)	0	-	-	2.5 (1.6)

The figures in paranthesis indicate the percentage of lizardfishes in the total demersal catch.

TABLE 7. *Depth-wise seasonal distribution (kg/hr) of lizardfishes along the coasts of India*

Seasons	Depth range (m)						
	21-40	41-60	61-80	81-100	101-150	151-200	201-300
Southwest coast							
Jan. - Mar.	0	0.5	16.1	0	3.6	0	8.9
Apr.-Jun.	0	105.8	204.1	20.2	9.0	-	0
Jul.-Sep.	0	56.8	16.6	11.5	0.7	0	0
Pct.-Dec.	-	0	0	0	34.0	5.0	0
Northwest coast							
Jan.-Mar.	-	0	1.0	6.2	-	-	0
Apr.-Jun.	-	0	0	-	-	-	-
Jul.-Sep.	0	1.2	8.5	57.1	10.0	0	-
Oct.-Dec.	0	41.5	62.9	12.2	0	-	-
Wadge Bank							
Jan.-Mar.	-	-	-	-	-	-	-
Apr.-Jun.	-	52.0	0	102.0	-	-	-
Jul.-Sep.	-	37.6	62.5	62.5	-	0	-
Oct.-Dec.	-	-	-	-	-	-	-
Southeast coast							
Jan.-Mar.	0	0	0	20.0	-	-	-
Apr.-Jun.	-	8.0	0	27.5	-	-	-
Jul.-Sep.	0	0	-	0	-	0	-
Oct.-Dec.	3.0	0	-	-	-	-	-
Northeast coast							
Jan.-Mar.	10.6	2.8	8.0	-	0	-	-
Apr.-Jun.	0	6.6	0.3	5.5	10.0	0	0
Jul.-Sep.	3.3	2.5	4.8	5.0	1.0	0	-
Oct.-Dec.	0.8	5.7	0.8	2.0	-	0	-
Andaman & Nicobar							
Jan.-Mar.	-	-	2.0	-	0.5	-	-
Apr.-Jun.	0	0	2.3	4.3	-	-	-
Jul.-Sep.	-	-	-	0	-	-	-
Oct.-Dec.	-	-	-	0	-	-	-

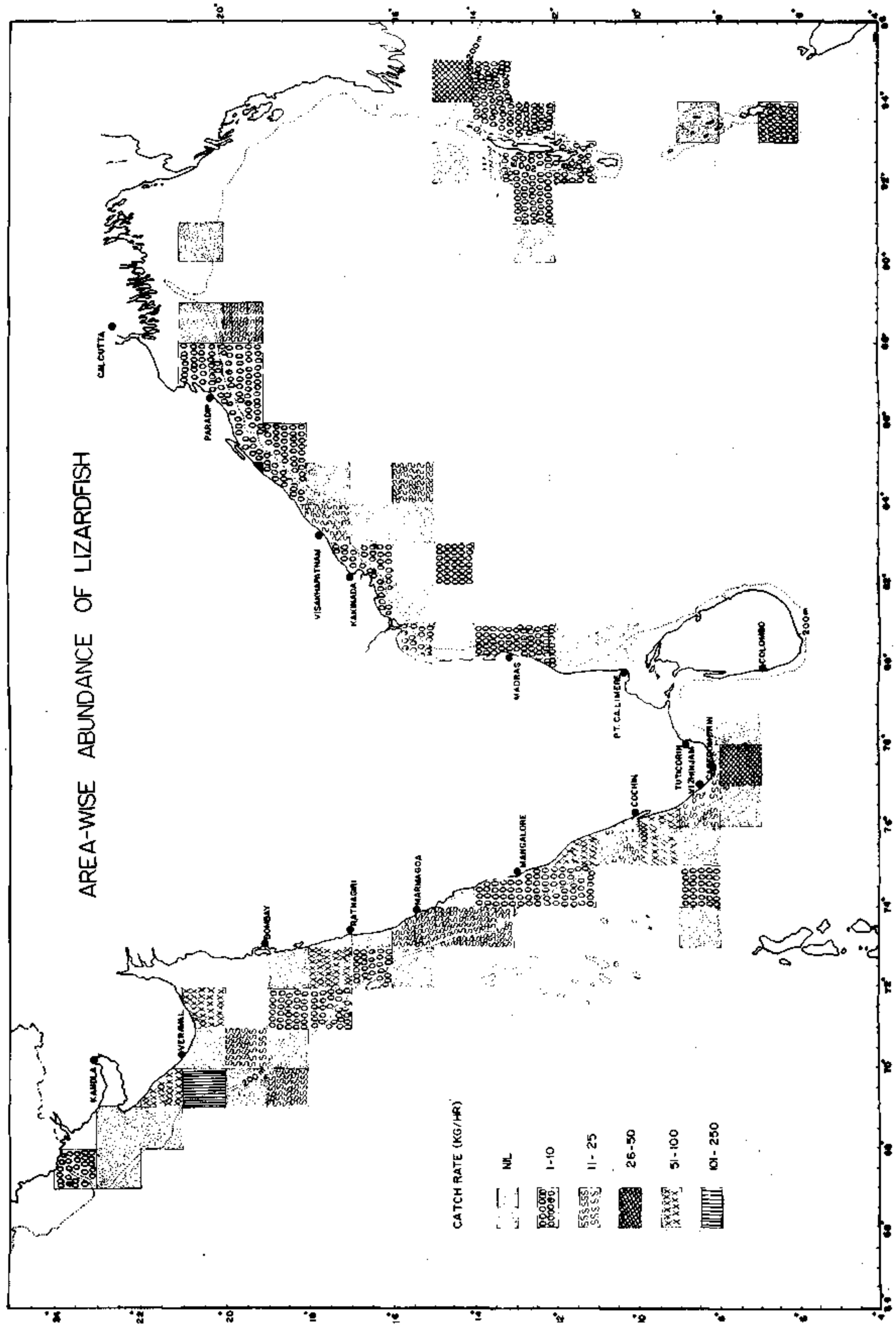

Fig. 4. Area-wise distribution of lizardfishes in kg/hr along the coasts of India.

TABLE 8. *Depth-wise species composition of lizard fishes (in percentage) along different latitude zones*

Latitudes	Depth range (m)										
	21-40		41-60		61-80		81-100			101-150	
	St	Su	St	Su	St	Sl	Su	St	Su	St	Su
Southwest coast											
8-9°N	-	-	97.8	2.2	99.8	-	0.2	100.0	-	-	-
10-11°N	-	-	100.0	-	100.0	-	-	100.0	-	100.0	-
12-13°N	-	-	-	-	50.0	-	50.0	100.0	-	-	-
14°N	-	-	100.0	-	-	-	-	-	-	-	-
Average	-	-	99.3	0.7	88.4	-	11.6	100.0	-	100.0	-
Northwest coast											
15-16°N	-	-	50.0	50.0	-	-	-	100.0	-	-	-
17-18°N	90.0	10.0	-	-	-	-	100.0	100.0	-	-	-
19-20°N	-	-	-	100.0	70.0	-	30.0	100.0	-	-	-
21-22°N	-	-	-	-	100.0	-	-	100.0	-	-	-
23°N	-	-	-	-	-	-	-	-	-	-	-
Average	90.0	10.0	46.4	53.6	97.9	-	2.1	100.0	-	-	-
Wadge Bank											
7-8°N	-	-	76.5	23.5	-	-	-	100.0	-	100.0	-
Southeast coast											
10-11°N	-	-	-	-	-	-	-	-	-	-	-
12-13°N	-	-	-	-	-	-	-	-	-	-	-
14°N	0	100.0	-	-	-	-	-	-	-	-	-
Average	0	100.0	-	-	-	-	-	-	-	-	-
Northeast coast											
15-16°N	0	100.0	0	-	-	-	-	-	-	-	-
17-18°N	-	-	95.0	5.0	100.0	-	-	-	100.0	1.0	99.0
19-20°N	100.0	0	100.0	-	6.2	15.6	78.2	-	-	-	-
21-22°N	-	-	-	-	-	-	-	-	-	-	-
Average	64.5	35.5	99.6	0.4	8.2	15.5	76.3	-	100.0	1.0	99.0
Andaman and Nicobar											
6-7°N	-	-	-	-	-	-	-	-	-	-	-
8-9°N	-	-	-	-	-	-	-	-	-	-	-
10-11°N	-	-	-	-	-	-	-	-	-	-	-
12-13°N	-	-	-	-	100.0	-	0	91.5	8.5	100.0	-
14°N	-	-	-	-	-	-	-	-	-	-	-
Average	-	-	-	-	100.0	-	0	91.5	8.5	100.0	-

St = *S. tumbil;* Su = *S. undosquamis;* Sl = *S. longimana.*

TABLE 9. *Depth-wise sex ratio and percentage of different maturity stages of females of* S. tumbil *along the coasts of India*

		Depth range (m)					
		41 - 60		61 - 80		81 - 100	
		M	F	M	F	M	F
Southwest coast							
Sex ratio		36.9	63.1	-	-	50.0	50.0
Stages	I	7.3	-	-	-	-	-
	II	19.5	-	-	-	80.0	-
	III - IV	61.0	-	-	-	20.0	-
	V - VI	4.9	-	-	-	-	-
	VII	7.3	-	-	-	-	-
Northwest coast							
Sex ratio		66.6	33.4	57.6	42.4	37.5	62.5
Stages	I	-	-	-	-	38.3	-
	II	5.9	-	-	-	6.7	-
	III - IV	64.7	-	86.1	-	40.0	-
	V - VI	29.4	-	13.9	-	15.0	-
	VII	-	-	-	-	-	-
Southeast coast							
Sex ratio		-	-	-	-	28.0	72.0
Stages	I	-	-	-	-	16.6	-
	II	-	-	-	-	22.2	-
	III - IV	-	-	-	-	61.2	-
	V - VI	-	-	-	-	-	-
	VII	-	-	-	-	-	-
Northeast coast							
Sex ratio		33.4	66.6	57.1	42.9	-	-
Stages	I	-	-	33.3	-	-	-
	II	37.5	-	33.3	-	-	-
	III - IV	37.5	-	33.4	-	-	-
	V - VI	25.0	-	-	-	-	-
	VII	-	-	-	-	-	-

fin bream is the predominant demersal fish resource in the Wadge Bank and southwest coast forming 34.6 and 44.3% of the total trawl catch respectively. In the southeast, the peak abundance of the resource is observed in 41-60 and 61-80 m depth zones. In the northwest the catch rate is higher in 61-80 m depth range showing a decreasing trend with increasing depth. In the southwest coast the resource is contributed mainly by *N. japonicus* in shallow depth ranges and *N. mesoprion* in 61-80 m and above. In the northwest *N. japonicus* formed the main constituent along most of the depth ranges.

The survey conducted by EFP vessels in the Wadge Bank area and M.T. *Muraena* in the northwest coast indicated an abundance of lizard fish resources in the deeper waters (E.F.P. Progress Report No.1, 1982; Bapat *et al.* ,1982). Sudarsan *et al.* (1988) estimated the potential yield of lizard fishes at 12,300 tonnes along the west coast.

The present studies have indicated the most productive area for lizardfishes to be the Wadge Bank followed by southwest and northwest zones. In the west coast the resource is comparatively more abundant in 41-60 m depth range showing a decreasing trend with increasing depth, whereas along the east coast the peak abundance is at 61-80 m depth. *Saurida tumbil* is the predominant species in depth ranges of 41-60 m and above.

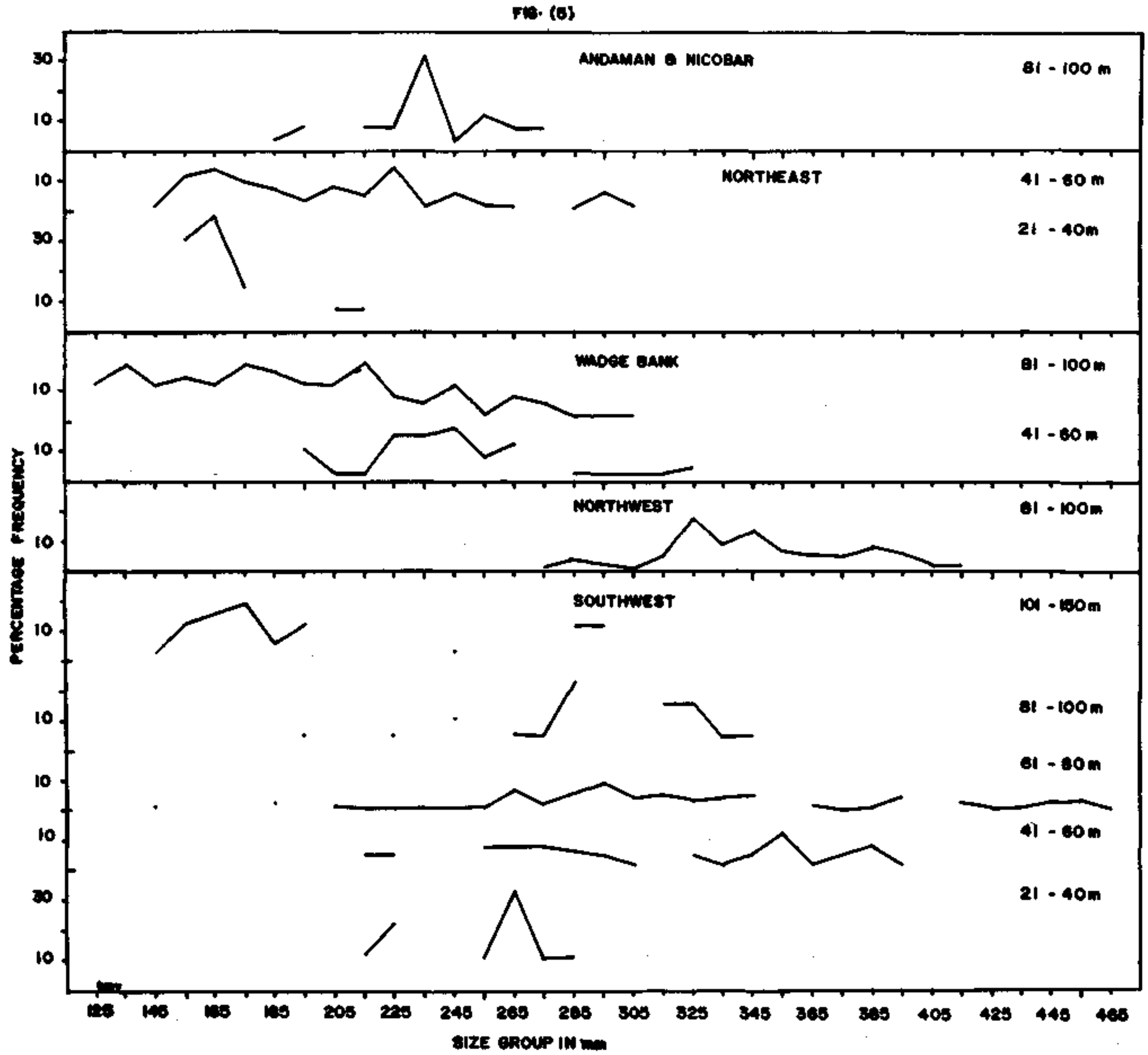

Fig. 5. Size frequency distribution of *S. tumbil* in percentage in different depth zones along the coasts of India.

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STUDIES ON THE BIOMASS IN THE DEEP SCATTERING LAYER OF THE INDIAN EEZ

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Abstract

The bioacoustic scattering layer of the EEZ of India is found in depths between 200 - 540 m. An additional layer is also recorded at a depth of 20-100 m in some regions. The DSL shows characteristic vertical migration, ascending to surface or epipelagic realm after dusk and descending down to a depth of 200-540 m during day. This study on the biomass of the DSL is based on samples of 364 horizontal hauls by IKMT from the appropriate layers of the DSL during day and night collected by FORV *Sagar Sampada* in her cruises 1 - 15 covering both the coasts of India. The estimated biomass in the DSL of the surveyed area vary from 0.1 ml to 38.1 ml/1000m^3 with the highest abundance recorded from the region 7° - 10°30'N and 70° -77° 30'E. Average monthly biomass varies from 2.1 to 21.0 ml/1000 m^3 during day and 2.2 to 14.7 ml/1000m^3 at night, with peak values noticed during April and December. The major constituents of DSL are euphausiids, decapods, larval crustaceans, siphonophores, medusae, copepods, pteropods and heteropods, amphipods, ostracods, prochordates, chaetognaths and larval, juvenile and adult fishes. An attempt is made here to study the qualitative and quantitative composition of the biological components of the DSL in different latitudes, depth zones and seasons.

Introduction

The widespread occurrence of deep scattering layers in world oceans and their rich biocomposition aroused scientific interest ever since their discovery in 1942 (Duvall and Christensen, 1946; Eyring *et al.,* 1948; and Raitt, 1948). The DSL is an important ecosystem of world oceans and supports a wide assemblage of zooplankton, micro and macronekton. The availability, abundance and vertical migration of several species of epipelagic and mesopelagic fishes are influenced or controlled by the occurrence and quantity of favourite food components in the DSL. Therefore, in order to study the food relationship in this ecosystem and its energetics from lower to higher levels of food web, it is essential to know the biomass of the principal groups which build up the system - the DSL. Johnson (1948) described diurnal vertical movements of various layers of the DSL and linked them with plankton concentration.

Kinzer (1969) reported strong DSL in the western Arabian Sea at 300-400 m and sporadically another at 900 - 1100 m during February -March, 1965. He found that the ratio of quantitative distribution of zooplankton between surface layer (0-100 m) and DSL (280 - 320 m) was 2:1. The observation further indicated that oxygen deficiency in the deeper layers of DSL is not a limiting factor for plankton concentration. Silas (1972) during the cruises of RV *Varuna* canducted acoustic surveys in the Lakshadweep Sea adjacent to islands and recorded DSL in the oceanic areas at depth of 300 - 450 m and 750-950 m with characteristic vertical migration. He found that the DSL close to the islands constituted an important source of forage to pelagic fishes and oceanic squids.

Though considerable work was done on different aspects of this ecosystem of world oceans, investigations from India on this subject are scanty. With an objective to study the occurrence, distribution, abundance characteristics of migration and the bicomposition of the DSL of Indian EEZ, regular samples were collected from the DSL during the cruises of FORV *Sagar Sampada.* This study is also aimed to understand whether the nekton stock of the DSL is sufficiently numerous to form exploitable resources of its own or whether it forms a source of food for commercially exploited epipelagic and mesopelagic fishes.

Material and Methods

Samples from DSL collected during the cruises 1 - 15 of FORV *Sagar Sampada* during February, 1985 - May, 1986 in the EEZ of India covering both east and west coasts were utilised for this study. The station depth varied from 50 - 4500 m in the shallow shelf to deep oceanic waters. Out of the 563 stations covered during the 15 cruises, DSL samples were collected from 445 stations with 82% positive stations (364 stations). Night samples were collected from 171 stations and day samples from 193 stations. Echosounders were used for obtaining continuous traces of echogram from different depth zones to study the characteristics of DSL at different times of day and night. The samples were collected with a 2.5 m IKMT (4 m vertical opening). The samples were collected from appropriate depths of DSL recorded by echosounders at a frequency of 38 khz and 120 khz. During the operations, the IKMT was fitted with a net sonde to monitor the position of the gear relative to the concentration of the DSL. Usually samples were taken from the principal layer of DSL of each station. However, stratified samples were collected from different layers of the DSL both during day and night in cruise 3B from off Cochin. The net was dragged at a speed of 3 knots for 30 minutes horizontally along the DSL and then hauled up. There was no closing mechanism for this net. Therefore, some contamination of the catches might have occurred with the passage of the net through the water column above the layer on setting and hauling. But the amount is probably negligible as the length of time the net would spent in the upper column was short in comparison to towing time at the desired depth. The samples were measured for wet volume in the laboratory. The samples were sorted out into major groups for micro-analysis of each group. The relative numerical abundance of different groups is also presented. The geographical and bathymetric position of IKMT stations are shown in Fig. 1.

Results

Characteristics of DSL

The DSL whether single or multilayered are recorded from all the geographical areas of Indian EEZ under investigation with varying intensities and characters. The scattering layer was generally found in depths between 200 and 540 m during day. In addition to this principal layer, a second layer was recorded in depths of 20 - 100 m at many stations. The principal layer itself was found sometimes split into two layers at 90 - 130 m and 320 - 500 m while descending in day. The thickness of each layer varied from 5 m to as high as 290 m. In some cases the layer was found to be very diffuse whereas in several instances it was dense and very prominent, indicative of high concentrations of organisms. Collections made at different times of day and night indicated that descrete bands or layers ascend to surface from the upper DSL by dusk and similarly descend down from surface to subsurface level at dawn (Fig. 2). Some of the recordings clearly showed a gradual mixing of layers and ascending to surface in dense concentrations during night. A micro-analysis of the bio-composition of each layer from the same station, however, was not possible, which would have thrown more behavioural information of various organism in relation to light intensities.

In the oceanic area between Cape Comorin and Cochin, the principal scattering layer was recorded at 220 - 440 m during day in August, 1985 and a thin discrete secondary layer was noticed at 60 - 90 m. At geographical areas lat. 09°30' - 10°30'N long. 73°00' - 75°30' E, lat. 10°00'N long. 71°39'E and lat. 11°00' N long. 72°01' E the DSL was multilayered and the thickness of each layer ranged from 30 to 140 m. Along shallow shelf stations the layer was thin 20 - 30 m, during day, composed mostly of planktonic organisms. At night the DSL was in the bathymetric position of 0 -35 m and/or 25 - 80 m and ususally single layered. The principal layer was thick in deeper stations off Cochin stations 09°30' N 73°00' E (2032 m), 09°30'N 75°00'E (2569 m), 10°00'N 73°38.06'E (2026 m), 10°02.7'N 79°31.1'E (2837 m) and 11°00.06'N 72°01'E (1645 m).

In the Mangalore - Ratnagiri region the DSL was either single or multilayered in August, 1985. The thickness of individual layer ranged from 50 - 290 m during day. The principal layer was thick, though diffuse during day, at deeper stations along the slope and oceanic waters as was recorded in stations 12°00' N 73° 30' E - 290 m, 12°00.5'N 72°30.5'E - 1864 m, 14°00'N 72°00'E - 1212 m, 15°00' N 69°59.5' E - 3412 m, 16°00'N 69°32'E - 3509 m and 16°00' N 71°30.3' E - 1330 m.

At shallow stations of the region Ratnagiri - Kandla the DSL was single layered in September, 1985 in the bathymetric realm of 20 - 60 m, whereas in deeper stations one to two layers were found, the principal layer at 180 - 400 m and the second layer at 40 - 70 m as was recorded in stations 20°00' N 67°30'E - 3049 m and 20°00' N 68°30' E - 3100 m. In the same region the DSL was single layered and occupied shallower position in most of the stations irrespective of depth of stations during October, 1985. The thickness of the scattering layer ranged

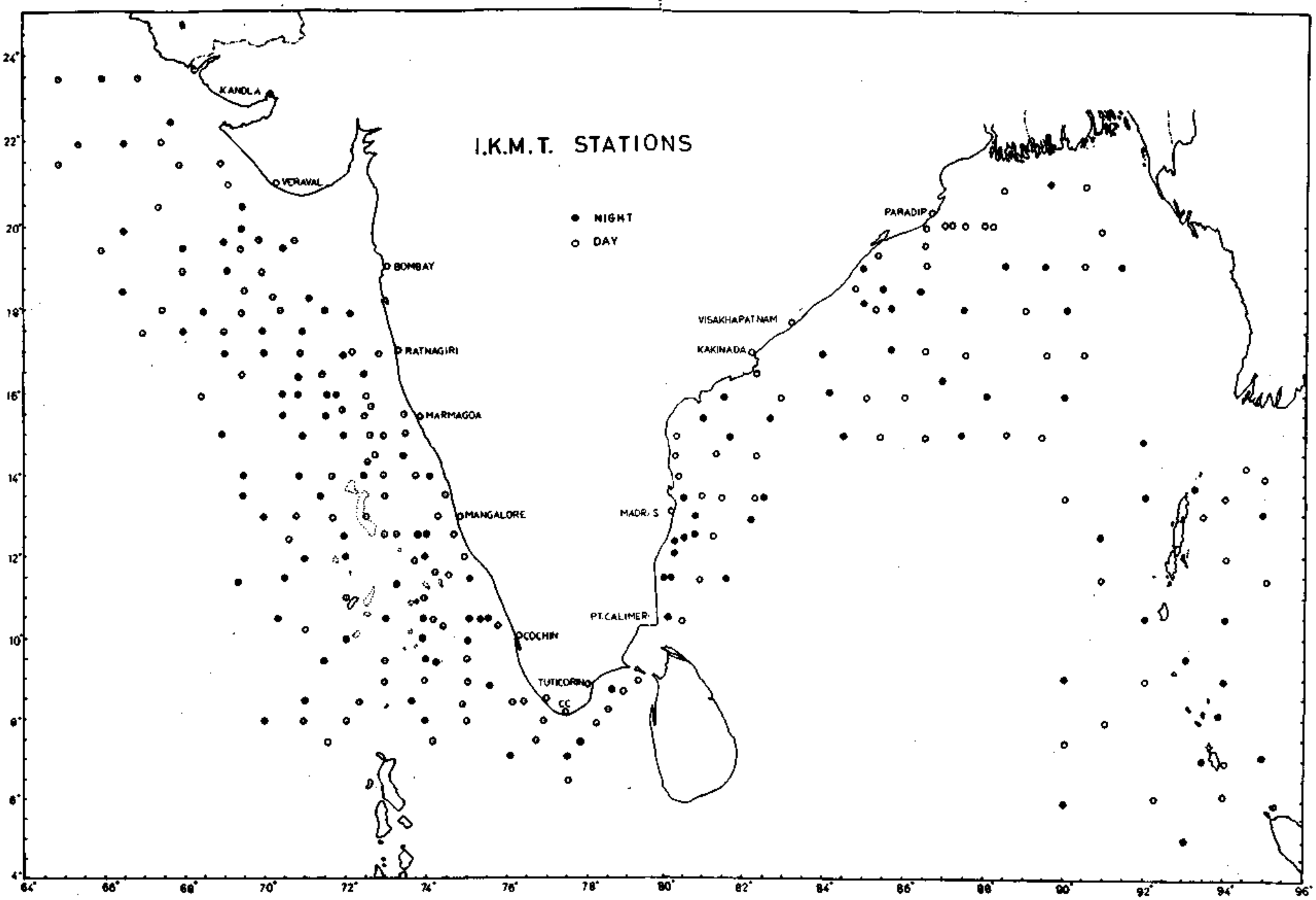

Fig. 1. Map showing the IKMT night and day stations covered by FORV *Sagar Sampada* cruises 1-15 during February, 1985 to May, 1986.

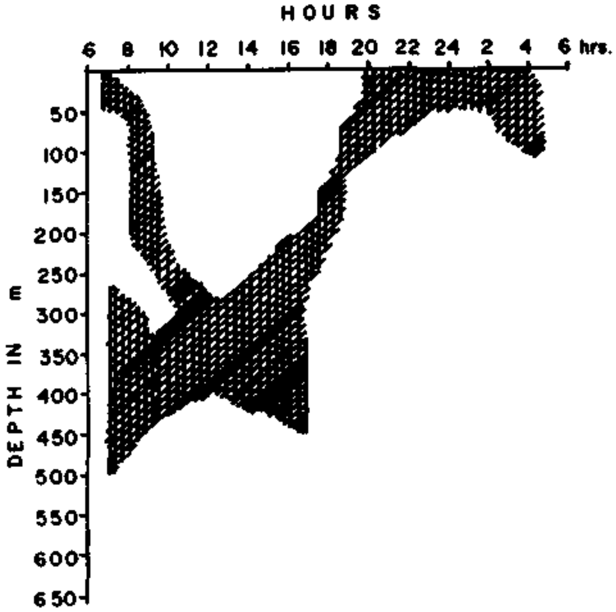

Fig. 2. Bathymetric position of Deep Scattering Layer during different times of day and night in the Indian EEZ.

from 5 - 30 m. Along the west coast the DSL was a thin layer in November and December, 1985, appeared either as single or two layers.

In the Equatorial Indian Ocean the DSL was found in one to several layers. A thick but diffuse layer was recorded at 900 - 1000 m depth in stations 01°00'N 80°00' E - 3500 m, 02° 00' N 84°00'E - 3231 m and 00°00'86°00'E - 3325 m during the day time. However, the principal layer was found at 250 - 400m in most of the oceanic stations during January and February, 1986. At night this layer ascend upto epipelagic zone at 20 - 50 m with concentrated scattering.

Observations on the movement and depths of occurrence of DSL of southeast coast showed that the scattering layer was either single or thin two layered with an average thickness of 10 - 30 m even along deep stations during night. At some areas this layer was generally faint and intermittent. Along the east coast the DSL was single or double layered and was found at 40 - 110 m and 260 - 400 m bathymetric position during day and the latter layer was prominent in slope/oceanic stations. Andaman Sea region recorded intense and persistent layers at 100 - 130 m, 340 - 430 m during day. At night the position of DSL was at 0 - 90 m and sometimes this layer splits into two thin layers at 0 - 30 m and 35 - 55 m in April, 1985.

The rate of ascend and descend were of the general order of 40 - 70 m/hour and 90-120 m/hour respectively. Horizontally the scattering layer continued all along the slope. In the open oceanic waters this layer was at a lower bathymetric position than its occurrence in the upper slope and shelf edge waters.

Biomass of DSL

The study showed that numerically about 94% of the total biomass in the DSL was composed of plankton and 6% micronekton. DSL showed characteristic vertical migration, ascending to surface or epipelagic realm towards dusk and descending down to depths upto 500 - 600 m during day time. In some stations the DSL was multilayered (1-3) with a principal layer between 200 and 540 m during day. In this report the biomass of the DSL in different geographical and bathymetric zones is given separately for day and night and for different seasons. The relative abundance of planktonic organisms and micronekton and their diurnal pattern of distribution and abundance are also dealt with.

The biomass of DSL is expressed in wet volume as ml/1000m^3 of water filtered by IKM Trawl from principal layer, the depth of occurrence of which varied diurnally, geographically, bathymetrically and seasonally. The biomass of the DSL of Indian EEZ varied from 0.1 to 38.1 ml/1000m^3 during night collection and 0.1 to 24.8 ml/1000 m^3 in day hauls. The mean biomass of west coast of India was 8.3 ml/1000 m^3 and 6.0 ml/1000m^3 in night and day hauls respectively, whereas in the east coast the average biomass was 4.6 ml/1000 m^3 in night and 3.4 ml/1000 m^3 in night and day hauls respectively. The average value for east and west coasts combined gave 7.7 ml/1000 m^3 in night hauls and 5.4 ml/1000 m^3 in day with a general average of 6.6 ml/1000 m^3 (day and night pooled). The geographical abundance of DSL biomass based on combined day and night samples is shown in Fig. 3. High values of biomass was recorded in night (Fig. 4) at stations 10°30' N 70°20' E, 09°29' N 71°39' E, 07° 30 'N 75° 30 'E, 10° 30 'N 73°00 'E (depth of operation 390 m), 16° 00 'N 69° 32 'E (depth of operation 500 m), 16° 00 'N 73° 30 'E, 20°30' N 69°32' E, 16°00' N 73°30' E, 20°30' N 69°30' E, 18°20' N 72°02' E, 15°00' N 71°00' E, 12°00'N 71°00'E, 18° 06 'N 87°16' E and 16°08' N 84°12' E. In the day stations (Fig. 5) fairly high values of biomass were recorded from stations 14°00'N 69°33.5'E, 45 m; 09° 00'N 70°00' E from an ascending concentrated thick layer at 25 m depth, 14°00'N

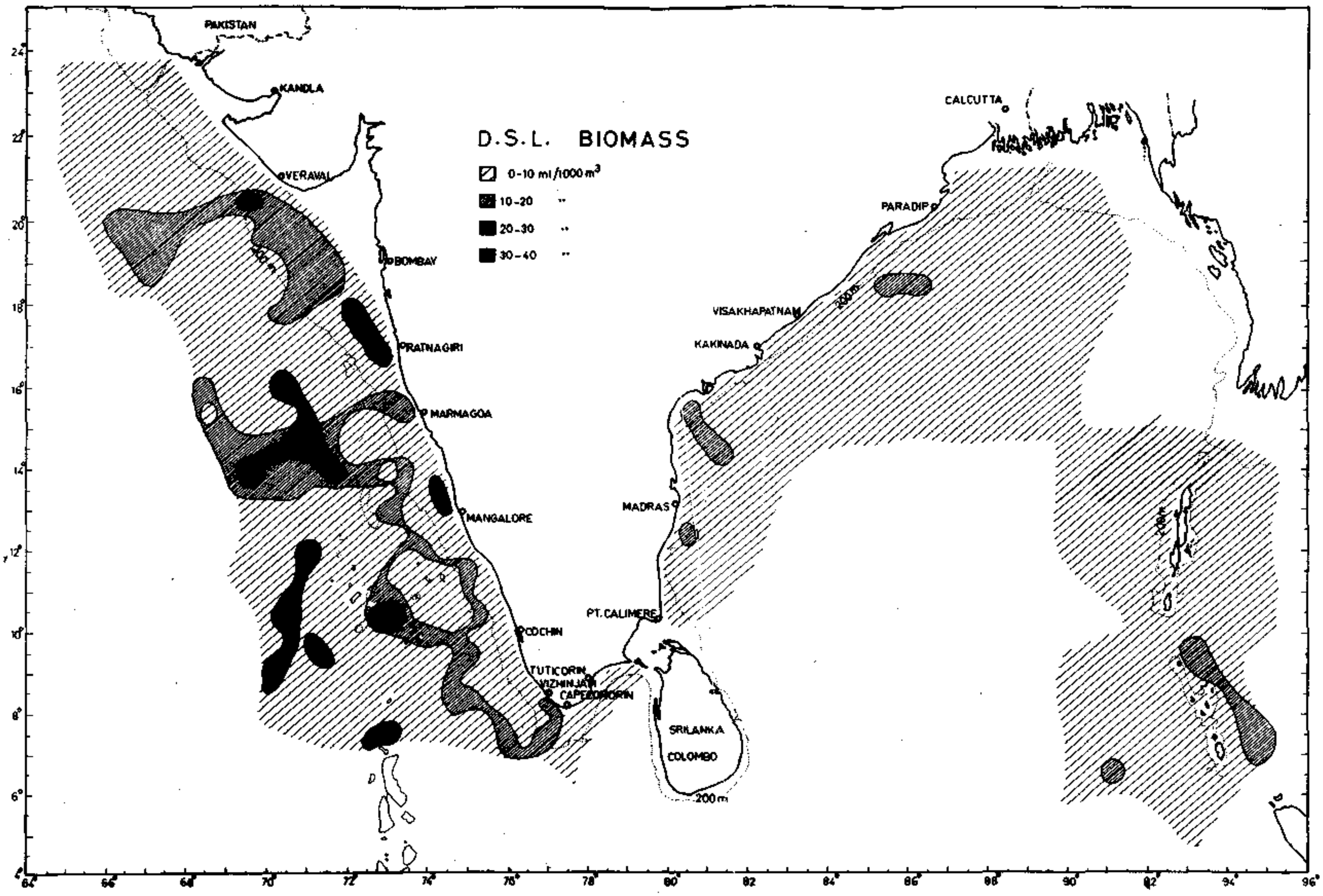

Fig. 3. Deep Scattering Layer biomass (ml/1000 m³) based on 364 IKMT day and night collections. during February, 1985 to May, 1986.

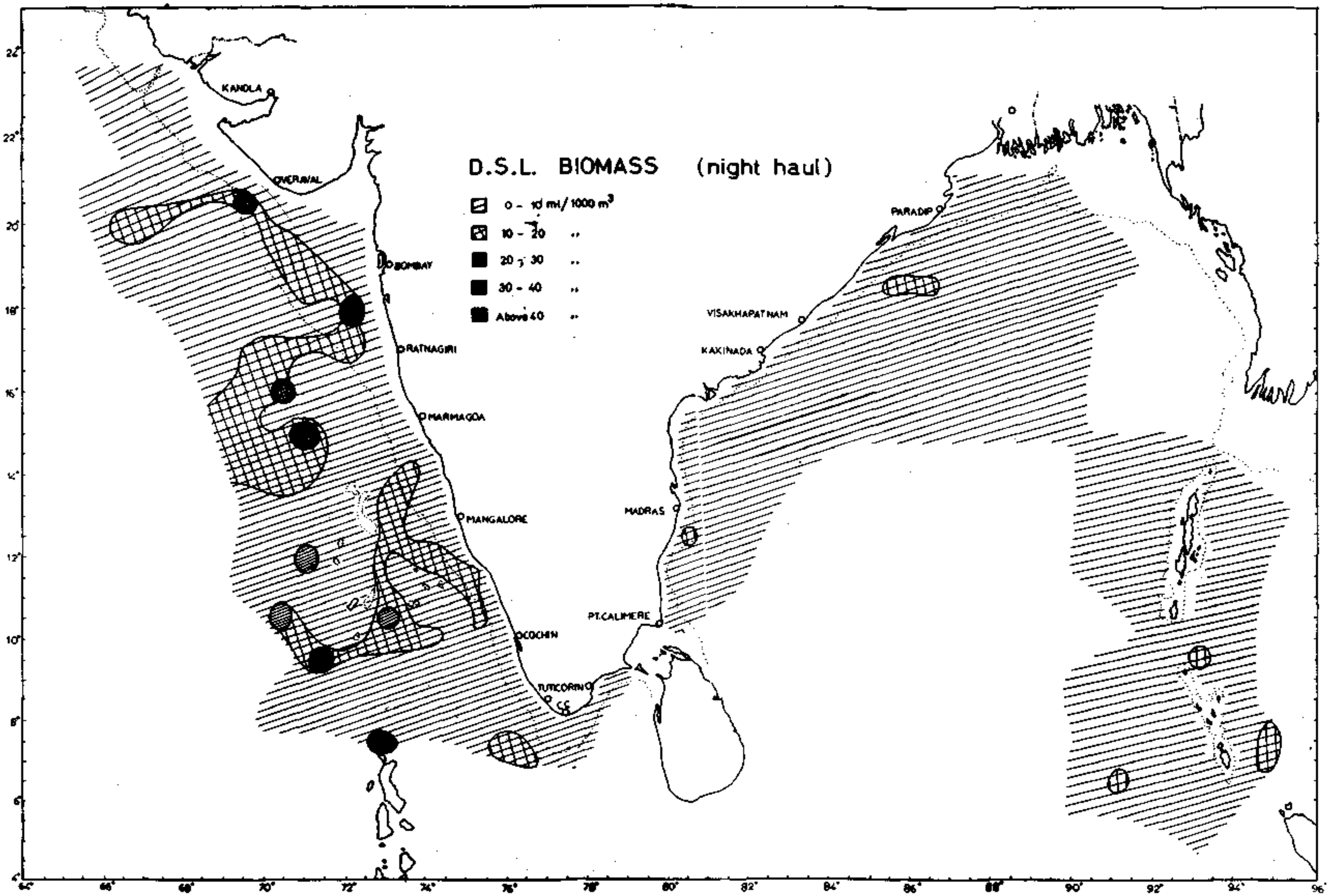

Fig. 4. Deep Scattering Layer biomass (ml/1000 m³) based on 171 night samples during February, 1985 to March, 1986.

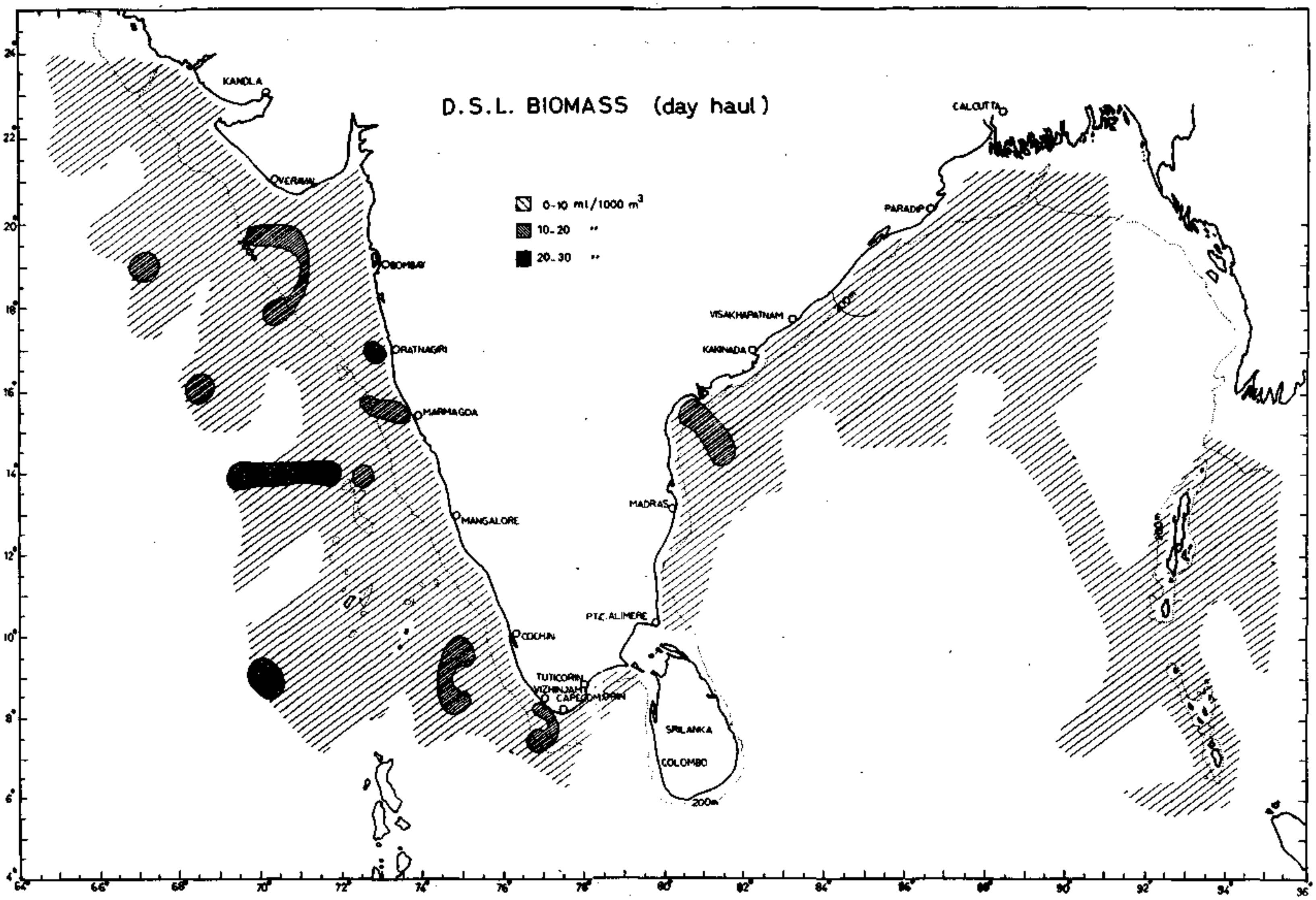

Fig. 5. Deep Scattering Layer biomass (ml/1000 m³) based on 193 day samples during February, 1985 to May, 1986.

70°50' E - a descending layer at 60 m depth.

A study of the geographic region-wise abundance showed that the southwest coast of India (Cape Comorin to Cochin) was the most productive with average biomass of 15.6 ml/1000 m^3 (night) and 10.8 ml/1000m^3 (day). Lakshadweep area was also equally productive, which recorded 10.7 ml/ 1000 m^3 (night) and 7.1 ml/1000m^3 (day). The region from Cochin to Ratnagiri was also quite rich in DSL biomass (10.3 ml/1000 m^3 in night and 9.2 ml/1000m^3 in day hauls). In the Equatorial Indian Ocean the DSL biomass abundance was low with 4.3 ml/1000 m^3 in night and 3.0 ml/1000 m^3 during day. Compared to the southwest coast, the biomass of the DSL of southeast coast was low (below the total average). Night hauls showed the biomass figure of this region as 5.7 ml/1000 m^3 and day value at 3.6 ml/1000 m^3. In the northern Bay of Bengal, DSL biomass was still poorer; night data showed 3.7 ml/ 1000 m^3 and day 2.6 ml/1000 m^3. The biomass of the scattering layer of the Andaman Sea showed an improved condition over the middle and northern parts of Bay of Bengal. The biomass abundance figure was 5.3 ml/1000m^3 during night and 3.7 ml/ 1000 m^3 in day (Table 1).

The DSL biomass abundance data of the Indian EEZ draws a very close similarity with zooplankton production from the various regions of the EEZ. The similarity was even noticed upto the level of geographical regions.

Since round the year observation was not possible from the various regions, the data showed only a general seasonal trend from the whole of the Indian EEZ with limited clarity in seasonal abundance. In general the DSL biomass was fairly high during March-April (Fig. 6), yet another peak was recorded in December (Table 2).

Depth-wise analysis of DSL biomass showed that the shallow waters upto 200 m was more productive with 6.3 ml/1000 m^3. The biomass abundance of the slope and open ocean was almost of the same magnitude with an average of 5.2 ml/ 1000 m^3.

Bio-composition of DSL

The DSL was composed of organisms from epipelagic, mesopelagic and bathypelagic environments which varied in concentration geographically, seasonally and bathymetrically from surface to sometimes as deep as 1000m in the oceanic realm.

TABLE 1. *Biomass in the Deep Scattering Layer of different geographical regions of Indian EEZ during day and night*

Region	Biomass ml/1000 m^3 Day	night
Cape Comorin - Cochin	10.8	15.6
Lakshadweep	7.1	10.7
Mangalore - Ratnagiri	9.2	10.3
Ratnagiri - Kandla	6.2	8.3
Mangalore - Kandla	3.9	5.5
Equatorial Indian Ocean	3.0	4.3
Cochin - Madras	3.6	5.7
Point Calimere to Madras	3.9	5.5
Bay of Bengal (Off Visakhapatnam)	2.6	3.7
Andaman Sea	3.7	5.3

The vertical movement was limited in the neritic shallow shelf regions. Quantitative/qualitiative analysis of DSL samples showed that zooplankton formed 94% in the total numerical biomass all along the neritic and oceanic realms upto 4500 m depth. The DSL plankton belonged to macroplanktonic groups such as euphausiids, small pelagic shrimps, siphonophores, copepods, salps and doliolums, amphipods, larvae of crabs, squilla and lobsters, medusa, ctenophores, pteropods and heteropods,

TABLE 2. *Monthly average biomass (ml /1000 m^3) in day and night collections*

Month	Day	Night
January	4.3	6.8
February	3.0	4.2
March	7.8	11.4
April	9.2	13.1
May	2.6	3.7
June	3.9	9.3
July	3.3	2.1
August	5.7	7.4
September	6.2	8.3
October	3.7	3.8
November	4.0	5.9
December	7.6	10.6

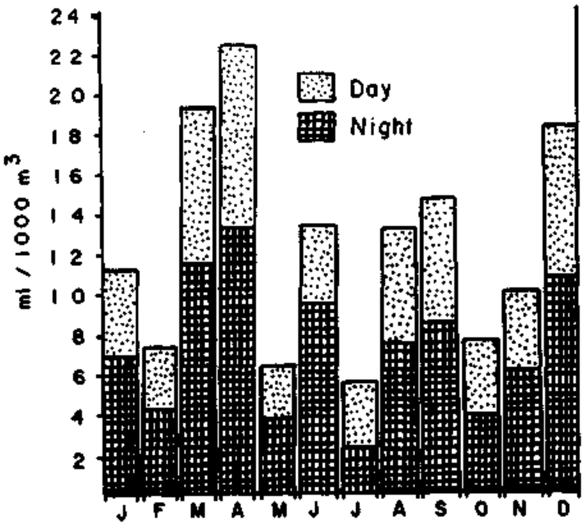

Fig. 6. Seasonal biomass abundance in the DSL of Indian EEZ during February, 1985 to May, 1986.

fish eggs and larvae etc. The remaining 6% was composed of micronekton such as crabs (0.28%), cephalopods (0.2%) and a wide variety of meso and bathy-pelagic fishes (5.4%).

Macroplankton

The geographical abundance (No./1000 m^3) of macro-plankton of Indian EEZ is shown in Figs. 7 and 8 based on day and night collections respectively. Percentage of abundance of macroplankton in the DSL ranged from 11.5 to 100% in the region Cape Comorin to Marmagoa of the southwest coast of India (08°00' - 15°00' N 68°00'-77°00'E); from 26.5 to 99.3% in the Marmagoa - Kandla (15°00' - 23°30' N 65°00' - 72°30'E); 60.4 to 100% in the Lakshadweep waters (07°20' - 10° 30' N 70° 00' -75° 00'E); 78.6 to 100% in the Cape Comorin to Point Calimere (06° 00' - 09° 30' N 77° 30' - 80° 30' E); 82.8 to 100% from Point Calimere to Paradweep (09° 30'- 20° 30' N 80° 30' - 89° 00' E) and 82.5 to 95.9% in waters around Andaman and Nicobar (05° 00' - 15° 00' N 90° 00' - 95° 00' E) during day hauls. The percentage abundance of plankton in night hauls ranged from 30.3 to 99.9 in Cape Comorin to Marmagoa; 25.1 to 99.7 in Marmagoa to Kandla; 3.4 to 100 in Cape Comorin to Point Calimere; 46.0 to 99.4 in Point Calimere to Paradweep and 79.9 to 100 in Andaman waters.

About 17 groups of planktonic organisms formed the component items of DSL plankton. The percentage composition of various planktonic groups in the total plankton biomass (numerical) of the DSL in day and night hauls are given in Table 3.

In the DSL plankton, euphasusiids were the most dominant component (36.2%) . In the night

TABLE 3. *Percentage composition of different plankton groups in plankton biomass (numerical) of the DSL during the day and night hauls*

Groups	Day	Night	Total
Euphausiids	15.2	48.9	36.2
Decapods	10.2	12.1	12.1
Alima larva	17.6	5.7	9.9
Copepods	13.9	7.0	9.4
Salps & doliolids	7.9	6.2	6.8
Chaetognaths	8.2	4.6	5.8
Pteropods	4.0	4.6	4.4
Lucifer	6.6	2.4	4.0
Amphipods	5.6	2.1	3.5
Zoea and Megalopa	4.2	2.7	3.2
Medusa	2.8	1.4	1.9
Siphonophores	1.3	0.5	0.8
Ostracods	0.6	0.7	0.7
Heteropods	0.8	0.5	0.6
Ctenophores	0.6	0.3	0.4
Phyllosoma	0.3	0.2	0.2
Gastropods	0.2	0.1	0.1

hauls they formed 48. 9% and in day hauls 15.2% of the total zooplankton biomass of scattering layers. They were abundant in the upper layers during night and sank down in day time, probably beyond the principal layer (Mathew, 1990). The next important item was pelagic shrimps (Decapoda), which formed 12. 1% in the total plankton biomass; with the bulk contributions in night hauls. The pelagic shrimp population was constitued by *Sergestes*, *Acetes*, *Thalassocaris*, *Pasiphaea*, and *Leptochela* (Suseelan and Manmadhan Nair, 1989). Alima larva and copepods formed 9.9 and 9. 4% respectively in the plankton. Both groups had high abundance in day samples. Plankton groups such as salps and doliolum and chaetognaths contributed 6.8 and 5.8% respectively with dominance in day hauls. Pteropods, amphipods and crab larvae like zoea and megalopa formed other important groups in the plankton, again with abundance in day hauls. Other less common groups were medusa, siphonophores, ostracods, heteropods, ctenophores, lobster-larvae like phyllosoma and gastropods. Analysis of plankton abundance in day and night samples showed clearly that most of the planktonic forms

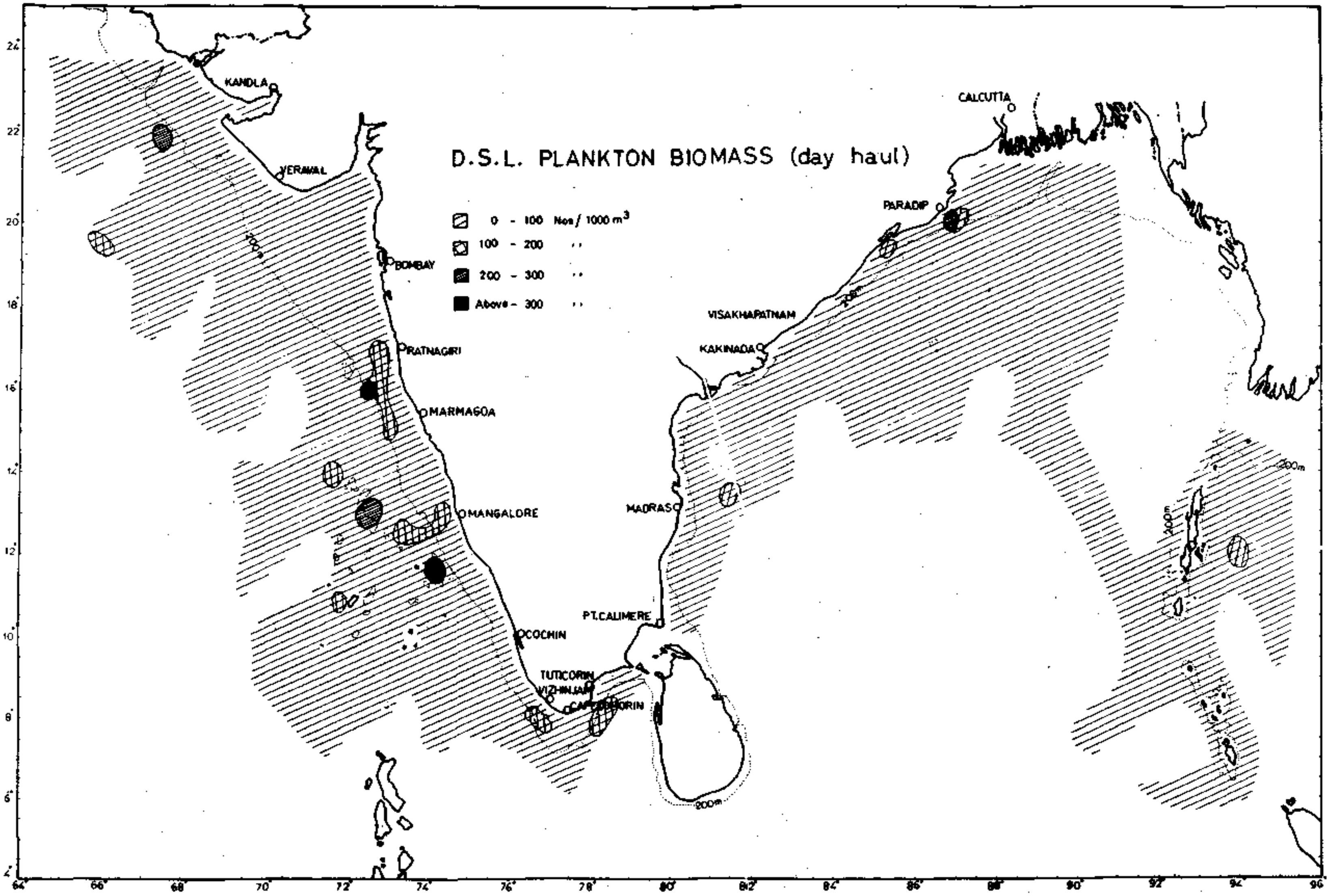

Fig. 7. DSL macro- zooplankton density based on 193 day samples during February, 1985 to May, 1986.

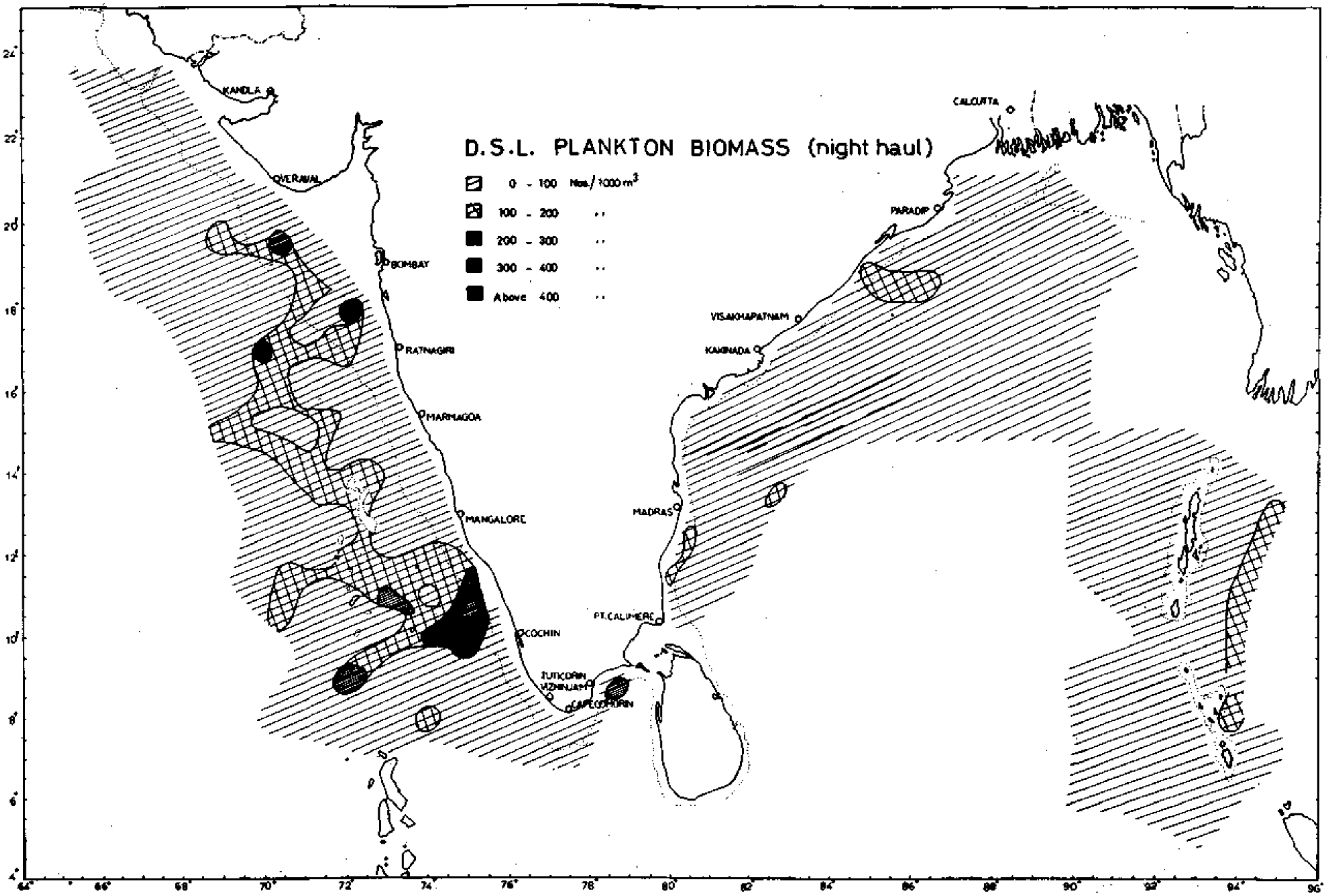

Fig. 8. DSL macro- zooplankton density based on 171 night samples during February, 1985 to May, 1986.

had high population density in night hauls (Table 4) . Euphausiids were more common in night (85. 4%) than in day collections (14. 6%). Similarly pelagic shrimps had higher abundance in night (69. 5%) than in day (50. 5%) hauls. Planktonic groups like ostracods and pteropods were common in the night hauls. On the contrary alima was abundant in day samples.

Seasonal abundance of plankton in the EEZ in general showed that the peak occurrence of zooplankton was in March, August - September and December. Monthly average nos./haul of plankton in the DSL is given in Tables 5 and 6 separately for day and night stations.

TABLE 4. *Diurnal variations of percentage occurrence of plankton groups in the DSL*

Plankton groups	Day	night
Euphausiids	14.6	85.4
Copepods	49.5	50.4
Medusa	48.8	51.2
Decapods	30.5	69.5
Chaetognaths	44.8	55.2
Amphipods	55.9	44.1
Zoea & Megalopa	48.2	51.8
Salps and Doliolum	37.8	62.2
Siphonophores	55.0	45.0
Alima larva	65.2	34.8
Ctenophores	47.0	53.0
Ostracods	30.7	69.3
Lucifer	55.6	44.4
Phyllosoma	50.0	50.0
Gastropods	43.5	56.5
Pteropods	30.2	69.8
Heteropods	42.9	57.1

Micronekton

Micronekton comprised of crabs, cephalopods and fishes formed only 6% (numerical abundance) in the total DSL biomass. Of the three major groups, fishes had the most wide distribution/ abundance in DSL. It occurred in 82% of the hauls. Cephalopods were well represented in DSL hauls, both during day and night in 46% of the stations. On the other hand crabs were recorded only from 17% of the stations with abundance in night hauls. The swimming crab, *Charybdis smithii* was the major component of crabs, often appeared in swarms in the DSL. The highest density (862 nos./haul) pocket was at 07° 31' N and 76° 47' E off Colachal with particular dominance all along the west coast (Balasubramanian and Suseelan, 1989).

TABLE 5. *Monthly average nos/ haul of crabs, cephalopods, fishes and macroplankton in the DSL during day hauls*

Month	Crabs	Cephalopods	Fishes	Plankton
Jan.	8.4	2.1	46.2	1,041.4
Feb.	—	1.5	63.6	1,024.8
Mar.	0.6	1.8	76.5	1,054.3
Apr.	0.6	7.7	136.6	1,544.4
May	3.1	2.1	46.9	631.4
Jun.	31.5	12.0	75.5	783.5
Jul.	2.3	1.3	81.7	2,160.2
Aug.	0.6	17.7	18.2	1,927.3
Sep.	5.1	5.5	102.3	1,645.1
Oct.	12.7	15.2	208.5	831.8
Nov.	—	—	463.0	1,290.7
Dec.	2.2	0.9	57.4	2,449.2
Average	8.9	5.8	91.3	1,320.2

Nekton including micro and macro formed 0 to 88.5% of the total DSL biomass (numerical) in the

TABLE 6. *Monthly average nos./ haul of crabs, cephalopods, fishes and plankton in the DSL during night hauls*

Month	Crabs	Cephalopods	Fishes	Plankton
Jan.	1.9	2.7	109.5	2,294.7
Feb.	0.1	4.4	195.3	2,417.8
Mar.	16.5	3.8	312.6	17,101.8
Apr.	40.0	13.1	81.6	1,173.0
May	1.5	2.5	137.0	971.3
Jun.	—	13.3	192.3	1,807.0
Jul.	4.0	1.0	94.0	1,204.3
Aug.	0.6	3.4	111.4	2,238.0
Sep.	2.2	1.3	84.3	2,717.9
Oct.	0.7	1.2	132.0	929.4
Nov.	—	2.0	1,560.5	940.0
Dec.	8.3	3.5	187.3	5,516.1
Average	2.7	4.4	158.9	3,084.6

Cape Comorin to Marmagoa region, from 0.7 to 73.5% in Marmagoa to Kandla, 0 to 39. 6% along Lakshadweep, 0.6 to 23.8% in Equatorial Indian Ocean, 0 to 21. 4% in Cape Comorin to Point Calimere, 0 to 17. 2% along Point Calimere to Paradweep and 4.1 to 17. 5% in Andaman and Nicobar Sea in day hauls. The nekton component of the night hauls from DSL of different geographical areas showed that the range was from 0.1 to 69.7% in Cape Comorin to Marmagoa area, 0.3 to 74.9% in Marmagoa to Kandla, 0 to 96.6% in Lakshadweep region, 0 to 21.1% in Equatroial Indian Ocean, 0 to 20. 1% along Cape Comorin to Point Calimere, 0.6 to 54% in Point Calimere to Paradweep and 0 to 20. 1% in Andaman & Nicobar region.

Fishes formed about 93% of the total micronekton, which was followed by crabs (4.4%) and cephalopods (2.6%) in the night samples, whereas in day hauls fishes formed 90. 4%, crabs 3.9% and cephalopods 5.7% in total micronekton (numerical). Combined night and day composition showed that fishes formed 91.8%, crabs 4.5% and cephalopods 3.7% in the total micronekton of the DSL.

Geogrphical abundance of the micronekton in the DSL (day samples) showed some density pockets along the west coast at stations at 07°31' N 76° 47' E (34 nos./1000 m^3), 23° 30' N 65° 00' E (22 nos./1000m^3), 18° 30' N 69° 30' E (40 nos./1000m^3), 15° 30' N 73° 30' E (55 nos./1000 m^3), 12° 00' N 75° 04' E (48 nos./1000m^3), 15° 40' N 72° 40' E (40 nos./ 1000m^3) and 17° 00' N 72° 50' E (26 nos./1000m^3). The micronektonic concentration along the east coast was low in the day collection (1 to 11 nos./ 1000m^3).

Dense pockets of nekton were found in night hauls all along the west coast especially along the southern and northern Arabian Sea. Stations of high concentration were 15° 29' N 71° 36' E (25 nos./ 1000m^3), 07° 24. 4' N 72° 49.6' E (22 nos./1000m^3), 15° 00.5' N 69° 59.5' E (32 nos./1000m^3), 20° 30'N 69° 30'E (44 nos. /1000m^3), 17° 58'N 72° 14' E (23 nos./1000m^3) and 14° 00'N 70° 50' E (24 nos./ 1000m^3) . Nektonic abundance was the highest at station 07° 10 'N 77° 30'E (depth 242 m) along the Wadge Bank with numerical abundance of 109 nos./1000 m^3. Most of the east coast regions (Bay of Bengal) were less populous as far as nekton was concerned, except stations at 18° 33' N 85° 28' E (36 nos./1000m^3), 18° 27' N 86° 28' E (29 nos./1000m^3) and 19° 00' N 91° 22' E (20 nos./1000m^3).

Seasonal trend of abundance of nekton component of DSL showed that crabs were more common in March- June, cephalopods in April, June, August and October and fishes in February-April, June and September - November (Tables 5 & 6). Fish component of the nekton of the DSL was dominated by a variety of juvenile fishes composed of Gonostomatidae, Myctophidae, Stomiidae, Leptocephali and Bregmacerotidae in their decreasing order of abundance. Juveniles of epipelagic, mesopelagic and bathypelagic fishes formed the bulk (39. 5% in total fish biomass of DSL) component. Gonostomatidae (27. 7%) were well represented from most of the geographical areas of the slope and oceanic waters. Myctophid was a dominant group in the DSL, which formed 17% in total fish biomass and were common along the northern Arabian Sea. Leptocephalii (7.5%) were collected from a large number of stations. All fish groups were abundant in night collections, with an average number of 159 nos./ haul, whereas day collection yielded only 91 nos./ haul. During night the depth zone 200- 1000m recorded the highest fish biomass (346 nos./ haul).

Discussion

Ever since the DSL was recorded in the world oceans, various studies were undertaken on the characteristics, distribution, vertical migration and bio- composition. Kinzer (1969) found that oxygen deficiency was not a limiting factor for plankton concentration in DSL and he found a ratio of 2:1 in the wet volume of plankton of surface (0-100m) and DSL (280 - 320). Mathew *et al.* (1989) reported the average zooplankton density of 88.3 cc/ 1000m^3 in the Indian EEZ. The present study on the DSL plankton gives only an average volume of 6.6 ml/ 1000 m^3. The ratio of surface plankton density to DSL biomass was 13:1, one of the probable reasons for this low ratio may be due to differential efficiency of the two sampling gears Bongo net (plankton) and the IKMT (DSL biomass). Mathew *et al.* (1989) observed high plankton concentration in monsoon. The DSL plankton was also abundant in monsoon. Prasad (1969) based on IIOE data on the standing crop of zooplankton in the Arabian Sea and Bay of Bengal reported that the Arabian Sea was rich in zooplankton biomass during southwest monsoon with high concentration towards the coast of Somalia, Arabian peninsula, Iran and south -

western parts of India both during night and day with a maximum intensity in the night samples. He found that the average volume is considerably less in the Bay of Bengal in the same period. However, night collection showed conspicuous increase towards the upper reaches of the Bay and the Andaman Sea. Further it was found that in northeast monsoon the plankton distribtuion was diffuse throughout the Arabian Sea in a lower magnitude. He also expressed that the coastal upwelling plays an important part in the fertilization of the surface waters of the regions which induce high organic production. Kabanova (1961) and Laird *et al.* (1964) also reported higher productivity of the Arabian Sea connected with the process of deep water ascent.

As the DSL plankton is a contribution of surface plankton, all the trends of production, seasonality etc. also will directly reflect on the DSL biomass. Any change from such pattern of distribution and abundance may be related to differential grazing in the surface and mesopelagic environments by different groups of predators operating on these two environments and their relative density. Bary (1966) reported such low populations of plankton in the scattering layers of Saanich Inlet at British Columbia. Kinzer (1969) also found variations in biomass at two different levels of DSL and suggested that uneven grazing by fishes could be the cause of the apparent "Patchiness". In general the present observation shows that DSL plankton abundance closely follows the surface plankton pattern except for the fact that DSL plankton is abundant by the close of southwest monsoon in August- September and by the end of northeast monsoon (December).

Silas (1972) in his cruises on board R V *Varuna* in the Lakshadweep Sea reported high concentration of zooplankton and micronekton in the DSL at 300 - 450 m during day with characterisitc diurnal migrations. He also noticed 1-3 discrete detectable bands sometimes upto 750-950m. Fishes, euphausiids and squids were the dominant component of the DSL along with macrozooplankton. He concluded that the dense occurrence of DSL around the Lakshadweep Islands provides an important source of forage for pelagic fishes like tunas. The present survey unfolds some of the rich areas around the Lakshadweep Sea and density pockets along the Indian EEZ with high DSL biomass. The DSL biomass constituents like macroplankton, pelagic shrimps, euphausiids, juvenile fish, squids etc. either directly or indirectly indicates the production potential of the mesopelagic zone of the Indian Exclusive Economic Zone.

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PRELIMINARY INVESTIGATION ON THE FISH BIOMASS IN THE DEEP SCATTERING LAYERS OF THE EEZ OF INDIA

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Abstract

The Fishery and Oceanography Reserach Vessel *Sagar Sampada* during her cruises 1-15 along the EEZ of India during 1985 to '86 conducted surveys of the bio-compositon of the DSL by using a 5 m Isaacs- Kidd Midwater Trawl. The survey revealed that the DSL is either single layered or some times multilayered mostly occupying depths from 200 to 540 m and 20 to 100 m. These layers were found to shift vertically from depths of 200 - 540 m during day to the surface during night, influenced by photoperiodic conditions. Out of a total of 563 stations surveyed, the IKMT gear sampled from 364 stations, which included day and night hauls. In additon to planktonic groups, under micronekton, fishes were the dominant item of the samples. The common fishes recorded in the DSL were myctophids, gonostomatids, *Bregmaceros*, eel larvae and juveniles of several other families of fishes. The estimated fish biomass varied from 0.01 to 45.5 g/ 1000 m^3 in the DSL. This paper describes the distribution and abundance of fish fauna in the DSL along various latitudes, depth, seasons and their diurnal vertical migration.

Introduction

The bio-composition of the Deep Scattering Layers of the world oceans has been well described by Marshall (1951), Tucker (1951), Barham (1957), Pearcy and Laurs (1966), Taylor (1968), Kinzer (1969), Silas (1972) etc. All the above works showed the predominance of macroplankton and micronekton in the DSL. Those studies also indicated the occurrence of a wide assemblage of young or adults of epipelagic, mesopelgaic and to a lesser extent bathypelagic fishes. For an understanding on the food relationships in the DSL and the rate of metabolism from the lower to the higher levels in the food web, it is pertinent to study the larger nekton, its extent and periodicity of migration, bathymetric and seasonal abundance and the degree to which these animals are predators or prey of other trophic levels. Johnson (1948) described the diurnal movements of DSL micro- and macro-nekton and linked them with plankton concentration. Tucker (1951) noticed a correlation between deeper, more intensive scattering and the vertical distribution of fishes and the shallower less intense scattering and the distribution of euphausiids. Pearcy and Laurs (1956) observed that day catch rates of mesopelagic fishes were larger than the night catch at depths of 150-500 m, and the reverse was the condition from the surface to 150 m. Taylor (1968) noticed that the largest night catches were usually smaller than the largest day catches and shallower. Alverson (1961) reported the unusual occurrence of bathypelagic myctophids at surface during day as 'reddish brown ball' and formed bait fishes for skipjack and yellowfin tunas.

This report gives a preliminary study on the geographical, bathymetric and seasonal distribution and abundance of DSL fishes of the Indian EEZ.

Material and Methods

The data base of this study was from the collections of FORV *Sagar Sampada* during her cruises 1-15 along the Indian EEZ during February, 1985 to May, 1986. The bio-compostion of the DSL was sampled with the help of a 5 m IKM Trawl net having a cod end mesh size of 1.5 mm at a speed of 3 knots. After ascertaining the depth of occurrence of the DSL from the echo-sounder (frequency of 38 khz and 120 khz), the net was shot to appropriate layer where there was maximum bio-concentration and horizontal hauls of 30 minutes duration were taken. Out of 563 stations covered during the cruise 1-15, the IKMT was operated from 364 stations (171 night and 193 day). Fishes occured in 83% of the total IKMT hauls with 90% and 84% of the IKMT day and night stations respectively. The surveyed area was sub divided into 4 bathymetric realms, 0-100, 100-200, 200-1000 m and above 1000 m for depthwise abundance study. The fish fauna were identified upto group level based on preserved samples. Stratified sampling along different layers

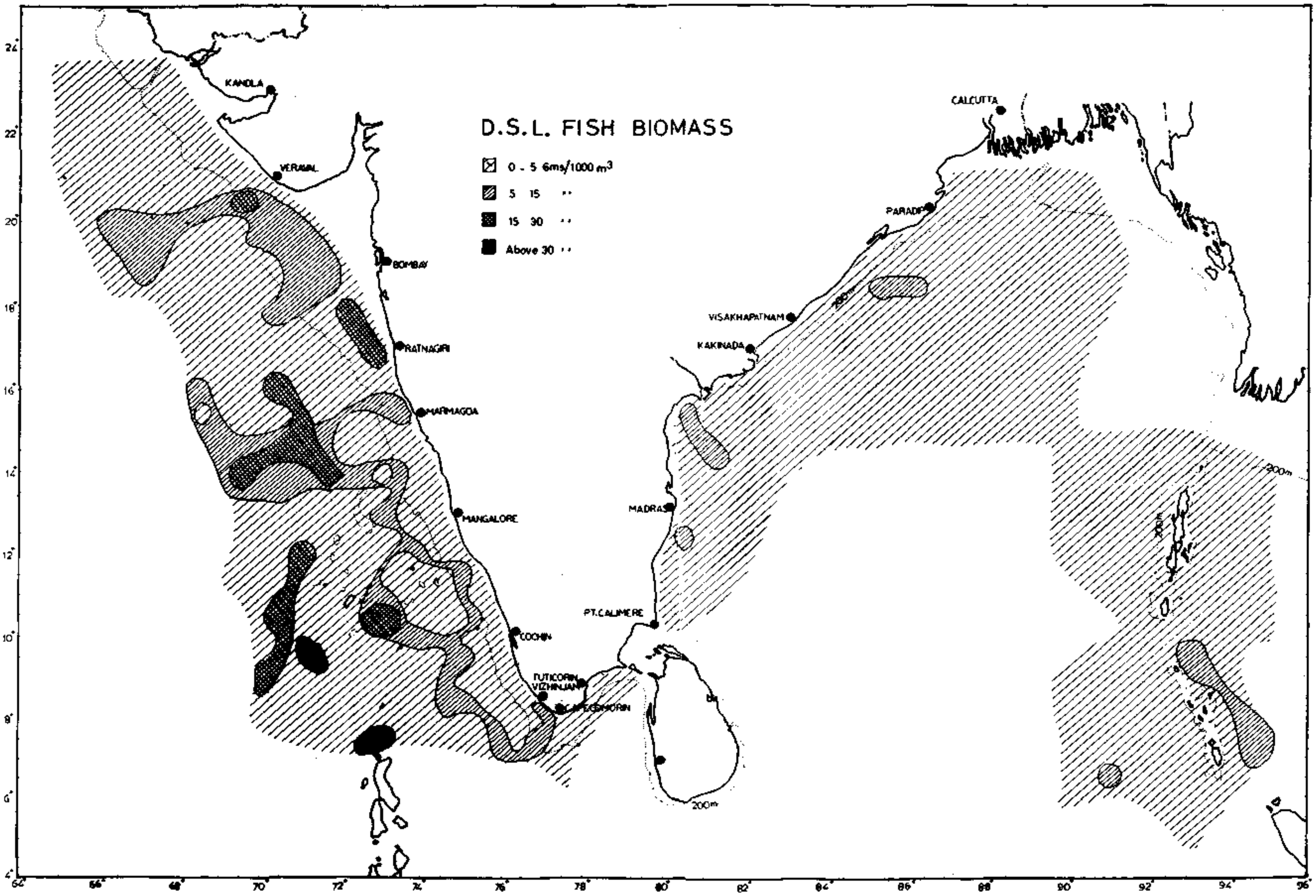

Fig. 1. Geographic distirbution and abundance (g/1000 m³) of fishes of the DSL of Indian EEZ.

of the DSL was also carried out in the area 09° 29.5'N- 10° 30'N latitude and 73° 00' E- 75° 30'E longitude in order to study the diurnal relative abundance and extent and speed of vertical ascends and descends of fishes.

Results

Geographic distribution and abundance of DSL fishes

In the total biomass (numerical) of the DSL, micro/macro nekton formed about 6% and the rest zooplankton. In the micro/macro nekton, fishes accounted for 5.4%. Fish abundance ranged from 0.01 to 45.5 g/1000 m^3 in the total DSL fish biomass. Fish was recorded in 82% of the total IKMT stations. Distribution and abundance of DSL fishes in various geographic areas of the EEZ is given in Fig. 1. The DSL of the southwest coast and Wadge Bank area showed rich concentration of fish biomass. The component groups (Table 1) of fishes occurred in the scattering layer showed that juveniles /sub-adult of several epi and mesopelagic fishes dominated the catches (39.5 % in total fish biomass). The next important item was *Vincigueria* spp. (25.7 %) of the family Gonostomatidae of meso-to bathypelagic realms with the habit of diel vertical migrations and wide distribution all along the EEZ. This genus was represented by 4 species namely *V. nimbaria, V. lucetia, V. poweriae,* and *V. attenuata.*

Table 1. *Percentage occurrence of different groups of fishes in the total fish biomass (numerical) of DSL during day and night by IKMT*

Groups	Day	Night	Combined total
Juvenile/sub adult & miscellaneous fishes	40.0	35.8	39.5
Vincigueria spp.	26.0	26.8	25.7
Myctophids	14.8	18.6	17.0
Leptocephali	6.8	8.0	7.5
Stomidae	9.5	6.3	7.0
Bregmacerotidae	2.0	2.7	2.4
Other fishes	0.9	1.8	0.9

Myctophids are yet another important group commonly recorded from the DSL both during day and night with dominance in night hauls. This group accounted for about 17 % of the total fish biomass of the scattering layers with wide distribution and represented by the genera *Diaphus, Myctophum* and *Benthosema*. This group was particularly abundant along the west coast. Some other important groups ecnountered in the fish catches of the DSL were Leptocephali (7.5 %) and Stomiidae (7 %); both the groups of fishes and larvae were widely distributed all along the surveyed areas. Fishes of the family Bregmacerotidae (2.67 %) were recorded from several stations and represented by the genus *Bregmaceros*. In addition to the above groups, a wide spectrum of miscellaneous fishes from mesopelagic and bathypelagic environments were found to inhabit the DSL and showed characteristic vertical ascends and descends diurnally.

Day hauls

Day operations of IKMT revealed wide occurrence of fish biomass in the DSL of Indian EEZ. The fishes occurred in 90 % of IKMT day stations and in the bio-compositon (numerical), fish formed 6.4 %. In the total nekton population, fish accounted for 90.4 % and the rest by crabs (3.9 %) and cephalopods (5.7 %). The average number of fishes per haul was 91 in day operation. The fish biomass in the surveyed areas of the DSL varied from 0.01 to 22.5 g/1000 m^3 of water of the bioacoustic scattering layers. Geographic abundance (g/1000 m^3) of fish biomass in the DSL of day hauls is given in Fig. 2. The pockets of high density DSL fish biomass were located at lat. 15° 30'N, long. 73°30'E (1,492 nos. /haul or 22.5 g/ 1000 m^3); 09°30'N, 75° 00'E (832 nos. /haul or 12.6 g/1000 m^3), 18° 30'N, 69°30'E (751 nos. / haul or 11.3 g/ 1000 m^3), 13°00'N, 75°04'E (1267 nos. / haul or 19.3 g/ 1000 m^3) and 15°40'N, 07°24. 8'E (945 nos. / haul or 14.3 g /1000 m^3).

Night hauls

Fishes were collected from 84 % of the IKMT night stations with an average catch rate of 159 nos./ haul. In the DSL nekton compositon of night hauls, fishes accounted for 93 % and crabs and cephalopods 4.4 and 2.6 % respectively. Geographic abundance (g/1000 m ^{3}) of DSL fishes in night collections are shown in Fig. 3. DSL fishes occurred in dense concentration along the areas lat. 09°30'N, long. 74°00'E (685 nos. /haul or 9.9 g/1000 m^3); 15° 5'N 68°58'E (810 nos. /haul or 12.2 g/ 1000 m^3) ; 20°30'N, 69°30'E (1144 nos. /haul or 17.3 g/1000 m^3); 18°33'N, 85°20'E (946 nos./haul or 14.3 g/1000 m^3) and 18°27'N, 86°28'E (784 nos. / haul or 11.8 g/ 1000 m ^{3}) of the EEZ. The highest fish catch was recorded from the density pockets in Wadge Bank at lat. 07°10'N, 77°30'E (3013 nos. /haul or 45.5 g/ 1000 m^3) and 07°10'N, 76°07'E (1228 nos./ haul or 16.6 g/1000 m^3).

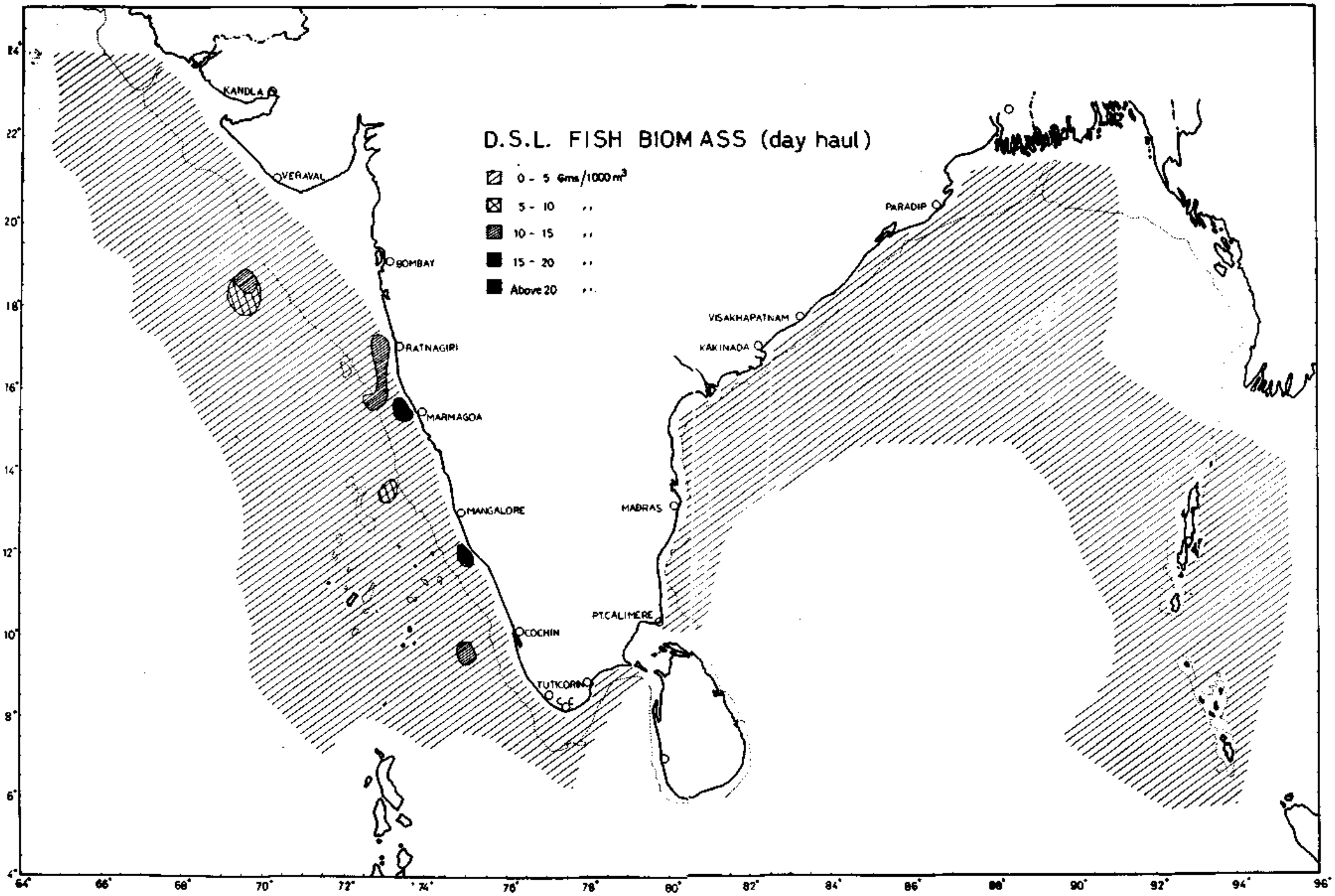

Fig. 2. Geographic distirbution and abundance (g/1000 m³) of fishes from day hauls of IKMT along the DSL of Indian EEZ.

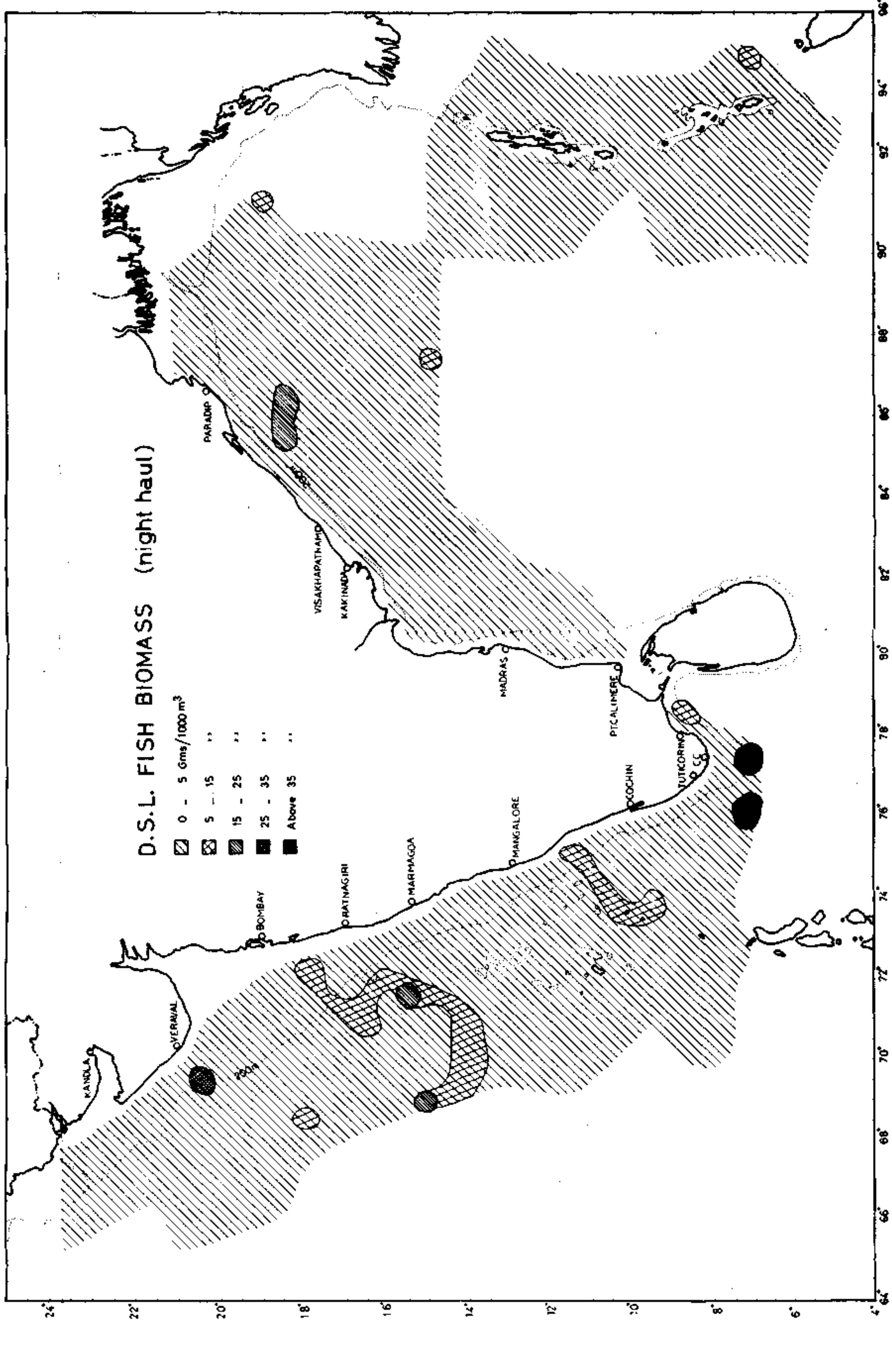

Fig. 3. Geographic distribution and abundance (g/1000 m³) of fishes from night hauls of IKMT along the DSL of Indian EEZ.

Seasonal abundance

The seasonal trend of abundance of DSL fishes in day and night hauls (Fig. 4) showed that the night catches were invariably higher than day catches except during July, September and October. The highest catch rate was recorded in Novemebr. The available data is not sufficient to give a conclusive picture of seasonal trends of abundance because of the lack of round the year coverage along all geographical areas of the EEZ. Therefore, the data is pooled into three seasons, premonsoon, monsoon and postmonsoon (Table 2), which gave the highest vaule (194 fishes/haul in night and 125 fishes /haul in day) during postmonsoon season both in the day and night collections. This fish peak was not coincided with plankton abundance; probably this differential abundance was due to high rate of grazing by the former. The night/day catch ratio showed high value (2.6) during monsoon; whereas it was low (1.6) in postmonsoon when the fish resource was abundant in the DSL.

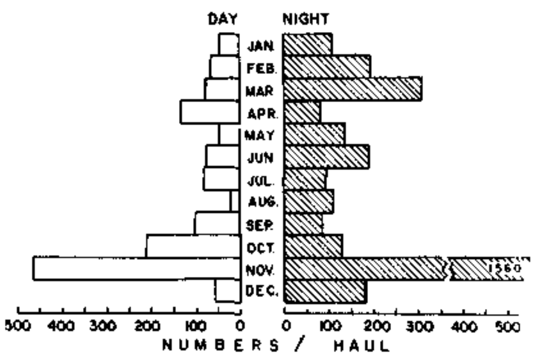

Fig. 4. Monthly average catch rates of DSL fishes in day and night IKMT hauls.

Bathymetric abundance

Depthwise analysis of fish catch from DSL showed that the resource was abundant in the slope during night hauls (340 nos./haul). In depth strata of less than 100 m the night haul yielded 181 nos./ haul (Fig. 5). The highest fish catch of 300 nos./haul

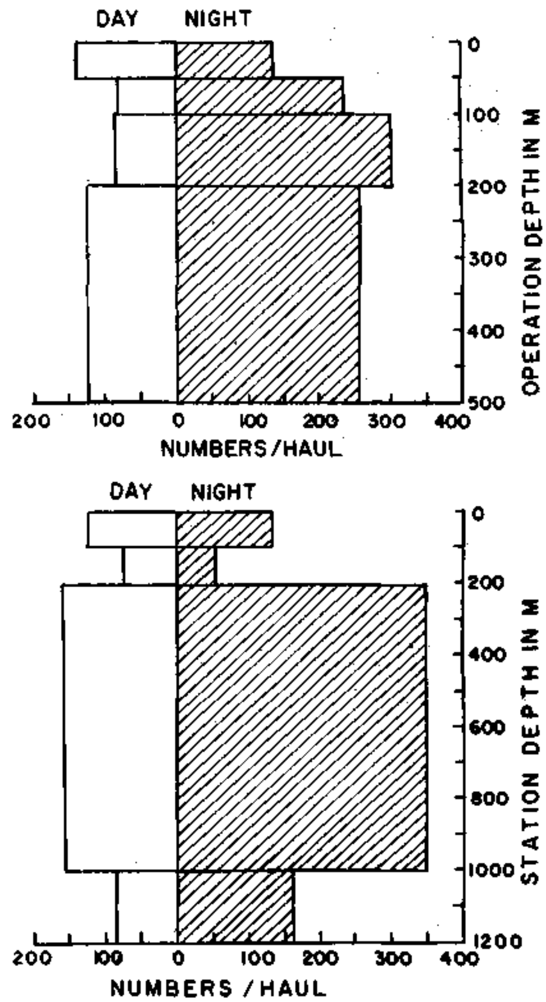

Fig. 5. Bathymetric abundance of DSL fishes.

was recorded from the depths of 100-200 m during night; whereas the catch was very low (132 nos./ haul) in the surface to 50 m. There was a clear indication that the vertical descend of fishes during night is at a slow pace. The surface (0-50 m) catches of day and night was almost of the same magnitude. In the intermediate depths (50-200 m), the night catches were far higher than the day catches. The deeper layers of the DSL (200-500 m) indicated

TABLE 2. *Seasonal catch rates of fishes and plankton in day and night DSL hauls and ratio of* N/D *fish catch rates*

Season	No. of fish/haul		Ratio N/D	No. of plankton/haul	
	Night	Day		Night	Day
Premonsoon	163	74	2.2	4174	972
Monsoon	117	45	2.6	1812	1928
Postmonsoon	194	125	11.6	2891	1445

TABLE 3. *Details of stratified sampling with IKMT in the area 09° 29.5 ' N to 10° 30' N latitude and 73° E to 75°3' E longitude during April, 1 1985*

Position		Depth of Stn.	Haul I				Haul II				Haul III			
Lat. (N)	Long. (E)		Time of operation	Depth of operation	Biomass/ haul (ml)	No.of fish/ haul	Time of operation	Depth of operation	Biomass/ haul (ml)	No.of fish/ haul	Time of operation	Depth of operation	Biomass haul (ml)	No.of fish/ haul
10°29.6'	75°29.5'	1125	N	18	30	208	N	35	100	345	N	50	200	-
10°29.3'	74°14.8'	2321	N	51	70	153	D	370	150	55	D	423	251	153
10°30'	73°00'	1730	N	27	570	24	N	115	100	46	N	390	1230	397
09°30'	73°00'	1778	D	50	260	179	D	320	25	19	D	440	240	152
08°28'	74°01'	2607	D	50	220	233	D	280	200	330	D	400	120	472
09°30'	74°07'	2525	N	75	220	348	N	310	206	137	N	320	120	167
09°30'	74°00'	2560	D	45	100	118	D	295	120	57	D	340	100	85
09°38'	74°20'	2671	N	44	60	25	N	120	60	85	N	410	-	-
09°30'	75°00'	2689	-	-	-	-	D	370	580	417	D	440	420	343

proportionately better catch rate during day. These diel differences in the catches are obvious in the mid- depths. The data indicated that the night ascend of fishes is at a slower pace than the day descend.

Stratified sampling results of IKMT

Samples collected from various layers of DSL by IKMT in the area 09°30'N to 10°30'N latitude and 73°00'E to 75°30'E longitude during day and night in April, 1985 (Table 3) showed that in the upper layer (18-75 m) of DSL the average day haul yield (177 nos. /haul) was higher than the average night catch rate (152 nos./haul). Similarly in the intermediate layer (115-370 m) the day hauls produced high catches (176 nos. /haul); whereas the night catch rate was distinctly low (89 nos. /haul). The opposite trend was apparent in the lower layer of the DSL with better average catch rate (282 nos./ haul) in night hauls than day (241 nos. / haul).

Discussion

Many earlier works on the vertical migrations of epipelagic and mesopelagic fishes occurring inthe DSL described larger catches of mesopelagic fishes in near-surface waters during night than during the day (Tucker, 1951 ; Aron, 1962; King and Iverson, 1962; Pearcy and Laurs, 1966). Some of them attributed this to visual avoidance of the gear during day. But the present data invariably show highest night catches with proportionately larger catch rates during the day in the surface and deeper water. In the mid layer the ratio of night /day fish catch was high. This may be due to different speeds of ascend in night and descend in day, the former being slower than the latter. However, the study will be conclusive only through a quantitative sampling in the entire vertical range of the animals, including the depths to which they migrate during day time with the help of opening and closing IKMT nets.

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OBSERVATIONS ON THE DISTRIBUTION OF LEPTOCEPHALI OF THE EEZ OF INDIA

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Abstract

Isaacs-Kidd Midwater Trawl samples form the Deep Scattering Layers (DSL) collected during FORV *Sagar Sampada* cruises 1-20 were analysed. A total of 6,000 leptocephali of various size classes were sorted out form 255 samples. The spatial distribution of leptocephali based on these observations showed that species compositon as well as abundance were maximum on the west coast, between Goa and Cochin, beyond 1000 metres line. The distribution of larvae coincided very well with the depth of DSL and no regular seasonality was noticed. The total length of the leptocephali varied from 2 to 70 cm for different stages of metamorphosis. Leptocephali belonging to six families of the order of Anguilliformes namely Synaphobranchidae, Netastomatidae, Ophichthidae, Muraenidae, Nemichthyidae and Congridae were identified of which the family Congridae was represented by maximum number of larvae. An interesting type of leptocephalus of the family Congridae, Ariosoma type with outer intestine occurred at 37 stations. The leptocephali of the order Elopiformes were also recorded from few stations of the west coast.

Introduction

Among eels, the commercially important family Anguillidae has attracted the attention of fishery biologists in India and studies were made mainly to estimate their production and distribution in the marine and brackishwater environments. Very few workers have focussed their attention to study the systematics of the leptocephalus larvae collected from the plankton samples of the nearshore waters from the west and east coasts of India. Gopinath (1950) summarised the earlier studies on the leptocephali of the Indo-Pacific region and attempted to describe a few leptocephali from Trivandrum coast.

Much work have been published on the anguillid leptocephali of the temperate and subtropical regions. Several cruises were conducted to locate the breeding grounds of the American and European eels in relation to water masses and other oceanographic features. (Kleckner and McCleave, 1985; McCleave and Klecker, 1987; Castonguay and McCleave, 1987). Karmovskaya (1986) worked out in detail the identification of the leptocephali of Anguilliformes based on the collection from the world oceans. No such studies have been carried out along the seas of Indian subcontinent.

Eventhough eel is considered as a food fish in India, the exploitation of this fish is limited as indicated in the catch data during 1982-'85 (Anon., 1986). Hence it is of utmost necessity to evaluate availability of the larvae of eels in the seas around India and their metamorphosis in order to estimate the resource potential.

The leptocephali of Anguilliformes formed one of the most important groups among the zooplankton collected from the mesopelagic zone during the cruises conducted by *Sagar Sampada*. The present study is aimed to bring out the availability and distribution of the leptocephali in space and time in the EEZ of India.

Material and Methods

Samples for this study were obtained during the cruises (No. 1-20) of FORV *Sagar Sampada*, using Isaacs- Kidd Midwater Trawl. The samples of leptocephali were sorted out and preserved in 10% formalcdhyde solution. The sampling operations were mainly carried out during day and night from the Deep Scattering Layer. For each operation the net was towed at limited speed of 3 knots for 30 minutes. The stations covered fell between 00°00' and 23°00'N and 65°00' and 95°00'E, The leptocephali were measured and counted under binocular microscope following the methods adopted by Jespersen (1942) and identified as per descriptions by Smith (1979).

Results

It was observed that the leptocephali formed one of the major groups in the total biomass collected from the mesopelagic zone almost in all the samples and particularly from the Arabian Sea. Leptocephali were recorded from the pelagic trawl catch from both the coasts and waters around Andaman and Lakshadweep islands. With regard to the depth distribution, the leptocephali were more abundant along the 1000 m depth zone whereas its abundance was at its minimum along the 200 m depth zone along the coasts. The biomass of leptocephali collected from the Arabian Sea off 1000 m depth zone was found to be maximum at all times and distributed from off Veraval to Trivandrum and around Lakshaweep and Maldives. Along the Bay of Bengal the larvae were distributed north of Gulf of Mannar and south of Paradip and they were also collected from the equatorial waters.

During the cruises 1- 20 a total of 719 stations were sampled and 255 stations recorded the presence of leptocephali (Fig. 1). The abundance of the larvae coincided with the night samplings from both the coasts. Leptocephali belonging to six families of the order Anguilliformes were identified, viz. Congridae, Synaphobranchidae, Netastomattidae, Ophichthyidae, Muraenidae and Nemichthyidae. The leptocephali of the order Elopiformes were also collected from two stations.

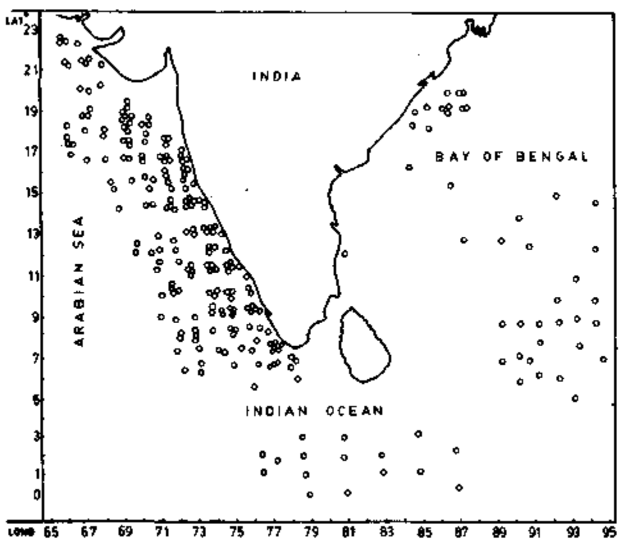

Fig 1. Distribution of Leptocephali in the EEZ of India.

The larvae of the family Congridae was the most dominant among others. The total length of the leptocephali ranged from 2 to 70 cm of different stages of metamorphosis.

Among Congridae the Ariosoma type larva with an outer intestine was found to occur at 37 stations. The total length of the larvae varied from 5 cm to 17. 8 cm. Based on the length of the outer intestine, the number of myomeres and melanophores, this larva can be grouped into different types (Mochioka *et al*., 1982). However, similar type of larvae have not been described by earlier workers from Indian waters. The distribution and abundance of exterillum type larva in the present observation is given in Fig. 2. It was found that the biomass of this type was high around Lakshadweep islands in particular and in the Arabian sea in general. Ariosoma type larvae were also recorded from four stations in the equatorial region and between south of Madras and Paradip along the east coast. There is no regular seasonality in the occurrence of this particular larvae and were collected throughout the year. The numerical abundance of the larvae was recorded during postmonsoon and premonsoon periods.

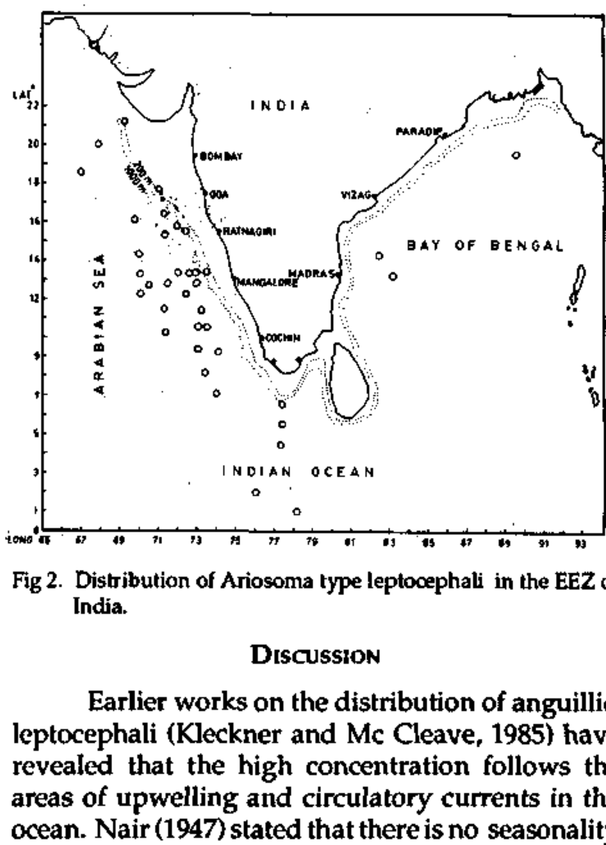

Fig 2. Distribution of Ariosoma type leptocephali in the EEZ of India.

Discussion

Earlier works on the distribution of anguillid leptocephali (Kleckner and Mc Cleave, 1985) have revealed that the high concentration follows the areas of upwelling and circulatory currents in the ocean. Nair (1947) stated that there is no seasonality in the occurrence of leptocephali and the eels in the tropics breed throughout the year. Seasonal variation in the abundance of ichthyoplankton in the Arabian Sea (Peter, 1973) was observed maximum during southwest monsoon in areas of upwelling and places under the influence of divergence. The present study on the occurrence of leptocephali showed maximum during postmonsoon and premonsoon periods eventhough regular seasonality was not observed in seas around India. However, extensive analysis of the data is inevitable. The present observation on the occurrence and distribution of leptocephali indicated that maximum number of larvae as well as positive stations were located in the Arabian Sea where high salinity water masses (Sen Gupta *et al.*, 1976) existed. Kleckner and Mc Cleave (1985) observed a positive correlation between the distribution of American eel spawning, and the shallow, warm, high salinity watermass of the subtropical underwater. It is obvious in the present study that the distribution of leptocephali in Bay of Bengal and the equatorial waters were less when compared to Arabian Sea. It is observed based on the IKMT Samples that high Salinity and temperature of the midwater in addition to depth form the major factors associated with the distribution of the larva.

The continuous distribution of the Ariosoma type larvae in the Arabian Sea, around Lakshadweep Islands may probably be due to high salinity and temperature in addition to high surface productivity. Nair *et al*., (1986) who detailed the environment around Lakshadweep have pointed out that the eddy-like circulatory motion of the waters helps to keep the fish eggs and larvae within the productive waters in the vicinity of the islands for a considerable length of time. The environment around Lakshadweep with the coral reefs are found suitable habitat for the eels to grow and breed as indicated in the present study. It seems possible that most species breed in the open sea as stated by Nair (1947) since the leptocephali were found in abundance at stations off 200 m depth zone on the west and east coasts of India. Without having adequate data of the pelagic trawl catch during the peirod of study and relating the major oceanographic parameters it is impossible to locate the breeding grounds in the Indian seas.

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DISTRIBUTION AND ABUNDANCE OF LANTERNFISHES OF THE FAMILY MYCTOPHIDAE IN THE EEZ OF INDIA

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ABSTRACT

Distribution and abundance of laternfishes of the family Myctophidae collected from the eastern Arabian Sea and the Bay of Bengal during cruises 1-15 of FORV *Sagar Sampada* are presented. This investigation is based on the IKMT samples from the DSL which was found in the depth ranges 200-540m during day and 0-75m during night. In the total biomass of the DSL, fish formed only 6% and the rest was constituted by the plankton. The fish fauna of the DSL comprised of meso and bathypelagic forms like myctophids, gonostomids and stomiformes. Among the myctophids the common generawere *Diaphus, Lampanyctus, Diogenichthys, Hygophum, Symbolophorus, Bolinichthys, Benthosema* and *Myctophum*. The myctophids comprised about 31% of the total fish biomass of the DSL. Off the west coast myctophids formed about 82% while off the east coast they formed only 17%. The abundance of myctophids varied in waters north and south of 15°N in both the seas. However, this difference was more pronounced off the east coast with the myctophids comprising about 64% off the southeast and 35% off the northeast coasts. There were differences in the numerical abundance of the myctophids in the day and night catches in both the seas, the night catches being more than day catches. While about 88% of the myctophids were caught at night, only 11.2% formed the day catch. Maximum density of myctophids was recorded in the depth ranges 200-500m during day and 20-90m during night in both the seas. There was no pronounced seasonal variation in the abundance except for April and October when maximum quantities were caught.

INTRODCUTION

Lanternfishes are one of the dominant components of the oceanic ecosystems. They occur in most regions and are included in the fauna of the sound scattering layers of the seas (Bekker, 1967). They have been collected predominantly in the open oceanic waters and are also found on continental and island shelves.

Although abundant and widespread, myctophids are only now beginning to draw attention as a potential source of animal protein. They are reported to contian fairly high quantities of wax esters and results of biochemical experiments in Soviet Union do not preculde the use of southern hemisphere myctophid *Gymnoscopelus nicholsi* for human consumption. These fishes are capable of crossing density gradients such as thermocline and halocline both of which normally inhibit mixing by physical processes. By migrating vertically into surface waters, they provide forage for commercial fishes (Moser and Ahlstrom, 1970). They serve as a vital link between zooplankton community and larger predatory fishes.

Taxonomy and distribution of myctophids from the Arabian Sea has been studied by Nafpaktitis and Nafpaktitis (1969) and by Kotthaus (1972) but their life history, ecology and abundance are largely unknown. Legand (1967) studied the ecology of mesopelagic fauna in the eastern Indian Ocean. Studies on the myctophid fish fauna of the western and northern Arabian Sea were carried out by R/V *Dr. Fridtjof Nansen* during the years 1975 - '76. The studies on the myctophid larvae of the Indian Ocean are limited to the works of Becker (1964), Pertseva - Ostroumuva (1964), Ahlstrom (1968), Valsa (1979) and Peter (1982).

MATERIAL AND METHODS

The material for this study was obtained from the preserved IKMT collections of FORV *Sagar Sampada* cruises made during January, 1985 to May, 1986. A total of 563 stations were covered during 15 cruises out of which IKMT was operated in 364 stations. The area covered ranged from 7°00'N to 23°30'N latitudes and longitudes 77°30'E to 85°E in the Arabian Sea and latitudes 6°00'N to 19°N and longitude 80°38'E to 95°E in Bay of Bengal. Horizontal hauls were made at depths ranging from 20-500 m. These operations were based on the level of DSL. There were 171 night stations and 195 day stations respectively.

Resutls

The resutls of this investigation provide a preliminary knowledge on the geographic variation, seasonal and depth-wise distribution and day and night variations in both the seas. In the total biomass of the DSL, fish formed only 6% and the rest was constituted by the plankton. The myctophids comprised about 31% of the total fish biomass of the DSL.

Geographic variations

Figure 1. shows the general distribution of myctophids in both the seas, the abundance being represented in terms of numbers/half hour haul. In the eastern Arabian Sea, the myctophids formed about 72% showing a wide distribution covering major parts of the nearshore, offshore and oceanic regions. The abundance of myctophids varied in waters north and south of 15°N latitude. Off northwest coast myctophids formed about 53.4% while off southwest coast they were about 46%. Off northwest coast, dominance was noticed in certain pockets along the Ratnagiri - Marmagoa areas (15° - 17°N), off Bombay (19 °- 20°N) and in the northern Arabian waters (23°30'N). Peak abundance of myctophids was in waters along 69°30'E longitude between 18°30'N and 21°30'N latitudes and in the waters north of 15°N between 68° and 73°E longitudes. Highest number of 546 myctophids /half hour haul was recorded from a station (23°30'N 65° 00'E) off northern Arabian coast.

Off the southwest coast, the density maximum pockets were centered along the shelf-slope waters near Mangalore and off Cochin areas. Highest number of 774 myctophids / half hour haul was recorded from a station (9°30'N 74°00'E) off Cochin.

Contribution of myctophids in the Bay of Bengal was 17%. Off the northeast coast, myctophids contributed about 35% while off the southeast coast they formed about 64%. Dominance was noticed in the Bay of Bengal fan area 15°00' - 19° 00'N 85°00'E -90°30'E). Highest number of 198 myctophids/ half hour haul was recorded from a station (19°00'N 91°30'E) off West Bengal.

Off the southeast coast, maximum abundance was found in areas off Madras and in the oceanic areas south of Nicobar Islands.

Diurnal variations

There were differences in the numercial abundance of myctophids in the day and night catches in both the seas (Figs. 2 and 3). Off west coast, about 93% was caught during the night. Similar trends in the day and night catches were found in Bay of Bengal with night catches contributing about 88% and day, only 11.2%.

Seasonal variation

A regular pattern of seasonal variation (Fig. 5) could not be obtained due to insufficient data but some trends are apparent. However, the catches were usually largest during April-May and October- November. The peak catches recorded were 1,000- 1,100/half hour haul.

Discussion

In both the seas, abundance of myctophids varied in waters north and south of 15°N latitude. Density maximum pockets were found to be centered along Ratnagiri - Marmagoa, off Bombay and off northern Arabian coast in the northwest coast, off Cochin and along slope waters near Mangalore in the southwest coast. Density peaks were also observed in the Bay of Bengal fan area, in areas off Madras and in oceanic areas south of Nicobar Islands. Analysis of the catch composition of the fish larvae collected from the Arabian Sea and the Bay of Bengal by Peter (1982) has revealed a similar distribution pattern of myctophid larvae and it was found that estimate of larvae in both the seas came to 25.3% of the total larval collections from the area. Highest number of 546 myctophids/haul was recorded from a station (23°30'N 65°00'E) off northern Arabian coast. Similar findings were obtained by Gjøsaeter, (1975) during the survey of western and northern Arabian Sea by R/V *Dr. Fridtjof Nansen*. The catch rate recorded was 20,000 kg/hr with pelagic trawl.

Differences between day and night catches clearly exist; night catches averaging 2-3 times more than day catches. These findings are consistent with the results of several other workers. Aron (1962) found that regardless of depth, night hauls caught a substantially greater biomass than day hauls. The cause of this difference is uncertain but it is most likely that during day fishes migrate to depths beyond the range of the net. Other possible causes might include better escapement and greater scatter during day. Similar observations were made by Pearcy (1965) in the distribution of mesopelagic fishes off Oregon.

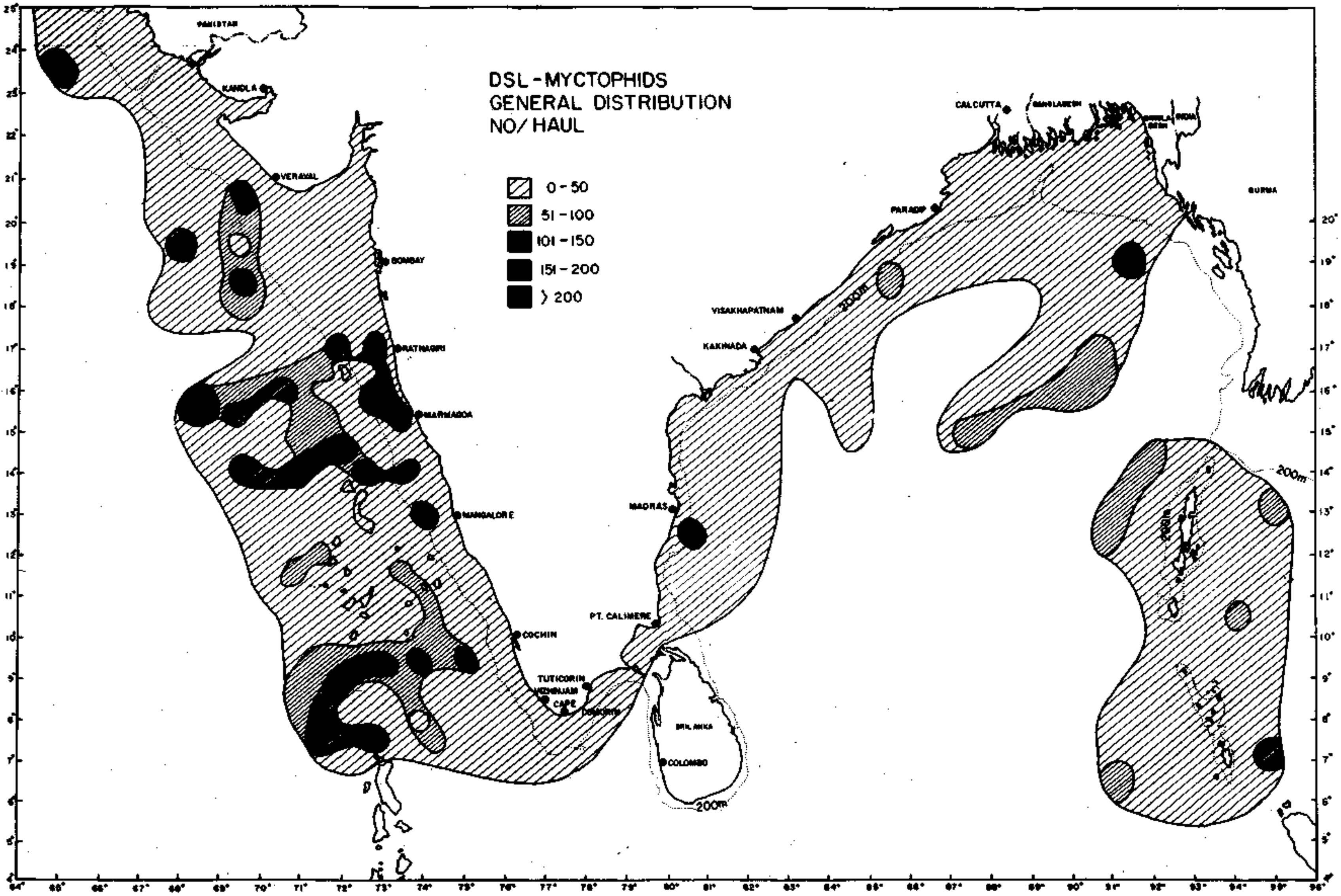

Fig. 1. General distribution of myctophids in the eastern Arabian Sean and the Bay of Bengal.

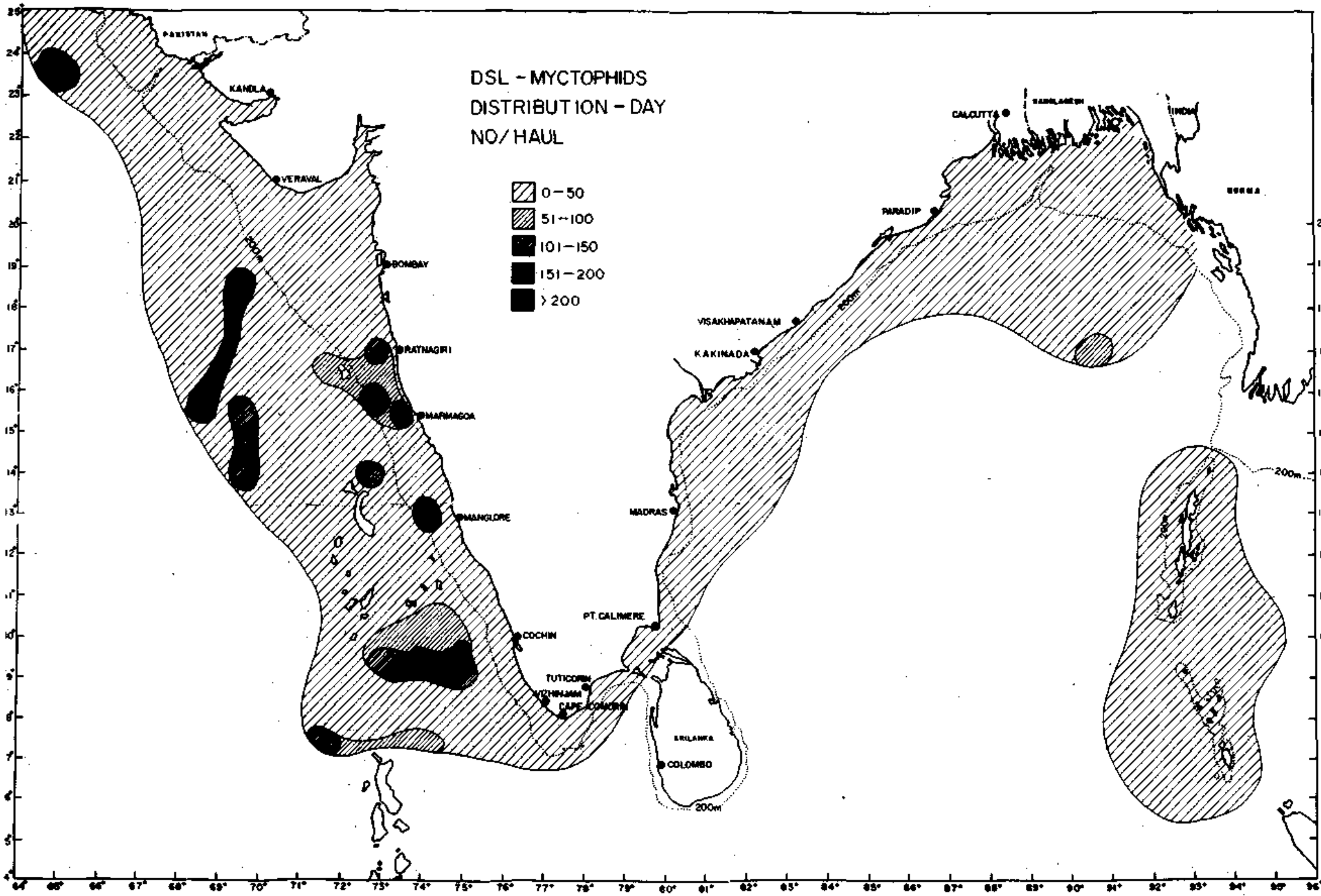

Fig. 2. Distribution of myctophids during day.

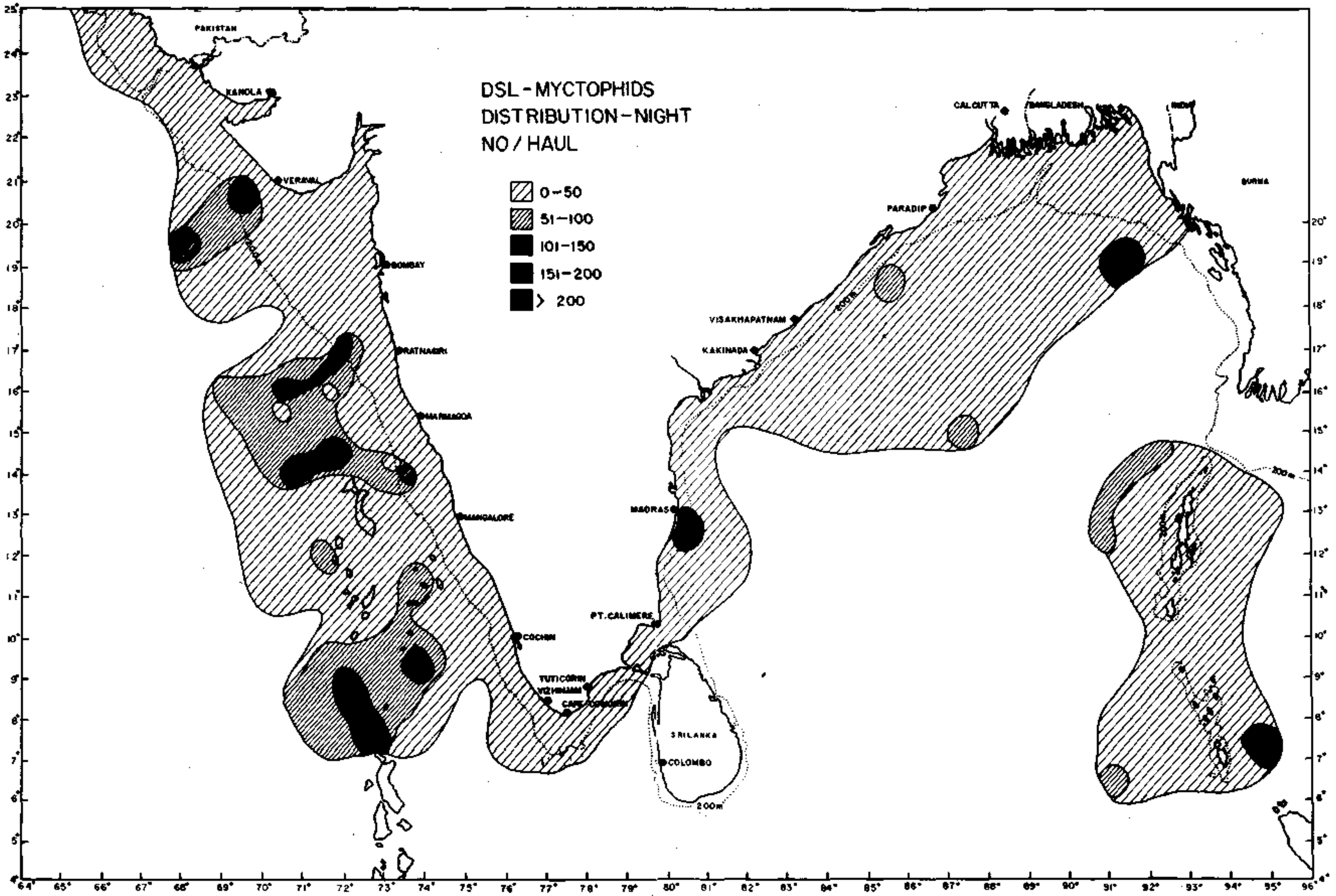

Fig. 3. Distribution of myctophids during night.

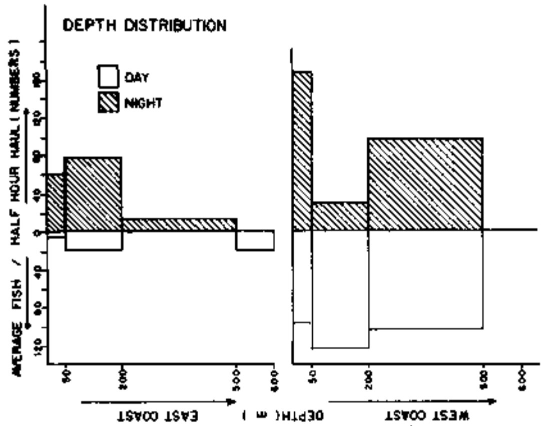

Fig. 4. Depth-wise distribution of myctophids.

Variations in the depth distribution reveal that maximum density was recorded in the depth ranges 200-500m during day and in surface waters 0-100m during night. An interesting observation was the occurrence of myctophids in large numbers in the shallow waters (50 - 60m) during day time. Alverson (1961) recorded similar observation on the day light surface occurrence of myctophid schools off the coast of central America. Skipkjack, yellow fin tuna schools and sea birds were found to forage on the myctophid schools during day.

Seasonal differences in the distribution pattern is not clearly evident due to non - availability of the data. However, catches were usually large during April-May and October-November, 1985. Pearcy (1965) has observed that catches of myctophids were higher during summer and are not related to depth or diel period.

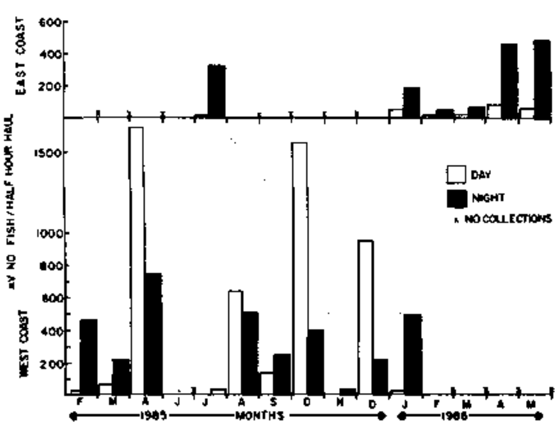

Fig. 5. Seasonal distribution of myctophids.

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VARIATION IN FISH CATCHES FROM THE CONTINENTAL SHELF BETWEEN QUILON AND GULF OF MANNAR AND ITS RELATION TO OCEANOGRAPHIC CONDITIONS DURING THE SOUTHWEST MONSOON PERIOD

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Abstract

The present paper is based on the fishing results of FORV *Sagar Sampada* during July-August, 1987 along the southwest coast of India. The fish fauna of the Quilon Bank and Wadge Bank has a dominant nemipterid element and the Gulf of Mannar area has a dominant population of barracudas. Nemipterids constituted 88.2 and 64.4% of the total trawl catch from the Quilon Bank and Wadge Bank respectively. Barracudas formed 58% of the total catch from the Gulf of Mannar. A comparison of the overall catch rates for the above three areas revealed that it was highest in the Gulf of Mannar (1,007 kg/hr) followed by Quilon Bank (555 kg/hr) and Wadge Bank (170 kg/hr). For nemipterids the maximum catch rate of 488 kg/hr was obtained from the Quilon Bank and 108 kg/hr from the Wadge Bank, whereas for barracudas it was 583 kg/hr from the Gulf of Mannar.

There is tremendous contrast among the three regions with respect to oceanographic conditions of the waters. Both temperature and salinity of the Quilon Bank waters are lower. The Wadge Bank waters are moderate in their temperature but high in salinity. The Gulf of Mannar waters are moderate with respect to salinity but warmer with regard to temperature and it differs much from the rest of the areas with respect to dynamic qualities. These waters showed thermal inversions in the middle region of the water column.

The bottom water temperature rather than salinity appears to be the probable reason for the species variations in the trawl catches of the region. Nemipterids were not present in the Gulf of Mannar waters, where the bottom temperature was high and barracudas were not present in the Wadge Bank and Quilon Bank, where the bottom waters were cool. Nemipterids constitute a good monsoon fishery off Cochin, where the upwelling cools the bottom waters and also reduces dissolved oxygen. Probably the good concentration of nemipterids in the Quilon Bank and Wadge Bank areas are due to the extended effect of upwelling towards the south down to Wadge Bank, as the drift currents which are southerly are favourable to cause this effect.

Introduction

The existence of good fishing grounds in the Wadge Bank and Pedro Bank areas are traditionally known to the fishermen of Kerala, Tamil Nadu and Sri Lanka. Exploratory surveys have indicated potentially rich fishing grounds off Quilon (Quilon Bank) for deep sea prawns and deep sea lobsters beyond the continental shelf edge.

The Quilon Bank and Wadge Bank attract the interest of fisheries scientists. Investigations on oceanography, primary and secondary production and fisheries were already carried out in the waters off the peninsular region of India. But they were all subject oriented, mainly limited to one or two aspects. The studies on the effect and influence of oceanographic parameters on the distribution and abundance of fish groups of southwest coast of India are comparatively little, but the work of Murty and Edelman (1971), Pillai (1982) and Rao *et al* . (1973) are worth mentioning. An attempt is made in this paper to bring out the reasons for the existence of demersal fisheries in relation to environmental conditions.

Material and Methods

The area between Quilon and Gulf of Mannar (07° to 9°N and 75°28' to 78°43'E), in transects more or less parallel to latitudes, was surveyed during July-August, 1987 by FORV *Sagar Sampada*. Altogether 18 stations were covered. Temperature in the water column from surface to 70 m depth from discrete levels was observed by an instant reading T-S Probe (T.S.K. Japan, accuracy T= ± .2°C, S= ± .1 ‰). Bottom trawling was conducted by employing the demersal HSDT-1 trawl designed and fabricated by CIFT, Cochin. The length of the foot rope was 44.7 m and the cod end mesh size was 40 mm. The

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fishery data were analysed and discussed in the light of the oceanographic conditions of the region under investigation.

Results and Discussions

T-S diagram for the three different areas, namely Quilon Bank, Wadge Bank and Gulf of Mannar are prepared and shown in Fig. 1. There was a tremendous contrast among the three regions with respect to oceanographic conditions of the waters. As far as the salinity is concerned, the Quilon Bank waters are much diluted with the lowest salinity having a surface value of about 34 ‰ with gradual increase with depth, reaching 34.6‰ at 70 m depth. The Wadge Bank waters are of highest salinity with a value of 36.0‰ at the surface and at the bottom with a slight increase at mid-depth (40 m) touching a value of 36.15‰. The Gulf of Mannar waters are very moderate in their salinity values ranging from 35.5 to 35.7‰.

The contrast of the three waters with respect to temperature conditions is interesting. At the Quilon Bank, while the surface waters are of moderate temperature (26°C), vertical cooling in the water column is so rapid that it reduced to 21.0° C at 70 m depth. The surface water temperature of the Wadge Bank was 27°C, while the bottom (70 m) temperature of the region was less than 24°C. In Gulf of Mannar, the surface water temperature was moderate, almost very close to that of the Quilon Bank. But there was thermal inversions in the mid-depth of 30-50 m, and at 50 m depth the temperature was 28.75°C. Barring one or two layers, the temperature range of the water layers of Gulf of Mannar was very narrow (26.0-27.5°C). Thus the Gulf of Mannar water mass differs from either Quilon Bank or Wadge Bank by attaining narrow ranges of temperature and salinity.

The lowered temperature conditions of sub-surface and bottom waters of Quilon Bank and Wadge Bank when compared to Gulf of Mannar waters can be interpreted in terms of differences of intensity and spread of upwelling.

Based on the dynamic depth variations during summer relative to winter, it was inferred that upwelling effect was reduced from about Cochin towards south upto Cape Comorin in the shelf and off shelf waters along the west coast of India (Lathipha and Murty, 1978). Pillai (1982) presented the average depth of 23°C isotherm during mon-

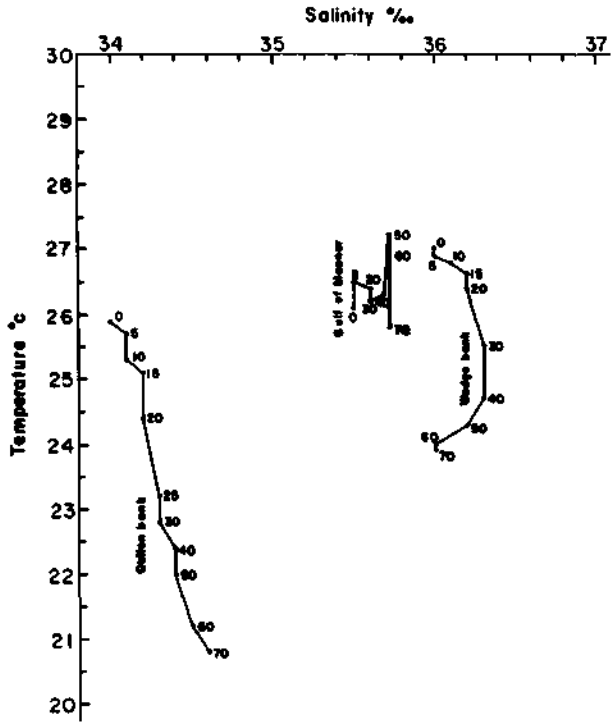

Fig. 1. Hydrographic conditions in the three fishing zones.

soon period from Cochin, Quilon and Cape Comorin for the years 1973 to 1978. The shallower the depth of the isotherm, the more would be the intensity of upwelling. Consistently the depth increased from Cochin to Cape Comorin through Quilon. The average depth of the 23°C isotherm for the above six years is 15, 20 and 40 m respectively for Cochin, Quilon and Cape Comorin.

Johannessen *et al.* (1987) observed from oxygen data for August, 1974 that the water having depleted oxygen retreated to the shelf edge and beyond, as we proceed southward from Cochin, Quilon and Cape Comorin, indicating the reduction in the area of spread of upwelling towards the coast in the south when compared to north.

The trawl catch composition from the three regions namely Quilon Bank, Wadge Bank and Gulf of Mannar during the cruise are presented in Tables 1& 2. The fish fauna of the Quilon Bank and Wadge Bank have a dominant population of barracudas. Nemipterids constituted 88.2 and 64.4% of the total trawl catch from the Quilon Bank and Wadge Bank respectively. Barracudas formed 58% of the total catch from the Gulf of Mannar (Fig. 3). A comparison of the overall catch rates for the above three areas revealed that it was highest in the Gulf of

TABLE 1. *Average group-wise catch (kg) and catch rate (in paranthesis) obtained in various regions surveyed*

Species/ groups	Quilon Bank	Wadge Bank	Gulf of Mannar
Sharks	Nil	16 (2)	167 (83.3)
Rays	13 (2.3)	20 (2.5)	67 (33.3)
Nemipterids	2,695 (488)	874 (108.2)	Nil
Barracudas	Nil	Nil	1,166 (583.3)
Perches	134 (24)	173 (21.7)	255 (127.5)
Lizard fish	16 (3)	24 (3)	Nil
Carangids	35 (6)	80 (10)	167 (83.3)
Penaeus indicus	42 (7)	21 (2.6)	8 (4)
Priacanthus sp.	28 (5)	12 (1.5)	Nil
Upeneus spp.	Nil	13 (1.7)	Nil
Squids & cuttle fish	42 (8)	14 (5.5)	45 (22.5)
Misc. fishes	52 (9)	79 (9.9)	138 (69)
Total	3,057 (555)	1,356 (169.5)	2,013 (1006.5)

TABLE 2. *Percentage composition of dominant group of fin fishes and shell fishes caught by bottom trawl from various regions*

Groups	Quilon Bank	Wadge Bank	Gulf of Mannar
Sharks & rays	Nil	Nil	11.6
Barracudas	Nil	Nil	57.9
Nemipterids	88.2	64.5	Nil
Perches	4.4	12.8	12.7
Squids & cuttle fishes	1.4	3.2	2.2
Carangids	1.2	5.9	8.3
Other fishes	4.8	13.6	7.3

Mannar (1,006.6 kg/hr) followed by Quilon Bank (555 kg/hr) and Wadge Bank (170 kg/hr). For nemipterids the maximum catch rate of 488 kg/hr was obtained from the Quilon Bank, whereas for barracudas it was 583 kg/hr from the Gulf of Mannar (Fig. 2).

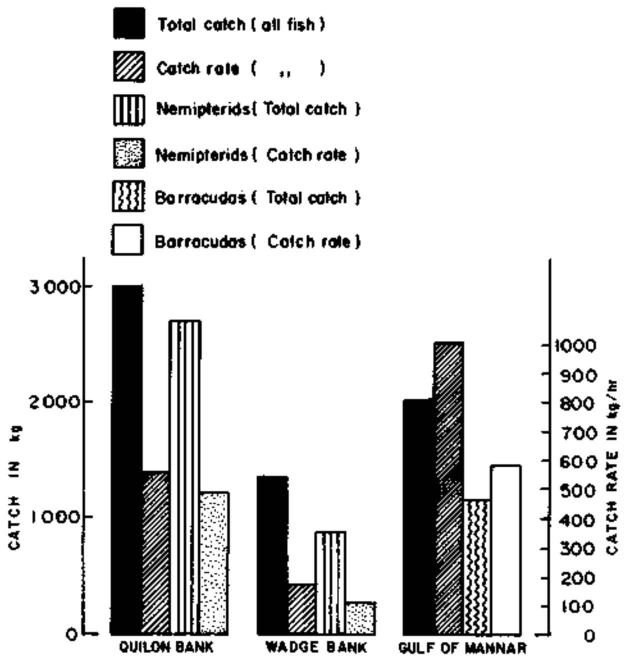

Fig. 2. Total catch and catch rate of all fish, nemipterids and barracudas obtained from three different fishing zones.

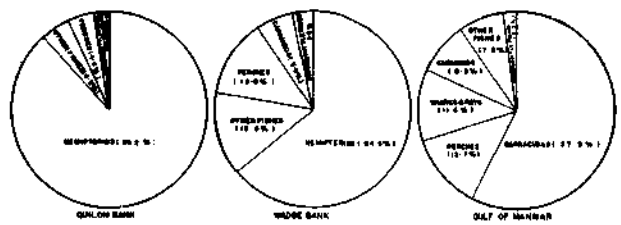

Fig. 3. Percentage composition of dominant groups of fishes landed from Quilon Bank, Wadge Bank and Gulf of Mannar.

The depth-wise catch rate obtained for nemipterids and barracudas from the three regions is given in Table 3. The pattern of distribution and abundance of nemipterid in relation to depth at both Quilon Bank and Wadge Bank regions were almost the same. The data revealed that the maximum catch rate at Quilon Bank (9,375 kg/hr) and Wadge Bank (2,327 kg/hr) was obtained from the depth zone of 60 to 80 m.

The commercial landings of nemipterids and barracudas during the southwest monsoon period

TABLE 3. *Depth-wise catch rate (kg/hr) obtained for nemipterids and barracudas*

Areas & groups	20-40m	40-60m	60-80m	80-100m
Quilon Bank				
Nemipterids	Nil	2,202	9,375	Nil
Wadge Bank				
Nemipterids	Nil	1,700	2,327	1,733
Gulf of Mannar				
Barracudas	4,666	Nil	Nil	Nil

cal conditions of these species are governed more by the subsurface and bottom water temperatures rather than salinities of the waters, nemipterids prefering the colder upwelled waters of Quilon-Wadge Bank region and barracudas prefering non-upwelled and turbulent Gulf of Mannar waters. It is interesting to note from Table 3 that nemipterids completely avoided the shallow waters upto 40 m from the coast, where the upwelling effect might not have reached from offshore waters. Barracudas confined themselves to shallow waters (less than 40 m depth) and completely absent in deeper waters beyond 40 m offshore.

TABLE 4. *The commercial landings (in kg) of nemipterids and barracudas at Cochin, Sakthikulangara and Tuticorin centres during the southwest monsoon period*

Landing centres	1985		1986		1987		1988	
	Nemip-terids	Barra-cudas	Nemip-terids	Barra-cudas	Nemip-terids	Barra-cudas	Nemip-terids	Barra-cudas
Cochin	854	7	5,606	-	3,178	12	2,941	154
Sakthikulangara	16,853	72	23,976	17	12,285	46	12,206	268
Tuticorin	321	50	-	-	-	-	-	-

at Cochin and Sakthikulangara on the west coast and at Tuticorin on the east coast during the years 1985 to '88 are presented in Table 4 (Anon., 1989). From the table it is understood that there is an encouraging catch of nemipterids from south of Cochin culminating at Sakthikulangara. But at Tuticorin both nemipterids and barracuda fisheries are almost negligible. Thus nemipterids constituted a good monsoon fishery off Cochin and especially off Sakthikulangara, where upwelling cools the bottom waters and also reduces dissolved oxygen. Probably, the good concentration of nemipterids in the Quilon Bank and Wadge Bank areas are due to the extended effect of upwelling towards south down to Wadge Bank, as the drift currents have perhaps lead to this effect. (During this season, the coastal currents are southerly).

From the view point of species contrast (barracudas verses nemipterids) and the characteristic difference of Gulf of Mannar waters verses the waters of Wadge Bank or Quilon Bank, the physiologi-

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ON THE RESULTS OF DEMERSAL TRAWLING CONDUCTED FROM FORV *SAGAR SAMPADA* IN THE EXCLUSIVE ECONOMIC ZONE (EEZ) OF INDIA - PERSONAL OBSERVATIONS

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Abstract

A critical review on the results of demersal trawling conducted during eleven cruises of FORV *Sagar Sampada* from 1985-'88 is presented. Fisheries resources survey and testing of various demersal trawls, both imported and CIFT developed, were conducted all along the Indian EEZ. Results showed some vast potential resources with high catch rates of 12, 109, 7, 5 t/hr and so on. Some unconventional deep sea demersal fish resources like *Psenes* spp., *Psenopsis* spp. and *Chlorophthalmus* spp. were obtained in substantial quantities besides other known resources like *Nemipterus* spp., *Priacanthus* spp., *Decapterus* spp. etc. Catch of some commercially important fishes like mackerel from non-traditional grounds and distribution of some species at divergent zones like the northwest coast and the north east coast are of great significance and offer scope for further investigations on the stock and distribution. Occurrence of large catches pose certain problems of handling onboard and preservation

Introduction

An overview of the eleven cruises of FORV *Sagar Sampada* covering almost the entire east and west coasts during a period of three years from 1985-'88 is presented. A critical analysis of occurrence and abundance of different species of deep sea demersal fishery resources was made and the results are presented in Table 1.

Results and Important Findings

Results showed vast potential resources with record catch rates of 12, 10, 9, 7, 5 tonnes/hr and so on. Some unconventional deep sea demersal fish resources viz., *Psenopsis* spp., *Chlorophthalmus* spp. and *Psenes* spp., besides other known resources like *Nemipterus* spp., *Priacanthus* spp. and *Decapterus* spp. were of great significance. Catch of commercially important species like mackerel, barracuda, perches, elasmobranchs etc. from non-traditional, divergent grounds and deeper zones of the sea was quite interesting. Distribution of some species like Bombay duck (*Harpodon nehereus*), 'Ghol' (*Pseudosciaena diacanthus* or *Protonibea diacanthus*), mackerel (*Rastrelliger kanagurta*), Razor edges (*Ilisha filigera, Pellona* spp.) and *Coilia* spp. at divergent zones like the northwest coast the and the northeast coast is of great significance and offer scope for further investigations on the origin and distribution of different fish stocks.

Comparatively better productive grounds were found in the Quilon Bank, Wadge Bank, Gulf of Mannar and the upper east coast followed by the northwest coast and the west coast central sector. All deep sea resources were caught in bulk quantities like 12, 10 and 9 t/hr from the Quilon Bank in the depth range of 300-350 m. Offshore resources like *Nemipterus* spp., *Sphyraena* spp., *Epinephelus* spp., *Lethrinus* spp., *Caranx* spp., *Priacanthus* spp. etc. were obtained from grounds with depths ranging from 60-100 m in the Wadge Bank, Gulf of Mannar, upper east coast, northwest coast and the central sector of the west coast. Mackerel obtained during 36/'87 cruise from 71 m, east off False Bay/southwest of Sand Heads in substantial quantity (4 t/hr) was of great significance. Similar observations were made by FSI also. Mackerel catches from south of Visakhapatnam and southeast of Chilka were recorded during 13/'86 cruise also.

Occurrence of bulk catches like 12, 10, 9 and 7 t/hr in demersal trawls pose certain problems onboard like lifting the catch onboard, sorting and disposal of catch over board.

Acknowledgements

The author expresses his thanks to Shri M.R. Nair, Director, CIFT, Cochin for permission to present this paper. Thanks are also due to Dr. P.S.B.R. James, Director, CMFRI, chief scientists, fishing

TABLE 1. *Particulars of cruises participated from FORV* Sagar Sampada *and important results obtained*

Cruise No.	Period of cruise	Area surveyed	Gear operated	Significant catch (CPUE) (t/hr)	Major composition
5/'85	15-7-1985 to 26-7-1985	East coast- southern sector, Wadge Bank and southwest coast 07° 00'N - 13° 00' N- east coast 07° 00' N - 10°00' N - west coast 75°30' E - 80° 44' E	(1) Star Trawl (2) GOV Chalute Trawl	Nil	Misc. fishes (unecoomic varieties)
13/'86	18-2-1986 to 20-3-1986	East coast- complete 10°30' N - 20°30' N 80°00' E - 88°30' E	(1) GOV Chalute Trawl	0.750 0.500 0.450	Sciaenids, 'Ghol', 'Karkara', Drift fish, Mackerel etc.
18/'86	7-7-1986 to 27-7-1986	West coast - central sector 13°00' N - 17°30' N 71°30' E - 74°00' E	(1) CIFT High Speed Demersal Trawl- I (2) CIFT HSDT-II	2.0 0.8 0.5	*Nemipterus*, 'Ghol', Ribbon fish, *Saurida* etc.
19/'86	30-7-1986 to 11-8-1986	Lakshadweep waters 08°30' N - 14°00' N 71°30' E - 74°30' E	No bottom trawl operation. Only pelagic trawling was conducted	Nil	Nil
21/'86	12-9-1986 to 27-9-1986	West coast - central sector 14°00' N - 18°30' N 69°30' E - 74°30' E	(1) CIFT HSDT - I	0.750 0.500 0.400	*Priacanthus*, Kalava, and other perches
33/'87	24-7-1987 to 10-8-1987	Quilon Bank, Wadge Bank and	(1) CIFT HSDT - I	10 6.6	*Nemipterus*,Barracuda, Kalava and other perches
		Gulf of Mannar 07°00' N - 09°00' N 75°28' E - 78°43' E	(2) CIFT HSDT - II	5.0 4.0 2.5 2.0 1.0	*Caranx* etc.
35/'87	8-9-1987 to 21-9-1987	East coast- central sector 14°30' N - 18°00' N 80° 18 E - 86°00' E	(1) CIFT HSDT - II	2.5 2.0	*Priacanthus*, Barracuda etc.
36/'87	29-9-1987 to 14-10-1987	East coast - northern sector 18°30' N - 20°50' E 84°23' E - 87°50' E	(1) CIFT HSDT - I	5.0 3.5 1.0	Mackerel, *Caranx*, sharks and skates, perches, 'Ghol', EeL, Silverbar, Razor edge etc.
38/'87	17-11-1987 to 2-12-1987	West coast - northern sector 17°00' N - 23°00' 66°00' E - 72°30' E	(1) GOV Chalute Trawl (2) Expo High Opening Trawl	2.0	*Nemipterus*, Ribbon fish etc.
40/'87	28-12-1987 to 30-12-1987	Off Cochin for demonstration purpose	(1) CIFT HSDT - III	Nil	Miscellaneous fishes
42/'88	5-2-1988 to 20-2-1988	West coast - southern sector - Quilon Bank	(1) CIFT HSDT _ III	12.0 10.0 9.3 3.0 2.0 1.0	*Psenopsis* spp., *Chlorophthalmus* spp., *Psenes* spp., *Trichiurus* spp., deep sea prawns, deep sea lobsters, deep sea sharks etc.

masters and fishing hands of the respective cruises for providing facilities and co-operation during the cruises, to the Department of Ocean Development for providing such a sophisticated fisheries research vessel and to the captains and shipping crew of the respective cruises for their co-operation

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BIOPRODUCTIVITY STUDIES IN THE SOUTHWEST COAST OF INDIA AND EQUATORIAL REGION

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ABSTRACT

This paper embodies the observations on the Isaacs- Kidd MidwaterTrawl collections made in the zone 0 3 ° S-11°N and 71°- 86°E. The depths in the area of study were recorded in the range 50 - 3,727 m. Significant variations in the occurrence and distribution of major zooplanktonic organisms and other pelagic fauna were noticed between stations. The percentage composition of planktonic organisms was comparatively high, being 49.6 in the stations covered south of the equatorial line. The average volume of plankton was high around Lakshadweep Islands, being 586 ml for a 30 minutes horizontal haul in the Deep Scattering Layer. Among the organisms, fish larvae and juvenile fishes, euphausiids and decapods, stomatopods (alima larvae of Squilla), copepods, caridian prawn *Pasiphus* sp. and pelagic squids were dominant in the collections of deep waters off southwest coast. *Bregmaceros mcClellandi* and decapods were common in the zone, 11°N and 73°-75°E. Similarly, the occurrence of Leptocephali was found in high percentage in the collections made at 08°00'N and 73° 35'E, off Ashtamudi estuary, revealing the spawning grounds of eels. In the Wadge Bank area, myctophids (*Diaphus* sp.) constituted 7% of the total collection. *Charybdis edwardsia* was found in swarms in deep waters off the southwest coast of India. The resource potentials of major pelagic organisms of commercial value from the less exploited deepsea waters have been studied and discussed.

INTRODUCTION

Considerable work has been done in India on the productivity studies of the coastal waters and several new concepts about the resources have been developed. Valuable data obtained from *Galathea* Exdpedition and cruise reports of R.V. *Varuna* , R.V. *Vityaz* and *Anton Brunn* have been pooled to compute the productivity of the comparatively highly fished inshore region within 50 m depth and rarely fished shelf region and deeper oceanic region (Nair *et al*., 1973). However, attempt has not been made to obtain intensive data to follow the organic matter through different trophic levels. The objective of marine resource studies is mostly to determine the factors influencing the harvest or fishing and to explore new grounds for profitable fishing. Subrahmanyan (1973) assessed the magnitude of production in the Indian coastal waters and reviewed the studies onthe vertical distribution of the biomass of zooplankton at different depths. In the present account, the data collected by participating in the cruises of the Fisheries Oceanographic research Vessel *Sagar Sampada* on secondary production in relation to Deep Scattering Layer are analysed to assess the resource potentials of the less known deep sea waters.

MATERIAL AND METHODS

A survey of young fish and bathy and mesopelagic fauna of the southeastern Arabian Sea, including the Wadge Bank and the Lakshadweep and bioproductivity studies in the equatorial region of Indian Ocean were made by participating in the cruises 6 and 12 of FORV *Sagar Sampada* during the period 31-7-'85 to 13-8-'85 and 21-1-'86 to 18-2-'86. Twenty seven stations in the zone 05° - 11°N and 71°43'- 77°31'E and 41 stations on either side of the Equator extending between 03°N and 03°S and 76° and 86°E were fixed (Fig. 1) and the plankton samples were collected by employing Isaacs-Kidd Midwater Trawl. Trawling time of this net was maintained at 30 minutes. Hauling was horizontal and time for completing the operation varied from 5 to 10 minutes according to the depth of the DSL. The depths in the area of study were recorded in the range of 50 - 3,727 m. The position of the Deep Scattering Layer varied between 20 and 400 m in these grounds and most of the samples were obtained during day time and that too from depths below 100 m. The volume of the samples was taken by displacement method and the samples were preserved in 5% formalin. The percentage composition of various organisms was recorded and the specimens

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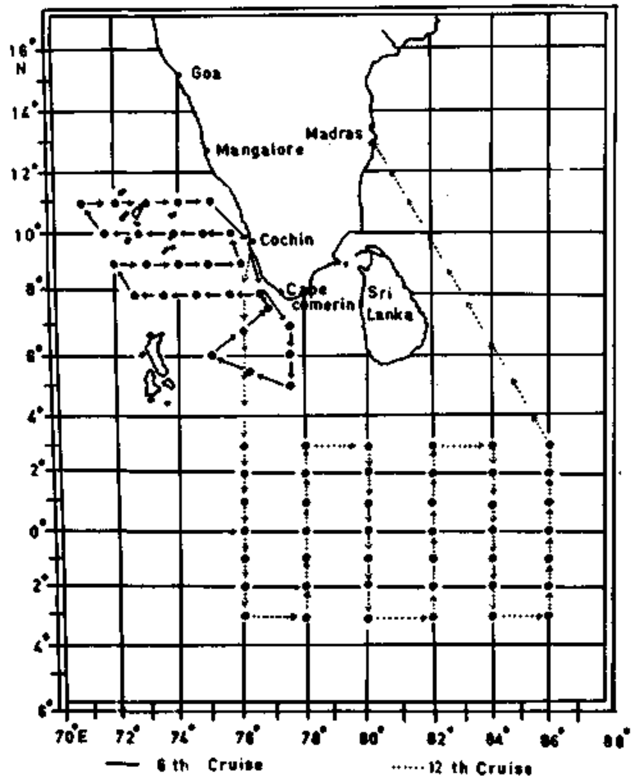

Fig. 1. IKMT collections were made at differnt stations during the 6th and 12 th cruises of FORV Sagar Sampada.

were identified upto genera or species levels wherever possible. Area-wise and depth-wise occurrence and distribution of different group of fishes and plankters were recorded.

Biomass Production

Riley (1944, 1950) and Clarke (1946) have accounted the total organic production for various waters and for the hydrosphere as a whole. Subrahmanyan (1959a, b) evaluated the production rate for the tropical environment and suggested for an increase in exploitation or harvest by 3 to 10 times the then level. Positive correlation between plankton crop and fisheries, as well as identification of indicative organisms have been made in temperate and Arctic regions, whereas little has been contributed in tropical waters, particularly around India due to paucity of investigations in deeper waters.

The biomass recorded at different depths of the Deep Scattering Layer are presented in Fig. 2. It may be seen that the average volume of the standing crop of zooplankton was rich in euphotic layers of 20-50 m depth accounting to 32.5% in the total. The average volume was 138 ml at 250 m and accounted

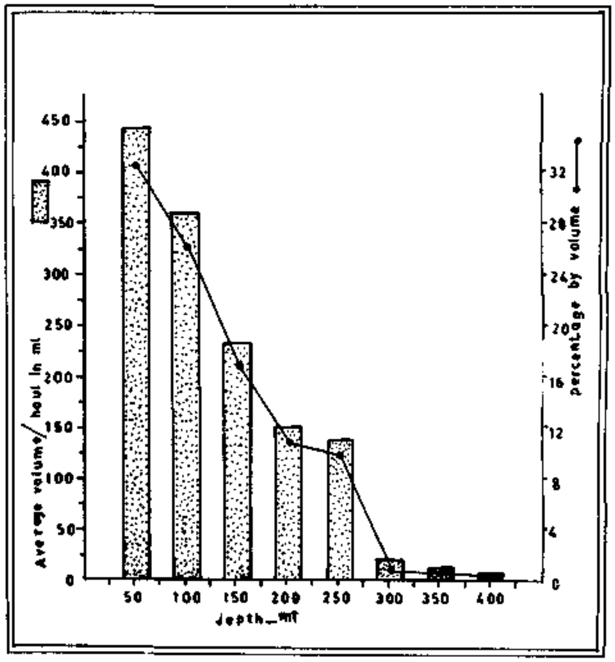

Fig. 2. The distribution of biomass recorded at different dapths of the deep scattering layer.

to 10.2% in the total. It is significant to note that the biomass production decreased as the depth of the DSL increased. The percentage contribution of standing crop was observed to be the lowest at the depth of 400 m being 0.4 (average 6 ml).

Subrahmanyan (1960) and Bogorov and Vinogradov (1961) observed rich standing crop inthe Arabian Sea and have attributed the cause to the upwelling or water mass circulation in the Arabian Sea during southwest monsoon. The present study also confirmed this observation as seen in Table 1. The distribution of major organisms in different zones revealed distinct variations both in number and volume. The standing crop was high inthe Lakshadweep Sea during July-August, and the average volume of collection was 586 ml, of which the plankton contributed 48.4% and micronekton 14.5%. Crabs, *Charybdis edwardsia* were found in high percentage (35.6%) in this ground. This species was dominating in the catches (58%) made inthe Wadge Bank area. The average volume of standing crop in the Wadge Bank was recorded as 414 ml. Plankton was next in importance (27%).

The standing crop of the equatorial region was comparatively less and the average volume varied from 138-148 ml. The percentage composi-

TABLE 1. *Biomass of the major organisms in different zones*

Area	No. of stations	Plankton (ml)	Young fishes (ml)	Prawn (ml)	Crab (ml)	Total organisms (ml)
Wadge Bank (05° - 09° N and 72° - 77° 31' E)	17	1,909.1	911.2	137.7	4,080.0	7,038.0
Average		112.3	53.6	8.1	240.0	414.0
Percentage		27.1	12.9	2.0	58.0	
Lakshawdeep Sea (10° - 11° N and 71° 43' - 75° 45' E)	10	2,837.0	848.0	88.0	2,091.0	5,864.0
Average		283.7	84.8	8.8	209.1	586.4
Percentage		48.4	14.5	1.5	35.6	
North of Equator (01° - 03° N and 76° - 86° E)	14	835.8	719.6	379.4	-	1,934.8
Average		59.7	51.4	27.1	-	138.2
Percentage		43.2	37.2	19.2	-	
Equator (00° and 76° - 86° E)	6	395.4	408.6	85.6	-	889.6
Average		65.9	68.1	14.3	-	148.2
Percentage		44.4	46.0	9.6	-	
South of Equator (01° - 03° S and 76° - 86° E)	21	850.5	1,476.3	751.8	-	3,078.6
Average		40.5	70.3	35.8	-	146.6
Percentage		27.6	48.0	24.4	-	

tion of plankton and young fishes was more or less equal (around 40%) but the occurrence of deep sea prawns was recorded at 19-24% on either sides of the Equator, whereas in upper latitude this was recorded in negligible percentages. It is interesting to note that the deep sea crabs recorded in high percentages in the Wadge Bank and the Lakshadweep (05° - 11°N and 71° - 77°E) was completely missing in the equatorial region (03°N - 03°S and 76° - 86°E).

OBSERVATIONS ON THE STANDING CROP

Information on the standing crop of zooplankton is available mostly for the nearshore region on the west coast of India. The Indian Ocean Biological Centre (IOBC), Cochin published the plankton atlas for the Arabian Sea. The richness of the standing crop has been noticed during southwest monsoon season along the Somali coast, Arabian coast and southwest coast of India upto Mangalore, between 0°-25°N and 45°-80°E (Prasad, 1966; 1968 a, b; Ponomareva and Naumov, 1962 and Wooster *et al.*, 1967).

Subrahmanyan and Sharma (1960) observed the bulk of standing crop on the west coast to contain a few species, unlike the composition noticed in the east coast, where a multiple species predominate the collection. A similar picture is reflected in the present study also (Table 2). The common zooplankters, young fishes, prawns, cephalopods and crabs observed in the collections have been tabulated and a distinct variation in oc-

TABLE. 2. *The numerical abundance of different organisms collected by Isaacs - Kidd Midwater Trawl*

Area covered	Wadge Bank 05°-09° N and 72°-77° 31' E	Lakshawdeep Sea 10°-11° N and 71° 43' - 75° 45' E	North of Equator 01°-03° N and 76° - 86° E	Equator 00° and 76° - 86° E	South of Equator 01°-03° S and 76° - 86° E
No. of stations :	17	10	14	6	21
Organisms	Number	Number	Number	Number	Number
Zooplankters :					
Euphausiids & decapods	17,195	30,965	5,677	4,046	11,042
Siphonophores	3,924	3,411	10,070	3,855	13,451
Copepods	332	1,226	1,613	872	2,625
Lucifer	-	-	1,369	359	2,105
Chaetognaths	859	1,921	646	422	696
Amphipods	382	463	415	144	814
Fish larvae	821	980	203	47	531
Pteropods	590	626	118	97	430
Stomatopods	496	20,317	8	24	63
Medusae	221	381	-	-	-
Gastropods	-	-	289	67	479
Leptocephali	340	165	105	12	91
Polychaetes	-	-	84	19	72
Fish eggs	-	-	29	5	25
Phyllosoma	-	-	8	1	7
Miscellaneous	457	787	1,851	330	1,224
Total	25,617	61,242	22,580	10,316	33,741
Fish, Prawn, Crab and Cephalopod :					
Myctophum elucens	1,864	1,012	353	30	70
M. evermanni	146	111	40	14	43
Caranx sp.	12	326	-	-	-
Stomias sp.	112	97	-	-	-
Bregmaceros mcClellandi	6	192	-	-	-
Diplophus taenia	77	-	-	-	-
Polypnus spinosus	43	22	20	4	5
Trichiurus sp.	6	10	-	-	-
Nemichthys scolop	3	-	6	1	20
Vinciguerria lucetia	-	-	3	1	20
Pasiphus sp.	425	211	37	9	59
Oplophorus sp.	-	-	202	3	18
Hymnopenaeus sp.	-	-	82	25	100
Charybdis edwardsi	381	148	-	-	-
Pelagic squid	125	52	-	-	-
Sepia sp.	3	1	-	-	-
Miscellaneous	54	56	187	46	155
Total	3,255	2,236	930	133	490
Grand Total	28,872	63,478	23,510	10,449	34,231

currence in different grounds was noticed. Among zooplankters, euphausiids and decapod larvae were the predominant groups in most of the stations and recorded in the range of 24-60%. Siphonophores were next in importance, except in the Lakshadweep Sea, where they exhibited a fall to 5.4%. Copepods and *Lucifer* were in negligible ratio in the Wadge Bank and Lakshadweep area but found more common in the collections made around the equatorial region (3-6% and 2-4% respectively). Chaetognaths and amphipods were noticed more or less in uniform strength in most of the stations. Fish larvae constituted 1.5 - 2.8% in the total collections made in the zone 05° -11°N and 71° - 77°E, whereas in the equatorial belt it was less. However, the samples made south of the Equator (01° - 03°S) contained an increased composition of fish larvae. Stomatopod larvae (alima larva of Squilla) were found in high percentage (32%) in the Lakshadweep sea only. Leptocephalus accounted for 1.2% in the samples obtained from the Wadge Bank area and in the rest of the ground they were in very low percentages. Similarly, phyllosoma larvae were noticed only from the collections of equatorial regions.

Among the teleosts, *Myctophum elucens* and *M. evermanni* were more common in the deep water collections of southwest coast of India. Cephalopods were noticed only in these stations and completely missing in equatorial grounds. Among deep sea prawns, *Pasiphus* sp. constituted 1.5% in the samples of the Wadge Bank and comparatively less in other stations. *Oplophorus* sp. and *Hymnopenaeus* sp. were noticed in increased percentages, being 0.9% and 0.3% respectively in the stations north of the equatorial line, but in poor combinations in the lower latitudes. It may also be seen that the deep sea crab, *Charybdis edwardsia* were more common (1.3%) in the Wadge Bank and the Lakshadweep waters but not so in the oceanic waters south of Kanyakumari.

Vinogradov (1962) and Voronina (1962 a,b) have dealt with the species distribution as well as quantitative distribution of some species of the Arabian Sea down to the Equator. The distribution patten of major organisms in these five zones at different depths of the DSL were analysed and is presented in Table 3. Euphausiids, decapods and siphonophores did not exhibit any distinct variation in their occurrence as they were recorded in all depths upto 400 m. A fall in the composition of copepods was noticed in depths below 300 m. *Lucifer* were recorded only in the upper 200 m depth level. Chaetognaths, stomatopods, amphipods, pteropods and leptocephali appeared in low per-

TABLE 3. *Percentage composition of major zooplankton groups at different depth of the Deep Scattering Layer*

Zooplankton groups	Depth of DSL (m)							
	50	100	150	200	250	300	350	400
Euphausiids & decapods	42.4	41.0	33.1	61.9	35.8	59.3	33.6	23.5
Siphonophores	17.0	32.7	22.6	14.3	27.7	10.1	28.2	52.9
Copepods	4.4	3.6	12.6	3.6	7.5	0.4	4.9	1.2
Lucifer	2.7	2.2	8.2	1.3	-	-	-	-
Leptocephalus	0.2	1.0	0.2	0.3	0.5	0.6	0.2	0.3
Phyllosoma	0.01	0.02	0.04	-	-	-	-	0.02
Fish larvae	1.3	1.9	2.7	1.8	8.5	1.4	1.8	0.9
Other plankters	29.7	12.3	14.8	9.1	13.8	15.4	13.3	7.7
Diaphus (Myctophid)	1.0	3.3	0.3	3.3	2.4	8.3	14.5	4.5
Prawns	0.2	0.6	2.5	1.9	0.7	2.5	2.7	5.4
Crabs	0.5	0.1	-	0.1	-	0.3	-	-
Cephalopods	0.1	0.2	0.3	0.6	-	-	-	-
Other fishes	0.4	1.1	2.8	2.4	3.1	1.7	0.7	3.5
Total organisms	58.2	24.1	3.1	4.0	1.2	5.7	1.2	2.5

centages but in all depths. Leptocephali were found entangled in the entire pelagic trawl net operated during night hours. The collection of Leptocephali in large numbers (average 9-21 per haul) from the ground at 50-100 m depth, off Ashtamudi estuary in southwest coast of India during July-August, revealed the spawning behaviour of eels at the onset of southwest monsoon in this zone. They measured 1.0 - 32.5 cm in length and were found common upto 100 m depth. Phyllosoma larvae were recorded from the collections of upper 150 m depth level. Fish larvae concentrated upto the depth of 250 m although it was noticed in still deeper waters. High concentration of deep sea fishes like myctophids were seen between 300 and 350 m and poorly represented in the upper layers. The cephalopods were obtained from the maximum depth of 200 m. It is interesting to note that the deep sea prawns occurred in increased percentage, below the depth of 300 m (2.5 - 5.4%). The portunid crabs were also more common from the depth of 300 m. Similar to the variations noticed in the volume of standing crop at different depths, the total organisms also exhibited distinct differences at different depth level. The surface waters upto 50 m depth contained 58.2% whereas it gradually declined and reached 2.5% at 400 m depth.

General Remarks

Subrahmanyan (1973) while reporting the observations made by Silas, stated that the standing crop of zooplankton fluctuated from 100 to 700 ml/ 1000 m^3 in the shelf waters and that the volume decreased in the deeper waters, and identified very rich area between Quilon and Calicut and the Wadge Bank in the south. The maximum production coincided with the southwest monsoon. The value for the oceanic area was recorded as 144 ml/ 1000 m^3. The same trend of fertility, revealing a high volume of standing crop at 414-586 ml/haul of 30 minutes was noticed in the Wadge Bank area and Lakshadweep waters during July-August.

Ponomareva and Naumov (1962) studied the vertical distribution of biomass of zooplankton and observed rich volume in the upper 100 m depth than 200-100 m or 500-200m. Vinogradov (1962) also found bulk of the plankton in the surface layers upto 100 m. This is in conformity with the present findings.

The euphausiids form the major food item of tunas which abound in the offshore waters and high seas. Vinogradov and Voronina (1961) opined, that tuna grounds are located in the areas where larger zooplankters and micronekton abound. Submarine ridges and banks and other irregular structures in the bottom hinder the flow of underwater currents and cause eddies which ultimately result in rapid sinking of plankton and become food for demersal fishes. Mendis (1965) correlated such causes to the potential resources of the Wadge Bank. Subrahmanyan (1973) remarked the convergence zones as indicators of potential fishing grounds, those about the equatorial region as is now known, are tuna long-line fishing zones. In the present study , the euphausiids, as they were found in high values (30-60%) in the Wadge Bank, Lakshadweep waters and the equatorial region can be considered as the indicator organism of tuna. The resource potential of tuna as they are directly related to this dietary organism in these grounds can be well recognised.

In the present investigation, *Hymnopenaeus* sp. and *Oplophorus* sp. were found common in the deep waters of the equatorial region, whereas *Pasiphus* sp. appeared in large numbers in the Wadge Bank . Mohamed and Suseelan (1973) have noticed these species in deep waters of the southwest coast of India, besides other dominant species. Rao *et al* . (1973) reported the existence of deep water crabs, *Charybdis (Goniohellenus) edwardsia* Leene and Buitendijk in large quantities from the western part of the Indian Ocean. As observed in the present exploratory survey, there is great possibility of tapping such hitherto unexploited oceanic resources of portunid crabs in the zone 05° - 11°N and 71° - 77°E. The rich fertility of the waters of the southwest coast, the Lakshadweep region and the equatorial region should be quite obvious from the data presented and support the views of earlier workers. It is apt to quote the statement given by Jones (1967) in this context. "There is evidence of significant fish resources in open parts of the Indian Ocean, first of all in waters of the Arabian Sea".

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A CHECK LIST OF FISHES OF THE EXCLUSIVE ECONOMIC ZONE OF INDIA COLLECTED DURING THE RESEARCH CRUISES OF FORV *SAGAR SAMPADA*

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ABSTRACT

A knowledge on the fish fauna of the Exclusive Economic Zone of India is essential to study the distribution, zoogeography and biological aspects of the fish resources. The present check list of fishes is based on the pelagic and bottom trawl collections of FORV *Sagar Sampada* during her cruises 1-30, in the EEZ along both the east and west coasts of India during the years 1985-'87. This list is arranged alphabetically by families and genera. The list consists of 87 families and 242 species, including both conventional and nonconventional fish fauna of the Indian EEZ. The depth-wise distribution of the species in the latitude zones are also given.

INTRODUCTION

The knowledge of the fish fauna of the EEZ of India is currently either lacking or whatever information available are improperly documented. Systematic, zoogeographical and vital biological studies of the conventional and nonconventional commercially important ichthyofauna of our waters are needed to assess the stock potential and exploitation. Such information, especially on nonconventional resources of the epipelagic, mesopelagic, bathypelagic and benthic fishes of outer shelf and beyond are higly essential in the present context of stagnating coastal fishery. Therefore, it is attempted to bring out a check list of all fishes collected from the EEZ of India by FORV *Sagar Sampada* in her cruises 1-30, as a preliminary requirement for the above mentioned studies.

Myers (1941) stated " by far the richest of the 4 tropical shore fish fauna in the Indo-Pacific, and it contains practically all the families and a considerable number of the genera that make up the fauna of the other 3, in addition to many families and genera not found elsewhere.....". Cohen (1973) reported that Indian Ocean may contain 3,000 to 4,000 species of tropical shore fishes. Though the coastal fish fauna were well studied for taxonomic, distributional and biological purposes, the deeper oceanic fish fauna were not attempted earlier. After the declaration of the EEZ, now it becomes imperative to have a thorough knowledge on the geographical, seasonal and bathymetric distribution of fishes of our waters.

MATERIAL AND METHODS

The samples for this investigation were colected from FORV *Sagar Sampada* during her cruises 1-30 from February, 1985 to June, 1987 covering 499 trawling operations. Immediately after the hauling of the net the ichthyofauna were sorted out and preserved for later identification and analysis. The gears used for the collection were Expo model pelagic trawl, High lift bottom trawl, Equal pannel midwater trawl, 400 mesh Chalut bottom trawl, Large granton bobbin trawl and German type rectangular pelagic trawl.

The list is arranged alphabetically by family and genera. The scientific and common names of fishes have been mostly followed after Fischer and Bianchi (1984) and Smith and Heemstra (1986). The details of the depth of occurrence, depth of fishing, position and the gear are also included.

RESULTS

ACANTHURIDAE

Acanthurus bleekeri Gunther, 1861 **Bleeker's surgeon fish**

Depth : 40 m ; Gear : Bottom trawl ; Location : Bay of Bengal 11°39'N 79°54'E.

Acanthurus nigricauda Duncker & Mohr, 1929 **Epaulette surgeon fish**

Depth : 33 m ; Gear : Bottom trawl ; Location: Bay of Bengal.

Acanthurus sp.

Depth : 285 - 1016 m; Gear : Pelagic trawl ; Fishing depth : 20 - 420 m; Location : Andaman Sea 07°01'-10°30'N 92°00' - 93°36'E.

Naso hexacanthus (Bleeker, 1855) **Sleek unicorn fish**

Depth : 75 m ; Gear : Bottom trawl ; Location : Andaman Sea 13°43'N 93°16'E.

ACROPOMATIDAE

Acropoma japonicum Gunther, 1859 **Glow-belly**

Depth : 140 m; Gear : Bottom trawl ; Location : Arabian Sea 11°29'N 74°30'E.

Howella sherboni (Norman, 1930) **Glow-belly**

Depth : 3458 m ; Fishing depth : 20-420 m; Gear : Pelagic trawl ; Location : Andaman Sea 09°00'N 89°00' E

Synagrops sp.

Depth : 729 m; Fishing depth : 20m ; Gear : Pelagic trawl ; Location : Bay of Bengal 20°00' N 87° 50' E.

ANTENNARIIDAE

Antennarius sp.

Depth : 2410 m; Fishing depth : 20 - 420 m; Gear : Pelagic trawl ; Location : Andaman Sea 07°30'N 75°30'E.

APOGONIDAE

Cheilodipterus quinquelineatus Cuvier, 1828 **Sharptooth cardinal**

Depth : 235 - 390 m ; Gear : Bottom trawl ; Location : Arabian Sea 14°28' - 15°28' N 72°49' - 73°10'E.

ARIOMMIDAE

Ariomma indica (Day, 1870) **Indian ariomma**

Depth : 52 - 3443 m; Fishing depth : 39 - 80 m (Pelagic trawl) , 57 - 200 m (Bottom trawl);
Gear : Bottom trawl and Pelagic trawl ; Location : Arabian Sea and Bay of Bengal 07°15' - 20°40' N 68° 30-' 88°15'E.

ASTRONESTHIDAE

Astronesthes sp.

Depth : 2985-3825 m; Fishing depth : 20-50 m; Gear : Pelagic trawl; Location : Bay of Bengal 07°00' - 13°30'N 83°00' - 91°00' E.

Borostomias antarcticus (Lonnberg, 1905) **Snaggletooth**

Depth: 3126-339 m; Fishing depth : 15-200 m; Gear: Pelagic trawl; Location : Equatorial IndianOcean and Arabian sea 05°00'- 17°00' N 69°00'- 77°00' E.

BALISTIDAE

Balistes vetula Linnaeus, 1758 **Queen trigger fish**

Depth: 52 m; Gear: Bottom trawl; Location : Bay of Bengal 19°40' N 88°15' E.

Odonus niger (Ruppell, 1840) **Red-toothed trigger fish**

Depth: 33-57 m; Gear : Bottom trawl; Location : Bay of Bengal 07°47' N 77°14' E.

Pseudobalistes fuscus (Bloch & Schneider, 1801) **Ripled trigger fish**

Depth: 64 m; Gear: Bottom trawl; Location: Andaman Sea 13°30' N 92°45' E.

***Pseudobalistes* sp.**

Depth: 45 m; Gear: Bottom trawl; Location: Andaman Sea 11°27' N 92°30' E.

BOTHIDAE

***Bothus* sp.**

Depth: 1016-3917 m; Fishing depth: 40-420 m; Gear: Pelagic trawl; Location: Arabian Sea and Andaman Sea 09°00' - 12°00' N 70°00'- 92°00'E.

BRAMIDAE

Brama dussumieri Cuvier, 1831 **Lesser bream**

Depth: 1990-3825 m; Gear: Pelagic trawl; Fishing depth: 40 m; Location: Arabian Sea and Bay of Bengal 14°00' N-72°30'E and 07°00' -13°30' N 83°00'-90°00' E.

Brama myersi Mead, 1972 **Ocean bream**

Depth: 1097 m; Gear: Pelagic trawl; Fishing depth: 20 m; Location: Lakshadweep Sea 10° 47' N-73° 45' E.

Brama orcini Cuvier, 1831 **Tropical pomfret**

Depth: 1875-2835 m; Gear: Pelagic trawl; Fishing depth: 25-100 m; Location: Arabian Sea 05°00' -11°00' N 71°00' -77° 30' E.

BREGMACEROTIDAE

Bregmaceros mcclellandi Thompson, 1840 **Spotted codlet**

Depth: 103-3791 m; Gear: Pelagic trawl; Fishing depth: 20-50 m; Location: Arabian Sea 15°00'-17°00' N 69°00'-73°00' E.

***Bregmaceros* sp.**

Depth: 2574 m; Fishing depth: 60-130 m; Gear: Pelagic trawl; Location : Bay of Bengal and Andaman Sea 17°30' N 84°40' E.

CAPROIDAE

Antigonia rubescens (Gunther, 1860) **Indo-Pacific boarfish**

Depth: 67 m; Gear: Bottom trawl; Location : Arabian Sea 08°42' N 76°11' E.

CARANGIDAE

Alectis sp.

Depth: 56 m; Gear: Bottom trawl; Location : Andaman Sea 14°14' N 93°26' E.

Atule mate (Cuvier, 1833) **Yellowtail scad**

Depth: 60 m; Gear : Bottom trawl; Location : Bay of Bengal 14°13' N 80°24' E.

Carangoides armatus (Ruppell, 1830) **Longfin trevally**

Depth: 38 m; Gear: Bottom trawl; Location: Andaman Sea 14°14' N 93° 26' E.

Carangoides ferdau (Forsskal, 1775) **Blue trevally**

Depth: 42 m; Gear: Bottom trawl; Location : Arabian Sea 07°51' N 77°56' E.

Carangoides malabaricus (Bloch & Schneider, 1801) **Malabar trevally**

Depth: 60-102 m; Gear: Bottom trawl; Location : Bay of Bengal and Andaman Sea 13°30'-15°24' N 73°06'- 92°45' E.

Carangoides oblongus (Cuvier, 1833) **Coachwhip trevally**

Depth: 38 m; Gear: Bottom trawl; Location : Andaman Sea 14° 14' N 93°26' E.

Caranx melampygus Cuvier, 1833 **Bluefin trevally**

Depth: 100 m; Gear: Bottom trawl; Location : Arabian Sea 15°24' N 73°06' E.

Caranx para Cuvier, 1833 **Banded scad**

Depth: 144 m; Gear : Bottom trawl; Location : Andaman Sea 12°30' N 91°30' E.

Decapterus macrosoma Bleeker, 1851 **Shortfin scad**

Depth : 57-71 m; Gear : Bottom trawl; Location : Arabian Sea and Bay of Bengal 19°30' N 87°50' E and 07°47' N 77°14' E.

Decapterus russelli (Ruppell, 1830) **Indian scad**

Depth: 62-88 m; Gear: Bottom trawl; Location : Arabian Sea and Bay of Bengal 11°28'-18°30' N 74°34'-80°23' E and 19°30' N 87°50'-88°50' E.

Decapterus sp.

Depth: 51-160 m; Gear: Bottom trawl; Location : Arabian Sea , Bay of Bengal and Andaman Sea 08°29'-09°30' N 75°51'-76°24' E; 18°31' N 84°46' E and 06°40' N 93°51' E.

Megalaspis cordyla (Linnaeus, 1758) **Torpedo scad**

Depth: 115 m; Gear : Bottom trawl; Location : Bay of Bengal 20°25' N 85°15' E.

Parastromateus niger (Bloch,1795) **Black pomfret**

Depth: 115 m; Gear: Bottom trawl; Location : Bay of Bengal 17°30' N 83°38' E.

Selar crumenophthalmus (Bloch, 1793) **Big eye scad**

Depth: 40 m; Gear: Bottom trawl; Location : Bay of Bengal 11°39' N 79°54' E.

Seriolina nigrofasciata (Ruppell, 1829) **Blackbanded trevally**

Depth: 35-100 m; Gear: Bottom trawl; Location : Arabian Sea and Bay of Bengal 14°31'-16°31' N 72°38'-73°24' E and 08°24' N 78°16' E.

Trachinotus russellii Cuvier, 1832 **Largespotted dart**

Depth: 23 m; Gear: Bottom trawl; Location: Bay of Bengal 20°20' N 87°00' E.

CARCHARHINIDAE

Carcharhinus dussumieri (Valenciennes, *in* Muller & Henle, 1839) **Whitecheek shark**

Depth: 56 m; Gear: Bottom trawl; Location : Andaman Sea 14°14' N 93°26' E.

Galeocerdo cuvieri (Peron & Le Sueur, *in* Le Sueur, 1822) **Tiger shark**

Depth: 51 m; Gear: Bottom trawl; Location : Andaman Sea 07°40' N 93°51' E.

Scoliodon laticaudus Muller & Henle, 1838 **Spadenose shark**

Depth: 92 m; Gear: Bottom trawl; Location : Arabian Sea 20°25' N 69°30' E.

CENTROLOPHIDAE

Centrolophus maoricus Ogilby, 1893 **Ruff**

Depth: 1016 m; Gear: Pelagic trawl; Location : Andaman Sea 10°30' N 92°00' E.

Psenopsis cyanea (Alcock, 1890) **Indian ruff**

Depth: 71-329 m; Gear: Bottom trawl; Location : Arabian Sea 08°42'-14°30 N 73°00'-76°11' E.

Psenopsis obscura Haedrich, 1967 **Ruff**

Depth: 235 m; Gear: Bottom trawl; Location : Arabian Sea 15°28' N 72°49' E.

CHAMPSODONTIDAE

Champsodon capensis Regan, 1908 **Gaper**

Depth: 1680-4280 m; Gear: Pelagic trawl; Location : Lakshadweep Sea.

CHAULIODONTIDAE

Chauliodus sloani Schneider, 1801 **Viper fish**

Depth: 2000-3689 m; Gear: Pelagic trawl; Location : Arabian Sea, Lakshadweep Sea and Andaman Sea.

CHIASMODOTIDAE

Chiasmodon niger Johnson, 1863

Depth: 3538 m; Gear: Pelagic trawl; Location : Andaman Sea 09°00' N 88°00' E.

CHIMAERIDAE

Rhinochimaera atlantica Holt & Byrne,1909 **Longnose chimaera**

Depth: 365-380 m; Gear: Bottom trawl; Location : Arabian Sea 09°00' N 75°50' E.

CHIROCENTRIDAE

Chirocentrus dorab (Forsskal, 1775) **Dorab wolf-herring**

Depth: 38 m; Gear: Bottom trawl; Location : Bay of Bengal 20°30' N 87°22' E.

Chirocentrus nudus Swanson, 1839 **Whitefin wolf-herring**

Depth: 175 m; Gear : Bottom trawl; Location : Bay of Bengal 20°25' N 86°50' E.

CHLOROPHTHALMIDAE

Chlorophthalmus agassizi Bonaparte, 1840 **Shortnose greeneye**

Depth: 220-390 m; Gear: Bottom trawl; Location : Arabian Sea 14°28'-15°28' N 72°19'-73°19' E and 07°15'-09°00' N 75°50'-77°50' E.

Clorophthalmus bicornis Norman, 1939 **Spinyjaw greeneye**

Depth: 260 m; Gear: Bottom trawl; Location : Arabian Sea 12°13' N 74°18' E.

Chlorophthalmus sp.

Depth: 320-380 m; Gear: Bottom trawl; Location : Arabian Sea 08°30'-09°00' N 75°50'-76°00' E.

CLUPEIDAE

Amblygaster sirm (Walbaum, 1792) **Spotted sardinella**

Depth: 203 m; Fishing depth: 39 m; Gear : Pelagic trawl; Location : Bay of Bengal 15°30' N 80°47' E.

Dussumieria acuta Valenciennes, 1847 **Rainbow sardine**

Depth: 1820 m; Fishing depth: 80 m; Gear: Pelagic trawl; Location : Bay of Bengal 19°30'N 87°50' E.

Dussumieria sp.

Depth: 56 m; Gear: Bottom trawl; Location : Arabian Sea 20°00' N 70°56' E.

Hilsa kelee Cuvier, 1829) **Kelee shad**

Depth: 56 m; Gear: Bottom trawl; Location : Andaman Sea 14°14' N 93°26' E.

Hilsa sp.

Depth: 52 m; Gear: Bottom trawl; Location : Bay of Bengal 19°40'N 88°15' E.

Ilisha filigera (Valenciennes, 1847) **Bigeye ilisha**

Depth: 51-175 m; Gear: Bottom trawl; Location : Bay of Bengal 19°30'-20°25'N 87°50'-88°50' E.

CYNOGLOSSIDAE

Cynoglossus sp.

Depth: 70 m; Gear: Bottom trawl; Location: Arabian Sea 08°30' N 76°40' E.

DACTYLOPTERIDAE

Dactyloptena orientalis (Cuvier, 1829) **Oriental flying gurnard**

Depth: 75m; Gear: Bottom trawl; Location : Arabian Sea 12°26' N 74°56' E.

DASYATIDAE

Dasyatis sp.

Depth: 50 m; Gear: Bottom trawl; Location : Arabian Sea 15°40' N 75°40'E.

Himantura sp.

Depth: 45 m; Gear: Bottom trawl; Location : Andaman Sea 12°30' N 92°30' E.

Himantura uarnak (Forsskal, 1775) **Honeycomb sting-ray**

Depth: 33 m; Gear: Bottom trawl; Location : Bay of Bengal

ECHENEIDAE

Remora remora (Linnaeus, 1758) **Remora**

Depth: 63 m; Gear: Bottom trawl; Location : Arabian Sea 11°40' N 74°56'E.

ENGRAULIDAE

Stolephorus commersonii Lacepede, 1803 **Commerson's anchovy**

Depth: 203 m; Fishing depth: 39 m; Gear: Pelagic trawl; Location : Bay of Bengal 15°30' N 80°47' E.

Stolephorus indicus (van Hasselt, 1823) **Indian anchovy**

Depth: 49 m; Gear: Bottom trawl; Location : Bay of Bengal 17°30'N 89°40' E.

Stolephorus waitei Jorden & Seale, 1926 **Spotfaced anchovy**

Depth: 40 m; Gear: Bottom trawl; Location : Bay of Bengal 17°30' N 84°40' E.

Stolephorus sp.

Depth: 40-56 m; Gear: Bottom trawl; Location : Bay of Bengal and Andaman Sea 17°30'N 84°40' E and 14°14' N 93°25' E.

Thryssa mystax (Schneider, 1801) **Moustached thryssa**

Depth 203 m; Fishing depth : 39 m; Gear: Pelagic trawl; Location : Bay of Bengal 15°30' N 80°47' E.

EXOCOETIDAE

Cheilopogon nigricans (Bennett, 1840) **African flyingfish**

Depth: 70 m; Gear: Bottom trawl; Location: Arabian Sea 18°58' N 72°00' E.

FISTULARIIDAE

Fistularia commersonii Ruppell, 1835 **Bluespotted cornetfish**

Depth: 54-328m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 09°00' N 75°50' E; 19°00'N 70°04' E and 19°00 N 84°50' E.

Fistularia petimba Lacepede, 1803 **Red cornetfish**

Depth: 100 m; Gear: Bottom trawl; Location : Arabian Sea 15°24' N 73°06' E.

GEMPYLIDAE

Gempylus serpen Cuvier, 1829 **Snake mackerel**

Depth: 1784-2250 m; Fishing depth: 50-150 m; Gear: Pelagic trawl; Location : Arabian Sea and Bay of Bengal 10°38'-14°55'N 72°00' - 74°00' E and 11°00' N 80°30' E.

Neoepinnula orientalis (Gilchrist & von Bonde, 1924) **Sack fish**

Depth: 84-4276 m; Fishing depth: 20-420 m; Gear: Pelagic trawl; Location: Arabian Sea 07°00'-20°00' N 66°00'-77°00' E.

Rexea prometheoides (Bleeker, 1856) **Royal escolar**

Depth: 32-119 m; Gear: Bottom trawl; Location: Bay of Bengal and Andaman Sea 13°30'-20°30 N 80°00'-87°22' E and 12°30' N 90°32' E.

GERREIDAE

Pentaprion longimanus (Cantor, 1850) **Longfin silverbiddy**

Depth: 32-119 m; Gear: Bottom trawl; Location : Bay of Bengal and Andaman Sea 13° 30'-20° 30' N 80° 00'-87° 22' E and 12° 30' N 90° 32' E.

GONOSTOMATIDAE

Cyclothone sp.

Depth: 84 m; Gear: Bottom trawl; Location : Andaman Sea 08° 42' N 76° 16' E.

Diplophos taenia Gunther, 1873 **Bristle mouth**

Depth: 1960-3126 m; Fishing depth: 20-420 m; Gear: Pelagic trawl; Location: Arabian Sea and Equatorial Indian Ocean 10°00'-12°30' N 73°30'-76°00' E and 01°00'S 76°00'E.

Photichthys argenteus Hutton, 1872 **Bristle mouth**

Depth: 3126-3396 m; Fishing depth: 20-420 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 01°00'S - 01°00' N 76°00'- 80°00' E.

Triplophos hemingi (Mc Ardle, 1901) **Bristle mouth**

Depth: 1960 m; Fishing depth: 712 m; Gear: Pelagic trawl; Location : Arabian Sea 12°30'N 73°30' E.

Vinciguerria lucetia Garman, 1899 **Bristle mouth**

Depth: 1690- 3126 m; Fishing depth: 20-420 m; Gear: Pelagic trawl; Location: Lakshadweep Sea and Arabian Sea.

Vinciguerria nimbaria (Jordan & Williams, 1895) **Bristle mouth**

Depth : 1690-3815 m; Fishing depth: 20-420 m; Gear: Pelagic trawl; Location: Lakshadweep Sea and Andaman Sea.

HAEMULIDAE

Diagramma pictum (Thunberg, 1795) **Painted sweetlips**

Depth: 39-55 m; Gear: Bottom trawl; Location: Bay of Bengal 10°30'-13°30' N 80°10'-80°28' E.

Plectorhinchus pictus (Tortonese, 1935) **Trout sweetlips**

Depth: 45 m; Gear: Bottom trawl; Location : Andaman Sea 12°30' N 92°30' E.

Plectorhinchus schotaf (Forsskal, 1775) **Minstrel sweetlip**

Depth: 33 m; Gear: Bottom trawl; Location: Bay of Bengal.

Plectorhinchus sp.

Depth: 75 m; Gear: Bottom trawl; Location : Andaman Sea 13°43'N 93°16'E.

Pomadasys argenteus (Forsskal, 1775) **Silver grunt**

Depth: 43-90 m; Gear: Bottom trawl; Location : Arabian Sea and Bay of Bengal 17°00'-18°00' N 83°30'-88°00'E and 16°52' N 72°26' E.

Pomadasys sp.

Depth: 50 m; Gear: Bottom trawl; Location: Arabian Sea 15°40' N 73° 20' E.

HOLOCENTRIDAE

Sargocentron caudimaculatum (Ruppell, 1835) **Silverspot squirrelfish**

Depth: 84 m; Gear: Bottom trawl; Location: Arabian Sea 08°42' N 76°11'E.

IDIACANTHIDAE

Idiacanthus atlanticus Brauer, 1906 **Sawtail fish**

Depth: 3126-3396 m; Fishing depth: 40-420 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 01°00' S-01°00' N 76°00'-80°00'E.

KYPHOSIDAE

Kyphosus sp.

Depth: 1784-3444 m; Fishing depth: 40-300 m; Gear: Pelagic trawl; Location : Lakshadweep Sea and Andaman Sea 10°30'-11°34' N 73°00'-74°00' E 17°58'N 67°00' E.

LABRIDAE

Epibulus insidiator (Pallas, 1770) **Sling-jaw wrasse**

Depth: 997-2837 m; Fishing depth: 25-100 m; Gear: Pelagic trawl; Location : Arabian Sea 05°00'-11°00'N 71°00'-77°30'E.

LACTARIIDAE

Lactarius lactarius (Bloch & Schneider, 1801) **False trevally**

Depth: 50-92 m; Gear: Bottom trawl; Location : Arabian Sea 14°30'-20°25'N 69°30'-73°32' E.

LEIOGNATHIDAE

Gazza sp.

Depth: 203 m; Fishing depth: 39 m; Gear: Pelagic trawl; Location : Bay of Bengal 15°30' N 80°47' E.

Leiognathus bindus (Valenciennes, 1835) **Orangefin ponyfish**

Depth: 52-60 m; Gear: Bottom trawl; Location : Bay of Bengal 18°30'-21°00' N 84°23'-88°50' E.

Leiognathus equulus (Forsskal, 1775) **Common ponyfish**

Depth: 58-68 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 16°31' N 82°22'E and 08°49' N 76°18' E.

Leiognathus fasciatus (Lacepede, 1803) **Striped ponyfish**

Depth: 63 m; Gear: Bottom trawl; Location : Andaman Sea 13°30' N 92°45' E.

Leiognathus lineolatus (Valenciennes, 1835) **Ornate ponyfish**

Depth: 30 m; Gear: Bottom trawl; Location : Bay of Bengal.

Leiognathus sp.

Depth: 51-119 m; Gear: Bottom trawl; Location : Andaman Sea and Bay of Bengal 06°40'-14°14' N 80°30'-93°51' E.

Leiognathus splendens (Cuvier, 1829) **Splendid ponyfish**

Depth: 43 m; Gear: Bottom trawl; Location : Bay of Bengal 18°00'N 84°00' E.

Secutor ruconius (Hamilton-Buchanan, 1822) **Deep pugnose ponyfish**

Depth: 51 m; Gear: Bottom trawl; Location : Bay of Bengal 19°40' N 88°15' E.

LETHRINIDAE

Gymnocranius robinsoni (Gilchrist & Thompson, 1908) **Blue-lined large-eye bream**

Depth: 80 m; Gear: Bottom trawl; Location: Andaman Sea 08°13' N 93°40' E.

Gymnocranius sp.

Depth: 80 m; Gear: Bottom trawl; Location : Andaman Sea 12°30' N 90°32' E.

Lethrinus elongatus Valenciennes, 1830 **Longface emperor**

Depth: 80 m; Gear: Bottom trawl; Location : Andaman Sea 12°30' N 90°32' E.

Lethrinus mahsenoides Valenciennes, 1830 **Saburbir emperor**

Depth: 40m; Gear: Bottom trawl; Location : Bay of Bengal 11°39' N 79°54' E.

Lethrinus nebulosus (Forsskal, 1775) **Spangled emperor**

Depth: 33 m; Gear: Bottom trawl; Location : Bay of Bengal.

Lethrinus rubrioperculatus Sato, 1978 **Spotcheek emperor**

Depth: 48 m; Gear: Bottom trawl; Location : Arabian Sea 11°29' N 74°30' E.

Lethrinus sp.

Depth: 35-82 m; Gear: Bottom trawl; Location : Arabian Sea, Bay of Bengal and Andaman Sea 08°24'-18°58' N 71°30'-78°16' E; 10°30'-13°30' N 80°10'-80°28'E and 06°40'-13°43' N 93°16'-93°52' E.

LOPHOTIDAE

Lophotus capellei (Temminck & Schlegel, 1845) **Crest fish**

Depth: 2595 m; Fishing depth: 110 m; Gear: Pelagic trawl; Location: Arabian Sea 15°00' N 71°00' E.

LUTJANIDAE

Lutjanus argentimaculatus (Forsskal, 1775) **Mangrove red snapper**

Depth: 40-250 m; Gear: Bottom trawl; Location : Arabian Sea 13°31'-17°00' N 72°55'-74°16' E.

Lutjanus johni (Bloch, 1792) **John's snapper**

Depth: 48 m; Gear: Bottom trawl; Location : Arabian Sea 11°29' N 74°30' E.

Lutjanus lutjanus (Bloch, 1790) **Bigeye snapper**

Depth :57 m; Gear: Bottom trawl; Location : Arabian Sea 07°47' N 77°14' E.

Lutjanus malabaricus (Bloch & Schneider, 1801) **Malabar blood snapper**

Depth: 40-60 m; Gear: Bottom trawl; Location : Bay of Bengal 11°39'-13°55' N 79°54'-80°23' E.

Lutjanus rivulatus (Cuvier, 1828) **Blubberlip snapper**

Depth: 65 m; Gear: Bottom trawl; Location : Arabian Sea 13°30' N 73°54' E.

Lutjanus sp.

Depth: 35-80 m; Gear: Bottom trawl; Location : Bay of Bengal and Andaman Sea 13°00'-18°58' N 71°30'-80°28' E and 06°40'-13°43'N 93°13'-93°51' E.

Pristipomoides sp.

Depth : 80 m; Gear: Bottom trawl; Location: Andaman Sea 08°13' N 93°40' E.

Pristipomoides types Bleeker, 1852 **Sharptooth jobfish**

Depth: 74 m; Gear: Bottom trawl; Location : Andaman Sea 13°43' N 93°16' E.

MACRORAMPHOSIDAE

Macroramphosus scolopax (Linnaeus, 1758) **Longspine snipe**

Depth: 200 m; Gear: Bottom trawl; Location : Arabian Sea 07°15' N 77°00' E.

MACROURIDAE

Bathygadus sp.

Depth: 3815 m; Gear: Pelagic trawl; Location : Andaman Sea 07°00' N 85°00' E.

Coelorinchus fasciatus (Gunther, 1878) **Grenadier**

Depth: 3734-3815 m; Fishing depth: 40-420 m; Gear: Pelagic trawl; Location: Andaman Sea 07°00' N 85°00'-87°00' E.

MALACOSTEIDAE

Malacosteus niger Ayres, 1848 **Lose jaw**

Depth: 3126-3396; Fishing depth: 20-400 m; Gear: Pelagic trawl; Location: Equatorial Indian Ocean 01°00' N-01°00'S 76°00'-80°00' E.

MELANOSTOMIIDAE

Echiostoma barbatum Lowe, 1843 **Scaleless dragonfish**

Depth: 3396 m; Fishing depth: 40-400 m; Gear: Pelagictrawl; Location: Equatorial Indian Ocean 01°00'N 80°00' E.

MENIDAE

Mene maculata (Bloch & Schneider, 1801) **Moonfish**

Depth: 1998 m; Gear: Pelagic trawl; Location : Arabian Sea 14°00' N 72°30' E.

MOBULIDAE

Mobula diabolus (Shaw, 1804) **Devil ray**

Depth: 120 m; Fishing depth: 53 m; Gear: Pelagic trawl; Location: Bay of Bengal 19°30' N 85°35' E.

MUGILIDAE

Mugil cephalus Linnaeus, 1758 **Flathead mullet**

Depth : 23 m; Gear: Bottom trawl; Location: Bay of Bengal 11°30' N 80°00' E.

MULLIDAE

Upeneus moluccensis (Bleeker, 1855) **Goldband goatfish**

Depth: 50-70 m; Gear: Bottom trawl; Location : Bay of Bengal 18°30'-21°00'N 84°23'-88°50' E.

Upeneus sp.

Depth: 70 m; Gear: Bottom trawl; Location : Arabian Sea 09°30' N 73°00'E.

Upeneus sulphureus Cuvier, 1829 **Sulphur goatfish**

Depth: 50-70 m; Gear: Bottom trawl; Location : Bay of Bengal 18°30'-21°00' N 84°23'-88°50' E.

Upeneus vittatus (Forsskal, 1775) **Striped goatfish**

Depth: 50-70 m; Gear: Bottom trawl; Location : Bay of Bengal and Andaman Sea 20°25' N 88°50' E and 14°30' N 92°00'E.

MURAENESOCIDAE

Congresox talabonoides (Bleeker, 1853) **Indian pike conger**

Depth: 62-68 m; Gear: Bottom trawl; Location : Arabian Sea 13°04'-16°30'N 73°00'-74°14' E.

Muraenesox cinereus (Forsskal, 1775) **Daggertooth pike conger**

Depth: 53 m; Gear: Bottom trawl; Location : Arabian Sea 13°33' N 73°24' E.

MYCTOPHIDAE

Bolinichthys sp.

Depth: 3166-3616 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 03°00' S-03°00' N 76°00'-86°00' E.

Ceratoscopelus warmingii (Lutken, 1892) **Lantern fish**

Depth: 3488 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Equatorial Indian Ocean 03°00'S- 03°00' N 76°00'-86°00' E.

Diaphus effulgens (Goode & Bean, 1896) **Lantern fish**

Depth: 2206-3684 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 03°00' S-03°00' N 76°00'-86°00' E.

Diaphus perspicillatus (Ogilby, 1898) **Lantern fish**

Depth: 3126 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 01°00'S 76°00'E.

Diaphus sp.

Depth: 3156 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Equatorial Indian Ocean 03°00'N 89°00' E.

Diaphus splendidus (Brauer, 1904) **Lantern fish**

Depth: 52 m; Gear: Bottom trawl; Location : Arabian Sea 13°33' N 73°24' E.

Gymnoscopelus (Nasolychnus) sp.

Depth: 2206-3722 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 03°00'S- 03°00'N 76°00'-86°00' E.

Lampanyctus pusillus (Johnson, 1890) **Lantern fish**

Depth: 3166-3616 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 02°00' S 80°00'-82°00' E.

Lobianchia sp.

Depth: 2206-3722 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 02°00' S -03°00' N 84°00'-86°00' E.

Myctophum sp.

Depth: 2206-3722 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Bay of Bengal and Arabian Sea.

Myctophum spinosum (Steindachner, 1867) **Lantern fish**

Depth: 2206-3616 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Equatorial Indian Ocean 02°00'S-02°00' N 76°00'-80°00' E.

Symbolophorus evermanni (Gilbert, 1905) **Lantern fish**

Depth: 2206-3684 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Equatorial Indian Ocean 03°00' S-02°00'N 76°00'-78°00' E.

Symbolophorus sp.

Depth: 3126-3166 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Equatorial Indian Ocean 02°00'S-03°00' N 76°00'-84°00' E.

Triphoturus nigrescens (Brauer, 1904) **Lantern fish**

Depth: 3156-3488 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Equatorial Indian Ocean 02°00' S-01°00' N 84°30'-86°00' E.

MYLIOBATIDAE

Aetobatus narinari (Euphrasen, 1790) **Spotted eagleray**

Depth: 42 m; Gear: Bottom trawl; Location : Arabian Sea 07°51' N 77°56' E.

Myliobatis aquila (Linnaeus, 1758) **Eagleray**

Depth: 23 m; Gear: Bottom trawl; Location: Bay of Bengal 20°20'N 87°00' E.

Rhinoptera javanica Muller & Henle, 1841 **Flapnose ray**

Depth: 42 m; Gear: Bottom trawl; Location : Arabian Sea 07°51' N 77°56' E.

NEMICHTHYIDAE

Nemichthys scolopaceus Richardson, 1848 **Snipe eel**

Depth: 1716-2767 m;Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Arabian Sea and Lakshadweep Sea.

Nemichthys sp.

Depth: 1638-3058 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location : Arabian Sea and Lakshadweep Sea.

NEMIPTERIDAE

Nemipterus bleekeri (Day, 1875) **Delagoa threadfin bream**

Depth: 25-64 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 11°30' N 75°00' E and 13°30' N 73°30' E.

Nemipterus japonicus (Bloch, 1791) **Japanese threadfin bream**

Depth: 57-128 m; Gear: Bottom trawl; Location : Arabian Sea and Bay of Bengal 07°20'-23°30' N 69°30'-77°26' E and 12°41'-13°55' N 80°23'-80°72' E.

Nemipterus mesoprion (Bleeker, 1853) **Redfilament threadfin bream**

Depth: 57-141 m; Gear: Bottom trawl; Location: Arabian Sea 07°47'-22°00'N 68°30'-74°56' E.

Nemipterus metopias (Bleeker, 1852) **Slender threadfin bream**

Depth: 64-134 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 11°30' N 75°00' E and 17°00' N 82°33' E.

Nemipterus sp.

Depth: 40-156 m; Gear: Bottom trawl; Location : Arabian Sea and Bay of Bengal.

NOMEIDAE

Cubiceps capensis (Smith, 1849) **Cape fat - head**

Depth: 2608-3624 m; Fishing depth: 20-150 m; Gear: Pelagic trawl; Location : Arabian Sea and Bay of Bengal 10°30' N 81°74' E; 05°59' N 77°29' E and 17°01' N 70°58' E.

Cubiceps pauciradiatus Gunther, 1872 **Longfin fat - head**

Depth: 673-3719 m; Fishing depth: 20-285 m; Gear: Pelagic trawl; Location: Arabian Sea and Bay of Bengal 12°00'-19°00'N 68°25'-74°19'E and 19°30' N 86°40'-88°05' E.

Psenes cyanophrys Cuvier & Valenciennes, 1833 **Frecked driftfish**

Depth: 1568-2715 m; Fishing depth: 20-160 m; Gear: Pelagic trawl; Location : Arabian Sea 07°30'-12°00'N 70°00'-75°30' E.

Psenes sp.

Depth: 45-3719 m; Fishing depth: 20-60 m; Gear: Bottom trawl and Pelagic trawl; Location : Arabian Sea, Bay of Bengal and Equatorial Indian Ocean 14°00'-19°20' N 69°00'-73°30' E 17°30'-19°30' N 83°40'-88°05' E and 02°00' S 80°00'E.

Psenes squamiceps Lloyd, 1909 **Indian driftfish**

Depth: 1050-3684 m; Fishing depth: 40-300 m; Gear: Pelagic trawl (Bottom trawl at 07°15 N 77°50' E at a depth of 200 m); Location : Arabian Sea, Bay of Bengal and Equatorial Indian Ocean 14°00'-19°20' N 69°00'-73°30' E; 17°30'-19°30'N 83°40'-88°05' E and 02°00' S 80°00' E.

OPHIDIIDAE

Monomitopus conjugator Alcock, 1896 **Cusk eel**

Depth: 250 m; Gear: Bottom trawl; Location: Arabian Sea 13°33' N 73°24' E.

OSTRACIIDAE

Ostracion sp.

Depth : 1016 m ; Fishing depth : 40-400 m ; Gear : Pelagic trawl; Location : Andaman Sea 10°30'N 92°00'E.

PARALEPIDIDAE

Lestidiops sp.

Depth : 3815 m; Fishing depth : 40 - 400 m; Gear: Pelagic trawl; Location : Andaman Sea 07° 00'N 85°00'E.

Paralepis sp.

Depth: 2632-3825 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Bay of Bengal 07°00' - 13°13'N 83°00'-91°00'E.

PERCOPHIDAE

Bembrops platyrhynchus (Alcock, 1893) **Duckbill**

Depth : 221 m; Gear : Bottom trawl; Location : Arabian Sea 07°50'N 77°50'E.

PERISTEDIIDAE

Peristedion weberi Smith, 1934 **Armoured gurnard**

Depth: 80m; Gear: Bottom trawl; Location: Arabian Sea 08°47' N 76°11'E.

PLATACIDAE

Platax sp.

Depth: 75m; Gear: Bottom trawl; Location: Arabian Sea 21°00'N 69°22'E.

PLATYCEPHALIDAE

Grammoplites suppositus (Troschel, 1840) **Spotfin flat-head**

Depth: 125 m; Gear: Bottom trawl; Location: Arabian Sea 12°20'N 74°12'E.

Platycephalus indicus (Linnaeus, 1758) **Bartail flat-head**

Depth: 50-80 m; Gear : Bottom trawl; Location: Arabian Sea 15°40'-21°00'N 69°22'-73°20'E.

POLYNEMIDAE

Polynemus sextarius Schneider, 1801 **Blackspot threadfin**

Depth: 51 m; Gear: Bottom trawl; Location: Bay of Bengal 19°30'N 85°40'E.

Polynemus sp.

Depth: 51-82 m; Gear: Bottom trawl; Location : Arabian Sea and Bay of Bengal 19°00'-20°00'N 70°51'-70°56'E and 19°00'N 84°50'E.

POMACENTRIDAE

Pomacentrus sp.

Depth : 2250 m; Fishing depth : 20-250 m; Gear: Pelagic trawl; Location : Arabian Sea 10°30'N 74°00'E.

PRIACANTHIDAE

Priacanthus hamrur (Forsskal, 1775) **Moontail bullseye**

Depth: 51-250 m; Gear : Bottom trawl; Location: Arabian Sea 07°47'-23°30' N 67°00'-76°00' E. (Occurred in the pelagic trawl at a depth of 1443 m (Fishing depth of 20 m) at 19°30' N 86°40' E).

Priacanthus sp.

Depth: 22-3719 m; Fishing depth: Bottom trawl 22-262 m; Pelagic trawl 60-300 m; Location: Arabian Sea, Bay of Bengal and Andaman Sea 07°30'-22°53' N 64°00'-88°57' E 08°13'-20°57' N 90°30'-94°29' E.

Priacanthus tayenus Richardson, 1846 **Purple-spotted big eye**

Depth: 87-729 m; Gear: Bottom trawl and Pelagic trawl; Fishing depth: Bottom trawl 79-90 m; Pelagic trawl 20 m. Location : Arabian Sea and Bay of Bengal 17°33'-19°30' N 69°58'-71°15' E and 20°00'N 85°50' E.

PSETTODIDAE

Psettodes erumei (Schneider, 1801) **Indian spiny turbot**

Depth: 40-75 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal.

RACHYCENTRIDAE

Rachycentron canadum (Linnaeus, 1766) **Cobia**

Depth: 42-102 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 07°51'-20°25' N 69°30'-77°56' E and 12°40' N 80°29' E.

RHINOBATIDAE

Rhinobatos annulatus Smith, 1841 **Lesser guitarfish**

Depth: 45 m; Gear: Bottom trawl; Location: Andaman Sea 12°30' N 91°30' E.

Rhinobatos sp.

Depth: 35 m; Gear: Bottom trawl; Location: Andaman Sea 13°30' N 94°10' E.

SCIAENIDAE

Atrobucca nibe Jordan & Thompson, 1911 **Longfin kob**

Depth: 51 m; Gear: Bottom trawl; Location: Bay of Bengal 19°40' N 88°15' E.

Johnieops vogleri (Bleeker, 1853) **Sharptooth hammer croaker**

Depth: 30-60 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 19°40' N 88°15' E and 08°04' N 74°06' E.

Otolithes cuvieri Trewavas, 1974 **Lessertigertooth croaker**

Depth: 104 m; Gear: Bottom trawl; Location: Arabian Sea 22°53' N 67°00' E.

Otolithes ruber (Schneider, 1801) **Tigertooth croaker**

Depth: 88 m; Gear: Bottom trawl; Location: Bay of Bengal 20°57' N 90°30' E.

Pennahia macrophthalmus (Bleeker, 1850) **Bigeye croaker**

Depth: 362 m; Gear: Bottom trawl; Location: Arabian Sea 08°00' N 75°00' E.

Protonibea diacanthus (Lacepede, 1802) **Spotted croaker**

Depth: 62-362 m; Gear: Bottom trawl; Location: Arabian Sea 08°00'-17°00' N 72°55'-75°00' E.

SCOMBRIDAE

Acanthocybium solandri (Cuvier, 1831) **Wahoo**

Depth: 4525m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Arabian Sea 09°59 N70°00'E.

Auxis rochei (Risso, 1810) **Bullet tuna**

Depth: 74-102 m; Gear: Bottom trawl; Location: Arabian Sea and Andaman Sea 13°31' N 73°38' E and 09°00' N 92°00' E.

Auxis thazard (Lacepede, 1800 **Frigate tuna**

Depth: 60-93 m; Gear: Bottom trawl; Location: Bay of Bengal and Arabian Sea 09°00' N 73°38' E and 19°00' N 67°00' E.

Katsuwonus pelamis (Linnaeus, 1758) **Skipjack tuna**

Depth: 3256-3719 m; Fishing depth; 60-300 m; Gear: Pelagic trawl; Location: Arabian Sea 16°00'-19°00'N 68°30'-70°30' E.

Rastrelliger kanagurta (Cuvier, 1817) **Indian mackerel**

Depth: 23-100 m; Gear: Bottom trawl; Location:Arabian Sea and Bay of Bengal 07°51'-19°30' N 72°31'-87°50' E.

Sarda orientalis (Temminck & Schlegel, 1844) **Striped bonito**

Depth: 104 m; Gear: Bottom trawl; Location:Arabian Sea 16°30' N 72°21' E.

Scomberomorus commerson (Lacepede, 1800) **Narrow-barred Spanish mackerel**

Depth: 64 m; Gear: Bottom trawl; Location: Arabian Sea 11°40' N 74°56' E.

Scomberomorus guttatus (Bloch & Schneider, 1801) **Indo-Pacific king mackerel**

Depth: 39-92 m; Gear: Bottom trawl; Location: Bay of Bengal and Arabian Sea 13°30'-14°30' N 80°00'-82°31' E and 20°25' N 69°30' E.

Scomberomorus sp.

Depth: 30-53 m; Gear: Bottom trawl; Location: Bay of Bengal 14°30'-18°30' N 80°12'-84°28' E.

SCORPAENIDAE

Scorpaena sp.

Depth: 85-95 m; Gear: Bottom trawl; Location: Arabian Sea 07°30' N 77°30' E.

SERRANIDAE

Epinephelus caeruleopunctatus (Bloch, 1790) **White-spotted grouper**

Depth: 3443 m; Fishing depth: 50 m; Gear: Pelagic trawl; Location: Arabian Sea 18°00' N 68°30' E.

Epinephelus chlorostigma (Valenciennes, 1828) **Brown-spotted grouper**

Depth: 79 m; Gear: Bottom trawl; Location: Arabian Sea 18°30' N 17°26' E.

Epinephelus diacanthus (Valenciennes, 1828) **Thorny cheek grouper**

Depth: 60-127 m; Gear: Bottom trawl; Location: Arabian Sea 11°00'-22°00' N 68°30'-75°19' E.

Epinephelus malabaricus (Schneider, 1801) **Malabar grouper**

Depth: 82-93 m; Gear: Bottom trawl; Location: Arabian Sea 18°58'-19°00' N 70°30'-71°30' E.

Epinephelus morrhua (Valenciennes, 1833) **Comet grouper**

Depth: 33m; Gear: Bottom trawl; Location : Bay of Bengal 08°48' N 78°23' E.

Epinephelus sp.

Depth: 23-140 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 08°24'-18°58' N 71°40'-93°16' E.

Epinephelus stoliczkae (Day, 1875) **Epaulet grouper**

Depth: 23 m; Gear: Bottom trawl; Location: Bay of Bengal 10°30' N 80°00' E.

Epinephelus tauvina (Forsskal, 1775) **Greasy grouper**

Depth: 33m; Gear: Bottom trawl; Location : Bay of Bengal 08°48' N 78°23' E.

SPARIDAE

Argyrops filamentosus (Valenciennes, 1830) **Soldier bream**

Depth: 75 m; Gear: Bottom trawl; Location: Bay of Bengal 15°00' N 83°00' E.

Argyrops spinifer (Forsskal, 1775) **King soldier bream**

Depth: 47 m; Gear: Bottom trawl; Location: Bay of Bengal 06°40' N 93°51' E.

Rhabdosargus sarba (Forsskal, 1775) **Goldlined seabream**

Depth: 60m; Gear: Bottom trawl; Location: Bay of Bengal 13°55' N 80°23' E.

SPHYRAENIDAE

Sphyraena barracuda (Walbaum, 1772) **Great barracuda**

Depth: 42-100 m; Gear: Bottom trawl; Location: Arabian Sea 07°51'-15°24' N 73°06'-77°56' E.

Sphyraena obtusata Cuvier, 1829 **Obtuse barracuda**

Depth: 70 m; Gear: Bottom trawl; Location: Bay of Bengal 19°30' N 88°50' E.

Sphyraena sp.

Depth: 23-80 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 10°30'-20°00' N 70°00'-80°50' E.

STERNOPTYCHIDAE

Argyropelecus hemigymnus Cocco, 1829 **Marine hatchetfish**

Depth: 3202 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Bay of Bengal 12°58' N 86°00' E.

Polyipnus polli Schultz, 1961 **Marine hatchet fish**

Depth: 3156-3488 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Equatorial Indian Ocean 02°00' S-03°00' N 84°00'-86°00' E.

STOMIIDAE

Stomias boaboa (Risso, 1810) **Scaly dragonfish**

Depth: 1645-2830 m; Fishing depth: 25-100 m; Gear: Pelagic trawl; Location: Arabian Sea 05°00'-11°00' N 71°00'-77°30' E.

Stomias nebulosus Alcock, 1889 **Scaly dragonfish**

Depth: 1195-4341 m; Fishing depth: 35-150 m; Gear: Pelagic trawl; Location: Arabian Sea11°25'-16°30' N 69°00'-74°50' E.

STROMATEIDAE

Pampus argenteus (Euphrasen, 1788) **Silver pomfret**

Depth: 33-51 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 19°40' N 88°15' E 08°00' N 75°00' E.

SYNODONTIDAE

Saurida gracilis (Quoy & Gaimard, 1824) **Gracile lizardfish**

Depth: 60 m; Gear: Bottom trawl; Location: Arabian Sea 08°04' N 74°06' E.

Saurida longimanus Norman, 1939 **Longfin lizardfish**

Depth: 70 m; Gear: Bottom trawl; Location: Bay of Bengal 19°30' N 88°50' E.

Saurida nebulosa Valenciennes *In* Cuvier & Valenciennes, 1849 **Clouded lizardfish**

Depth: 32-125 m; Gear: Bottom trawl; Location : Arabian Sea and Bay of Bengal 08°29'-21°00'N 69°22'-94°29' E.

Saurida tumbil Bloch, 1795 **Greater lizardfish**

Depth: 33-235m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 07°20'-23°30' N 69°22'-85°00'E.

Saurida undosquamis (Richardson, 1848) **Brushtooth lizardfish**

Depth: 33-235; Gear : Bottom trawl; Location : Arabian Sea and Bay of Bengal 07°47'-19°30' N 72°49'-87°50' E.

Synodus sp.

Depth: 2632-3826 m; Fishing depth : 100-400 m; Gear: Pelagic trawl; Location: Bay of Bengal 07°00'-13°30' N 83°00'-91°00' E.

Trachinocephalus myops (Forster, 1801) **Bluntnose lizardfish**

Depth: 47-87; Gear: Bottom trawl; Location: Bay of Bengal 06°40'-13°30' N 93°05'-93°51' E.

TACHYSURIDAE

Tachysurus sp.

Depth: 33-81 m; Gear: Bottom trawl; Location: Arabian Sea 07°51'-17°57' N 72°14'-77°56' E.

Tachysurus tenuispinis Day, 1877 **Thinspine sea catfish**

Depth: 49 m; Gear: Bottom trawl; Location: Arabian Sea 10°00' N 75°50' E.

Tachysurus thalassinus (Ruppell, 1837) **Giant catfish**

Depth: 33-101 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 08°00'-14°30' N 73°24'-75°50' E and 19°32'-20°50' N 87°42'-89°15' E.

TERAPONIDAE

Terapon **sp.**

Depth: 41 m; Gear: Bottom trawl; Location: Bay of Bengal 14°00' N 80°20' E.

Terapon theraps (Cuvier, 1829) **Largescaled terapon**

Depth: 29 m; Gear: Bottom trawl; Location: Bay of Bengal.

TETRAODONTIDAE

Arothron stellatus (Bloch & Schneider, 1844) **Star blassop**

Depth: 33 m; Gear: Bottom trawl; Location: Bay of Bengal 08°48' N 78°23' E.

Lagocephalus spadiceus Richardson, 1844 **Pufferfish**

Depth: 1645-2837 m; Fishing depth; 25-100 m; Gear: Pelagic trawl; Location: Arabian Sea 05°00'-11°00'N 71°00'-77°30' E.

TRIANCANTHODIDAE

Triacanthus biacleatus (Bloch, 1786) **Shortnosed tripodfish**

Depth: 595 m; Fishing depth : 230-400 m; Gear : Pelagic trawl; Location : Arabian Sea 13°00'-14°21' N 73°09'-73°43' E.

Triacanthodes **sp.**

Depth: 2025 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Arabian Sea 10°00' N 73°38' E.

TRACHIPTERIDAE

Trachipterus **sp.**

Depth: 2379-3577 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Arabian Sea and Andaman Sea 10°00' N 73°25' E and 09°00' N 87°00' E.

Trachipterus woodi Smith, 1953 **Polkot ribbonfish**

Depth: 1645-2837 m; Fishing depth: 25-100 m; Gear: Pelagic trawl; Location: Arabian Sea 05°00'-11°00'N 71°00'-77°30' E.

TRICHIURIDAE

Benthodesmus **sp.**

Depth: 2983-3826 m; Fishing depth: 40-400 m; Gear: Pelagic trawl; Location: Bay of Bengal 07°00'-13°30' N 83°00'-91°00' E.

Lepidopus caudatus (Euphrasen, 1788) **Butter snoeck**

Depth: 1568-4276 m; Fishing depth: 100-400 m; Gear: Pelagic trawl; Location: Arabian Sea 08°00'-17°00'N 70°00'-75°00' E.

Trichiurus auriga Klunzinger, 1884 **Pearly hairtail**

Depth: 110 m; Fishing depth: 70 m; Gear: Pelagic trawl; Location: Bay of Bengal 17°00'N 82°50' E.

Trichiurus gangeticus Gupta, 1966 **Ganges hairtail**

Depth: 52 m; Gear: Bottom trawl; Location: Bay of Bengal 19°40' N 88°15' E.

Trichiurus lepturus Linnaeus, 1758 **Largehead hairtail**

Depth: 33-104 m; Gear: Bottom trawl; Location: Arabian Sea and Bay of Bengal 08°00'-20°25' N 69°30'-75°00' E and 19°40' N 88°15' E.

TRIGLIDAE

Lapidotrigla riggsi Richards & Saksena, 1977 **Rigg's gurnard**

Depth: 127 m; Gear: Bottom trawl; Location: Arabian Sea 12°20' N 74°12' E.

Pterygotrigla hemisticta (Temminck & Schlegel, 1842) **Blackspotted gurnard**

Depth: 127 m; Gear: Bottom trawl; Location: Arabian Sea 11°29' N 74°30' E.

URANOSCOPIDAE

Uranoscopus sp.

Depth: 127 m; Gear: Bottom trawl; Location: Arabian Sea 12°20' N 74°12' E.

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STUDIES ON PROTOZOAN PARASITES OF DEEP WATER FISHES FROM THE BAY OF BENGAL

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Abstract

Parasitic Protozoa cause diseases to fish, some of which are highly pathogenic in nature. The present paper purports to show incidence of protozoan infections among fishes collected from different areas (depth 60-330 m) in the Bay of Bengal on board FORV *Sagar Sampada* during July, 1988. A total of 245 fishes belonging to 21 genera were examined for the purpose, of which nearly 19% of them were found infected. While the fishes appeared apparently healthy, a microscopic examination of their organs revealed presence of infected stages. In all, 11 species of parasites (8 myxosporidians, 2 microsporidians and 1 haemoflagellate) were identified as new to science. They are, the myxosporidians, *Davisia sauridae* n. sp. from *Saurida tumbil*, *D. cynoglossi* n. sp, from *Cynoglossus*, *Neobipteria coramandelensis* n. sp. from *Nemipterus mesoprion*, *Leptotheca apogoni* n. sp. from *Apogon aureus*, *Ceratomyxa sagarsampadae* n. sp. from *Cynoglossus*, *C. dissimilaris* n. sp. from *Nemipterus mesoprion*, *Auerbachia chakravartyi* n. sp. from *Megalaspis cordyla*, *Thelohanellus parastromataei* n. sp. from *Parastromataeus niger*, the two microsporidians *Loma* sp. I from *Tricropterus*, *Loma* sp. II from unidentified sciaenid and the haemoflagellate *Trypanoplasma parastromataei* n. sp. from *Parastromataeus niger*. The paper, the first of its kind to deal with protozoan infections in deep water fishes in India, contains details on the morphology and life cycles of the parasites.

Introduction

A comprehensive approach to the study of fishery biology also must include an examination of fish parasites, because they impose an overwhelming influence on the general well being of the host, which is an important aspect in overall management of fish stocks. Such a study involves assessment of possible damages the parasites can cause to the host which in turn is effected by the environment or a combination of parasite-host-environmental relationships. A systematic approach to survey fish under different ecological conditions, becomes therefore inevitable. In the process, newer parasites have come to light as also their ecology or biology together with descriptions of hosts and associated environmental conditions. The present study, perhaps the first of its kind, on fishes inhabiting deep water regions in the sea in India is intended to give an account of taxonomy and ecology of protozoan parasites of fishes in the Bay of Bengal.

Protozoan parasites of fishes are known from a variety of aquatic habitats, divergent hosts and geographical locations and depths. Among them the haemoflagellates and myxozoans are the most widely distributed and possibly the best studied on account of their pronounced pathogenicity caused to their hosts by forms such as *Myxosoma cerebralis* and *Hexacapsula neothunni*.

In this context it may be mentioned that while there has been a wealth of literature on the myxosporidians of fishes living in fresh water and brackish water areas throughout the world, studies relating to marine fishes particularly, the deep water forms in the sea have, however, remained practically untouched. Within the last 10 years or so pioneering investigations have been made by several workers, notably, Schulaman *et al.* (1979), Zubchenko and Krasin (1980), Kovaliova and Gavaeskaya (1981) on the myxosporidian parasites of northeastern Atlantic and Noble (1973), Yoshino and Noble (1973) and Yoshino and Moser (9174) on macruroid fishes of northeastern Pacific.

In India, studies on the protozoan parasites of fishes have, out of necessity remained restricted to rivers, estuaries, bays and such other shallow water bodies, and there is virtually no information concerning deep water fishes. So far only 8 species of myxosporidians, namely, *Henneguya otolithi* (Ganapathi, 1941), *Kudoa tetraspora* and *K. sphyraeni* (Narasimhamurti and Kalavati, 1978, 1979), *K. tachysurae*, *K. bengalensis* and *Thelohanellus coeli*

(Sarkar and Mazumdar, 1983), *T. auerbachia* and *Zschokkella platystomi* (Sarkar, 1987) have been reported among fishes collected from coastal waters (<50 m). With a view to find out the nature of parasites, the incidence and intensity of infections among the deep water fishes, the present study was undertaken during July, 1988 at selected locations (depth 60 - 330 m) in the Bay of Bengal.

Material and Methods

Fish samples for the examination of protozoan parasites were collected from trawl catches on board FORV *Sagar Sampada* during its 49th cruise in July, 1988 at selected locations in the Bay of Bengal, along the east coast of India. A total of 245 fishes representing 21 genera and 28 species were collected on six different dates and depths ranging from 60-330 m, and examined for protozoan parasites, details of which are given in Table 1. Immediately after collection, the individual organs of the fish were examined under a low power binocular microscope to locate possible presence of protozoan parasites. The cysts if any were carefully isolated from the adhering tissue with fine needles and smears prepared by rupture of contents of the infected organs examined directly. Smear were either air dried, fixed in acetone-free methyl alcohol and stained with Giesma or wet fixed with Schaudinn's or Carnoy fluid and stained with Heidenhain's haematoxylin. Fresh spores were treated with Lugol's iodine. Infected tissues were fixed in alcoholic Bouin's fluid for sectioning and further processing. For haematozoans, blood smears were prepared from live fish by cardiac puncture and stained suitably.

Results

Altogether 47 fishes were found infected with a number of protozoan parasites of which as many as 11 species (1 haemoflagellate, 8 myxosporidians and 2 microsporidians) were identified as new to science. Among them, the myxosporidians were the most represented and were found in 45 (18.36%) fishes, the nature of infection being coelozoic, confined to gall bladder. During the study, there were no cases of histozoic infections caused by these parasites. The other group, namely, the microsporidia were histozoic, seen in only 2 fishes (0.8%) and exhibited host reaction and formation of conspicuous 'Xenomas'. During the study, there was only one incidence of haemoflagellate infection of the genus *Trypanoplasma* and no other protozoan parasites, either coccidia or ciliata were noticed. The appendix shows a classified list of the protozoan parasite encountered during this investigation. The following is an account of their taxonomy.

Phylum : Sarcomastigophora

Class : Mastigophora

***Trypanoplasma parastromataei* n. sp.**

Host	:	*Parastromataeus niger*
Site of infection	:	Blood
Locality	:	East coast of India, Bay of Bengal Lat. 20°00'N Long. 86°46'E
Depth	:	60 m

Cell body : Typically monomorphic, short, broad, often irregular in shape.

Pellicle : With 5-8 striations.

Cytoplasm : Homogenous, granulated.

Nucleus : Distinctly ovoidal or crescent shaped, dorsal, always posterior in position.

Kinetoplast : Lies on ventral side, distinctly rod shaped, dorsal, with lightly stained hyaline area around.

Flagella : Two flagella arise from kinetosomes. Anterior free flagelleum longer than body. Posterior flagelleum curved, runs over body, free trailing portion small. No undulating membrane.

Body dimension	Range (μm)	Mean (μm)
Length of cell body	12.8 - 20.8	16.56
Width of cell body	6.4 - 12.8	9.87
Length of nudeu	1.6 - 3.58	2.6
Width of nucleus	1.2 - 2.5	1.58
Length of anterior flagellum	12.84 - 18.8	16.01
Length of posterior flagellum	6.12 - 9.5	7.28

Systematic position : So far 11 species of Trypanoplasms have been reported from India, all of which from fresh water fishes. The present species is the first report of *Trypanoplasms* from the blood of a marine fish, *Parastromataeus niger*. Of the 11 species of Trypanoplasms reported from marine fishes from all over the world, *T. (cryptobia) bullocki* Strout (1965) (12.5 - 23.1 (17.6) x 1.2 - 4.5 (2.7)) noticed in *Furduleus heterocitus* from Great Bay resembles closest to the present form (12.8 - 20.8 x 6.4 x 12.8), in the overall body measurements, but differs considerably being long and slender with an undulating membrane. A comparison of this species with all other haemoflagellates showed it

TABLE 1. *List of fishes examined onboard FORV* Sagar Sampada (*Cruise No. 49*)

Name of fish	Number examined	Number infected	Name of parasite
Cynoglossus sp.	23	4	*Davisia cynoglossi* n. sp.
		8	*Ceratomyxa sagarsampadae* n. sp.
Nemipterus mesoprion	11	1	*Neobipteria coromandelensis* n. sp.
		4	*Ceratomyxa dissimilaris* n. sp.
N. japonicus	10	2	*Leptotheca apogoni* n. sp.
N. bleekeri	1	-	
Nemipterus. sp.	4	-	
Upeneus molucceusis	12	-	
Parastromateus niger	6	3	*Thelohanellus parastromataei* n. sp.
		1	*Trypanoplasma parastromataei* n. sp.
Caranx malabaricus	5	-	
Megalaspis cordyla	5	1	*Auerbachia chakravarthyi* n. sp.
Saurida tumbil	40	15	*Davisia sauridae* n. sp.
Rastrelliger kanagurta	5	-	
Stolephorus indicus	2	-	
Pseudorhombus javanicus	6	-	
Decapterus sp.	11	-	
Pomadasys hasta	4	-	
Apogon aureus	14	6	*Leptotheca apogoni* n. sp.
Priacanthus sp.	18	-	
Lampogrammus sp.	6	-	
Psenopsis cyanae	5	-	
Selar sp.	4	-	
Trichiurus sp.	5	-	
Sphyraena sp.	5	-	
Sphyraena obtusata	14	-	
Platycephalus sp.	5	-	
Exocoetus sp.	4	-	
Psenes indicus	5	-	
Tricropterus sp.	6	1	*Loma* sp. I
Sciaenids (unidentified)	9	1	*Loma* sp. II
Total	245	47	

distinct, without forming an undulating membrane. In view of the marked differences, based on its occurrence in a new host, the species is considered new to science for which the name *Trypanoplasma parastromataei* n. sp. after the host is proposed.

Phylum : Myxozoa

Class : Myxosporea

***Davisia sauridae* n. sp.**

Host : *Saurida tumbil*
Site of infection : Gall bladder
Locality : East coast of India, Bay of Bengal
Lat. 18°41'N Long. 84°58'E
Depth : 140 m

Incidence : Thirteen out of 28 *Saurida tumbil* collected on 16-7-'88 were infected. Infection of moderately high intensity.

Spores (Figs. 2, 3): Spore body rectangular, broad, width almost twice the body length. Anterior end broader than posterior end with distinct sinuous sutural ridge. Lateral appendages oval and solid. Junction of appendage to spore body marked by distinct furrow. Spore valves thin. No parietal folds or intercapsular ridges, polar capsules oval;

very small, one on either side of sutural ridge. Sporoplasm oval, binucleate in posterior part of spore body. Polar filaments form 2 or 3 coils while inside capsule. They are thick and deeply stained when extruded. No iodinophilous vacuole. Pansporoblasts di-and tetrasporous.

Pathogenicity : Apparent hypertrophy of the gall bladder noticed.

Spore dimension (n=30)	Range (μm)	Mean (μm)
Spore body length	7.24 - 10.8	9.6
Spore body width	14.8 - 22.6	18.2
Lateral appendage length	2.6 - 5.4	3.52
Polar capsule length	3.2 - 1.6	1.8
Polar capsule width	2.4 - 1.2	1.6
Polar filament length	12.0 - 16.8	14.58
Total width of spore	17.4 - 28.0	22.65

Systematic position. : Members of the genus *Davisia* are characterised by spores with 2 lateral appendages attached to the spore body with a demarcated joint. So far, only 14 species of this genus are known, all of which, with the exception of *Davisia murtii* Padma Dorothy and Kalavati (in press) noticed in the gall bladder of an estuarine fish, *Liza macrolepis* , are parasites in their urinary bladder or kidneys of marine, deep water fishes. The present form, in *Saurida tumbil*, is the only species record from a truly nektonic form in the sea, without any resemblance to the already known *D. murtii* reported from the Indian waters. In spore morphometrics, this species (9.6 x 18.2 μm) resembles *D. coryphaenoidia* Yoshino and Noble (1973) noticed in the urinary bladder and kidney of *Coryphaenoides acrolepis* (10.8 x 18.6). But the polar capsules in the present form are oval in shape (1.8 x 1.6 μm) while they are spherical and larger in diameter (4.1 μm) in *D. coryohaenoidia*. The 2 distinct furrows at the junction of the appendage and rectangular spore body, appear unique to the present species.

In view of the above and its record occurrence in *Saurida tumbil*, in relatively shallow waters, the species is considered new to science for which the name *Davisia sauridae* n. sp. is proposed.

Davisia cynoglossi **n. sp.**

Host	:	*Cynoglossus* sp.
Site of infection	:	Gall bladder
Locality	:	East coast of India, Bay of Bengal Lat. 15°58'N Long. 81°31'E
Depth	:	330 m

Incidence : Four out of 23 *Cynoglossus* sp. collected on 10-7-'88 showed infection. Intensity of infection moderate.

Spores (Figs. 4, 5 and 6): Flattened, bent with a downward curvature. Lateral appendages hollow, with distinct junction to spore body. Proximal portion of the appendage broad, distal end oval narrow with a number of deeply stained granules. Spore body oval. Shell valves thin. Sutural line distinct, slightly wavy. Polar capsules oval, capsular foramina widely separated slightly away sutural line. Sporoplasm oval, binucleate and granular. Two nuclei present on either side of the sutural line. Polar filaments thin and tubular. No parietal folds or inter capsular ridges. Iodinophilous vacuole absent.

Pansporoblasts : Disporous.

Pathogenicity : No apparent pathogenicity.

Spore dimensions (n=30)	Range (μm)	Mean (μm)
Spore body length	12.6 - 16.8	14.24
Spore body width	11.4 - 15.8	12.6
Lateral appendage length	20.8 - 36.4	28.5
Polar capsule length	5.8 - 6.8	6.2
Polar capsule width	2.8 - 4.2	3.4
Polar filament length	22.4 - 28.6	24.8
Total width of spore	32.2 - 42.2	37.01

Systematic position: Moser and Noble (1975) suggested use of the nature of appendages as a taxonomic character for differentiating the species of *Davisia*, based on which they divided the species into two categories, namely, 'hollow' species and 'solid' species. The present form noticed in the gall bladder of *Cynoglossus* sp. has 'hollow' appendages unlike the other two Indian examples, namely, *D. sauridae*, described earlier in this paper and *D. murtii* from *Liza macrolepis*. The present species resembles very closely *D. diplocrepis* Laird 1953, (spore size 12-14 x 9-12 μm) reported from the urinary bladder of *Diplocrepis puniceus* and *Davisia longibrachia* Kabata 1962 (12 x 12-15 μm) also from the urinary bladder of *Callionymus lyra*. However, the present species differs from the other two in having lateral appendages smaller (28.5 μm) to that of *D. longibrachia* (100 μm) and larger when compared with *D. diplocrepis* (10-14 μm). Further, the spores in the present form are characteristically flattened with a downward curvature at the ends. Also, the present occurrence of the species is the first report from *Cynoglossus*, a demersal fish and third from the Indian sub-continent having no resemblance with other known species. Hence, the species is considered new to science and the name *Davisia cynoglossi* n. sp. is proposed after the host.

Neobipteria coramandelensis n. sp.

Host	:	*Nemipterus mesoprion*
Site of infection	:	Gall bladder
Locality	:	East coast of India, Bay of Bengal Lat. 15°58'N Long. 81°31'E
Depth	:	330 m

Incidence : One out of two *Nemipterus mesoprion* collected on 10-7-'88 was found infected. Intensity of infection was low.

Spores (Figs. 7, 8 and 9): Triangular, posterior end pointed anterior end flattened with small depression in the centre. Sutural line straight, thick. A pair of median keel like membranes arising from the sutural line present. The two shell valves extended into two wing like appendages at anterior end. Polar capsules spherical widely separated on either side of the sutural line. Capsular foramina distinct near the edge of keel. Polar filament forms 6-7 coils while inside the capsule. Sporoplasm oval binucleate. No iodinophilous vacuole. Polar filament flat, ribbon-like.

Pansporoblasts : Di - or polysporous.

Pathogenicity : No apparent pathogenicity.

Spore dimension (n= 30)	Range (µm)	Mean (µm)
Spore length	4.8 - 6.8	5.91
Spore width	7.2 - 10.4	8.76
Polar capsule diameter	2.6 - 3.4	3.18
Polar filament length	36.8 - 52.6	43.75

Systematic position : Genus *Neobipteria* Kovaliova, Gaevskaya and Krasin (1986) is characterised by the presence of oval spores with median keel like membranes and wing-like appendages on the anterior surface of the spore valves. The present form has both the keel like appendages and anterior wing-like extensions of the spore valves. The only species, known so far is *N. macrouri*, from a macrourid fish *Coryphaenoides acrolepis* in Bering Sea and Kuri Island area. Taxonomically, it is different from the present form in its larger spore size (13.3 - 14.4 x 14.6 - 17.3 µm). Polar capsule diameter: 6-6.5 µm and longer polar filaments length: 88 µm.

In view of the distinct differences in the spore morphometrics, so important for taxonomic differentiation of species of myxosporidia and on the basis of the species' new locality and its record occurrence in *Nemipterus mesoprion* in the Bay of Bengal, the form is considered new to science for which the name *Neobipteria coramandelensis* n. sp. is proposed after the Coramandel coast, where it occurred.

Leptotheca apogoni n. sp.

Hosts	:	*Apogon aureus* *Nemipterus japonicus*
Site of infection	:	Gall bladder
Locality	:	East coast of India, Bay of Bengal Lat. 19°52'2"N Long. 86°26'5"E
Depth	:	75 m

Incidence : Six out of 14 *Apogon aureus* and two out of 10 *Nemipterus japonicus* collected on 15-7-'88 were infected. Intensity of infection moderate.

Spores (Figs. 10, 11 and 12): Hemispherical or at time trapezoidal. Anterior end broad and flattened. Posterior end bluntly oval. Shell valves lightly stained, thick and transversely striated. Sutural ridge prominent, clearly seen near the posterior margin. Polar capsules spherical; one on either side of the sutural ridge. Polar filament coiled, watch-spring like while inside the capsule. Two uninucleate oval sporoplasms; one on either side of the sutural ridge. Cytoplasm alveolar. Polar filament thick and short.

Pansporoblasts : Disporous.

Pathogenicity : Gall bladder visibly hardened and discoloured.

Spore dimensions (n=30)	Range (µm)	Mean (µm)
Spore length	16.8 - 18.2	17.56
Spore width	24.6 - 26.2	25.40
Polar capsule diameter	2.4 - 4.2	3.8
Polar filament length	22.0 - 28.0	24.82

Systematic position: Although as many as 50 species of *Leptotheca* have been reported from different parts of the world, only 3 species, namely *Leptotheca latesi* Chakravarty (1943) from *Lates calcarifer* gall bladder, *Leptotheca macronesi* Chakaravarty (1943) from *Mystus gulio* gall bladder, and *L. asymmetrica* Lalitha Kumari (1969) from gall bladder, gill and intestine of *Osteochilus neilli* are known from the Indian sub-continent. In comparison, the spore size in the present form is larger (mean 17.56

x 25.4µm) than the above 3 species where it is 10.3 - 12.4 x 6.2 µm in *L. latesi*, 10.0 - 14.0 x 6.2 - 7.2 µm in *L. macronesi* and 6.8 x 9.4 µm in *L. asymmetrica*. Besides, the spore has no morphological resemblance. However, the form appears closest to *L. elegans* Noble, 1938 noticed in *Gibbonsia elegans elegans* collected from California coast on account of its spore dimension (17 x 9 µm) but appreciably differs from it in the spore shape with a broader, flat anterior end assuming a trapizodial form. Secondly, the spherical polar capsules in the present species are comparatively larger (3.8 µm) than in *L. elegans* (3 x 2.2 µm). The present finding of *Leptotheca* in *Apogon aureus* and *Nemipterus japonicus* is the first report of the species from marine fishes. In view of this and other criteria mentioned above, particularly the morphological characteristics, the present species is considered new to science for which the name *Leptotheca apogoni* n. sp. after the host is proposed.

Ceratomyxa sagarsampadae n. sp.

Host	:	*Cynoglossus sp.*
Site of infection	:	Gall bladder
Locality	:	East coast of India, Bay of Bengal Lat. 15°58'N Long. 81°31'E
Depth	:	330 m

Incidence : Eight out of 23 *Cynoglossus* collected on 10-7-88 were infected. Intensity of infection moderate.

Spores (Figs. 13 and 14): Coelozoic, transversely elongated and hat-shaped. Spore-wall thick, smooth. Sutural line wavy. Polar capsules spherical, slightly away from the apex. Polar filaments form 6-7 coils while inside capsule one wound in clockwise and the other in anticlockwise direction. No parietal folds or intercapsular ridges. Sporoplasm binucleate extending below the capsule in the entire extra capsular region. Nuclei vesicular with irregular masses of chromatin. Cytoplasm hyaline. Polar filaments thin, uniformly stained and both the filaments extruded through a common foramen forming a cross (x).

Pansporoblasts : Disporous.

Pathogenicity : No apparent pathogenicity.

Spore dimension (n=30)	Range (µm)	Mean (µm)
Spore length	14.2 - 18.4	16.2
Spore width	68.6 - 82.4	74.2
Polar capsule diameter	8.4 - 9.86	8.52
Polar filament length	48.0 - 68.4	59.76

Systematic position: Among the coelozoic myxosporidia, the genus *Ceratomyxa* is probably the most prevalent in marine fishes infecting gall and urinary bladders. They are characterised by a hollow spore with conical shell valves of breadth more than twice the sutural diameter. Altogether 5 species, namely, *Ceratomyxa hilsae* Chakravarty, 1939 in *Hilsa ilisha*, *C. gobioides* Chakravarty, 1939 in *Odontamblyopus rubicundus*, *C. scatophagi* Charkaravarty, 1943 in *Scatophagus argus*, *C. sagarica* Chaudari and Nandi, 1973 in *Boleophthalmus boddarti* and *C. tartoori* Sarkar, 1986 in *Opisthopterus tardore* have been so far reported among fishes from India. An examination of the available literature on the spore morphology of these parasites showed that the present species resembles closely *Ceratomyxa anoplopoma* (Moser, 1976) observed in *Anoplopoma fimbria* whose spore dimensions are 65.0 - 70.0 x 17.0 - 25.0 µm, but differs from it in possessing hat-shaped spores with wavy sutural line and two large spherical polar capsules. Further, the polar filaments in this species are characteristically extruded through a common foramen forming a cross (x) at the spore apex. Finally, the occurrence of this species in an altogether new host, namely, *Cynoglossus* sp. which is demersal in nature, together with its morphological differences from the rest of the species, justified its consideration as a new species and therefore named *Ceratomyxa sagarsampadae* n. sp. after FORV *Sagar Sampada*, the research ship.

Ceratomyxa dissimilaris n. sp.

Host	:	*Nemipterus mesoprion*
Site of infection	:	Gall bladder
Locality	:	East coast of India, Bay of Bengal Lat. 18°40.5'N Long. 84°21'E
Depth	:	140 m

Incidence : Four out of nine *Nemipterus mesoprion* collected on 16-7-'88 were infected. Incidence of infection low.

Spores (Figs. 15-16): Coelozoic, found floating in the bile, spores transversely elongated with slightly bent oval ends. Spore valves thin, smooth. Sutural line straight. Shell valves unequal, left being always smaller than right valve. Polar capsules spherical, unequal. Polar filaments from 3 or 4 coils inside the capsule. Sporoplasm irregular binucleate with numerous eosinophilic granules extended into lateral arms usually displaced towards the larger valve. No parietal folds or inter capsular ridges. Polar filaments thin, unequal.

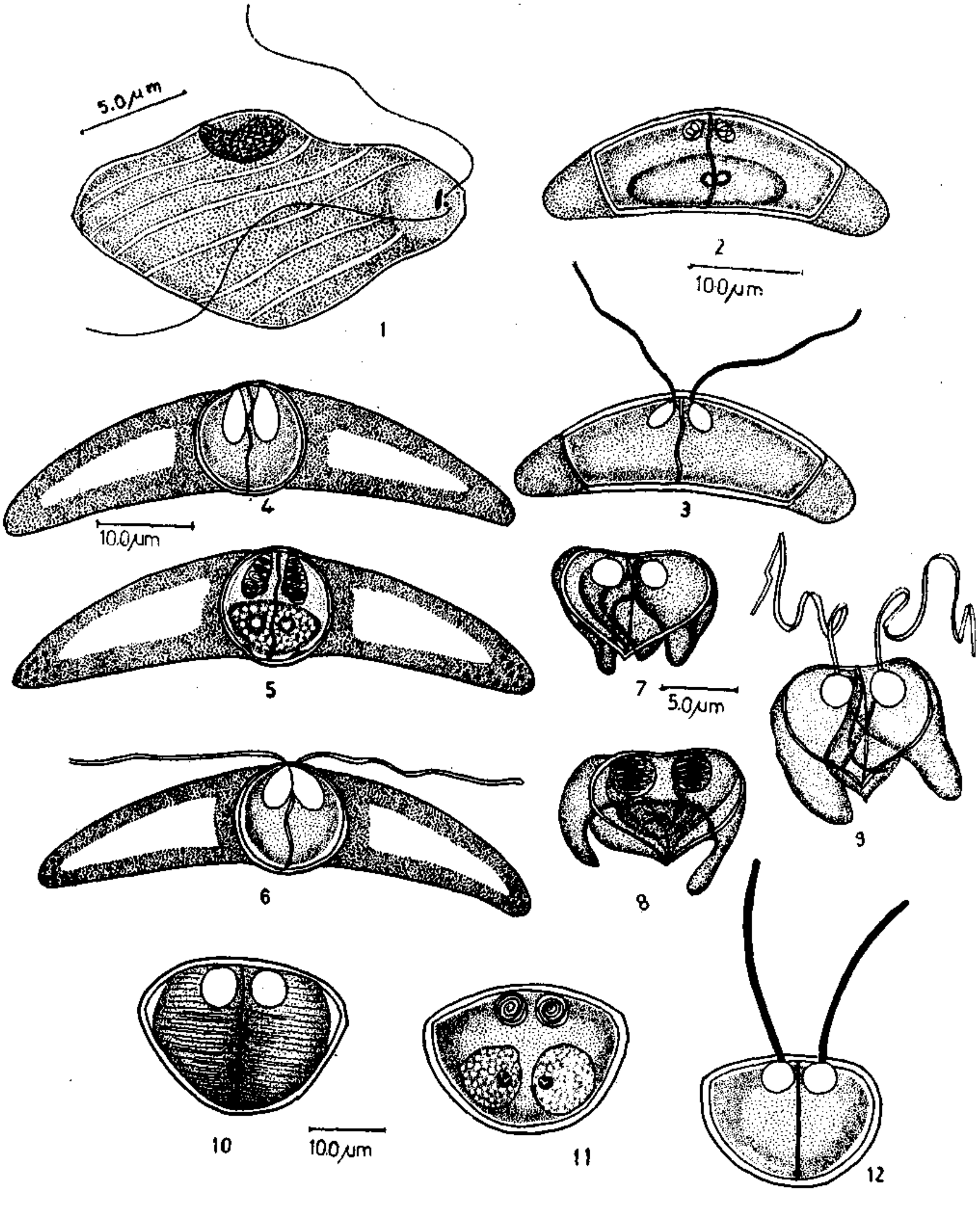


Fig.1 : *Trypanoplasma parastromataei* n. sp.; Figs. 2-3. *Davisia sauridae n.* sp. : 2. Spore stained with Giemsa, 3. Spore with extruded polar filament; Figs. 4-6. *Davisia cynoglossi n.* sp. : 4. Fresh spore, 5. Spore stained with Giemsa, 6. Spore with extruded polar filament; Figs. 7-9. *Neobipteria coramandelensis* n. sp. : 7. Fresh spore, 8. Spore stained with Giemsa, 9. Spore with extruded polar filament; Figs. 10-12. *Leptotheca apogoni* n. sp. : 10. Fresh spore, 11. Spore stained with Giemsa, 12. Spore with extruded polar filament.

Pansporoblasts : Mono or di-sporous.

Pathogenicity : No apparent pathogenicity.

Spore dimension n=30	Range (μm)	Mean (μm)
Spore length	9.2 - 11.8	10.36
Spore width	36.4 - 45.8	41.6
Spore valve (left)	17.6 - 22.4	19.2
Spore valve (right)	20.8 - 26.8	22.4
Polar capsule (small)	2.4 - 3.8	3.56
Polar capsule (large)	3.0 - 5.2	4.82
Polar filament (short)	24.4 - 32.2	28.6
Polar filament (large)	34.8 - 38.4	36.2

Systematic position: The present species of *Ceratomyxa* is characterised by the presence of asymmetrical spore valves with bent ends, unequal polar capsules and polar filaments. Instances of such dissimilar nature have been reported earlier in *C. globulifera* Thelohan, 1895 found in *Merluccius merluccius*, *C. inaequalis* Doflein, 1898 in *Crenilabrus mediterraneus*, *C. ramosa* Awerinzew, 1908 from *Hippoglossus vulgaris*, *C. drepanopsettae* Awerinzew, 1908 from *Pleuronectes platessa*, *C. attenuata* Davis, 1917 from *Scoliodon terrae novae*, *C. agglomerata* Davis, 1917 from *Synodus foetans*, *C. amorpha* Davis, 1917 from *Synodus*, *C. asymmetrica* Moser and Noble, 1976 from *Coryphaenoides cinereus*. In all the above examples, there is, however, no asymmetry in the spore organelles such as unequal polar capsules and polar filaments as is characteristic of the present form. Further, the irregular mass of sporoplasm in the present species showed eosinophilic granules throughout, displaced always towards the larger valve.

In view of the organism's specific asymmetry observed all through the spore organelles coupled with its occurrence in altogether new host, *Nemipterus mesoprion* and locality (east coast of India, Bay of Bengal), the species is considered new to science and the name *Ceratomyxa dissimilaris* n. sp. is proposed.

Auerbachia chakravartyi n. sp.

Host	:	*Megalaspis cordyla*
Site of infection	:	Gall bladder
Locality	:	East coast of India, Bay of Bengal Lat. 19°52'N Long. 85°26'E
Depth	:	75 m

Incidence : one out of five *Megalaspis cordyla* collected on 15-7-'88 was infected. Intensity was high. Both pansporoblasts and spores were found floating freely in the bile.

Spores (Figs. 20, 21): Broadly oval, spatula shaped with a beak like spore apex. Anterior end sharply pointed, posterior end drawn out into blunt caudal prolongation just beneath polar capsule. Sutural ridge not clear. Spore valves thin. Polar capsules single pyriform, generally shifted to a side opening near the spore apex. Capsular foramen at the tip of the beak like extension of the spore body. Polar filament coiled longitudinally forming 2 or 3 turns. Sporoplasm posterolateral to the polar capsule, often only in main body, but occasionally extending into the hollow caudal process. Sporoplasm uninucleate. Iodinophilous vacuole absent. Polar filament when fully extruded short and club shaped.

Pansporoblasts : Mono or di-sporous.

Pathogenicity : No apparent pathogenicity.

Spore dimension (n=30)	Range (μm)	Mean (μm)
Total length of spore	14.0 - 21.0	17.83
Width of spore	7.0 - 9.8	7.92
Length of spore body	8.4 - 12.6	10.22
Length of caudal process	5.6 - 9.8	8.5
Length of polar capsule	5.6 - 9.8	8.31
Length of sporoplasm	5.8 - 10.6	9.21
Width of sporoplasm	3.8 - 5.4	4.28
Length of polar filament	18.6 - 22.8	20.82

Systematic position : Genus *Auerbachia* Meglitsch (1968) is poorly known among the myxosporidians of deep-sea fish which remained practically static after the first discovery. So far only 3 species, namely *A. anomala* Meglitsch, 1968 in *Genyplerus blacodes*; *A. monstrosa* Meglitsch, 1968 in *Coelorinchus australis*, *A. pulchra* Lom, Noble and Laird, (1975) in *Coelorinchus coelorinchus* all from gall bladders, were described. The present species noticed in *Megalaspis cordyla* also in the gall bladder has not shown any resemblance to any of the above 3 species on account of the differences between its spore size (17.33 x 7.92μm), and others namely *A. anomala* (22.4 x 8.8 μm), *A. monstrosa* (25.2 x 9.5 μm) and *A. pulchra* (24.0 x 17.6 μm). Further, the spatula shaped spores with a beak - like apex seen in the present form appear to be specific to the species, which character distinguishes it from others.

In view of the above and differences in its spore morphometrics and also taking into account the species' first occurrence in Bay of Bengal in an altogether new host *Megalaspis cordyla*, a truly pelagic fish, the present species is considered new to science for which the name *Auerbachia chakravartyi* n. sp. is proposed after Late Prof. M.M. Chakravarty a renounced protozoologist in India.

Thelohanellus parastromataei n. sp.

Host	:	*Parastromataeus niger*
Site of infection	:	Gall bladder
Locality	:	East coast of India, Bay of Bengal Lat. 20°00'N Long. 86°46'E
Depth	:	60 m

Incidence : Three out of six*Parastromataeus niger* collected on 14-7-'88 were infected. Intensity of infection low.

Spores (Figs. 17, 18, 19) : Oval or pyriform. Anterior end narrow. Posterior end broadly rounded. Spore valves smooth. Sutural line thin straight-headed in appearance. Two or three parietal folds at antero-lateral regions. Polar capsule single, deeply stained occupying the spore cavity almost entirely. Polar filament showed characteristic double rows of coiling (Fig. 18) while inside capsule. Sporoplasm binucleate compressed into a narrow cup shaped strip in posterior region. Iodinophilous vacuole elongated, always displaced to a side. Nuclei vesicular with dispersed chromatin. Polar filament long, flat and ribbon like.

Pansporoblasts : Not observed.

Pathogenicity : No apparent pathogenicity.

Spore dimension (n=30)	Range (µm)	Mean (µm)
Spore length	10.75 - 12.04	11.18
Spore width	8.6 - 10.32	9.46
Polar capsule length	7.74 - 9.03	8.6
Polar capsule width	6.45 - 7.31	6.88
Polar filament length	78.26 - 85.41	81.7

Systematic position : Of the 21 species of *Thelohanellus* Kudo, 1933, reported so far from fishes in India, only 2 species namely, *T. coeli* Sarkar and Mazumdar, 1983 in *Tachysurus tenuispinis* and *T. auerbachia* Sarkar, 1987 in *Tachysurus platystomus* both from gall bladers were of marine origin. The record of the present new species in *Parastromataeus niger* is the third instance of the genus *Thelohanellus* to occur in a fish collected from the marine environment. It differs considerably from the rest of the species both in its structure and morphometry. In the present species, the slightly bent curved neck like anterior region of the spore and the conspicuous sutural ridge noticed in *T. coeli* are not seen.

The other parasite *T. auerbachia* has a larger spore size (14.85 x 5.35 µm) than observed in the present form (11.8 x 9.46 µm). *T. auerbachi a* also has a subterminal capsular foramen. The beaded appearance of the sutural line and double folding of the polar filament appear to be unique to the present species.

In view of these distinct features and its association with *Parastromataeus niger*, the present species is considered new to science for which the name *Thelohanellus parastromataei* n. sp. is proposed.

Phylum : Microspora

Class : Microsporea

Loma sp. I.

Host	:	*Tricropterus*
Site of infection	:	Intestine
Locality	:	East coast of India, Bay of Bengal Lat. 15°58'N Long. 81°31'E
Depth	:	330 m

Incidence : One out of two *Tricropterus* examined on 10-7-'88 was infected. Intensity of infection low.

Xenoma : 0.25 - 0.5 mm, milky white. Embeded in the intestinal muscles tissue.

Spores (Figs. 22, 23): Pyriform. Anterior end sharply pointed. Posterior end bluntly rounded 4.8 - 6.87 (5.78) x 3.6 - 5.6 (4.2) µm in size. Polar cap dot like deeply stained at anterior apex. Polaroblast clear, refractile. Sporoplasm oval, in posterior region. Single vesicular nucleus. No posterior vacuole. Polar filament thin uniformly stained, 85-100 µm long.

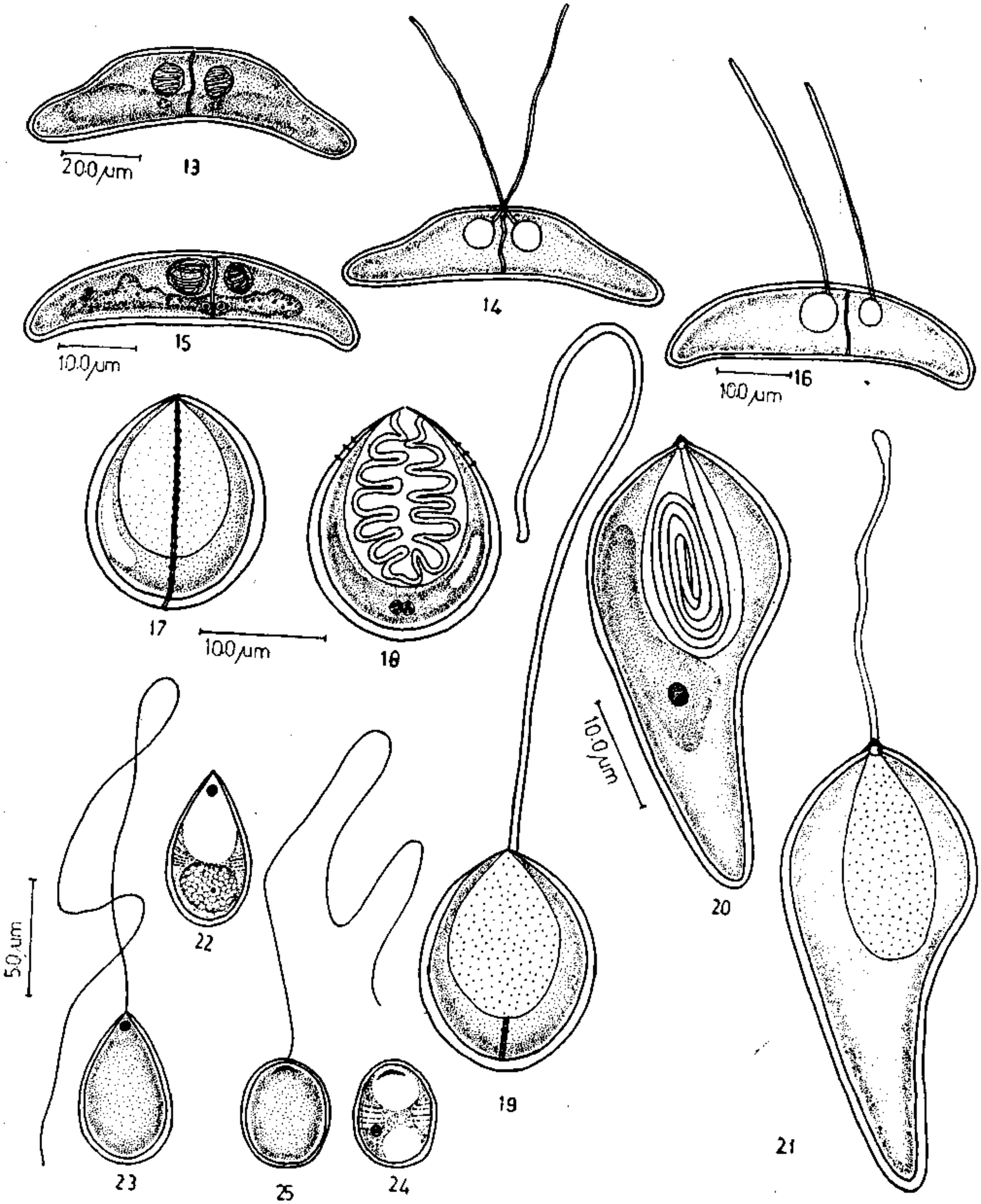
Loma sp. II

Host	:	Unidentified sciaenid
Site of infection	:	Visceral peritoneum
Locality	:	East coast of India, Bay of Bengal Lat. 15°58'N Long. 81°31'E
Depth	:	330m

Incidence : One out of six sciaenids collected on 10-7-'88 was infected. Intensity very low.

Xenoma : 0.5 - 2.0 mm attached to peritoneum in the viscera near intestinal region.

Spores (Figs. 24, 25): Oval with rounded ends and refringent wall 3.8 - 5.6 (4.5) x 2.8 - 4.2 (3.65) µm in size. Polar cap crescent shaped, sub-terminal. Polaroblast small, posterior vacuole eccentric. Spo-



Figs. 13-14. *Ceratomyxa sagarsampadae* n. sp. : 13. Spore stained with Giemsa, 14. Spore with extruded polar filament; Figs. 15-16. *Ceratomyxa dissimilaris* n. sp. : 15. Spore stained with Giemsa, 16. Spore with extruded polar filament; Figs. 17-19. *Thenohanellus parastromataei* n. sp. : 17. Fresh spore, 18. Spore stained with Giemsa, 19. Spore with extruded polar filament; Figs. 20-21. *Auerbachia chakravartyi* n. sp. : 20. Spore stained with Giemsa, 21. Spore with extruded polar filament; Figs. 22-23. *Loma* sp. I : 22. Spore stained with Giemsa, 23. Spore with extruded polar filament; Figs. 24-25. *Loma* sp. II : 24. Spore stained with Giemsa, 25. Spore with extruded polar filament.

roplasm band-like between polaroblast and posterior vacuole. Vesicular nucleus eccentric. Polar filament uniformly thin 75 - 92.4 μm long.

Systematic position: Morrison and Sprague, 1981 established the genus *Loma*, to accommodate fish microsporidia which are characterised by the formation of *Xenoma*, a host-parasite symbiotic complex and uninucleate isolated spores. While there were many subsequent descriptions of the species of *Loma* from other countries, in India there has been only a single report on this genus, *L. trichiuri* noticed over the gills of *Trichiurus savala* (Sandeep and Kalavati, 1985) so far. The two species encountered in the present study are assigned to genus *Loma* following the generic characteristics namely the uninucleate, single spores found in *Xenoma*. Recent advances in microsporidiology specify examination of organelle characters through electron microscopy for proper species diagnosis. In the present study these aspects of the parasites require finalisation owing to which their specific identity could not be established.

In conclusion, the present study revealed that even the deep water inhabiting fish had moderately high prevalence of infection as is the case with littoral waters (<50 m). Among the 5 major taxa of protozoans which infected fish, namely, Mastigophora, Coccidia, Myxozoa, Microspora and Ciliophora, the myxozoans appeared to be the most widely distributed with exceptionally high diversity. They were organ specific being parasites of gall bladder throughout. Of the 11 new species of myxozoans reported, 10 species were host specific. It is noteworthy that primitive species of myxozoa such as *Auerbachia, Davisia, Leptotheca* and *Ceratomyxa* appeared more dominant among the deep water fish collected during the study. Kovaliova and Schulman (1987) made similar observations in fishes in the Atlantic and Pacific oceans and threw light on the phylogeny and evolutionary aspects of these organisms. In the Indian context, comparable results have been obtained in the present study.

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APPENDIX

Classified list of new species of the protozoan parasites encountered in the present study

Phylum : Sarcomastigophora
Class : Mastigophora
Order : Kinetoplastida
Species :
Trypanoplasma parastromataei n. sp.
Phylum : Myxozoa
Class : Myxosporea
Order : Bivalvulida
Family : Sinuolinidae
Species :
Davisia sauridae n. sp.
Davisia cynoglossi n. sp.
Neobipteria coramandelensis n. s
Family : Ceratomyxidae
Species :
Leptotheca apogoni n. sp.
Ceratomyxa sagarasampdae n. sp.
Ceratomyxa dissimilaris n. sp.
Family : Auerbachidae
Species:
Auerbachia chakravartyi n. sp.
Sub order : Platysporina
Family : Myxobolidae
Species :
Thelohanellus parastromataei n. sp.

Phylum : Microspora
Class : Microsporea
Order : Microsporida
Genus : *Loma* sp. I
Loma Sp. II

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RESULTS OF BOTTOM TRAWLING BY FORV *SAGAR SAMPADA* WITH SPECIAL REFERENCE TO CATCH AND ABUNDANCE OF EDIBLE CRUSTACEANS

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Abstract

A detailed study of the crustacean components of the trawl catches taken by FORV *Sagar Sampada* between 30 and 450 m depth during cruises 1 to 50, (February , 1985 to August, 1988) has been carried out. Analysis of the catches of 378 trawl hauls spread over the entire coast line of India reveals that the existence of appreciable quantities of edible crustaceans which could be commercially exploited beyond the conventional fishing grounds, is highly localised and depth-specific. The productive areas for prawns, lobsters and crabs as revealed by the survey have been indicated, together with information on important species and their sizes. On the west coast, the coastal prawn *Parapenaeopsis stylifera* ('Karikkadi') has been encountered in varying densities in the offshore waters upto 53 m depth during the southwest monsoon period almost as a continuous belt between Quilon and Marmagoa. Commercial exploitation of this offshore stock of 'Karikkadi' during the monsoon period is worth attempting throughout the west coast. The abundance of the sand lobster *Thenus orientalis* at 40-75 m depth off Veraval to Dwaraka and Kanyakumari to Alleppey and that of the deep-sea crustaceans in the southwestern region offers scope for commercial fishing.

Introduction

Lack of adequate information on the availability and extent of commercially exploitable resources beyond the conventional fishing grounds has been a major constraint for the development of deep-sea fishing in Indian waters. Deep-sea fishing being highly capital intensive, the main concern of the entrepreneurs is to catch exportable varieties of resources which would bring in sufficient foreign exchange and sustain the industry. Among the various marine living resources, crustaceans are much sought after on account of their high export value and as such any indication of their occurrence in commercial quantities outside the presently exploited zone would be encouraging to the fishing industry.

The exploratory fishery surveys conducted by the Government of India vessels in the past have demonstrated exploitable stocks of crustaceans in the shelf waters of Indian coasts, the details of which are described by George *et al.* (1963), Kagwade (1967), Rao and Dorairaj (1969), Rao (1973), Pai and Pillai (1973), Sekharan *et al.* (1973) and Muthu *et al.* (1975) to mention a few. Occurrence of deep-sea crustaceans in appreciable quantities beyond the continental shelf has also been reported by Kurian (1965), Silas (1969), Mohamed and Suseelan (1973), Suseelan (1974, 1985), Oommen (1980) and James (1987) from the southwest coast and Gulf of Mannar.

FORV *Sagar Sampada* has been conducting bottom trawling in the Indian EEZ eversince she was commissioned for fishery-oceanographic surveys along the Indian coasts. This has yielded valuable data to throw light on the fishery potential of the offshore waters hitherto unexploited or underexploited. The present paper deals with the results of a detailed analysis of the crustacean components of the catches taken by bottom trawls during cruises 1 to 50 from February, 1985 to August, 1988.

Material and Methods

The catch and effort data of 378 trawl hauls taken between 30 and 450 m depth spread over the entire coast line of India covering the continental shelf and upper continental slope have been examined for the edible crustacean groups such as prawns, lobsters and crabs. Catch composition and biological aspects of important species constituting the catch in different regions of the coast were studied by analysing 112 samples taken onboard the vessel, haul-wise.

Analysis of the catch and effort data was made depthwise for each of the 1° - latitude zones of the west and east coasts demarkated by the 77°30'E longitude line. The catch data were then compiled against trawling effort for the four major regions, namely South-Western Region, North-Western Region, South-Eastern Region and North-Eastern Region demarkated by the 15°N latitude line. For depthwise analysis of data the entire depth region between 30 and 450 m was divided into the following six depth zones.

Depth zone	1	:	30- 50	m
Depth zone	2	:	51-100	m
Depth zone	3	:	101-200	m
Depth zone	4	:	201-300	m
Depth zone	5	:	301-400	m
Depth zone	6	:	401-450	m

Results and Discussion

The distribution of trawling stations occupied by *Sagar Sampada* is shown in Fig. 1. Tables 1 to 5 also furnish details of the trawling effort and catch returns of edible crustaceans in different regions of the Indian coasts.

Out of the 378 hauls, which involved a total effort of 339 hours of actual trawling, 317 hauls were attempted on the shelf region (30-200 m) and 61 hauls on the upper continental slope (201-450 m). The duration of each haul varied between 0.25 and 2.17 hours depending on bottom conditions and other factors. In general, the decapod crustaceans were less abundant in the offshore waters although in certain pockets they occurred in fairly good concentrations worth considering for commercial exploitation. The productive areas of prawns, lobsters and crabs as revealed by the present survey are indicated in Fig. 2.

South-Western Region

This region comprises the coasts of Kerala and Karnataka states and the Kanyakumari district of Tamilnadu. The continental shelf of this region is much narrower than that of the northern part of the west coast and is highly influenced by upwelling during the monsoon period. The upper continental slope drops suddenly in most parts except off Quilon where it forms an extensive bank upto a depth of about 375 m which is commonly referred to as the 'Quilon Bank'. Two other important submarine banks namely, the 'Chettuva Bank' (Oommen, 1974) and the 'Wadge Bank' also occur in this region and they have good trawling grounds.

A total of 169 bottom trawl operations were made in this region expending 138 hours of actual trawling. Of these, 115 hauls were taken on the shelf and 54 on the upper continental slope. In the total number of hauls, 100 hauls were negative for crustaceans. The maximum frequency (89 %) of negative hauls was recorded in the 51-100 m depth zone. In the positive hauls the amount of crustaceans varied from 0.1 to 1,080 kg/hr.

Out of a total quantity of about 2,900 kg of crustaceans recorded from this region, prawns accounted 1,877 kg (64.7%), lobsters 318 kg (11.0%) and brachyuran crabs 706 kg (24.3%).

Prawns

Prawns were recorded in varying degrees of abundance in all the depth zones except zone 6 where the sampling was extremely poor (Table 1). Littoral penaeids, whose catch varied highly with depth, were encountered in depth zones 1 and 2. *Parapenaeopsis stylifera* ('Karikkadi Chemmeen') was the only species represented in the catch from depth zone 1, and it was caught almost throughout the Kerala and Karnataka coasts north of Quilon during the southwest monsoon period (Table 2). Its catch rate worked out to 1-53 kg/hr with the highest production between 40 and 50 m depth off Quilon. In depth zone 2, the meagre catch recorded was constituted by *Penaeus canaliculatus*, *P. semisulcatus* and *Trachypenaeus* spp. The nonconventional penaeid prawns of the genus *Metapenaeopsis* (*M. coniger* and others) accounted for the major portion of the catch from the outer continental shelf coming under depth zone 3. The upper continental slope provided an entirely different picture of faunistic composition in which members of all the deep-sea penaeidean families (Solenoceridae, Aristeidae and Penaeidae) and the caridean prawns of family Pandalidae were represented commonly. In depth zone 4, the important species in the order of abundance were *Plesionika spinipes* (60.5%), *Penaeopsis jerryi* (26.3%), *Solenocera hextii* (5.6%), *Metapenaeopsis andamanensis* (3.7%) and *Heterocarpus woodmasoni* and *H. gibbosus* (2.7%). The relative abundance of the various species changed considerably in depth zone 5 where the major components in the order of importance were *H. woodmasoni* and *H. gibbosus* (44.1 %), *Plesionika spinipes* (35.3%), *P. martia* and *P. ensis* (7.9%), *P. jerryi* (5.7%), *Aristeus alcocki* (3.4%) and *M. andamanensis* (2.7%). Suseelan (1985, 1988) has dealt with in detail the systematics, biology and bathymetric distribution and abundance of the deep-sea prawns of this region based on the results of earlier exploratory surveys. The present analysis of the catches of *Sagar Sampada* has shown that commercially exploitable stocks of deep-sea prawns exist as a narrow belt extending

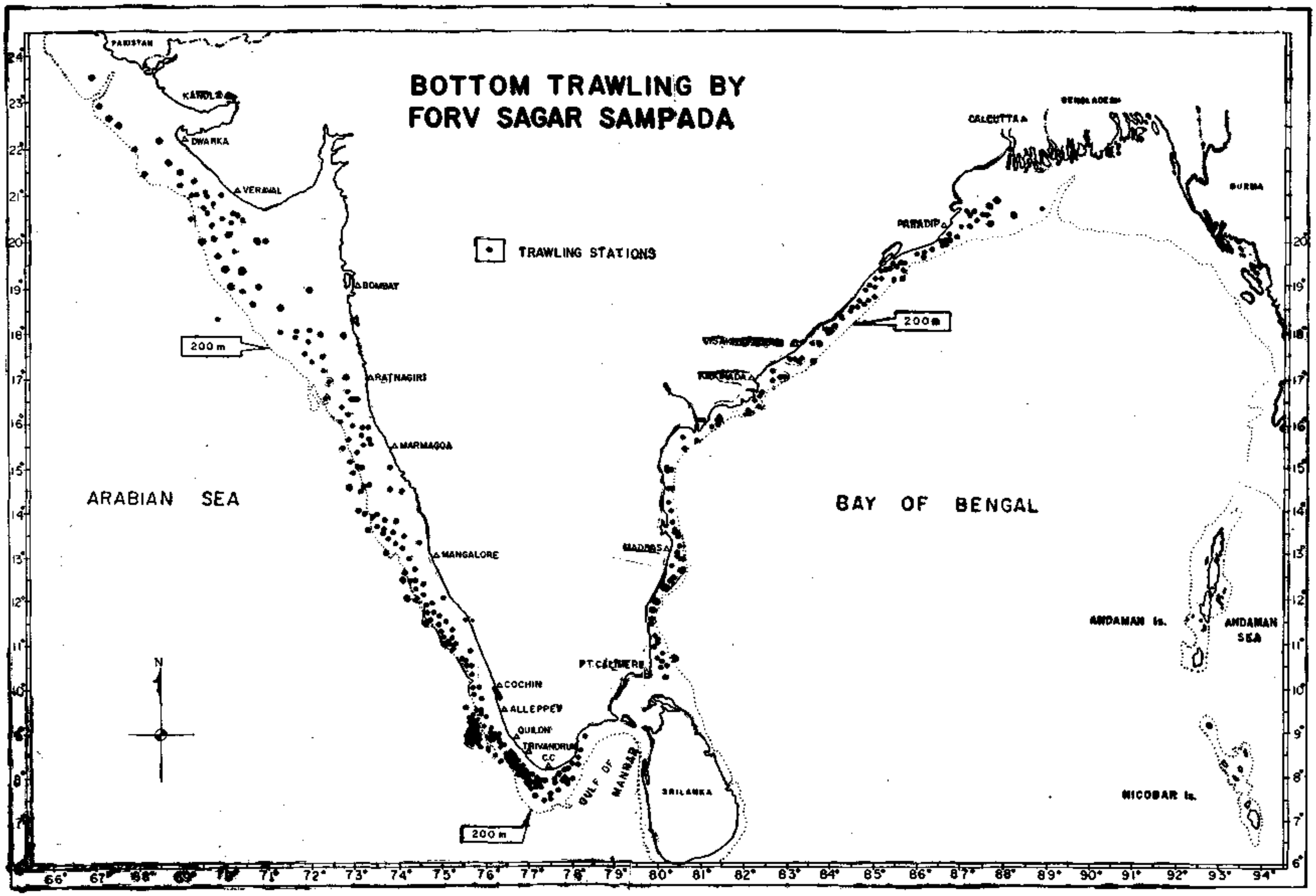

Fig. 1. Distibution of trawling stations of FORV *Sagar Sampada*.

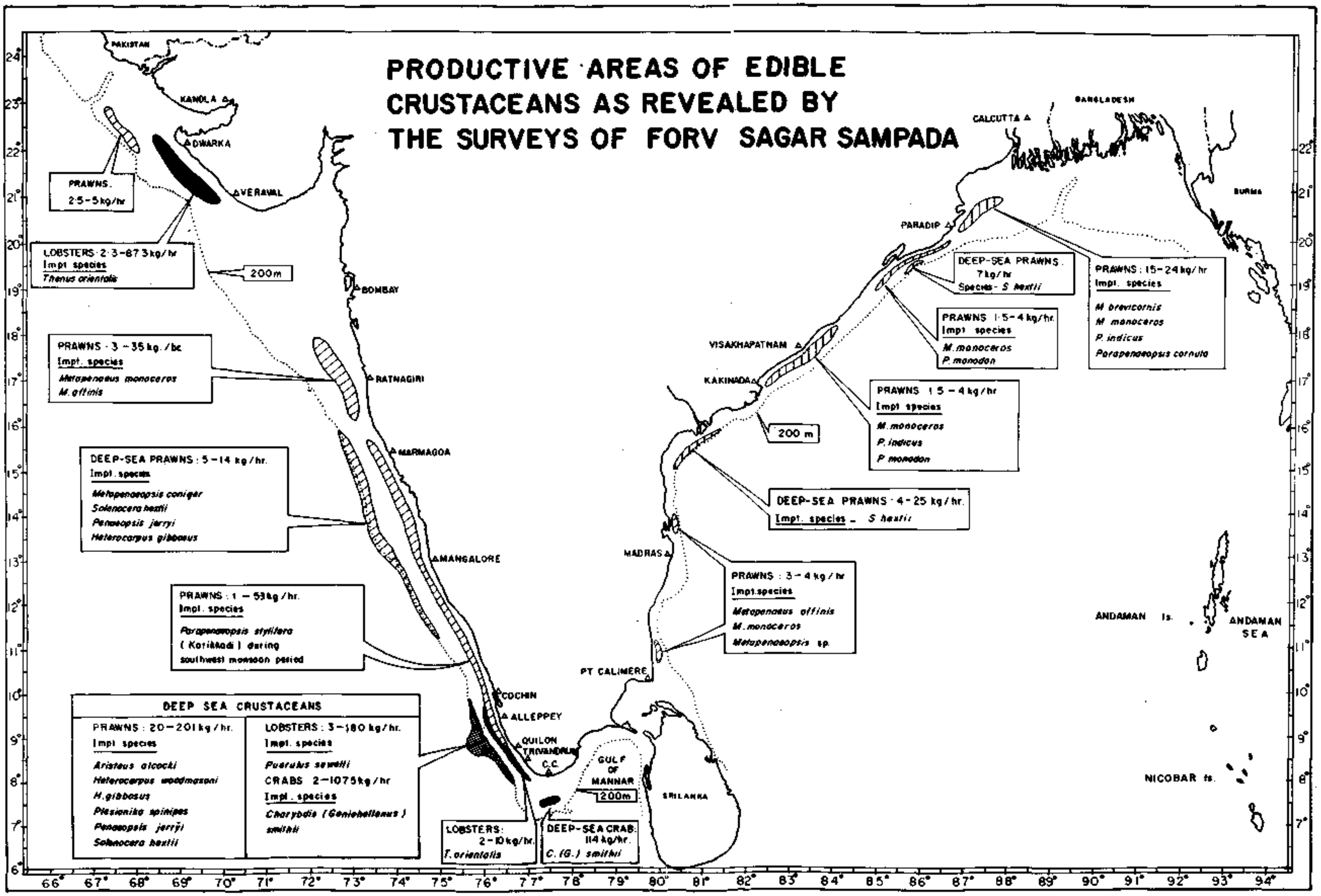

Fig. 2. Productive areas of edible crustaceans as revealed by bottom trawling of FORV *Sagar Sampada*.

TABLE 1. *Details of trawling operations, catch and catch/ hour of edible crustaceans by depth zones in the South - Western Region*

Particulars			Continental shelf			Upper continental slope			Total
			Depth zones						
			1	2	3	4	5	6	
Total No. of hauls			19	71	25	15	38	1	169
Total No. of trawling hrs			16.50	61.35	22.10	11.14	27.20	0.25	138.54
No. of negative hauls			13	63	17	4	2	1	100
No. of positive hauls			6	8	8	11	36	-	69
Catch and catch/hour in kg									
Prawns	-	C	57.5	2.9	10.2	297.0	1,509.8	-	1,877.4
		C/hr	3.5	-	0.5	26.7	55.5	-	13.6
Lobsters	-	C	-	29.2	-	151.0	137.7	-	317.9
		C/hr	-	0.5	-	13.6	5.1	-	2.3
Crabs	-	C	-	0.2	34.0	152.4	519.0	-	705.6
		C/hr	-	-	1.5	13.7	19.1	-	5.1
Total crustaceans		C	57.5	32.3	44.2	600.4	2,166.5	-	2,900.9
		C/hr	3.5	0.5	2.0	53.9	79.7	-	209.9

C = Catch, C/hr =Catch per hour.

from Cannanore to Marmagoa between 160 and 285 m depth (5-14 kg/hr), and in the Quilon Bank between 250 and 400 m depth (20-201 kg/hr). The important species occurring are *M. coniger, S. hextii, P. jerryi* and *H. gibbosus* in the former ground and *H. woodmasoni, H. gibbosus, P. spinipes, P. jerryi, A. alcocki* and *S. hextii* in the latter.

An interesting finding that has emerged from this survey is that *S. hextii* which enjoys a distribution throughout the west coast is represented by two different populations, each one being formed by a type distinctly different from the other in colour, size and other morphological features. One of these, is originally described by Wood-Mason (1891) from the Bay of Bengal and the other recorded by others from the Arabian Sea. Attaining about 155 mm in total length, this form has robust body which is more fleshy and appealing to the industry. It occurs mainly in the southern part of the southwest coast with maximum density in the Quilon Bank. The other form, which is being described as a new variety of the species in a separate communication, is a smaller one not exceeding 85 mm in total length. It has a thin and more reddish body, and is found to inhabit slightly shallower areas (160-285m) along with *M. coniger*. This variety of *S. hextii* is the most common along the coasts of Karnataka and Goa.

The size range of *P. stylifera* recorded during the monsoon period was 65-114 mm, but the bulk of the catch was constituted by the size groups 71-95 mm. Among females, which numbered about half of the population, mature specimens were extremely rare. The dominant sizes of the other important species of prawns were 61-70 mm for *M. coniger*, 81-105 mm for *P. spinipes*, 71-100 mm for *P. jerryi*, 101-120 mm for *H. woodmasoni*, 91-125 mm for *H. gibbosus*, 110-135 mm for *S. hextii* (Quilon Bank) and 136-170 mm for *A. alcocki*.

Lobsters

In the bottom trawls, lobsters were caught only in depth zones 2, 4 and 5. The sand lobster *Thenus orientalis* occurred at the rate of 2-10 kg/hr in depth zone 2 off Kanyakumari and Alleppey, with an average catch rate of 0.5 kg/hr. The deep-sea spiny lobster *Puerulus sewelli* was trawled in appreciable quantities (3-180 kg/hr) from depth zones 4 and 5 mainly between Kanyakumari and Alleppey.

The highest catch per haul was recorded in depth zone 4 (201-300 m) off Trivandrum. The size of this lobster ranged from 71 to 200 mm in total length, with the dominant size group 136-175 mm. Among females, which formed more than half of the catch by number, over 67% were in ovigerous state particularly during January-February period. The lobster was found to feed predominantly on deep-sea prawns, bivalves and fishes.

Crabs

The swarming crab *Charybdis* (*Goniohellenus smithii*) formed an important constituent of the catch in the offshore waters. It was recorded in depth zones 2 to 5 at catch rates varying from 2 to 1,075 kg/hr. The greatest concentration was observed in depth zones 4 and 5 between Trivandrum and Alleppey. The size of the crab ranged from 42 to 72 mm in carapace width. In most of the hauls females predominated, and among females majority were in ovigerous condition.

North-Western Region

This region includes the coasts of Goa, Maharashtra and Gujarat where the continental shelf is the widest with a maximum extent of about 350 km from the shore. The trawling operations in this region were mostly confined to the shelf waters particularly in depth zone 2. A total of 73 hauls were taken involving about 70 hours of trawling. Of this, 54 hauls did not yield any catch of crustaceans. In most of the positive hauls the amount of crustaceans recorded was very poor.

In the total crustacean catch of 147 kg realised from this region, prawns accounted 56 kg, lobsters 91 kg and crabs 0.4 kg (Table 3).

Prawns

Prawns were recorded from depth zones 1-4, with the highest yield in depth zone 2, where the average catch rate worked out to 1.1 kg/hr. Off Marmagoa, *P. stylifera* was caught in moderate numbers from the offshore waters (53 m depth) dur-

TABLE 2. *Occurrence and catch details of 'Karikkadi'* (P. stylifera) *in the offshore waters during the monsoon period*

Position (latitude)	Depth (m)	Coast	Month	Duration of haul (hours)	Catch (catch/hr)
9° 00' N	40	SW : Off Quilon	July, '87	0.75	40.0 kg (53.3 kg)
9° 05' N	49	SW : Off Quilon	June, '87	1.00	12.0 kg (12.0 kg)
12° 00' N	35	SW : Off Mangalore	June, '87	0.50	2.0 kg (4.0 kg)
12° 30' N	42	SW : Off Mangalore	July, '87	0.75	2.0 kg (3.0 kg)
13° 16' N	35	SW : Off Mangalore	June, '87	0.50	1.0 kg (2.0 kg)
14° 28' N	30	SW : Between Karwar and Marmagoa	July, '87	0.50	0.5 kg (1.0 kg)
15° 30' N	53	NW : North of Marmagoa	July, '87	0.75	0.5 kg (0.8 kg)

ing the southwest monsoon period (Table 2, Fig. 2). In still deeper areas fairly good catches of other littoral penaeids, such as *Metapenaeus monoceros* and *M. affinis*, were obtained off Ratnagiri (3-35 kg/hr) and Kandla (2.5-5 kg/hr). Rao (1973) recorded maximum catch rates for prawns between 41 and 65 m depth along the Bombay-Saurashtra coasts.

The size range of *P. stylifera* caught during the monsoon season was 60-89 mm for males and 60-109 mm for females. The major size constituting the population was 75-79 mm for both sexes. *M. affinis* and *M. monoceros* were represented by the size ranges 106-145 mm for the former and 105-180 mm for the latter.

Lobsters

The sand lobster *T. orientalis* and the spiny lobster *Panulirus polyphagus* were caught in depth zones 1 and 2, the former species in fairly good quantities (2-85 kg/hr) between 40 and 75 m depth off Veraval to Dwaraka. The size range of this species was 76-198 mm in total length, with the dominant size group of 101-115 mm.

Crabs

The catch of brachyuran crabs was negligible throughout the region.

The bottom trawling surveys conducted by M. T. *Muraena* between 55 and 360 m depth along this coast (Bapat *et al.*, 1982) have indicated average catch rates of 0.35 kg/hr in 55-90 m depth range, 0.03 kg/hr in 91-125 m depth range and 0.34 kg/hr in 126-360 m depth range for crustaceans comprising of prawns, lobsters and crabs, The total crustacean catch realised by this vessel for 247 hauls amounted to only 113 kg with minimum catch (4 kg) from 91-125 m depth range.

South-Eastern Region

This region extends from Kanyakumari to north of Nellur in Andhra Pradesh and includes the Gulf of Mannar, Palk Bay and the Coromandal coast. Off Kanyakumari, the 'Wadge Bank' continues eastwards. The shelf area is relatively less extensive and the continental slope plunges suddenly along the Coromandal coast.

Bottom trawling was conducted in the Gulf of Mannar and Coromandal coast only. A total of 58 hauls involving about 53 hours of trawling effort were made. Except for a single haul attempted in depth zone 6, the survey was almost entirely confined to the shelf waters. Most of the hauls (54) were taken within 100 m depth. In general the crustacean component was extremely poor in this region, the

TABLE 3. *Details of trawling operations, catch and catch/ hour of edible crustaceans by depth zones in the North-Western Region*

Particulars			Continental shelf			Upper continental slope			Total
			Depth zones						
			1	2	3	4	5	6	
Total No. of hauls			14	44	12	2	-	1	73
Total No. of trawling hrs			13.6	41.75	11.15	2.25	-	1.0	69.75
No. of negative hauls			11	32	9	1	-	1	54
No. of positive hauls			3	12	3	1	-	-	19
Catch and catch/hour in kg									
Prawns	-	C	0.6	46.7	8.5	0.2	-	-	56.0
		C/hr	-	1.1	0.8	0.1	-	-	0.8
Lobsters	-	C	81.2	9.8	-	-	-	-	91.0
		C/hr	6.0	0.2	-	-	-	-	1.3
Crabs	-	C	-	0.4	-	-	-	-	0.4
		C/hr	-	-	-	-	-	-	-
Total crustaceans		C	81.8	56.9	8.5	0.2	-	-	147.4
		C/hr	6.0	1.4	0.8	0.1	-	-	2.1

total catch recorded being 154 kg formed by prawns (37 kg) and crabs (117 kg) (Table 4). Moderate catches of prawns (3-4 kg/hr) predominantly constituted by *M. affinis*, *M. monoceros* and *Metapenaeopsis* spp. were observed in two pockets; one north of Pt. Calimere and the other off Pulicat Lake, between 30 and 50 m depth. A good haul of 25 kg of the deep-sea prawn *S. hextii* was also recorded for an hour of trawling between 170 and 180 m depth north off Nellur. The deep-sea crab *C. (G.) smithii* showed dense concentration (114 kg/hr) in the Wadge Bank area off Kanyakumari.

North-Eastern Region

This region includes most part of the Andhra coast and the coasts of Orissa and West Bengal. The narrow continental shelf extends upto about Paradip in the north and beyond that the shelf is much wider. The continental slope, however, takes a steep course throughout.

Bottom trawling was conducted in depth zones 1 to 4. Out of the total number of 78 hauls taken in this region, expending over 78 hours of actual trawling, 75 hauls were tried on the shelf and 3 on the upper continental slope. The survey was mainly restricted to depth zones 1 and 2. An important feature noticed in this region is that though the catches of crustaceans in individual hauls were relatively poor, fairly good percentage of positive hauls were recorded as in the South-Western Region.

The total crustacean catch from this region amounted to 222 kg (2.84 kg/hr) formed by crabs (145 kg), prawns (74 kg) and lobsters (3 kg) in the order of their abundance (Table 5).

Prawns

This group occurred in all the depth zones covered during the survey in varying quantities ranging from 0.1 kg to 24 kg per hour of trawling. Depth zone 1 registered maximum catch and catch rates. Moderate catches of littoral penaeids (15-24 kg/hr) chiefly constituted by *Metapenaeus lysianssa* and *M. monoceros* were recorded at 30-35 m depth off Paradip. Though in lesser quantities (1.5-4 kg/hr), prawns were also encountered more frequently off Chilka Lake and Visakhapatnam between 30 and 60 m depth. The deep-sea prawn *S. hextii* occurred in fair abundance on the shelf edge off Chilka Lake.

The major size groups of important species of prawns recorded from this region were 70-89 mm for *M. lysianassa*, 116-139 mm for *M. monoceros* and 55-69 mm for *S. hextii*.

TABLE 4. *Details of trawling operations, catch and catch/ hour of edible crustaceans by depth zones in the South-Eastern Region*

Particulars		Continental shelf			Upper continental slope			Total
		Depth zones						
		1	2	3	4	5	6	
Total No. of hauls		24	30	3	-	-	1	58
Total No. of trawling hrs		17.97	26.29	3.33	-	-	1.00	52.61
No. of negative hauls		19	27	2	-	-	1	49
No. of positive hauls		5	3	1	-	-	-	9
Catch and catch / hour in kg								
Prawns -	C	10.25	1.70	25.00	-	-	-	36.95
	C/hr	0.57	0.07	7.51	-	-	-	0.71
Lobsters -	C	-	-	-	-	-	-	-
	C/hr	-	-	-	-	-	-	-
Crabs -	C	3.50	114.00	-	-	-	-	117.50
	C/hr	0.20	4.34	-	-	-	-	2.23
Total crustaceans	C	13.75	115.70	25.00	-	-	-	154.45
	C/hr	0.77	4.40	7.51	-	-	-	2.94

TABLE 5. *Details of trawling operations, catch and catch/ hour of edible crustaceans by depth zones in the North - Eastern Region*

Particulars		Continental shelf			Upper continental slope			Total
		Depth zones						
		1	2	3	4	5	6	
Total No. of hauls		33	32	10	3	-	-	78
Total No. of trawling hours		31.67	32.21	9.25	4.00	-	-	78.13
No. of negative hauls		17	21	6	1	-	-	45
No. of positive hauls		16	11	4	2	-	-	33
Catch and catch/hour in kg								
Prawns -	C	51.95	9.05	8.35	4.30	-	-	73.65
	C/hr	1.59	0.28	0.90	1.07	-	-	0.94
Lobsters -	C	2.00	1.25	-	-	-	-	3.25
	C/hr	0.06	0.04	-	-	-	-	0.04
Crabs -	C	2.00	46.00	12.00	85.0	-	-	145.00
	C/hr	0.06	1.42	1.29	21.25	-	-	1.85
Total crustaceans	C	55.95	56.30	20.35	89.30	-	-	221.90
	C/hr	1.71	1.74	1.19	22.32	-	-	2.84

Lobsters

Stray catches of the sand lobster *T. orientalis* were recorded occasionally in depth zone 2.

Crabs

Brachyuran crabs formed a significant portion of the catch in several hauls and were represented in all the depth zones 1-4. The highest production was observed in the upper continental slope (201-250 m) off Visakhapatnam where small spider crabs yielded catch rates upto 85 kg/hr.

GENERAL CONSIDERATION AND RECOMMENDATIONS

The overall performance of bottom trawling conducted by FORV *Sagar Sampada* indicates that the existence of appreciable quantities of edible crustaceans which could be commercially exploited beyond the conventional fishing grounds is highly localised and depth-specific in most part of the Indian coasts. Among the potential stocks, the abundance of deep-sea crustaceans on the shelf edge and upper continental slope of the south-western region is encouraging for commercialised fishing. The sand lobster *T. orientalis* has assumed considerable importance in recent years as an export commodity. It contributes significantly to the lobster landings of Maharashtra and Gujarat states. The survey indicates good potential for this species between Veraval and Dwaraka in Gujarat where it could be tapped better at 40-75 m depth. The availability of a moderate population of the species between Kanyakumari and Alleppey also offers scope for commercial exploitation of the sand lobster along this coast.

A noteworthy feature observed on the west coast is the occurrence of *P. stylifera* in varying densities in the offshore waters upto 53 m depth during the southwest monsoon period (June and July) almost as a continuous belt between Quilon and Marmagoa. This species is basically a coastal species inhabiting areas within the 30 m depth contour. On the Kerala coast it is caught in enormous quantities during the southwest monsoon period by shrimp trawlers at centres like Cochin and Sakthikulangara (Quilon). Suseelan *et al.* (1988, 1989) have recently established by conducting experimental shrimp trawling off Cochin that during the southwest monsoon period *P. stylifera* migrates in large numbers to the offshore areas upto about 60 m depth as a result of upwelling, and is being caught by shrimp trawlers which venture into the high-seas during that period.

The present finding suggests that the offshore migration of 'Karikkadi' during the monsoon period may be taking place throughout the west coast and therefore commercial trawling to exploit this offshore stock is worth attempting throughout the coast.

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RESULTS OF AN EXCLUSIVE SURVEY FOR THE DEEP-SEA CRUSTACEANS OFF SOUTHWEST COAST OF INDIA

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Abstract

Southwest coast of India has great potential for development of deep -sea fishing for crustaceans. Earlier exploratory surveys have revealed the existence of commercially exploitable stocks of deep-sea prawns, lobsters and crabs along the Kerala coast and schemes are under way for their large scale exploitation. FORV *Sagar Sampada*, in her 40th and 42nd cruises, undertook a detailed survey of the resource characteristics of deep-sea crustaceans between Trivandrum and Ponnani during January-February, 1988 and the results are presented in this paper.

In the bottom trawls operated between 60 and 777 m depths, prawns formed sizable portion of the catch from the 'Quilon Bank', with maximum abundance (64-201 kg/hr) between 290 and 370 m depth. The multi-species catch consisted of appreciable quantities of large and medium sized species such as *Aristeus alcocki, Heterocarpus woodmasoni, H. gibbosus, Plesionika spinipes, Solenocera hextii* and *Penaeopsis jerryi* suggesting scope for their commercial exploitation and export. The deep-sea spiny lobster *Puerulus sewelli* recorded the highest yield (180 kg/hr) at 235-307 m depth off Trivandrum. Among other crustaceans, the swarming crab *Charybdis (Goniohellenus) smithii* was an important component registering maximum catch at 240-380 m depth off Alleppey. Information on sex ratios, size frequency and mean size distribution, abundance of breeding population etc., from different bathymetric zones have been provided for important species.

Introduction

The discovery of commercially exploitable stocks of crustaceans beyond the continental shelf off the southwest coast of India in the recent past has offered scope for deep-sea fishing to enhance production of shellfish. The deep-sea prawns and deep-sea lobsters, which have already proved to be sufficiently rich to support large scale exploitation along the coast, can contribute significantly to the seafood export industry of the country. As tapping of the potential resources of our seas has been assigned top priority in the national fishery development programmes, schemes are under way for commercial exploitation of the deep-sea crustaceans from the southwest coast. For judicious exploitation and management of this new resource, a thorough understanding of the population characteristics and biology of the constituent species is an essential prerequisite. Keeping this in view, two cruises of FORV *Sagar Sampada*, namely cruise No. 40 and 42 undertaken during January and February, 1988 were used for an intensive study of the deep-sea crustaceans off the Kerala coast by experimental fishing and the results are presented in this paper. The study was mainly aimed at furnishing details of the various species of prawns, lobsters and other useful crustaceans occurring on the upper continental slope, their relative abundance, size distribution, sex ratios, breeding population etc. which would serve as baseline information on their unexploited stock.

General accounts on the deep-sea crustacean resources of this coast have been given by Kurian (1965), Suseelan and Mohamed (1968), Silas (1969), Mohamed and Suseelan (1973), Suseelan (1974), Oommen (1980), James (1987) and Kathirvel *et al.* (1989) based on the results of exploratory fishing conducted by the erstwhile Indo-Norwegian Project and other agencies. Recently Suseelan (1985, 1988) has studied the bathymetric distribution and some aspects of the biology of important species of deep-sea prawns from this coast.

Details of Fishing

The study involved a series of bottom trawling using the High Speed Demersal Trawl (HSDT III) designed by the CIFT, Cochin. During Cruise 40, which extended from 1-1-1988 to 11-1-1988, a total of 20 trawling operations were conducted between 130 and 777 m depth off Cochin to Trivandrum

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between Lat. 08° 35'N to 09° 32'N and Long. 75° 33'E to 76° 15'E (Fig. 1). The cod-end mesh size of the net operated during this cruise was 22 mm stretched knot-to-knot. Cruise No. 42, performed during 5-2-1988 to 20-2-1988, covered the area between Lat. 08° 30'N to 10° 39'N and Long. 75° 25'E to 76° 37'E lying off Ponnani to Trivandrum using a larger mesh size of 40 mm for the cod-end of the net. A total of 25 trawl hauls were taken during this cruise at depths between 60 and 368 m. During both the cruises, the fishing was mainly confined to the 'Quilon Bank' which is considered to be the most productive area of deep-sea crustaceans on this coast.

Haul-wise details of trawling operation and total catch recorded for the two cruises are given in Tables 1 and 2.

Observations

Catch and catch rates of crustaceans

During Cruise-40, a total of 16 tonnes of catch was recorded of which crustaceans accounted 1,663 kg (10.3 %), fish 14,430 kg (89.4 %) and cuttlefish 45 kg (0.3 %). The total catch obtained during Cruise-42 amounted to 36 tonnes, of which only 548 kg (2 %) was constituted by crustaceans and the rest 35,067 kg (98 %) by fish items. Tables 3 and 4 give details of catch and catch rates of the different crustacean groups for each of the hauls taken during the two cruises.

Prawns

They formed the common element of crustaceans caught during both the cruises. In Cruise-40, prawns were represented in all the hauls except haul No. 3 and 17 operated within and on the edge of the continental shelf (130-203 m) and haul No. 14 operated in the deep sea at 731-777 m depth. With a total catch of 776 kg of prawns for the entire cruise forming 47 % of the total crustacean catch, the catch rates varied considerably in different areas operated. The maximum catch rate of 201 kg/ hr was recorded at station 12 at 299 m depth. Appreciable quantities of prawns, ranging from 130 to 150 kg/ hr of trawling were also obtained at stations 1, 4 and 10 lying in the Quilon Bank. In general, comparatively higher production rates were noticed between 290 and 360 m depth.

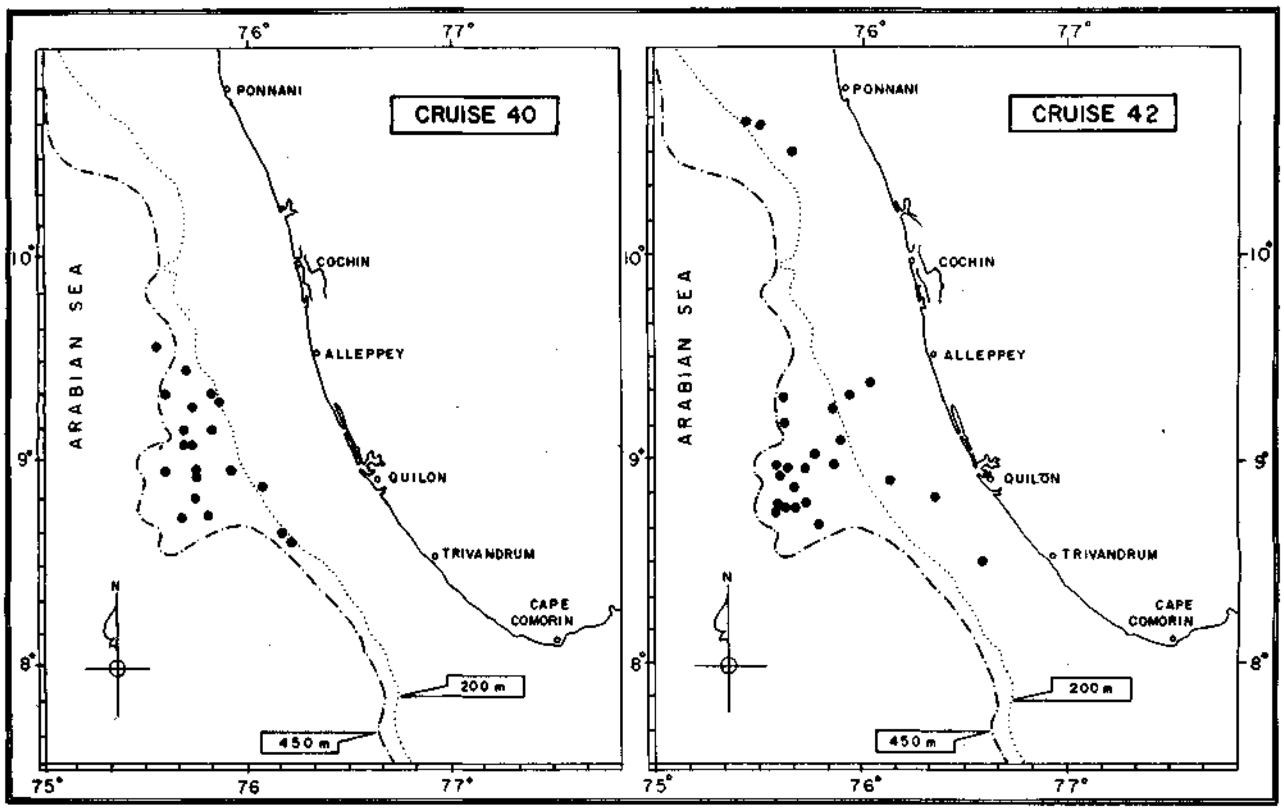

Fig. 1. Study area. Black rounds indicate trawling stations.

TABLE 1. *Trawling details of Cruise No. 40*

Stn. No.	Date	Position Lat. /Long.	Depth (m)	Time (hrs)	Duration of hauls (minutes)	Total catch (kg)
1	2. 1. '88	08° 35' N 76° 15' E	235-307	0820-0900	40	470
2	2. 1. '88	08° 38' N 76° 11' E	273-293	1140-1203	23	512
3	2. 1. '88	08° 50' N 76° 00' E	130-156	1716-1746	30	470
4	3. 1. '88	08° 48' N 75° 45' E	322	0735-0830	55	350
5	3. 1. '88	08° 56' N 75° 45' E	328-334	1055-1155	60	5,000
6	3. 1. '88	08° 42' N 75° 41' E	312-314	1810-1855	45	155
7	4. 1. '88	08° 43' N 75° 49' E	398-421	0842-0907	25	90
8	4. 1. '88	08° 55' N 75° 35' E	304-307	1652-1740	48	6,000
9	5. 1. '88	08° 55' N 75° 55' E	348-350	0740-0815	35	1,250
10	5. 1. '88	08° 55' N 75° 45' E	344-358	1515-1548	33	160
11	6. 1. '88	09° 04' N 75° 40' E	246-260	1005-1035	30	60
12	6. 1. '88	09° 04' N 75° 45' E	299	1223-1257	34	300
13	6. 1. '88	09° 08' N 75° 40' E	341	1504-1530	30	110
14	7. 1. '88	09° 32' N 75° 33' E	731-777	1515-1530	15	1
15	8. 1. '88	09° 12' N 75° 44' E	361-382	1135-1208	33	110
16	8. 1. '88	09° 09' N 75° 50' E	313-315	1612-1642	30	100
17	8. 1. '88	09° 16' N 75° 55' E	135-203	1912-1942	30	115
18	8. 1. '88	09° 18' N 75° 35' E	239-306	2056-2130	34	270
19	9. 1. '88	09° 19' N 75° 52' E	275-380	1036-1105	29	550
20	10. 1. '88	09° 26' N 75° 41' E	348	1832-1910	38	65

In Cruise - 42, out of the 25 hauls taken, only 16 hauls contained prawns in varying quantities ranging from 0.4 to 90 kg/hr of trawling. There was absolutely no prawn catch at stations 1, 2, 3, 12, 13, 14, 24 and 25 lying in the mid-shelf between 60 and 120 m depth and at station 16 lying in the Quilon Bank. The catch rates of the positive stations were also relatively less when compared to the catch rates recorded during Cruise - 40 from more or less the same depth zone of the Quilon Bank. The total prawn catch for the entire cruise amounted to 537 kg forming 95 % of the crustacean catch, with the highest catch rate of 90 kg/hr at Station 6 at 325 m depth. Fairly good concentration of prawns (64-88 kg/hr) was also noticed at Stations, 7, 8, 9 and 18 between 330 and 370 m depth.

The prawn catches of both the cruises were multispecies in composition, and represented by atleast 15 species of which eight species, namely, *Heterocarpus woodmasoni* (7-41 %), *H. gibbosus* (12-17 %), *Plesionika spinipes* (33-52 %), *P. martia* (1-2 %), *Aristeus alcocki* (3-4 %), *Solenocera hextii* (1-2 %), *Penaeopsis jerryi* (8-13 %), *Metapenaeopsis andamanensis* (1-4 %) were common (Figs. 2-9). The species composition varied considerably at different depths as observed by Suseelan (1985, 1988). In general, the penaeid prawns *P. jerryi, M. andamanensis* and *M. coniger* and the pandalid prawn *P. spinipes* formed the major constituents of the catch in the 201-300 m depth zone while in still deeper waters the pandalid prawns *H. woodmasoni, H. gibbosus, P. spinipes* and *P. martia* and the aristeid prawn *A. alcocki* dominated the catch.

The maximum abundance of *H. woodmasoni* was recorded at stations 4 to 6 (11-15 kg/hr) of Cruise 40 and stations 6, 9 and 18 (31-69 kg/hr) of Cruise 42. In the case of *H. gibbosus*, the highest

Fig. 2. *Heterocarpus woodmasoni.*

TABLE 2. *Trawling details of Cruise No. 42*

Stn. No.	Date	Position Lat. / Long.	Depth (m)	Time (hrs)	Duration of haul (minutes)	Total catch (kg)
1	8. 2. 88	10° 30' N 75° 40' E	60	1725-1755	30	225
2	9. 2. 88	10° 37' N 75° 30' E	80	0820-0920	60	200
3	9. 2. 88	10° 39' N 75° 25' E	120	1210-1225	15	250
4	11. 2. 88	09° 17' N 75° 35' E	350	1115-1200	45	500
5	11. 2. 88	09° 10' N 75° 47' E	348	1610-1710	60	9
6	12. 2. 88	09° 05' N 75° 52' E	325	1110-1210	60	1,000
7	12. 2. 88	08° 58' N 75° 51' E	332	1440-1540	60	2,000
8	12. 2. 88	09° 01' N 75° 46' E	340	1735-1820	45	250
9	13. 2. 88	08° 57' N 75° 37' E	360-368	0840-0940	60	2,000
10	13. 2. 88	08° 51' N 75° 40' E	360-365	1200-1230	30	53
11	13. 2. 88	08° 40' N 75° 48' E	340	1640-1740	60	450
12	14. 2. 88	08° 54' N 76° 09' E	63-65	0750-0850	60	40
13	14. 2. 88	08° 49' N 76° 22' E	60	1140-1225	45	14
14	14. 2. 88	08° 30' N 76° 37' E	84-86	1615-1715	60	53
15	15. 2. 88	08° 57' N 75° 42' E	328-335	1345-1430	45	7,000
16	15. 2. 88	08° 46' N 75° 43' E	337-340	1720-1750	30	5,000
17	16. 2. 88	08° 58' N 75° 34' E	362	0845-0930	45	68
18	16. 2. 88	08° 57' N 75° 33' E	361-366	1055-1155	60	200
19	16. 2. 88	08° 47' N 75° 34' E	335-340	1715-1720	5	10
20	17. 2. 88	08° 47' N 75° 35' E	324-326	1020-1050	30	27
21	17. 2. 88	08° 44' N 75° 32' E	315	1335-1435	60	12,000
22	17. 2. 88	08° 46' N 75° 39' E	305	1650-1720	30	200
23	18. 2. 88	09° 15' N 75° 53' E	225-238	0830-0900	30	5
24	18. 2. 88	09° 19' N 75° 56' E	73	1215-1315	60	10
25	18. 2. 88	09° 22' N 76° 02' E	60	1455-1555	60	1

concentration was observed at stations 4, 7, 13 and 20 (15-24 kg/hr) of Cruise 40 and stations 6 and 9 (12-16 kg/hr) of Cruise 42. *P. spinipes* recorded maximum catch rates at stations 1, 4, 10 and 12 (48-90 kg/hr) of Cruise 40 and stations 7 to 10 (20-59 kg/hr) of Cruise 42. The highest catch rate of *A. alcocki* (9 kg/hr) was obtained at station 4 of cruise 42. Among the other important species, significant catch rates were recorded for *P. jerryi* at stations 1, 12 and 18 (12-29 kg/hr), *M. andamanensis* at station 1 (18 kg/hr) and *S. hextii* at station 12 (6 kg/hr) of Cruise 40.

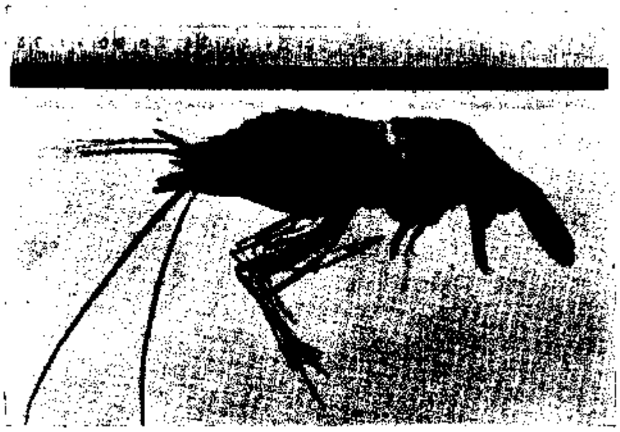

Fig. 3. *Heterocarpus gibbosus.*

Fig. 4. *Plesionika spinipes.*

TABLE 3. *Haulwise catch (C) in kg and catch rate (C/E) in kg/hr of crustaceans during Cruise No. 40 of FORV* Sagar Sampada

Haul	Depth	Prawns		Lobsters		Crabs		Total crustaceans	
No.	(m)	C	C/E	C	C/E	C	C/E	C	C/E
1	235-307	100	150	120	180	50	75	270	405
2	273-293	16	42	12	31	11	29	39	102
3	130-156	—	—	—	—	—	—	—	—
4	322	120	132	5	5	—	—	125	137
5	328-334	50	65	2	3	—	—	52	68
6	312-314	43	57	5	7	—	—	48	64
7	398-421	44	106	5	12	—	—	49	118
8	304-307	25	31	5	6	—	—	30	37
9	348-350	20	34	7	12	—	—	27	46
10	344-358	80	146	9	16	—	—	89	162
11	246-260	10	20	—	—	12	24	22	44
12	299	114	201	7	12	25	44	146	257
13	341	46	92	3	6	1	2	50	100
14	731-777	—	—	—	—	—	—	—	—
15	361-382	19	35	2	4	—	—	21	39
16	313—315	29	58	5	10	—	—	34	68
17	135—203	—	—	—	—	—	—	—	—
18	239-306	23	40	2	3	79	139	104	182
19	275-380	10	21	—	—	512	1059	522	1,096
20	348	27	43	7	11	1	2	35	56

Lobsters

The deep-sea spiny lobster *Puerulus sewelli* (Fig. 10) was caught from the upper continental slope between 235 and 421 m depth, with maximum abundance upto 350 m depth. During Cruise 40, a total quantity of 196 kg of the lobster was obtained at an average catch rate of 17 kg/hr, which formed nearly 12 % of the total crustaceans caught. It was encountered at most of the stations occupied on the upper continental slope in varying proportions. It is interesting to note that the lobster, with a catch of 120 kg for 40 minutes trawling accounted the largest crustacean component at station 1, which was the highest catch recorded for this species during the entire cruise. The catch rate and percentage contribution of lobster in this particular haul were as high as 180 kg/hr and 44.4 % respectively. The catch rates for the other positive stations ranged from 3 to 31 kg/hr. During cruise 42, the lobster catch was much less when compared to the catches obtained during cruise 40. Out of the 17 stations occupied on the upper continental slope, *P. sewelli* was recorded

Fig. 5. *Plesionika martia.*

Fig. 6. *Aristeus alcocki.*

TABLE 4. *Haulwise catch (C) in kg and catch rate (C/E) in kg/hr of crustaceans during Cruise No. 42 of FORV* Sagar Sampada

Haul No	Depth (m)	Prawns C	Prawns C/E	Lobsters C	Lobsters C/E	Total crustaceans * C	Total crustaceans * C/E
1	60	—	—	—	—	—	—
2	80	—	—	—	—	—	—
3	120	—	—	—	—	—	—
4	350	20	27	2	3	22	30
5	348	3.7	3.7	0.3	0.3	4	4
6	325	90	90	2	2	92	92
7	332	76	76	4	4	80	80
8	340	66.3	88	1.5	2	68	90
9	360-368	88	88	4	4	92	92
10	360-365	21	42	0.1	0.2	21.1	42.2
11	340	31.5	31.5	—	—	31.5	31.5
12	63-65	—	—	—	—	—	—
13	60	—	—	—	—	—	—
14	84-86	—	—	—	—	—	—
15	328-335	4.9	6	2.1	3	7	9
16	337-340	—	—	—	—	—	—
17	362	18	24	1.1	1		19.1
25							
18	361-366	64	64	3.2	3.2	67.2	67.2
19	335-340	1	12	3.5	42	4.5	54
20	324-326	0.2	0.4	2.9	6	3.1	6.4
21	315	24	12	—	—	24	12
22	305	1	2	—	—	1	2
23	225-238	0.2	0.4	—	—	0.2	0.4
24	73	—	—	—	—	—	—
25	60	—	—	—	—	—	—

* There was no catch of crabs during the cruise

at 12 stations all beyond 315 m depth. The total catch for the entire cruise amounted to only 27 kg, forming 5% of the total crustacean catch. The highest catch rate of 42 kg/hr was recorded off Quilon at station 19 between 335 and 340 m depth. The catch rates at other positive stations ranged from 0.2 to 6 kg/hr.

Apart from *P. sewelli*, stray specimens of the Indian Ocean lobsterette *Nephropsis stewarti* (Fig. 11) were also recorded during both the cruises from 304 to 421 m depth off Quilon - Alleppey coast. On the west coast of India, it is known to occur off

Fig 7. *Solenocera hextii*.

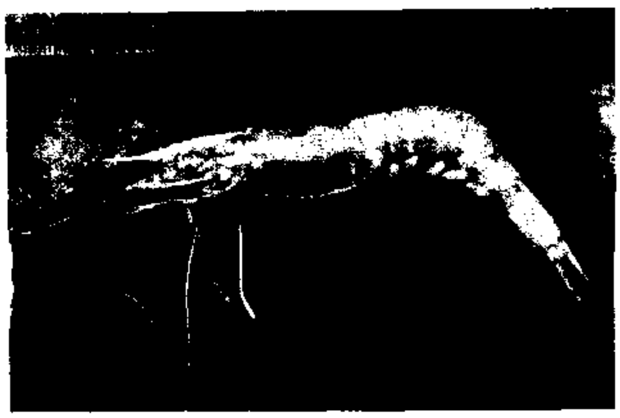

Fig 8. *Penaeopsis jerryi*.

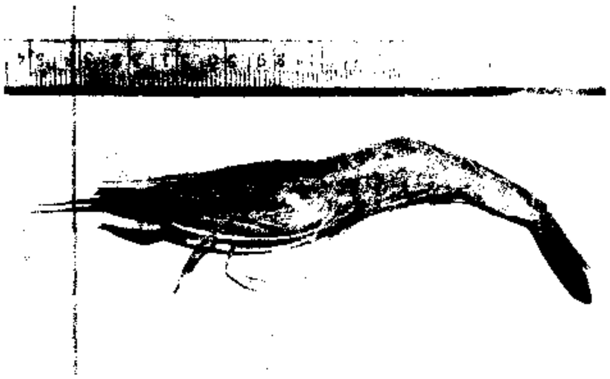

Fig. 9. *Metapenaeopsis andamanensis.*

Lakshadweep Islands between 660 and 840 m depth (Alcock, 1901; Holthuis, 1984) and the present collections extend its distributional range to the upper continental slope off the mainland. The total length of the lobster ranged from 105 to 112 mm for males and 120 to 128 mm for females. Some of the females above 125 mm were found to be in ovigerous state.

Crabs

The swarming crab *Charybdis (Goniohellenus) smithii* (Fig. 12) was an important component of the crustacean catch taken during cruise 40 between 235 and 380 m depth. It was represented at 8 stations, majority having bottom depths less than 310 m. A total of 691 kg of the crab obtained during this cruise at an average catch rate of 59.5 kg/hr formed nearly 42 % of the whole crustacean catch. The species formed the bulk of the catch at station 19 with a total harvest of 512 kg for 29 minutes trawling. The catch rate for this haul worked out to 1,059 kg/ hr, while the same for the other positive hauls ranged from 2 to 139 kg/hr.

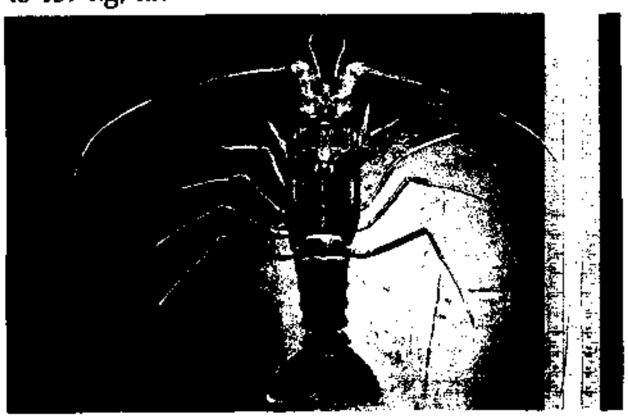

Fig. 10. *Puerulus sewelli.*

Among other crabs recorded during the survey, two species namely *Thelxiope megalops* (Fig. 13) and *Carcinoplax verdensis* showed moderate concentrations between 300 and 400 m depth.

Other crustaceans

A variety of other deepsea crustaceans including those listed by Mohamed and Suseelan (1973) have been encountered during this survey. Among them a species that deserves special mention is the deep-sea stomatopod *Squilla leptosquilla* (Fig. 14) which was observed quite often in the catches, some times in fairly good numbers indicating the existence of a rich population of it in the study area. Distinguished by a prominent red spot on telson this species was first reported from this coast by Rao *et al.* (1965). By virtue of its large size (120-160 mm TL) it might prove to be potentially important in due course.

Fig. 11. *Nephropsis stewarti.*

Population characteristics and biology

Data on population parameters such as sex ratios, size- frequency distribution, breeding stock etc. of the major species of crustaceans have been collected from each of the trawling stations. The size of the animal refers to total length of body measured from tip of rostrum to tip of telson in the case of prawns and from anterior margin of carapace to tip of telson in the case of *P. sewelli*, while for crabs (*C. (G.) smithii*) it refers to carapace width measured between the last pair of anterolateral teeth. The length measurements were grouped into 5 mm size classes sex-wise, and the frequency data of all the individual samples pooled together for two major depth zones, namely, 201-300 m and 301-400 m cruise-wise. Tables 5-9 give the overall size frequency distribution (indicated against mid-points of length groups) together with estimates of mean sizes of different species in the two depth zones.

Fig. 12. *Charybdis (Coniohellenus) smithii.*

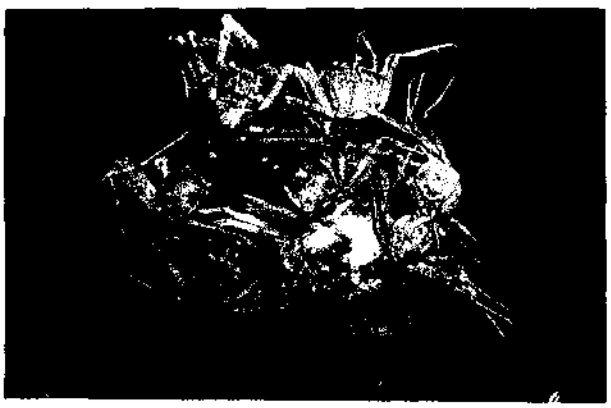

Fig 13. *Thelxiope megalops.*

Heterocarpus woodmasoni (Table 5)

This species was caught mainly in the depth zone 301-400 m. Out of 830 specimens examined, as many as 683 were males forming 82 % of the total population. A high degree of male dominance over females was observed in almost all the samples examined.

Fig 14. *Squilla leptosquilla.*

TABLE 5. *Length- frequency and mean size distribution of* Heterocarpus woodmasoni *at 301-400 m depth by cruise and sex*

Total Length	Cruise No. 40		Cruise No.42	
(mm)	Male	Female	Male	Female
83		1	1	
88			2	
93	5	1	5	2
98	10	3	19	1
103	24	1	49	12
108	35	2	109	18
113	30	3	177	43
118	9	2	169	42
123	1	1	34	11
128			1	3
133			3	1
Total number	114	14	569	133
Mean size (mm)	107.6	106.2	112.6	113.9

The size of the prawns ranged from 81 to 135 mm for both sexes. About 78-95 % belonged to the size group 96-120 mm. The larger size groups above 120 mm were more numerous in the catches of Cruise-42. The mean sizes ranged 107.6-112.6 mm for males and 106.2-113.9 mm for females.

The species was found to breed intensively during February when nearly 90 % of the females carried eggs on the pleopods. The smallest egg-laden female measured 92 mm in total length.

Heterocarpus gibbosus

This species was recorded at depths between 235 and 421 m. Males and females were almost equally represented in the catch. The size range of a total of 288 specimens measured was 73-138 mm for males and 83-143 mm for females, the major size groups being 96-110 mm and 101-125 mm for the two sexes respectively. Among females 5.5 % were in ovigerous state.

This is the largest among the pandalid prawns of this coast and hence can attract the processing industry.

Plesionika spinipes (Table 6)

Previously known as *Parapandalus spinipes*, this species has been recently placed under genus *Plesionika* by Chace (1985). Occurring at all depths between 225 and 421 m it formed one of the most common deep-sea prawns of the area. Females invariably outnumbered the males, the overall sex ratio of 1,463 specimens examined being 40 : 60.

The size ranged from 46 to 123 mm for males and 51 to 125 mm for females. In general, the size group 81-110 mm constituted over 80 % of the population. Comparison of the size-frequency data from different depth zones reveals the occurrence of younger prawns in relatively deeper waters. The mean sizes were 90.9 mm for males and 97.6 mm for females in depth zone 201-300 m, while in depth zone 301-400 m the same were 92 mm and 98 mm for the two sexes respectively during Cruise-40. The prawns caught during Cruise-42 were considerably larger in size than those caught during Cruise-40, the mean sizes being 98.7 mm for males and 102.5 mm for females.

Active breeding of the species was noticed at all depths. Out of the total number of 879 females examined, 497 (57 %) were in berried condition. The percentage of berried females in total females was relatively more at 201-300 m depth (85 %) than at 301-400 m (40-73 %), which would suggest that the species prefers shallower areas for breeding. The minimum size of berried female was 80 mm in total length.

TABLE 6. *Length-frequency and mean size distribution of* Plesionika spinipes *by depth, cruise and sex*

Total length (mm)	Depth : 201 - 300 m		Depth : 301 -400m			
	Cruise No. 40		Cruise No. 40		Cruise No. 42	
	Male	Female	Male	Female	Male	Female
48			1			
53			2	2		
58				1		
63	1		2	2		
68	1	1	1	1		
73	1		2	1		
78	5	2	4	1		
83	12	8	22	10	3	
88	20	18	16	10	16	15
93	18	33	52	32	62	44
98	17	43	42	53	123	144
103	4	34	23	65	84	155
108	2	11	5	22	27	97
113	2	8	1	9	8	22
118		2		3	1	23
123		1			2	5
Total number	83	161	175	213	326	505
Mean size (mm)	90.9	97.6	92.0	98.0	98.7	102.5

Aristeus alcocki (Table 7)

Many authors have reported this species from Indian waters as *A. semidentatus* assigning commercial prospects. Recently Suseelan (1985, 1989) established its true identity as *A. alcocki*. During the present survey this species was caught between 273 and 421 m depth. Out of 321 specimens examined only 4 were males and the rest were all females.

The species exhibited a high degree of sexual dimorphism, males being considerably smaller than females. The sizes ranged from 91 to 98 mm for

TABLE 7. *Length-frequency and mean size distribution of* Aristeus alcocki *by depth, cruise and sex*

Total length (mm)	Depth : 201 - 300 m Cruse No. 40 Male	Female	Depth : 301 -400m Cruise No. 40 Male	Female	Cruise No. 42 Male	Female
93			1		1	
98			2			
103						1
108				1		2
113				1		3
118				3		
123				4		3
128		1		6		6
133				9		4
138				12		6
143		3		18		15
148		4		20		18
153		1		28		16
158		2		25		23
163		2		28		10
168				14		7
173				8		3
178				5		
183				3		
188				2		
Total number	nil	13	3	187	1	117
Mean size (mm)		148.0	96.3	152.8	93.0	148.5

males and 102 to 188 mm for females. Among females, majority were in the size range 141-165 mm. The mean size of female prawns ranged 148.0-152.8 mm.

Impregnated females were quite common in the catches at all depths. Spawners were, however, observed only in the 301-400 m depth zone. The smallest mature female measured 123 mm in total length. Fully mature ovary was purple in colour, with the posterior lobe extending upto the end of 6th abdominal segment. At 301-400 m depth about 18 % of the females were in fully mature condition.

Being the largest of the deep-sea prawns of this area, this species is likely to be targeted for large-scale exploitation.

Penaeopsis jerryi (Table 8)

Previously known from these waters as *P. rectacuta* , this species occupied more or less the same habitat of *P. spinipes*.. Females were found far in excess of males in the population, the overall sex ratio of 931 specimens studied being 30 : 70.

Females were invariably larger than males. The total length ranged from 51 to 100 mm for males and 62 to 120 mm for females. Bulk of the catch, however, was constituted by the size groups 71-90 mm in males and 81-105 mm in females. The mean sizes were slightly smaller for male (78.8 mm) as well as for female (88.0 mm) prawns at 201-300 m depth, while at 301-400 m depth the mean sizes of the male and female populations ranged 79. 5-85.6 mm and 89.4-92.5 mm respectively.

Fully mature females were encountered in

TABLE 8. *Length-frequency and mean size distribution of* Penaeopsis jerryi *by depth ,cruise and sex*

Total length (mm)	Depth : 201 - 300 m Cruse No. 40 Male	Female	Depth : 301 -400m Cruise No. 40 Male	Female	Cruise No. 42 Male	Female
53	1					
58	1		4			
63	5	9	4	12	1	1
68	3	11	3	2	1	4
73	11	6	6	6	2	2
78	15	6	13	1	15	12
83	23	8	16	21	42	44
88	8	18	13	23	64	75
93	3	31	3	34	14	117
98	1	24	2	26	3	79
103		9		12		39
108		4		4		5
113				1		4
118		1		1		2
Total number	71	127	64	143	142	384
Mean size (mm)	78.8	88.0	79.5	89.4	85.6	92.5

the catches at 301-400 m depth. In February, about 5 % of the female population were in spawning condition. The minimum size at first maturity of female was observed at about 83 mm. In fully mature condition the ovary appeared dark green as in most of the littoral penaeids.

Solenocera hextii

Though numerically less abundant in the deep-sea catches, this species assumes importance on account of its attractive size. It can be easily made out in a catch from its light colour and robust body. The males and females were more or less evenly distributed in the population. The size ranged from 80 to 115 mm for male and 91 to 140 mm for female. Majority of the catch belonged to the size groups 110-115 mm and 120-135 mm for the two sexes respectively.

Puerulus sewelli (Table 9)

Represented in both the depth zones. A total number of 932 lobsters have been examined, of which 513 were males and 419 females. In 201-300 m depth zone females dominated forming 63 % of the entire population. In 301-400 m depth zone, the proportion of females reduced to 46 % in January and 34 % in February.

The size range of the lobster observed during this survey was 71-200 mm, of which the size group 121-170 mm accounted the bulk of the catch in 301-400 m depth. Between the sexes no appreciable difference in size was noticed. In 201-300 m depth zone the principal size group was 136-145 mm for males and 151-175 mm for females. Individuals smaller than 96 mm total length were caught only during Cruise - 40 at 301-400 m depth. The mean size of the species was estimated at 141.4 mm for male and 157.9 mm for female in the 201-300 m depth zone. The distribution of mean sizes in the 301-400 m depth zone showed slightly a different picture. In males, the mean size values for the two cruises were significantly higher (142.1 & 147.2 mm), while in females a marked reduction in the mean size values (143.5 & 143.7 mm) was noticed as compared to the mean size estimates of the 201-300 m depth zone.

The species was found to breed more actively in depth zone 201-300 m as evidenced by a greater proportion of ovigerous females (85.3 %). In the 301-400 m depth zone also a high percentage of ovigerous females (30.5-59.4 %) was noticed during both the cruises. According to Kathirvel *et al*. (1989) the species breeds throughout the year, with two

TABLE 9. *Length- frequency and mean size distribution of* Puerulus sewelli *by depth, cruise and sex*

Total length (mm)	Depth : 201 - 300 m		Depth : 301 -400m			
	Cruse No. 40		Cruise No. 40		Cruise No. 42	
	Male	Female	Male	Female	Male	Female
73				2		
78				1		
83			1	1		
88			2			
93	1	1	6	4		
98			3	4	2	
103			1	5	2	3
108	1		3	2	4	6
113		1	3	2	4	
118	2	2	6	7	7	5
123	3	1	10	11	11	5
128	5		12	9	10	13
133	4	5	25	11	10	8
138	10	4	41	14	28	11
143	12	7	30	26	17	10
148	6	5	24	34	21	8
153	4	17	28	19	19	4
158	2	12	24	21	15	7
163	2	11	8	11	10	4
168	3	12	10	11	20	7
173	4	10	9	7	9	7
178		9	2	4	6	1
183		2	2	2	3	3
188	1	1		3	3	1
193		1		1	2	2
198		1				
Total number	60	102	250	212	203	105
Mean size (mm)	141.4	157.9	142.1	143.5	147.2	143.7

peaks, the major one during January-April and the other in October. The smallest berried female encountered during the present study measured 120 mm.

Examination of the stomach contents of 100 specimens has revealed that the lobster mainly feeds on deep-sea prawns, bivalves, cephalopods and fishes.

Charybdis (Goniohellenus) smithii

The swarming crab was recorded only during Cruise 40. A total number of 260 specimens were sexed and measured. In the record haul at station 19, females accounted about 75 % by number, while in all the other hauls males dominated. The overall size ranged from 42 to 72 mm in carapace width. The major size groups were 56-65 mm for males and 46-55 mm for females. All the crabs examined were mature. Among females, about 90 % were berried thereby indicating that the species breeds actively in January.

Discussion

A comparison of the prawn catches obtained during the two cruises of *Sagar Sampada* would indicate that Cruise-40 registered higher catch rates than cruise-42 from more or less the same fishing grounds. This may be due to the change in the cod end mesh size of the nets used for the survey. During Cruise-40, the smaller cod end mesh size (22 mm) has yielded better prawn catch together with the capture of smaller size groups for some of the species in significant numbers (Tables 6 and 8). A cod end mesh size of 40 mm, which was used during Cruise-42, appears unsuitable for the exploitation of prawn resource which includes several species growing to different sizes. It is therefore possible that for economic shrimp fishing in the Quilon Bank, a medium mesh-size of about 30 mm for the cod end may prove better in terms of yield and size of the prawns. From the conservation point of view also this will be helpful since distruction of young prawns will be less when the resource is subjected to commercial fishing.

Among the various species of prawns observed during the survey, species such as *A. alcocki, H. woodmasoni, H. gibbosus, S. hextii, P. spinipes* and *P. jerryi* attain fairly good sizes which are comparable to many of the coastal species presently used for export. It is therefore suggested that commercialised fishing on these specific resources may be encouraged in order to augment our export earnings. The post-harvest technology for deep-sea prawns in the country does not seem to have attained perfection which is an essential prerequisite for promotion of their export. Priority attention is therefore required for more research input on preservation and processing of this new resource. Being cold water species, the chances of post-harvest spoilage are more for these animals as compared to coastal shrimps. During the course of this survey it was observed that the vulnerability to and time taken for spoilage (indicated by blackening of cephalothorax) on deck varied considerably from species to species. Some of the species like *P. jerryi* and *S. hextii* were found to spoil quickly and hence required immediate removal from the catch and proper preservation. It will be worthwhile to investigate on the biochemical or other factors responsible for the quick spoilage of these species.

The deep-sea lobster *P. sewelli* is an important resource considering its high export potential. During the present survey considerable variations were noticed in the proportion of male and female in the population. The distribution of sex ratios with reference to depth indicates migration of females to shallower areas during January-February. According to Kathirvel *et al.* (1989), *P. sewelli* performs bathymetric movements associated with breeding activity. In January the lobsters move to 150-200 m depth zone from the deeper waters and linger there till April/May. They return to the deeper waters in June and remain there till December. These authors have also observed that in the Quilon Bank females dominated in the population during January-April and August-December. The data on hand suggest that among the two sexes female lobsters tend to migrate to shallower areas earlier or more actively than males. The reduction in mean size of females at 301-400 m depth and a corresponding increase in the same at 201-300 m depth would be an added evidence pointing to migration of larger population from deeper to shallower areas. As maximum percentage of ovigerous females is recorded in the 201-300 m depth zone the migration of larger population to shallower areas may be correlated with breeding.

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QUANTITATIVE DISTRIBUTION OF PELAGIC SHRIMPS IN THE DEEP SCATTERING LAYERS OF THE INDIAN EEZ

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ABSTRACT

A study of 383 samples of Isaac - Kidd Midwater Trawl collections taken by FORV *Sagar Sampada* during 1985-'86 has shown that the Deep Scattering Layers of the Indian EEZ harbour rich population of pelagic shrimps, with maximum abundance in the west coast. The mean density of shrimps estimated is 311 nos/haul for the west coast induding Lakshadweep, 82 nos for the east coast and 107 nos for Andaman-Nicobar region. In most part of Indian coasts the shrimp population is more numerous in the neritic waters than in the oceanic. Season- wise analysis of catch data from the west coast indicates that the abundance of shrimp is higher during premonsoon and monsoon seasons in the oceanic waters and during postmonsoon season in the neritic waters. In general, the shrimp catch is better during night than in day time.

The pelagic shrimp population is multispecies in character and represented chiefly by the genera *Sergestes*, *Acetes*, *Thalassocaris*, *Pasiphaea* and *Leptochela*. Speices of *Sergestes* dominate in the oceanic waters. The possible feeding relationship between oceanic tunas and pelagic shrimps is discussed.

INTRODUCTION

Among the various species of prawns and shrimps occurring in the sea, the great majority are benthic in existence throughout their life except for a short pelagic phase during metamorphosis. The commercial shrimp fishery is predominantly supported by the benthic forms. A number of species, however, live permanently in the columnar layers of the ocean where they are fed upon by fishes and other aquatic organisms, besides some of them being caught commercially by man from the inshore waters. According to Omori (1974), out of a total of about two thousand species of prawns recorded from the world oceans, as many as 210 species pass their complete life in the pelagic realm. Though the occurrence of pelagic shrimps in the mid and deep waters of the ocean has been reported as early as the middle of nineteenth century, serious attention to study their role in the productivity of the sea has been paid only in recent years (Pearcy and Forss, 1966; Aizawa, 1969; Foxton, 1970 a, b; Omori *et al.*, 1972; Matthews and Pinnoi, 1973). In Indian waters, the earliest attempt to throw light on pelagic shrimps was the faunistic work of Alcock (1901) who enlisted several species along with the benthic forms from the collections of the marine survey ship *Investigator*. Later, Kemp (1917, 1925), Menon (1937), Nataraj (1942, 1947), Pillai (1955), George and Rao (1966), Rao (1968) and others have recorded many more species from the west and east coasts of India and studied their taxonomy. The complete larval history of some of the oceanic species was worked out by Menon and Williamson (1971) and George and Paulinose (1973). Most of the species of pelagic shrimps recorded by these authors belong to the families Sergestidae, Benthesicymidae, Pasiphaeidae, Oplophoridae and Thalassocarididae. Among sergestid shrimps, species of the genus *Acetes* generally occupy the inshore or neritic waters and contribute to the commercial fishery in many parts of the Indian coasts. In the oceanic realm, this family is mainly represented by the genus *Sergestes*.

Pelagic shrimps form an important forage of oceanic tunas, flying fish etc. (George and George, 1964; George and Paulinose, 1973; James *et al.*, 1987) and a number of fish species inhabiting the shelf waters which support commercial fisheries (Nataraj, 1947; Chacko, 1949; Venkataraman, 1960; Suseelan and Nair, 1969). They link the zooplankton and large animals of the higher trophic levels in the food chains and transport organic matter produced in the upper layers to the lower layers of the sea through vertical migrations. A knowledge of the distribution and biology of the pelagic shrimp population would, therefore, be of great relevance in the management of fishery resources. Lack of such information from Indian waters has prompted the authors to carry out detailed investigations on the pelagic shrimps based on the collections of FORV *Sagar Sampada*. The present paper, which forms part of these studies, deals with distribution and numerical abundance of pelagic shrimps excluding *Lucifer* in the Deep Scattering Layers (DSL) off the Indian coasts including the Lakshadweep and Andaman seas.

Material and Methods

The Isaacs-Kidd Midwater Trawl (IKMT) collections taken from the Deep Scattering Layers during the period February, 1985 to May, 1986 by *Sagar Sampada* were used for this study. Details of the IKMT operations have been described by Menon and Prabhadevi in their account on the biomass in the DSL of Indian waters being published elsewhere in this volume. The catches of 383 hauls of IKMT covering almost the entire area of EEZ of India and some contiguous waters have been examined for the pelagic shrimps. Each haul was operated for 30 minutes duration at a towing speed of 3 knots per hour in the sonic scattering layers which occupied depths upto about 600 m from the sea surface. The sampling distribution in each of the half-degree squares demarkated by longitude and latitude lines for the entire area of investigation is shown in Fig.1.

The numerical data of pelagic shrimps were analysed area-wise and average number per haul worked out for each of the half-degree squares for all practical purposes. The geographical limit of the major regions dealt with in the paper are as follows.

West coast	:	Lat. 7°00'N - 24°00'N and Long. 65°00'E- 77°30'E
East coast	:	Lat. 6°00'N - 15°00'N and Long. 77°30'E - 83°00'E
		Lat. 15°00'N - 22°00'N and Long. 80°00'E - 92°00'E
Andaman-Nicobar region	:	Lat. 5°00'N - 15°00'N and Long. 88°00'E-95°30'E

Observations

Spatial distribution and abundance

The pelagic shrimps formed a regular component of the IKMT collections throughout the Indian EEZ, although their number varied considerably in individual hauls. Out of the total number of 383 hauls operated, 348 hauls indicated the presence of pelagic shrimps in varying degrees of abundance. The distribution pattern and areas of abundance of the shrimps are shown in Fig. 2.

West coast

The IKMT was operated in all the months of the year except in May and June, covering the shelf and oceanic waters between 33 and 4,600 m depth including the seas around Lakshadweep. A total of 244 hauls were taken from this coast, of which 235 (96%) recorded pelagic shrimps and the rest were negative hauls. The number of shrimps per haul ranged from 1 to 10,986, the average number per haul being 311 for the entire coast. Table 1 gives details of shrimp catch for each of the one-degree squares arranged latitude-wise. A comparison of the population density in individual squares would indicate that the maximum abundance of shrimps was recorded in 9-75, 11-75 and 18-72 degree squares where the catch rate exceeded 2,000 nos/haul. The greatest density of over 10,000 nos/haul was observed in the 18-75 degree square lying off Bombay-Ratnagiri coast in Maharashtra during December. As a whole, the southern latitudinal areas including Lakshadweep are found to be more productive than the northwest coast where the shrimp abundance is rather patchy and productive areas are less extensive (Fig. 2).

Analysis of the catch data of pelagic shrimps with reference to inshore-offshore regions has shown that the shrimp population is relatively more numerous in the shelf waters than in the oceanic (Table 4). While the difference in abundance was only moderate between the neritic (393/haul) and oceanic (317/haul) regions along the southwest coast, nearly a three fold increase in abundance was noticed in the neritic waters (632/haul) as compared to the standing stock of shrimps in the oceanicwaters (219/haul) along the northwest coast, which was particularly due to the heavy occurence of shrimps in the near-shore areas of Bombay-Ratnagiri coast.

East coast

Covering almost the northern half of the Bay of Bengal and the entire Coromandel coast and Gulf of Mannar, the IKMT was operated in the months of February, March, May, June, July and November, extending from 14 to 3,639 m depth at bottom. A

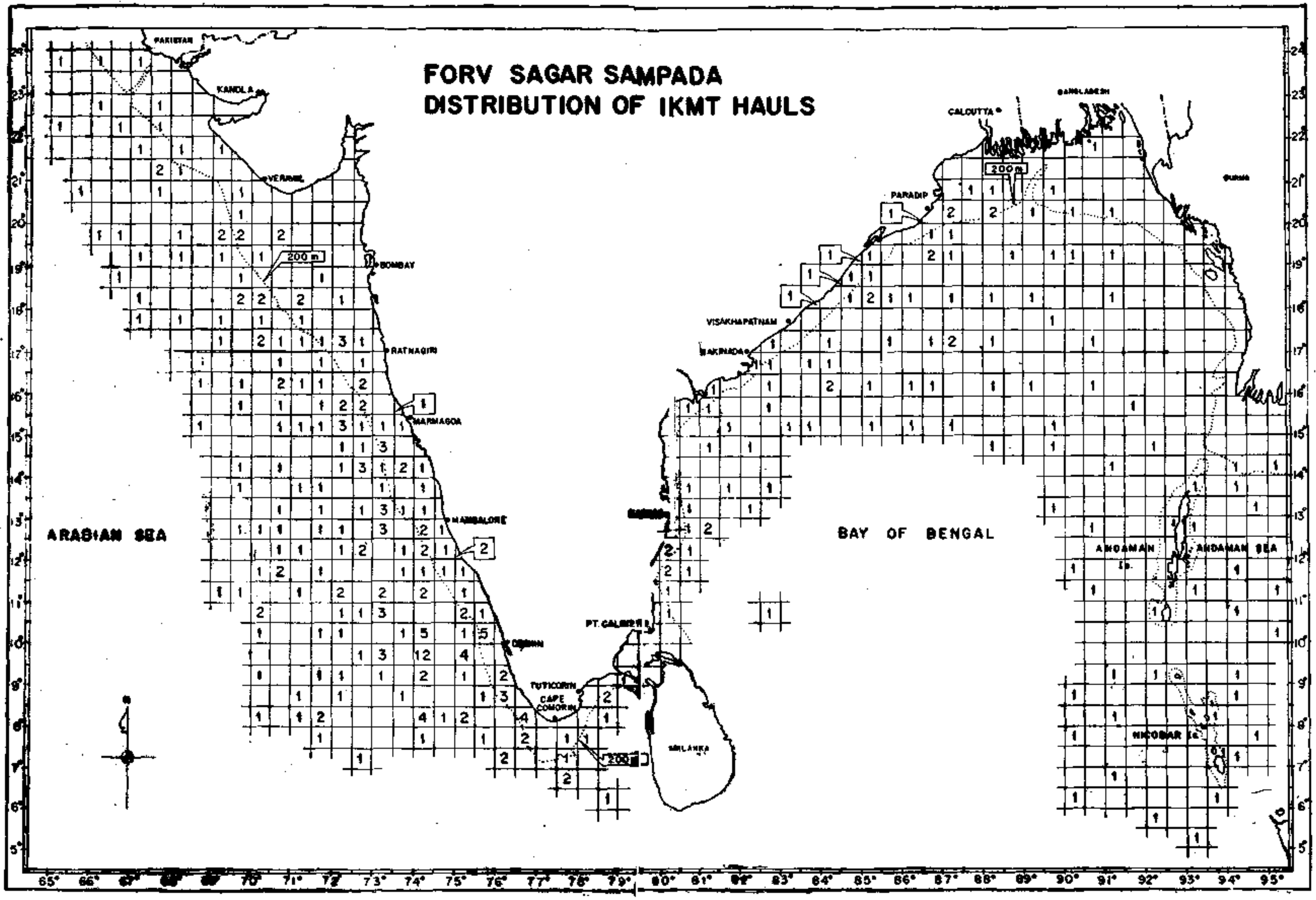

Fig. 1. Map showing the distribution of IKMT hauls in Indian EEZ and contiguous seas. Number in squares indicates total number of hauls taken in each of the half-degree squares.

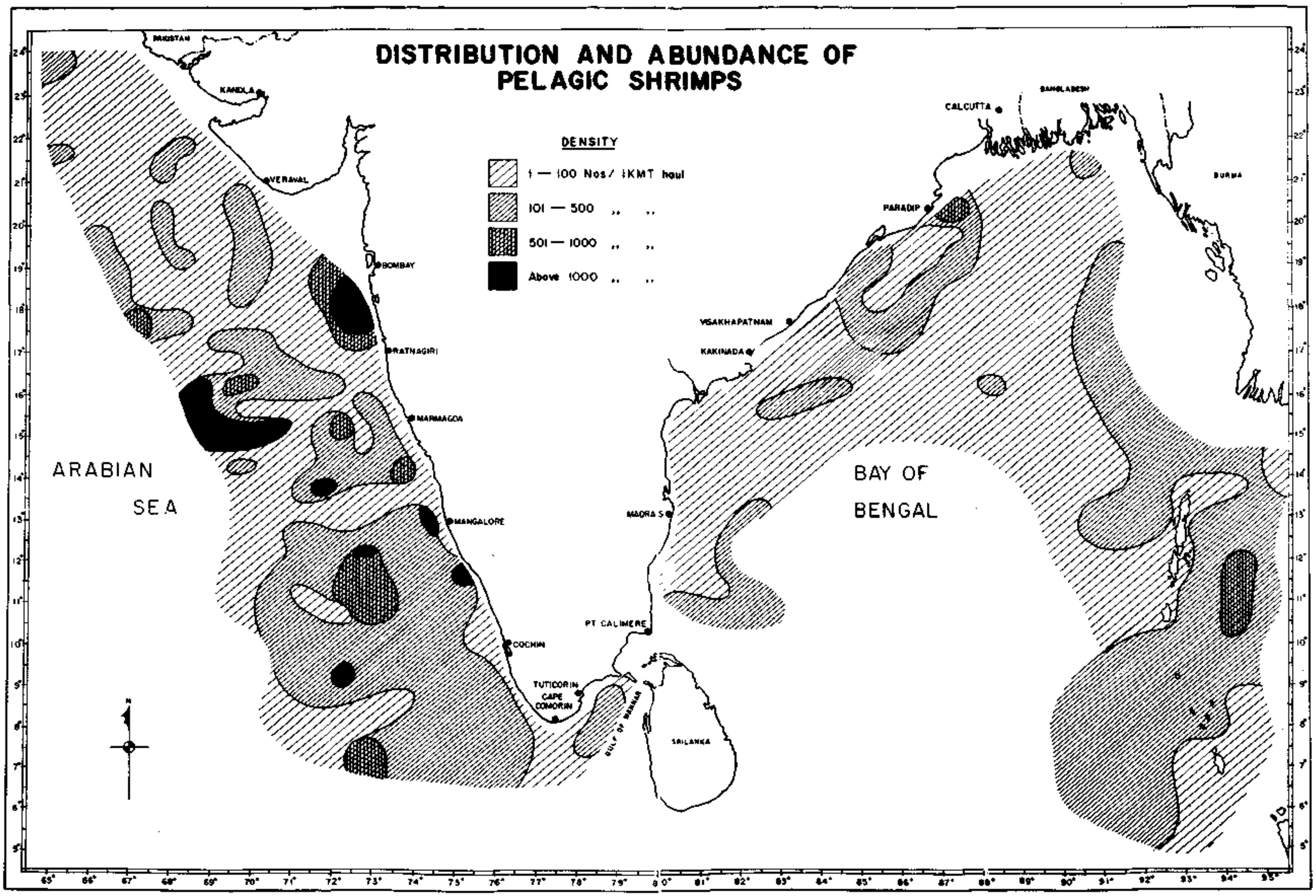

Fig. 2. Spatial distribution and abundance of pelagic shrimps.

TABLE 1. *Area-wise catch and abundance of pelagic shrimps on the west coast*

Area (1° square) Lat. (°N)	Long. (°E)	Total No. of hauls	No. of positive hauls	Total No. of shrimps	Mean No. per haul
7	76	4	4	587	147
	75	1	1	178	178
	74	1	1	165	165
	73	-	-	-	-
	72	1	1	548	548
	71	1	1	93	93
8	76	7	7	1,739	248
	75	3	3	264	88
	74	5	5	1,034	207
	73	1	1	47	47
	72	1	1	127	127
	71	4	2	437	109
	70	1	1	2	2
9	76	2	1	232	116
	75	5	5	891	178
	74	14	13	2,627	188
	73	4	4	356	89
	72	2	2	4,882	2,441
	71	1	1	183	183
	70	1	0	0	0
10	75	9	8	1,083	120
	74	5	5	2,238	448
	73	4	4	1,456	364
	72	3	3	1,269	423
	71	1	1	313	313
	70	3	2	257	86
11	75	2	2	5,122	2,561
	74	4	3	429	107
	73	3	3	1,009	336
	72	2	2	1,005	503
	71	2	1	276	138
	70	3	3	416	139
	69	2	2	96	48
12	75	2	2	142	71
	74	6	5	1,155	193
	73	4	4	410	103
	72	4	4	3,259	815
	71	2	2	601	301
	70	3	3	976	325
	69	1	1	54	54
13	74	2	2	189	95
	73	5	4	331	66
	72	1	0	0	0
	71	3	3	3,246	1,082
	70	1	1	17	17
	69	1	1	62	62
14	74	1	1	30	30
	73	6	6	1,837	306
	72	6	6	1,376	229
	71	-	-	-	-
	70	1	1	29	29
	69	1	1	275	275
15	73	3	3	234	78
	72	8	8	2,469	309
	71	3	3	215	72
	70	2	2	1,267	634
	69	1	1	2	2
	68	1	1	1,598	1,598
16	72	3	3	251	84
	71	3	3	243	81
	70	3	3	712	237
	69	3	3	758	253
	68	3	3	1,033	344
17	72	4	4	2,100	525
	71	3	3	174	58
	70	4	3	318	80
	69	2	2	280	140
	68	1	1	100	100
	67	1	1	630	630
18	72	1	1	10,986	10,986
	71	3	3	1,098	366
	70	2	2	140	70
	69	3	3	392	131
	68	-	-	-	-
	67	1	1	45	45
	66	1	1	301	301
19	70	3	2	171	57
	69	5	4	435	87
	68	2	1	107	54
	67	1	1	96	96
	66	2	2	270	135
20	69	2	2	279	140
	68	-	-	-	-
	67	2	2	190	95
	66	-	-	-	-
	65	1	1	13	13
21	69	1	1	11	11
	68	2	2	330	165
	67	3	3	417	139
	66	-	-	-	-
	65	1	1	189	189
22	67	2	2	134	67
	66	2	2	48	24
	65	1	1	4	4
23	67	1	1	14	14
	66	1	1	6	6
	65	1	1	312	312

total of 103 hauls were attempted along this coast, of which 80 hauls (78%) were positive and 23 hauls negative for the occurrence of pelagic shrimps. The number of shrimps per haul ranged from 2 to 948, the average abundance worked out for the entire coast being 82/haul. Details of the shrimp catch from different squares are given in Table 2. In general, the density of pelagic shrimps in this coast was considerably less as compared to the same in the west coast. The maximum catch rate of 458 nos/haul was recorded in the 20-87 degree square off Paradip in Orissa coast from where the largest haul (948 nos) was taken (Fig. 2) in the month of March. The areas of abundance were relatively less and more widely spaced than in the northwest coast.

A comparison of the numerical abundance of shrimps in the neritic and oceanic waters (Table 4) would reveal that a denser population exists in the oceanic areas of the southeastern region, whereas in the northeastern region the neirtic zone is more productive.

TABLE 2. *Area-wise catch and abundance of pelagic shrips on the east coast*

Area (1° square) Lat. (°N)	Long. (°E)	Total No. of hauls	No. of positive hauls	Total No. of shrimps	Mean No. per haul
6	77	2	2	17	9
	78	1	0	0	0
7	77	2	2	72	36
	78	1	1	300	300
8	78	3	3	687	229
9	79	1	1	67	67
10	80	1	0	0	0
	82	1	1	197	197
11	80	4	4	273	68
12	80	4	4	229	57
	81	2	2	142	71
13	80	3	3	14	5
	81	1	1	75	75
	82	2	2	247	124
14	80	2	2	39	20
	81	1	1	6	6
	82	1	1	11	11
15	80	2	2	21	11
	81	2	1	10	5
	82	1	1	183	183
	83	2	1	72	36
	84	-	-	-	-
	85	1	1	16	16
	86	1	1	7	7
	87	1	1	98	98
	88	-	-	-	-
	89	1	0	0	0
	90	-	-	-	-
	91	1	1	10	10
16	81	1	0	0	0
	82	3	2	79	26
	83	1	0	0	0
	84	3	2	267	89
	85	1	1	43	43
	86	2	0	0	0
	87	-	-	-	-
	88	1	1	160	160
	89	1	0	0	0
	90	1	1	125	125
17	82	1	0	0	0
	83	-	-	-	-
	84	1	0	0	0
	85	1	1	144	144
	86	1	1	30	30
	87	2	2	8	4
	88	1	0	0	0
	89	1	1	79	79
	90	1	1	129	129
18	83	1	0	0	0
	84	3	3	361	120
	85	4	4	249	62
	86	1	1	163	163
	87	1	1	3	3
	88	1	0	0	0
	89	1	0	0	0
	90	-	-	-	-
	91	1	0	0	0
19	84	1	1	172	172
	85	1	1	195	195
	86	3	2	150	50
	87	2	2	496	248
	88	1	1	10	10
	89	1	1	70	70
	90	1	0	0	0
	91	1	1	106	106
20	86	1	1	16	16
	87	3	2	1,374	458
	88	3	3	135	45
	89	2	1	32	16
	90	1	0	0	0
	91	1	1	2	2
21	90	1	1	125	125

Andaman-Nicobar Region

The study from this region is restricted to 36 IKMT hauls taken during April, 1986 from the oceanic waters between 635 and 4,101 m depth at bottom. As many as 33 hauls (91%) were positive and the rest negative. The number of shrimps present in individual hauls ranged from 2 to 717, with an average catch rate of 107/haul for the whole region. The square-wise catch details are given in Table 3. When compared with the east coast region, it is observed that the seas around Andaman-Nicobar Islands are more populated with pelagic shrimps. The greater part of the region is characterised by moderate abundance of shrimps ranging from 101 to 1,000 nos/haul, with the maximum density off Middle and Little Andaman islands in the Andaman Sea (Fig. 2).

Seasonal variations

As the west coast provided almost an year-round coverage of IKMT sampling, an attempt was made to analyse the catch data of this region to study the seasonal pattern in the occurrence of pelagic shrimps. For this purpose the period of an year was divided into three seasons, namely pre-monsoon (February-May), monsoon (June-September) and postmonsoon (October-January), and the average number of shrimps per haul was worked out for each of the seasons separately for the neritic and oceanic waters (Table 5).

It is evident from the analysis that the pelagic shrimp population occurs throughout the year in the neritic as well as oceanic areas. During the pre-monsoon and monsoon seasons, the shrimp abundance is considerably higher in the oceanic waters than in the neritic zone. The post-monsoon period, however, exihibit an opposite trend, the shelf region being highly productive than the oceanic. The increase in shrimp population in the neritic waters during this season was due to the heavy occurrence of the same in the near-shore areas of regions like the Bombay-Ratnagiri coast during December.

Day and night variations

Changes in abundance of shrimps in the IKMT during day and night could throw light on the nature of vertical migration of these crustaceans (Foxton, 1970 a, 1970 b) as the DSL is characterised by cyclic changes in position in the upper columnar region of the sea with change of day and night (Menon and Prabhadevi, MS; Mathew and Natarajan, MS). According to the latter authors, the deep scattering layers ascend to surface or epipelagic realm during night and descend to deeper waters during day. In order to understand the diurnal

TABLE 3. *Area-wise catch and abundance of pelagic shrips on the Andaman - Nicobar region*

Area (1° square) Lat. (°N)	Long. (°E)	Total No. of hauls	No. of positive hauls	Total No. of shrimps	Mean No. per haul
5	92	1	1	228	228
	93	1	1	24	24
6	90	1	1	137	137
	91	1	1	378	378
	92	-	-	-	-
	93	1	1	18	18
7	90	1	1	200	200
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	90	90
	94	2	2	172	86
8	90	1	1	380	380
	91	1	1	101	101
	92	-	-	-	-
	93	1	1	168	168
	94	1	1	64	64
9	91	1	1	435	435
	92	1	1	148	148
	93	-	-	-	-
	94	1	1	198	198
10	92	1	1	2	2
	93	-	-	-	-
	94	1	1	717	717
	95	1	0	0	0
11	90	2	2	61	31
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	257	257
	94	1	1	505	505
	95	1	1	124	124
12	90	1	1	113	113
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	150	150
13	89	1	1	13	13
	90	-	-	-	-
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	51	51
	94	2	2	309	155
14	88	1	1	14	14
	89	1	0	0	0
	90	-	-	-	-
	91	1	0	0	0
	92	1	1	127	127
	93	-	-	-	-
	94	1	1	105	105
	95	1	1	26	26

TABLE 4. *Relative abundance (Av. No. /haul) of pelagic shrimps in the neritic and oceanic waters of different regions of Indian coasts*

Regions	Neritic waters	Oceanic waters
South-western region including Lakshadweep (Lat. 7° N to 15° N)	393	317
North-western region (Lat. 16° N to 24°N)	632	219
South-eastern region (Lat.6°N to 22°N)	114	87
Andaman and Nicobar islands	-	107

TABLE 5. *Seasonal abundance of pelagic shrmps along the west coast of India*

Particulars	Neritic waters	Oceanic waters
Premonsoon		
Total number of hauls	7	50
Total number of shrimps	1,275	11,214
Average number of shrimps/haul	182	280
Monsoon		
Total number of hauls	20	44
Total number of shrimps	5,938	16,230
Average number of shrimps/haul	297	369
Postmonsoon		
Total number of hauls	43	80
Total numhber of shrimps	21,491	16,978
Average number of shrimps/haul	500	212

variations in shrimp distribution, the catch data of day and night hauls were analysed separately and the results are presented in Table 6. It can be seen that the pelagic shrimps occur in greater abundance during night in all the regions of investigation. On the west coast, out of the 17 latitudinal areas as many as 13 have recorded higher catch rates for the night collection. The average density of shrimps during night (473 nos/haul) was over three times greater than the same during day time. For the other regions, the increase in overall abundance of shrimps during night was to the extent of 39% on the east coast and 67% in the Andaman Nicobar region.

TABLE 6. *Day and night variations in abundance of pelagic shrimps in different regions of Indian EEZ*

Latitudinal areas	Average number of pelagic shrmps per haul					
	West coast		East coast		Andaman & Nicobar region	
	Day	Night	Day	Night	Day	Night
5°N	-	-	-	-	228	24
6°N	-	-	6	-	18	256
7°N	113	246	-	124	137	98
8°N	164	200	283	122	83	380
9°N	121	499	67	-	148	317
10°N	178	322	-	99	-	360
11°N	59	971	75	66	236	3
12°N	151	479	72	51	150	113
13°N	38	596	41	64	25	162
14°N	144	342	14	-	44	64
15°N	137	506	9	53	-	-
16°N	329	212	15	92	-	-
17°N	194	293	28	72	-	-
18°N	80	2,094	29	96	-	-
19°N	141	15	77	135	-	-
20°N	95	97	170	16	-	-
21°N	156	10	125	-	-	-
22°N	37	38	-	-	-	-
23°N	163	6	-	-	-	-
Total No. of hauls	128	116	57	46	19	17
Av. No. of shrimps/haul	141	473	64	89	112	188

Composition of pelagic shrimps

The pelagic shrimp collections were invariably multispecies in nature and represented by the penaeidean as well as caridean groups. A gross examination of representative samples from the different regions of Indian coasts has shown that the shrimp population is predominantly constituted by species of the genera Sergestes and Acetes (Sergestidae) Thalassocaris (Thalassocarididae) and Pasiphaea and Leptochela (Pasiphaeidae). In the oceanic waters around Lakshadweep and off the southwest coasts, species of Sergestes were observed in large swarms. In some of the hauls they formed as much as 72-100% of the shrimp catch by number. Voracious feeding on species of this genus by tunas (albacore) has been reported from the Pacific waters, besides the same being eaten in large quantities by fin and sei whales (Omori et al., 1972; Omori, 1974). Among caridean shrimps recorded during the present study, a species that deserves special mention is Leptochela robusta which was caught in fair quantities throughout the west coast. This species is reported to form an important forage of tunas and other pelagic fishes in the Lakshadweep and neighbouring seas (George and Paulinose, 1973; James et al., 1987).

The shrimp catch near the coast was characterised by dominance of *Acetes*. Off Bombay-Ratnagiri coast where the maximum density of pelagic shrimps was observed, species of *Acetes* accounted over 80% of the catch. *A. johni* predominated in the population followed by *A. indicus* and other species.

Discussion

The present study of the IKMT collections taken by FORV *Sagar Sampada* reveals that the Deep Scattering Layers harbour rich population of pelagic shrimps throughout the Indian EEZ. Among the larger pelagic crustaceans occurring in the sea, shrimps appear to occupy a position next to euphausiids in numerical abundance. Looking at their distribution pattern in different regions of Indian coasts (Fig. 2, Tables 1 to 4) it becomes apparent that the southwest coast including Lakshadweep and the seas around Andaman-Nicobar region are the most productive. As tunas are the important predators of pelagic shrimps, as already pointed out, a positive relationship between the abundance of these two groups could be expected. According to George *et al.* (1977) the maximum density of tunas and allied fishes in Indian EEZ is in the southwest coast and the oceanic islands. It is therefore reasonable to presume that the high productivity of pelagic shrimps could be one of the influencing factors for the abundance of tunas and allied fishes in these regions. The observation of James *et al.* (1987) that oceanic tunas in Lakshadweep feed heavily on *Leptochela robusta* is indicative of selective feeding of tunas on such species of pelagic shrimps. Perhaps a detailed study of the interrelationship between the forage species of shrimps and tunas may reveal that the former could serve as indicator for tuna shoals. Use of selected species of pelagic shrimps as live bait for tuna fishing is also worth attempting in view of the increasing shortage of live-bait fishes in the traditional fishing grounds around Lakshadweep.

The occurrence of *Acetes* in large quantities in the coastal stations off Bombay -Ratnagiri coast in Maharashtra shows that potentially exploitable stocks of these shrimps exist outside the present fishing areas covered by the indigenous gears like 'dol' nets. Commercial mid-water trawling for the exploitation of *Acetes* in the offshore waters along the northwest coast could be an alternative for augmenting production of non-penaeid prawns in the country.

According to Omori (1974), pelagic shrimps are distributed at various depths ranging from surface to at least 4,000-6,000 m in the sea. Distinct diurnal migration of pelagic shrimps in Indian seas is evident from the day and night variations in the catch of the IKMT hauls. Foxton (1970 a, 1970 b), in his exhaustive work on vertical distribution of pelagic decapods in the eastern North Atlantic, has observed that several species of shrimps exhibit active vertical migrations between surface and deeper waters upto about 1,000 m depth. Species living in the depth range 800-1,500 m, however, perform only limited upward migration (Omori, 1974). As the data on hand is limited to only the epi-and mesopelagic realms, no conclusion is possible as to the lower limit of the distribution of pelagic shrimps in Indian waters. Systematic survey of the deeper strata of the columnar sea is needed for proper understanding of the ecology and biological characteristics of this interesting group.

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ON THE SCARLET SHRIMP *PLESIOPENAEUS EDWARDSIANUS* (JOHNSON) CAUGHT FROM THE CONTINENTAL SLOPE OFF TRIVANDRUM, SOUTHWEST COAST OF INDIA - AN INDICATION OF A POTENTIAL DEEP-SEA PRAWN RESOURCE

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Abstract

The Scarlet shrimp *Plesiopenaeus edwardsianus* (Johnson) is one of the larger species of the family Aristeidae known to be widely distributed in the continental slopes of the tropical and subtropical belt of the Atlantic and also reported from the Indo-West Pacific oceans. It contributes to commercial fisheries in some areas along the West African coast. The present communication deals with the occurrence of this species in Bobbin Trawl operations off Trivandrum at 876-976 m depth in the latter half of January, 1985. This is the first authentic report of the species from the Indian seas. While the catch in terms of quantity may not be significant, it is felt that it is indicative of the presence of a larger population, which might sustain a commercial fishery of this jumbo sized prawn. Taxonomy, distribution and available information on the existing commercial fisheries of the species are given.

Introduction

From Indian waters little is known of the fishery potential of continental slope beyond 500 m depth. During one of the deep-sea trawling operations of FORV *Sagar Sampada* a few specimens of prawns, which were unusually large in size, were taken from about 900 m depth off Trivandrum on the southwest coast. The specimens were subsequently identified as the scarlet shrimp *Plesiopenaeus edwardsianus* (Johnson) belonging to the family Aristeidae (Penaeidea). As this is the first authentic record of the species from Indian seas the same is reported here, indicating its fishery potentiality.

Systematics

Prawns of the family Aristeidae are all deep-sea forms, which generally occupy the continental slope upto a depth of about 5,400 m. The following characters distinguish the family : Rostrum very long in females and young males but becoming considerably short in adult males, with three or more dorsal teeth; carapace without postorbital spine; eye stalks with a tubercle on inner border; upper antennular flagella very short and flattened almost throughout their length; endopods of second pair of pleopods in males bearing appendix masculina and appendix interna; third and fourth pairs of pleopods biramous; telson armed with 1 or 4 movable spines on each side; two well developed arthrobranchs on penultimate thoracic segment.

In the western Indian Ocean this family is represented by seven genera including *Plesiopenaeus* (Miquel, 1984). Of this, species of the genera *Aristeus* and *Aristaeomorpha* contribute to the deep-sea prawn catches off the southwest coast of India (Suseelan, 1985, 1988).

Plesiopenaeus edwardsianus (Johnson) (Fig. 1)

Penaeus edwardsianus Johnson, 1967, p. 897.

Aristeus edwardsianus Miers, 1878, p. 308, pl. 17,fig.3.

Plesiopenaeus edwardsianus, Faxon, 1895, p. 199;

Alcock, 1901, p. 36; Barnard, 1950, p. 624; Crosnier and Forest, 1973, p. 292, fig. 98 (with synonymy); Holthuis, 1980, p.11; Dore and Frimodt, 1987, p. 182.

The species was originally described by Johnson (1867) and subsequently reported on by several authors like Crosnier and Forest (1973), Holthuis (1980), Dore and Frimodt, (1987) to mention a few recent ones.

Material

Three female specimens ranging in total length from 207 to 245 mm (rostrum partly broken in all specimens) and carapace length from 79 to 96 mm obtained in Bobbin Trawl at 876-976 m depth

Fig. 1. *Plesiopenaeus edwardsianus* (Johnson), female.

off Trivandrum (Lat. 8° 28'3"N and Long. 76°14'7"E), 24th January, 1985 at 1225 hrs.

Description

Integument glabrous; rostrum long, about 0.6 times as long as carapace, armed dorsally with three teeth, middle one placed directly above orbital margin; hepatic and postantennal spines absent, antennal spine small, pterygostomian spine well developed; cervical groove moderately distinct; postrostral carina sharp, extending to end of gastric region and thereafter becoming obtuse; a strong and sharp longitudinal ridge from orbit to cervical groove, and other ridges and longitudinal grooves distinct; third to sixth abdominal terga strongly carinated, each carina ending in a spine posteriorly; posteroventral corners of pleurae of 3rd to 5th segments rounded bearing a small spine; telson acute, shorter than inner rami of uropod, dorsally flattened, feebly channelled, sides armed with 3 or 4 pairs of movable spinules (not clearly visible as they were all broken); third thoracic sternite unarmed, fourth one carrying a triangular tooth with anteriorly directed sharp point, fifth sternite with an ovoid tubercle or shield-shaped plate inclined anteroventrally and covered with stiff setae (the above two structures represent parts of thelycum); third maxilliped stouter than all pereopods and much longer than first and second pereopods, third pereopod largest carrying a podobranch, fourth pereopod with a large epipod; exopods of all pleopods very long.

Colour

All the three specimens in fresh condition were uniformily pink in colour.

Distribution and Remarks

The general distribution of *P. edwardsianus* as given in the FAO Species Catalogue on Shrimps and Prawns of the World (Holthuis, 1980) is as follows: "Eastern Atlantic: Portugal to South Africa, not in the Mediterranean; Western Atlantic: Grand Bank (43° 42' S) to the Gulf of Mexico, Carribean Sea and north coast of South America. Also reported from the Indo-West Pacific region, but it is not certain whether this is really the same species".

Alcock (1910) in his descriptive catalogue of the Indian deep-sea crustacea collected by "Investigator" reported on *Aristaeus* (*Plesiopenaeus*) *edwardsianus* and gave a description of the species. He mentioned the species having been recorded from the Arabian Sea near the Malabar coast (430 fathom), Gulf of Mannar (507 f and 457-589 f) Bay of Bengal (475 f) and Andaman Sea (188-220 f and 271 f). However, Holthuis (1980) doubted the species identity of Alcock (1901).

Dore and Frimodt (1987) in their illustrated guide to shrimps of the world, state that the scarlet shrimp is found in the eastern Altantic from Portugal to South Africa, western Atlantic from the Grand Banks to the Gulf of Mexico and the north coast of South America, east coast of Australia, New South Wales, south coast of Africa, Madagascar and from the Arabian Gulf (Fig. 2). According to them all reported quantities have been very small and caught from muddy bottoms ranging in depth from 275 to 1,850 m and most are found between 400-900 m. They report the colour as bright red and like many other deep water shrimps the species has rather soft sweet flesh. Crosnier and Forest (1973) while giving distribution of the species also include the Andaman Sea and Sumatra. Graham and Gorman (1985) mention about catch of several specimens of the 'Scarlet prawn' *Plesiopenaeus edwardsianus* from 550-900 m depth, especially between lat. 27° -28° and 33°-34° off New South Wales in Australia.

The maximum total length of the species, according to Hotlhuis (1980), is 193 mm for male and 334 mm for female. It is also mentioned that the species is fished commercially by Spanish trawlers, off Senegal, Guinea, Congo and Angola (4° to 10° S). Crosnier and Jouannic (1973) reported on a shrimp assigned to the species as a potential resource on the continental shelf of Madagascar. The commercial catches from West Africa are reportedly frozen whole for sale mainly in Spain and France.

During the present trawling operations of

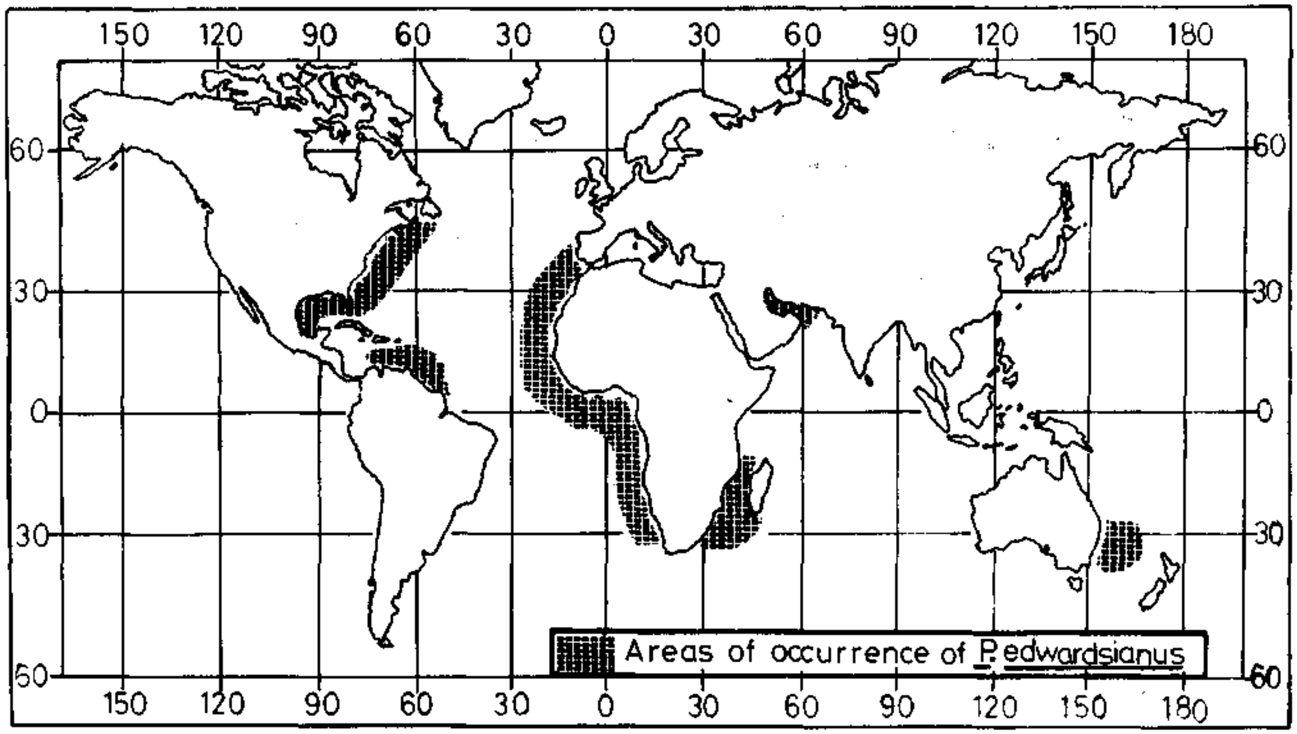

Fig. 2. Distribution of the scarlet shrimp *P. edwardsianus* - after Dore and Frimodt (1987).

Sagar Sampada , the one hour haul at 876-976 m depth yielded a total catch of only 8.6 kg of fish and prawns including the 3 specimens of *P. edwardsianus* and 5 specimens of *Acanthoyphra* sp. All the three specimens of *P. edwardsianus* were females with fully mature ovary, which was reddish pink in colour. Alcock (1901) stated that the male of the species he assigned as *P. edwardsianus* was of the same size as the female, the rostrum being smaller in the females.

The fish components consisted of 4 chimaeras, 1 skate, 9 rat rails (Macruridae), one squaloid shark and few small flat fishes, medusae and a starfish. The present observations, while confirming the occurrence of the pink shrimp *P. edwardsianus* in the Indian waters indicate the possibility of its wider occurrence in the area. It may be recalled here that the observations of a few numbers of the deep-sea lobster *Puerulus sewelli* later led to the discovery of trawling grounds for the species now being exploited commercially. In the context of commercial exploitation of the scarlet shrimp in West African waters it is not unlikely that this species can form a potential resource for commercial exploitation in the Indian Exclusive Economic Zone.

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INVESTIGATIONS ON THE DSL OF THE INDIAN EEZ WITH SPECIAL REFERENCE TO EUPHAUSIIDS AS A COMPONENT

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ABSTRACT

The paper embodies the results of a study on the behaviour of Deep Scattering Layer in general and the role of euphausiids in the DSL based on observations made in the EEZ of India. Continuous monitoring on the behaviour of DSL carried out in the early morning and late evening hours revealed that the DSL oscillated between surface and around 600 m depth. The descent from surface started as discrete layers which detached one by one and went down to ultimately settle at depth more than 400 m. Similarly the upward migration in the evening also took place as definite layers from the main DSL and moved upto the surface.

Apart from the above, 190 observations were made for understanding the position and vertical thickness of the DSL during day as well as night. It was found that the first symptom of descent of DSL started as early as 0520 hrs and settled at the day time level by 0815 hrs thereby exhibiting a mean downward velocity of 3.76 m per minute. Similarly, the upward movement which started from the deepest level of 550 m as early as 1435 hrs and reached the surface by 1800 hrs was found to be at a mean velocity of 2.04 m per minute.

A total of 308 samples collected from the DSL were analysed for a study of euphausiids as a component of the DSL. It was found that the euphausiids were present in all except 51 samples. While the night hauls had euphausiids at the rate of 568 per 30 minutes trawling, the day hauls had them at a rate of 158, thus registering about 3.6 times increase in the night samples. This shows the DSL independent behaviour of the euphausiids. The study also revealed the existence of two separate populations of euphausiids; one of which oscillating between the surface and 300 m of depth and the other between 300 and 500 m.

INTRODUCTION

The sonic scattering layer in the sea, popularly known as the Deep Scattering Layer has been a matter of interest to science eversince the echosounder was invented. The association of biological organisms to the DSL has been undoubtedly proved as a result of direct as well as indirect observations carried out the world over. These studies have also brought to light the existence of a vast resource - the mesopelagic resource - composed mainly of smaller fishes, crustaceans and some other invertebrates.

In spite of a rather rich literature available on the DSL of many parts of the world oceans (Anon., 1946; Dietz, 1948; Raitt, 1948; Boden, 1950, 1962; Moore, 1950; Hersey *et al.*, 1952; Bernard, 1955; Uda, 1956; Backus and Banner, 1957; Clarke and Backus, 1964; Barham, 1966; Barry, 1966a, 1966b; Kinzer, 1969), the Indian Ocean, particularly the Indian seas remained the least investigated for the DSL. The only information available for the Indian Ocean are those of Daniel *et al.*, (1969), and Silas (1972). Daniel *et al.* (1969) made a preliminary study of the zoological constituents of the sonic scattering layer based on observations made at seven stations in the Bay of Bengal. Silas (1972) made some valuable studies on the DSL in the Lakshadweep Sea. He made visual observations on echograms at different times of the day, especially in the early morning and late evening hours and recorded the sequences in the downward or upward movement of the DSL in relation to time. However, the results of these studies are not conclusive in themselves for there were only meagre facilities available for locating and sampling the DSL.

MATERIAL AND METHODS

The material for the present study was obtained from the EEZ and contiguous seas of India during the cruises of FORV *Sagar Sampada.*

As modern sophisticated facilities were available in FORV *Sagar Sampada*, aimed fishing in the exact location of DSL at any time of the day was possible. The mini T.V. monitor provided at the bridge of the ship facilitated continuous visual monitoring of the behaviour of the DSL during day or night.

A total of 308 samples collected during cruises 6-15 were made use of for the study. Majority of the samples were collected from the major DSL. The DSL was visually located on the colour monitor screen and also on the echogram. An Isaacs-Kidd Midwater Trawl was made use for sampling the mesopelagics. The net attached with a net sonde was lowered to the DSL each time and the position of the net, its mouth opening and the temperature at the depth of sampling were monitored using an echosounder. Horizontal trawling was carried out for half an hour at a speed of three knots per hour. In the laboratory, first the total volume of the samples was determined by settling method after which the euphausiids as well as other groups were separated and enumerated. The values of numerical abundance were presented as number per 30 minutes trawling.

Besides the above, continuous watch on the DSL on the monitor screen in the morning and evening hours when the DSL performed active downward and upward movement was carried out on a particular day during one of the cruises under study.

Results and Discussion

Behaviour of DSL

Ten stations were engaged from 25th to 30th April, 1985 in the oceanic waters within a four degree square area in the Lakshadweep Sea between 08°30' and 10°30'N and 73°00' and 75°00' E for a special study on DSL. At each station, three samplings, one each in succession from three discrete layers of DSL were made using the IKM Trawl for understanding the composition of the DSL at different depths during different times of the day. In addition to the above, continuous visual observations on the DSL were carried out on 29th April, 1985 on a monitor screen (provided at the bridge of the ship) between 0600 and 0810 hrs and between 1800 and 1930 hrs.

In the day time the DSL was found to generally occupy a position below 400 m which migrated upto the surface in the night. It was observed that the active movement of the DSL downward was between 0500 and 0800 hrs and upward between 1700 and 1900 hrs. It was observed on the monitor screen that the downward migration took place as thin but distinct layers; each layer getting detached from the main DSL in the surface waters and travelling at different velocities. It is quite possible that the animals constituting the DSL after a common assembly in the surface waters during the night time start moving down at their preferred time in the morning hours in accordance with their tolerance to light. Similarly, towards the evening, definite layers constituted by similar type of organism or organisms which preferred definite level of light intensity get detached from the main DSL of the day level as definite layers and migrate upwards one by one at varying speeds finally reaching the surface in the night. It was also observed that the minor layers while travelling up or down unite themselves at some depths in between and then migrate together. This is effected due to the differential velocities of each migrating layer.

Quite often each minor layer had one dominant group of organism namely euphausiids, pelagic decapods, lantern fishes, pelagic crabs, siphonophores, pyrosoma or deepwater pelagic shrimps. This was evident from sampling the various layers at different times of the day.

It was observed that while the crabs occupied the surface layers between 25 and 50 m in the night, the deep water prawns were found around 400 m and downward only. They never ascended above 400 m. The euphausiids were found in almost all layers but had greater concentrations between 200 and 400 m of depth. However, there was discrete layering according to species of euphausiids. Thus while *Euphausia sibogae* occurred in the upper layers, *Thysanopoda monacantha* and *T. tricuspidata* occupied the deeper layers.

Given below is the result of visual observations on the behaviour of DSL made on the monitor screen at the bridge of the ship. It may be mentioned here that the observations could not be started at the time when the first symptoms of descent as early as 0500 hrs or ascent by 1400 hrs started to occur and hence the sequences in migration may not be complete.

At 0600 hrs, a compact band was seen on the monitor screen to occupy between 0 and 90 m. The major part of this layer might have been formed of phytoplankton which remained in the surface waters at all times of the day. However, five distinct layers could be recognized in this surface layer by 0600 hrs which could be the aggregations of zooplankters either oriented to remain in the surface itself or getting ready for a downward movement. As time advanced, some of these layers were found to descend one after the other at varying speed to occupy intermediate positions in the subsurface waters. These minor layers cannot be considered as true DSL for they do not travel to greater depths and do not form high density layers.

At 0600 hrs, below 90 m and upto 200 m the water column was practically devoid of any zooplankton layer. The next layer, which was the true DSL was found between 200 and 420 m and was composed of six distinct layers, one close to the other, whose bottom portions were at 250, 300, 350, 370, 400 and 420 m. Some of them would have been those layers which migrated from the surface even before visual observations started at 0600 hrs.

By 0630 hrs, the layer which was at 250m moved down upto 330 m depth. The original layer at 300 m descended down to 350 m and united with the original layer at this level. The layers at 370, 400 and 420 m remained at their respective levels. No distinct layer was observed between 450 and 750m.

By 0645 hrs the DSL at 300 m had migrated down to 340m, that at 330 m migrated down to unite with the layer at 350 m and that at 350 m descended to 380 m. The original layer at 370 m joined the layer at 400 m. The layer at 420 m remained as such.

At 0655 hrs the layer at 340 m remained there. The layers at 350 and 380 m united together and descended to 390 m. The layers at 400 and 420 m moved down to 450 m.

By 0700 hrs the upper layer travelled down to 350 m. The middle and bottom layers remained at their respective places.

Even at 0700 hrs, the very surface band remained between surface and 105 m lending support to its phytoplankton nature. However, there could be smaller zooplankters which were either positively phototropic or tolerant to light of some intensity. According to preference to light, the organisms involved formed into four layers whose bottom portions were found to be at 10, 40, 70 and 105 m depth.

At 0705 hrs, the upper layer of the real DSL which was at 350 m at 0700 hrs moved down to 370 m. The layers at 390 and 450 m got disintegrated leaving no indication of their presence or movement.

At 0725 hrs a new layer of low density was visible between 250 and 270 m. This was actually an aggregation of the evenly distributed plankton over a wider range. After forming into a layer, it started moving down.

By 0800 hrs, the layer at 370 m was found to set at 390 m. The new layer formed by 0725 hrs at 270 m descended to 340 m. Another feeble layer was found to form with its bottom portion at 240 m.

At 0810 hrs all the deep scattering layers under observation were found to settle at their day time depths between 350 and 400 m (Fig. 1). Below this level no other DSL was indicated upto 750 m which was the maximum depth that could be probed by the sonar used for observation.

In the evening also continuous observations on the monitor screen were carried out for understanding the behaviour of the DSL while migrating upwards. AT 1800 hrs, the surface band composed mainly of phytoplankton was found to remain in the same position as in the morning say between surface and 105 m with more density between 30 and 90 m. At 120 m level there was a narrow band of very thin layer below which there was no indication of any DSL upto 200 m. One broad diffused layer of about 40 m thickness was seen migrating fast upward from 230 upto 200 m. Between 230 and 300 m, again there was not much of organisms. Below 300 m and upto 500 m there was a very thick layer. Below 500 m and upto 700 m there was a layer of a diffused nature.

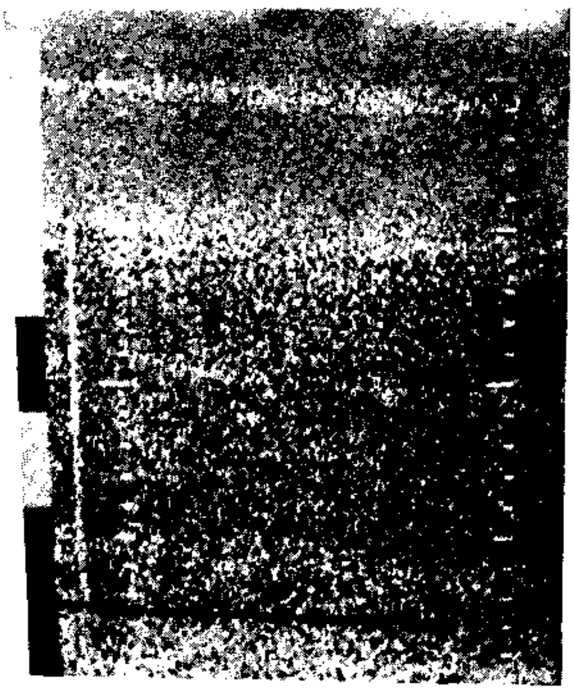

Fig. 1. The day time position of the DSL observed between 200 and 400 m in the Lakshadweep Sea. Note the thin but discrete layer at 100 m (phased scale with each division representing 20 m).

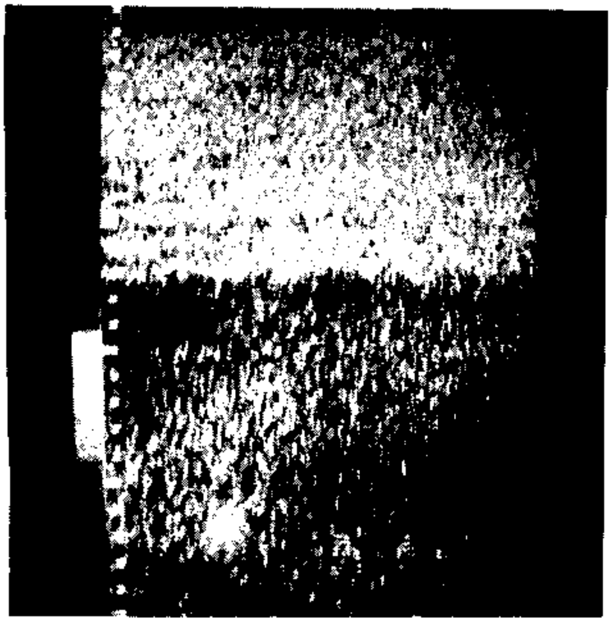

Fig. 2. The DSL in active upward migration. Organisms from greater depth come up late in the night to join the DSL already reached the surface. In the early morning it is these components that make the downward migration first (normal seale with each division representing 2 m).

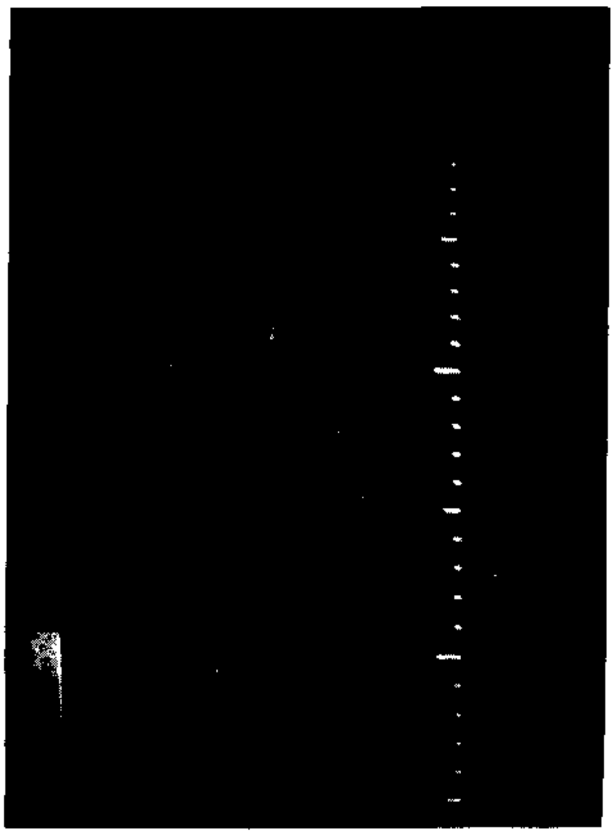

Fig. 3. The DSL migrated upto the surface during night. Note the different layers, each probably composed of assemblages of animals of the same variety (normal scale with each division representing 2 m).

At 1900 hrs, the layer which was at 200 m was found moving fast upwards at a rate of 5 m per minute. By 1915 hrs, this layer came upto 125 m and by 1930 hrs this layer came up (Fig. 2) and merged with the surface band (Fig. 3). All this time other layers at the deeper depths were also moving upwards. At 1930 hrs they were found to have been occupying between 300 and 400 m and between 450 and 600 m. Below 700 m there was nothing special except some very weak and thin layers.

Silas (1972) also made somewhat similar observations on the DSL of the Lakshadweep Sea. He started one observation at 0500 hrs and ended at 0730 hrs. At the start, two distinct bands, one at the surface and the other between 75 and 200 m were present. Between 0520 and 0600 hrs discrete bands got separated and descended from the second band and by about 0615 hrs the second band split and the lower layer migrated down and by 0730 hrs the latter descended to 350 and 450 m. The intermediate layer remained around 175 to 350 m. The upper bioscattering layer close to the surface (which could have been formed mainly of phytoplankton) showed a slight decrease in intensity.

During one of his evening observations at 1840 hrs Silas (1972) found three distinct bands; one between 50 and 100 m, the second between 175 and 275 m and the third between 350 and 420 m. By about 1900 hrs the second diffused and merged with the upper band.

Daniel *et al.*, (1969) found that the upper sonic scattering layer extended from 70 to 150 m. A diffused layer between 150 and 450 m was also detected. According to them, the DSL could not be detected with clarity during the day light hours, faint traces being first discerned only after dusk. This points to the limitation of the instruments used for the detection of the DSL.

A further study based on 190 samples which were known to be collected exactly from the DSL was made for understanding the diurnal behaviour of the DSL and the speed of descent or ascent and the results are given in Fig. 4. In the figure each vertical line represents the vertical thickness of the layer at the time of sampling as was observed on the monitor screen and the sampling was carried out at about the middle of the DSL. The closed circles here and there indicate the depth of sampling for certain samples which when collected, the thickness of the DSL was not noted. It is seen from the figure that the DSL occupied a vertical thickness of about 100 m from the surface between 1800 and 0520 hrs. On the other hand, the general day-time thickness of the DSL was 250 m. This behaviour of the DSL shows its tendency to aggregate to the maximum during night and to diffuse during day time. These were necessitated by the habit and habitat of the organisms involved. A night time aggregation was necessary at the surface waters where the food was plentiful. On the other hand, the day time depth of each component of the DSL was determined by its physiological needs, in that, each component has its own preferred depth of living with reference to the photic conditions of the water column or its pressure or temperature. Thus during the day time, according to the needs, the animals occupy their preferred depths by natural instincts. In this act several organisms like euphausiids and pelagic shrimps may even dissociate themselves from the major DSL and migrate far down to occupy their own preferred depths. This is explained in detail elsewhere in this paper where the day-night abundance of euphausiids is dealt with.

From the Fig. 4 it is seen that the first symptom of descent of animals from the surface started as early as 0520 hrs and they reached the upper most level of

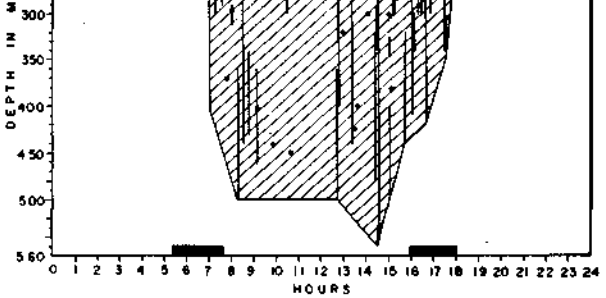

Fig. 4. The position and pattern of migration of the DSL at different times of the day, based on samples collected at different times of the day from the DSL. Each vertical line indicates the thickness of the DSL observed at a particular time of the day and the sampling was conducted somewhere from the DSL. Each black spot represents the depth of sampling without indicating the thickness of the DSL.

the day time depth at 0745 hrs thus travelling a distance of 220 m. In such an event the speed of descent may be calculated as 1.52 m per minute. Also it is seen that the descent from the lowest night level of 100 m started at 0700 hrs and reached the deepest day level of 550 m by 0815 hrs. In such a case the speed of descent may be calculated as 6.00 m per minute. From the above two values the mean velocity of descent from the surface to the deeper waters has been calculated to be 3.76 m per minute.

A similar estimation of velocity was made for the ascent also. From Fig. 4 it is seen that the first symptom of upward movement from the deeper level of 550 m started as early as 1435 hrs and the animals reached the lowest level of the night depth of 130 m at 1840 hrs thus taking 245 minutes to travel a distance of 420 m. From this, the speed of ascent was calculated as 1.87 m per minute. The speed of the ascent from the uppermost day level to the very surface was also computed. Thus it was seen that the ascent from this level (265 m) started by 1600 hrs and lasted till 1800 hrs when the animals reached the very surface. From the time taken for ascent (120 minutes) the speed of ascent has been calculated as 2.20 m per minute. From the above two values the average speed of ascent from the day time depth to the night time level has been computed to be 2.04 m per minute. A comparative study of the velocities for descent and ascent indicated that the former was faster than the latter. There are very clear reasons for this. The prime factor influencing the vertical migration of planktonic forms is the light which presses them down to the depths. The first ray of the sunlight when falls on the very surface of the water penetrates down and this creates a panic among the plankters which rush down as fast as possible to reach their day level. On the other hand, in the afternoon as the sun tilts to the western horizon, the isolume gradually shifts upwards according to which the animals also gradually ascend upwards. In other words it may be stated that there is no hurry for the organisms to rush upwards for the fading of the light is a gradual process.

Figure 5, 6 and 7 show the behaviour of DSL in the morning, noon and late evening hours respectively. The echo traces were obtained using a Simrad EK-400 echosounder during the cruises of FORV *Sagar Sampada* in the oceanic waters around the southern Indian Peninsula in December, 1986. The echo traces in Fig. 5 were obtained between 0600 and 0800 hrs. In the figure the DSL is seen as three major

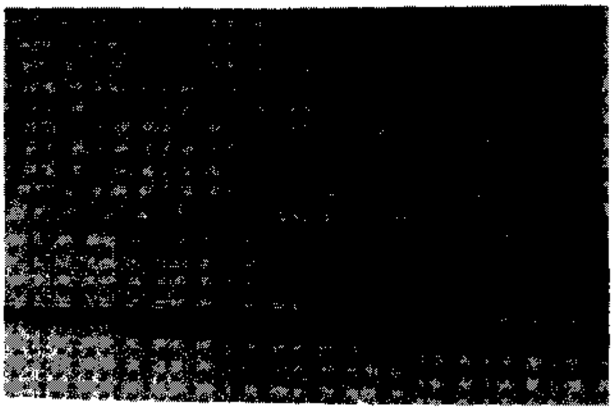

Fig. 5. The downward migration of the DSL as differnt layers from 6-8 hrs in the morning.

layers with the uppermost one constituted by atleast three distinct sub-layers. In the two hours time, the uppermost layers which occupied between 100 and 200 m at 0600 hrs got merged and descended to 360 m by 0800 hrs. The middle layer descended from 280 m to 440 m and the lowermost layer which was at 340 m at 0600 hrs descended to 560 m by 0800 hrs.

The Fig. 6 shows the position of the DSL observed between 1030 and 1130 hrs. The DSL is found settled at about 600 m. Another very feeble layer is also seen around 350 m.

The echo trace of the DSL obtained between 1800 and 1930 hrs is given in Fig. 7. The DSL at 650 m at 1800 hrs is seen migrated upto 200 m by 1930 hrs. Another layer observed at 540 m migrated upto 200m and got merged with the previously mentioned layer by 1930 hrs. A third layer distinguished itself at about 250 m sometimes after 1900 hrs migrated almost to the surface by 1930 hrs.

Day-night variations in abundance of euphausiids of DSL

There was significant difference in the occurrence of euphausiids in samples collected during day and night from the DSL, being more in the night samples. In the area surveyed, while the day time occurrence was of the order of 158 per 30 minutes trawling, the average night time density was 568, thus registering about 3.6 times increase in the latter samples. Separate analyses were made for the eastern Arabian Sea and the Bay of Bengal and found that in both the seas there was considerable day-night difference in the concentration of euphausiids. Off the west coast, the rate of occurrence was 274 and 591 respectively in the day and night samples. The increase registered in the night samples was about

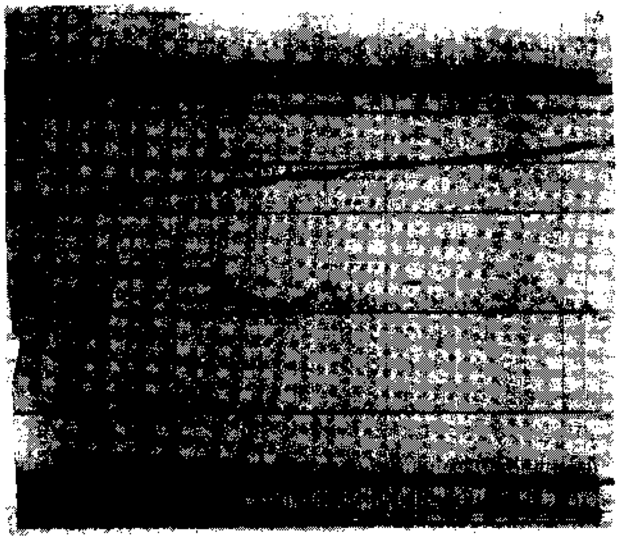

Fig. 6. The position of the DSL between 1030 and 1130 hrs. Note the DSL along the 600 m line.

116%. The corresponding day-night values for the Bay of Bengal were 75 and 206 indicating an increase of 175% in the night samples. The above results clearly show the DSL- independent behaviour of the euphausiids. The DSL exhibits rhythmic up and down movement in accordance with the time. The sampling during both day and night was always adjusted to the DSL depth, i .e ., the net was lowered far deep during the day to fish from the DSL. If the euphausiids were always a part of the major DSL there would not have been any difference in their day-night abundance. Such a vast increase in the night samples lends positive evidence to the fact that the euphausiids living at depths greater than 500 m during the day time make fast upward migration to join the major DSL in the night which was subjected to sampling.

Depth-wise diurnal abundance in comparison with total biomass

This study enabled to understand the different populations of euphausiids that lived at various depth zones at different times of the day. The results are given in Fig. 8. It is seen from the figure that one population came upto the surface during night and went down to occupy the depth between 251 and 300 m during day. Another population came from far deeper water upto 300 m during night and migrated down to more than 500 m during day. There was no DSL observed between 200 and 300 m during night which indicates that the layer which remained there during day migrated upwards in the night and occupied between surface and 200 m depth.

Fig. 7. The upward migration of different layers of the DSL from 1800-1930hrs.

Day -night abundance in relation to depth of sampling

A consideration of day-night occurrence of euphausiids in relation to water depth revealed the following (Fig.9). In the night samples collected from less than 100 m, the euphausiids occurred in relatively large numbers. Whenever they were present in the day samples taken from less than 100 m, their

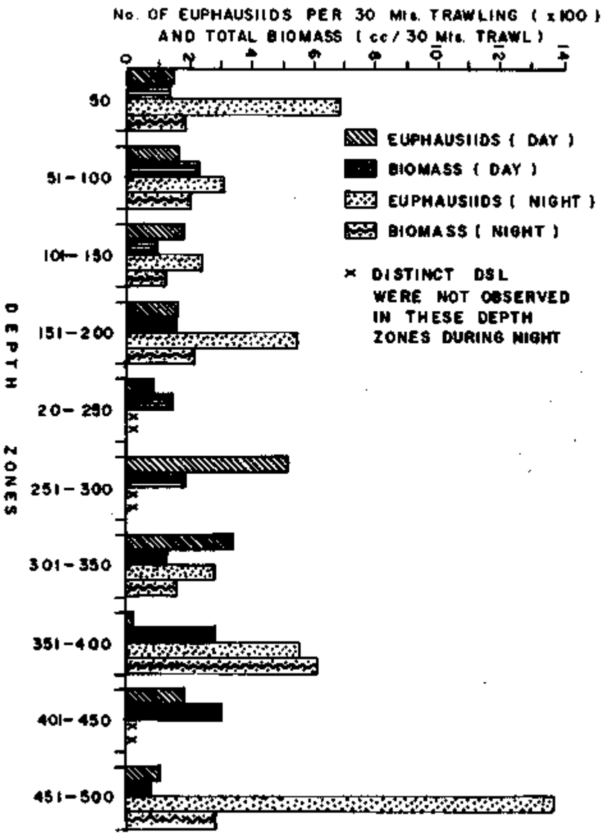

Fig. 8. Depth-wise diurnal abundance of euphausiids in comparison with total biomass.

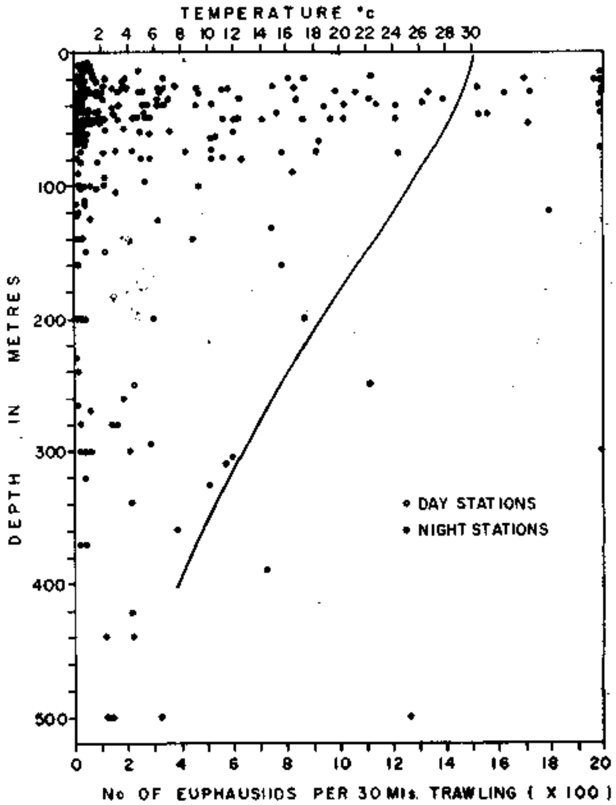

Fig.9. Day-night abundance of euphausiids in relation to depth of sampling. The diagonal line indicates the vertical gradiant of temperature.

numbers were significantly low or often absent. However, the day time samples collected from DSL of depths greater than 100 m contained good numbers of euphausiids. Except on two occasions their number never exceeded 2,500 per 30 minutes trawling. From, this figure it is also seen that during day time, the euphausiids occurred between 250 and 350 m and migrated to the surface during night. The gap created by their migration was not seen to be taken up by euphausiids coming up from the deep areas, for they restricted their migration to the 350 m level.

Density of euphausiids in the DSL of the study area

The variations in the occurrence of euphausiids in the DSL observed at different localities in the eastern Arabian Sea and the Bay of Bengal including the Andaman and Nicobar seas are presented in Fig. 10. On the whole it was found that the eastern Arabian Sea was rich in euphausiids. Very high concentrations of over 1,000, and high density between 500 and 1000 euphausiids per 30 minutes trawling occurred at several localities in the shelf and oceanic waters of this sea area especially during the night.

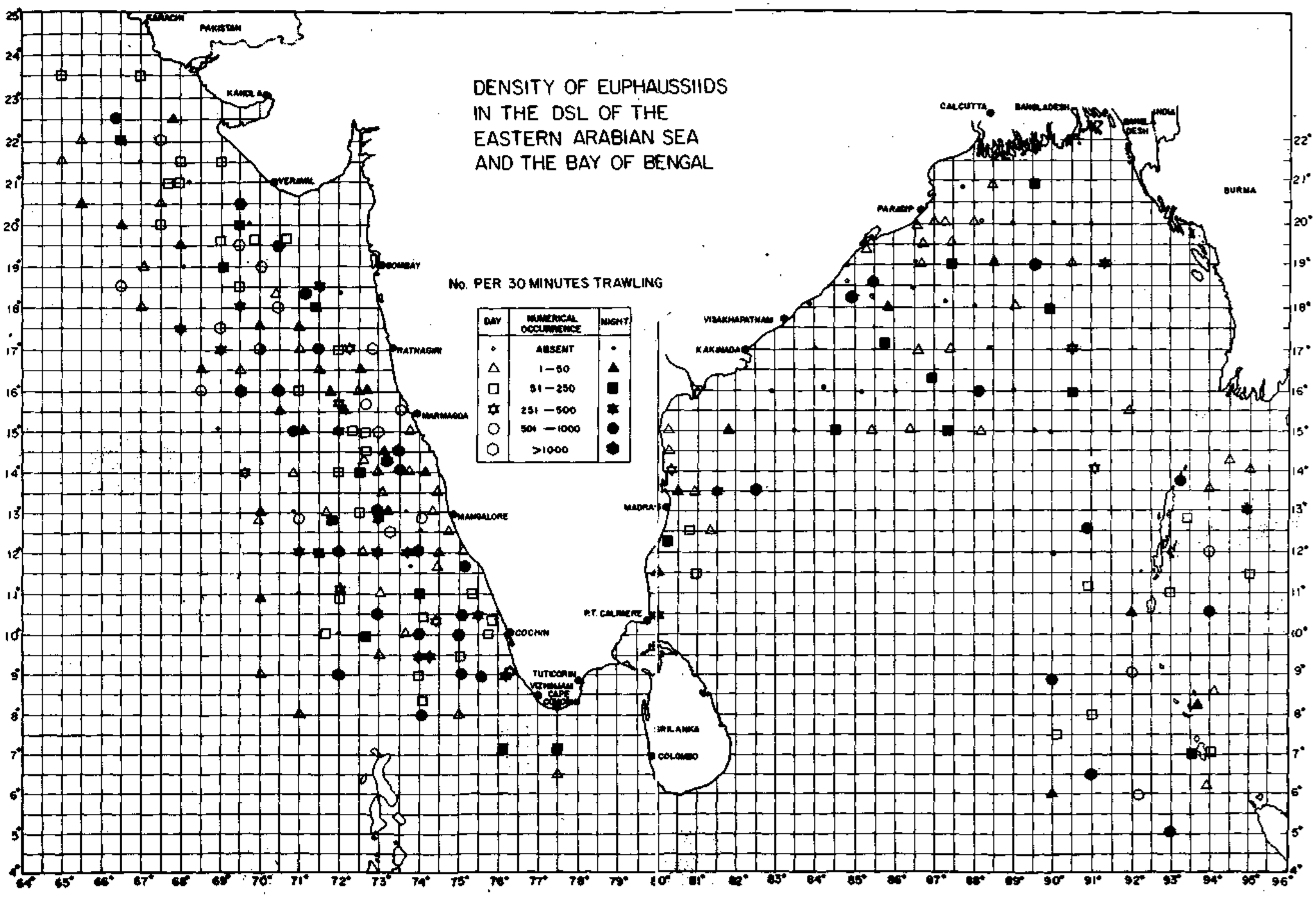

Fig.10. Density of euphausiids in the DSL of the area investigated in the eastern Arabian Sea and the Bay of Bengal.

Very high and high density of euphausiids were rarely observed in the Bay of Bengal. Whenever occurred it was beyond the continental shelf waters.

Acknowledgements

The authors are thankful to Dr. P.S.B.R. James, Director, Central Marine Fisheries Research Institute, Cochin for his keen interest in this work. Their thanks are also due to Dr. N.G. Menon, Scientist, for providing the basic data on euphausiids and to Shri. K. Solomon for the help rendered in processing the data.

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PRELIMINARY OBSERVATIONS ON THE DISTRIBUTION AND ABUNDANCE OF THE SWARMING CRAB *CHARYBDIS (GONIOHELLENUS) SMITHII* MACLEAY IN THE DEEP SCATTERING LAYERS ALONG THE WEST COAST OF INDIA

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Abstract

Results of a preliminary study of the distribution and abundance of the swarming crab *Charybdis (Goniohellenus) smithii* Macleay in the Deep Scattering Layers on the west coast of India are presented based on the analysis of 244 IKMT samples collected by FORV *Sagar Sampada* during February, 1985 to January, 1986. The swarming crab is found to exist thoughout the west coast of India as against its known distributional limit in the north upto Bhatkal in Karnataka coast. Maximum density was observed along the southwest coast. The DSL population included all life stages of the crab such as zoea, megalopa, juvenile, subadult and adult, of which juveniles in the size range 12-20 mm carapace width dominated.

Introduction

The swarming crab *Charybdis (Goniohellenus) smithii* Macleay is an endemic species to the Indian Ocean where it has been reported from the Arabian Sea and off Southeast Africa as *Charybdis smithii* Macleay and *Charybdis (G.) edwardsi* Leene and Buitendijk (Della Croce and Holthuis, 1965; Sankarankutty and Rangarajan, 1962; Silas, 1969; Mohamed and Suseelan, 1973). Recently it has also been encountered in the Bay of Bengal during the fishery-oceanogrpahic cruises of FORV *Sagar Sampada*. The correct systematic position of the species was ascertained only recently in an exhaustive revision of the portunid crabs by Stephenson (1972).

In Indian waters *Charybdis (G.) smithii* is considered to be a potentially important deep sea crab occupying the outer shelf and upper continental slope regions. It is often found swimming in large numbers in the oceanic waters. Considering the commercial prospects of this species, a detailed investigation on its biology and resource characteristics has been taken up recently based on the collections of FORV *Sagar Sampada*. In the present paper the results of a preliminary study of the distribution and abundance of this crab in the Deep Scattering Layers (DSL) off the west coast of India are given together with notes on the biology of the crab population occurring in the DSL. So far no study has been carried out on these aspects in any part of the world in general and in the Indian EEZ in particular.

Material and Methods

The material for the study was obtained from the Isaacs-Kidd Midwater Trawl (IKMT) collections taken by FORV *Sagar Sampada* during her fishery-oceanographic cruises from February, 1985 to January, 1986. The IKMT collections were taken in the Deep Scattering Layers which occupied depths upto about 600 meters from the surface. Each haul was of 30 minutes duration. A total of 244 IKMT samples were analysed for the crabs covering the entire west cost of India between Latitudes 07°00'N and 23°30'N and Longitudes 64°30'E and 77°00'E. The distribution of IKMT hauls in the study area is shown in Fig.1.

The crab population of each sample was completely sorted out and measurements of the carapace width (C.W.) were recorded sexwise to the nearest millimetre for all specimens except larval stages whose numerical abundance alone was recorded. A total of 1,542 specimens were measured comprising of both sexes. The measurements of carapace were grouped into 2 mm size classes sexwise for studying the size frequency distribution. Sexes were separated based on the shape of abdomen and the number of pleopods present in it.

Observations

Spatial distribution and abundance

Out of the 244 samples of midwater collection analysed from the entire west coast of India, 59 samples contained the swarming crab in varying

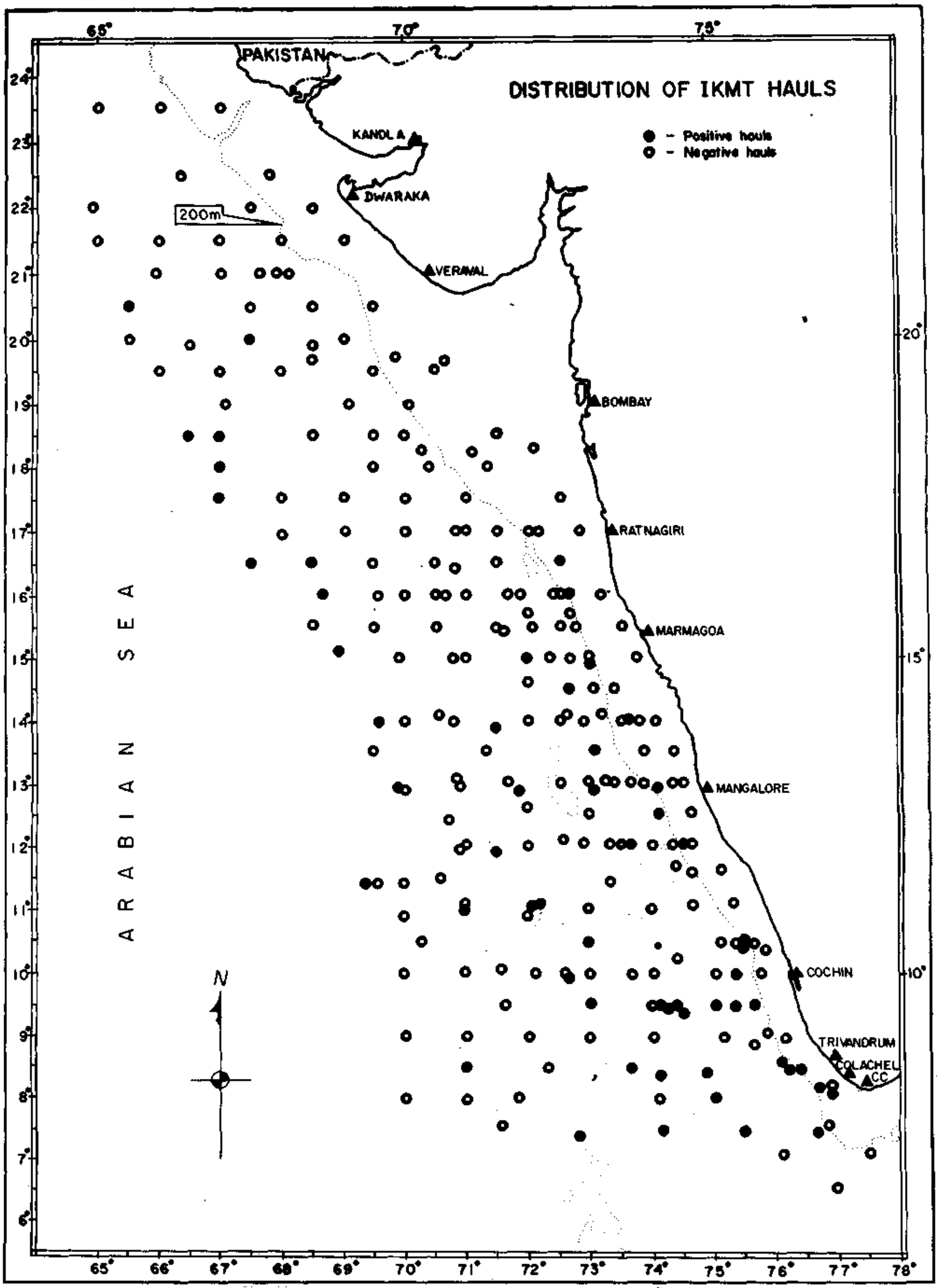

Fig. 1. Positions of IKMT hauls along the west coast of India.

numbers mixed with other pelagic groups. The species accounted for about 0.3% in the total DSL population in terms of number (Menon and Prabhadevi (1990), the maximum percentage being 81.3 recorded in the oceanic waters off Colachel on the southwest coast. The species is found to be occurring all along the west coast between Kanyakumari and Dwaraka (Fig. 2). In the positive hauls, the abundance of crab showed vast variations. Majority of these hauls yielded only stray specimens numbering less than 10 crabs per haul. Table 1 gives details of the samples containing more than 10 crabs per haul. In general, relatively more number of samples rich in crab population was recorded in the region between Ratnagiri and Mangalore, and Cochin and Kanyakumari, the maximum abundance having been observed off Trivandrum to Kanyakumari. Whenever rich catches were recorded, they were found to be sporadic and there was no consistency in the occurrence of crab in any particular region. The maximum number per haul amounted to 862 which was recorded off Colachel in the oceanic waters where the depth of the sea bottom was over 2,700 m.

Analysis of catch with reference to different depths of occurrence indicates that the species is distributed only in the outer continental shelf and in the oceanic waters. The minimum depth of the station from where the species has been encountered was 93 m at Lat. 18°30'N. The species showed its presence in varying densities within the shelf region upto about Ratnagiri, and beyond this it was encountered only in the oceanic waters far beyond the continental shelf.

Table 1. *Catch details of* Charybdis (G.) smithii *in the IKMT collections yielding more than 10 crabs/haul*

Sl. No.	Position		Depth at station (m)	Total number of crabs	Percentage in total biomass by number
	Lat. (N)	Long. (E)			
1.	08° 24'	72° 50'	1821	13	3.6
2.	07° 30'	75° 30'	2765	862	81.3
3.	07° 30'	76° 31'	1492	13	13.6
4.	07° 31'	76° 47'	1670	76	22.3
5.	08° 00'	76° 50'	99	17	21.2
6.	08° 30'	76° 12'	680	11	4.5
7.	09° 29'	74° 15'	2671	162	48.0
8.	11° 00'	72° 01'	1645	10	15.8
9.	14° 00'	66° 33'	4109	59	8.5
10.	14° 59'	73° 00'	229	37	14.8
11.	16° 00'	72° 40'	504	96	59.2
12.	16° 00'	68° 30'	3751	13	3.6

Seasonal distribution and abundance

The species was encountered in the samples throughout the year except during May and June when there was no IKMT collection. In order to study the seasonal variation in the abundance of crab in the DSL, the catch data have been pooled and averages taken for 3 seasons, namely, premonsoon (February-May), monsoon (June-September) and postmonsoon (October-January). It is found that the average number of crabs per haul varied significantly in different seasons of the year. The average catch rate per haul worked out to 64.79, 7.62 and 23.6 for premonsoon, monsoon and postmonsoon seasons respectively. The maximum number of crabs recorded in individual sample (862) was obtained during the premonsoon season (April).

Diurnal variation in abundance

From the analysis of the data collected during day and night separately, it is seen that during night, crab abundance was very high occasionally, but such rich collections were rather sporadic. (Tables 2 & 3). In the day series of collection, however, wide fluctuations in the abundance of crab were not observed as in the night series of collection. The maximum number of crab per haul recorded during the day time was 68 as against 862 crabs in the night.

Biological observation

Size composition

The IKMT samples contained all the life stages of the swarming crab, viz. zoea, megalopa, juvenile, subadult and adult. The juveniles dominated in most of the samples examined. The size frequency data have been pooled together and plotted sexwise to study the general size composition of the species in the DSL (Fig. 3A). It is seen that there is not much variation in the size composition between the two sexes. The size range of the crab, after the megalopa stage, was from 12 to 64 mm C.W. for male and 12 to 60 mm C.W. for female. Juveniles measuring 12 to20 mm C.W. formed the major component of the crab population for both sexes. In the advanced size groups, comprising of subadults and adults, individuals in the size range 34 to 54 mm C.W. were fairly common for both sexes. A study of size frequency distribution of some of the rich collections of the crab (Fig. 3 B-E) has shown that the richness of the crab samples was due to the abundance of juveniles in the size range 12 to 20 mm C.W.

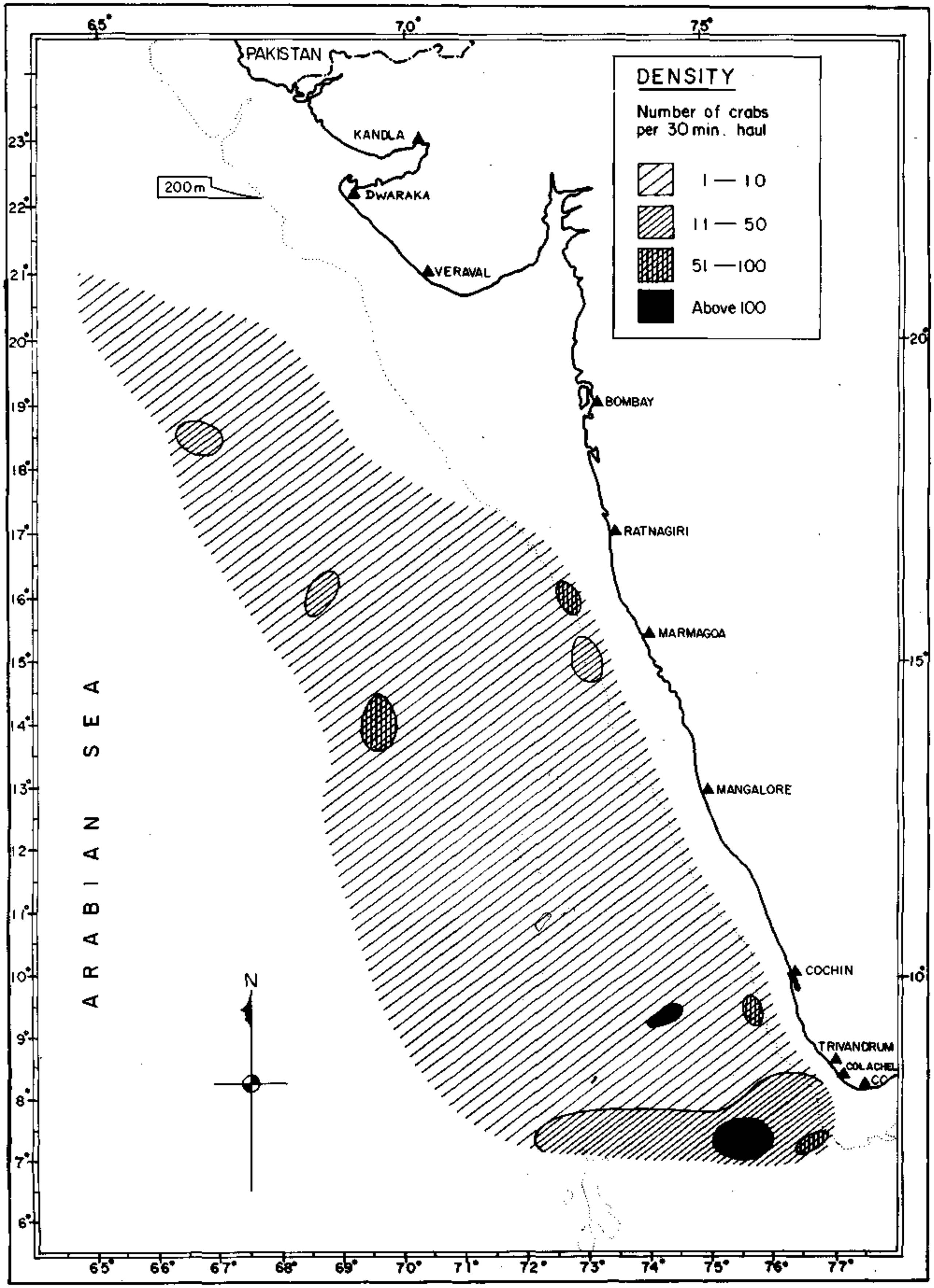

Fig. 2. Distribution pattern and abundance of *C. (G.) smithii* in the Deep Scattering Layers on the west coast of India.

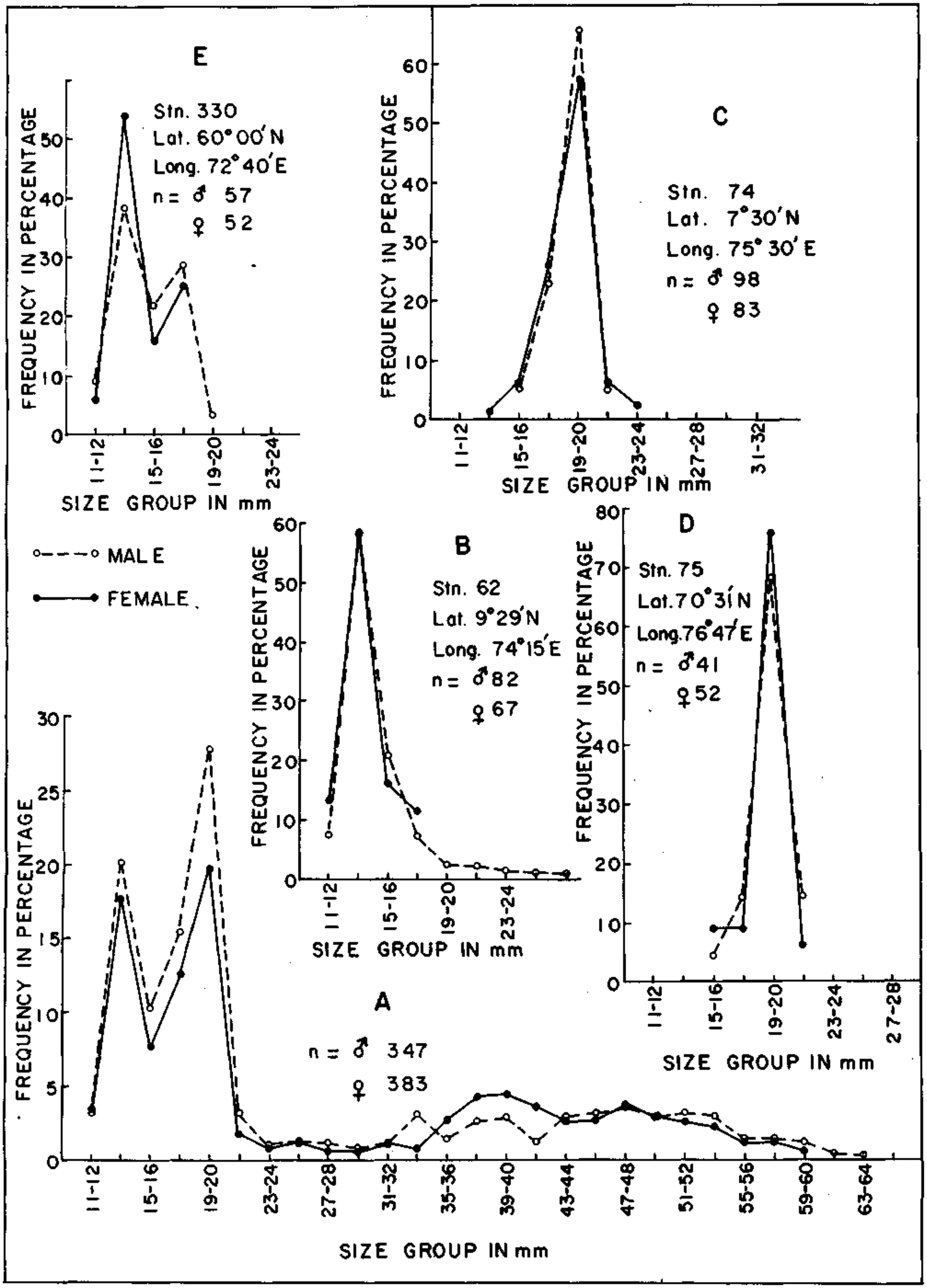

Fig. 3. Size distribution of *C.(G.) smithii*. A, pooled for all samples; B-E, individual samples rich in crab specimens.

TABLE 2. *Catch details of* Charybdis (G.) smithii *in the day series of IKMT hauls arranged monthwise*

Sl. No.	Month & year	Position Latitude E	Position Longitude E	Total number of crabs
1.	Feb., 1985	11° 00'	71° 00'	1
2.	Mar., "	09° 30'	75° 32'	68
3.	" "	08° 21'	74° 54'	2
4.	" "	08° 30'	76° 12'	1
5.	Apr., "	07° 30'	74° 10'	9
6.	" "	09° 30'	73° 00'	1
7.	" "	08° 28'	74° 01'	1
8.	" "	09° 30'	75° 00'	3
9.	Jul., "	07° 30'	76° 38'	13
10.	" "	08° 00'	76° 50'	17
11.	" "	08° 14'	76° 38'	1
12.	" "	08° 30'	76° 26'	2
13.	" "	09° 30'	75° 24'	3
14.	" "	10° 00'	75° 25'	1
15.	Aug., "	11° 01'	72° 01'	10
16.	" "	12° 00'	74° 30'	3
17.	" "	12° 50'	69° 59'	4
18.	" "	14° 00'	60° 34'	59
19.	" "	14° 59'	73° 00'	37
20.	" "	15° 00'	72° 00'	4
21.	" "	16° 00'	68° 31'	13
22.	Sep., "	18° 00'	67° 00'	1
23.	" "	20° 00'	67° 30'	1
24.	Oct., "	17° 30'	67° 00'	1
25.	" "	14° 30'	72° 41'	1
26.	" "	13° 30'	73° 03'	1
27.	" "	16° 30'	67° 30'	2
28.	Jan., 1986	09° 00'	75° 00'	1

TABLE 3. *Catch details of* Charybdis (G.) smithii *in the night series of IKMT hauls arranged monthwise*

Sl. No.	Month & Year	Position Latitude (N)	Position Longitude (E)	Total number of crabs
1.	Mar., 1985	11° 29'	69° 26'	1
2.	" "	10° 31'	75° 52'	8
3.	" "	09° 29'	74° 15'	162
4.	Apr., "	08° 30'	73° 38'	1
5.	" "	08° 30'	73° 00'	1
6.	" "	07° 24'	72° 50'	13
7.	" "	07° 30'	75° 30'	862
8.	" "	07° 31'	76° 47'	76
9.	" "	10° 29'	75° 30'	4
10.	" "	10° 30'	73° 00'	2
11.	" "	09° 30'	74° 07'	1
12.	" "	09° 30'	74° 20'	4
13.	Jul., "	08° 30'	76° 02'	2
14.	Aug., "	09° 51'	72° 40'	2
15.	" "	11° 02'	72° 02'	2
16.	" "	12° 50'	73° 01'	3
17.	" "	12° 00'	71° 30'	3
18.	" "	12° 50'	71° 00'	1
19.	" "	14° 00'	71° 30'	5
20.	" "	14° 00'	73° 31'	1
21.	" "	15° 01'	68° 58'	4
22.	" "	16° 00'	68° 31'	13
23.	Oct., "	20° 30'	65° 30'	2
24.	" "	20° 30'	65° 30'	3
25.	" "	18° 30'	66° 30'	2
26.	" "	18° 30	67° 30'	3
27.	" "	16° 30'	72° 30'	1
28.	" "	12° 30	74° 03'	1
29.	" "	16° 30'	68° 30'	2
30.	Nov., "	12° 00'	73° 42'	3
31.	Dec., 1985	16° 00'	72° 40'	96

Sex ratio

In the total crab population, the percentage composition of male and female was 52 : 48, thereby showing a slight preponderance of males. In the larger size group comprising of subadults and adults, the overall sex ratio was 47 : 53.

REMARKS

Available information on the distribution pattern of the swarming crab along the west coast of India shows that the species occurs only in the southwest coast upto about Bhatkal in Karnataka coast (Silas, 1969). The present study reveals that the species enjoys a distribution throughout the west coast of India. Since the present investigation is only based on the IKMT samples taken from the pelagic realm, it is not certain whether at the bottom also the species occurs throughout the west coast of India. The fishery resource surveys carried out by the Polish vessel M. T. *Muraena* on the continental shelf and upper continental slope along the northwest coast of India in late seventies (Bapat *et al.*, 1982) have not indicated the presence of this species in the bottom trawl catches from any areas north of Karnataka. Examination of the trawl catch data of FORV *Sagar Sampada* also does not reveal the presence of this species in this region (Suseelan *et al.*, 1990). The poor abundance of C. *(G.) smithii* in the IKMT collections examined from this region during the present study could indicate less possibility of the existence of a rich benthic population of the species along the northwest coast.

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OCCURRENCE OF KING CRAB, *TACHYPLEUS GIGAS* (MULLER), OFF THE NORTHEAST COAST OF INDIA

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Abstract

The occurrence of *Tachypleus gigas* (Muller) at 35-81 m depths off Orissa coast, between Paradwip and Palmyras Point (Lat. 20° 31' - 20° 47 ' N and Long. 87° 63' - 87° 41' E) is reported, based on the collections of FORV *Sagar Sampada*.The earlier reports show that this species is marine, distributed from the intertidal zone to 40 m depth. The species is described based on five specimens, two females and three males ranging in size from 270 to 390 mm along with a brief description of the ecology of the collection ground.

Introduction

Tachypleus gigas (Muller) has been reported earlier from the inshore regions of West Bengal and Orissa by Rao and Rao (1974) . They have also studied three specimens from the collections of the Zoological Survey of India, two of them collected by Dr. J. Anderson from Mergui, Burma coast and the third by an unknown collector from the Orissa coast. During a programme of experimental fishing in the EEZ by FORV *Sagar Sampada* as part of her Cruise 36, the authors could collect five specimens of *T. gigas* from the depth range of 35 -81 m off Orrissa coast while operating Chalut Trawl (400 mesh). The earlier recorded distribution of this species has been only upto 40 m depth and the present observation indicates an extended occurrence beyond this. However, the species is found mainly on sandy and muddy bottoms in the intertidal to 40 m area (Annandale, 1909; Sewell, 1912) and also commonly along the deltaic region of Ganges and Mahanadi (Panikkar, 1951).

Class : Arachnida

Subclass : Merostomata

Order : Xiphosura

Family : Xiphosuridae

Subfamily : Tachypleinae

Tachypleus gigas (Muller)

1785. *Limulus gigas* Muller, *Entomostraca*, p 126 (in part). 1802, *Limulus moluccanus* Latreile, *Hist. Nat. Crust. Ins.*, 4: 92. 1902, *Tachypleus gigas* Pocock, *Ann. Mag. nat. Hist.*, 9: 262. 1974, *Tachypleus gigas* (Muller), *Proc. Indian natn. Sci. Acad.*, 38: 206-211.

Material

Lat. 20° 30'N Long. 87° 36 ' E : One specimen, 390 mm in total length, collected at Station 1204 from 70 m depth on 6-10-87 between 1440 and 1540 hrs (Figs. 1 & 2).

Lat. 20° 24' N Long. 87° 37' E: Two specimens, 300 and 305 mm in total length, collected at Station 1205 from 81 m depth on 6-10-87 between 1730 and 1830 hrs. The left side of opisthosoma in the 300 mm specimen and anterior right margin of the prosoma in the 305 mm specimen were found deformed.

Lat. 20° 38 'N Long. 87° 22 'E : One specimen, 270 mm in total length, collected at Station 1206 from 35 m depth on 7-10-87 between 0645 and 0730 hrs.

Lat. 20° 47' N Long. 87° 41' E : One specimen, 300 mm in total length, collected at Station 1207 from 42 m depth between 1015 and 1100 hrs.

Diagnosis : Triangular caudal spine crested dorsally and concave ventrally. The other species (*Carcinoscorpius rotundicauda*) known to occur in Indian waters is reported to have round caudal spine (Rao and Rao, 1974).

Size : The minimum and maximum sizes recorded were 270 mm and 390 mm respectively. The details of other body measurements are given in Table-1.

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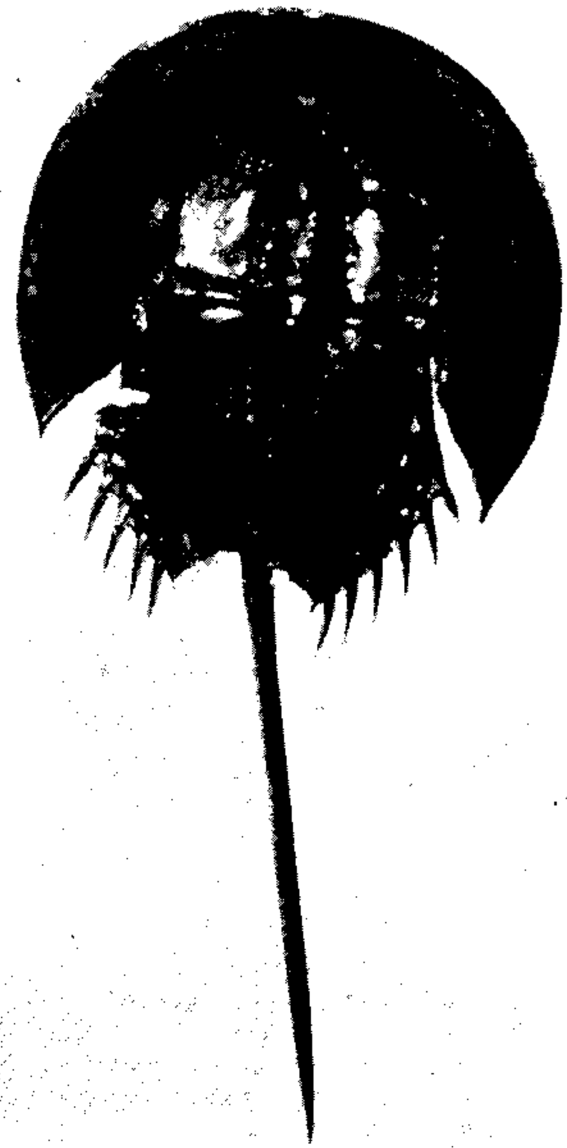

Fig. 1. *Tachypleus gigas* (Muller) - dorsal view.

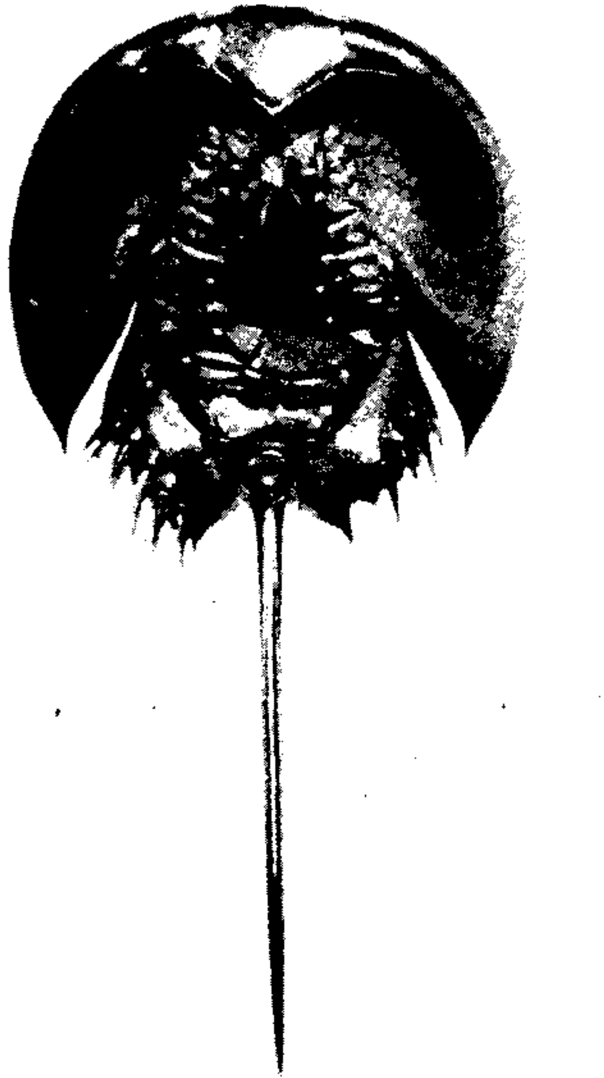

Fig. 2. *Tachypleus gigas* (Muller) - ventral view.

Sex : Of the five specimens, two were female and three male. In males and young females lateral spines of opisthosoma were long, but the posterior ones were short in the adult female. The claspers of the male were hemichelate.

Colour: Prosoma and opisthosoma glossy ash grey, caudal spine dark-brown, lateral spines cream-yellow and eyes black.

Ecology : The stations from where the specimens were collected had muddy bottom. The salinity of the water in the first two stations was found to be higher than that of the other two stations; 21.67‰ in Station 1204 and 21.31‰ in station No. 1205. In Station 1206 and 1207 the salinity noted was 17.32‰ and 12.8‰ respectively. Dissolved oxygen values were found low in station 1204 and 1205 (4.89 and 2.53 ml/l respectively) and higher in Station 1206 (5.46 ml/l)and 1207 (5.37 ml/l). Thus, the animal seems to tolerate wide ranges of salinity and oxygen. The water temperature recorded at the stations ranged narrowly : 30.5° C at 1205 and 1207 and 29.6° C and 29.4°C respectively at stations 1204 and 1206 . The fish fauna landed along with the king crab were : *Rastrelliger kanagurta, Ariomma indica, Decapterus russelli, Upeneus vittatus, Lutianus malabaricus, Nemipterus metopias, Priacanthus hamrur, Johnius dussumieri, Saurida undosquamus, Ilisha megaloptera, Trichiurus lepturus,* skates, rays, *Leiognathus bindus,* and *L . lineolatus.* The prawns, *Penaeus canaliculatus* and *P. semisulcatus* and the weaving mussel *Modiolus* sp. were found in stray numbers.

TABLE 1. *Morphometric measurments (mm) of* Tachypleus gigas

	Specimen No.				
	1	2	3	4	5
Total length	390	300	305	270	300
Length of prosoma	115	85	82	82	88
Length of opisthosoma	75	60	60	67	60
Length of caudal spine	190	152	170	135	166
Inter- orbital distance	95	70	71	74	75
Maximum width of prosoma	175	147	145	140	143
Maximum width of opisthosoma	115	95	90	90	90
Sex	Female	Female	Male	Male	Male

Distribution : The area of the present collections is shown in Fig. 3. Out of 22 stations covered during the cruise between Visakhapatnam and Plamyras Point, the king crab could be collected only from four, between off Paradwip and Palmyras Point. The earlier reports suggest its distribution from Bay of Bengal to Malay Archipelago besides the deltaic region of Ganges and Mahanadi.

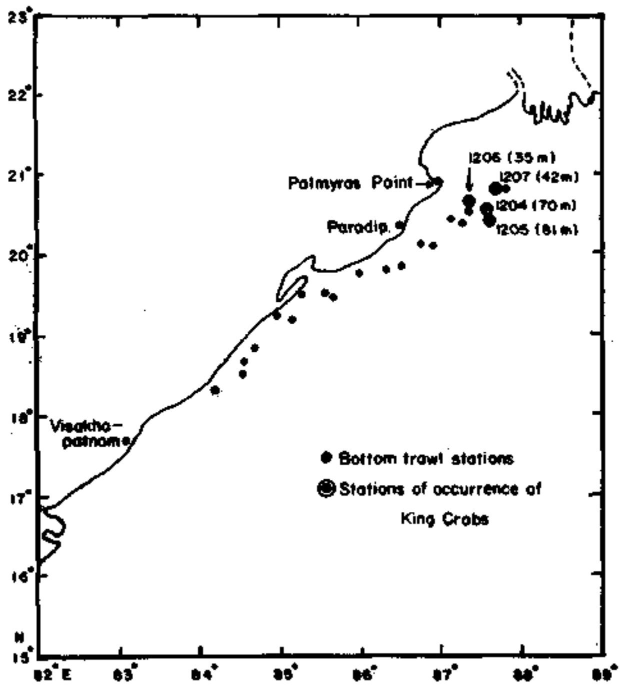

Fig. 3. Map showing the stations where bottom trawl was operated and locations of occurrence of king crab.

REMARKS

The maximum size of king crab reported so far is 300 mm (Rao and Rao, 1974), and the 390 mm specimen in the present collection seems to be the largest recorded so far. The king crabs are described as "mobile museums of natural history" as they carry varied epifauna on the dorsal and ventral surfaces of the body. But in the present collection no eqifauna was present. The species known to occur upto 40 m depth from previous records, is now shown to enjoy wider distribution.

ACKNOWLEDGEMENTS

The authors wish to express their sincere thanks to Dr. P. S. B. R. James, Director , Central Marine Fisheries Reaserch Institute, Cochin for the encouragements, Shri. C. Mukundan, for critically going through the Manuscript and Shri. G. P. K. Achary for the helps received at the time of preparation of the paper.

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PRELIMINARY STUDIES ON THE CEPHALOPODS COLLECTED FROM THE DEEP SCATTERING LAYERS OF THE INDIAN EXCLUSIVE ECONOMIC ZONE AND ADJACENT SEAS

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Abstract

Results of the preliminary studies on the cephalopods collected from the operation of Isaacs - Kidd Midwater Trawl net in the Deep Scattering Layers of the Indian Exclusive Economic Zone and adjacent seas during the cruises 1-15 of FORV *Sagar Sampada* are presented in this paper. Spatial, monthly and seasonal distributions of cephalopod biomass and its abundance in the DSL have been discussed. Differences in the biomass during day and night periods are also given.

Introduction

The early juveniles belonging to the cephalopod families Sepiolidae, Sepiidae, Loliginidae and Octopodidae and juveniles and adults of Enoploteuthidae, Onychoteuthidae, Ommastrephidae and Cranchiidae are pelagic in habit. Some of these organisms which were caught in the plankton and midwater trawl collections are dealt with by Issel (1908), Pfeffer (1912), Allan (1945), Aravindakshan and Sakthivel (1973), Clarke (1966), Clarke and Lu (1974 and 1975), Okutani (1965), Okutani and McGowan (1969), Silas (1968, 1969), Sakthivel and Aravindakshan (1971), Roper (1977), Roper and Young (1975) and Roper *et al.* (1984). The present paper deals with the data on the collections of cephalopods by Isaacs - Kidd Midwater Trawl operated from FORV *Sagar Sampada* in the Indian EEZ and contiguous seas during February, 1985 to May, 1986.

Data Examined

The data on cephalopods collected by the Isaacs - Kidd Midwater Trawl (IKMT) during the cruises 1 to 15 are considered here. These pertain to the west coast of India including the Lakshadweep Sea (6° to 23°N), east coast (6° to 21°N), Andaman and Nicobar Islands (5° to 15°N) and the central equatorial region of the Indian Ocean (0° to 3°N and 0° to 3°S). Based on the location of the Deep Scattering Layer (DSL), the depth of operation of IKMT varied from 10 to 500m on the west coast, east coast and the Andaman and Nicobar Islands and 501 to 1000 m in the central equatorial region. The duration of each haul was 30 minutes. The present study pertains to the numerical data available for each haul from all the four regions.

Irrespective of cruise numbers, the data were pooled together to study the regionwise and seasonwise distribution. To understand the distribution and abundance of cephalopods in relation to DSL, the hauls taken from each region were grouped on a 3-hour interval basis and the average number per haul was calculated accordingly. The average number of cephalopods per haul is taken as the index of abundance.

Observations

Regionwise distribution

The details of the number of hauls made and the number of cephalopods obtained are given in Table 1. A total of 472 hauls were made in the four areas studied, the maximum being on the west coast (57.6%), followed by east coast (25.2%), Andaman and Nicobar Islands (8.7%) and the minimum in the central equatorial region (8.5%); however, the percentage of hauls which contained cephalopods in the total number of hauls was 44.1, 36.1, 56.1 and 52.5% respectively in these regions. In the pooled data, the maximum abundance (18 number per haul) came from the Andaman and Nicobar Islands, followed by the west coast (12/haul), central equatorial region (8/haul) and the east coast (5/haul). However, 345 numbers per haul from 18°55'N and 69°30'E in the west coast and 172 number/haul from 9°03'N and 94°03'E in the Andaman and Nicobar

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islands were also obtained.

TABLE 1. *Regionwise abundance of cephalopods*

Area	Total number of hauls	Number of haul with cephalopod	Total number of cephalopod	No. /haul
West coast	272	120	1,423	12
East coast	119	43	206	5
Andaman & Nicobar Islands	41	23	425	18
Central equatorial region	40	21	172	8
For all region	472	207	2,226	

Seasonal distribution

The occurrence of cephalopods in different months in the four regions stuided is illustrated in Fig. 1.

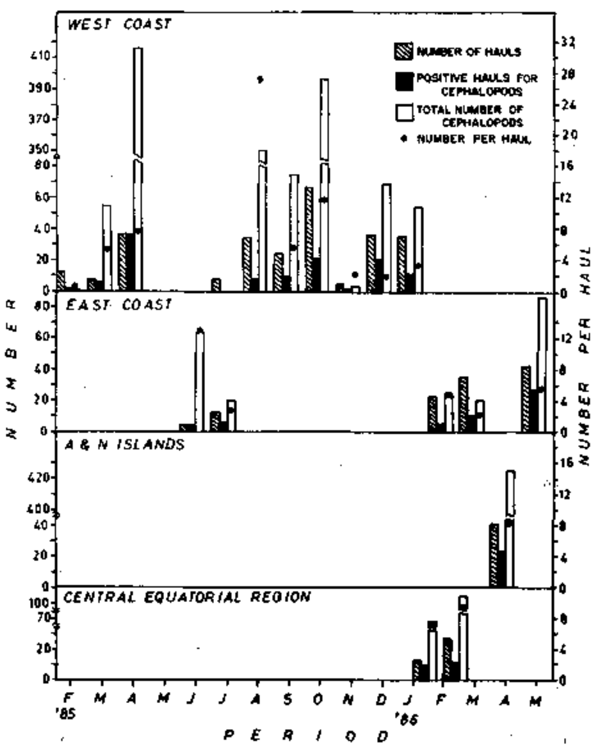

Fig. 1. Distribution of cephalopods (number/haul) in different months during February, 1985 to May, 1986.

West coast

The collection period was February- April, 1985 and July, 1985 - January, 1986. Out of 272 hauls, 120 contained cephalopods; only in March and April, 1985, all the hauls were positive. In other months of observation 15 to 57% of hauls yielded cephalopods. The number per haul varied from 1 to 44. Maximum number per haul of 8 in April, 44 in August and 12 in October, 1985, indicate the premonsoon, monsoon and postmonsoon occurrence of cephalopods with peak abundance in the mosoon period.

East coast

The collections were made only during June-July, 1985 and February, March and May, 1986. Out of 119 hauls, 43 hauls yielded 206 cephalopods. All the hauls made during June, 1985, were positive but only 22-46% of hauls in the other months contained cephalopods. The number per haul varied from 3 to 13 during June-July, 1985 and 2 to 5 during February -May, 1986. Since the data were discontinuous, no picture of the peak occurrence could be obtained.

Andaman and Nicobar Islands

Only one cruise was made in the oceanic waters of the islands (April, 1986) during which 41 hauls were taken; 23 hauls yielded cephalopods amounting to 425. The average number per haul was 18.

Central equatorial region

A total of 40 hauls were made in a single cruise during January-February, 1986, of which 21 hauls netted 172 number of cephalopods. The average number per haul was 8.

Diurnal variation in distribution

The number of cephalopods obtained in day and night hauls from the four regions are illustrated in Fig. 2. On the west coast, exceptionally high number of cephalopds were recorded in two hauls: 278 in April and 345 in August, 1985. The reasons for this concentration are not known. Without regard to these high numbers, as they were exceptional, the number per haul was more in the day hauls as a whole (1-78) than in the night hauls (1-15) as shown in the Figure. The day hauls were richer during March and August-November, 1985; the night hauls were negative in November, 1985, and in other months the number per haul was either equal or more.

On the east coast the number per haul ranged from 2 to 12 during day and from 2 to 13 during night, indicating that the night hauls were slightly richer. In the Andaman and Nicobar waters the highest number of 24 per haul was taken in the night with the average night catch of 12; the average for day hauls was only 5. In the central equatroial region the variation was from 5 to 10 for day hauls and from 8 to 9 for night hauls. In this case also the night catches on an average were a little better than those taken during the day.

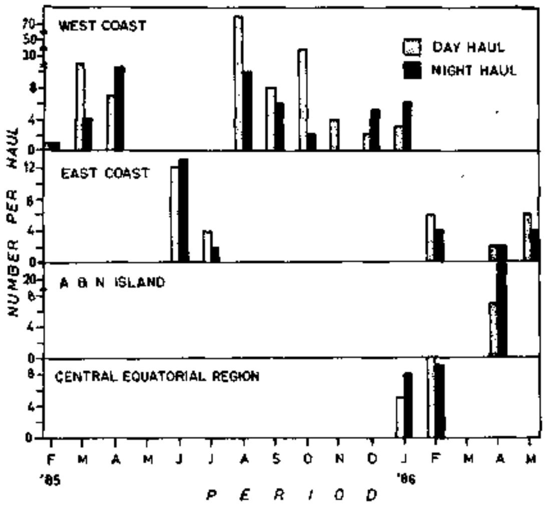

Fig. 2. Distribution and relative day-night abundance of cephalopods (number/haul) in four regions.

Depthwise abundance

The number of cephalopods caught from different depth zones of the four regions is given in Table 2. The depth of operation of the gear on the west coast ranged from 10 to 500 m with some gaps in between. The maximum number per haul (139) came from 101-150 m depth zone, followed by 18 and 12 from 251 - 300 m and 301 - 350 m respectively. On the east coast, the depth of operation was confined to 10 - 250 m, and the maximum number per haul (6) came from 51-100 m and the least (3) from 10-50 m. In the Andaman and Nicobar Islands also the same depth range was covered. The maximum number of 29 cephalopods per haul came from 51-100 m , followed by 12 from 10-50 m. In the central equatroial region, the depth of operation ranged from 10 to 200 m and from 501 to 1000 m. The number per haul was more (11) in the 10-50 m depth and varied from 2 to 4 in the other depth zones. In general, the cephalopods were found concentrated in the upper water column ranging from 10 to 150 m in all the regions, and again in 251 to 300 m on the west coast and in 501-1000 m in the central equatorial region.

Table 2. *Depthwise distribution (number per haul) of cephalopods*

Depth range (m)	West coast	East coast	Andaman & Nicobar Islands	Central equatorial region
10-50	4	3	12	11
51-100	5	6	29	3
101-150	139	5	3	2
151-200	8	—	—	4
201-250	4	-	-	-
251-300	18	-	-	-
301-350	12	-	-	-
351-400	-	-	-	-
401-450	-	-	-	-
451-500	6	-	-	-
501-1000	-	-	-	4

Distribution in relation to Deep Scattering Layer

An attempt was made to study the distribution of cephalopods in relation to the position of the Deep Scattering Layer (DSL). The depths of the DSL and the number of cephalopods per haul at 3-hour intervals during day and night are given in Table 3. These are based on the regionwise pooled data for the entire period of observation. It was seen that on the west coast the position of the DSL during day time (0600-1800 hours) ranged from 35 m depth to 540 m ; during night hours (1800-0600) it has moved up, occupying the water column from surface to a depth of 110 m. Similar trend was noticed in other regions also. In the central equatorial region the DSL has descended up to 1000 m during day time, and has moved up to 500 m during night.

The distribution of cephalopods in the DSL and their relative abundace in 3-hour duration show that on the west coast the number per haul varied from 3 to 12 during day with the average of 6, and from 6 to 20 during night with an average of 11. The maximum of 20 cephalopods per haul came during 2100-2400 hours when the position of the DSL was at 0-100 m.

On the east coast and in the Andaman and Nicobar waters the day hauls contained more

TABLE 3. *Distribution of cephalopods in relation to Deep Scattering Layer*

Time (hours)	Depth of DSL (m) cephalopods (No./haul)	West coast	East coast	A & N Islands	Central equatorial region
0600-0900	DSL	35-440	70-110	40-500	100-275
	Cephalopods:	3	24	3	15
0900-1200	DSL	30-410	60-100	100-150	250-1000
	Cephalopods:	12	—	27	—
1200-1500	DSL	50-540	90-125	130-500	100-900
	Cephalopods:	5	5	5	3
1500-1800	DSL	40-410	40-160	100-470	60-500
	Cephalopods:	3	2	6	4
1800-2100	DSL	0-120	0-100	20-72	35-500
	Cephalopods:	6	5	2	6
2100-2400	DSL	0-100	0-100	0-225	45-300
	Cephalopods:	20	4	25	10
0000-0300	DSL	0-80	0-80	0-330	20-125
	Cephalopods:	8	5	4	13
0300-0600	DSL	0-110	0-100	0-500	40-160
	Cephalopods:	9	2	5	9

number of cephalopods than the night hauls. But in the central equatorial region a reverse order was noticed, with the average of 6 cephalopods per haul during day and 10 during night. However, taking all the regions as a whole, more number of cephalopods were obtained during night than during day.

General Remarks

The analysis of data on cephalopods taken by IKMT from the Deep Scattering Layers of the Indian Exclusive Economic Zone and the central equatorial region has shown their distribution and relative abundance in different areas, seasonal availability and diurnal variations. Earlier studies on the abundance of juvenile cephalopods in the Indian Ocean based on plankton net collections by Aravindakshan and Sakthivel (1973) have indicated that the area off Gujarat on the west coast, the Bay of Bengal including the Andaman waters and the equatorial waters are rich nurseries for cephalopods. This finding is confirmed by the present record of a maximum number of 12 per haul on the west coast and 18 per haul in the Andaman and Nicobar waters. Silas (1968) has recorded a catch rate of 2 to 6 per haul in the IKMT collections made along the west coast of India.

In the present study, the peak abundance was noticed during March-April and August-October in the west coast, February-June in the east coast, April in the Andaman and Nicobar waters and January-February in the central equatorial waters. This is in agreement with the observations made by Aravindakshan and Sakthivel (1973), who recorded the peak occurrence of cephalopods during November and June-July in the northern Arabian Sea, April-September in the Bay of Bengal and July-August and January in the equatorial waters. Silas (1968) recorded greater number of cephalopods during June and December-April in the plankton net collections made from the southwest coast of India.

Roper (1977) has studied the efficiency of different types of midwater trawl either with or without a closing device and recorded a catch rate of 4 per haul in the closed-type IKMT and 6 per haul in the midwater trawl without a closing mechanism. In the present study the IKMT used was devoid of a closing device, and yielded a catch rate of 5 to 18 cephalopods per haul. Silas (1968, 1969) also employed a net similar to the present one, in which the number of cephalopods obtained varied from 2 to 6 per haul.

Among the collections made during the day and night, those made during the night contained more number of cephalopods. According to Roper *et al.* (1984), oceanic cephalopods undergo diel vertical migrations, abounding in 400-1000 m depth during the day and in the uppermost 200 m during the night. Moreover, the present data on depthwise distribution also have indicated the greater abundance of cephalopods in 10-150 m zone. The distribution of cephalopods in relation to the Deep Scattering Layers has shown that they occur in more numbers during the dark hours. Silas (1969) recorded greater representations of the major constituents of zooplankton including cephalopods in the night-time IKMT hauls taken in the Lakshadweep waters.

Clarke (1966) and Clarke and Lu (1974, 1975) are of the opinion that the occurrence and abundance of oceanic cephalopods in the columnar waters in relation to different depths is species-specific. Only a qualitative study of the material collected by IKMT will throw some light on this aspect of the distribution of planktonic cephalopods in our waters.

Acknowledgements

The authors are greatful to Dr. P. S. B. R. James, Director, Central Marine Fisheries Research Institute, Cochin for suggesting this problem, to their colleagues Dr. N. Gopinatha Menon for making available the data and to Mr. M. Kathirvel and Dr. V. Selvaraj for the help rendered in the preparation of the paper.

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OCEANIC SQUID RESOURCES OF THE EEZ OF INDIA

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Abstract

Surveys made by FORV *Sagar Sampada* using pelagic trawl specifically for oceanic squids in the Arabian Sea within 6°30'-22°07'N and 64°16'-78° 00'E and in the Bay of Bengal within 15° 00'- 19° 00'N and 82°40'-87°25'E have revealed the occurrence of the squid *Symplectoteuthis oualaniensis* (Lesson) at many stations with depths over 1000 m. About 95% of the squids were taken in night hauls, which indicates that this species has the habit of nocturnal vertical migration towards surface. There was great variation in size, from 20 mm dorsal mantle length to the largest squid of 472 mm weighing over 4.5 kg. Most of the squids were immature and of small size, with unequal sex ratio. Mature squids were almost equal in number. This species feeds mainly on fish and crustaceans.

Introduction

The neritic squids of the family Loliginidae and the oceanic squids of Ommastrephidae account for over 70% of the world's cephalopod catch. A substantial portion of the squid catch is constituted by oceanic squids of the Atlantic and Pacific Oceans. There is very little exploitation from the Indian Ocean and more so from the Indian waters. The occurrence of different species of oceanic squids in our waters had been recorded by Fillippova (1968), Silas (1968, 1969), Okutani (1973), Yamanka *et al.* (1976, 1977) and Roper (1984), and some of these authors have indicated the possibility of oceanic squids being potential species for exploitation. However, no attempts have been made to locate and identify the stock of potential species primarily because we did not have the means to venture into the oceanic waters. With the acquisition of FORV *Sagar Sampada* for making exploratory surveys and oceanographic studies in the Exclusive Economic Zone of India, it has become possible to study the distribution of oceanic squid resources in the Arabian Sea and the Bay of Bengal. This account is based on the results of surveys made during 1985-'88 period.

Material and Methods

Three surveys were made in the Arabian Sea and one in the Bay of Bengal with the objective of locating and assessing the oceanic squid resources; apart from these, the data available on the squids obtained in another cruise (SS/20/86) are also included here. The details of the cruises, including the number of stations from where oceanic squids were obtained are given in Table 1. Data on squids collected in many other cruises are not included as they were not direct observations of the authors. The oceanic squids were netted in pelagic trawl. The bottom depths of stations varied from 250 m to 3,671 m , and the depth at which the net was operated was 40-250 m from the surface. The squids obtained were analysed for species composition, and the most abundant species (*Symplectoteuthis oualaniensis*) was biologically sampled for length-frequency, maturity stages and food habits. The size of squid always refers to dorsal mantle length.

Observations

Species

The most important squid at all stations was the purpleback flying squid *Symplectoteuthis oualaniensis* (Lesson) of the family Ommastrephidae which comprises the economically important species of oceanic squids of the world. Apart from this species very stray numbers of *Onychoteuthis bnksii* (Leach) of the family Onychoteuthidae, *Thysanoteuthis rhombus* Troschel (family: Thysanoteuthidae) and fairly good numbers of small species of oceanic squids belonging to the family Enoploteuthidae were also collected.

Areas of occurrence

The geographical position of stations from where the purpleback flying squid was obtained

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TABLE 1. *Survey of oceanic squids - details of cruises*

Cruise No.	Month	Area	Depth (m)	No. of squid stations
9	Oct., 1985	15°30'-18°30'N 67°30'-71°00'E	1550-3671	5
20	Aug. - Sep., 1986	06°30'-15°23'N 72°00'-78°00'E	941-2893	5
22	Oct., 1986	17°58'-22°07'N 64°16'-69°03'E	2475-3437	10
37	Oct., 1987	15°59'-21°00'N 67°00'-69°50'E	1307-3200	3
44	Mar., 1988	15°00'-19°00'N 82 °40' 87°25'E	250-3100	6

and the number of squids collected in each pelagic trawl operation at these stations are shown in Fig. 1. In Cruise 9, the occurrence of the squid was noticed at five stations. Attracted by the ship's lights at night, the squids were seen aggregating near the surface, but they were not caught in the pelagic trawl. At Station 242 (17°30'N, 71°00 'E), a squid of 268 mm dorsal mantle length was taken in a hand-jig operated at night from the deck of the ship. In Cruise 20, the objective of which was to study the distribution and abundance of demersal and pelagic resources, the purpleback flying squid was obtained from five stations within 6°30'- 15°23'N and 72°-78°E, varying from 11 to 33 squids.

In Cruise 22 in which the northeastern Arabian Sea off Maharashtra-Gujarat coasts within 17°58' - 22°07'N and 64°16'- 69°03'E was surveyed, this squid was obtained from as many as ten stations, and their number ranged from one to 318 squids. Cruise 37 also was in the same area but slightly towards the coast. Squids came from three stations, the number varying from 15 to 56.

Cruise 44 was in the northern Bay of Bengal with pelagic trawl operation at nine stations out of

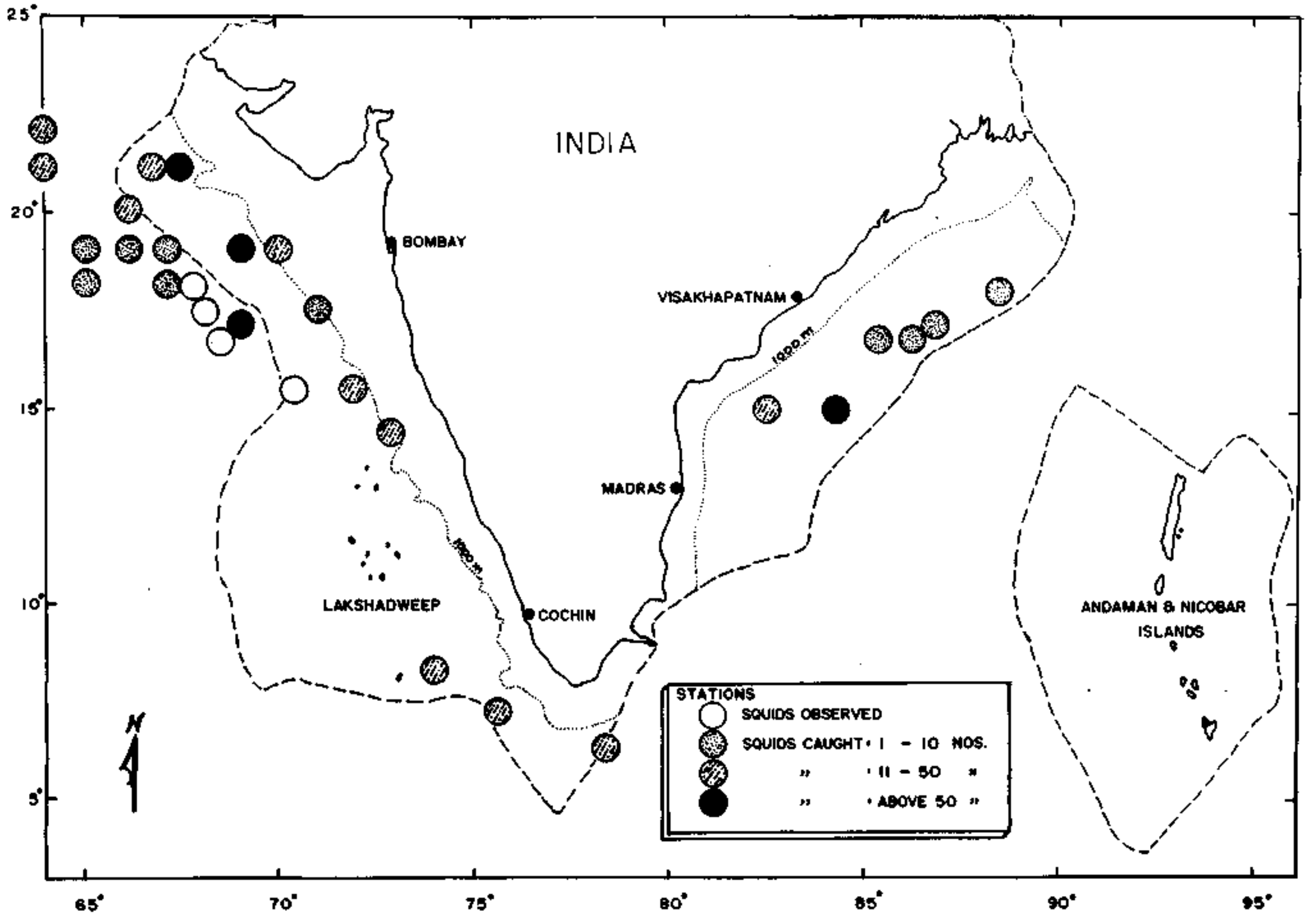

Fig. 1. Sagar Sampada cruise stations where *Symplectoteuthis oualaniensis* occurred, and the intensity of occurrence.

which six stations within 15°-19°N and 82°40'-87°25'E gave oceanic squids. A total of 119 squids was obtained in this cruise and the maximum number (65) was at Station 1366 (15°N, 84°15'E) where the depth was 3,100 m and the depth of operation of the net 60 m.

Diel variation

It was observed that the number of squids caught during the night was much higher than those taken during day. Table 2 gives the number of squids caught in night and day hauls during the 5 cruises. It is seen that out of a total of 837 squids, as many as 765 (91%) were taken at night and only 72 (9%) at day. This trend was noticed during all the cruises.

TABLE 2. *Day-night variations in number of* Symplectoteuthis oualaniensis

Cruise No.	Day	Night	Total
9	-	1	1
20	17	100	117
22	3	494	497
37	15	88	103
44	37	82	119

Size range

The length-frequency data of *Symplectoteuthis oualaniensis* available for three cruises are presented in Fig. 2. The squids collected in cruise 20 had a size range of 50-210 mm (Fig. 2A). Of these, the males had a smaller size range between 70 mm and 120 mm, with a modal size of 95 mm. The females were in larger size range with the maximum length of 210 mm but their modal size was smaller than that of males, 75 mm. There were no female squids in sizes between 130 and 160 mm, and above this upto 210 mm they were very rare.

The length data separately for males and females are not available for Cruise 22, and therefore the combined frequency is shown in Fig. 2 B. The size range was very large, 20-480 mm. The length classes between 30 and 60 mm were not represented; from 250 mm onwards the occurrence was discontinuous. There were two main modes, the larger mode at 115 mm and the smaller at 175 mm. The largest squid had a length of 472 mm (470-480 mm length class) and it weighed 4.7 kg. Another squid measuring 456 mm weighed 3.5 kg. There were six squids above 400 mm, and they were caught from depths of 110-250 m, four of them at night and the rest during day and evening hours.

In cruise 37, the size of squids varied from 90 mm onwards, and the largest squid caught was 425 mm in length weighing 4.5 kg. This was caught from a depth of 120 m at station 1225 (20°N and 67°E) where the bottom depth was 2,034 m .

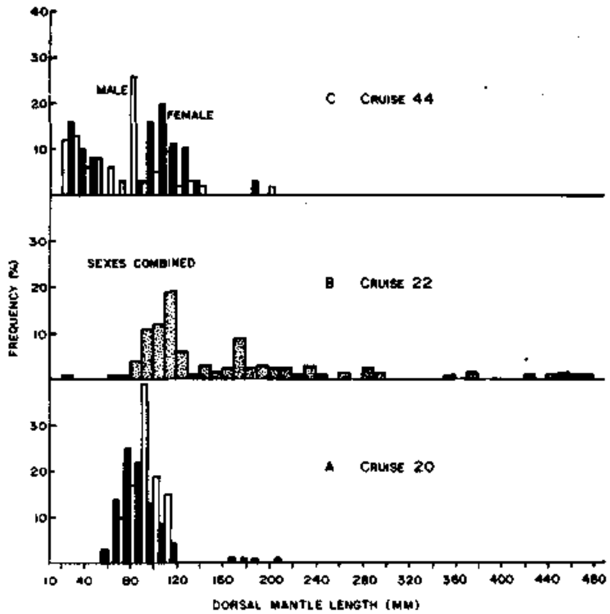

Fig. 2. Length-frequency of *Symplectoteuthis oualaniensis* collected during Cruise 20 (A), 22 (B) and 44 (C).

In cruise 44 (Fig. 2 C) the males measured 20-210 mm with gaps of length groups in between. The main mode was at 85 mm. The females ranged from 20 mm to 190 mm with discontinous length classes within 50-80 mm and within 140-180 mm. The main modal size for females was 105 mm.

Food

Symplectoteuthis oualaniensis feeds on a variety of organisms, as observed from the stomach contents. They include small fishes, pelagic crustaceans and other cephalopods. Since stomach contents are very small fragments, the prey animals are not easily identified. The fish component of food included mainly small myctophids, while crustaceans were mostly young crabs, stomatopod larvae and euphausiids. This squid is observed to have fed on other squids but it could not be confirmed whether the food included its own kind.

Size at maturity

Data on maturity stages of *Symplectoteuthis oualaniensis* are available for Cruise No. 9, 20 and 44. In the collections the minimum size of mature males was observed to be 85 mm and that of females 95 mm, as determined from the presence of spermatophores in the Needham's sac in the former, and mature eggs in the oviduct in the latter. Based on the length data of 44 mature males and 41 mature females, the size at which 50% of the squids of either sex attain maturity was derived. These values were 100 mm for males and 110 mm for females (Fig. 3), which can be considered as the sizes at first maturity.

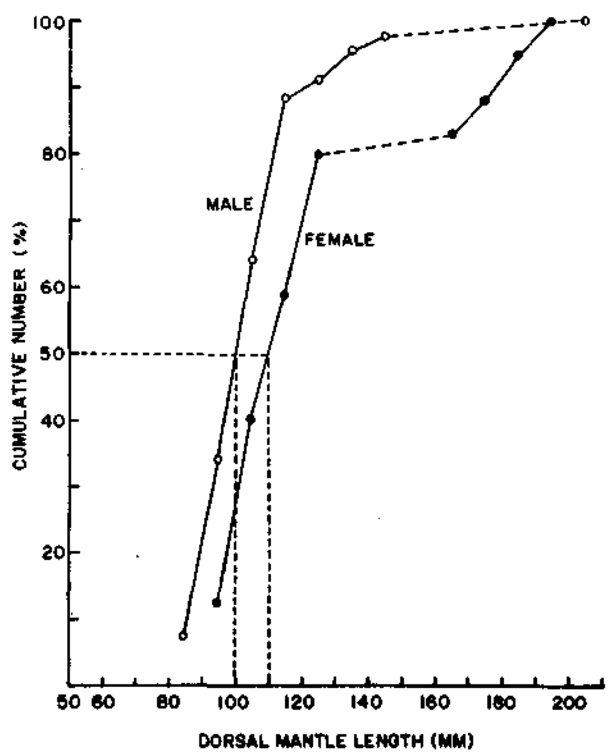

Fig.3. Size at first maturity of male and female *symplectoteuthis oualaniensis*.

Sex ratio

The data on number of squids by size for each sex collected during Cruise 20 and 44 show that males were numerically more than females in the ratio 1 : 0.8. But the sex ratio was different for immature squids and for mature squids. The ratio between immature males and immature females was 1 : 0.6, which in the mature squids was almost equal, 1 : 0.9.

Discussion

The purpleback flying squid *Symplectoteuthis oualaniensis* is a widely distributed Indo-Pacific oceanic species. In the Indian Ocean it occurs in the entire area north of 25°S (Roper *et al.*, 1984). The importance of this squid as a potential species in the Indian Ocean in general has been pointed out by many workers (Filippova, 1968; Zuev, 1971; Okutani, 1973). The distribution of adults and young ones off the west coast of India was discussed by Silas (1968) and the abundance in the northern Arabian Sea was indicated by Yamanaka *et al*. (1976, 1977). Chikuni (1983) also has pointed to the possibility of commercial fishery for this species in the eastern Arabian Sea. At present there is virtually no exploitation of oceanic squids from Indian waters, but assuming the vast scope this resource gives, Silas (1986) has given the projection that by 1990 the potential harvest would be of the order of 2,500 t, and by 2000 A. D. it would be somewhere between 25,000 and 50,000 t.

The surveys made by *FORV Sagar Sampada* have revealed the occurrence of *Symplectoteuthis* in the Arabian Sea and the Bay of Bengal, and though its number and quantity were minimal, the results of these surveys have provided information on some biological and behavioural aspects. There was wide variation in the size form 20 mm to 480 mm. Since the squids were taken in pelagic trawls, the smaller sizes were well represented. On the other hand, the squids caught by jigs with light attraction at night by Japanese research vessel in the northern Arabian Sea had a size range of 240-500 mm in 1976 and 180-360 mm in 1977 (Yamanaka *et al*., 1976, 1977). This may be due to the fact that the jig is a highly selective gear and only medium and large sized squids are hooked by it. However, Roper *et al.* (1984) are of the opinion that two sympatric species are known under the name *S. oualaniensis*, a large one with a dorsal photophore on the mantle, and a smaller one without photophore. Unfortunately this aspect was not studied here, one reason being that larger squids above about 200 mm were extremely rare. More number of squids have to be observed for further studies on this aspect.

The length at first maturty obtained here, 100 mm for males and 110 mm for females, is more or less comparable to 136 mm for males and 107 mm for females of the species without dorsal photophore, given by Roper *et al*. (1984); however, according to these authors the female squids with dorsal light organ mature at about 180 mm. This also is an aspect that has to be studied for ascertaining whether similar phenomenon occurs in *Symplectoteuthis* of the Indian waters.

Silas (1969) has observed that the Rhynchoteuthis larvae of *S. oualaniensis* were present in planktonic collections off the southwest coast of India beyond the continental shelf throughout the year with abundance in March to May and November- December. In the present study, mature squids were observed in March (Bay of Bengal), August, September and October (Arabian Sea), and this suggests that spawning might have followed in the subsequent months. This is in partial agreement with the earlier observation, and both these observations suggest that spawning may also take place within the Exclusive Economic Zone. Again, this aspect needs further investigation to understand more about the spawning periods, intensity and areas.

Symplectoteuthis is known for its strong positive phototaxis, and this makes the squids to aggregate near the surface of the sea at night, often seen attracted by the lights of the ship. One squid of 268 mm was taken in hand-jig from Stn. 242 during Cruise 9, and many were seen in small schools near the surface. This behaviour of the squid is taken advantage of in the commercial fishery by hook and line in the waters around Okinawa to Taiwan, using lights as an aggregating device (effectively used in jigging at night for many species of squids).

The purpleback flying squid is noted for its diel migration. The squids remain at about 120-200 m depth at day time and move to the surface at night (Chikuni , 1983). This is well corroborated by the preponderance of squids caught in night hauls over those taken in day hauls. About 91% of the total number of squids taken during the surveys was in the night hauls of pelagic trawl.

The present study is only a beginning, and much remains to be understood on aspects such as stock abundance, biology and behaviour for developing suitable catching devices and making feasibility study on commercial fishing. The future strategy should be planned for working in these directions.

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ON THE CEPHALOPODS COLLECTED DURING THE EXPLORATORY SURVEY BY FORV *SAGAR SAMPADA* IN THE ANDAMAN-NICOBAR SEAS

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Abstract

The cephalopods collected by FORV *Sagar Sampada* from the Andaman-Nicobar seas (5° - 15°N; 90° - 95°E) are reported. Altogether twenty six species belonging to 22 genera were recorded. Of the 41 Isaacs- Kidd Midwater Trawl stations, 16 recorded cephalopods. Eggs and developing embryos were also present at these stations, while juveniles of *Abralia andamanica*, *Abralia* sp., *Abraliopsis gilchristii*, *Octopoteuthis* sp., *Cranchia* sp, and *Liocranchia* sp., were recorded in some of the stations.

In the pelagic trawl, cephalopods were recorded from 26 of the 30 stations covered. Sixteen species belonging to 15 genera were recorded in the catches, the most dominant species being *Symplectoteuthis oualaniensis* followed by *Abralia* sp., *Abralia andamanica*, and *Onycoteuthis banksi*. A large specimen of *Thysanoteuthis rhombus* measuring 585 mm DML (weighing 5.3 kg) was also caught at station 495.

The bottom trawl catches were composed of the neritic water species *Sepia pharaonis*, *S. aculeata*, *S. prashadi*, *S. trigonina*, *Euprymna stenodactyla*, *Loligo duvaucelii* and *Octopus* sp.

The present observations indicate a wide distribution of the cephalopods both in the coastal and oceanic waters of the Andaman-Nicobar Archipelago. It is suggested that steps may be taken to exploit the resources by adopting suitable techniques such as light fishing with lift net.

Introduction

Cephalopods constitute one of the important exploited marine fishery resources of our country at present. The annual cephalopod landings were less than 1,400 t until 1972 but gradually increased from 1973 onwards with the commencement of export of frozen cephalopod products to several countries. At present the exploitation from Indian waters stands at 35,000 t.

Regarding the potential cephalopod resources of the Indian Ocean, our information is limited. Gulland (1970) estimated it to be over several hundreds of thousand tonnes. Voss (1973) estimated the potential at 5, 00, 000 t and Tussing (1974) also put it at the same figure. Yet another estimate is 2, 00, 000t (Anonymous, 1977). George *et al.* (1977) have estimated that the cephalopod resource potential of the Indian economic zone would be of the order of 1,80,000 t, of which 55% would be contributed from the upper east coast, 11% from the lower east coast, 20% from the southwest coast, 11% from the northwest coast and the remaining 3% from the Lakshadweep Sea.

So far, no estimate has been made of the cephalopod resources of the Andaman-Nicobar seas. There is no organized fishery in this region and little attention has been paid to the existing incidental catches, and the different species which contribute them. The present account is only an initial attempt to attract the attention of the various fishing agencies towards this potential resource which is yet to be recognised and exploited.

Material and Methods

The data presented in this account were from the cruise of FORV *Sagar Sampada* conducted in March-April, 1986. The cruise covered the Andaman-Nicobar Archipelago between Lat. 5° and 15° N and Long. 90° and 95° E, with a track distance of 5,049 n. miles and an area of 1,70,526 sq. n. miles. Totally 41 stations were sampled along the cruises track at an interval of 1°. The area surveyed and the locations of the different sampling stations are given in Fig. 1.

In the present work, collections obtained from IKMT, pelagic trawl and bottom trawl only are considered. While IKMT was operated in all the 41 stations, pelagic trawl was operated in 30 stations and the bottom trawl in 3 stations (where the depth was less).

Eggs, developing embryos and juveniles were collected in the IKMT. Cephalopods obtained in pe-

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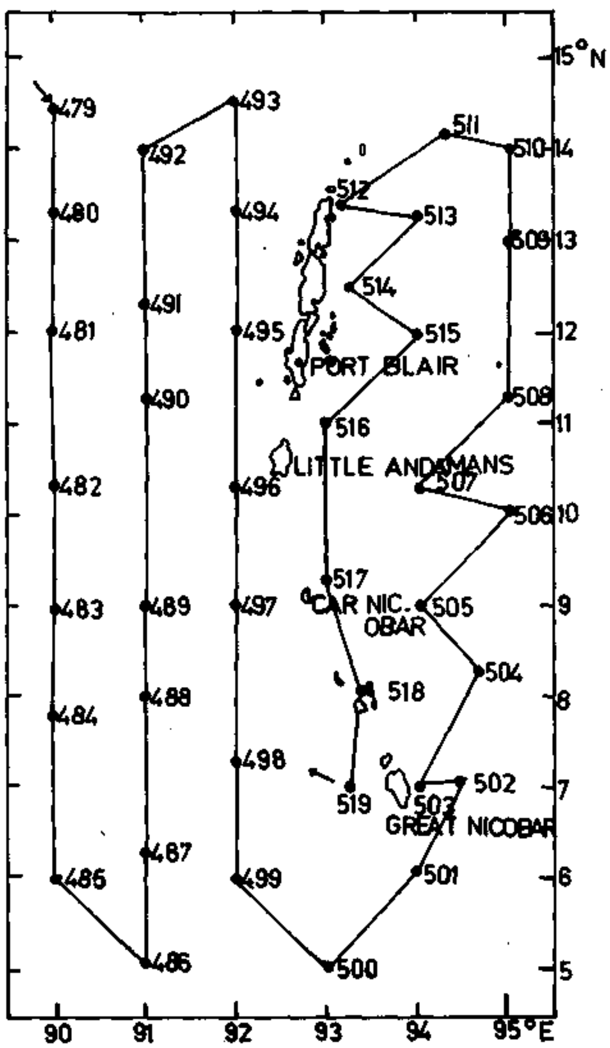

Fig. 1. Locations of sampling stations and the track of the Cruise No. 14 of FORV *Sagar Sampada* in Andaman-Nicobar Archipelago.

lagic and bottom trawls were sorted out and weighed to find out their percentage contributions in the total quantity of the collections and to estimate the species composition. Mantle lengths of the specimens of different species were taken to find out the size composition.

Observations

Distribution of cephalopods

The details of occurrence of cephalopods in the study area are presented in Table 1. Of the 41 stations where IKMT was operated, cephalopods were recorded at 16 stations. The stations were 483-487, 492-495, 499, 502, 503, 507, 508, 516 and 518. Cephalopod eggs and developing embryos were present at all the stations, while juveniles were recorded at seven of the above stations.

In the pelagic trawl, which was operated at 30 stations, cephalopods were caught from 26 stations (90%). Cephalopods contributed to the entire catch at station 490 and substantially to the total catch at stations 480, 491, 492, 495 and 517.

Cephalopods were caught in all the three operations of the bottom trawl at stations 511, 512 and 518. They contributed to 12.1% at the first station while in the latter two stations their contribution was about 3%.

Species composition

Totally 26 species belonging to 22 genera were recorded. It was observed that the species belonging to the genera *Sepia, Loligo, Doryteuthis, Euprymna* and *Octopus* were found exclusively in the coastal waters, while the squids of the genera *Ancistrocheirus, Enoploteuthis, Abralia, Abraliopsis, Cranchia, Licocranchia, Helicocranchia, Onycoteuthis, Gonotopsis, Histioteuthis, Ctenopteryx, Chiroteuthis, Octopoteuthis, Corynomma, Japetella, Symplectoteuthis* and *Thysanoteuthis* were recorded in the oceanic waters. Occurrence of eggs, early stages of life history and also adults suggests that their entire life cycle is completed in the pelagic zone.

Among the cephalopods collected, species like *Sepia pharoanis, S. prashadi, S. aculeata, Loligo duvacelii* and *Doryteuthis sibogae* are being exploited along the Indian coasts and elsewhere. Species like *Symplectoteuthis oualaniensis* and *Thysanoteuthis rhombus* are potential oceanic squid resources.

Sepia pharoanis

This cuttlefish was caught in the bottom trawl from three stations viz., 511, 512 and 518 (Fig. 2). It formed 10.0, 63.0 and 53.0% of the cephalopods caught respectively. The mantle length ranged from 133 mm to 251 mm.

Doryteuthis sibogae

This squid was also caught in the bottom trawl along with the above species. The size ranged from 60 to 146 mm. Percentage contributions of this species was 89.0, 3.0 and 11 of the total cephalopods respectively at stations 511, 512 and 518 (Fig. 2).

Symplectoteuthis oualaniensis

This oceanic squid was obtained frequently during the cruises over an extensive area (Fig. 2). It

TABLE 1. *Catch of cephalopods (kg) and their percentage contribution at different stations*

Stn.	Pelagic trawl		Bottom trawl	
	Quantity	%	Quantity	%
479	-	-	-	
480	0.210	65.6	-	
481	0.110	3.1	-	
482	1.300	11.8	-	
483	0.120	16.1	-	
484	0.445	20.9	-	
485	0.056	0.1	-	
486	0.070	9.8	-	
487	-		-	
488	-		-	
489	0.080	12.1	-	
490	0.250	100	-	
491	1.375	57.4	-	
492	0.740	75.5	-	
493	0.091	8.0	-	
494	X		-	
495	6.720	62.0	-	
496	0.060	6.9	-	
497	0.280	0.6	-	
498	0.005	0.9	-	
499	2.790	43.1	-	
500	0.300	43.5	-	
501	0.005	2.5	-	
502	0.160	13.6	-	
503	-		-	
504	1.010	2.5	-	
505	0.890	10.0	-	
506	-		-	
507	9.561	13.6	-	
508	-		-	
509	X		-	
510	X		-	
511	-		7.510	12.1
512	-		5.785	3.2
513	-		-	
514	-		-	
515	1.065	8.1	-	
516	0.040	0.2	-	
517	3.183	60.3	-	
518	-		2.500	3.1
519	-		-	

X = Absent, - = No fishing

occurred at 23 stations (70% of the stations sampled). It was caught in the pelagic trawl only and formed the entire or substantial part of the catch at most of the above stations. The mantle length ranged from 13 to 125 mm. It is of interest to record a catch of 3,537 juveniles at station 517 (DML 13 to 26 mm), which suggests that this may be a nursery ground for this species.

Thysanoteuthis rhombus

This oceanic squid was caught from two stations 495 and 516 (Fig. 2). At the former station a single large female was caught and because of its large size, the morphometric measurements (in mm) are given below:

Total weight of the specimen (kg)	:	5.3
Total length	:	912
Mantle length	:	585
Head length	:	350
Eye diameter	:	40
Width across the fins	:	490
Length of gladius	:	573
Width of the gladius	:	43
Length of nidamental gland	:	221
Diameter of the intra-ovarian egg	:	4

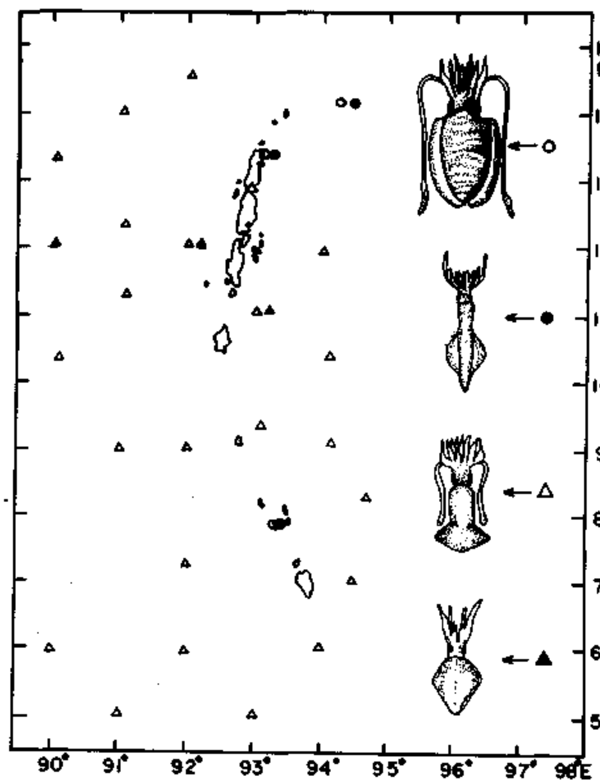

Fig. 2. Occurrence of four species of cephalopods in the seas around Andaman-Nicobar Archipelago.

At station 516, a juvenile specimen of this species measuring 50 mm in length and weighing 10 g was caught.

Details regarding the occurrence of the other 22 species are given in Table 2. *Abralia andamanica*, *Abralia* sp., *Abraliopsis* sp., *Onychoteuthis* sp. and *Gonotopsis* sp. were found to occur frequently in the catches.

General Remarks

From the foregoing account, it is evident that the distribution of cephalopods in the seas around the Andaman-Nicobar Archipelago is wide and appears to be substantial. Cephalopods are distributed both in the oceanic and neritic waters. Faunal composition indicates the richness of the distribution which needs further study in this area.

Cephalopods are considered to be potentially important marine living resource and further exploitation to a high magnitude is possible. The present world production is estimated to be 1.5 million tonnes which can be increased substantially. Nearly 70% of the presently exploited resource of cephalopods come from the neritic waters, but directed fishing for this resource is limited. While cephalopods are considered a non-conventional resource in many areas, their high protein and low fat content can make it an important item of human diet. In fact there has been a leap in the cuttlefish and squid catches in the world during 1970-'80 and it is projected that the contribution of cephalopods to the world fisheries will be about 2 million tonnes by 1990 (Silas, 1985). It is also opined that India can play an important role in exploiting this projected potential, by expanding the present fishing operations from the neritic waters to the oceanic. The Andaman-Nicobar waters offer a virgin area for cephalopod fishing.

Since there is no directed fishing at present for cephalopods in the continental shelf waters, there is

Table 2. *Occurrence of different species of cephalopods in the Andaman - Nicobar area*

Species	IKMT	Pelagic trawl	Bottom trawl
Sepia aculeata	—	—	518
S. prashadi	—	—	511
S. trigonina	—	—	518
Euprymna stenodactyla	—	—	518
Loligo duvaucelii	—	—	511, 512, 518
Ancistrocheirus lusueuri	—	499	—
Enoploteuthis sp.	—	484	—
Abralia andamanica	493	482, 490, 493, 495, 499, 501, 505, 517	—
Abralia sp.	483, 493, 499, 518	480, 482, 484, 490, 493, 496, 499, 500, 501, 505, 507, 517	—
Abraliopsis gilchristii	507	486, 493, 499, 501, 517	
Onychoteuthis banksi	—	482, 484, 489, 499, 504, 505, 507, 515, 518	—
Gonotopsis sp.	—	483, 505, 515	—
Histioteuthis sp.	—	515	—
Ctenopleryx sp.	—	483	—
Chrioteuthis sp.	—	493	—
Octopoteuthis sp.	499, 503	515	—
Cranchia sp.	487, 499, 502, 508, 518	499, 502	—
Licocranchia sp.	493	515	—
Helicocranchia sp.	—	502, 516	—
Corynomma sp.	—	502	—
Japatella sp.	—	481, 515	—
Octopus sp.	—	—	515

Numbers indicate the stations.

an urgent need for developing the same. Steps should also be taken to use some of the mechanised boats for light-fishing with lift nets for exploiting oceanic squids. There is also need for improving the traditional gears for specific capture of squids and cuttlefishes, besides making attempts to catch the octopus by using traps, pots etc., in the coastal waters. There is also scope for improving the utilization of the presently exploited resources from the continental shelf by creating an awareness among the people of its utility and by developing varied products from the squids and cuttlefishes.

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OBSERVATIONS ON A LARGE SCHOOL OF SPINNER DOLPHINS, *STENELLA LONGIROSTRIS* OFF SOUTHWEST COAST OF INDIA WITH NOTE ON ITS BEHAVIOUR

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ABSTRACT

A large school of spinner dolphins, *Stenella longirostris* numbering about 120 were observed at 08° 52'N, 75° 36'E off Quilon coast along the southwest coast of India. The dolphins measured 2.0-2.5 m. They were bow-diving the vessel making acrobatic acts. The dolphins followed the vessel for about 45 minutes. Behaviour of the dolphins and an attempt made to study them in close quarter are also discussed.

INTRODUCTION

The spinner dolphin, *Stenella longirostris* has been reported from various parts of Atlantic, Pacific and Indian oceans (Gilpatric *et al.*, 1987). They are very often caught in large numbers in Pacific tuna fishery (Perrin, 1975). Along the Indian coast, they are caught in the gill net fishery as a by-catch. (Mohan, 1985). They are reported from other parts of Indian Ocean also. (Alling 1983; Leatherwood, 1985; D'Silva, 1987). However there are only a very few reports of them in large numbers from the Indian Ocean. Further as Indian Ocean is declared as a marine mammal sanctuary, the observations on their occurrence and behaviour are of interest.

OBSERVATIONS

While collecting fishery data in the FORV *Sagar Sampada* on 21-2-1987 at a depth of 100 m at 08°52'N and 75°36'E at a distance of 100 km off Quilon, a large school of about 120 spinner dolphins, *Stenella longirostris* was observed at about 1630 hrs (Figs. 1 & 2.) Soon they were found to bow-ride vessel in a batch of 10-12. The vessel was cruising at a speed of 3.75 knots per hour in the northsouth direction. The sea was calm and the surface temperature was 28.5°C.

The dolphins were characterised by the presence of an elongated beak and a broad dark band extending from the eye to the origin of the flippers. The body colour was dark grey on back, light cast on the sides and lighter on the belly. They were found to feed on a shoal of *Caranx kalla.*

The dolphins appeared in a pack of 10-12 numbers at the bow of the vessel. When one pack completed the bow-riding another pack replaced it. This process was continued for some time. While bow-diving, some of them swam ventro-dorsally also exposing the ventral side. A few of them were seen jumping over the water and spinning on their longitudinal axis. Some of them jumped over the water and dropped with a splash. While surfacing and jumping over the water they made an audible squirking vocal sound which could be heard well on the deck about 5 m above. When they dived deep in front of the vessel, trails of air bubbles were left behind them. As the water was clear the dolphins were visible for some depth.

Fig. 1. A School of Spinner dolphins off Quilon.

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As large number of dolphins were seen in the viscinity of the vessel, a life boat fitted with an outboard engine was lowered to reach the core area of the dolphin school and observe them in close quarters. The school was persued for about 30 minutes for a distance of about 3 km, but could not reach closer than about 50 m to the dolphins. The sound of the engine seemed to frighten them. The school disappeared with setting of the sun and the appearence of large sharks in the area.

Fig. 2. *A School of Spinner dolphin off Quilon.*

As Indian Ocean is declared as a marine mammal sanctuary by the International Whaling Commission, various efforts have been taken to study the population status of cetaceans of the Indian Ocean. Leatherwood (1985) and D'Silva (1987) reviewed cetaceans reported from Indian Ocean. Alling (1988) observed that about 38,000 odontocetes were caught in the gill nets in Sri Lankan coast out of which about 40% were spinner dolphins followed by Risso's dolphins (*Grampus griseus*) 17%, *Stenella attenuata* (13%) and the rest formed by other dolphins. Mohan (1985) also observed that *Stenella longirostris* formed 52.9% of the dolphins entangled off Calicut coast while *Tursiops aduncus* (*T. truncatus*), *Delphinus delphis* and *Sousa chinensis* formed 32.7%, 8% and 6.3% respectively.

It was observed that along the Indian coasts 133 dolphins were entangled in gill net fishery during 1988, of which 50.5% was *Delphinus delphis*. The other species *Stenella longirostris, Tursiops aduncus* and *Sousa chinensis* contributed 32.3, 9.7 and 7.5% respectively. There seems to be some difference in the species composition of the dolphins caught along the Indian coasts and Sri Lankan coast (Anon., 1989)

Further, a large number of this species are caught in the Pacific tuna fishery causing concern about the population of this species. However, our knowledge of the species from Indian Ocean is far from satisfactory and more information is required for any meaningful estimate of the stock which is essential for management.

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DISCOVERY OF A DEEP WATER GORGONID BED OFF BOMBAY AND ITS QUALITATIVE APPRAISAL

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ABSTRACT

During the 22nd cruise of FORV *Sagar Sampada* (1-10 - '86 to 18 -10 -'86) a survey of the bottom fauna, especially of fishes, was made along the northwest coast of India between Lat. 18°N and 23°N, from 10 stations (*Sagar Sampada* St. Nos. 777-786) at depths varying between 65 and 130 m. Of these 10 stations, gorgonids were present at two stations (St. Nos. 783, Lat. 19°00'N and Long.71'00'E; 784, Lat. 19°00'N and Long. 72°00'E) in appreciably good numbers.

The sample obtained from station 783 (depth: 86 m) was quantitatively and qualitatively richer with 8 species refereable to 5 genera and 4 families, and was dominated numerically by two species, viz. *Gorgonella umbella* (Esper) and *Parisis fruticosa* Verrill. Samples from station 784 (depth: 68 m) included the above two species only indicating that both *G. umbella* and *P. fruticosa* are widely distributed in the depth range 68 to 86 m.

Two species, *Muricella initida* Verrill and *Acanthogorgia turgida* Nutting are here reported from the Arabian Sea, and *Muricella dubia* Nutting from the Indian Ocean. It is also worth mentioning in this context that both *G. umbella* and *P. fruticosa* are not common in the near-shore areas, and when present never form extensive beds. Hence, the presence of these two uncommon species in extensive areas off Bombay is significant.

The information on the deepwater gorgonid bed presently gathered should never be used to indiscriminately exploit and export this rare commodity of our waters. Instead, attempts may be initiated to ascertain if the above two common and wide-spread species could form the source of any life-saving drugs, as are common in some other gorgonids. Since deepwater gorgonids from Indian waters are poorly known, the salient features of each species collected, together with suitable illustrations, are also presented in this paper.

INTRODUCTION

During the 22nd cruise of FORV *Sagar Sampada* an exhaustive survey of the bottom fauna, was made along the northwest coast of India from 23°N to 18°N . Out of 7 BTR (Bottom trawling) stations surveyed, gorgonids were collected from two stations (Nos. 783 and 784) situated at a distance of 1°. The gear employed for their collection was HSDT-1, the High Speed Demersal Trawl developed by C. I. F. T, Cohcin, and the depth of operation varied from 65 to 130 m.

The species dealt with in the present account were collected from station No. 783 (10°00'N and 71° 00'E; depth: 86m), but 2 species, *Gorgonella umbella* (Esp.) and *Parisis fruticosa* Verrill, were also observed to be luxurient in Stn. No. 784. This extended availability to Station No. 784 (19° 00'N and 72° 00'E; depth: 68 m) indicates their wide distribution in depth zone varying between 68 and 86 m off Bombay. Numerically speaking, *G. umbella* formed the dominant species followed by *P. fruticosa* in Stn. No. 783. All the other species were represented by one or two specimens each; and the total number of species recorded from this deep-water bed is eight inclusive of four species that are new to the Arabian Sea. The present discovery of *Muricella nitida* (Verrill) and *Acanthogorgia ceylonensis* Thomson and Henderson, from the Arabian Sea has extended their distribution considerably in the Indian Ocean since both of them were known in the past from Sri Lanka waters only. *Muricella dubia* Nutting and *Acanthogorgia turgida* are here recorded from the Indian Ocean.

The general classifcation adopted here is that of Bayer (1963). Detailed descriptions and illustrations of the available species have been furnished here for their easy identification. Some ecological notes on the species, especially on the colony structure, as compared to their counterparts inhabiting the shallow water realms, have also been given along with each species to indicate the possible limiting effect of the depth factor on the colony structure in gorgonids.

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The following species were present in this deep-water bed:-

List of Species

Order : Gorgonacea Lmx.

Suborder : Scleraxonia Studer

Family : Parisididae Aurivillius

1. *Parisis fruticosa* Verrill

Suborder : Holaxonia Studer

Family : Paramuriceidae Bayer

2. *Muricella nitida* (Verrill)
3. *M. dubia* Nutting
4. *Echinomuricea indica* Thomson and Simpson

Family : Acanthogorgiidae Gray

5. *Acanthogorgia turgida* Nutting
6. *A. ceylonensis* Thomson and Henderson

Family : Ellisellidae Gray

7. *Gorgonella umbraculum* (Ell. & Sol.)
8. *G. umbella* (Esper)

Systematics

Order : Gorgonacea Lmx.

Suborder : Scleraxonia Studer

Axial part with spicules that are bound together either by horny or by calcareous material. Cortical spicules quite different from those of axial part.

Family : Parisididae Aurivillius

Arborescent monomorphic forms possessing internodal tubercultae spicules and nodal lobate rods; cortical spicules coarse plates; branches originate from calcareous internodes.

Genus: *Parisis* Verrill

Colonies branched in one plane; branches originate from calcareous internodes. Spicules thick and irregular with a median constriction and often beset with verrucae. Type, *Parisis fruticosa* Verrill.

1. ***Parisis fruticosa*** Verrill

(Fig. 1a: 1-9, Pl. 1G)

Parisis fruticosa Wright and Studer,1889, p. 182, pl. 41; Thomson and Simpson, 1909, p. 176, figs. 74, 75; Nutting, 1911, p. 54; Kukenthal, 1924, p. 83 (Synonymy). *P. indica* Thomson and Henderson, 1905, p. 23, pl. 4, figs. 4, 5, 8, 9.

Material : Several specimens from stations 783 and 784.

Description : All specimens exhibit the same pattern of growth and branching. Basal attachment zone is not preserved well in any of the specimens examined. Branches and branchlets divide freely in one plane forming a more or less triangular expanse. Fusion of branches /branchlets not common. The main stem may measure upto 2.5 mm in diameter and is circular in cross section, but at places may show a tendency to get flattened in the plane of the colony. The utlimate branches may come upto 1 mm in diameter (excluding calyces). The largest specimen obtained had a height of 12. 5 cm with an expanse of 4.7 cm for its lamella.

Calyces arranged laterally in a serial pattern; they are conical to dome-shaped and tilted to the distal end of the branch/branchlet, measure 0.6 mm in height and are distributed at distances of 1.3 mm on an average. Though the above given arrangement may be taken as the normal pattern, in older parts of the clony the calyces have been observed around the stem in an irregular pattern. But such calyces are fewer in number and placed well apart.

The axial skeleton is distinctly segmented with calcareous internodes and horny nodes (Fig. 1a: 5). The length of these internodes varies considerably from place to place within a range of 2-7 mm and are striated longitudinally (Fig. 1a: 6,7,9) , and these striae may continue through the nodes also. The diameter of the nodes may be the same as that of internodes in the main stem, while on branches and branchlets it may be slightly smaller; division is always from the internodes only (Fig. 1a: 5, 8).

The general surface, including that of calyces, is ornamented minutely with tubercles arising from cortical plate-like spicules. The coenenchyme is slightly thicker on the lateral parts of branches/ branchlets.

Spicules : 1) Cortical plate -like spicules. With coarse tubercle - bearing mammiform protuberences from the surface; circular, oval or irregular in shape. Size upto 0.37 mm in diameter (Fig. 1a: 1). Nutting (1911) reported large plate-like spicules measuring upto 0.6 mm, but in all the present specimens they were smaller in size. 2) Quadriradiate, multiradiate or cruciform spicules. Size 0. 028 to 0. 080 mm (Fig. 1a: 2). 3) Spiny rods of internodes.

These spicules, in advanced stages, fuse to form a dense axial condensation, and is difficult to separate any single spicule from the internode when fully developed. Some young spicules could be separated and are figured in Fig. 1a: 3. At this young stage they may measure 0. 18 - 0. 33 X 0.008 - 0. 020 mm (excluding spines). 4) Lobate rods of axial nodes. Curved with lobulations; size 0.12X 0.004 mm (Fig. 1a: 4).

Biological notes : Earlier workers have reported the presence of associates like sponges and *Palythoa* on the specimens examined by them from different parts of the Indian Ocean. But all the present specimens were free from such associates.

Colour : Pink when alive, turning to white or yellow on dying. Those dried under direct sunlight turned white while those dried under diffused sunlight yellow. Internodes are white in colour while nodes, pale yellow. Spicules colourless.

Distribution : Widely distribted in the Indo-Pacific.

Depth : Littoral to deep-sea. Present specimens came from a depth range of 68 to 86 m off Bombay.

Order : Holaxonia Studer

The central axis, in this order, is made of horny material only, and may be reinforced with calcareous matter in varying degrees.

Family : Paramuriceidae Bayer

Central chord wide and chambered; polyps retractile within protruding calyces and with an armature of strong points of *en chevron* spicules ususally resting on a transverse collaret; cortical spicules usually spindles, but modified 'thorn-scales' with or without the addition of other forms may also be included.

Genus : *Muricella* Verrill

Colonies branch in one place, branches may or may not anastomose. Calyces distinct and are in the form of truncated cones. Rind spicules in two layers; mostly spindles to which clubs or discoidal forms may be added. Tentacular operculum very distinct. Type, *Muricella nitida* (Verrill).

2. *Muricella nitida* (Verrill)

(Fig. 1b : 1-3, Pl. 1A)

Muricella nitida Thomson and Henderson, 1905, p. 302; Kuken thal, 1924, p. 172 (synonymy).

Material : One specimen from station No. 783.

Description : Colony fan shaped; branches/branchlets show no sign of fusion. Branching irregularly dichotomous in the lower 2/3rd and branches / branchlets formed at this part are of unequal size, one being stouter than the other. Dichotomous division at the distal 1/3rd of the colony produces branchlets of equal size and dimensions. Diameter of the stalk is 2 mm and of branchlet, about 1 mm (excluding calyces). Height of the specimen is 9.8 cm and breadth, about 7 cm.

Calyces are arranged more abundantly towards the lateral parts of the branches/branchlets, leaving the front and back surfaces bare. At some places the calyces are arranged in an alternating manner; they are tubular to truncate in shape measuring 0.9 - 1.3 mm in height.

Spicules : 1) Warty spindles. Straight or slightly curved; size upto 1.6 X 0. 18 mm (Fig. 1b: 1) 2) Small spindles of operculum. Size 0. 37 X 0. 037 mm (Fig. 1b : 2), 3) Crosses. Two arms may or may not be longer than others, when longer they may attain a size of 0. 169 X 0. 03 mm (Fig. 1b : 3).

Colour : Colony crimson red, axis brown and tentacular operculum, yellow. Spicules crimson red except those which are in their early stage of development.

Distribution : Known from Japan and Ceylon (=Sri Lanka), and is here reported from the Arabian Sea, off Bombay.

Depth : Upto 631 m; the present specimen was collected from a depth of 86 m.

3. ***Muricella dubia*** **Nutting**

(Fig. 1c: 1-3; Pl. 1 F)

Muricella dubia Nutting, 1910, p. 34; Kukenthal, 1924, p. 173.

Material : Two specimens from Station 783.

Description : Colonies subflabellate and branched in one plane; branches simple or divide dichotomously without any trace of fusion. The basal attachment zone is retained in both specimens. Size of the first specimen, 3 X 2 cm and of the other, 5.8 X 3 cm.

Calyces are borne on both sides as also along the front and back portion of the stem and branches, they are globular in shape with a size of 0.6 X 1 mm (height X diameter), and covered with warty spindles which are irregularly placed. Polyps retractile completely, operculum is usually sunk and is made of longitudinal spindles arranged *en chevron* over the tentacular base. Diameter of the stalk is 0.75 mm and that of branches about 0.5 mm.

Spicules : 1) Warty spindles, tuberculated, short and stout; one end broader than the other in some. Size upto 0.35 X 0.16 mm (Fig. 1c : 1). 2) Smaller spindles and crosses are also common in both specimens (Fig. 1c : 2, 3).

Colour : Colony light brown, axis dark brown fading to light brown in branches, spicules colourless.

Distribution : Known previously from Flores Sea and is here reported from the Arabian Sea.

Depth : 73 to 86 m.

Genus : *Echinomuricea* Verrill

Characteristic spicules of the genus are 'thorn-scales' with a single median spine bearing several root-like tuberculated structures from the basal part. Colonies branched in one plane and often reticulate. Thorn-scales are distributed over the calyces and general surface alike and their presence gives a characteristic appearance to the general surface. Type, *Nephthya coccinea* Stimpson

4. *Echinomuricea indica* Thomson and Simpson (Fig. 1d: 1-4; Pl. 1H)

Echinomuricea indica Thomson and Simpson, 1909, p. 204, pl. 3, figs. 2, 3; pl. 8, fig. 4; Kukenthal, 1924, p. 188, fig. 17; Thomas and Rani Mary Jacob, 1987, p. 23, fig. 1g, 2A; Thomas and Rani Mary George, 1987a, p. 104, Fig. 1i: 1-5.

Material : One specimen from Station 783.

Description : Colony complete except for its partly denuded skin on the basal branches and stalk portion. The attachment zone is well preserved in the specimen obtained and the stem is continued as the main branch up to a height of 2.5 cm. Smaller branches are given off from both sides of the stem and they divide as they go in one plane. There is no sign of anastomosis and the branchlets end bluntly. Size of the specimen, 6 X 5.5 cm (height X width).

The other details tally well with those of the specimens described from the Indian seas by Thomas and Rani Mary Jacob (1987).

Spicules : 1) Thorn scales. Thorn-like part is well developed and robust; may measure upto 0. 21 X 0. 016 mm when well developed. The entire spicule may come upto 0.43 X 0. 33mm when well developed (Fig. 1d: 1). Other spicules include spindles (Fig. 1d: 2), multiradiates (Fig. 1d: 4) and crosses (Fig. 1d: 3).

Ecological notes : This species forms an important item of the 'black type' gorgonid now exported from India which is abundant at depths varying between 5 and 8 m in the Gulf of Mannar. Specimens collected from the Gulf of Mannar show that anastomosis of branches appears at an early stage, even before attaining the size of the present specimen. Simple branches, free from anastomosis as seen in the present case, may be a growth pattern induced by the depth factor.

Colour : Colony light yellow when collected, axis black and spicules colourless.

Distribution : Indo-Australian.

Depth : Upto 86 meters.

Family : Acanthogorgiidae Gray

Axis horny with wide-chambered axial chord; rind thin and polyps non retractile; calyces prominent, tubular with spindles arranged *en chevron* and in characteristic crown-like fashion along the margin. Spicules include bent spindles (thorn-like spindles) ordinary spindles, multiradiates etc.

Genus : *Acanthogorgia* Gray

Typical genus of the family with type *Acanthogorgia hirsuta* Gray.

5. ***Acanthogorgia turgida* Nutting** Fig. 1e: 1-4; Pl.1C)

Acanthogorgia turgida Nutting , 1910, p. 21, pl. 1, fig. 2; Kukenthal, 1924, p. 241.

Material : One specimen from Station 783.

Description : Colony fan shaped; branches and branchlets show no signs of fusion. Basal attachment zone is well developed. The lateral branches are given off from the stalk at about 1 cm above the attachment disc. Several lateral branches may be also seen arising above its first division on both sides of the main stalk in an alternating fashion. The size of the specimen is 14 cm (height) X 8.2 cm (width). Stalk about 1.5 mm in diameter and branchlets about 0.5 mm.

Polyps are arranged on all sides of the stem, branches and branchlets. They are cylindrical in shape and may measure upto 1.6 mm in height with a diameter varying 1-1.5mm. The crown of thorn quite distinct on the polyps that are seen along the actively growing parts of the colony. The rim of the calyces are generally darker than the rest of the calyces. *En chevron* arrangement of spicules give a distinct appearance to the calyx margin.

Spicules : 1) *Acanthogorgia* type of spicule with smooth pointed distal end and a warty basal portion. Size, 0.42 X 0. 029 mm on an average (Fig. 1e: 1). 2) Large warty spindles. Slightly curved or even 'S' shaped. Size upto 1.13 X 0. 09 mm (Fig. 1e: 2). 3) Small spindles. Size upto 0.37 X 0. 029 mm (Fig. 1e: 3). 4) Multiradiates. Diameter up to 0.1 mm (Fig. 4e: 4).

Colour : Colony brown, axis golden brown and spicules colourless.

Distribution : Known only from Malay Peninsula and is here recorded from the Arabian Sea.

Depth: Upto 520 m.

6. *Acanthogorgia ceylonensis* Thomson and Henderson
(Fig. 1f: 1-3; Pl.1D)

Acanthogoriga ceylonensis Thomson and Henderson, 1905, p. 290; Nutting, 1910, p. 19; Kukenthal, 1924, p. 240.

Material: : Two specimens from Station 783.

Description : Colonies flabellate; basal attachment disc rather prominent. The stem and basal parts are mostly denuded. Division of the colony in one plane giving rise to an oval outline to the specimens. Main branches arising from the stalk are traceable upto 2/3rd of the colony; branchlets are given off in an opposite and alternate manner. The diameter of the stalk protion is about 1 mm while that of branches and branchlets vary from 0.4 - 0.6 mm. The larger specimen at hand is about 8.6 cm high and 9.8 cm wide.

Calyces small, tubular to conical in shape depending on the degree of contraction and measure about 0.6 - 1 mm in height and 0. 6 mm in average diameter. They are sparsely distributed with a tendency to get arranged laterally on branches/ branchlets. The crown of spines is conspicuous in almost all calyces and their presence gives a characteristic bristle-like appearance under magnification. The calyces at their basal parts are covered with spindles arranged horizontally. Coenenchyme, which is rather thin, is densely charged with tuberculated spindles, stars and crosses. Rind and calyces deciduous in dry condition.

Spicules : 1) *Acanthogorgia* type of spicules; one end smooth and pointed and the other tuberculated in varying degrees. Their basal parts remain buried inside the clayx wall. Size upto 0.45 X 0. 029 mm (Fig. 1f: 1). 2) Spindles. Straight or slightly curved; size upto 0.28 X 0.025 mm (Fig. 1f : 2). 3) Multiradiates. Size upto 0. 16 mm (Fig. 1f: 3).

Colour : Calyces light yellow to white when dry, axis golden brown fading to white or yellow distally; spicules colourless.

Distribution : This was first reported from Ceylon (=Sri Lanka) and then from Malay Archipelago. It is here reported from the Arabian Sea.

Depth : Upto 112 m.

Family : Ellisellidae Gray

Colonies unbranched or sparingly branched and with or without anastomosis. Axis strongly calcified. Spicules small, consisting of characteristic dumb-bells, some modified into clubs or double spindles.

Genus : *Gorogonella* Val.

Colonies flabellate and often reticulate, calyces veruciform; cortex with double heads and double spindles to which others like crosses and stars may be added. Type, *Gorgonella umbraculum* (Ell. & Sol.)

7. *Gorogonella umbraculum* (Ell. & Sol.)
(Fig. 1g: 1-3; pl.1E)

Gorgonella umbraculum Nutting, 1910, p.8 (synonymy); Kukenthal, 1924, p. 381 (synonymy); Thomas and Rani Mary George, 1987a, p. 109, fig. 1s: 1-3.

Material : Two specimens from Station 783.

Description : Colonies flabellate and profusely branching in one plane; branches may rarely get interconnected. Calyces small and measure upto 0.5 mm in height and are densely distributed towards the actively growing parts of the colony, but may be lateral at other places. Height of the larger specimen, 14 cm with a lateral spread of 21 cm. The stalk portion is 3.2 mm in diameter and branchlets, 1.1 mm in diameter on an average.

Other details tally well with those of the specimens recorded from the shallower areas of the southwest coast of India where they are exploited commercially (Thomas and Rani Mary George, 1987a).

Spicules : 1) Spindles . Size 0. 06 - 0.1 X 0. 024 mm (Fig. 1g: 1). 2) Dumb-bells. Size 0.06 X 0. 02-0. 03 mm (Fig. 2g: 2). 3) Small dumb-bells. Size 0.04 X 0. 02 mm (Fig. 1g: 3).

Ecological notes : This species is widely distributed along the southwest and southeast coasts of India contributing considerably to the gorgonid fishery (of 'red- type') in these areas. Specimens in the aforementioned areas are collected from shallower depths (5 to 8 m) where they grow luxuriently attaining a size of 100 X 80 cm or even more (Thomas and Rani Mary George, 1987a). The specimens dealt with here, when compared with those collected from the southwest and southeast coasts of India, appear rather frail with poorly developed branches and branchlets. The anastomosis of branches and branchlets were also very weak and a closely reticulated lamellar structure , as a rule, is wanting. It is also difficult to sort out specimens of *Parisis fruticosa* Verrill (*Vide supra*) that coexist with the present species, based on morphological differences. Whether the depth factor has anything to do with the morphology or not has to be ascertained by comparing several specimens from different depth zones.

Colour : Colony light orange, axial part pale white and spicules light yellow.

Distribution : Indian Ocean and Red Sea.

Depth : Upto 100 m.

8. ***Gorgonella umbella*** (Esper)
(Fig. 1h: 1-3; Pl.1B)

Gorgonella verriculata Hickson, 1905, p. 816. *Gorgonella flexuosa* and *G. umbella* Thomson and Simpson, 1909, p. 372. *G. umbella* Kukenthal, 1924, p. 382.

Material : Several specimens from both stations.

Description : The stalk portion is not retained in some. Colonies flabellate and usually divide in one plane; but occasionally additional lamella may be seen arranged at an angle to the original one. Branches and branchlets, soon after their emergence, may curve out and grow, which results in the formation of curved or sinuous branches and brachlets. Branches end blindly and no sign of fusion could be noted. The largest specimen in the collection had a height of 13 cm and a width of 11.6 cm.

Calyces distributed on all sides but their size and shape depend upon the degree of contraction; in some areas they may be conical and truncated while in others they may be flush with the surface. When conical, height upto 0.7 mm. Coenenchyme is thick and densely packed with warty spindles. Polyps fully contractile. Stem 4 mm and branchlets 3 mm in average diameter.

Spicules : 1) Spindles. Size upto 0. 092 X 0. 037 mm (Fig. 1h: 1). 2) Dumb-bells. Size upto 0. 071 X 0. 046 mm (Fig. 1h: 2). 3) Crosses. Diameter upto 0. 05 mm (Fig. 1h: 3).

Colour : Colony white or pale yellow, axis black and spicules, colourless.

Distribution : Known only from the Indian Ocean.

Depth : Upto 495 m.

Discussion

The occurrence of 8 species of gorgonids, of which two (*Gorgonella umbella* and *Parisis fruticosa*) in moderately good numbers, off Bombay in depth zone 68 to 86 m, is quite interesting. The above mentioned two species are not represented in any of the inshore areas.

The information gathered here on the distribution and abundance of the above mentioned two species should never be utilised to exploit them commercially for export.

The commercial exploitation of gorgonids initiated in 1975 has resulted in the depletion of many of our erstwhile rich gorgonid grounds. The average size of specimen fished out from the inshore areas has come down considerably in recent years, and hence a ban on the export of this commodity will only help in enriching our gorgonid beds (Thomas and Rani Mary George, 1987b).

Since many of the chemicals extracted from Gorgonids (Prostaglandins and the like) have biodynamic properties, we have suggested in the above paper that attempts should be initiated in India to extract various 'life saving drugs' from the raw material available in our inshore areas.

The bed now discovered off Bombay is rich, alteast in the case of the above mentioned species. Therefore, attempts may be initiated to ascertain if

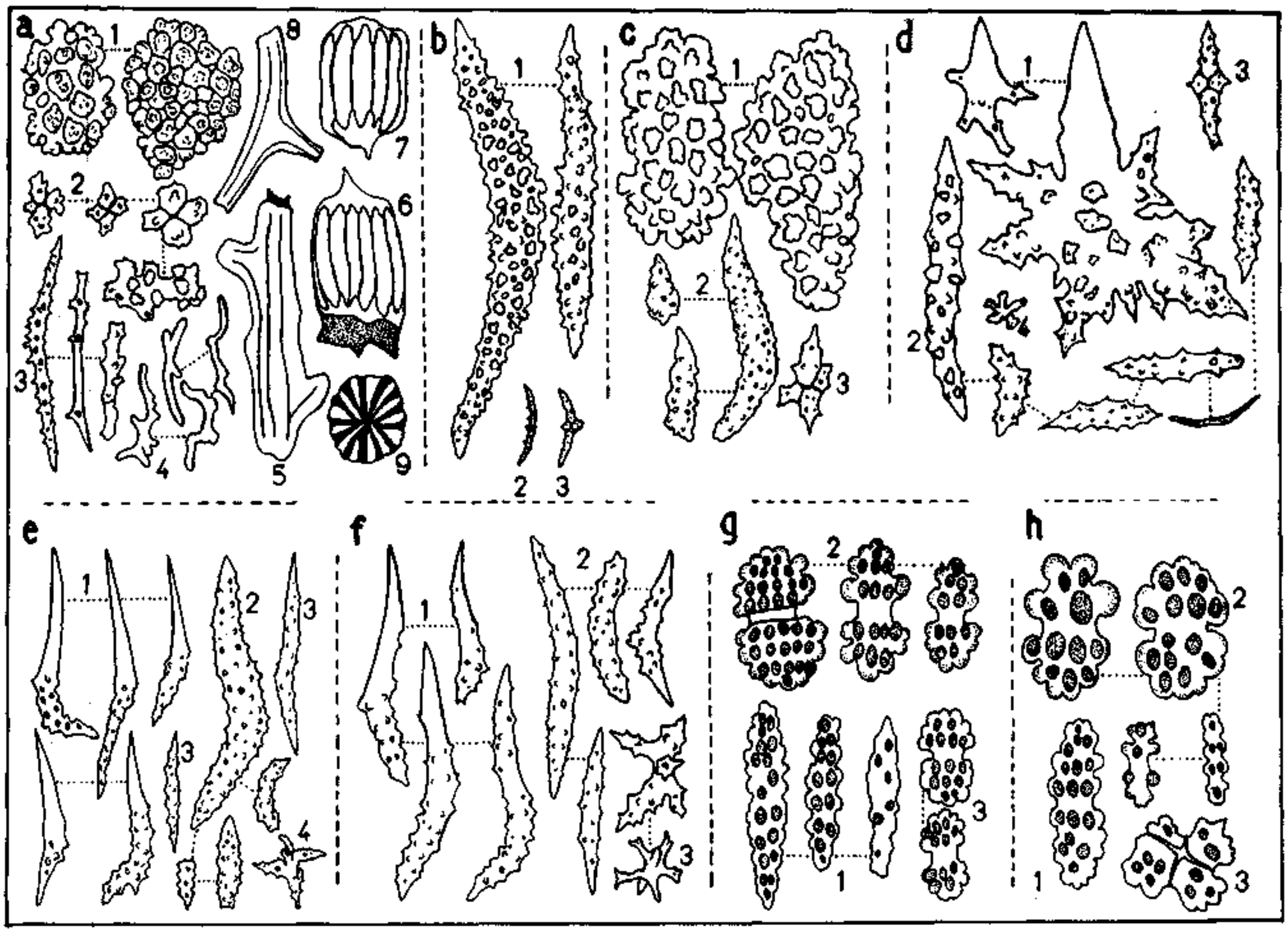

Fig. 1. a) *Parisis fruticosa* : 1. Plate-like spicules of cortex, 2. Quadriradiate and cruciform spicules, 3. Spiny rods of internodes, 4. Lobate rods of axial nodes, 5. Axial skeleton, 6 and 7. Nodes and internodes, a magnified view, 8. Axial skeleton showing the branch formation, 9. Enlarged view of the internode showing the surface ornamentation.

b) *Muricella nitida*: 1. Warty spindles, 2. Small spindles, 3. Cross.

c) *Muricella dubia*: 1. Warty stout spindles, 2. Small spindles, 3. Cross.

d) *Echinomuricea indica*: 1. *Echinomuricea* type spicules, different growth stages. 2. Spindles, 3. Cross, 4. Multiradiate.

e) *Acanthogorgia turgida*: 1. *Acanthogorgia* type spicules, 2. Large warty spindles, 3. Small spindles, 4. Multiradiate.

f) *Acanthogorgia ceylonensis*: 1. *Acanthogorgia* type spicules, 2. Spindles, 3. Multiradiates.

g) *Gorgonella umbraculum*: 1. Spindles, 2. Dumb-bells, 3. Small dumb-bells.

h) *Gorgonella umbella*: 1. Spindle, 2. Dumb-bell, 3. Cross.

the above species could form the source of any 'life saving drugs' as are common in some other gorgonids.

Acknowledgements

We are greatful to Dr. P. S. B. R. James, Director, C. M. F. R. Institute for giving us the opportunity to go onboard FORV *Sagar Sampada*, to collect and study the material and also to publish the findings. It is a special pleasure to acknowledge the helpful suggestions and criticism of Shri C. Mukundan, Scientist (Retd.), C. M. F. R. I., that we received during the preparation of this paper. We also wish to acknowledge the enthusiasm that has been shown by various crew members, especially S/Shri. Thomas Teles and Nirmal Mathews, Fishing Masters, in sorting out the trawl catches after every operation.

The photographs presented in Plate 1 have been prepared by Shri. Raghavan, Artist Photographer, C. M. F. R. I., and we wish to record our appreciation for this courtesy.

TECHNICAL SESSION V

Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5-7 *June*, 1989: 427 - 434 (1990)

FORV *SAGAR SAMPADA* AND DEVELOPMENT OF DEMERSAL TRAWLS FOR INDIAN EEZ — A STATUS PAPER ON PROSPECTS AND CONSTRAINTS

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Central Institute of Fisheries Technology, Cochin - 682 029

Abstract

A summary of R&D programme on the harvest technology of the demersal resources of EEZ leading to the development of the new concept of high speed demersal trawling as the most suitable method for the exploitation of low density multi-species tropical demersal fishery resources, light Bobbin Trawl for the exploitation of the rich demersal fishery resources of hard, uneven and even rocky areas of the Indian EEZ otherwise not accessible for trawling and multipurpose Hybrid Trawl for squid and cuttle fish is presented. The design details and performance of the three high speed demersal trawls, Cift HSDT I, II & III, Cift Bobbin Trawl and Cift Hybrid Trawl are discussed.

How the inherent constraints of sharing the facility of a primarily biological and oceanographic research vessel and the fixation of priorities on the above line have affected the R&D programmes on the harvest and post harvest technology of fish is discussed in detail and suggestions are made to minimise these constraints.

Introduction

FAO (1977) has estimated an annual potential yield of World Fisheries to range from 240 to over 455 million tonnes and aimed at 130 million tonnes from the then 70 million tonnes range by the turn of the century with a total investment cost of US $ 30,000 million at an input rate of US $ 1,500 million over a period of 20 years from 1980. Most of the technology input being readily available, what is needed is the adoption of policies and programmes especially by developing countries like India with a vast area of EEZ for the judicial exploitation of the resources.

It is rather disheartening to record that even after a decade of our declaration of the EEZ, we have still not even touched the fringe of our EEZ outside the traditional coastal area of nearly 0.2 million sq km i.e. 10% of the EEZ. It is also worth metioning here that 99% of the national marine fish production of nearly 1.8 million tonnes is from the traditional coastal area and hardly 1% is the contribution of nearly 90% of the EEZ with an estimated potential yield of 2 million tonnes annually.

Thanks to the Department of Ocean Development, Government of India and Dr. S. Z. Qasim former Secretary, Department of Ocean Development in particular, the situation is steadily changing with the acquisition of the two prestigeous research vessels ORV *Sagar Kanya* during 1983 and subsequently FORV *Sagar Sampada* during 1984 basically designed and equipped for oceanographic and biological research and exploration of the EEZ. However, due to the inherent constraints in sharing the limited facilities of FORV *Sagar Sampada* made available to Indian Council of Agricultural Research for fishery development purposes, it was not possible to have much headway in the fishing technology aspects of the EEZ. Addition of a third research vessel, an FTRV alongwith FORV & ORV can go a long way in an overall development and exploitation of the living resources of the EEZ.

Even though, different types of demersal trawls were used for survey and limited exploitation of the demersal fishery resoruces along the continental shelf and slope by sister institutions like FSI and IFP, they were all imported designs of very heavy trawls suitable for temperate regions with entirely different fishery and fishing conditions. These nets are desinged for an optimum trawling speed ranging between 2 and 3 knots with heavy materials and ground ropes to cope with bulk catches of a few commercially important slow swimming demersal fishery resources of high population density. However, for the commercial exploitation of the comparatively active, multi species, low population density tropical fishery resources like ours, these designs are not suitable.

It is in this context that Central Institute of Fisheries Technology, Cochin has taken up the challenge of developing suitable demersal trawls for the commercial expolitation of the deep sea demersal fishery resources of the EEZ leading to the perfection of high speed demersal trawling, a concept still in the developmental stage elsewhere, as the most suitable design for commercial exploitation. The Institute has taken up development of Bobbin Trawl for the exploitation of the rich and varied demersal fishery resources of vast areas of hard, uneven and even rocky patches of the EEZ not suitable for conventional trawling and development of High Speed Multipurpose Hybrid Trawl for the exploitation of squid and cuttle fish. A summary of the salient features of the gear and performance from FORV *Sagar Sampada* is disucssed.

High speed demersal trawling

Commercial exploitation of active, multispecies low population density fishery resources like ours requires encountering of fish at a high speed. To attain a high speed trawling system especially for the exploitation of demersal fishery resources problems are many. They are,

i. The power requirement to increase the speed of a ship is far from proportional to the increase in speed.

ii. The resistance of the trawl increases more than proportionately to the increase in speed.

iii. An increase in the speed necessitates an increase in the scope ratio and use of heavy otter boards and ground rope leading to a further increase in the power consumption.

iv. Fishing power of a trawler, depends upon the "area swept" by the gear which is proportional to its "gape" and to the speed of towing.

v. The speed of water inside the trawl and perhaps also infront of it is less than the speed of tow due to the resistance of webbings, thereby enabling greater chance of escape of fast swimmers. The amount of water strained being the criterion of fishing power, it is evident that a large trawl towed at a slow speed might have the same straining capacity of a small trawl at a high speed. Hence a smaller trawl, with light material, larger meshes, with appropriate angle of attachment of webbing at the wings, trawl mouth and belly region to get a smooth catenery of the framing rope and a smooth tapering along the belly facilitating even distribution of stress along the entrie net to allow a wide opening of mesh from square to diamond shape from wing to cod end is the main feature of a high speed demersal trawl. Due to the even distribution of force all along the net from wing to cod end, it opens horizontally and vertically to the optimum thereby facilitating smooth water flow and herding of fish to cod end without gilling at any part of the net. Taking into consideration of all the above facts, CIFT has developed three high speed demersal trawls Cift HSDT-I, II & III with a common belly but with different configuration at the trawl mouth.

Cift HSDT-I

***Scientists responsible* : K. K. Kunjipalu, B. Meenakumari & T. M. Sivan**

Cift HSDT - I is basically a two seam demersal trawl. The design details are presented in Figs. 1& 2. The gear was tested from FORV *Sagar Sampada* on 24-6-1986 and continued upto 7- 10- 1987 at depth ranging between 50 and 380 m at a speed ranging between 3.5 and 4. 5 k. A total of 57 operations of 50 hr duration landed 59. 6 tonnes of demersal fin and shell fishes resulting in an overall catch/hr of 1.152 t. Of the 57 hauls, 35 were aimed at biological sampling wihout any consideration of the productivity of the ground and the total catch for the above 35 hauls of 30 hr duration was only 4.57 t resulting in a catch per hour of 0.119 t. The pre-commercial feasibility studies of 22 hauls of 20 hr duration landed 55.03 t recording a catch per hour of 2.75 t. A maximum catch of 10 t/hr was recorded on 29-7-1987. The normal catch ranges between 0.5 and 2.5 t per hour with occasional catches of 9.5 and 3.5 t per hour respectively on 8-9-1986, 4-8-1987 and 4-7-1987. The catch consisted of *Nemipterus* sp., horse mackerel, mackerel, *Priacanthus* sp., perches, cephalopods and deep sea prawns and lobsters. The main feature of the net is its easy manoeuvrability to a limited height from the bottom.

Cift HSDT- II

***Scientists responsible* : B. Meenakumari, K.K. Kunjipalu & T. M. Sivan**

Cift HSDT-II, is also basically a two seam demersal trawl but with different configuration at the mouth and wing region. The design details are presented in Figs. 3 & 4. The gear was tested on 26-6-1986 from FORV *Sagar Sampada* and continued up to 18-9-1987. A total of 40 hauls of 39 hr landed 24.96 t resulting in an overall catch per hour of 0.65 t. Twenty three hauls of 23 hr earmarked for biological sampling landed 3.15 t resulting in a catch/ hour of 0.146 t and pre-commercial feasiblility studies of 16

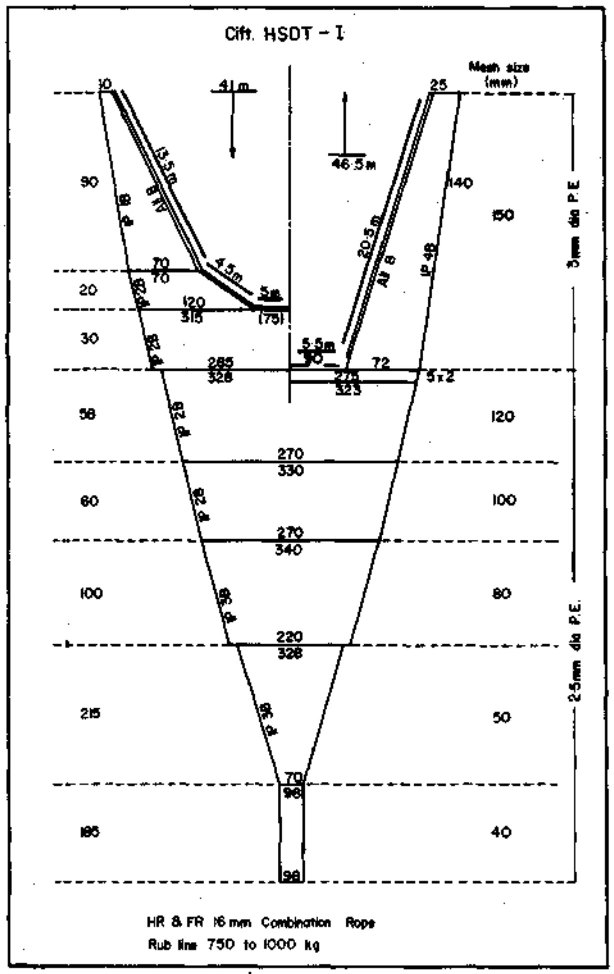

Fig. 1. Design of High Speed Demersal Trawl : Cift HSDT - I.

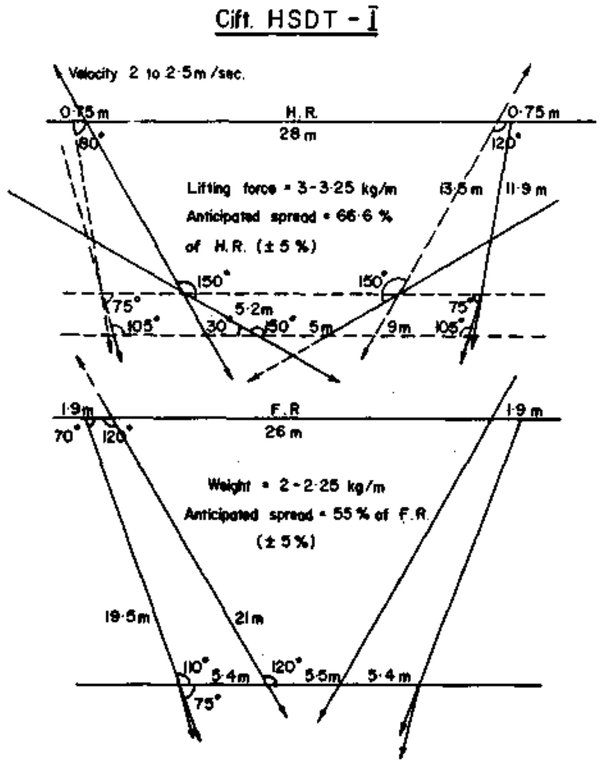

Fig. 2. Orientation of wings at the trawl mouth of Cift HSDT - I.

hr landed 21.8 t resulting in an average catch per hour of 1.36 t. The maxmium catch recorded was 4 t/hr on 1-8-1987 with repeated catches of 2.5 t/hr on 28-6-1987, 1-7-1987 and 14-9-1987. The catch ranged between 0.5 and 2 t per hour. The catch consisted of *Nemipterus* sp., *Priacathus* sp., perches, mackerel, cephalopods, prawns and lobsters. The operational details are same as in the case of Cift HSDT- I.

Cift HSDT- III

Scientists responsible **: B. Meenakumari, K. K. Kunjipalu & T. M. Sivan**

Cift HSDT-III is basically a four seam type of demersal trawl with 3 bridle arrangement. The design details are presented in Figs. 5 & 6. The gear was operated from 4-8-1986 to 19-2-1988 form FORV *Sagar Sampada*. The ground and operational details are same as in the case of Cift HSDT- I & II. A total of 60 hauls of 42 hr duration landed 57.8 t. A total of 24 hr was utilized for biological sampling and landed 4.17t resulting in an average catch per hour of 0.171 t and 21 hauls of nearly 18 hr of pre-commercial feasibility studeis landed 53.36 t resulting in a catch/ hour of 3.03 t. Cift HSDT-III has the maximum adaptability to sea bottom and has recorded the maximum catch of 12 t/hr of deep sea prawns and lobsters on 17- 2-1988 at 315 m depth off Quilon, followed by 7 t and 5 t per hour on 15-2-1988, 4.5 t/ hr on 13-2-1988 and 2 t/hr on 12-2-1988 and 13-2-1988 from the same area. The normal catch ranged between 0.5 and 2.5 t per hour. The catch consisted mainly of deep sea prawns, lobsters, deep sea fishes, *Nemipterus* sp. *Priacanthus* sp. and perches.

The rigging and performance details of HSDT series are given in Figs. 7 & 8 and Table 1. The average catch per hour of 1.086 t for 131 hours of trawling can be considered as very good performance with the limited freedom of operation due to biological sampling and fixing of stations without any consideration of fish abundance. The actual cost of the gear wil be between Rs. 70 to 75 thousand per net whereas for an imported gear it is more than double.

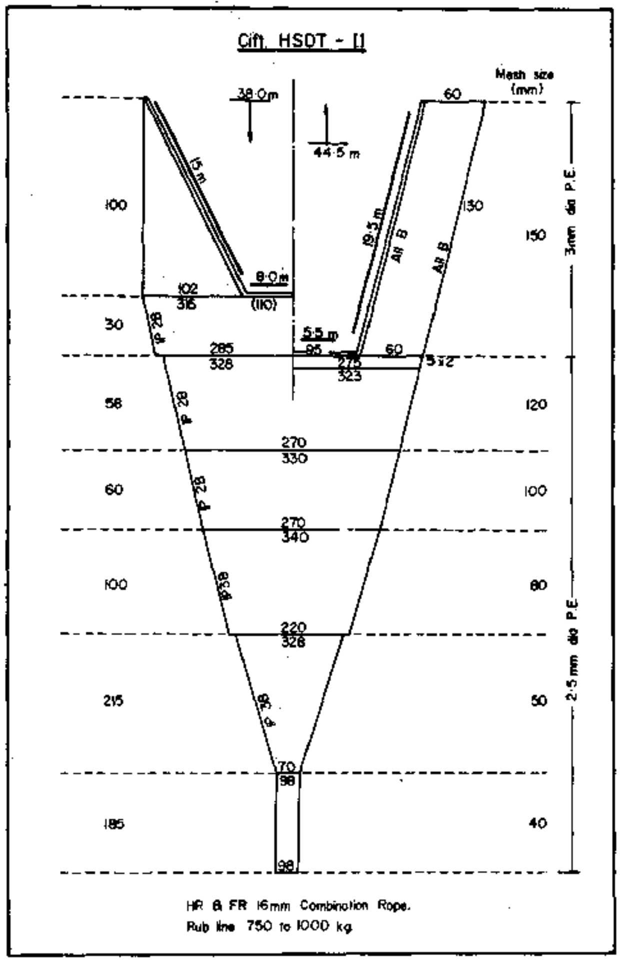

Fig. 3. Design of High Speed Demersal Trawl : Cift HSDT - II.

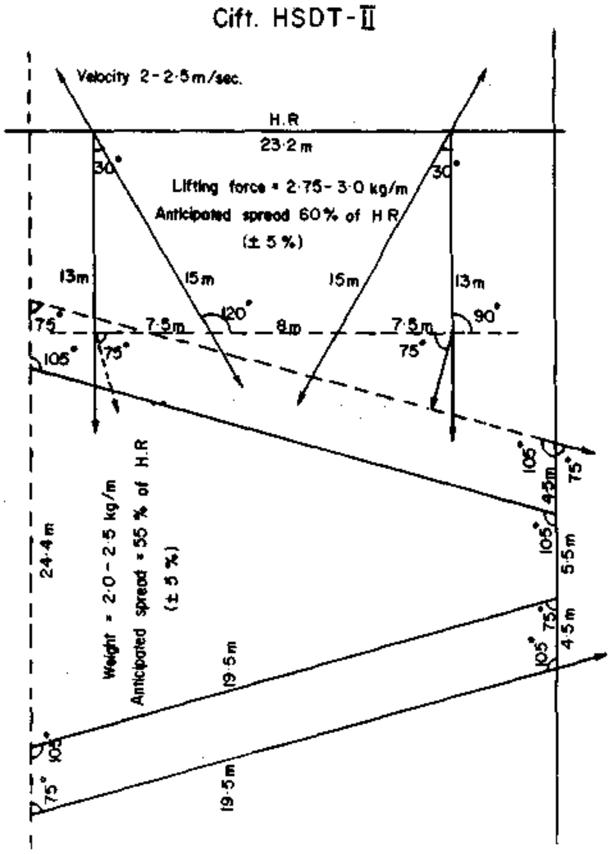

Fig. 4. Orientation of wings at the trawl mouth of Cift HSDT - II.

Cift Bobbin Trawl

Scientists responsible : **B. Meenakumari, M. R. Boopendranath & Pravin Puthran**

Earlier attempts of exploitation of the demersal resources of hard, uneven and rocky areas of Indian EEZ made by imported gear and expertise could not make any headway and most of the imported gear are lying still in the godowns of FSI, PFP and IFP either discarded or without being used. The same was the condtion of the Bobbin trawls imported along with FORV *Sagar Sampada*. However, the scientists of CIFT have designed a light bobbin trawl and rigged with imported rubber discs and bobbin spacers availiable with the erstwhile PFP as suitable bobbins were not available. The design details and foot rope assembly of Cift Bobbin Trawl are given in Figs. 9 - 12.

The gear was tested and put into operation from 15-12-1987 from FORV *Sagar Sampada* along the Wadge Bank area. The very first trial operation has landed 1 tonne of rock cod (*Epinephelus* sp.) in one hour of trawling. The second haul, again of one hour duration landed 0.75 t of rock cod and the susbsequent catches ranged between 0.2 and 0.5 t/hr. The maximum catch of 1.7 t in one hour haul was recorded on 29-5-1988 consisting of 80% of *Priacanthus* sp. It is proposed to have intensive and extensive trial fishing and pre-commercial feasibility studies after rigging the gear with bobbins of our specification imported under Danish aid along Andaman and Wadge Bank areas. The foot rope assembly of the Cift Bobbin Trawl is shown in Figs. 10 and 11.

Cift High Speed Multipurpose Hybrid Trawl for squid

Scientists responsible : **B. Meenakumari, M. R. Boopendranath, Pravin Puthran & T. M. Sivan**

The high Speed Multipurpose Hybrid Trawl for squid was originally designed for operation from 23/25 m shrimp trawlers for the exploitation of neritic squid and cuttle fish as a diversified fishing,

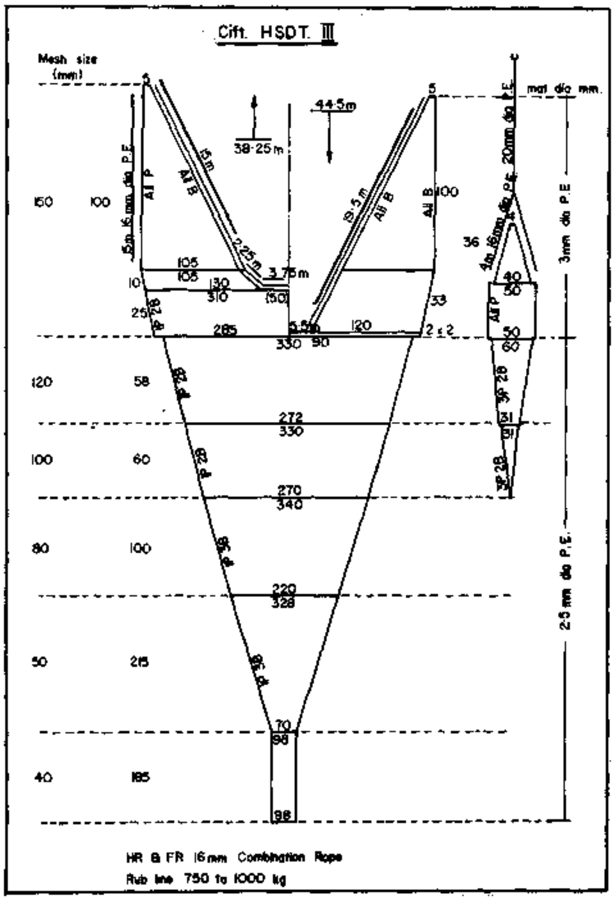

Fig. 5. Design of High Speed Demersal Trawl : Cift HSDT - III.

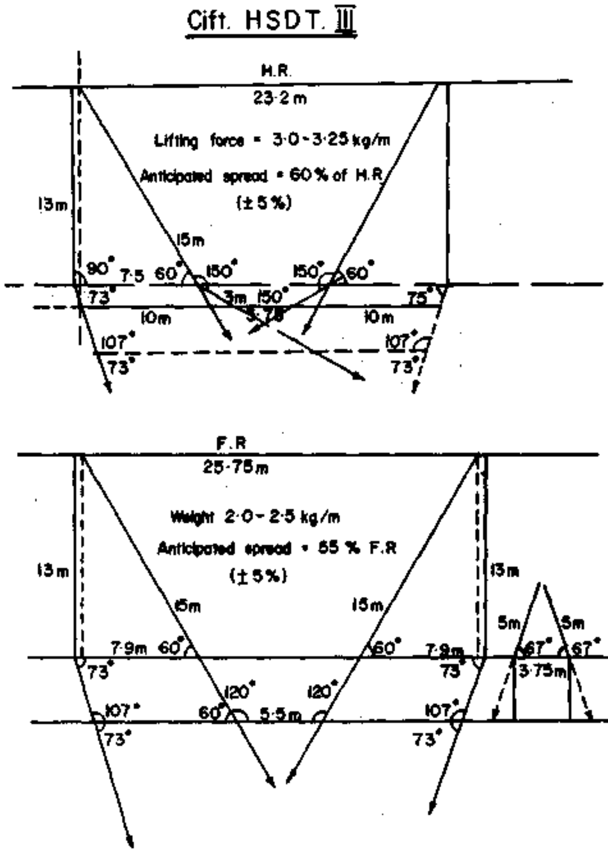

Fig. 6. Orientation of wings at the trawl mouth of Cift HSDT - III.

as demersal and pelagic/midwater trawl. The net is also suitable for operation as pair trawl and is being tested from medium class vessels at Veraval. This net was also tried from FORV *Sagar Sampada* as demersal trawl using rub line on 11-12-1987 along Wadge Bank area resulting in a catch rate of 0.25 - 0.5 t per

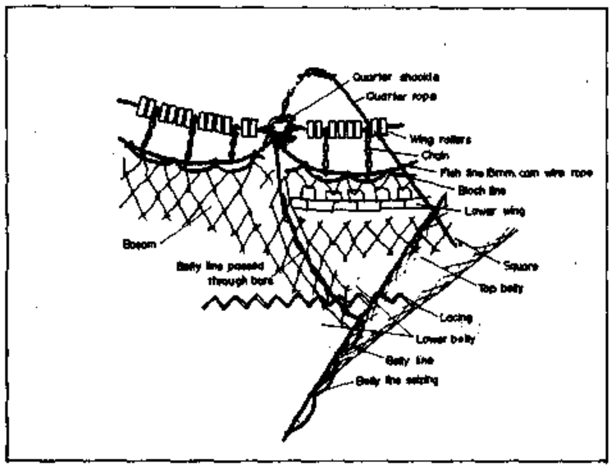

Fig. 7. Belly- line assembly of High Speed Demersal Trawls.

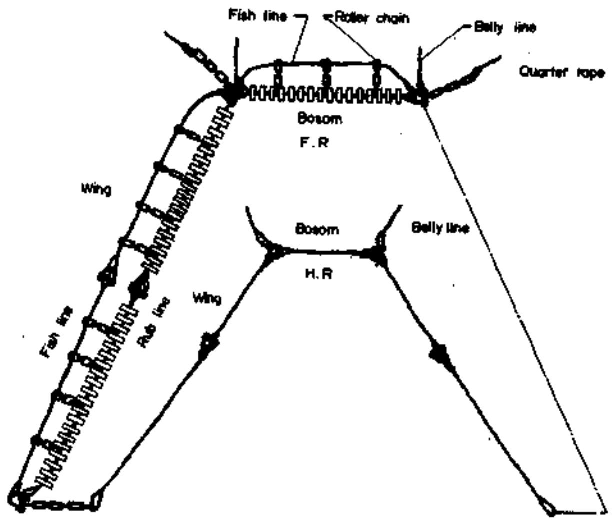

Fig. 8. Head and foot rope assembly of Cift High Speed Demersal Trawls.

Table 1. Summary of fishing performance of Cift HSDT series from FORV Sagar Sampada (24-6-1986 to 19-2-1988)

Gear	Details of fishing efforts				Details of fishing efforts utilised for biological sampling				Details of pre-commercial feasibility study				Remarks
	No. of hauls	Duration (hrs,mts)	Catch (t)	Catch per hour (t)	No. of hauls	Duration (hrs,mts)	Catch (t)	Catch per hour (t)	No. of hauls	Duration (hrs,mts)	Catch (t)	Catch per hour (t)	
Cift HSDT - I	57	50, 00	59.6	1.152	35	30, 00	4.57	0.119	22	20, 00	55.03	2.75	Record catch of 10 t/hr
Cift HSDT - II	40	39, 00	24.96	0.65	23	23, 00	3.15	0.146	17	16, 00	21.80	1.36	Record catch of 4 t/hr
Cift HSDT - III	60	42, 05	57.80	1.37	39	24, 20	4.17	0.171	21	17, 40	53.36	3.03	Record catch of 12 t/hr
Total of the series	157	131, 05	142.36	1.086	97	77, 20	11.89	0.153	60	53, 40	130.19	2.426	

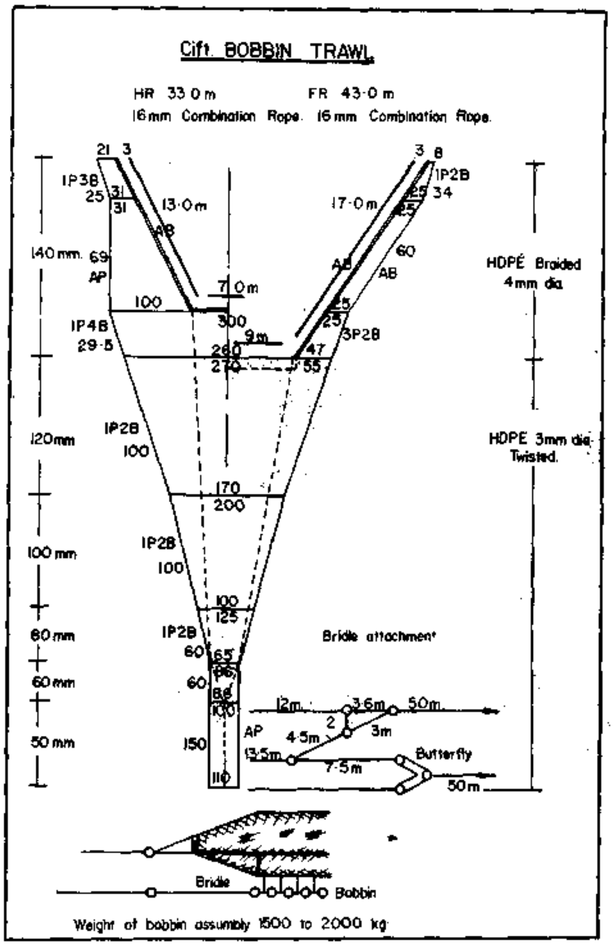

Fig. 9. Design of Cift Bobbin Trawl.

hour of rock cod and other perches. The poor catch was due to escape of fish. The design details of the modified gear is given in Fig. 13. It is proposed to operate the gear as both demersal and mid-water / pelagic trawl during day and night to study its efficiency as a squid trawl for Indian EEZ.

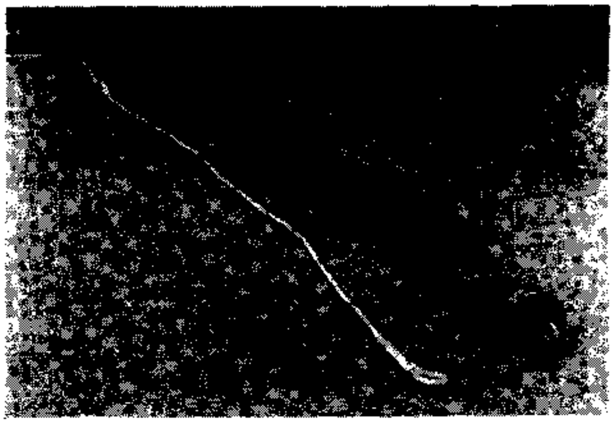

Fig. 10. Foot- rope assembly of Cift Bobbin Trawl.

Fig. 11. Foot- rope assembly Cift Bobbin Trawl - another view.

In additon to the above, the secientists of the Institue are engaged in developing two designs of rectangular demersal trawls which are likely to be tested during the last quarter of 1989.

Constraints

The concept of sharing facilities of oceanographic or biological research vessels for fishery technology reserach comprising of harvest and post harvest technology of fish has got its own inherent design constraints. They are usually jam packed with sophisticated oceanographic and biological equipments, facilities, laboratories *etc* . without much fishing facilities, fish hold capacity, proper fish handling and processing facilities and consequently not much fit for any fishing technology work. The work schedule of such research vessels are also conflicting in the sense that everything is pre-planned, whereas for a fishery technology work, the programmes cannot be preplanned and fixing of priorities starts from survey and identification of resource. Hence most of the time is wasted, as many of the stations happen to be either non-productive or not suitable for fishing.

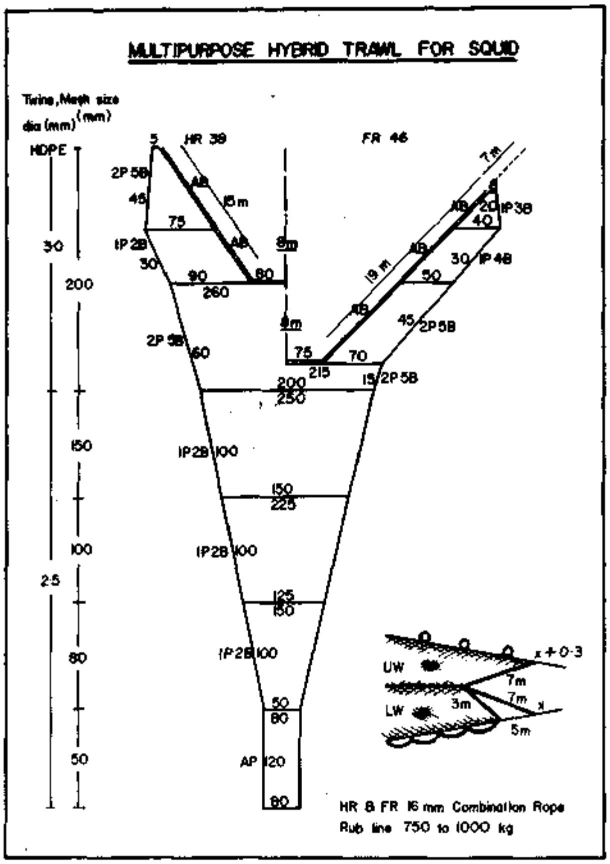

Fig. 13. Design of Cift Multipurpose Hybrid Trawl for squid fishing.

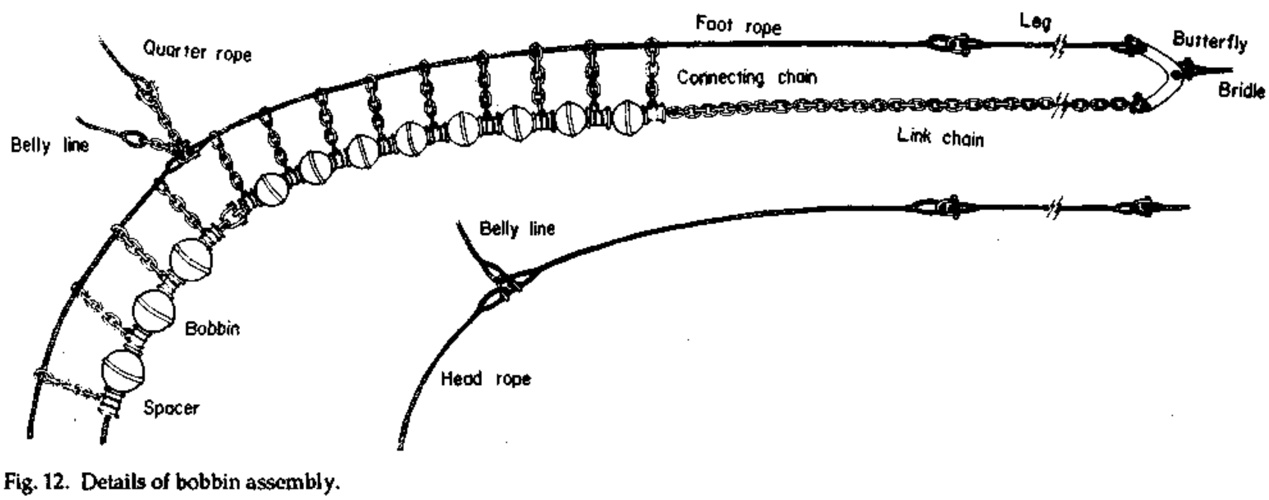

Fig. 12. Details of bobbin assembly.

As in the case of a biological or oceanographic vessel, a fishery technology vessel cannot have all the fishing techniques in one package and such a vessel will end up with overloaded compromise combinations. Hence an ideal fishery technology research vessel can be much less sophisticated than a biological or oceanographic vessel with R&D facilities for two or maximum three main fishing techniques incorporated according to priority on a commercial outfit style. Taking into consideration of our priority sector the FTRV should have facilities for trawling both pelagic and demersal combined with long lining and squid jigging with sufficient laboratory, fish handling and processing facilities and refrigeration and hold capacity.

The most important constraint that could be avoided is the customs bonding of the material. This has created problems in replenishing the fishing gear as the materials cannot be taken out from the vessel for the fabrication of the gear, which is not possible to carry out in the vessel for want of space and time. This constriant can be remedied by exempting the items required for gear fabrication from customs duty payments.

The unutilized aquarium space and sparsely used dry fish lab, if converted into processing facilities can go a long way in making FORV *Sagar Sampada* better suited for fish technology work also. The present dry fish lab could be accommodated in the sparsely used Carbon 14 lab or in the hydrography lab.

Alternate exclusive fishing technology cruises can speed up the R&D programme on harvest and post harvest technology of fish to cope with the immediate requirement of exploitation and utilization of the deep sea fishery resources of the EEZ.

Absence of properly trained technical personnel to handle and maintain acoustic and other electronic equipments and computers have resulted in malfunctioning and even breakdown of such equipments frequently.

Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5-7 *June*, 1989 : 435 - 439 (1990)

DEVELOPMENT OF MID WATER TRAWLS

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Abstract

Equal and unequal panel mid water trawls of 46.4 m head rope length were tested from FORV *Sagar Sampada*. Performance of the gear system under various rigging and operational conditions was monitored with acoustic and elctro-mechanical equipments. Increased sweep length had positive effect on the vertical opening, constraints for operation of mid water trawls and suggestions for remedying the same are also discussed.

Introduction

Great progress has taken place in the development of one boat mid water trawl during the last two decades. Basically, true mid water trawls are of fourseam pattern, having equal or unequal panels, the cross section of the mouth being square or rectangular. Mid water trawling as a fishing method can be used as circumstances demand (Brandt, 1979) and is supposed to fill the gap between the working range of conventional near surface and bottom fishing gear for exploiting the known fish stocks and opening up the so far untapped resources (Scharfe, 1964). The latter is also of the view that a mid water trawl of a rectangular cross section caught more fish than pair trawlers operated during rough weather conditions. Nakamura (1971) suggests that a high opening can be obtained by sacrificing, to some extent, the opening width of the net and for this purpose, trawl nets with side panels almost equal to that of upper and lower panels are mainly used in mid water trawls.

Eventhough mid water trawling has been successfully carried out as a viable fishing method elsewhere, the technique has not been systematically developed in India. Perumal (1966) Sivan *et al.* (1970), Kartha and Sadanandan (1973), Mhalathkar *et al.* (1975, 1983) have made experimental attempts from small and medium class of vessels in Indian waters.

Mid water trawling from larger vessels was carried out in the southwest coast (Varghese, 1975) and in the northwest coast (Dwivedi *et al.*, 1977).

With a view to standardising the various parameters of mid water trawl, three trawls with square and rectangular cross sections of the mouth were designed and tested from FORV *Sagar Sampada*. This communication deals with the results obtained and constraints experienced.

Material and Methods

It is generally accepted that the net mouth, the nature and thickness of material used as well as the towing speed influence the efficiency of mid water trawl gear.

Three nets of 46.40 m head rope length, one having four equal panels (square mid water trawl - SMT) and two rectangular trawls with 80 and 60 per cent side panels (RMT 8 & RMT 6) were designed to assess their efficiency using different sweeps, lengths (50.0, 75.0 and 100.0 m) and towing speed (3.5, 4.0 and 4.5 knots). The design details of all the three nets are given in Fig. 1 (a, b,c). Twenty three numbers of 200 mm fibreglass floats were attached to the head rope. Iron chains weighing 200 kg were fastened to the foot rope. In addition to the above, bunched chain depressors of 175 kg each were attached to the distal end of the legs of foot rope to keep the mouth of the net open.

Lindholmen type K-230, pelagic otter boards of circular spherical shape (750 kg each) having high values of hydrodynamic lift and drag coefficients (Fridman, 1979) were used. Net sonde was operated for measuring vertical opening and position of the gear in relation to depth of operation. Horizontal opening between the otter boards was estimated using the method suggested by Ben-Yami (1959) and Deshpande (1960). The total tension offered was noted from the load cell readings in the trawl bridge panel.

Results and Discussion

46.40 m SMT, RMT-8 and RMT-6 nets were operated during the course of different cruises to study the effect of speed and sweep length on vertical/horizontal opening and towing tension. In the

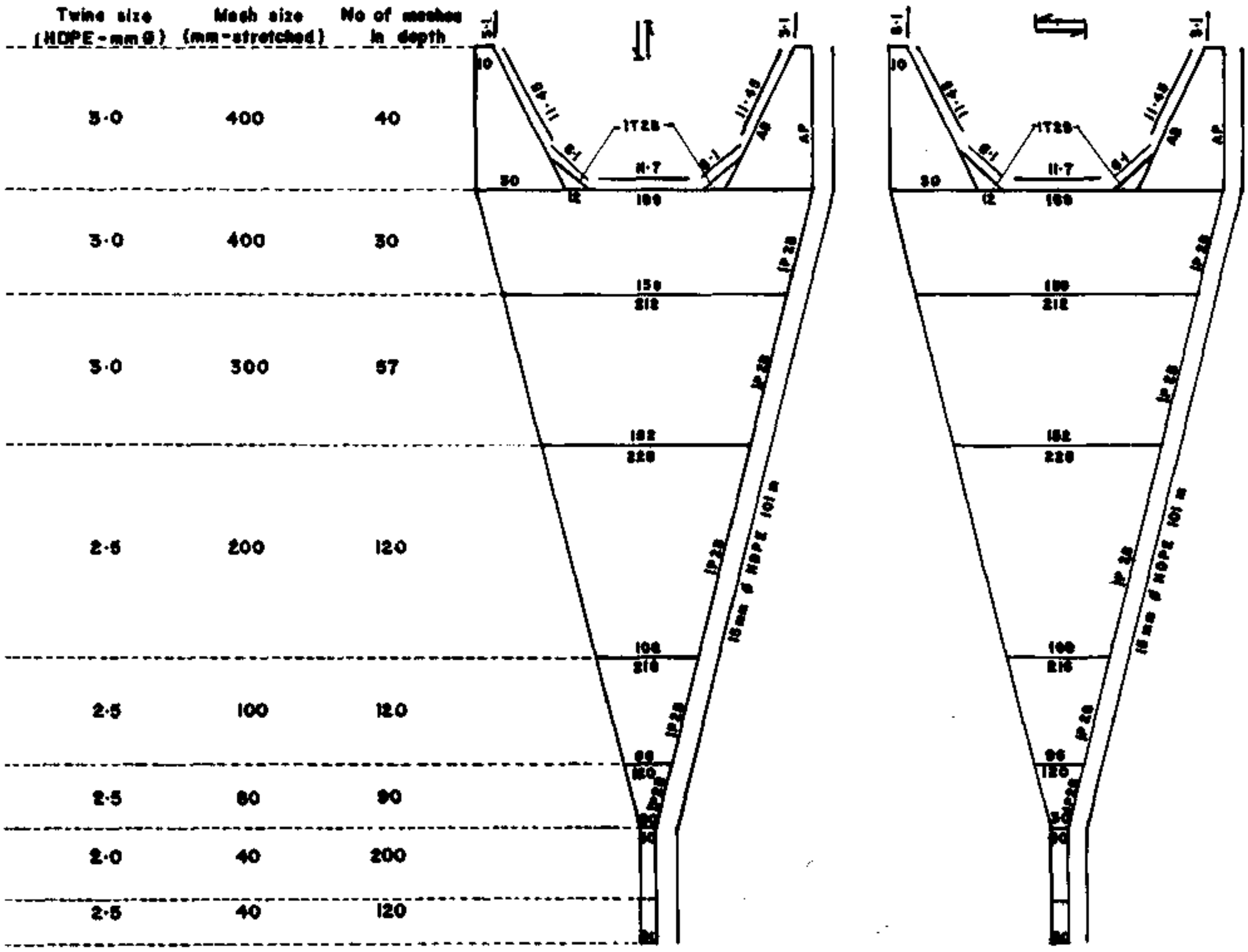

Fig.1(a). 46.4 m SMT Net. HR & FR - 18 mm ø combination rope. Mounting line for side -25 mm ø HDPE. Balche line - 12 mm ø HDPE.

case of equal panel net, higher vertical opening could be obtained in comparison to other unequal panel nets. Since, valid data on all the parameters could be collected in respect of RMT-8 only, the same are discussed. The data on the total tension, vertical and horizontal opening are furnished in Table 1.

It was observed that the tension increased with increase in towing speed and that change in sweep length had no significant effect on tension. A relationship on towing speed and tension was worked out and the correlation coefficient between the two was obtained as,

$$r = +0.8112$$

which is highly significant at 1% level. Hence a general formula was arrived at,

$$Y = 2.233\,x - 1.765$$

where Y is total tension in tonnes and X towing speed in knots.

Significant variation in respect of vertical opening was obtained at three towing speeds using sweeps of varying length. It is evident that the vertical opening increases with increase in sweep length whereas it decreases with increase in speed (Table 1). This is in conformity with the observations of Parrish (1959), Scharfe (1964) and Steinberg (1971). The values of towing speed and vertical opening were analysed statistically and the correlation coefficient is found to be, -0.6223 which is highly significant at 1% level. Based on this an equation of the form,

$$Y = -2.833X + 21.35$$

could be arrived at where Y is vertical opening in metres and X towing speed in knots.

46·4m. RMT-8

Twine size (HDPE – mm ø)	Mesh size (mm – stretched)	No. of meshes in depth
3·0	400	40
3·0	400	30
3·0	300	57
2·5	200	120
2·5	100	120
2·5	80	90
2·0	40	200
2·5	40	120

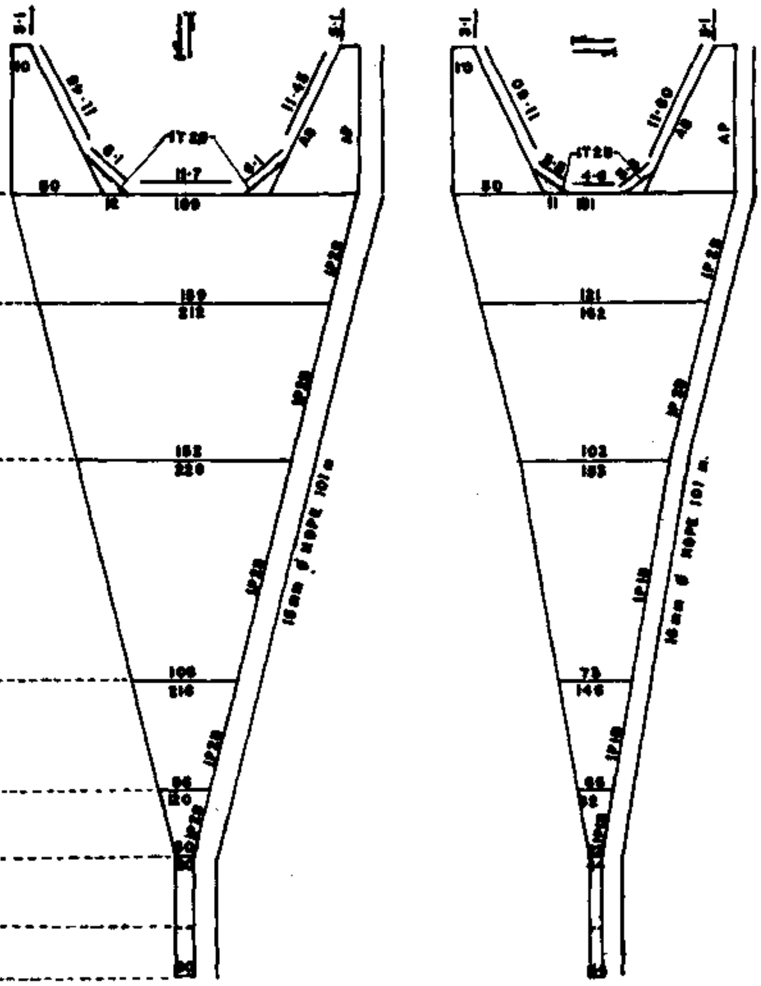

Fig.1(b). 46.4 RMT- 6 Net. HR & FR - 18 mm ø combination rope. Mounting line for side - 16 mm ø HDPE .Balche line - 12 mm ø HDPE.

Horizontal opening increases with increase in towing speed (Table 1). Similar observations were also made by Baranov (1969). According to him, fishing spread of a trawl depends on its drag and length of sweep. The correlation coefficient, based on the above parameters, was worked out as +0.7070 which is highly significant at 1% level. A general formula was evolved,

$$Y = 9.7833X + 14.6720$$

where Y = horizontal opening in metres and X = towing speed in knots. The performance of the net was highly satisfactory as far as measured values and type of fishes caught were concerned (Table 2).

Constraints

Mid water trawling has not been very successful in terms of catch, the reason for this state of affairs has to be discussed. As a standard arrangement, fisheries research vessels are equipped with sonar and trawl eye for detection of fish and monitoring of the gear during fishing. Mid water trawling being an aimed fishing method, success cannot be achieved without proper functioning of these equipments. Observations of MT *Muraena* (Dwivedi *et al.*, 1977) and MV *Bluefin* (Varghese, 1975) showed that fish detecting devices onboard were helpful in conducting mid water trawling successfully, whereas in FORV *Sagar Sampada*, the functioning of these equipments were none to poor. The infrastructure available at present for the routine maintenance of these equipments is not upto expectation. This state of affairs, if allowed to continue, will adversely affect mid water trawling from FORV *Sagar Sampada*.

Certain stray success in terms of catches with mid water trawling has been attained in shelf waters

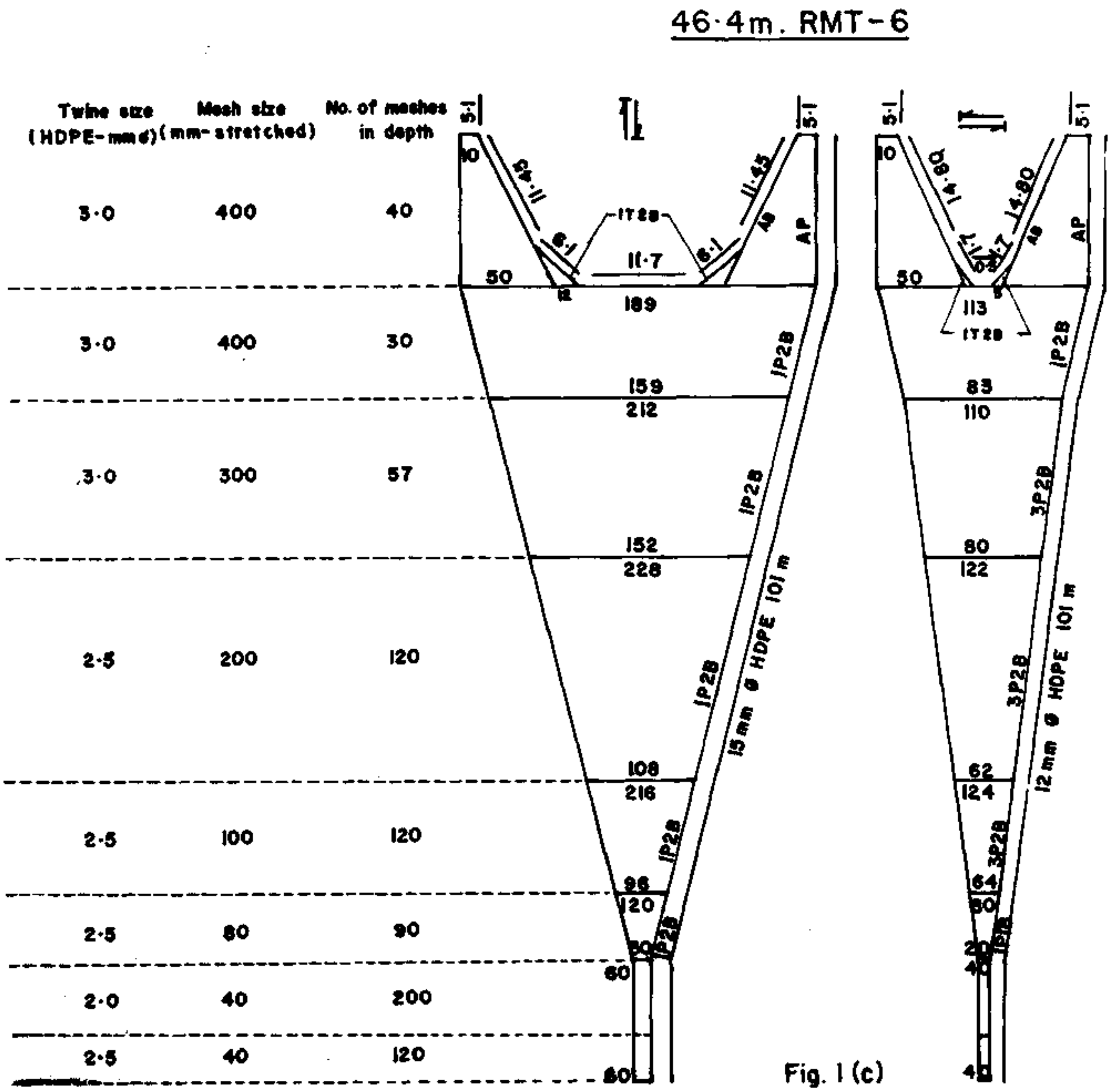

Fig.1(c). 46.4 RMT- 6 Net. HR & FR - 18 mm ø combination rope. Mounting line for side -16 mm ø HDPE. Balche line - 12 mm ø HDPE.

(Table 2), having dense fish concentration (Diu head) without operating net-sonde but this cannot be taken as a standard practice in view of the existing mid water trawling techniques.

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TABLE 1. *Operational parameters of RMT - 8*

Length of sweep (m)	Towing speed (knots)	Total towing tension (tonnes)	Vertical opening (m)	Horizontal opening (m)	Position of head rope below surface (m)
50.00	3.5	6.0	12.0	52.5	74.0
	4.0	7.0	9.0	56.0	63.0
	4.5	7.0	8.0	59.5	53.5
	3.5	6.0	9.0	43.5	54.0
	4.0	7.0	8.8	46.5	40.0
	4.5	8.0	8.0	58.5	19.2
	4.5	8.0	8.0	55.5	29.0
75.00	3.5	6.0	9.0	49.0	38.3
	4.0	8.0	8.5	57.0	23.0-20.0
	3.5	5.0	14.0	43.0	58.0
	4.0	6.0	12.0	50.5	30.2
	4.5	8.4	8.0	55.5	14.0
100.0	3.5	6.4	14.0	48.0	45.0
	4.0	7.0	11.0	53.0	23.0
	4.5	9.0	9.5	58.5	16.0
	4.0	7.0	12.0	59.5	56.6
	45.5	9.0	9.5	63.0	34.0
	3.5	7.0	11.0	55.5	38.0
	4.0	8.0	10.0	58.5	30.0

TABLE 2. *Catch details of successful operations*

Cruise No.	No. of hauls	Position of head rope below the surface (m)	Catch (kg)	Composition
25	8	25-54	95.4	myctophids, *Cubiceps*, squids, barracudas & crabs
26	3	26-30	140.0	*Leiognathus*, *Priacanthus*, *Nemipterus*, barracudas
37	2	not known	647.4	*Nemipterus*, *Epinephelus*, squids, *Trichiurus*, pomfrets, horse mackerel, myctophid, *Cubiceps*, tuna
39 (a) and 39	2	35	11.0	horse mackerel, mackerel, squids
43	1	38	25.0	sharks
51	1	not known	29.0	seer fishes, rays, moonfish, upenoids

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PROXIMATE CHEMICAL COMPOSITION AND OCCURRENCE OF SOME PATHOGENIC BACTERIA IN FROZEN FISH FROM UPPER EAST COAST OF INDIA

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ABSTRACT

Some studies on bacteriology and proximate chemical composition were carried out on the frozen fish and shell fish samples brought from 27th cruise of FORV *Sagar Sampada*. Out of 21 samples screened for bacteriological studies, 17 samples have shown the presence of enterobacters, 12 samples contained *Pseudomonas* and *Proteus* was found in two samples. *Salmonella* and *Shigella* were absent in these Samples.

The edible muscle of frozen and thawed samples was analysed for moisture, protein, fat, ash and nutritive minerals like calcium, phosphorous and iron. The total protein content of the muscle of different fishes studied varied from 16.25 to 20.88 per cent on wet weight basis. The fat content is found to be more in deep sea fishes namely black ruff (6.074 per cent) and *Psenes* (3.796 per cent) than in other common varieties of inshore fishes analysed.

INTRODUCTION

Since long time, a fishery fleet of Exploratory Fisheries Project (1983) presently known as Fishery Survey of India, has been surveying the fisheries resources of the east coast in offshore as well as deep sea waters. The research vessels of National Institute of Oceanography also have been surveying for fish and other marine resources in the region of Bay of Bengal. Recently as a part of exploratory survey of Bay of Bengal along the east coast of India, the FORV *Sagar Sampada* of Department of Ocean Development, Government of India, is also conducting some fishing operations. Earlier, Imam Khasim *et al.* (1987) have done proximate composition analysis of some deep sea varieties of fishes caught in Bay of Bengal off Andhra Pradesh coast by FSI vessel. Kureishy *et al.* (1983) had analysed some trace metals in fishes and zooplankton from the Andaman Sea. As such, much information is not available on the bacteriology and biochemical composition of the fishes available in the waters of Bay of Bengal. During the 27th cruise of FORV *Sagar Sampada*, some fishing operations both pelagic and bottom trawling were conducted and from seven different stations about 17 varieties of fish and shell fish samples were collected and in this paper, the qualitative bacterial flora, biochemical proximate composition and some nutritive mineral elements viz., Ca, P and Fe of the fish samples are reported which may serve as a useful reference data for fish processing technologists and the consumers.

MATERIALS AND METHODS

Seventeen varieties of some common and deep sea fish and shell fish (as per the list given in Table 1) were collected off upper east coast in the Bay of Bengal from seven stations lying in the area between latitudes 18°30' and 20° 30' and longitudes 85° 13' and 88° 50' during the 27th cruise of FORV *Sagar Sampada*. Immediately after the catch, the fish were packed in polythene bags and were frozen onboard the vessel in the cold storage at —20°C. These frozen samples were brought to the laboratory in an insulated box along with ice and were again stored in deep freezer at —20°C. For analysis, the fish samples were taken from the deep freezer and thawed in closed polythene bag. These samples were washed with water and edible muscle was taken for further chemical analysis.

Bacteriological methods : Twenty one samples of fish and shell fish were screened for pathogenic and spoilage bacteria. The edible muscle was taken in sterile condition for analysis. Since the samples were kept in frozen condition prior to testing, to facilitate injured organisms to recover, the samples were inoculated into lactose broth in 1 : 10 ratio which served as non-selective or pre-enrichment broth. (North, 1961). For testing Coliforms, U.S. Pharmacopoeia method was used (USFDA, 1984). USFDA (1972) method was followed for screening of *Salmonella* and *Shigella*.

Isolates were picked up from selective and non-selective media, purified and characterised. Pre-enrichment broth, selective broths and media used in this study were of Difco make. Proximate composition analysis for moisture, total protein, fat and ash contents were analysed following AOAC (1975) methods . Calcium was done from the ash content following AOAC (1965) methods. Phosphorous was determined from the ash content using Fiske and Subbarao method (1925). Iron estimation was also done from the ash content following AOAC (1970) method.

Results and Discussion

In the Table 1, the proximate composition showing moisture, total protein, fat, ash content and some of the nutrient elements like calcium, phosphorous and iron contents of the fishes analysed are given. The protein content of the fishes ranged from a minimum of 16.25% to a maximum of 20.80%. From the table it appears that the protein content is as same as or more both in quality table-fish and shell fish such as pomfret, mackerel, prawn as well as in low cost fishes such as *Psenes*, threadfin bream, silver bellies and others. The fat content was within 2% in almost all fishes but conspicuously in the deep sea varieties viz., *Psenes indicus* and *Centrolophus niger* (black ruff). The fat content was high, 3.79 and 6.074% respectively which is in full agreement with earlier analysis of these varieties by Imam Khasim *et al.*, (1987). Ash content was normal in all the fishes. Calcium and phosphorus were present in good required amounts in most of the fishes whereas the values of iron content were found to be low. This might be mainly due to the leaching of blood contents from the flesh, along with the driploss,during thawing of the frozen samples. It is to be remembered that the above analysis pertains to the edible muscle of fishes which were frozen and then thawed but not as such fresh i.e. raw fishes.

Bacteriological analysis

Based on morphological and biochemical characters, all the isolates were divided into three

TABLE 1. *Proximate chemical composition of fish/shell fish smples (on wet weight basis)*

Station No.	Fish %	Moisture %	Protein %	Fat %	Ash %	Calcium mg/100g	Iron mg/ 100g	Inorganic phosphate mg/100g
930	Black ruff (*Centrolopohus niger*)	75.00	17.25	6.074	1.3325	78.52	2.89	911.10
934	Mackerel (*Rastrelliger kanagurta*)	76.15	17.50	1.239	2.459	114.08	5.49	753.44
934	Indian drift fish (*Psenes indicus*)	74.60	18.80	2.694	2.219	276.37	1.295	614.22
934	Synagris (*Synagris* sp.)	77.60	17.375	0.5354	1.5321	39.27	4.10	177.68
935	Indian white prawn (*Penaeus indicus*)	76.80	17.50	0.58	1.4639	257.728	0.80	644.48
935	Japanese threadfin bream (*Nemipterus japonicus*)	74.90	18.125	0.7655	3.1299	195.37	1.566	1131.87
935	Banded barracuda (*Sphyraena jello*)	75.90	18.50	0.755	2.536	406.47	2.50	747.42
936	Indian drift fish (*Psenes indicus*)	72.00	20.275	3.796	2.002	128.40	1.713	936.95
939	Caranx (*Caranx* sp.)	76.40	17.625	1.173	2.834	160.10	5.20	812.75
944	Prawn (*Metapenaeus monoceros*)	77.40	20.00	0.739	2.109	279.42	2.03	639.56
944	Silver belly (*Leiognathus bindus*)	74.70	18.75	0.881	1.971	273.67	0.996	743.71
944	Coastal mud prawn (*Solenocera crassicornis*)	76.58	20.50	0.63	1.379	256.89	2.80	578.18
944	Ribbon fish (*Trichiurus haumela*)	78.10	18.00	0.567	1.401	169.64	1.143	650.80
944	Yellow goat fish (*Upeneus sulphureus*)	74.80	19.46	2.796	1.172	223.17	1.366	600.86
944	Ilisha (*Ilisha filigera*)	77.65	18.125	1.266	1.223	167.20	1.03	427.80
946	White pomfret (*Stromateus chinensis*)	78.10	16.25	0.596	1.513	199.60	2.006	625.48
946	Snappers (*Lutjanus* sp.)	73.00	20.88	1.405	1.872	152.48	0.691	1086.49
946	Japanese threadfin bream (*Nemipterus japonicus*)	75.50	19.125	2.425	2.376	186.34	1.60	659.99
946	Yellow goat fish (*Upeneus sulphureus*)	75.60	18.50	2.667	2.852	467.19	1.774	760.85

groups. The source for first group of isolates is Mac Conkey agar. The indole, methyl-red, Voges-proskauer and citrate utilisation results (IMViC), in sequence of two negatives and two positives, and other biochemical characters indicates the first group of isolates are typical *Enterobacter aerogenes* (Table 2) as described by Morris Fishbein *et al.* (Morris Fishbein *et al.*, 1976). There is need for identifying the source of enterobacters. The reason is that enterbacter genera are described as coliforms because of their certain common properties with *E. coli*. Besides, they are found in a variety of habitats. (Hayes, 1985).

This study shows occurrence of enterobacters which are freeze resistant. Raj and Liston (1961) have reported the effect of freezing enterobacters and pointed out the variability of strain to strain. Survival of this bacteria sometimes for longer periods at freezing temperatures was reported by Lamprecht

TABLE 2. *Characterisation of th isolates*

Morphology	I	II	III
	rods	rods	rods
Motility	+	+	+
Gram staining	-	-	-
Oxidase	-	+	-
Indole	-	-	+
Methyl red	-	-	+
Voges - Proskauer	+	-	-
Citrate utilization	+	+	+
Urea broth	-	-	R
Urea slant	-	-	R
On triple sugar iron			
1. Slant	A	NC	A
2. Butt	Ag	NC	Ag
3. H_2S production	-	-	+
On Friewer shaughnessy medium			
1. Motility	-	+	+
2. Fermentation	Ag	NC	NC
3. H_2S	-	-	+
Dextrose	Ag	NC	Ag
Lactose	Ag	NC	NC
Mannitol	Ag	NC	NC
Salicin	Ag	NC	Ag
Growth in K. C. N. broth	+	+	+

-	No reaction	NC	No change
+	Reaction positive	A	Acid
R	Red	Ag	Acid gas

and Elliott (1971). The actual quality of fish landed at ports is dependent upon the time it has been held in ice and hygienic conditions onboard fishing vessels (Hayes, 1985). The initial reduction in numbers of bacteria immediately after freezing can range from only one or two per cent to ninety per cent (Shewan, 1961; Simmonds and Lamprecht, 1980).

The second group of isolates have their origin from MacConkey agar as well *Salmonella* and *Shigella* agar (S.S. agar) (Table 3). Out of 21 samples of fish and shell fish tested, 12 samples have shown the presence of this group of isolates. These isolates were further tested on pigment enhancing media. Five isolates have produced blue water soluble pigment on medium - A and the rest seven isolates have produced water soluble, fluorescent yellow pigment (Table 3). These pigment producing *Pseudomonas* isolates come under *Pseudomonas aeruginosa* (Pyocyaenea) (King *et al.*, 1954).

Presence of indigenous flora composed of *Pseudomonas* in fishing vessels was reported by Shewan (1961). *Pseudomonas* is absent in all shell fish samples. Enterobacters were isolated from all the samples excepting *Synagris* spp., prawns (*Metapenaeaus monoceros*), ribbon fish and white pomfrets (Table 3).

The third group of isolates has the source Bismuth Sulphite agar. Use of TSI agar has helped in identification of these isolates as *Proteus vulgaris* (AOAC, 1975). Presence of *Proteus* in frozen foods is unwanted as it can spoil the fish when they are at ambient temperatures (Hayes, 1985).

Presence of *Pseudomonas* and *Proteus* could be attributed to a degree of protection afforded by greater numbers in initial stages. Clumping of cells could be another possibility. The occurrence of *Pseudomonas* shows their ability to compete with coliforms.

The important points to be observed in the study are that the fish and shell fish samples were screened for pathogenic and spoilage bacteria immediately after bringing the samples to the laboratory. Although, the samples were brought in frozen condition they were not stored for longer time in the same condition. Assessment of these bacteria is qualitative in nature, but not quantitative. *Salmonella* and *Shigella* are absent in these samples.

There is need for further studies to know the qualitative nature of spoilage and pathogenic bacteria in fresh and processed sea-foods in this area.

TABLE 3. *Occurrence of spoilage bacteria in fish samples*

Stn.No.	Name of the fish	*Pseudomonas*	*Enterobacter aerogenes*	*Proteus vulgaris*
930	Black ruff	Blue pigment	+	-
934	Mackerel	Blue	+	+
934	Oil sardine	-	+	-
934	Indian drift fish	Yellow	+	-
934	*Synagris* sp.	Blue	-	-
935	Indian white prawn	-	-	-
935	Japanese threadfin bream	Yellow	+	-
935	Banded barracuda	Yellow	+	-
936	Black ruff	Yellow	+	-
936	Indian drift fish	Blue	+	-
939	*Caranx* sp.	-	+	-
944	Prawns (*Metapenaeus monoceros*)	-	-	-
944	Silver bellies	-	+	-
"	Coastal mud prawns	-	+	-
"	Ribbon fish	Blue	-	-
"	Yellow goat fish	-	+	-
"	Ilisha	-	+	-
946	White pomfrets	-	-	+
"	Sciaenids	Yellow	+	-
"	Japanese threadfin bream	Yellow	+	-
"	Yellow goat fish	Yellow	+	-

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HEAVY METALS IN FISH FROM UPPER EAST COAST OF INDIA

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Abstract

Nineteen samples belonging to seventeen varieties of fish/shell fish collected during the twenty seventh cruise of FORV *Sagar Sampada* from the area lying between latitude 18°13' and 20° 30' and longitude 85° 13' and 88°50'E of Bay of Bengal off east coast of India were analysed for mercury, cadmium, copper, nickel and lead. Mercury was present in negligibly small quantities in all the samples. None of the samples contained more than 1 ppm of cadmium. Two samples of prawn contained concentrations of more than 5 ppm of copper. Nickel was present in concentrations of less than 3 ppm in all the samples. Barracuda and yelow goat fish samples were found to contain 6.9 and 5.48ppm of lead respectively while none of the other samples contained the metal in concentrations greater than 5 ppm. These results have been discussed in relation to hazardous levels for man.

Introduction

Analysis for trace metals particularly toxic heavy metals such as Hg, Pb, Cd, Ni, and Cu is also very important from a public health point of view. Information on the concentration levels of these heavy metals in marine fish on the east coast is very meagre. So this paper gives levels of some toxic heavy metals in some varieties of fishes, caught in the 27th cruise of *Sagar Sampada*, which may serve as a baseline information and will be useful to concerned research workers as well as the consumer.

Materials and Methods

Fish/shell-fish samples were collected from the FORV *Sagar Sampada* during its cruise in the area lying between latitude 18°13' and 20° 30'N and longitude 85° 13' and 88°50'E on the east coast during the period from 22.1.'87 and 29.1.'87. Samples of fish/shell fish were collected from pelagic trawl at stations 930, 934, 935, 936 and 939 while at stations 944 and 946, samples were obtained from bottom trawl. Immediately after collection, samples were kept in cold storage (-20°C) and on reaching the laboratory, extraction was carried out with edible meat from different samples according to wet digestion method of AOAC (1975). The extracts were analysed for lead, cadmium, copper and nickel using Atomic Absorption Spectrophotometer GBC Model 902 (Australia). Total mercury in the digested extracts was determined by cold vapour Atomic Absorption Spectrophotometer (Mercury Analyser-Model MA 5800A ECIL, India).

Results and Discussion

Results of analysis of fish/shell fish samples for copper, nickel, lead, cadmium and mercury are presented in Table 1.

Maximum level of Cu, 14.439 ppm was observed in the muscle of coastal mud prawn (*Solenocera crassicornis*) followed by 10.561 ppm in another variety of prawn *Metapenaeus monoceros*. The next highest value of 4.336 ppm was also encountered in another variety of prawn *Penaeus indicus*. Thus the three highest values of copper obtained in the present study were from prawns. The highest concentration of copper found in the muscle of fish was 3.119 ppm in *Nemipterus japonicus*. Eleven out of sixteen fish samples were found to contain copper at levels of less than 1 ppm. Kureishy (1981) reported maximum concentration of 3.25 ppm of copper in an unidentified deep sea prawn. The highest concentration recorded among fish was 2.93 ppm in the muscle of yellow fin tuna. In another study (Kureishy, 1985), a maximum value of 24 ppm and a minimum concentration of 3.5 ppm were reported in prawns from northern Indian Ocean. In fish, the values ranged from non-detectable level to 4.9 ppm. Copper is one of the metals categorised as a micro-nutrient and was reported to be toxic in quantities of 100 mg (McKee and Wolf, 1963). Considering the requirement of 30 g of fish meat for a balanced diet, the average daily intake of copper obtained in this study based on the level will be far below the hazardous level. An

TABLE 1. *Heavy metals in fish/shell fish*

Station	Species	Cu µg/g	Ni µg/g	Pb µg/g	Cd µg/g	Hg ng/g
930	Black ruff (*Centrolophus niger*)	0.393	0.8112	3.3	0.3643	1.5
934	Mackerel (*Rastrelliger kanagurta*)	0.748	0.3349	1.9833	0.9833	2
934	Indian oil sardine (*Sardinella longiceps*)	1.446	0.4684	1.046	0.2750	1
934	Indian drift fish (*Psenes indicus*)	0.303	0.864	0.928	BDL	0.5
934	Synagris (*Synagris* sp.)	0.206	0.462	2.19	BDL	1
935	landan white prawn (*Penaeus indicus*)	4.336	2.572	NA	0.6215	1
935	Banded barracuda (*Sphyraena jello*)	0.711	1.5907	6.9	0.559	6
935	Japanese thread fin-bream (*Nemipterus japonicus*)	3.119	1.3303	NA	0.3673	5
936	Black ruff (*Centrolophus niger*)	0.674	0.4114	3.478	0.1754	1.5
936	Indian drift fish (*Psenes indicus*)	0.571	0.1934	0.857	0.2393	16
939	*Caranx* sp.	2.961	2.672	NA	0.6965	10
944	Prawn (*Metapenaeus monoceros*)	10.561	0.447	1.966	0.1923	4
944	Silver belly (*Leiognathus bindus*)	0.58	0.5005	3.1	BDL	4
944	Coastal mud prawn (*Solenócera crassicornis*)	14.439	0.7950	4.3615	0.2118	2
944	Ilisha (*Ilish filigera*)	2.703	0.6255	1.4357	BDL	1
944	Ribbon fish (*Trichiurus haumela*)	0.513	0.372	3.002	BDL	1
944	Yellow goat fish (*Upeneus sulphureus*)	1.374	1.0484	5.480	0.1093	1
946	White promfret (*Stromateus chinensis*)	0.446	BDL	0.6946	BDL	20
946	Sciaenids	0.596	0.912	3.4	0.2715	4

NA : Not analysed, BDL: Below detectable level.

additional safeguard in the consumption of aquatic foods containing high levels of copper is the unpalatability of foods containing concentrations of even 5 to 7 ppm (Portmann, 1970).

Caranx sp. contained the highest concentration of 2.672 ppm of nickel followed by *Penaeus indicus* which contained 2.572 ppm. Next in the order were barracuda, which contained 1.5907 ppm and *N. Japonicus* containing 1.3303 ppm. All the remaining samples of fish/shell fish contained levels of less than 1 ppm Kureishy (1981) reported 0.2 ppm. in *N. japonicus*, non-detectable levels in mackerel and oil sardines and 0.22 ppm in barracuda. In a subsequent study Kureishy (1985) observed 0.1 to 0.3 ppm in barracuda and non-detectable levels in mackerel and fin fish. The toxicity of most nickel compounds to human does not appear to be great (Portmann, 1970). But nickel has been reported to possess carcinogenic properties in laboratory animals (Hueper).

Barracuda was found to contain 6.9 ppm lead and Yellow goat fish (*Upeneus sulphureus*) 5.480 ppm. Kureishy (1985) reported 1.6 ppm in prawns, mackerel, promfret and barracuda. Higher levels were reported in crabs, flying fish and sharks (1.0 to 7.88 ppm). Chronic lead poisoning to humans from contaminated food or water was reported to be common (Sollaman, 1949) though individual susceptibility varies greatly. Considering a provisional tolerable weekly intake of 3 mg of lead indicated by

WHO expert committee on food additives, 14.3 µg/g, becomes the critical level for lead concentration in fish muscle.

Highest concentration of 0.69 µg/g of cadmium in the present study was recorded in the muscle of *Caranx* sp. *P. indicus* was found to contain 0.62 µg/ g of cadmium. The values of cadmium found in fish / shell fish are in general agreement with those reported by Kureishy (1985). Considering the requirement of fish meat as 30 g per day in a balanced diet and the provisional weekly tolerable intake of cadmium as indicated by WHO/FAO expert committee (1972) , the critical concentration in seafood is required to be 2.4 µg/g. All the fish/ shell fish samples examined in the present study revealed concentrations of less than 1 µg/g of cadmium.

All the fish samples analysed contained very low values of total mercury ranging from 0.5 ng to 20 ng per g of wet tissue which are very much negligible when the tolerance limit of either 0.5 or 1.0 ppm of total mercury is considered. The results of mercury levels correlate well with the earlier results of Desai *et al.* (1975) and Ramamurthy (1979), who also reported very low levels of total mercury ranging from 5 ng to 93 ng on wet weight basis in different varieties of fish and shell fish from different coastal regions of India.

More comprehensive studies on the subject are indicated to get a better picture of the levels and types of heavy metal contamination of the sea foods from the seas around India especially Bay of Bengal.

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EDIBLE MEAT AND FISH MEAL FROM *PRIACANTHUS HAMRUR*: CHEMICAL COMPOSITION AND NUTRITIVE VALUE

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Abstract

Yield of edible meat from *Priacanthus hamrur* varied from 35 to 40% of the wet raw fish. Fish powders from *Priacanthus hamrur* had a balanced amino acid composition and were shown to have a high nutritional value using growth experiments on albino rats. Analysis of the meal prepared from the waste obtained during filleting of the fish showed that although the protein content of the meal conformed to grade 2 fish meal and the essential amino acids were present in required quantities, PER and NPU values of the meal were lower than those for control protein casein.

Introduction

Exploitation and utilization of different varieties of deep sea fish have attained great attention in many fishing nations. Presence of many new species has been detected in our Exclusive Economic Zone. Several attempts have been made to study their nutritional and toxicological properties so that they may be introduced to the local consumers (Gopakumar *et al.*, 1983; Mukundan and Devadasan, 1988 a, b; Lekshmy Nair *et al.*, 1988).

Priacanthids popularly known as 'Big eye' or 'Bulls eye' are reported to be common food fishes in South East Asian countries. In 1984 Thailand and Hongkong have landed about 33,000 tonnes of big eye from the South China Sea (Anon., 1983). It is available from 50 to 200 m depth with peak catch rates in 100-200 m depth along both the west and east coasts of India.

Methods of processing *Priacanthus* into frozen blocks, fillets, minced fish, canned fillets and salted and dried fish, and their marketability have been reported by Samuel *et al.* (1987). PER of the edible meat from the fish has been reported by Mukundan and Devadasan (1988b). Results of the studies on the proximate composition, amino acid profile and nutritive quality of *Priacanthus hamrur* and of meal prepared from filleting waste of the fish are presented below.

Material and Methods

P. hamrur caught during cruise Nos. 17, 18 and 23 of FORV *Sagar Sampada* of the Department of Ocean Development, Government of India during June-July, 1986 and October-November, 1986 from the southwest and central west coasts of India were used in these studies. The fish was washed and frozen immediately after catch onboard the vessel and stored at -18°C. At the end of the cruise, the fish was transferred to the laboratory and stored at -23°C for 2 weeks before further processing.

Separation of edible meat from the thawed fish was carried out according to Perigreen *et al.* (1979). The meat was minced well and dried at 45-50°C in a tunnel drier for 8 hrs, powdered and used for studies on the quality of uncooked meat.

The fish was cleaned, filleted and the fillets (skinless) were cooked in 0.5% acetic acid for 10 min, cooked liquor was drained off and the residue was dried at 45-50°C in a tunnel drier for 8 hrs and pulverised.

The total waste so obtained from filleting the fish was cooked under steam at 0.7 kg/sq. cm for 10 min, the stickwater was removed and the press cake was dried at 45-50°C in a tunnel drier. The stickwater was concentrated on a water bath and added back to the partially dried meal and the drying operation was completed.

Proximate composition of the products was determined according to AOAC (1975) procedure. The bacteriological quality was evaluated by APHA methods (1966).

Amino acid analysis of the products was performed by hydrolysis of the samples with 6 N hydrochloric acid at 110°C for 22 hr. The hydrolysed samples were then injected into a Technicon NC2P Auto Analyser equipped with a Spectraphysics Computing Intergrator for amino acid determination.

Biological evaluations were performed on albino rats as nitrogen balance and growth experiments following the method of Chapman *et al.* (1959). Casein was used as the standard reference Protein. The diet formulations comprised of 10% protein, 10% fat (refined groundnut oil, corrected for fat contribution from test protein sample), 1% cellulose, 4% USP salt mixture No. XIV (corrected for the contribution of ash from the test protein sample), 1% vitamin mixture (Hubbel *et al.*,1937) and com starch to make up to 100%. The rats were given food and water *adlibitum*. Six rats were used for each diet. At the end of 28 days, weight gain and food intake were recorded for individual animals and PER was calculated.

Net protein utilization (NPU) was determined following the method of Miller (NAS/NRC, 1963) using rats body N technique. Potato starch was used for the preparation of the non-protein diet. The level of protein in the diet was adjusted to 10% and 4 rats were used for each test diet.

Results and Discussion

Yield of picked meat from bulls eye collected during different periods in 1986 varied from 35 to 40% of the whole wet fish. Proximate composition of the products is presented in Table 1. The composition and calorific value of the fish is comparable to the values reported for marine fish (Mukundan and Devadasan, 1988 a, b). *Priacanthus* waste meal was an yellow powder, yield varying from 11.8 to 13.3% on the basis of whole wet fish. It may be seen from Table 1 that the meal conforms to grade 2 fish meal prescribed by the relevant specifications (IS: 4307, 1973). The black to brownish black unappealing colour associated with many deep sea fish meals (unpublished data) was absent in this case. Appearance of the meal was good.

The total plate count for the raw and cooked muscle powders and the meal was respectively 4.31×10^3, 6.59×10^2 and 8.44×10^2 organisms per g. *Escherichia coli*, faecal streptococci and coagulase positive staphylococci were absent. The products were bacteriologically safe.

The amino acid spectrum of the raw and cooked muscle powders and of the meal are shown in Table

Table 1. *Proximate composition of products from Bulls eye* (%)*

	Edible meat[a]	Cooked muscle powder[b]	Filleting waste meal[b]
Moisture	74.9	4.5	6.3
Ash	1.4	5.8	6.3
Protein	20.7	84.0	60.9
Carbohydrate	1.7		
Calorific value Kcal/100g	102.2		

*=Mean of three samples; a =On wet basis; b= On as is basis.

2. Values for essential amino acids of the references protein as advocated by FAO/WHO (1973) are also included for comparison. Glutamic acid was the major constituent of the amino acids followed by aspartic acid, lysine and leucine in the three products. The values for muscle powders compare well with those reported by Gopalan *et al.* (1980) and by Geiger and Borgstrom (1962) and for the meal with amino acid pattern of different types of fish meals (Windsor and Barlow, 1981). The three products had a balanced amino acid pattern.

Table 2. *Amino acid pattern of products from Bulls eye (g/100g of protein)*

Amino acid	FAO/WHO	Raw muscle powder	Cooked muscle powder	Meal
Aspartic acid		13.9	11.9	10.9
Threomine	4.0	5.4	4.6	4.5
Serine		4.2	6.5	4.1
Flutamic acid		19.7	17.0	16.8
Proline		4.2	3.4	4.0
Glycine		5.6	4.5	4.2
Alanine		7.3	6.7	6.9
Valine	5.0	6.1	5.6	6.0
Cystine	3.5	0.8	0.9	0.8
Methionine		3.0	3.1	3.0
Isoleucine	4.0	5.4	4.8	4.6
Leucine	7.0	8.4	7.9	7.8
Tyrosine	6.0	3.2	3.1	3.0
Phenylalanine		4.0	3.8	3.5
Histidine		6.5	3.4	5.1
Lysine	5.5	12.1	12.0	10.6
Arginine		2.2	2.4	2.4
Tryptophan	1.0	-	-	-
Total EAA	36.0	48.4	45.8	43.8
Total essential and non essential		112.0	101.6	98.6
Ratio : $\frac{\text{Essential}}{\text{Total}}$ %		43.0	45.1	44.6

The PER values are listed in Table 3. At the end of 28 day's feeding, the animals were observed to be in a healthy state. The uncooked bulls eye protein showed a higher PER value than the cooked protein and reference protein casein. The heating and leaching out of the soluble nutrients involved in the production of the cooked muscle powder must have reduced the availability of certain essential amino acids, thus lowering its PER value. However, PER of the cooked bulls eye protein is higher than that of casein. The PER value for dried edible portion of *P. harmur* has been reported by Mukundan and Devadasan (1988b) to be lower than that of non fat skim milk powder. PER data obtained in the present studies coincide with the amino acid values, thus confirming the high nutritional quality of bulls eye protein. Although the protein content of the meal conformed to grade 2 fish meal (IS: 4307 - 1973) and the amino acid profile showed required amounts of essential amino acids, the PER of the filleting waste meal was much lower than the value for casein. The imbalance of the essential amino acids of the residual waste may be the probable cause for this observation. The heat treatments used during the production of the meal would also result in a lowering of the nutritional quality. Since consumption of the various diets were similar with significant differences in net weight gain (Table 3), it may be concluded that there is a definite lowering in availability of some of the essential amino acids during processing of the cooked products.

Determination of net protein utilization of these products also supports the above observation. The values recorded for the raw and cooked meat powder and the meal were 80, 72 and 65 respectively.

Table 3. *Protein efficiency ratio of products from Bulls eye*

Protein source	Weight gain g/28 days	Protein intake g/28 days	True PER	Adj. Per
Raw muscle powder	78.06± 2.42	24.22± 0.90	3.20 0.12	2.8
Cooked muscle powder	74.30± 3.60	25.10± 0.50	2.99 0.08	2.6
Meal	58.50± 2.73	26.88 5.90	2.35± 0.14	2.1
Casein	76.32± 7.15	27.56± 2.12	2.77 0.13	2.5

Priacanthus hamrur, a deep sea fish from the west and east coasts of India is comparable to other tropical marine fishes in chemical and nutritional quality and can be used as a source of wholesome protein. Upgradation of the meal from filleting waste is necessary for its use in animal feeds.

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VALUE ADDED PRODUCTS FROM *CHLOROPHTHALMUS AGASSIZI* (GREEN EYE), AN UNEXPLOITED FISH FROM EXCLUSIVE ECONOMIC ZONE OF INDIA

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ABSTRACT

Texturised meat, wafers and soup powder prepared from *Chlorophthalmus agassizi* (Green eye), a hitherto unexploited fish from the west coast of India had appealing appearance and good functional properties. Organoleptic rating of the products was good. More detailed studies are necessary to decide whether the fish could be a potential source for the production of good quality sauce.

INTRODUCTION

According to Prasad and Nair (1973) the upper continental slope (180-450m depth zone) showed high abundance of smaller sized species of fish viz. *Chlorophthalmus agassizi, Chascanopsetta lagubris, Epinnula orientalis, Rexea promethoides, Polymyxia nobilis, Pseneopsis cyanea, Cubiceps natalensis* etc. *Chlorophthalmus agassizi* (Green eye) is available in plenty along the east and west coasts of India in the deeper waters between 200-600 m (Sivaprakasam, 1986). It formed 4% of the exploratory sample catch of the IFP vessels (Jhingran, 1982). However, because of its unfamiliarity, there is no demand for the fish in the local markets. An attempt to popularise the fish and promote its market acceptability by preparing certain value added products from it was, therefore, made. The results of these studies are presented in this paper.

MATERIALS AND METHODS

Chlorophthalmus agassizi caught in the trawl nets of the FORV *Sagar Sampada* of the Department of Ocean Development, Government of India during August-September, 1986 and November-December, 1986 from the west and southwest coast of Kerala was used for product development. The fish was washed well, frozen immediately after catch onboard the vessel at - 40°C and stored in the cold storage of the vessel (-18°C) till the end of the cruise. The frozen blocks were transferred to the laboratory and stored at -23°C for 2-4 weeks before processing.

The fish was thawed, washed, beheaded and gutted and minced. Meat was separated using a meat bone separator. The minced fish was used for the preparation of texturised meat (Suzuki, 1981).

The dressed fish prepared by removing the head, fin and viscera from the thawed *C. agassizi* was cooked in boiling water for 10 min, the cooked meat was separated manually and used for the preparation of wafers and soup powder according to Gopakumar *et al.* (1975).

The whole minced fish was mixed with salt in the ratio of 4:1 and was packed in screw capped polythene jars and allowed to mature at 30 ± 2°C for the production of fish sauce. Periodical sampling was done according to Lekshmy Nair *et al.* (1988).

Proximate composition of the products was determined following the methods of AOAC (1975). Rehydration capacity of the texturised meat was measured as described by Shenoy *et al.* (1988).

Physicochemical and organoleptic evaluation of the sauce were carried out as described by Lekshmi Nair *et al.* (1988). α amino nitrogen was determined following the method of Pope and Stevens (1939).

RESULTS AND DISCUSSION

C. agassizi used for the study had an average length of 20.2 ± 0.9 cm and an average weight of 71.3 ± 10.3 g. The flow diagram for preparation of texturised meat is shown in Fig. 1. Details of the

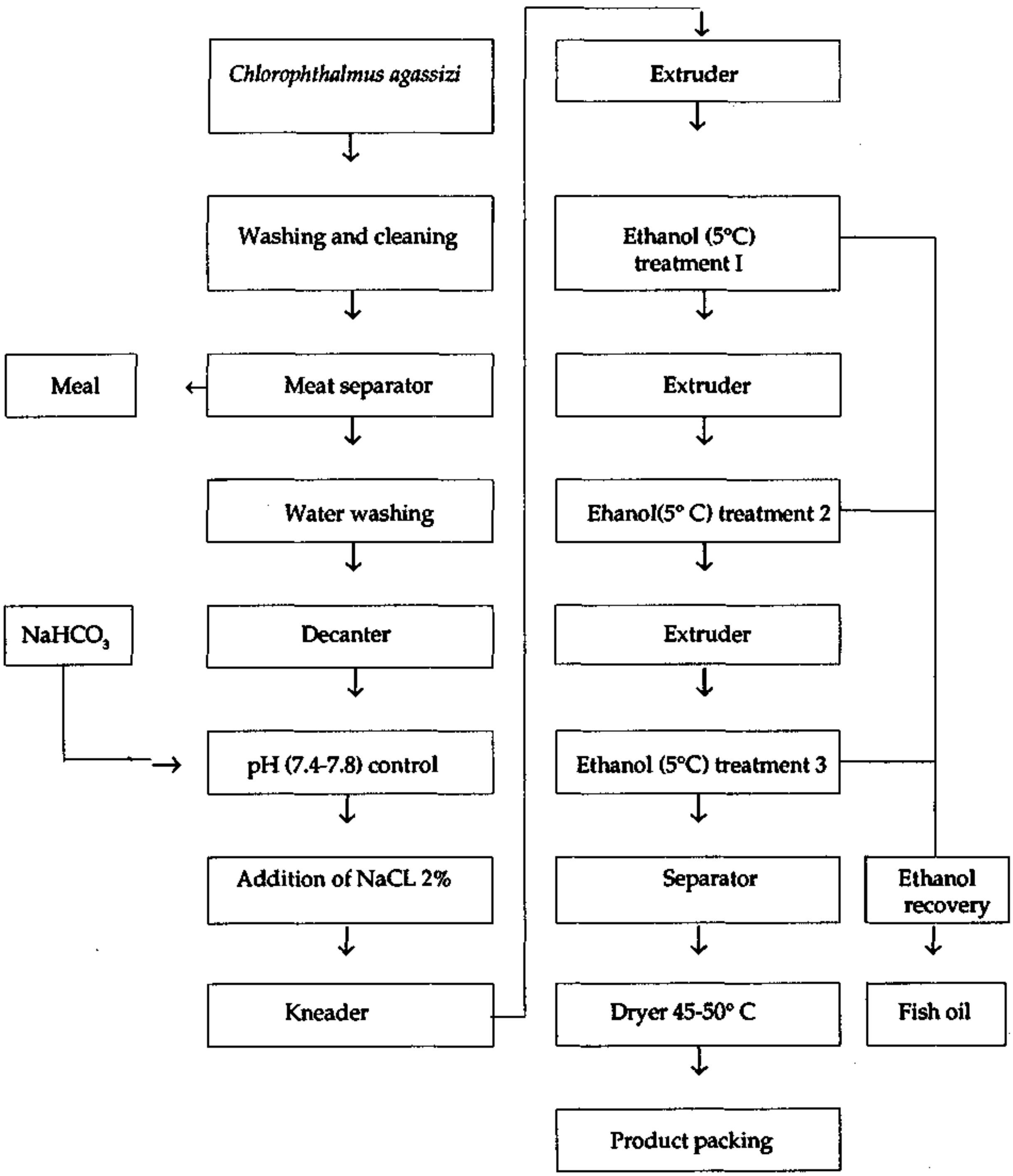

Fig. 1. Flow diagram showing the steps in the production of texturised meat from *Chlorophthalmus agassizi.*

preparation of and properties of texturised meat from Green eye are presented in Table 1. The yield is lower than those reported for texturised meat from other marine fishes (Suzuki, 1981; Lekshmy Nair *et al.*, 1988). This may be attributed to the comparatively lower protein and higher fat content of the fish in comparison to the fishes studied earlier. The product was off-white in colour with practically no fish smell and had a pleasant texture when rehydrated. Net protein content was in the range reported by Shenoy *et al.* (1988) and Suzuki (1981) for sardine, but was lower than those reported for various material fishes by Suzuki (1981). Lipid content of the product was high and this could affect its shelf-life. However, extrusion of the product through hot ethanol before putting it for drying removes most of the fat and gives an excellent low fat product.

TABLE 1. *Yield and composition of texturised meat from* Cholorophthalmus agassizi

Dresssed fish[a]	50.0
Minced fish[a]	33.3
Texturised meat[a]	3.3
Rehydration capacity	2.9
Moisture[b]	6.6
Protein[b]	86.7
Ash[b]	1.9
Fat[b]	4.4

a = % on whole wet fish, b = % on sample.

Proximate composition and organoleptic assessment of the wafers and soup powder prepared from Green eye are presented in Table 2. Both products had appealing colour and appearance and good functional properties. The chemical characteristics of both products are similar to those reported earlier for these items prepared from marine fish (Gopakumar *et al.*, 1975). Acceptability studies showed that over 90% of the taste panel members rated the products as good.

TABLE 2. *Proximate composition and organoleptic rating of wafers and soup powder prepared from* Chlorophthalmus agassizi

	Wafers	Soup powder
Moisture	7.4	8.8
Protein	11.4	21.2
Ash	3.0	18.0
Overall acceptability	Good	Good

The attempt to prepare sauce from Green eye could not be completed, since there was fungal growth in the substrate and an unpleasant mouldy odour developed after two months of maturation. Table 3 shows the physicochemical characteristics of the product after one month of maturation. Solubilization of protein is low during this period. However, since the trial could not be extended over the normal fermentation period of 9-12 months at ambient temperature, more data regarding the various processes involved during the different stages of maturation have to be collected before any definite conclusion can be drawn.

Appealing value added products like texturised meat, wafers and soup powder can be prepared from *Chlorophthalmus agassizi*, a hitherto unexploited fish from the west coast of India. All the products possessed good organoleptic rating. Its suitability for the production of fish sauce of good quality can be assessed only after further detailed studies.

TABLE 3. *Physicochemical and organoleptic characteristics of fish sauce from* Chlorophthalmus agassizi*

pH	6.3
Sodium chloride %	26.4
Total solid g/100 ml	36.1
Total protein g/100 ml	5.8
α amino-N mg/100 ml	80.4
Total volatile acids, ml of 0.01 N Na OH/100 ml	31.0
Colour	Yellowish brown
Odour	Chessy
Taste	Salty, acceptable

*Fermentation period - 1 month.

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STUDIES ON PROCESSING OF DEEP SEA FISH CAUGHT ONBOARD FORV *SAGAR SAMPADA*

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Introduction

The marine fish landing of India has been remaining more or less at a stationary level during the past few years. The exploitation being limited to the traditional resources, the picture is not going to change immediately unless exploration and exploitation of non-traditional resources of the deeper waters are attempted. There is more or less virgin resources of fishery wealth in the Exclusive Economic Zone of the country, exploitation of which can significantly change the scenario of the Indian fishery sector. However, this calls for an indepth and comprehensive study covering different aspects like availability and identification of the resources, capture techniques and development of suitable gears, maximum sustainable yield, postharvest handling and processing requirements, product development, quality control, consumer responses, marketing etc. It was only recently that such a co-ordinated effort in this direction was initiated with the operation of FORV *Sagar Sampada* involving different agencies and organisations connected with fisheries research and development.

The Central Institute of Fisheries Technology has been and continues to be involved with the *Sagar Sampada* cruises executing its part in both harvest and post-harvest fields. This paper summarises some of the achievements of the institute in the post-harvest handling, processing and related aspects of fish caught onboard the vessel.

Chemical composition and nutritive value

Chemical composition and nutritional qualities are very important and critical parameters in deciding upon the edibility of fish. Variations in nutritional qualities may be observed between the same species of fish caught from inshore and deep sea areas. One of the first attempts in the post-harvest handling of deep sea fish was in establishing the chemical composition and nutritive value of meat of several species of fish. Proximate composition together with mineral contents of few representative species of fish are presented in Table 1. Proximate composition of these species is similar to those reported for other marine fishes.

The amino acid make up of proteins largely accounts for its nutritive value. For evaluation of nutritive value, both chemical means (by analysing the amino acid composition) as well as biological means (employing rat feeding experiments) have been made use of. Amino acid composition of the muscle of a few representative species of fish is presented in Table 2. It can be seen that many species of fish had a fairly balanced amino acid composition signifying their nutritional superiority.

Table 1. *Proximate composition and mineral contents in few species of fish*

Sl. No.	Name	Moisture	Protein	Fat	Carbohydrate	Calorie	Ash	Sodium	Potassium	Calcium	Iron
1.	*Psenus indicus*	62.0	17.5	17.6	0.9	233.8	2.3	416.7	458.3	437.5	10.9
2.	*Chlorophthalmus agassizi*	77.8	18.2	1.9	0.8	95.0	1.4	361.1	525.2	558.0	12.0
3.	Bat fish (*Platacid* sp.)	74.0	21.8	0.9	1.2	102.4	1.5	230.4	576.0	587.6	9.0
4.	*Priacanthus hamrur*	75.1	20.4	1.4	1.5	102.4	1.4	295.9	510.0	510.0	9.9
5.	Slipper lobster (*Thenus orientalis*)	73.6	21.7	0.4	1.0	96.7	2.3	726.0	452.0	488.0	8.0
6.	Lantern fish (Myctophids)	69.9	15.3	12.1	0.8	174.9	1.7	366.5	401.4	445.0	10.7
7.	Glow belly (Acropomatidae)	74.7	21.2	1.7	0.9	105.9	1.3	326.3	431.6	473.7	7.5
8.	*Porogadus* sp.	83.9	13.1	0.5	1.1	62.7	1.8	613.1	412.0	465.0	20.0
9.	*Caranx* sp.	67.6	22.8	5.5	1.9	150.8	1.9	255.9	485.0	543.0	13.5
10.	*Sphyraena barracuda*	75.0	21.5	0.5	1.7	99.6	1.2	206.2	464.0	556.0	8.0
11.	*Epinephelus* sp.	67.4	24.3	0.3	2.1	111.5	2.6	331.2	448.7	555.0	6.7
12.	Moon fish (*Mene maculata*)	87.1	11.0	0.5	0.7	52.5	0.9	52.0	463.8	565.0	10.0

TABLE 2. *Percentage composittion of amino acids in the fish muscle hydrolysate*

Amino acids	*Psenus indicus*	*Neoepinula* sp.	*Priacanthus* sp.	*Caesio* sp.	Deepsea cuttle fish	Deep sea prawns
Aspartic acid	9.35	7.88	5.47	9.21	9.37	7.84
Threonine	4.58	4.57	5.90	4.34	4.08	3.76
Serine	5.19	4.57	6.82	4.56	4.79	4.15
Glutamic acid	16.03	13.02	5.45	14.58	14.56	14.37
Proline	1.39	2.67	1.66	1.21	1.76	1.15
Glycine	9.15	7.21	6.96	9.64	10.06	16.61
Alanine	7.09	8.01	5.12	7.12	6.59	8.33
Valine	4.77	4.30	4.69	5.09	3.89	3.84
Cystine	0.71	0.66	4.67	0.66	—	0.25
Methionine	2.85	2.89	5.65	2.37	2.52	2.24
Isoleucine	3.55	4.27	5.06	3.65	3.79	3.11
Leucine	8.67	8.65	6.66	8.44	8.79	7.66
Tyrosine	2.90	3.04	6.28	2.85	2.87	2.07
Phynylalanine	3.63	3.20	6.07	3.54	3.79	2.46
Histidine	2.86	8.04	9.73	5.81	2.87	2.69
Lysine	11.56	11.66	7.51	11.87	9.60	10.38
Arginine	5.69	5.34	6.18	5.04	6.03	9.00

The animal feeding experiments were carried out on albino rats using prepared feeds incorporating fish meat as the source of protein. Control experiments were carried out using a similar diet containing skim milk powder or casein as the source of protein. All the diets were adjusted to have 10% protein and 10% fat. The feeding experiments were carried out for a period covering four weeks. The results are presented in Table 3. It can be seen from the Table that except one, all other fish proteins are either better than or comparable to milk protein in promoting growth in rats.

Many deep sea fishes had high fat content. Fat content has a bearing on the calorific value of fish muscle, however, its degree of unsaturation also influences its storage characteristics. Fatty acid composition of several deep sea fishes has been carried out, few of which are presented in Table 4.

Handling and processing

a) ***Iced storage and freshness of fish***

Fish held for varying period at ambient temperature immediately after catch were stored in ice and their freshness was tested using an Intelectron

TABLE 3. *Results of feeding experiments using different diets containing fish protein of deep sea fish*

Protein source	PER	Nitrogen content (mg/ml) of Liver	Nitrogen content (mg/ml) of Serum	Rat's physical feature
Heterocarpus parapandalus	2.64 ± 0.091	28.4 ± 1.15	12.9 ± 1.150	Normal
Sphyraena barracuda	3.55 ± 0.275	33.1 ± 1.350	9.4 ± 1.150	"
Epinula orientalis	2.21 ± 0.151	27.5 ± 1.007	14.8 ± 1.080	"
Priacanthus hamrur	2.01 ± 0.181	27.9 ± 0.778	14.4 ± 1.210	"
Chlorophthalmus agassizi	1.9 ± 0.146	26.4 ± 1.065	11.5 ± 0.282	Reduced growth, discoloured hair, less active
Non-fat mild powder	2.56 ± 0.101	28.4 ± 1.150	12.9 ± 1.150	Normal

TABLE 4. *Fatty acid composition of three deep sea fishes*

	Chlorophthalmus (%)	*Psenes indicus* (%)	*Nioepinula* sp. (%)
$C_{12:0}$	-	-	5.22
$C_{14:0}$	5.02	4.71	1.05
$C_{16:0}$	28.08	23.03	29.77
$C_{17:0}$	1.87	2.97	—
$C_{18:0}$	31.98	39.79	—
$C_{18:3}$	0.15	0.22	2.39
$C_{20:0}$	1.41	1.79	—
$C_{20:1}$	0.09	1.33	2.91
$C_{20:2}$	1.95	8.54	5.71
$C_{22:0}$	4.90	—	0.11
$C_{22:2}$	—	2.48	1.94
$C_{22:3}$	3.77	-	-
$C_{22:5}$	19.83	14.97	17.34

Fish Tester during progressive storage. It was observed that a delay of 6 hours between catching and icing reduces the freshness as also the shelf life by about 50%. In most cases, the rigor sets in one hour and lasts 5 hours at 28°C and 5 days in ice.

b) *Freezing*

Extensive studies have been carried out on freezing and frozen storage characteristics of several species of fish collected from the catches of *Sagar Sampada. Priacanthus harmur , Psenopsis cyanea, Elacate niger,* rock cod (*Epinephelus* sp.), oceanic squid and cuttle fish are some of the species of which storage characteristics have been studied in detail and shelf lives assessed. Of particular interest is the frozen storage of *Psenopsis cyanea* because of its high fat content of around 52% which is comparable to or more than that of the highly oily fish, oil sardine. However, this fish has a very attractive meat and very good organoleptic characteristics. The frozen shelf life of some of the species at - 23°C as decided by the assessment of their chemical and organoleptic characteristics during storage are presented in Table 5.

TABLE 5. *Frozen shelf-life of different fish*

Species	Shelf life
Psenopsis cyanea	32 weeks
Elacate niger (fillets)	9-10 months
Priacanthus sp.	12 „
Epinephelus sp.	17 „
Cuttle fish (ink sac tied)	18-19 „

Freezing of cuttle fish immediately after catch after tying the ink sac yields highly beneficial results as is indicated by the Table. Even at the end of estimated shelf life, the important deteriorative changes noticed were the discolouration of the inside portion of the mantle and some change in flavour.

Time lag between the capture and processing of fish can greatly influence the quality and shelf life of the resultant product. This is more significant in the case of freezing because thawed fish will resemble fresh fish and any deterioration in quality will be more evident than in fish processed by any other method. Practically no work has been reported on the effect of delayed freezing on the frozen storage characteristics of the product. Effect of delayed freezing on the shelf life of rock cod (*Epinephelus* sp.) has been studied in detail. Fresh fish was frozen at — 40°C immediately after catch as also after a lapse of 5 and 10 hours respectively, fish being left at ambient temperature (30°C) in the meantime, and frozen fish was stored at — 23°C. The studies indicated that neither the changes in non- protein nitrogen fractions nor those in salt soluble nitrogen fraction could serve as an indicator of the quality difference between the different samples. However, the content of total volatile basic nitrogen is a good indicator of the quality differences, the same increasing with increase of time the fish was left at ambient temperature. Organoleptic score also recorded specific differences between these samples, the score being the highest for fish immediately frozen after catch and least for fish left for 10 h at ambient temperature.

Though there was some difference in the total bacterial count of the different samples initially, it narrowed down during storage. The faecal streptococci and total presumptive coliforms became absent

TABLE 6. *Effect of delayed freezing quality of stored product*

Storage period weeks	TVBN mg/100mg			Organoleptic score (average)			Faecal streptococci/g			Total presumptive coliforms/g		
	1	2	3	1	2	3	1	2	3	1	2	3
9	2.8	14.0	15.4	8.5	7.4	6.4	7.5×10^2	4.8×10^2	3.78×10^4	2.8×10^2	5.9×10^2	5.5×10^3
14	12.6	16.8	16.8	8.2	7.2	6.1	Nil	Nil	1.18×10^4	35.0	-	4.8×10^2
18	8.4	9.8	11.2	7.4	6.3	5.3	"	"	—	1.6×10^2	2.2×10^2	8.3×10^2
36	21.0	21.0	25.8	7.4	6.2	5.2	"	"	2.9×10^2	Nil	Nil	97.0
48	11.2	20.0	42.0	7.3	6.2	4.5	"	"	Nil	"	"	Nil
62	16.0	20.0	38.0	6.5	5.2	4.0	"	"	"	"	"	"

Estimated shelf life 1. 17 months, 2. 15 months, 3. 10 months.

in two of the samples in 14 weeks, but still persisted upto 36 weeks in the sample kept for 10 hrs at ambient temperature. Some of the salient features of the results obtained are summarised in Table 6.

Freezing of rock cod in whole as well as gutted form immediately after catch and after progressive storage in ice also has been carried out. As judged by physical, chemical and organoleptic parameters, whole fish frozen after iced storage for 3 and 7 days became tough in texture and was rated only moderately good in 30 weeks storage and became unacceptable after 36 weeks. However, whole fish frozen immediately, gutted and immediately frozen, gutted and iced stored for 3 days and frozen as well as frozen as fillets were all acceptable upto 44 weeks.

c) *Canning*

Several species of fish from the catches of *Sagar Sampada* were screened for their suitability for preservation by canning. Out of them, three species viz. *Psenopsis cyanea, Elatcae niger* and *Priacanthus* sp. were found to yield very good quality product during the trial experiments. Detailed studies were, therefore undertaken to work out the process to can them. The process for canning *Psenopsis cyanea* is given in the flow sheet in Table 7.

Elacate niger has been found suitable for canning after initial cooking only. However, frozen and stored fish becomes quite tough on canning due to loss of soluble nitrogenous fractions.

d) *Drying/smoking*

Being a fish not very much relished fresh, barracuda (*Sphyraena* spp.) was processed by drying and smoking. Fresh fish frozen immediately onboard was later used for experiments. Thawed fish was split opened from back and salted in saturated brine overnight followed by drying in sun for a day.

TABLE 7. *Flow sheet for canning* Psenopsis cyana

Fresh fish

↓

Remove fins, tail and guts

↓

Wash and dip in 0.5% lactic acid solution

↓

Wash well, cold blanch in solution of 15% salt, 0.1% each citric acid and alum

↓

Drain, pack in cans, exhaust and seam

↓

Heat process in steam 1 kg/cm² -45 mts

OR

Pre-cook blanched fish in steam

↓

Drain away drip and fill hot oil

↓

exhaust and seam

↓

heat process in steam

This semi-dried fish was either further dried to attain a moisture level of 40% to get a dried product or smoked for 5 hours at 45° C to get the smoked dried fish. Both samples organoleptically rated very good,

TABLE 8. *Flow sheet for dried/smoked barracuda*

Frozen and thawed barracuda
↓
Split open, remove gills, entrails, wash
↓
Keep overnight in saturated brine
↓
Drying in sun for a day
↓

↓	↓
Repeat drying for one day (Shelf - life 8 weeks)	Smoke at 45° C for 5 hours (Shelf - life 18 weeks)

however, they varied very much in their shelf life, the former remaining well for 8 weeks and the latter about 18 weeks, the important quality deterioration factors noticed being the change in colour as well as incidence of fungus apart from the fall in organoleptic rating.

e) *Minced meat and meat based products*

Fish, small enough, making them unsuitable for processing and preservation by other methods can be used for preparation of fish minces which can serve as a base for the preparation of several unconventional and value added products. In most cases the meat was separated using a deboning machine. The yield of minced meat varied between 21 and 30%. Some of the species used for preparation of mice are *Nemipterus mesoprion, Trigala* sp., *Lepidotrigala* sp. *Cubiceps natalensis* and *Epinephelus tauvina.*

i) *Fish wafers*

Fish wafers were prepared using meat of different species of fish and prawns. The process employed is the one standardised at CIFT. Except two species of fish viz. *Psenus indicus* and *Pseneopsis cyanea,* most of the other species were judged quite good for processing as wafers. Few species like *Priacanthus* and deep sea prawns yielded excellent quality wafers. High fat contents in *Pseneopsis cyanea* and *Psenus indicus* are the primary factors limiting their use in wafers. Wafers prepared using these fish did not expand to the desired level as with other fishes and also had an unpleasant after taste.

ii) *Fish cutlets*

The species of fish which could be used in the preparation of wafers could be used for making fish cutlets. Taste, texture, flavour and shelf-life under frozen conditions were similar to those obtained with other fishes.

iii) *Fish patties and breaded fish sticks*

Fish patties, breaded fish sticks etc. are some of the value added products that can be processed out of minced meat. Mince from species found suitable for processing wafers and cutlets were also tried for processing fish patties and fish fingers. They were comparable to similar products prepared using other fishes. However, *Psenopsis cyanea* and *Psenus indicus* were found unsuitable for processing patties and fingers. Table 9 gives a brief summary of work on the use of deep sea fish for processing into mince and mince based products.

TABLE 9. *Mince based products*

Species suitable	:	Non-fatty, lean fish
Method of making mince	:	Using a deboning machine
Products processed	:	i Fish wafers ii Fish cutlets iii Fish patties iv Fish fingers
Species found specifically unsuitable	:	Oily fish in general and *Psenus indiucs* and *Psenopsis cyanea* in particular

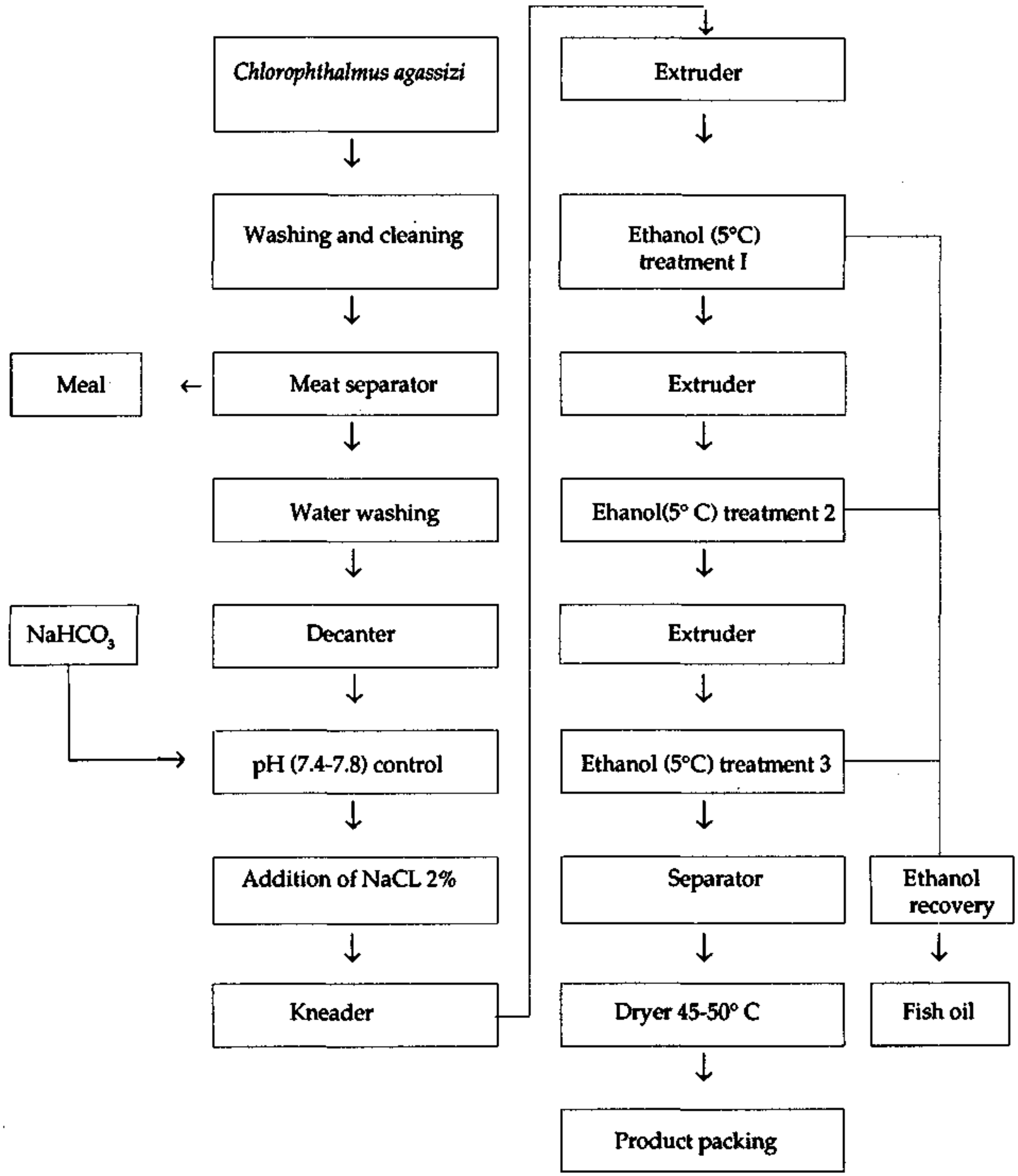
iv) *Texturised meat*

Texturised meat or meat replacers now being processed from fish is popularly called marine beef. An attempt was made for processing a similar product using the meat of *Chlorophthalmus agassizi.* The product had an off-white colour, with practically no smelll of fish and had appropriate texture when rehydrated. In chemical composition, it was comparable to similar products prepared out of other fishes like sardine. Flow diagram for preparation of texturised meat is presented in Table 10.

v) *Fish soup powder*

Most of the lean edible varieties of fish studied could be used for production of fish soup powder having very good organoleptic qualities and shelf life.

Table 10. *Flow diagram showing the steps in the production of texturised meat from* chlorophthalmus agassizi



f) *Byproducts and waste utilisation*

i) *Fish meal*

Conversion of very small and otherwise not utilisable fish meal is an important method of their disposition. They can find effective use in animal nutrition depending upon their nutritional qualities. Detailed studies on preparation of fish meat from few species of fish have been carried out. The quality of the meal in promoting animal growth was tested in albino rats. The method of preparation of meal consisted in cooking the fish, removing the stick water, drying and powdering to the required size. Their proximate composition and mineral contents are presented in Table 11, amono acid composition compared to FAO pattern in Table 12 and protein efficiency ratios in Table 13. The results presented clearly indicate that all the samples are comparable to or better than casein in their growth promoting properities.

Fish meal was prepared also from filleting wastes of *Priacanthus*. The sample had a protein conforming to the requirement of grade 2 fishmeal and the essential amino acids were present in required quantities, but the animal feeding experiments revealed a low PER and NPU values.

ii) *Fish sauce*

Detailed studies have been carried out on fermentation of *P. adeni* and *P. weberi* at ambient temperature (30± 2°C) in presence of salt for production of fish sauce. One part of fish was thoroughly mixed with 4 parts of blended fish. Solubilisation of protein was more or less optimum in 9 months time and the sauces had brownish yellow colour and conformed to the special grade of the standards prescribed by the Foods and Drugs Administration. Yield and physicochemical characteristics of the sauce obtained are presented in Table 14. Though the other characteristics were comparable to the sauce produced from fish like sardine, anchovy, barracuda etc. the yield was lower with both fishes.

Quality control

Fish toxins

Scombroid fishes are known to cause histamine poisoning so much so that scombroid poisoning has been synonymously used to represent histamine poisoning. Histamine poisonoing is known to cause serious health hazards in humans.

TABLE 11. *Proximate composition of fish meals*

Composition	Species		
	Cubiceps natalensis	*Peristedion adeni*	*Peristedion weberi*
Moisture %	4.20	5.53	5.26
Crude protein % (N x 6.25)	70.00	55.13	57.05
Ash %	13.70	19.58	16.94
Acid insoluble ash %	—	0.08	0.04
Fat %	9.80	18.13	17.68
Ca (mg/100g)	3940	4540	4280
Na	650	830	780
K	780	920	860
Fe	4.56	17.25	16.67
Zn	15.41	6.87	11.67
Cu	6.80	0.20	0.20
Mn	Nil	2.39	1.89
Cd	0.01	Nil	Nil

TABLE 12. *Amino acid compostion of fish meals (g amino acid/100 g protein)*

Amino acid	FAO/ WHO recommended pattern	C.Natalensis	P. adeni	P. weberi
Aspartic acid	-	10.9	9.7	9.2
Threonine	4.0	5.1	4.3	6.2
Serine	-	4.8	4.1	3.8
Glutamic acid	-	16.8	16.1	15.6
Proline	-	1.7	6.1	5.2
Glycine	-	5.1	7.9	5.9
Alanine	-	6.1	6.2	5.8
Valine	5.0	4.4	4.8	4.3
Cystine } Methionine }	3.5	5.1 { 1.9	0.5	2.3
		3.2	4.2	3.1
Isoleucine	4.0	3.8	4.0	3.6
Leucine	7.0	7.2	6.7	5.8
Tyrosine } Phenylalanine }	6.0	3.3	3.8	2.8
		4.9	4.5	3.5
Histidine	-	4.1	2.4	1.9
Lysine	5.5	9.1	10.3	8.7
Arginine	-	3.9	7.2	6.9
Total EAA	36.0	42.9	43.1	40.3

TABLE 13. *Protein efficiency ratio of fish meals from three species of fish*

Protein source	Initial wt. (g)	Final wt. (g)	Wt. gain in 28 days (g)	Protein intake (g)	True PER	Adjusted PER
P. adeni	40.02 ± 3.00	118.08 ± 11.34	69.80 ± 12.00	26.76 ± 7.44	2.44 ± 0.13	2.16
P. webri	43.12 ± 5.90	111.15 ± 16.40	68.03 ± 15.29	25.74 ± 0.17	2.41 ± 0.17	2.13
C. natalensis	38.90 ± 2.70	111.10 ± 9.20	72.10 ± 11.00	22.40 ± 2.30	3.20 ± 0.20	2.70 ± 0.10
Casein	38.90 ± 3.40	102.60 ± 4.80	63.70 ± 5.80	21.10 ± 1.10	3.00 ± 0.20	2.50

TABLE 14. *Yield and physico-chemical characteristics of fish sauce*

Characteristics	*P. adeni*	*P. weberi*
Yield (%)	18.00	16.40
Colour	Brownish yellow	Brownish yellow
Odour	Fair	Fair
pH	6.20	6.20
Sp. gravity	1.21	121
Sodium chloride (%)	24.20	24.40
Total solids (g/100 ml)	36.70	35.90
Total protein (g/100 ml)	9.20	8.90
Amino N (mg N/100 ml)	480.00	454.40
TVN (mg N/100 ml)	182.00	202.00
TMA (mg N/100 ml)	17.00	16.00
Total volatile acids ml N/100 NaOH/100 ml	25.00	27.00

Mackerel and sardine are quite prone to cause histamine poisoninig. To follow its pattern of development, studies have to be conducted with absolutely fresh fish. Such a study was started with mackerel from the catches of *Sagar Sampada*. The studies revealed that the formation of histamine is not very significant upto 7 hours at ambient temperature. In iced fish there was no significant development upto 72 hours whereas fairly good amounts were recorded after 56 hours at 10°C. At 26°C the histamine content shot up to very high level after 10 hours. It was also shown that there is no correlation between the content of histamine and overall quality of fish, the fish becoming organoleptically and otherwise unacceptable even when the histamine levels be minimised if the fish is kept at low temperature, preferably in ice.

Development of histamine as related to storage temperature and time is presented in Table 15.

TABLE 15. *Histamine in mackerel stored at different temperature*

Temperature of storage	Time (hrs)	Histamine (Max) (mg/100g)	Quality rating
2°C (ice)	8	0.40	Excellent
	24	1.62	Good
	40	4.28	Good
	56	0.78	Fair
	64	0.88	Fair
	72	0.74	Fair
10°C	8	0.60	Excellent
	24	1.24	Good
	40	4.60	Fair
	56	8.72	Poor
26°C	4	0.00	Excellent
	6	0.20	Good
	8	0.67	Fair
	10	11.31	Poor
	16	103.32	-

Heavy metals

Heavy metals content of fish is a matter of serious concern. Several species of fish caugh on board *Sagar Sampada* were screened for their heavy metals contents. Table16 provides a compilation of results obtained with few species of fish.

TABLE 16. *Heavy metal content in deep sea fish (ppm)*

	Ni	Zn	Cu	Fe	Pb	Cd	Hg
Sphyraena sp.	1.47	4.83	1.16	14.70	2.58	0.89	0.07
Priacanthus sp.	1.35	4.42	0.48	12.56	3.37	0.77	0.11
Psenus indicus	4.05	1.95	0.82	15.13	1.72	0.96	0.03
Chlorophthalmus	1.76	6.93	1.06	8.37	1.53	0.66	0.02
Neoepinnula sp.	1.82	6.86	0.49	6.70	1.68	0.75	0.03
Caesio sp.	1.94	5.13	0.54	6.20	2.65	0.74	0.02
Porogadus melampeplus	2.51	4.10	1.38	24.13	5.76	0.95	0.02
Deep sea cuttle fish	2.32	19.60	2.49	9.40	8.46	0.66	0.001