FURTHER STUDIES ON THE PROCESS OF COASTAL UPWELLING ALONG THE SOUTH WEST COAST OF INDIA-POSSIBLE CORRELATIONS WITH BIOLOGICAL PRODUCTIVITY.

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BY

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DECLARATION

I, Dr. V. Narayana Pillai, candidate for the Degree of D.Sc. hereby declare that the work described in this Thesis has been carried out by me independently at the Central Marine Fisheries Research Institute during the period 1985-1993 and that it has not been submitted previously to any University or Institution for the award of a D.Sc. Degree.

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Dr. V. NARAYANA PILLAI

FURTHER STUDIES ON THE PROCESS OF COASTAL UPWELLING ALONG THE SOUTH WEST COAST OF INDIA-POSSIBLE CORRELATIONS WITH BIOLOGICAL PRODUCTIVITY

CONTENTS

CHAPTER 1

BACKGROUND

I was born and brought up in the seaside city of Trivandrum, the capital of Kerala. Right from my early childhood I developed a facination for the sea. I use to sit on the beach for hours together and watch the waves slowly advancing towards the coast and breaking on the beach. After graduating from the University of Kerala in the year 1959 I had the benefit of taking up post graduate studies in biological oceanography in the same University and came out with flying colours by securing a first class and first rank in the University in the year 1961.

The basic interest which I developed in the field of marine sciences was on account of inspiration derived from my professor, Late Dr.C.C.John and Dr.C.V.Kurien, the then Reader in the Department of Aquatic biology and fisheries in the University of Kerala. Dr.John, a D.Sc from the University of London, took personal interest in my career after post-graduation which resulted in my joining the Naval Physical and Oceanographic Laboratory, Cochin under the able guidance of Dr.D.Srinivasan. My professor always use to emphasise on the importance of obtaining practical training out at sea which was possible on board naval vessels drafted for the purpose by the Laboratory. I was a regular sailor on board these vessels carrying my hydrographic equipment kit for the collection of basic sea truth data.

I had fish, fisheries and marine products of commerce as special subjects for post-graduation which provided me with an opportunity to gain knowledge on the various aspects of marine biology and marine fisheries. Instructions received from eminent professors like Dr. N. Krishna Pillai and Dr. K. Sadasivan Pillai, specia-lists in the field of marine biology and biochemistry respectively in the Kerala University in the late fifties and early sixties, inspired my basic thinking to imbibe more knowledge in the respective disciplines which, in the long run, helped me in taking up applied aspects of the science of oceanography especially those related to marine fisheries.

Eversince I started my research career in the field of marine sciences after post-graduation in the year 1961, I always thought and worked on applied aspects of oceanography (as applied to marine fisheries) at the same time trying to contribute creative thoughts of conceptual research in fisheries oceanography.

My experience in the Naval Physical and Oceanographic Laboratory, Cochin (1961-1962) provoked my mind to interact with the physical and chemical aspects of the sea. The experience gained onboard naval vessels engaged in hydrographic work gave me sufficient opportunity to observe the vertical thermal structure along the Kerala coast within the continental shelf region, the vertical and horizontal distribution of sea water temperature, salinity, density and water masses in the upper 500 m in the Arabian sea under the able guidance of late Dr. K.V. Sundararamam, The results were published in the form of four departmental reports in the years 1963 and 1964. Dr.D.Srinivasan, the former Director of the Laboratory who has contributed immensely to our knowledge of oceanography and underwater acoustics inspired me to review the research work undertaken in the field of 'noise production by marine life' with the ultimate aim of identifying and segregating underwater noise produced by marine life for the improvement of hydro acoustic equipment used for submarine research studies. A review paper entitled 'Noise production by marine life' was published in the Defence science journal in the year 1963.

I joined the Indian National Committee on Oceanic Research in the year 1962 as a participant of the International Indian Ocean Expedition and gained experience in the collection and analysis of oceanographic and marine biological data onboard INS **KISTNA** and various other research vessels viz. **ANTON BRUUN, ARGO, HORIZON, VITIAZ** etc. The results of studies made during the expedition were subsequently published by the National Institute of Oceanography in the form of collected reprints of IIOE.

My experience with the IIOE provoked my mind to interact with the various physical processes which resulted in higher productivity in a particular region of the sea ultimately leading to higher fish production. This was a changing phase. During my tenure with the National Institute of Oceanography, Goa as a Senior Research Fellow (1967-1970) under the able guidance received from eminent scientists like late Dr. N.K. Panikkar and Dr. S.Z. Quasim, I could slowly build up the necessary biological base in support of my persuit of the applied field of fisheries oceanography in later years. Simultaneously I took up studies on the variation of important hydrographic parameters within the Cochin back water system which interested me because of the presence of strong semi-diurnal tidal currents. The results were published in the year 1971. The environmental data pertaining to IIOE collections were also published in the same year.

During the late sixties and early seventies the importance of correlating meteorological and oceanographic data with fish catch data was felt which resulted in the creation of teaching positions in oceanography and marine meteorology at the Central Institute of Fisheries, Nautical and Engineering Training (CIFNET), the only national institute of its kind in the country which caters to the requirement of trained operative personnel for the large ocean going fishing vessels. As per guidance received from eminent people like late Dr. N.K. Panikkar and Dr. S.Z. Quasim, I took up a teaching position at CIFNET in the year 1970 and continued with the institute until 1977. Teaching oceanography and marine meteorology to the cadets of the institute who ultimately qualified as Masters and Chief Engineers of large sized ocean going fishing vessels and providing them with practical training onboard a fleet of training vessels attached to the institute gave me the opportunity to strengthen my fishery base and also the applied aspects of oceanography and marine meteorology as related to marine life. This also helped in creating an awareness in the minds of fishing vessel operatives personnel the importance of collecting both oceanographic and marine meteorological data side by side with fishing data to attempt possible correlations. It may please be noted that during my tenure with the training institute as a teacher, I could contribute my own share of building up the future skippers/mates of the distant water fishing fleet of the country through whom the country expects the collection of valuable sea truth data with the ultimate objective of bettering fishing results. I have great expectations from these young men who are responsible for the collection of sea truth data in relation to fishing activity which will ultimately help the scientists, shore managers and administrative personnel in arriving at positive correlations/managerial decisions/formulating government policies for better management and conservation of the marine fisheries of the country.

During the period spent at the national training institute I could bring out around 23 publications dealing with the various aspects of oceanography and marine meteorology in relation to fisheries simultaneously strengthening my biological base to attempt possible correlations. My tenure with CIFNET also provided me with an an opportunity to regularly participate on fishig voyages onboard training vessels rigged up for undertaking different kinds of fishing activity. The importance of collecting basic oceanographic/meteorological data side by side with fishing activity was always emphasised during my theory and practical classes. The operation and usefulness of simple oceanographic and meteorological equipment which could be carried onboard such vessels was very well made understood to individual cadets onboard.

In the year 1972 I was selected by Govt. of India to participate in the FAO/NORAD training course in fish detection and abundance estimation conducted at Cochin. During the training I had the benefit of acquiring knowledge in the operation and utility of modern fish detection and abudance estimation equipments like SONAR, Fish finders, Net sondes and Echo integrators onboard R.V.RASTRELLIGER and R.V.SARDINELLA under the able guidance from FAO experts.

In the year 1974-1975 I took up part-time studies leading to the award of a post-graduate diploma in Business management from the Bhavan's Institute of Mass Communications. I was awarded the Kulapathy medal for the meritorious performance and securing first rank. The topic chosen for the dissertation was "Management of technical personnel in the fishing industry" which was well appreciated by the examining faculty members.

Looking back after a period of nearly two decades I have immense satisfaction to see my former trainees functioning as Masters of most of the large sized sea going fishing vessels, fishery survey vessels, training vessels and research vessels now being operated around Indian waters. I am sure, with the sound footing they had at the training institute, they will fulfil a dream which will come true in the near future. It gives me great pleasure to watch with satisfaction the reasonably good quantum of useful sea truth data which is pouring in through the effort put in by these trained personnel.

In the year 1977 I was given the responsibility of organising the cruises of the supporting vessel '**BLUE FIN**' as Chief Scientist on board in the Indo-Polish Industrial fishery survey along the north west coast of India undertaken by the Polish industrial fishing vessel, '**M.T. MURAENA**'. The supporting vessel collected valuable environmental data side by side with fishing activity in the same fishing squares where '**MURAENA**' operated. The results of study undertaken on board were subsequently brought out in the form of a special departmental report of CIFNET in the same year.

I joined the FAO/UNDP Pelagic Fishery Project along the south west coast of India as Senior Oceanographer in the latter half of 1977 and remained with the project till the end of 1979. The tenure with the FAO Project gave me the rare opportunity of working with internationally reknowned scientists representing several nations on an integrated programme of assessing the pelagic fishery resources along the south west coast of India. I was also given the responsibility of managing the cruise programmes of the FAO Research vessels, **R.V. RASTRELLIGER** and **R.V. SARDINELLA** attached to the project. During my two-year tenure with the project I could fill up gaps in the environmental/fishing data especially during the monsoon season by team participation and compile the final consolidated report on oceanographic investigations undertaken by the Project. (FAO report FIRS/IND/75/038, 1980). I could complete the final report before the target date which was well appreciated by FAO and Government of India authorities.

In 1979 I visited United Kingdom under an FAO study tour felowship. I was attached to the MAFF Fisheries Laboratory, Lowestoft where I received training in the application of oceanographic, ocean climatological and remote sensing data for marine fisheries management and forecasting under the able guidance of Dr. R.R. Dickson, Dr. John Ramster and Dr. Paul Gurbutt. Based on work carried out at the laboratory a paper entitled 'Satellite evidence on enhanced upwelling along the European continental slope' along with Dr. Dickson and Dr. Gurbutt was published in the journal of physical oceanography in the year 1980. I could also get involved in studies connected with the possible relationship between wind and mackerel fishery off Cornwall (south west coast of England) during 1940-1979. Another work which interested me at the laboratory was an investigation into the possible relationship between Wood head sea bed drifter returns and on/offshore winds along the north east coast of England. Results of these studies were subsequently brought out in the form of departmental reports of the laboratory.

My tenure with the MAFF Fisheries Labortory, England gave me immense opportunity of widening my field of knowledge, especially the applied aspects related to remote sensing in marine fisheries to which I could contribute in later years when the applied aspect was taken up by the concerned Institutions in India with the ultimate aim of mapping possible areas of higher fish production in the waters around Indian sub continent.

During my tenure with the FAO/UNDP Pelagic Fishery Project (1977-1979) I got registered at the Cochin University of Science and Technology for Ph.D. Degree under the able guidance of Dr. A.V.S. Murthy, the former head of Fishery Environment Mangement Division, CMFRI, Cochin. The basic data collection and analysis were completed in 1979 and the thesis entitled 'Physical characteristics of the coastal waters off the south west coast of India with an attempt to study the possible relationship with sardine, mackeral and anchovy fisheries' was submitted in 1982. The Cochin University of Science and Technology awarded me a Ph.D. degree in 1983 for the above research persuit.

On my return to India towards the end of 1979, the work of the FAO Project was completed and I continued teaching fishery oceanography and marine meteorology to the deck/engine side officer cadets of the National Training Institute.

During the year 1980 the training institute acquired a fleet of new training vessels (**SKIPPER-II**, **SKIPPER-III** and **PRASHIKSHANI**). The responsibility of organising an effective training programme for officer cadets onboard these vessels was entrusted with me. I have participated onboard these training vessels on several cruises during this period with the basic objective of providing training in the collection of environmental data using standard equipment to a large number of cadets.

In 1981 (December) considering my interest and past experience in organising suitable training programmes for the benefit of fishing vessel operatives personnel, Government of India selected me to undergo a management development programme for Senior administrators held at the Indian Institute of management, Calcutta. The topic chosen by the group under my leadership was 'Behavioural characteristics of an independent group in the public sector-resultant situations and possible remedies for achieving group/organisational objectives.' The dissertation which was chosen as the best among 8 similar studies submitted for the final assessment brought out the behavioural characteristics of different groups in the fishing industry and possible remedies towards achieving group/organisational objectives in the larger interests of the nation.

In early 1982 I was selected by the Union Public Service Commission for the post of Deputy Director (Experimental fishing) at the Integrated Fisheries Project, Cochin. I was assigned the responsibility of increasing the fish catches of selected Project vessels by way of employing improved types of fishing gear and accessories and by adopting suitable fishing techniques and above all by motivating the operative personnel totalling to around 110 by evolving and adopting suitable personnel management techniques. I was greatly appreciated by the higher authorities in the Ministry of Agriculture, Government of India for exceeding the targets fixed by the authority in this regard and for bagging the covetted 'MEENAKSHY TROPHY' instituted by the Ministry.

During my tenure with the Integrated Fisheries Project (1982-1985) I have effectively organised the compilation of very useful information with regard to the design and rigging of various types of bottom trawls, midwater trawls and shrimp trawls developed by the Project over a period of 30 years in the form of 3 bulletins for the benefit of end users. Details regarding a newly designed bottom trawl which was found effective for catching off bottom fishes was also brought out in the year 1983 in the form of a Bulletin for the benefit of the industry. The results of fishing activities of the project vessels during the period 1964-1981 was compiled and brought out in the form of a Departmental report in the year 1982. Similarly a paper on the fishing potentiality of the shelf waters along the south west coast of India based on the fishing results of IFP vessels was presented and discussed in the "International seminar on training and education for marine fisheries management and development" organised by the Ministry of Agriculture, Govt. of India at Cochin during February, 1986. The detailed paper was published in the proceedings of the seminar brought out subsequently for the benefit of the industry.

In December, 1985 I joined the Central Marine Fisheries Research Institute (ICAR) as Scientist Grade-S.3

by direct selection through the Agricultural Scientists Recruitment Board. I was also inducted into the Indian Agricultural Research Service with effect from December, 1985. Consequent on the introduction of new U.G.C. package for ICAR Scientists, I became a Principal Scientist in 1986 and continued my research pursuits in the same institute. As Principal Scientist and Chairman of **SAGAR SAMPADA** Management Committee I was assigned the responsibility of scientific management of the 71m OAL Fishery oceanographic research vessel **SAGAR SAMPADA** owned by the Department of Ocean Development, Government of India. I have carried out this assignment creditably well and to the full satisfaction of the concerned authorities during the period 1986-1990.

The results of the first 40 scientific cruises of the vessel **SAGAR SAMPADA** was discussed at a workshop organised jointly by the Department of Ocean Development and Indian Council of Agricultural Research at Cochin during June, 1989 where around 100 scientific papers were presented and discussed. Selected contributions by scientists from various user agencies (60 scientific papers) were brought out in the form of proceedings of the worshop for the benefit of the fishing industry, planners, administrators and scientists.

I took over as the Principal Scientist and Officer-in-charge of the Calicut Research Centre of CMFRI in July, 1990 and continued my research work in this capacity. This research centre, one of the oldest research centres of CMFRI, continues to carryout investigations on the resource characteristics of commercially important pelagic fishes (oil sardine, mackerel etc), demersal fish, crustaceans and molluscs along the north Kerala coast. Investigations on selected environmental parameters are also undertaken to attempt possible correlations with changes observed in the fishery of major resources exploited from the Malabar coast.

CHAPTER 2

BRIEF SUMMARY OF DOCTORAL WORK UNDERTAKEN DURING THE PERIOD 1977-1982

Introduction

Soon after joining the FAO/UNDP Pelagic Fishery Project in 1977 I took up part time research work under the able guidance of Dr.A.V.S.Murthy, Head, Fishery Environment Management Division of CMFRI, Cochin. Taking into consideration my past research experience in the field of Oceanography as applied to marine fisheries, the Cochin University of Science and Technology accepted my registration as a part time research student. The topic chosen for the study was 'Physical characteristics of the coastal waters off the south west coast of India with an attempt to study the possible relationship with sardine, mackerel and anchovy fisheries'.

The data collection and preliminary analysis of the basic data were completed towards the end of 1979. I had the unique opportunity of visiting the MAFF Fisheries Laboratory, Lowestoft, England towards the end of 1979 under an FAO study tour fellowship programme. During my tenure with the Fisheries laboratory I had the benefit of discussing the findings of my research persuit with some of the eminent scientists of the laboratory viz. Dr.John Ramster, Dr.R.R.Dickson, Dr.Paul A.Gurbutt etc. The helpful criticisms and sound advice which I received wholeheartedly from these eminent scientists helped me to orient my thinking towards useful interpretation of basic data in consultation with my guide soon after my return to India.

Objectives

The study was aimed at observing the variations, in space and time, of important hydrographic parameters such as sea water temperature, salinity and dissolved oxygen content of coastal waters along the south west coast of India. These nearshore waters are improtant since they constitute the environment for significant part of Indian fisheries. Considerable seasonal variations are also characteristic of this environment. Specific data relating to the processes of upwelling and sinking was collected mainly to evaluate the extent and intensity of these processes active in the area under study. The study also attempted possible correlations between some of the selected observed parameters and the occurence and migrations of some of the major pelagic fishery resources such as oil sardine, mackerel and anchovy in the area under study.

Results

Sea water temperature within the area under study showed very wide seasonal and spatial fluctuations. In areas where the upwelled water reached surface levels, the sea water temperature fell considerably below what could be expected for the season without the influence of the process. The salinity maximum, characteristic of tropical oceans, was found at depths of 100-150 m. during north east monsoon period and between 30-50m. during the south west monsoon period. The variations in salinity, which are mainly brought about by the influence of rainfall, river runoff and the prevailing seasonal surface currents, are characteristic of the surface layers above the salinity maximum layer. The horizontal distribution of salinity indicated the existence of a pronounced convergence zone between Karwar and Ratnagiri in 1974 and less pronounced convergence zone south of Kasaragod in 1973. In general the shelf waters were found to be well aerated during the major part of the year except during the south west monsoon period in areas of intense upwelling where low oxygen intermediate waters reached surface levels.

No regularity in the occurence of upwelling could be observed for any specific locality. The process of upwelling which commenced in February at deeper layers continued during the south west monsoon and the upwelled water reached surface levels during June-October depending upon the vertical velocity of upwelling.

The immediate effect of upwelled water reaching the surface levels was the expulsion of all animal life including fishes from the vicinity as the same was highly oxygen deficient. Dissolved oxygen concentrations of these water masses slowly increased due to dissolution of atmospheric oxygen brought about by wind and wave action.

The process of upwelling was initiated by the prevailing north east wind system which removed surface waters away from the coast thereby inducing subsurface waters to move towards comparatively shalloweer depths near the coast. Once the south west monsoon sets in, the resulting southerly current continues the induction process with the result the sub surface waters slowly rise towards surface levels inspite of south westerly winds which do not favour the process to intensify.

The vertical time sections for sea water temperature and dissolved oxygen were found to be good indicators of the commencement, intensity and duration of the process of upwelling.

The process of sinking which resulted in the spreading of more or less uniform temperature and dissolved oxygen conditions in the subsurface layers lead to an increase in the vertical extent of the habitat of major pelagic fish populations viz. oil sardine, mackerel and anchovy within the area under study. As in the case of upwelling, vertical time sections for sea water temperature and dissolved oxygen were found to be good indicators of the commencement, intensity and duration of the process of sinking.

A study of the occurence, abundance and migration of oil sardine, mackerel and anchovy based on observations indicated that factors such as sea water temperature, dissolved oxygen content, salinity characteristics and plankton biomass at surface levels influenced the abundance and seasonal migrations of these fishes along the south west coast of India. All these fishes were found to avoid areas of intense upwelling activity mainly because of the low dissolved oxygen concentrations and comparatively low sea water temperature conditions. Anchovy was found to move with the changing surface currents and remain within the optimum temperature range avoiding oxygen deficient upwelled water and taking advantage of the prevailing surface currents.

CHAPTER 3

POST-DOCTORAL WORK UNDERTAKEN SINCE 1985 WITH SPECIAL REFERENCE TO THE MANNER AND EXTENT BY WHICH THE INVESTIGATIONS CONTRIBUTED TO THE ADVANCEMENT OF KNOWLEDGE IN THE FIELD OF STUDY

Introduction

In 1985 (December) I left the Ministry of Agriculture, Government of India and Joined the Central Marine Fisheries Research Institute, Cochin under the Indian Council of Agricultural Research consequent on my selection to the post of Scientist Grade-S.3 under the Fishery Environment Management Division of the Institute. (The post was redesignated as Principal Scientist in 1986). I was also inducted into the all India service viz. Indian Agricultural Research Service is December, 1985.

I was entrusted with the main task of organising collection of sea truth data and attempting possible correlations with the occurence, abundance and migration of commercially important fishes with the ultimate aim of evolving a prediction system based on selected oceanographic/meteorological indices. I was also responsible for the possible application of remote sensing data in marine fisheries in joint research programmes by CMFRI, Fishery Survey of India and National Remote Sensing Agency.

Background

During the fifties and sixties our knowledge regarding the process of upwelling along the south west coast of India was mainly based on a few published papers prepared out of limited quantum of sea truth data collected for short periods of time at a few stations. Upwelling in varying intensities have been reported all along the south west coast, the occurence of the phenomenon mainly corresponding to the onset of the south west monsoon (summer monsoon) and the effect of the monsson wind system and the resultant current system on the shelf waters.

According to Banse (1959, 1968), prevailing current system and not the wind is to be regarded as the main cause generating and maintaining the upwelling. According to him even if a uniform current velocity is considered all along the coast, the rise of denser, deep water will be stronger in the north farther away from the equator. He expressed the view that off the south west coast of India, upwelling starts with the onset of the south west monsoon and reached the maximum intensity during July-August, established by late September and ends by mid October. Varadachari (1961) found that a northerly wind driven current on the east coast and a southerly wind driven current on the west coast in the northern hemisphere induce upward motion near the coast.

Sharma (1966) while reviewing the opinion given by earlier workers (Banse, 1959; Ramasastry and Myrland, 1960; Ramamirtham and Jayaraman, 1960) based on work carried out by them during the late fifties and early sixties expressed the view that owing to limitations of facilities, none of the reports are based on continuous studies for at least one year. According to him unless the continuous variation of any one of the relevant parameters is considered, it is not possible to get a clear picture of the commencement and cessation of upwelling and sinking. Sharma (1966) after analysing hydrographic data (in the absence of adequate Bathythermograph data) for the period March, 1964 to August, 1965 (there was no data for November and December, 1964) and constructing topographic maps for the top of the thermocline and vertical time sections for sea water temperature for a coastal station near Cochin noticed that in the month of February the prevailing winds being northerly to north easterly and with offshore transport of the surface water, the conditions are favourable for upwelling. In the month of August the winds are south westerly to westerly and the surface flow few miles away from the coast being easterly to south easterly, turns parallel to the coast owing to boundary conditions giving rise to a southerly component. Further, the precipitation and river discharge near the coast stratify the surface layers opposing any tendency for upwelling. Except for a slight southerly component in the current, in general, all other conditions are unfavourable for upwelling in August and September along the south west coast of India.

Darbyshire (1967) concluded that there is no system of wind generated upwelling during the south west monsoon period along the west coast of India and the dense bottom waters approached the surface because of the immediate interplay of the current with the tilting of the sea surface and the thermocline. According to Wooster et al (1967), the exact mechanism which drives the upwelling has been unclear because the summer monsoon appears to blow almost directly onshore. Wyrtki (1973) concluded that upwelling is nothing more than the shoaling of nearshore isopleths, a consequence of baroclinic adjustment to the anticyclonic monsoon circulation and hence is remotely forced.

Sharma (1968) after conducting a study of the seasonal variations of some hydrographic parameters of the shelf waters off the west coast of India concluded that upwelling along the west coast of India starts earlier in the south and slowly extends towards north. The process commenced at deeper depths earlier in February and reached the surface by May. Upwelling comes to an end by July-August when the top of the thermocline reaches the surface layers. The influence of the river run off and rain stratify the surface layers from July onwards thereby opposing the process.

Studies made by the auther (Pillai, 1983-Ph.D.Thesis) revealed that any one of the above mentioned theories is not directly applicable to the south west coast of India as a whole. The causative factors which bring up the subsurface waters to surface levels vary is space and time. The studies revealed that the process of upwelling started as early as February at the bottom levels. It started at the different sections at different times each year. The commencement of the process in February was possibly initiated by the northerly winds which would transport the surface water away from the coast there by initiating a vertical ascending motion from below. Perhaps the depth at which the motion gets started, would to a great extent, depends upon the velocity, direction and duration of the prevailing wind system in a specific area, the bottom topography, the prevailing current system at the surface levels and also the vertical stability of the water column. The speed of the ascending motion would also depend on the continuance of the above mentioned favourable factors with more or less the same intensity. A closer examination of the prevailing wind system during the south west monsoon season revealed the presence of favourable northerly and north westerly components in certain localities where upwelling intensity also showed correspondingly higher values.

It may please be noted that the author had the benefit of analysing and interpreting voluminous data collected onboard the FAO Project vessels '**RASTRELLIGER**' and '**SARDINELLA**' during the period 1971-1978. Each section/station was covered the following number of time using standard meteorological/oceanographic/zooplankton collection equipments and fishing gear.

Section (Off)	No. of Stations	Coverage (No. of times)
Ratnagiri	8	28
Karwar	6	43
Kasaragod	5	38
Cochin	5	65
Quilon	5	34
Cape comorin	5	27
Tuticorin	5	20

The analysis and interpretation of the above mentioned voluminous data brought out areas of upwelling, sinking zooplankton abundance and information on pelagic fish populations. Possible correlations between selected oceanographic parameters, zooplankton biomass and selected varieties of pelagic fish viz. oil sardine, mackerel and anchovy was also attempted. An attempt was also made to evolve a system to forecast pelagic fish concentrations based on selected oceanographic indices. The study highlightened the hypothesis of 'upwelling' transfering nutrients to the surface layers and ultimately resulting in higher zooplankton biomass, with a time lag, the extent of whcih is dependent on various meteorological and oceanographic factors. The study also highlightened the phenomenon of sinking and concluded that the warmer water which is aerated will hold large pelagic fish populations.

Murthy (1986), while postulating a new concept of coastal water upwelling reasoned out that the upwelling of the eastern boundary of the oceans and the intensified meridional flow along the western boundary constitute the two parts of the subtropical gyre in each of the oceans. The Somali current and the Indian west coast upwelling may in a way be considered as counterparts to one another in the Arabian sea.

According to Longhurst and Wooster (1990) sea level can be an indicator of upwelling. The authors compared variations in oil sardine abundance sea level as an upwelling index at Cochin and monsoon rainfall as an indicator of recruitment success. One has to consider the invasion of the shelf with oxygen poor waters which occurs during Malabar coast upwelling, would tend to exclude oil sardine from the coastal region where diatom blooms are most intense. In such an event it is oil sardine rather than mackerel whose spawning strategy will place at risk that year's recruitment. This is the most likely explanation of statistical relationship between sardine recruitment failure and unusually early remotely forced upwelling. According to them the abundance of oil sardine on the Malabar coast is highly variable in the decadal scale. O-group recruitment to the fishery begins towards the end of summer monsoon. At this time sea level indicates remote forcing of upwelling (caused by the geostrophic upsloping of the isopleths towards the coast) rather than the wind driven upwelling that occurs during the monsoon. Unusually early remote forcing appears to inhibit subsequent recruitment perhaps through the exclusion of spawning fish from the neritic zone by oxygen deficient upwelled water.

Post-Doctoral Research Work Undertaken by the Author

Post-Doctoral research work was undertaken by the author since December, 1985 on the same subject at the Central Marine Fisheries Research Institute mainly utilising the data collected onboard '**RASTRELLIGER**' and '**SARDINELLA**' of the erstwhile FAO/UNDP Pelagic Fishery Project during the period 1971-1978 and also utilising facilities available onboard the modern Fishery Oceanographic Research Vessel '**SAGAR SAMPADA**' during the period 1986-1991. The work was undertaken with the following major objectives:

1. To establish the link between vertical stability characteristics of the continental shelf and slope waters along the south west coast of India and the processes of upwelling and sinking. (Pillai, 1989).

2. To establish the link between sea water temperature and salinity characteristics of the coastal waters along the south west coast of India and major pelagic fisheries of the region. (Pillai, 1991).

3. To establish the link between the occurence of oxygen minimum layer within the shelf waters along the south west coast of India and upwelling activity. (Pillai, 1993).

4. To evolve a possible method for the estimation of the intensity of the process of upwelling along the south west coast of India. (Pillai and Rajagopalan, 1993).

5. To establish the relationship between the process of upwelling and zooplankton biomass in the shelf waters along the south west coast of India. (Pillai, 1993).

The above studies clearly revealed the importance of monitoring the connecting link between the process of upwelling and the higher zooplankton biomass viz. the nutrient levels in the upwelled water and resultant primary production in the upper levels of the euphotic zone. Studies undertaken onboard FORV **SAGAR SAMPADA** during the peak of south west monsoon in July, 1991 revealed that 'upwelling' can be 'positive' or 'negative' from the point of view of higher nutrient levels resulting in a phytoplankton bloom and subsequently a zooplankton bloom. It could be also established that the blooms always occured after a certain lapse of time and away from the area where the upwelled water reached surface levels. An attempt was also made by the author to find out possible reasons for this time lag as well as changes in the location of 'Cause' (upwelled water reaching surface levels) and 'Effect' (resultant phytoplankton/zooplankton bloom).

1. Quantum of inorganic nutrients in the upwelled water

Observations made by the author during the past few years clearly revealed that upwelling can be 'positive' or 'negative' from the point of view of inorganic nutrient levels in the upwelled water. Unless the upwelled water contains adequate quantities of important plant nutrients, especially phosphates which is known to have a direct relationship with chlorophyll production, the upwelling may not result in a higher phytoplankton production even in areas with a cloud free sky. The nutrient content of the upwelled water would depend on the depth from which it has originated and also the time taken for the water to reach surface levels. (upwelling velocity). This was clearly revealed in the observations made for Quilon and Cape comorin sections in the year 1977 where in spite of comparatively higher upwelling velocities the zooplankton biomass at these stations did not indicate a proportionate increase during the following months. This was in sharp contrast to the condition at the cochin and Kasaragod sections where a proportionate increase in the zooplankton biomass was observed following the peak upwelling season. Perhaps the difference observed might be due to the comparatively low nutrient level of upwelled water which reached surface levels both off Quilon and Cape Comorin. Moreover the sea bottom on the shallower areas of the continental shelf between Quilon and Cape Comorin is mostly rocky in contrast to the region north of Quilon where it is mostly muddy. Unfortunately no data was collected on the nutrient levels of surface/subsurface waters to attempt a direct correlation.

2. **Incoming radiation**

Along the south west coast of India since upwelled water reached surface levels during the south west monsoon season characterised by heavy monsoon clouds and rainfall, sufficient quantity of sunlight does not reach the surface of the sea to promote photosynthetic activity in areas where nutrient rich subsurface waters are induced upwards during the process of upwelling. Unless sufficient quantity of solar radiation reaches the sea surface, the upwelled water, in spite of it's higher nutrient content, may not promote any photosynthetic activity in the area resulting in a phytoplankton bloom.

3. **Presence or absence of strong surface currents in the area where upwelled water reaches surface levels**

The author noticed that very often a higher zooplankton biomass is observed away from the point where the upwelled water reached surface levels. It also varies from year to year. The upwelled water is carried away from the point of surfacing by wind generated or density currents which change it's direction from place to place and from time to time. Hence the 'effect' of upwelling is to be looked at a distance from the point where the upwelled water reached surface levels. Higher concentration of nutrients, phytoplankton and zooplankton observed in the coastal areas during the upwelling season should be interpreted with care especially with regard to it's origin. There are rare occasions where in the absence of strong surface currents the 'cause' and 'effect' can be observed side by side. The results of the 1991 monsoon survey in the same area revealed very interesting features in support of the above claims.

Comparatively low sea surface temperature (25^{o}c) was observed between Lat.8^{o} and 10^{o}S and Long.76^{o} and 77^{o}E (Between Cape comorin and Cochin). The values increased to 28^{o}c at Long. 76^{o}E and to 29^{o}c at 73^{o}E Longitude clearly indicating the presence of low temperature water near the coast. (Fig. A) Horizontal variation of dissolved oxygen content of sea water indicated low concentration of 0.5ml 02/L at 100m, 1ml at 30m and 1.5ml at 10m near the coast between Cape comorin and Cochin.

The surface values increased to 4ml at a distance of about 60 nautical miles away from the coast clearly revealing the presence of low oxygenated sub surface waters near the coast (Fig. B). Chlorophyll-a concentrations at sea surface revealed a maximum of $4mg/m^3$ near the coast off Quilon decreasing to $1mg/m^3$ thirty nautical miles seaward. (Fig. C). Vertical movement of $23^{o}c$ isotherm between longitude 69^{o} 30'E and the south west coast of India for the different latitudes, which in turn can be interpreted in terms of intensity of the process of upwelling, is clearly brought out in Fig. D. Depth of occurence of $23^{o}C$ isotherm at different stations along six sections located south of Goa, off Karwar, Calicut, south of Ponnani, Alleppey and Trivandrum plotted and presented in the same figure can be used as a possible indicator for the presence of upwelling, especially it's horizontal spread in space.

Studies conducted by Balachandran et al (1989) off Cochin did not reveal a monsoon maximum for chlorophyll-a either in 1987 or 1988. The reduction in the magnitude of production was attributed to late onset of monsoon and scanty rains as evidenced by the June-August rainfall data for the same years. They also found positive correlation of phosphates with Chlorophyll-a and a negative correlation in the case of nitrites. They concluded that regeneration of nutrients consequent on monsoon related factors followed by stability of water column coupled with abundant sunlight trigger the Chlorophyll production whereas intense grazing accounts for abrupt increase in pheopigment production resulting in partial or sometimes total depletion of phytoplankton standing stock in the inshore waters of Cochin.

Studies made by the erstwhile FAO/UNDP Pelagic Fishery Project (Anon. 1980) revealed that there is general agreement in the pattern of larval density distribution compared to the results of the First phase (PFP Progress Reports NO.7, 10, 15 and 17) in that the overall larval abundance tends to show an increasing trend in May, attaining a peak by July-August. Clupeoid larvae were found in abundance in April, July-August and November during the First phase (1971-1975). During the Second phase (1975-1978) June-August was found to be the period of highest abundance and slightly higher densities were found in October. Such variations are evidently related to the changing environmental conditions and consequent fluctuations in the productivity of the shelf waters. Larval abundance was found to be high during the period of upwelling and the regions of abundance shifted seawards during this peirod when compared to the rest of the year.

Studies made by the author clearly revealed that the area of upwelling is the geographic location where the vertical motion occurs, but upwelled water and it's effect on oceanographic conditions may extend for hundreds of miles. The importance of the phenomenon lies in the fact that deep water having properties different from those of the surface water is brought up to or near the sea surface. It is very important that all the connecting links are monitored in a systematic manner every year during pre-monsoon, south west monsoon and post-monsoon seasons to arrive at a conclusion regarding "cause" and 'effect' which varies from year to year and also from place to place.

Observing/monitoring any one or few of the meteorological/oceanographic/biological parameters described above is not going to help to arrive at a conclusion.

Seasonal monitoring of the essential ingrediants listed as Annexure A is essential to study the 'Cause' and 'Effect' of the phenomenon of coastal upwelling on the occurence, abundance and migration of target species of fish in the area under study. If any one of the ingredients is missing (due to lack of information) a reasonable prediction of the target fishery becomes impossible.

The economic benefit of upwelling is mainly due to the large concentrations of commercially important fishes in these areas. (eg. Oil sardine, mackerel, anchovy etc). Most of these resources consist of clupeoid fishes with short food chains (feeding on phytoplankton and zooplanton) and their predators like tunas.

Accurate forecasts will assist the fishing vessel operators in better planning of fishing operations and to minimise searching time, thereby reducing the running expenses for the craft and the crew.

The net result would be a proportionate lowering of prices which in turn would make cheaper fish protein available to low income groups.

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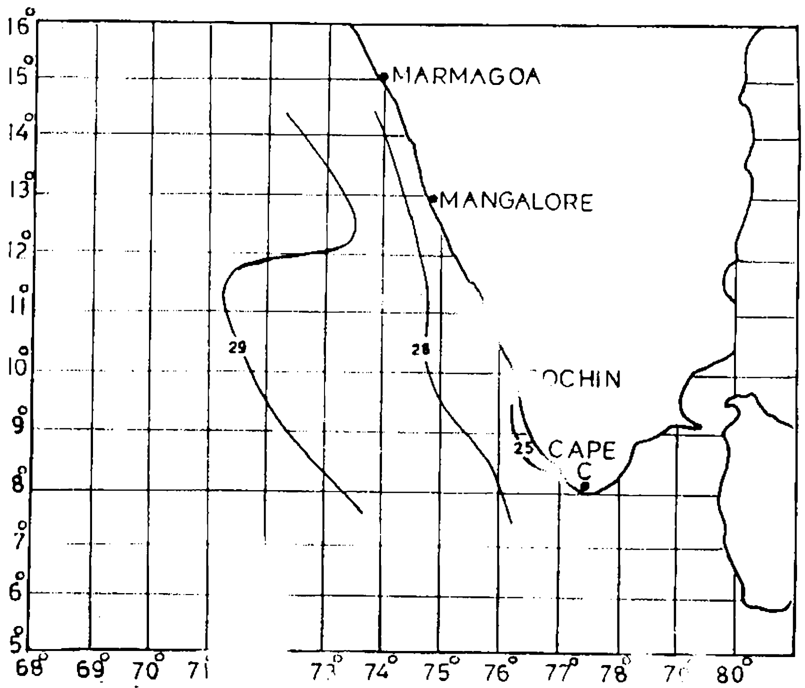
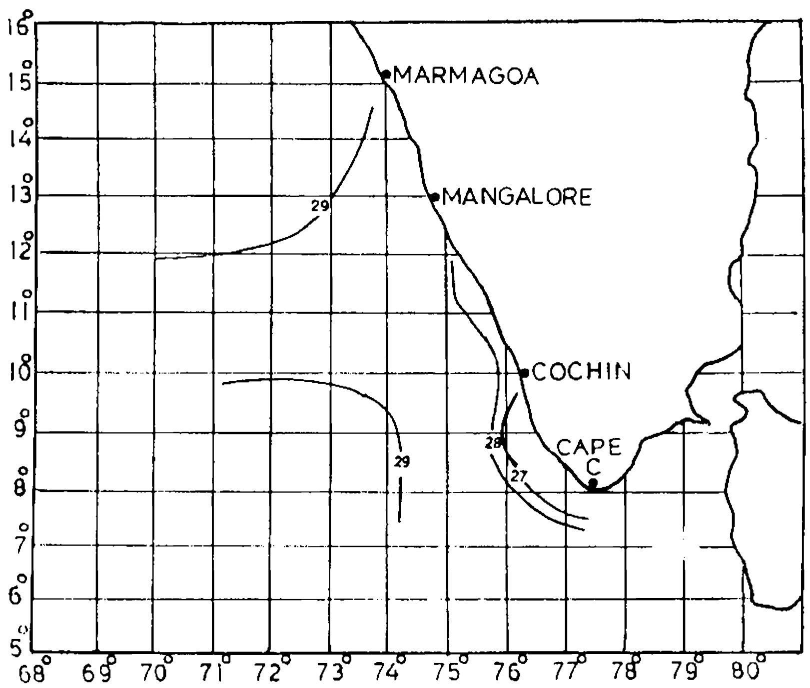
FIG. A.

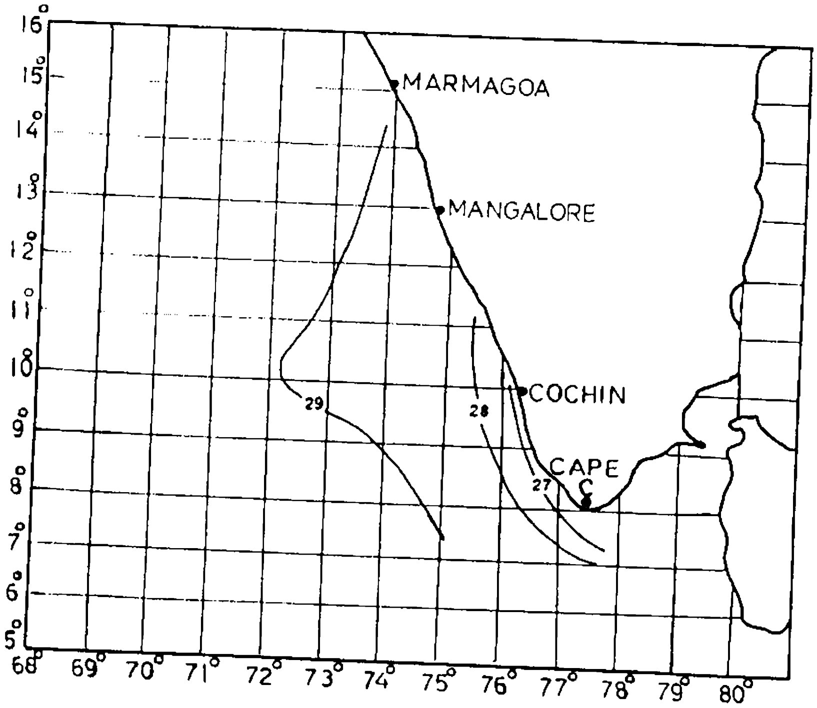


Horizontal variation of Sea surface Temperature (°C)
at 0600 hrs.



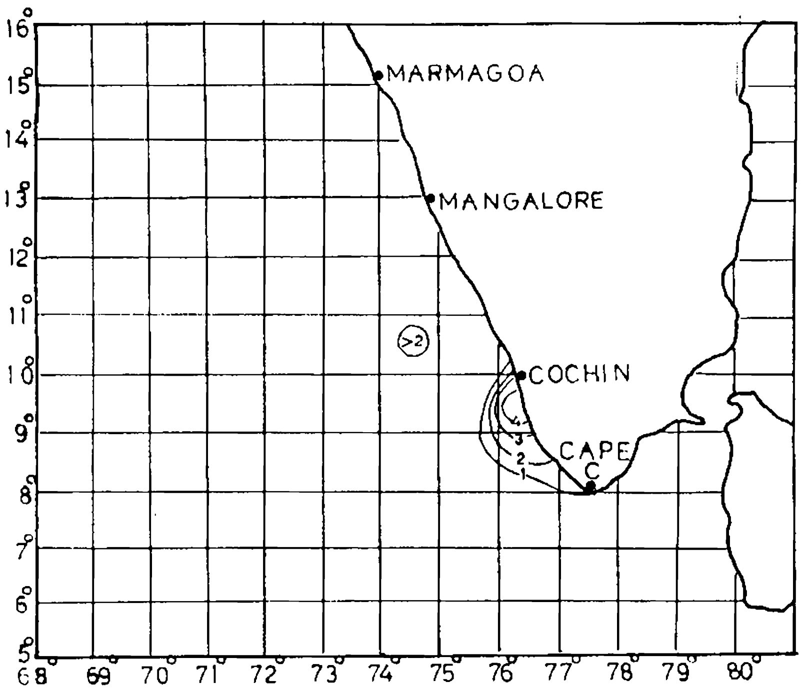
Horizontal variation of Sea surface Temperature (°C)
at 1200 hrs.

FIG. A



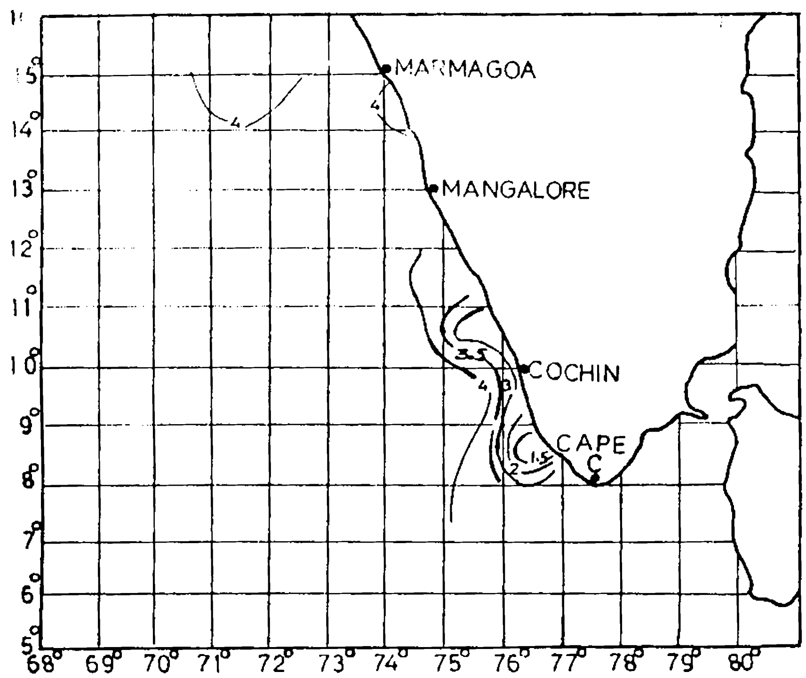
Horizontal variation of Sea surface Temperature (°C)
at 1800 hrs.

FIG. C

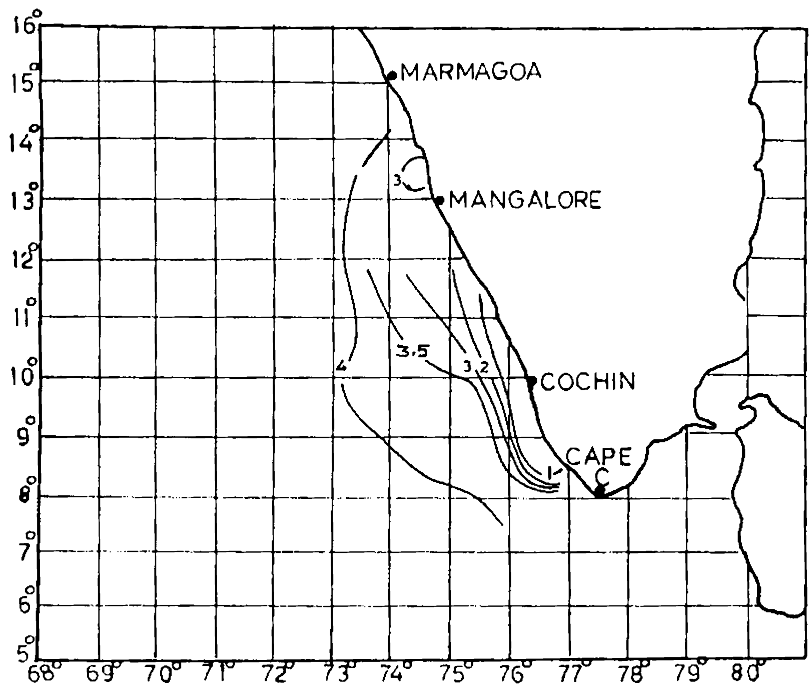


...izontal variation of Chlorophyll-a (mg/m^3) at sea surface
...d around the area of Possible upwelling activity.

FIG. B

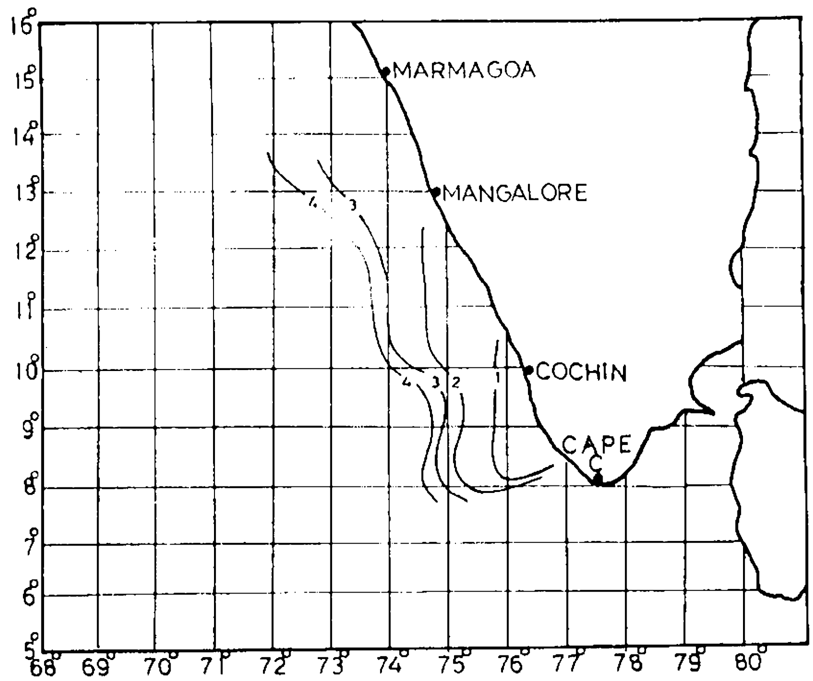


Horizontal variation of Dissolved oxygen content of Sea water at 10 m. (ml O_2/ L)

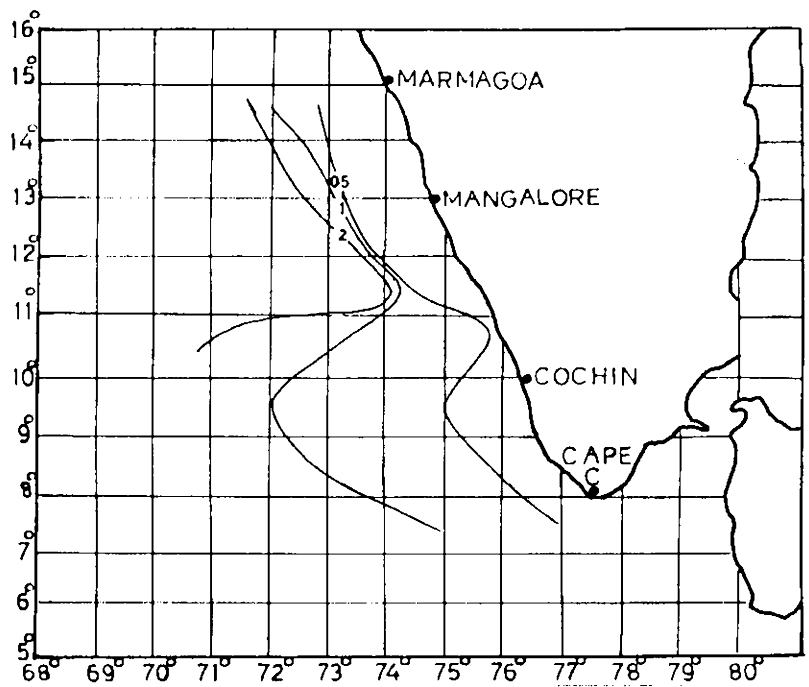


Horizontal variation of Dissolved oxygen content of Sea water at 30 m. (ml O_2/L)

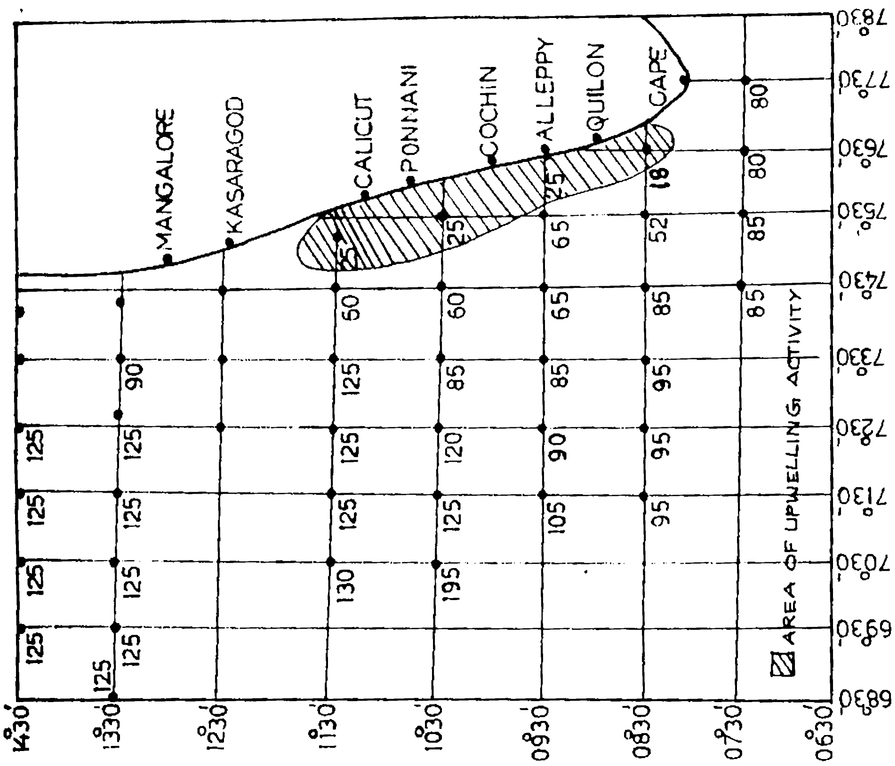
FIG. B



Horizontal variation of Dissolved oxygen content of Sea water at 50 m. (ml O_2/L)



Horizontal variation of Dissolved oxygen content of Sea water at 100m. (ml O_2/L)



Depths of occurence (m) of 23°C-isotherm at different stations as a possible indicator of the process - of upwelling (July, 1991).

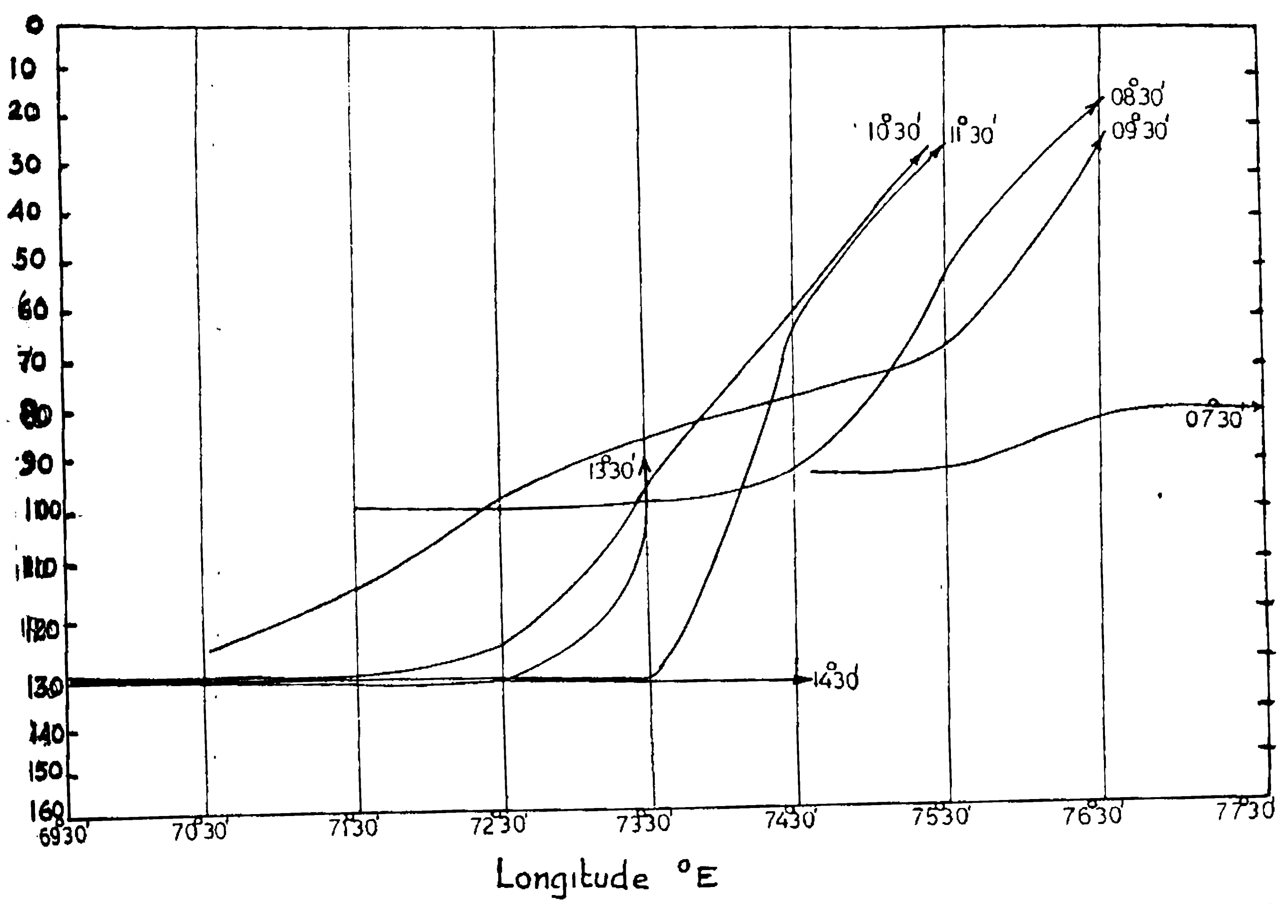


FIG. D

Vertical movement of 23°C-isotherm between Longitide 69°30'E and south-west coast of India during July, 1991 at different latitudes.

ESSENTIAL INGREDIENTS TO BE MONITORED TO STUDY THE 'CAUSE' AND 'EFFECT' OF COASTAL UPWELLING THE OCCURENCE, ABUNDANCE AND MIGRATION OF TARGET SPECIES OF FISH

Oceanographic factors

Sea water temperature (from vessels & satellites)

Salinity, Dissolved oxygen

Nutrients

Surface currents

Construction of vertical time sections

Computation of Vertical stability parameter

Horizontal distribution patterns

UPWELLING
(Location and intensity)

'CAUSE' & 'EFFECT' STUDIES

NUTRIENTS

PRIMARY PRODUCTION
(Chlorophyll-a, Phytoplankton (from vessels & satellites)

SECONDARY PRODUCTION
(Zooplankton)
(including egg & larval studies of target species)

TARGET SPECIES OF FISH
(Occurence, abundance and migration of individual species)

Meteorological factors

Wind (direction & velocity speed)

Rainfall

Cloudcover (type & amount)

Studies on sea level variations

(to check remote forcing of upwelling which appears to inhibit subsequent recruitment through exclusion of spawning fish from the neritic zone-observed in the case of oil sardine).

Annexure B

LIST OF PUBLICATIONS OF DR. V.NARAYANA PILLAI

A. FISHERIES OCEANOGRAPHY AND RELATED ASPECTS

Narayana Pillai, V. 1993. Possible relationship between the process of upwelling and zooplankton biomass in the shelf waters along the south west coast of India. (Under publication).

Narayana Pillai, V., & Rajagopalan, M.S. 1993. A possible method for the estimation of the intensity of the process of upwelling along the south west coast of India. (Under publication in the Indian Journal of Marine Sciences).

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POSSIBLE RELATIONSHIP BETWEEN THE PROCESS OF UPWELLING AND ZOOPLANKTON BIOMASS IN THE SHELF WATERS ALONG THE SOUTH WEST COAST OF INDIA.

V.Narayana Pillai *

ABSTRACT

An attempt is made to study the possible relationship between the process of upwelling and zooplankton biomass in the shelf waters along the south west coast of India between Cape comorin and Ratnagiri based on oceanographic and zooplankton data collected by the erstwhile FAO/UNDP Pelagic Fishery Project, Cochin between 1973 and 1978. Different factors such as the depth from which the bottom waters are induced upwards during the process of upwelling, the depth to which the bottom waters are drawn, vertical velocity of upwelling and the resultant zooplankton productivity were considered while arriving at the deductions. Except for nutrients and phytoplankton productivity, for which simultaneous data is lacking, all the major factors were taken into consideration before cocluding on positive/negative correlation.

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INTRODUCTION

In the sea, whereever nutrient rich subsurface waters are induced upwards towards the sunlit surface levels through the process of upwelling, it provides favourable environmental conditions for phyto plankton production followed by similar bloom in zooplankton production.

There is always a time lag between the arrival of nutrient rich subsurface waters at surface levels and the resultant phytoplankton and zooplankton production. This time lag is dependent on factors such as incoming radiation and the quantum of inorganic nutrients (Phosphates, nitrites, silicates etc.) readily available in the upwelled water to promote phytoplankton production. The time lag varies from year to year and also from place to place. This would mean that the time lag is likely to increase with the monsoon rain continuing with a cloudy sky, thereby reducing the incoming solar radiation.

The nutrient content of the upwelled water would depend on the depth from which it has originated and also the time taken by the waterbody to reach the surface levels. As regards upwelling indices and zooplankton biomass correlations, the phytoplankton form the first step, as many of the commercially important pelagic fishes are plankton feeders. A careful evaluation of the intensity and duration of upwelling and the physico-chemical characteristics of the upwelled water in a specific area may enable us to undertake a prediction of phytoplankton/zooplankton blooms and the possibilities of a good fishery for plankton feeding pelagic fishes.

DATA AND METHODS

The basic hydrographic and zopplankton biomass data collected durđng the period 1973-1978 onboard the fishery research vessels, RASTRELLIGER and SARDINELLA attached to the erstwhile FAO/UNDP Pelagic Fishery Project, Cochin were utilised in the present study.

Location of oceanographic sections/stations chosen for the present study are given in Figure-1. The number of times each station was covered by one of the above mentioned research vessels during the period 1973-1978 is given in Table-1. Stations within the continental shelf were fixed at an interval of 10 nautical miles at right angles to the coast line.

Zooplankton samples were collected employing standard sampling gear viz. BONGO-20 (20cm dia.) and BONGO-60 (60cm dia.) both fitted with nylon net of 0.5mm mesh size and equipped with calibrated flow meters. The BONGO nets were operated in continuous oblique hauls at minimum winch speed and 2-3 knots vessel speed. The samples were preserved in 5% formaline. From the flow meter readings and the measured wet displacement volumes of the samples the mean density of plankton in ml/m^3 of water filtered was computed.

Vertical time sections for sea water temperature and dissolved oxygen were found to be good indicators of the commencement, intensity and duration of the process of upwelling along the south west coast of India. The vertical oscillations of the 23^0C isotherm and 1ml O_2/L isoline for dissolved oxygen were utilised to arrive at the abovementioned parameters.

DISCUSSIONS

The eff ct of upwelling on the local fishery, to a great extent, depends on :

(1) The depth from which the upwelled water reaches surface levels

(2) The depth to which upwelled water is induced upwards.

(3) The nutrient content of upwelled water.

(4) The resultant phytoplankton/zooplankton activity.

(5) The vertical velocity of upwelling.

(6) The period for which the upwelled water remains at the surface levels retaining it's inherrent thermal, salinity dissolved oxygen and nutrient characteristics.

Out of the above, except for nutrients and phytoplankton activity, all other factors were considered while arriving at the conclusions.

Earlier work along these lines attempting a possible correlation between nutrients (Phosphate phosphorous) and monsoon in the coastal waters along the south west coast of India (off Calicut) during June-August by George (1953) has shown substantial increase in the phosphate content of surface waters during the south west monsoon period possibly caused by stormy weather conditions resulting in disturbances in the muddy bottom in shallow areas and the influence of fresh water which flows into the system through river runoff. Bhavanarayana and Lafond (1957) from a study of the nutrient changes, currents and meteorological conditions during upwelling period along the east coast of India concluded that the nutrient replenishment (phosphates and silicates) in spring is the result of vertical and horizontal circulation.

Figures 2A, 2B, 2C, 2D, 2E and 2F shows the relationship between the process of upwelling (in terms of vertical oscillations of the 23^0c isotherm and 1ml O_2/L isoline) and plankton biomass off Cape comorin, Quilon, Cochin, Kasaragod, Karwar and Ratnagiri during the period 1973/1975-1978.

In the present study the plankton biomass curve for Cochin section showed maximum values during July-August in 1976, 1977 and 1978. The minimum values were observed during November-March.

CONCLUSIONS

In general,it was found that the zooplankton biomass was comparatively high in areas where upwelling activity was intense.During July-August 1973,the zooplankton abundane was very significant between Kasaragod and Karwar and the increase was double fold when compared with values observed during July-August survey of 1977.

In spite of high upwelling velocities observed for Quilon and Cape comorin sections during the year 1977(July-August) supported by the other typical characteristics of comparatively low sea water temperature,high salinity and low dissolved oxygen content of bottom waters reaching the very surface,it was found that the plankton biomass at these stations did not indicate a proportionate increase during the following months. This was in sharp contrast with the condition off Cochin and Kasaragod where a proportionate increase in the zooplankton biomass was observed following the peak of upwelling. Perhaps the difference observed might be due to the comparatively low nutrient level of the upwelled water which reached the surface ;evels both off Quilon and Cape comorin. In the absence of comparable nutrient and phytoplankton data for the area covering the same period,it is difficult to arrive at any positive conclusions. This very important requirement points to the necessity of collecting simultaneous data on oceanographic parameters,nutrients phytoplankton and zooplankton biomass to gather the complete picture. The sea bottom in the shallower areas of the continental shelf between Quilon and Cape comorin is mostly rocky in contrast to the region north of Quilon where it is mostly muddy or mud mixed with sand which could be one of the possible basis causes for the comparatively higher nutrient content of these waters contributed through the disintegration of putrifying organic matter.

ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks to Dr.P.S.B.R.James, Director, CMFRI, Cochin and Dr.A.V.S.Murthy, Principal Scientist (Retd.), CMFRI, Cochin for their encouragement and interest in the present investigations.

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TABLE-1

COVERAGE OF DIFFERENT OCEANOGRAPHIC SECTIONS/STATIONS DURING THE PERIOD 1973-1978

Sections	No. of coverages made						Total coverages
	1973	'74	'75	'76	'77	'78	(1973-'78)
Ratnagiri	5	7	5	1	3	2	23
Karwar	8	6	5	6	3	3	31
Kasaragod	7	6	5	5	2	2	27
Cochin	10	9	9	6	5	5	44
Quilon	7	7	5	2	1	2	24
Cape comorin	6	7	6	4	2	2	27

LEGEND TO FIGURES

Fig.1.Map showing location of oceanographic/plankton stations/ sections

Fig.2A.Relationship between the process of upwelling and zooplankton biomass off Cape comorin during the period 1973-1975.

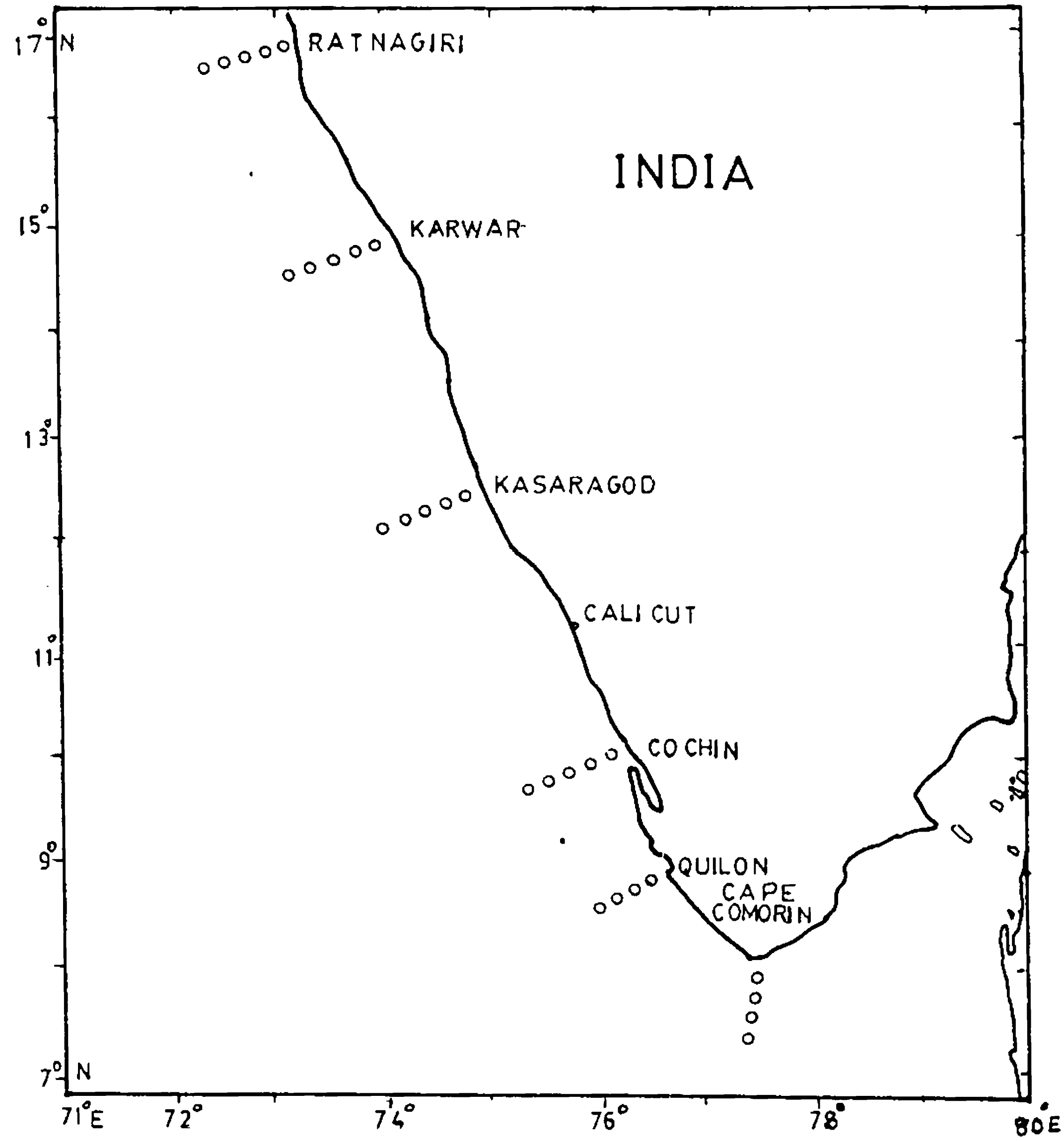
Fig.2B.Do. off Quilon during the period 1973-1975.

Fig.2C.Do. off Cochin during the period 1973-1978.

Fig.2D.Do. off Kasaragod during the period 1973-1975.

Fig.2E.Do. ofr Karwar during the period 1973-1975.

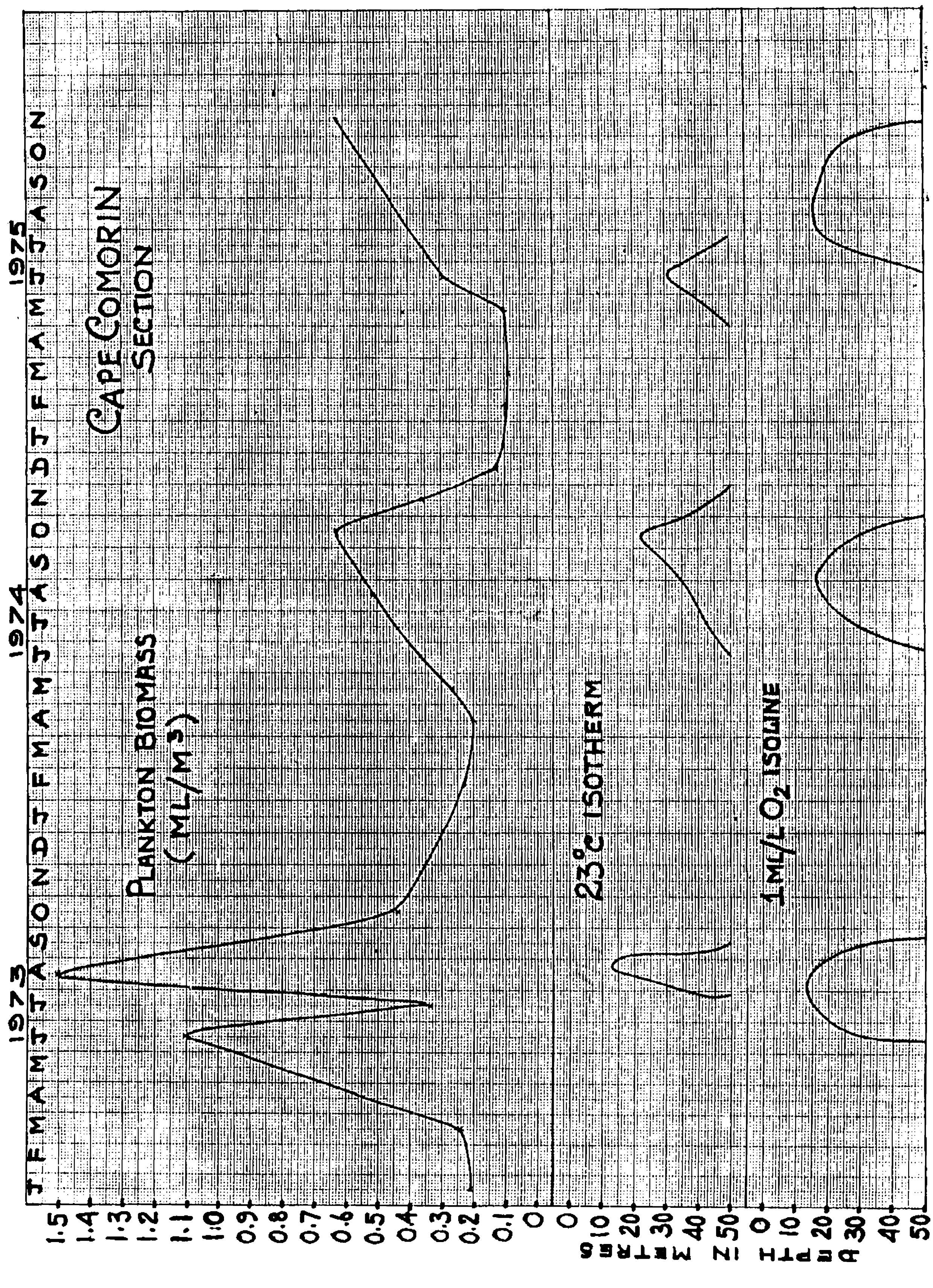
Fig.2F.Do. off Ratnagiri during the period 1973-1975.



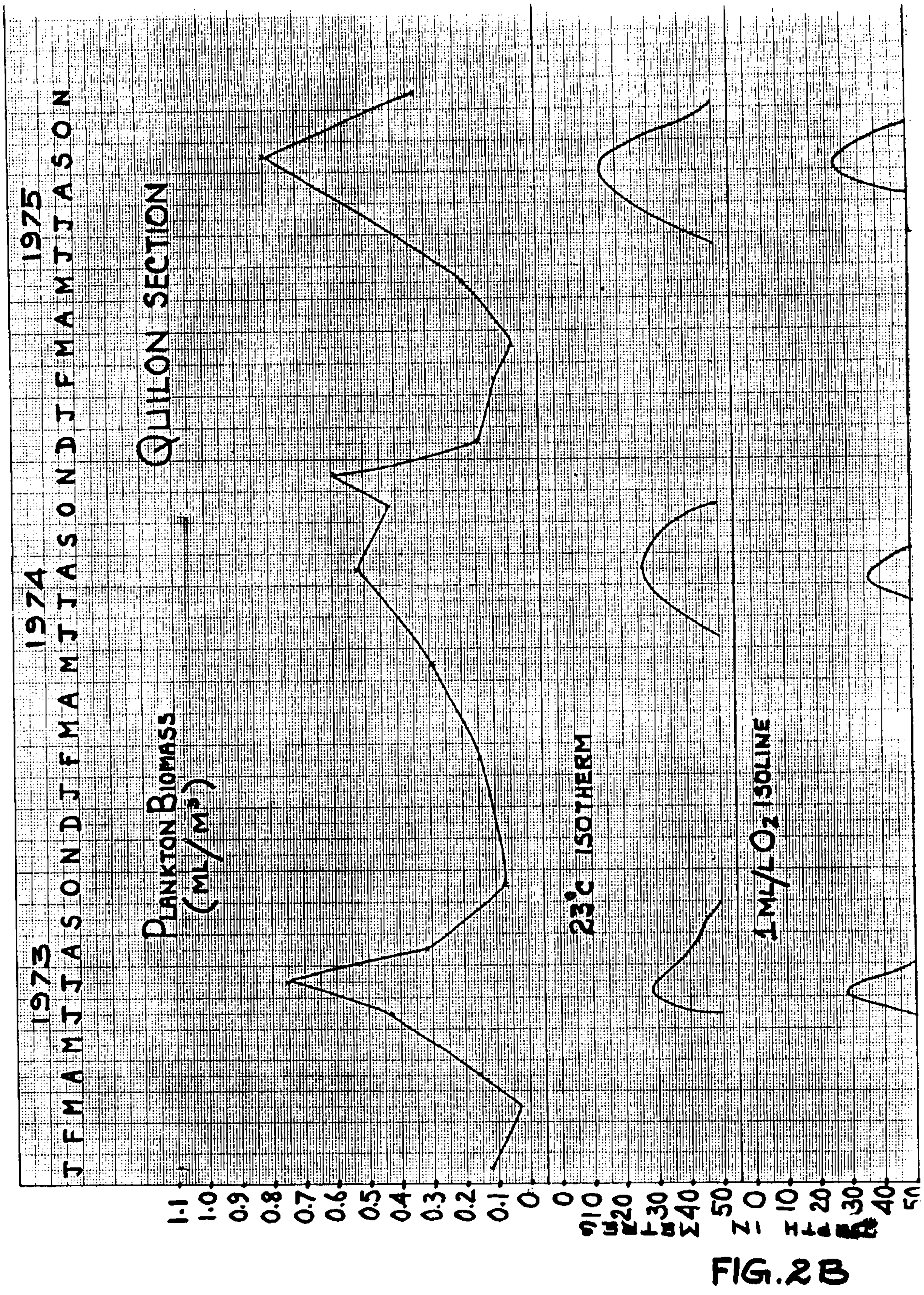
INDIA
RATNAGIRI
KARWAR
KASARAGOD
CALI CUT
CO CHIN
QUILON
CAPE
COMORIN
17° N
15°
13°
11°
9°
7° N
71°E
72°
74°
76°
78°
80°E

FIG. 1.

FIG.2A

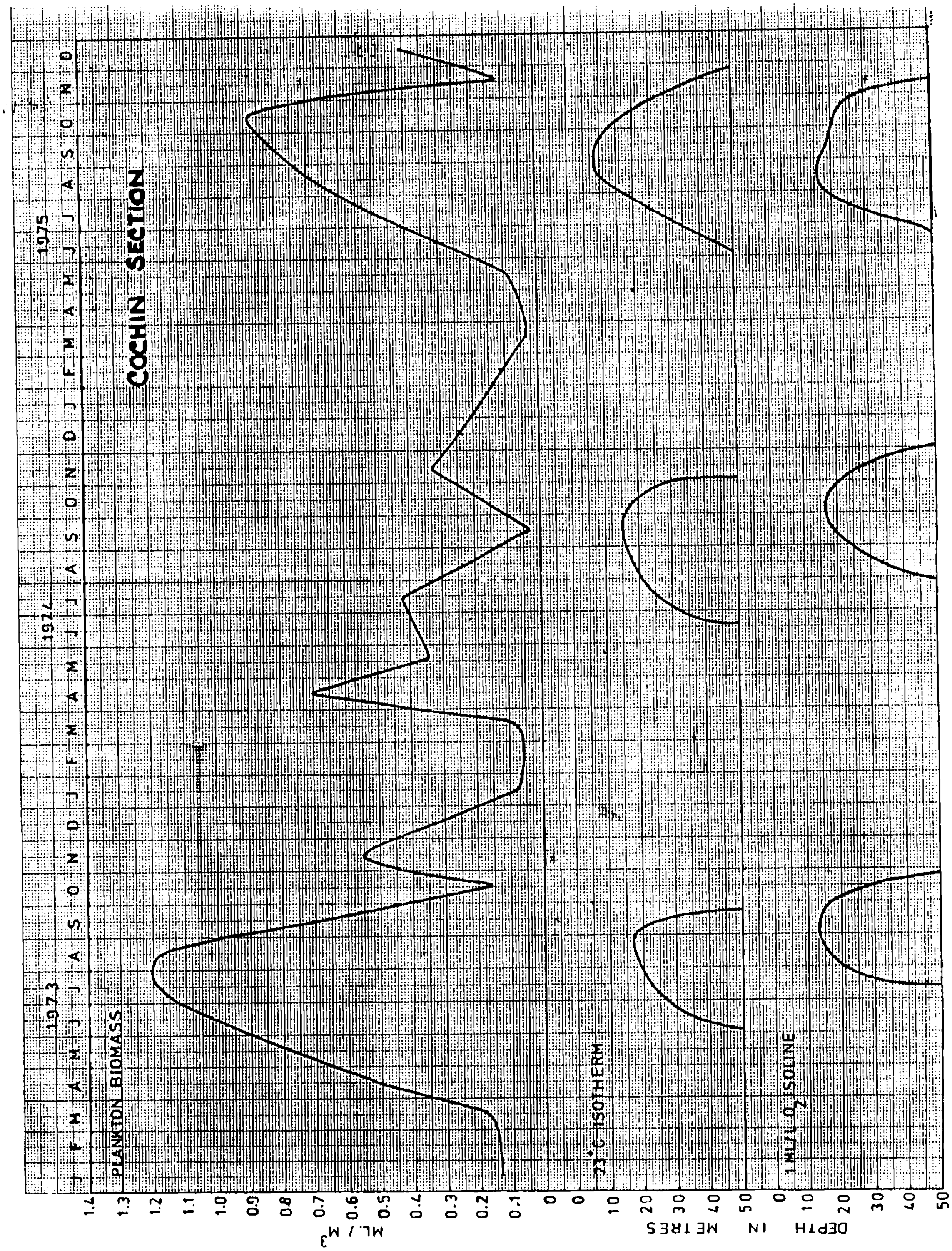


CAPE COMORIN
SECTION
PLANKTON BIOMASS
(ML/M³)
23°C ISOTHERM
1 ML/L O2 ISOLINE
DEPTH IN METRES
1973
1974
1975
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N
1.5 1.4 1.3 1.2 1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 10 20 30 40 50
0 10 20 30 40 50



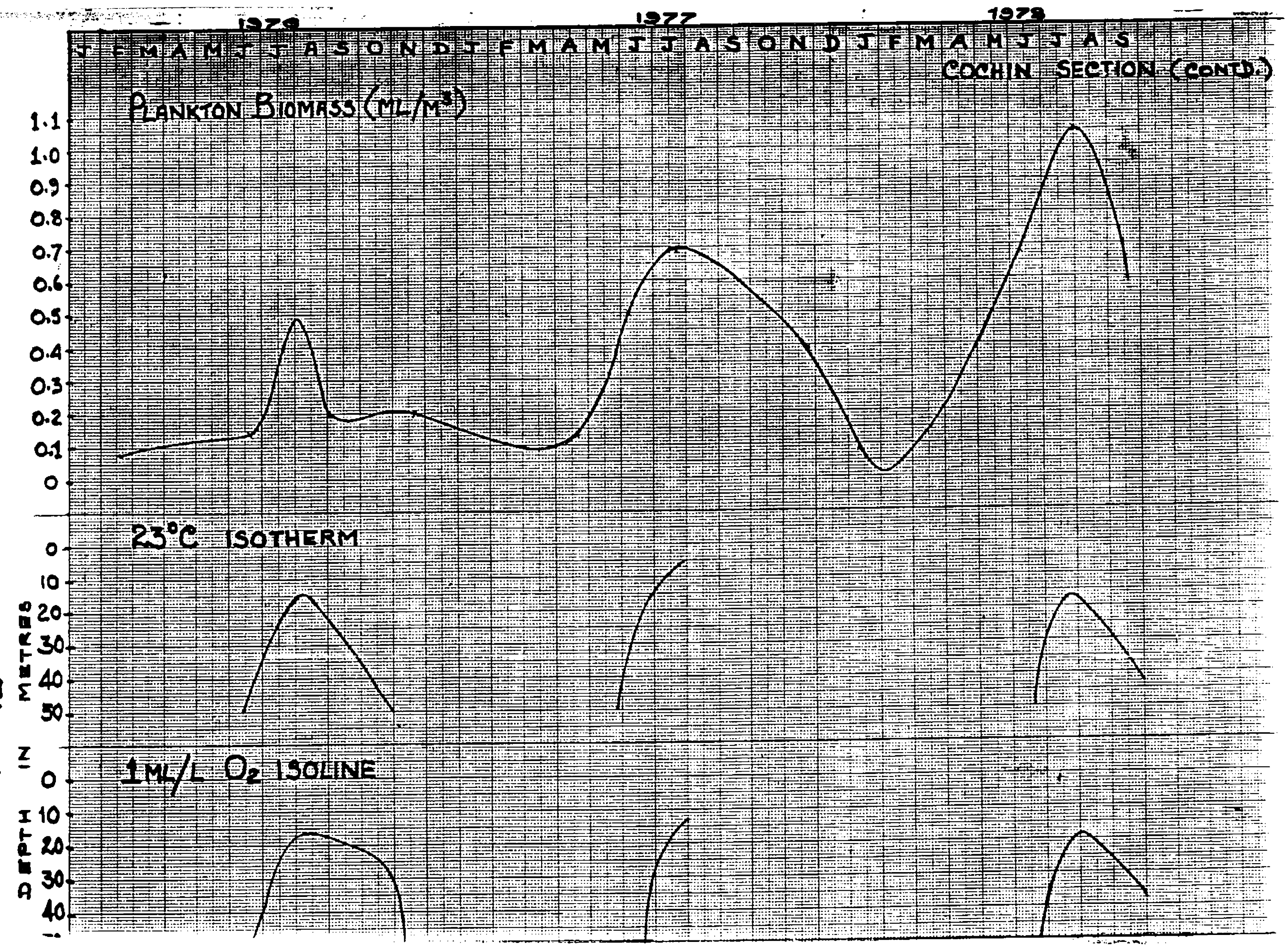
1973
1974
1975
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N
QUILON SECTION
PLANKTON BIOMASS
(ML/M³)
23°C ISOTHERM
1 ML/L O2 ISOLINE
DEPTH IN METRES

FIG.2B



COCHIN SECTION
1973
1974
1975
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
PLANKTON BIOMASS
23°C ISOTHERM
1 ML/L O_2 ISOLINE
1.4 1.3 1.2 1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
ML / M^3
0 10 20 30 40 50
DEPTH IN METRES

FIG.2.C



1976
1977
1978
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
COCHIN SECTION (CONTD.)
PLANKTON BIOMASS (ML/M³)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
23°C ISOTHERM
0
10
20
30
40
50
DEPTH IN METRES
1ML/L O₂ ISOLINE
0
10
20
30
40

FIG. 2.C (CONTD)

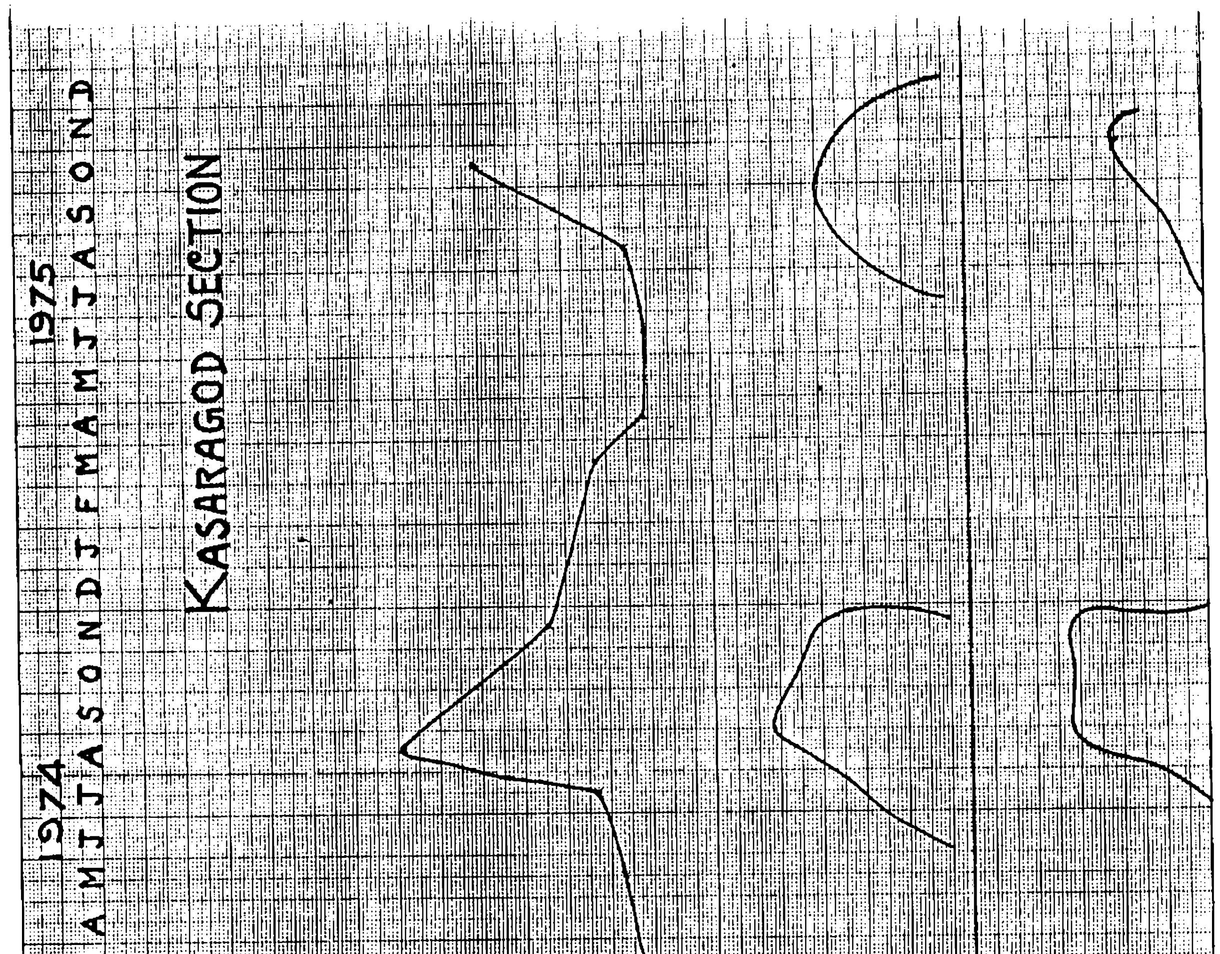

1973
1974
1975
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
KASARAGOD SECTION
PLANKTON BIOMASS (ML/M³)
23°C ISOTHERM
1ML/L O₂ ISOLINE
1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 10 20 30 40 50
0 10 20 30 40 50
DEPTH IN METRES

FIG. 2D.

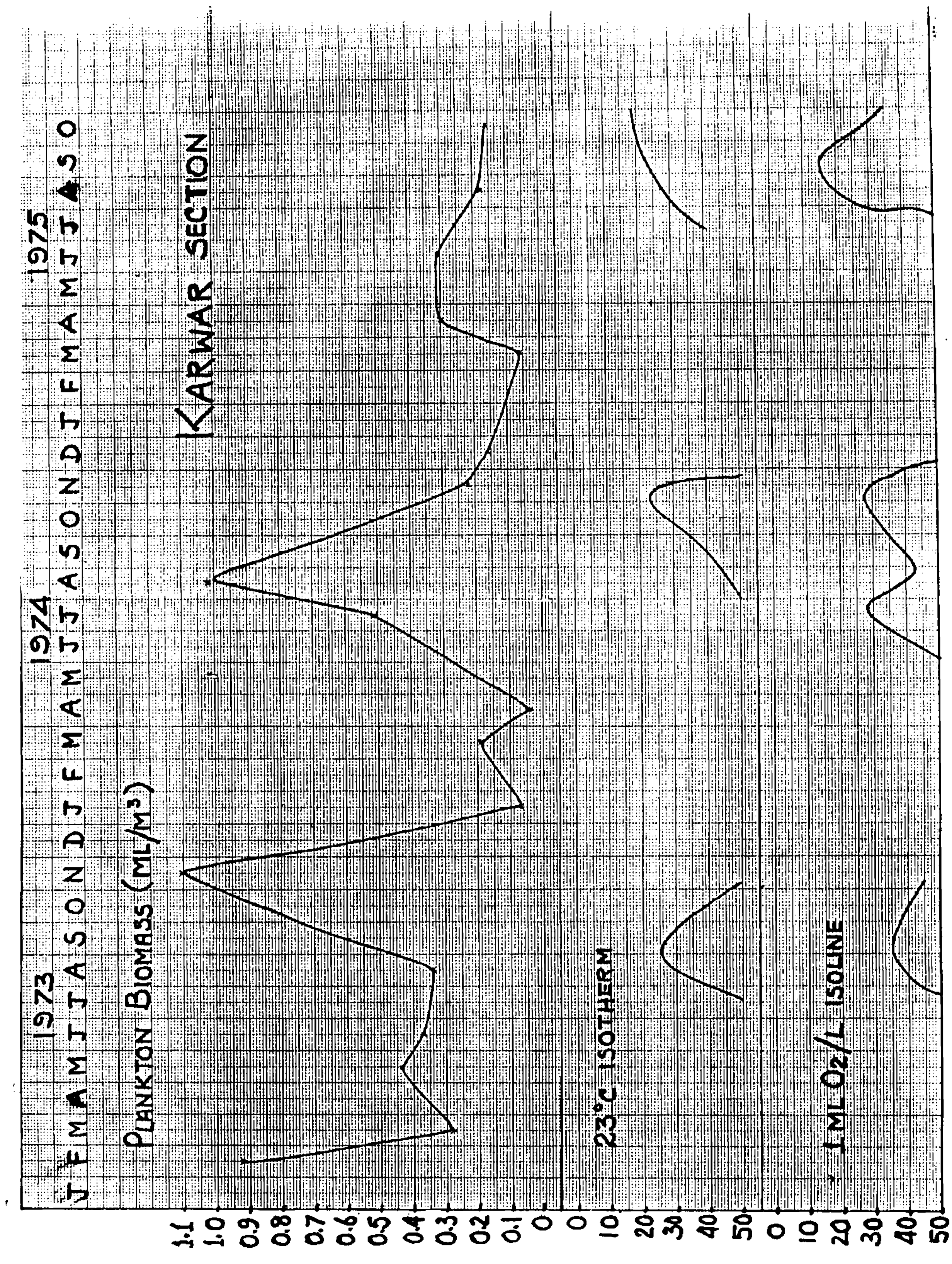
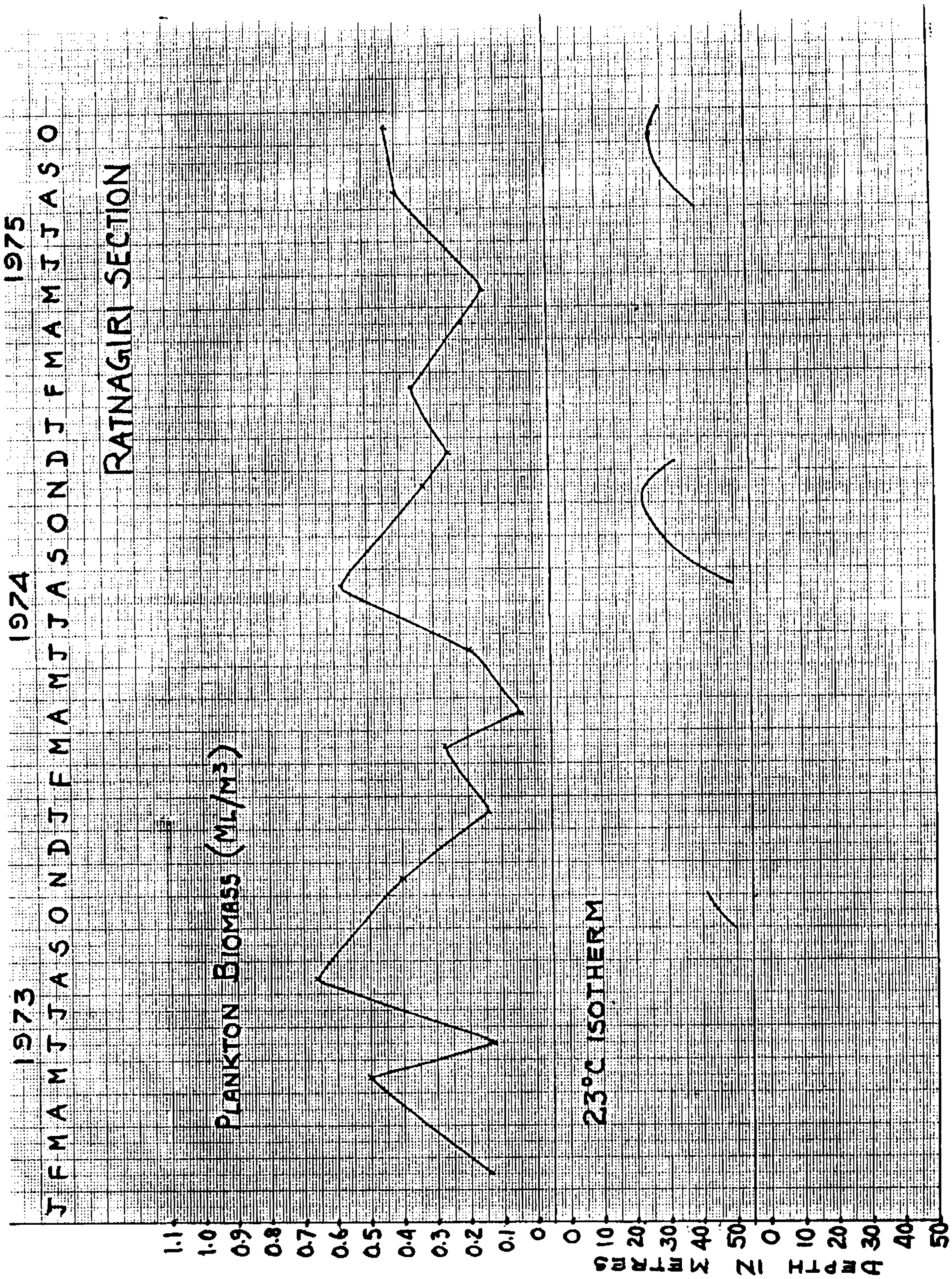

KARWAR SECTION
1973
1974
1975
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
PLANKTON BIOMASS (ML/M³)
23°C ISOTHERM
1 ML O2/L ISOLINE
1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 10 20 30 40 50
0 10 20 30 40 50

FIG. 2E



1973
1974
1975
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
RATNAGIRI SECTION
PLANKTON BIOMASS (ML/M³)
23°C ISOTHERM
1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 10 20 30 40 50
0 10 20 30 40 50
DEPTH IN METRES

FIG.2.F.

A POSSIBLE METHOD FOR THE ESTIMATION OF THE INTENSITY OF THE PROCESS OF UPWELLING ALONG THE SOUTH WEST COAST OF INDIA.

V. NARAYANA PILLAI * AND M.S.RAJAGOPALAN **

ABSTRACT

A study of the variations in the vertical movement of different isotherms within the continental shelf along the south west coast of India revealed that 23 C isotherm exhibited maximum oscillations. An attempt is made to compute the net upward movement of 23 C isotherm in terms of upwelling velocity along the coast during the south west monsoon season. The phenomenon of upwelling along the south west coast is known to influence the pelagic fisheries in the region by way of increasing the productivity of the euphotic zone thereby promoting phytoplankton and zooplankton productivity in the area under study.

INTRODUCTION:

Upwelling is an important process in the sea whereby the comparatively cooler, high saline and nutrient rich subsurface waters are induced upwards towards the surface layers. This phenomenon is of great significance in the biological productivity of the sea. The reson for higher production in the upwelling area is the high fertility effected by the basic nutrient salts (nitrates, silicates, phosphates etc) which are brought upwards into the euphotic zone resulting in the development of large populations

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of phytoplankton, Zooplankton and higher organisms Induced upwelling is conspicuous along the coasts of Morocco, California, north west and south west Africa and Peru (Sverdrup et al 1942) Coastal upwelling areas lie mostly along the western coasts of the continents. The above mentioned localities and the west coast of India, expecially the south west coast are good examples of such areas. Exception to this pattern are found along the north eastern African coast, somali coast, east coast of Arabia and east coast of India. Localised upwelling is found around areas of divergences. Whereever upwelling is influenced by monsoon wind system and accompanying currents, the phenomenon is more seasonal.

The economic benefit of upwelling is mainly due to the large concentrations of commercially important fishes in these areas. Most of these resources consist of clupeoid fishes with short food chains (feeding on phyto and zooplankton) and their predators like Tunas.

The best example of highly productive upwelling area is the coast off Peru with its tremendous catches of Anchoveta. Other important productive upwelling areas are the south west African coast with its rich fisheries for pilchard and California coast with the sardines. It is well known that major pelagic fishery resources of India like Oil sardine and mackerel lie along the south west coast, where regular seasonal upwelling is prevalent. It is estimated that the upwelling areas of the world, a little over 0.1% of the ocean surface, produce about half the world's fish supply.

Upwelling in varying intensities has been observed along the west and east coast of India. The occurence of the phenomenon corresponds to the onset of the south west monsoon (Summer monsoon) and the effect of the monsoon wind system and the resulting current system on the shelf waters.

Along the south west coast of India, the causative factors which bring up the subsurface waters to the surface levels vary in space and time. The process of upwelling starts as early as February at the bottom levels. It starts at the different locations at different times each year. The commencement of the process in February was possibly initiated by the northerly winds which would transport the surface water away from the coast there by initiating the vertical ascending motion from below. Perhaps the depth at which the motion gets started, would to a great extent, depends upon the velocity, direction and duration of the [illegible] wind system in the [illegible]ty, the bottom topography, the prevailing current system at the surface levels and also the vertical stability of the water column. The speed of the ascending motion also would depend on the continuance of the above mentioned favourable factors with more or less the same intensity. A closer examination of the prevailing wind system during the south west monsoon season revealed the presence of favourable northerly and north westerly components in certain localities where the upwelling intensity also showed correspondingly higher values.

DATA AND METHODS

Oceanographic data collected onboard Research vessels ''RASTRELLIGER'' and ''SARDINELLA'' belonging to the erstwhile UNDP/FAO pelagic Fishery Project, Cochin during the period' 1971-78 ~~was~~ were made use of in the present study. Oceanographic data collected from stations fixed at an interval of about 18 km on the continental shelf along sections located off Cape comorin, Quilon, Cochin, Kasaragod, Karwar and Mangalore was made use of in the present study (Fig.1). Vertical time sections of sea water temperature drawn for the different sections representing the southern region (Cape comorin and Quilon) central region (Cochin and Kasaragod) and the northern region (Karwar and Ratnagiri) were made use of to compare the variations noticed in the vertical movement of the various isotherms in time and spane. (Figures 2 A and 2 B). The net vertical movement was estimated from the oseillations of the 23°C isotherm which exhibited the maximum movement on the vertical plane. Vertical velocity of upwelling at the different sections was approamately estimated after taking into consideration the upward movement of the 23°C isotherm which exhibited maximum oscillations on the vertical plane and also the time taken to complete the said motion.

DISCUSSION:

The upward titling exhibited by the ~~x~~ 23°C isotherm in the vertical time sections prepared for cape comorin, Quilon, Cochin, Kasaragod, Karwar and Ratnagiri sections clearly indicated the occurrence and intensity of the upwelling phenomenon in the area under study.

...5/-

Vertical velocity of upwelling at the different sections was approximately estimated after taking into consideration the net upward movement of the 23°C isotherm and the time taken to complete the said motion.

It was evident from the time sections for sea water temperature that the process of upwelling commenced earlier(January-February) in deeper (170 m) waters at different sections. The intensity of upwelling was comparatively higher towards south expecially in the area south of Karwar.

Fig. 3 gives a diagramatic representation of the rate of the upward movement in cm/day of 23°C isotherm sectionwise/yearwise (1973-78) The rate of ascent of the isotherm has been calculated from the vertical distance travelled and the number of days taken to cover the distance (Table I) A comparison of the velocity at the different sections. According to Banse (1963), upwelling which begins with the south-west monsoon causes an uplift of the 20°C isotherm by 20-100 m and regular upwelling to the surface is unknown north of 15°N ~~lat~~ in different years indicated large variations in the onset, intensity and duration of upwelling in different years at different sectors.

The estimates indicated that upwelling was strongest dueing 1977 with vertical velicities ranging from 65.4 cm/day to 865cm/day in the area between Kasaragod and cape comorin, North of Kasaragod, both off Karwar and Ratnagiri, the intensity was comparatively less throughout the period, the highest being 55.7 cm/day and 56.3 cm/day during 1973 and 1975 respectively. The least depth of occurence of 23°C isotherm was the minimum associated with the highest velocity showing an inverse relationship between the two parameters.

...6/-

Off Cochin, Quilon and Cape comorin the isotherm reached depths of 7 m, Om and Om corresponding to the highest velocities of 73.6 cm. 83.0 cm and 86.5 cm/day respectively. According to Mc Even (1934) the rate of upwelling in the region off San Diego computed from serial temperatures was about 66 cm/day. Figures 2 A and B throw light on the depth at which the 23°C isotherm started tilting towards the surface earch year at the different sections, the approximate duration and also the shallowest depth where the isotherm reached at the cessation of the upwelling process. The figures also indicate the net upward motinn at the different sections in the different years.

Yoshida and Mao (1957) found that a measure of the increase in the density of sea water at a depth of 150 m is proportional to the intensity of upwelling along the California coast. A similar correlation was attempted for the area under study; but the result did not indicate a defenite correlation.

CONCLUSIONS: A study of the variations noticed in the vertical movement of various isotherms in time and space within the area under observation revealed that the 23°C isotherm exhibited maximum oscillations on the vertical plane. An estimate of the upwelling velocity during the south-west mansoon season based on the net upward motion of the 23°C isotherm at the different sections has shown strong upwelling in the area between Kasaragod and Cape comorin with vertical velocities ranging from 65.4 cm/day to 86.5 cm/day. The least depth of occurence of 23°C isotherm was the minimum associated with the highest velocity showing an inverse relationship between the two parameters. The upwelling velocities estimated for the area very well compared with those estimated for the SanDiego coast by MC Even from serial temperatures. (66 cm/day)

ACKNOWLEDGEMENTS:

The authors wish to express their sincere gratitude to Dr. P.S.B.R. James, Director, C.M.F.R.I., Cochin for his encouragement and interest in the present study.

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Legend to figures

Fig. I Location of sections/stations

Fig. 2 A. Diagramatic representation of the extent and duration of vertical tilting of the 23°C isotherm secionwise/ yearwise. (Cape Comorin, Quilon, Cochin- 1973 - 1978).

Fig. 2 B. Diagramatic representation of the extent and duration of vertical tilting of the 23°C isotherm sectionwise/ yearwise. (Kasaragod, Karwar, Ratnagiri - 1973-1978).

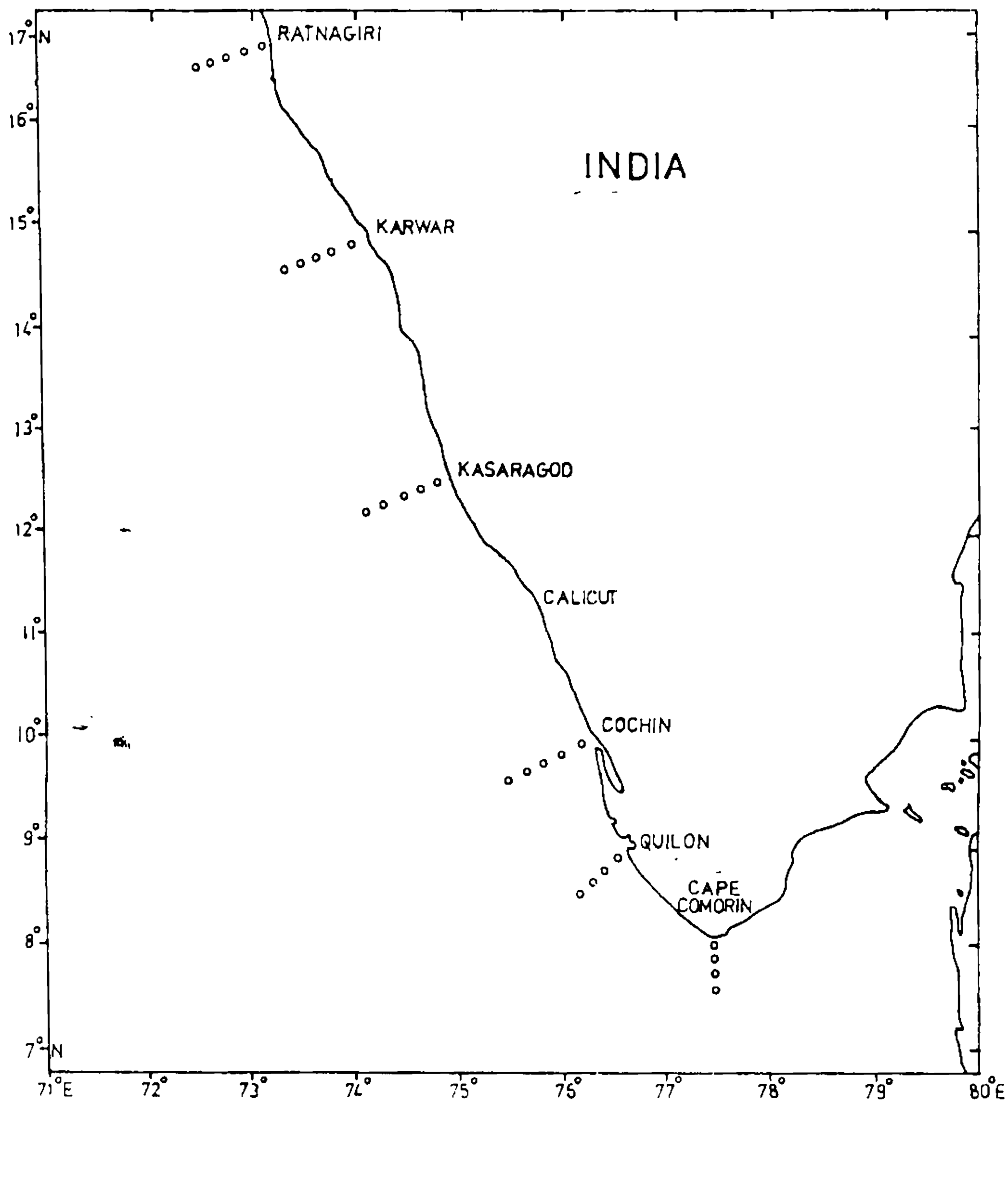
Fig. 3. Diagramatic representation of the upwelling velocity (cm/day) off Cape Comorin, Quilon, Cochin, Kasaragod, Karwar and Ratnagiri during the period 1973-1978.

Table I

Upwelling intensity (sectionwise/yearwise) based on the vertical movement of 23°C isotherm (1973 - 1978).

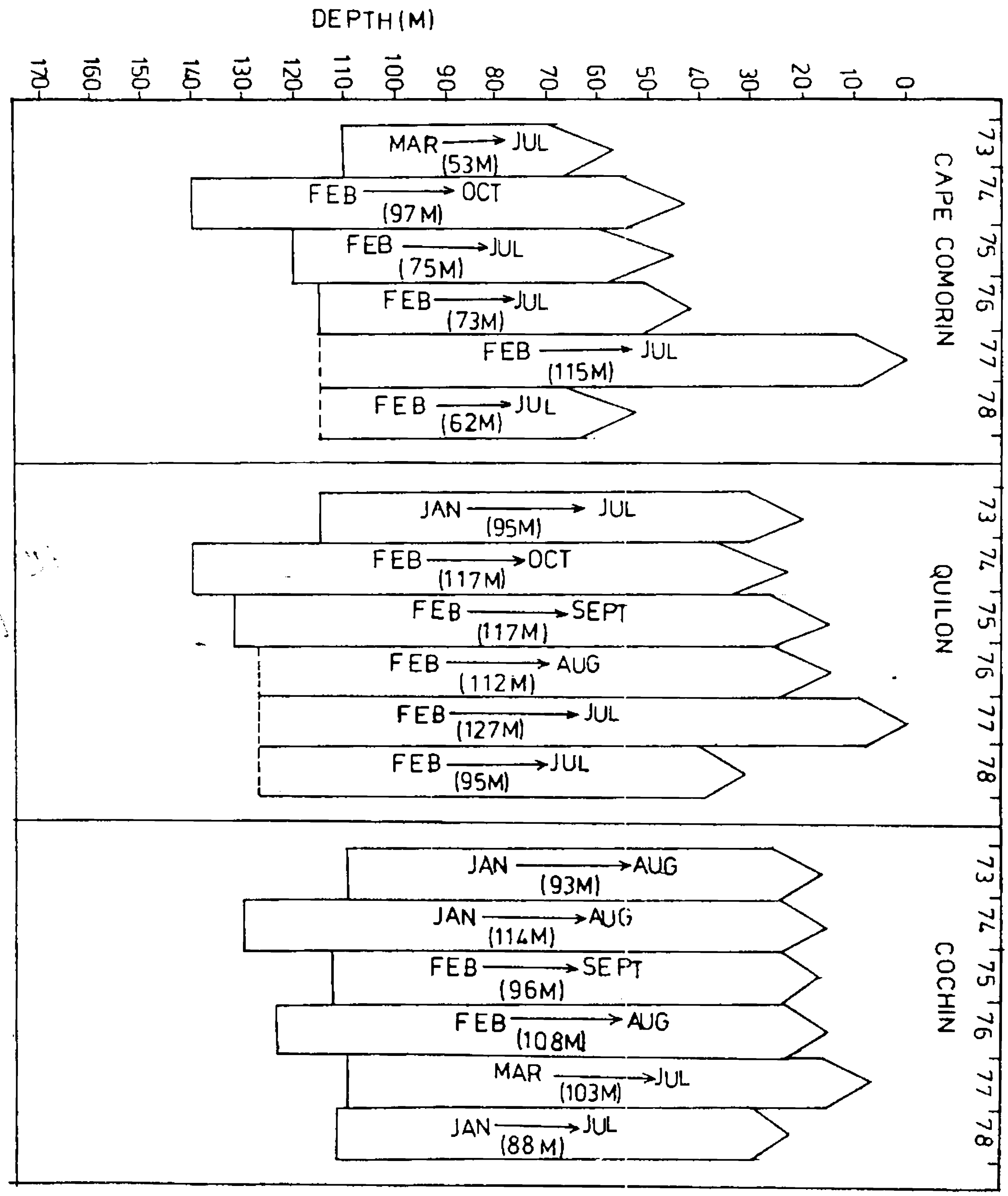
Section	Year	Duration (days)	Upward movement (m)	Speed (Cm)	Last depth (m) for 23°C Isotherm
Cape Comorin	1973	109	53	48.6	57
	1974	239	97	40.6	43
	1975	155	75	48.4	45
	1976	159	73	43.9	42
	1977	133	115	86.5	0
	1978	157	62	39.5	33
Quilon	1973	170	95	55.9	20
	1974	238	117	49.2	23
	1975	194	117	60.3	23
	1976	164	112	68.3	15
	1977	153	127	83.0	0
	1978	160	95	59.4	32
Cochin	1973	211	93	44.1	17
	1974	212	114	53.8	16
	1975	195	96	49.2	17
	1976	167	108	64.7	16
	1977	140	103	73.6	7
	1978	201	88	43.8	24
Kasaragod	1973	173	101	58.4	27
	1974	217	78	35.9	32
	1975	155	92	59.4	30
	1976	205	127	62.0	17
	1977	179	117	65.4	27
	1978	186	117	62.9	27
Karwar	1973	201	112	55.7	16
	1974	290	86	29.7	34
	1975	239	103	43.1	35
	1976	209	86	41.1	48
	1977	240	112	46.7	22
	1978	249	119	47.8	15
Ratnagiri	1973	262	75	28.64	50
	1974	290	66	22.8	50
	1975	240	125	56.3	45
	1976	-	-	-	-
	1977	202	100	49.5	70
	1978	220	100	45.5	70

Fig. 1.



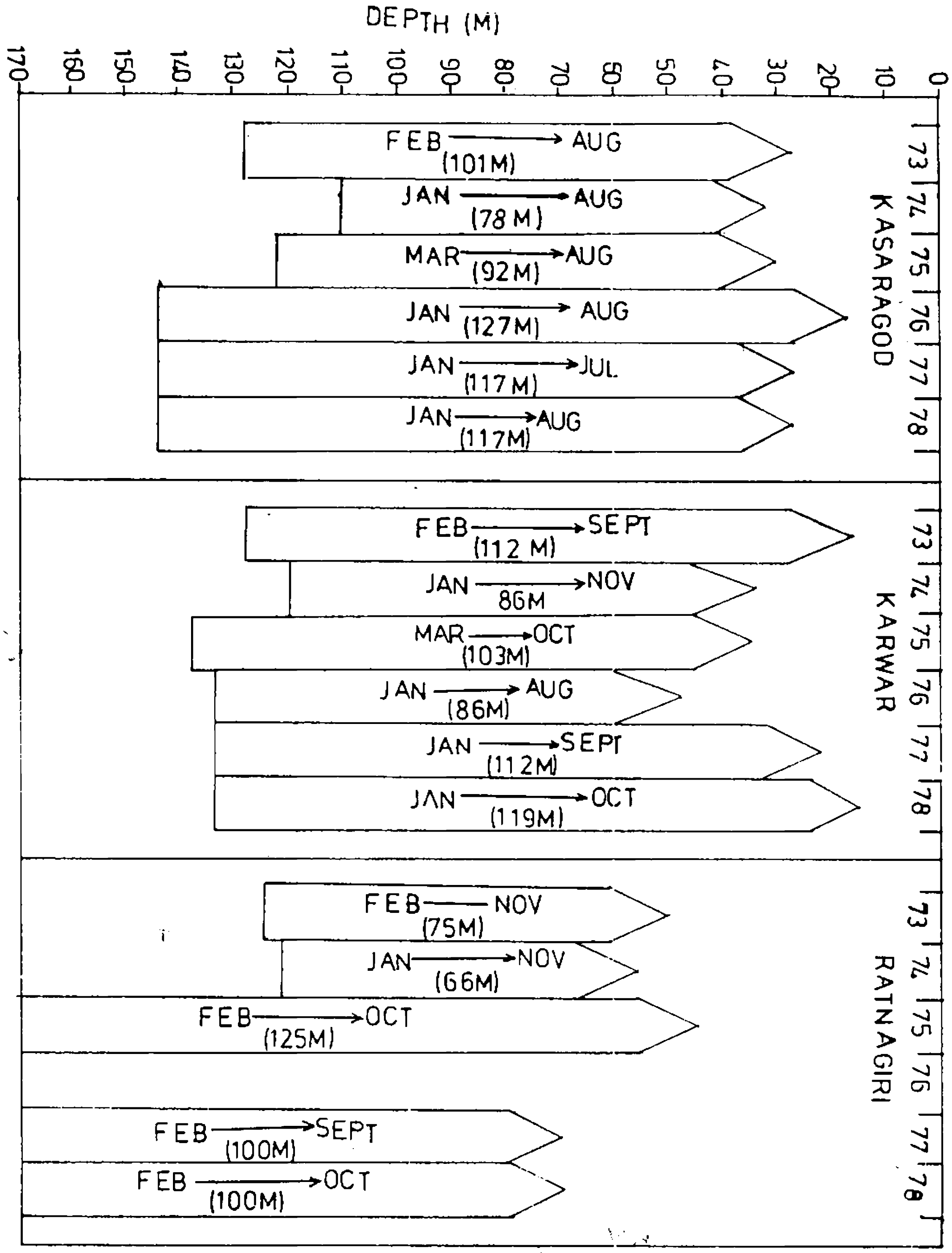
RATNAGIRI
INDIA
KARWAR
KASARAGOD
CALICUT
COCHIN
QUILON
CAPE
COMORIN
17°N
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°N
71°E
72°
73°
74°
75°
76°
77°
78°
79°
80°E

FIG 2A



DEPTH (M)
CAPE COMORIN
QUILON
COCHIN
MAR → JUL (53M)
FEB → OCT (97M)
FEB → JUL (75M)
FEB → JUL (73M)
FEB → JUL (115M)
FEB → JUL (62M)
JAN → JUL (95M)
FEB → OCT (117M)
FEB → SEPT (117M)
FEB → AUG (112M)
FEB → JUL (127M)
FEB → JUL (95M)
JAN → AUG (93M)
JAN → AUG (114M)
FEB → SEPT (96M)
FEB → AUG (108M)
MAR → JUL (103M)
JAN → JUL (88 M)

FIG. 2 B



DEPTH (M)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
KASARAGOD
73
74
75
76
77
78
FEB → AUG
(101M)
JAN → AUG
(78 M)
MAR → AUG
(92 M)
JAN → AUG
(127M)
JAN → JUL
(117 M)
JAN → AUG
(117M)
KARWAR
FEB → SEPT
(112 M)
JAN → NOV
86M
MAR → OCT
(103M)
JAN → AUG
(86M)
JAN → SEPT
(112M)
JAN → OCT
(119M)
RATNAGIRI
FEB — NOV
(75M)
JAN → NOV
(66M)
FEB → OCT
(125M)
FEB → SEPT
(100M)
FEB → OCT
(100M)

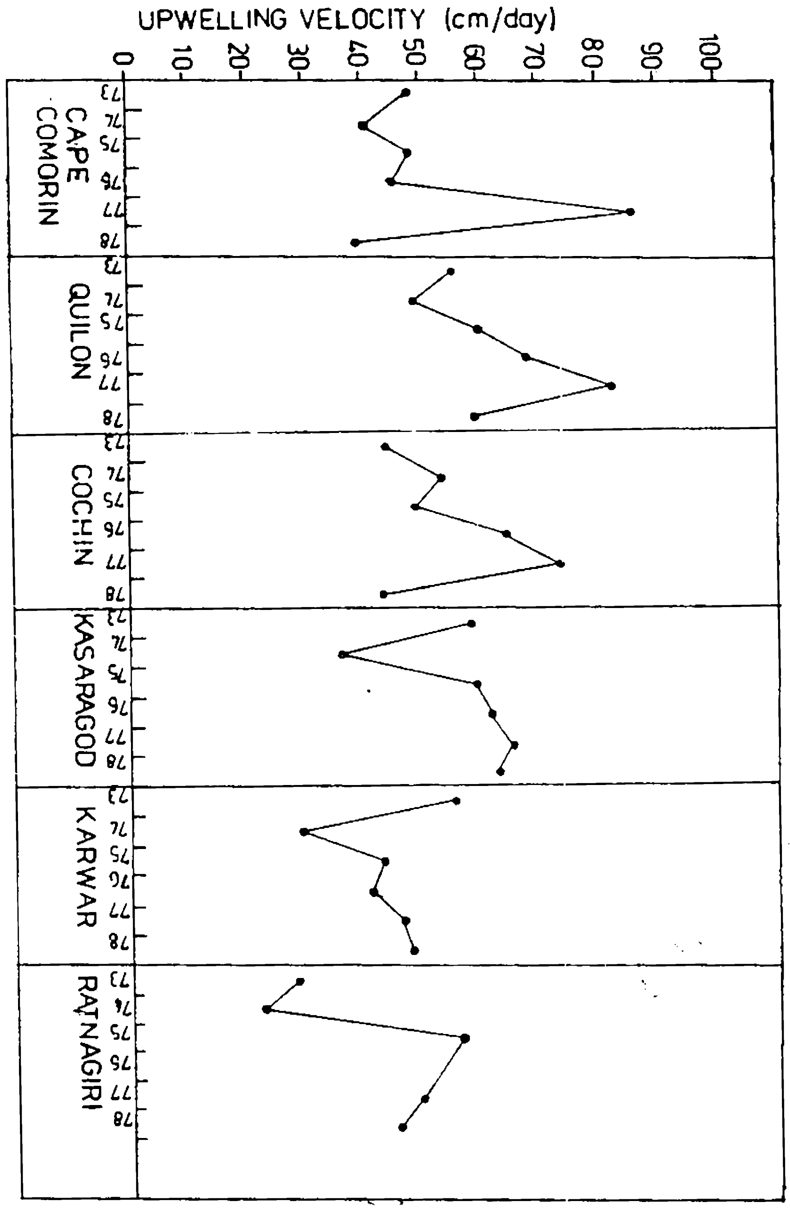

UPWELLING VELOCITY (cm/day)
0
10
20
30
40
50
60
70
80
90
100
CAPE COMORIN
QUILON
COCHIN
KASARAGOD
KARWAR
RATNAGIRI
73
74
75
76
77
78

FIG. 3

Variations in dissolved oxygen content of coastal waters of the southwest coast of India in space and time.

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A B S T R A C T

Dissolved oxygen content of coastal waters along the southwest coast of India between Cape Comorin and Ratnagiri was studied along 6 sections for 8 years. Vertical time sections were used to compare variations noticed in the vertical oscillation of oxygen minimum layer in space and time. Isoline of maximum vertical oscillation,net vertical movement of oxygen minimum layer and areas of possible upwelling activity were also delineated.

Introduction:

Dissolved oxygen content of seawater plays an important role in controlling the distribution of fish in marine environment. This is especially the case with pelagic and column fishes whose oxygen demands are comparatively higher. A certain amount of balance is maintained at surface levels where the consumption of dissolved oxygen more or less equals the replenishment through the process of dissolution from the atmosphere and the photosynthetic activity. In deeper layers the supply of oxygen does not depend somuch upon the process mentioned above, but it mainly depends upon the sinking and the movement of water masses which form at the sea surface.

The aim off the present study is to discuss the occurence of oxygen minimum layer within the shelf waters along the southwest coast of India between Ratnagiri and Cape Comorin and processes leading to the shifting of oxygen minimum layer in time and space.

Materials and methods:

Basic hydrographic data ,collected during 1971-1978 onboard R.V.Rastrelliger, R.V.Sardinella and R.V.Varuna, were utilised. Most of the sections covered only the continental shelf which constituted the environment for a significant part of the Indian fisheries. Considerable seasonal variations are also characteristic of this environment. The oceanographic stations (Fig.1) within the continental shelf were fixed at an interval of approximately 18 km at right angles to the coast line. The number of times each section was covered during 1971-1978 is given in Table-1.

Standard Winkler method was employed for dissolved oxygen measurements. Vertical time sections for dissolved oxygen were prepared for 4 sections.

Results and discussion:

Dissolved oxygen content of surface waters showed large variations in space and time. In general, the shelf waters were well aerated during most of the year except during the southwest monsoon (July-September) The upward tilting of the isolines for dissolved oxygen and the relative position of the oxycline are indicated in the vertical time sections for the southern region and northern region. Vertical time sections were prepared based on information pertaining to the deepest station located near the outer shelf with an approximate depth of 200m which represents the conditions on the outer shelf on 4 sections (Fig.2-5)

In May the oxygen deficient waters slowly started ascending and by August the oxycline became very shallow and in areas of upwelling activity between Quilon and Kasaragod it reached the surface. By December once again the shelf waters became well aerated. In general the concentration of dissolved oxygen at the surface levels during the upwelling season (July-September) showed variations, the concentration showing an increase towards northern sections corresponding to the decrease in the intensity of upwelling north of Kasaragod.[1] The period for which the oxygen deficient waters remained on the continental shelf is longer in the northern region than in the southern region. Off Karwar the period was nearly 6 months when compared to Quilon where it was 2 months.

Upwelling:

Through the process of upwelling waters from comparatively deeper areas of the continental shelf are slowly brought towards surface layers. The present study indicated evidence of strong upwelling in areas off and south of Calicut during July, 1977. Relatively very low values of sea surface temperature(21.1°c) and dissolved oxygen(1ml/l) indicating the presence of upwelled cool and oxygen poor waters were seen at the inshore stations off Calicut and southwards. Similarly a study conducted in July,1978 revealed the presence of upwelling off Quilon. Comparatively low temperature(23.9°c) and low oxygen concentrations(1.46ml/l) were observed at the surface levels near the coast.[1] During July-August at most of the coastal stations off Quilon,Calicut and Kasaragod the oxygen concentrations were low at the surface levels.

The upward tilting exhibited by some of the selected isolines of dissolved oxygen in the vertical time sections (Fig 2-5) clearly indicated the occurence and intensity of upwelling in the area under study. Kasaragod,Cochin and Quilon sections exhibited lowest oxygen concentrations on the shelf. When cold upwelled water with the associated oxygen minimum layer rose along the shelf,it was observed that part of the fish population moved in front of it into shallow surf mixed waters and part moved offshore away from the centre of strong upwelling. Studies along the southwest coast of India revealed that bulk of the pelagic fish population consisting of oil sardine,mackerel and whitebait avoided temporarily areas of intense upwelling activity because of low oxygen concentrations.[1]

Sinking:

Along the southwest coast of India sinking has been reported by several workers in the past. According to Ramamirtham and Jayaraman[2] sinking occurs over the shelf during December and a well defined isothermal layer of about 75-100m thickness is present along the coast at this time. Sharma[3] after conducting a detailed study of the thermocline characteristics concluded that along the southwest coast of India sinking is present from September to January. The present study revealed the existence of sinking in the area between Cape Comorin and Ratnagiri during September-February. It started earlier in the south off Cape Comorin and off Quilon. The sinking water was found to spread more or less uniform dissolved oxygen conditions at the sub-surface layers. Vertical time sections for dissolved oxygen were found to be good indicators of the commencement, intensity and duration of the process of sinking in the area under study.

In general, the shelf waters were well aerated during major part of the year except during the southwest monsoon season. The process of sinking which resulted in the spreading of more or less uniform dissolved oxygen conditions in the subsurface layers led to an increase in the vertical extend of the habitat of major pelagic fish populations within the area under study.

Acknowledgement:

The author wishes to express his sincere thanks to Dr.P.S.B.R. James, Dr.A.V.S.Murthy and Dr.M.S.Rajagopalan for their encouragement and interest in the present investigations.

References:

1.Anon; Progress Report Phase-II FIRS/IND/75/038(FAO,Rome) 1980.
2.Ramamirtham,C.P. &Jayaraman,R. J Mar biol Ass.India;2,1960
3.Sharma,G.S. J Mar biol Ass India 8, 1966

Table-1.

Coverage of the different oceanographic sections during 1971-1978

Location	1971	'72	'73	'74	'75	'76	'77	'78	Total
	Number of coverages made during								
Ratnagiri	Nil	5	5	7	5	1	3	2	28
Karwar	2	10	8	6	5	6	3	3	43
Kasaragod	2	9	7	6	5	5	2	2	38
Cochin	10	11	10	9	9	6	5	5	65
Quilon	2	8	7	7	5	2	1	2	34
Cape Comorin	Nil	Nil	6	7	6	4	2	2	27

Legend to figures

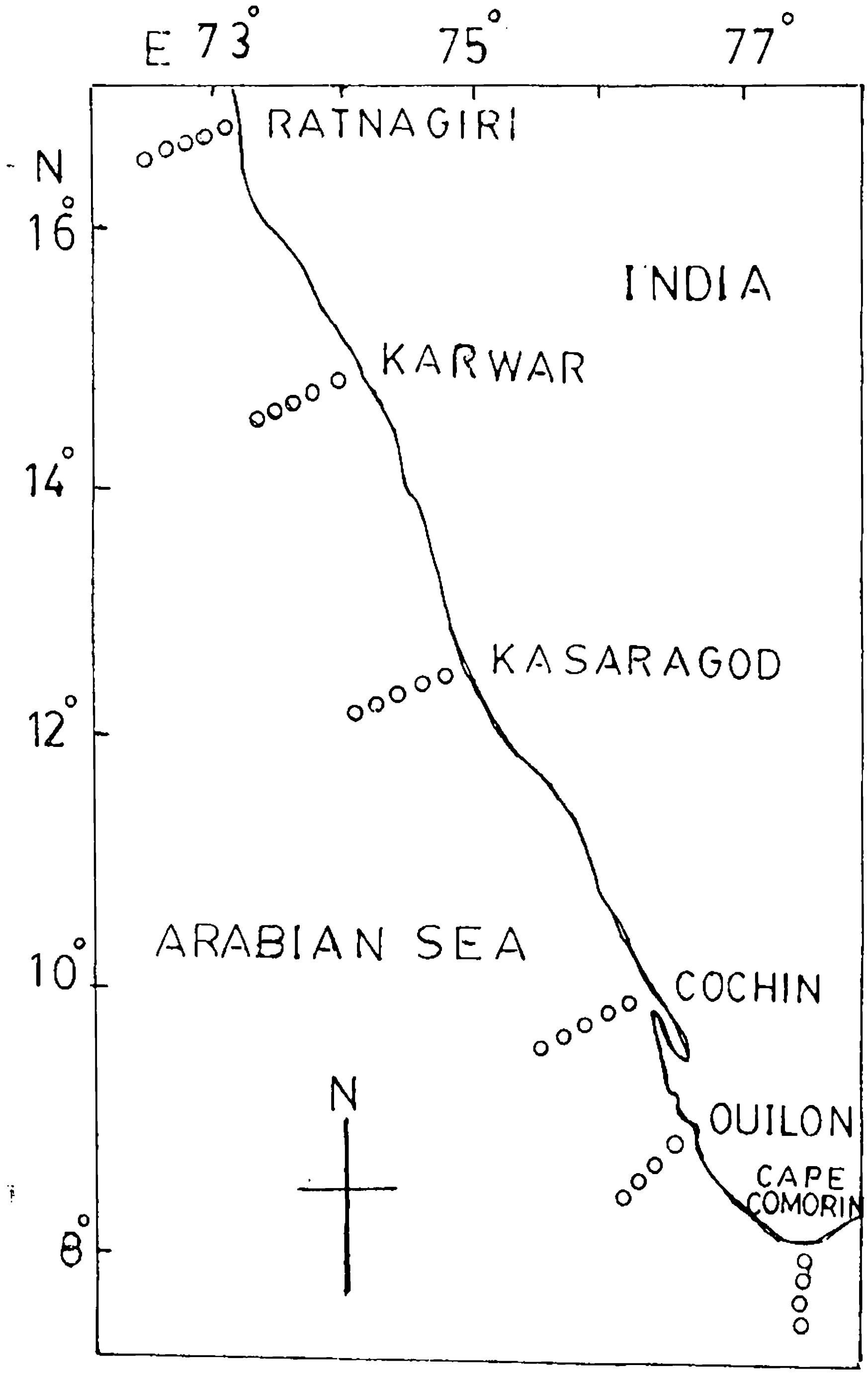
Fig.1 Location of oceanographic sections/stations

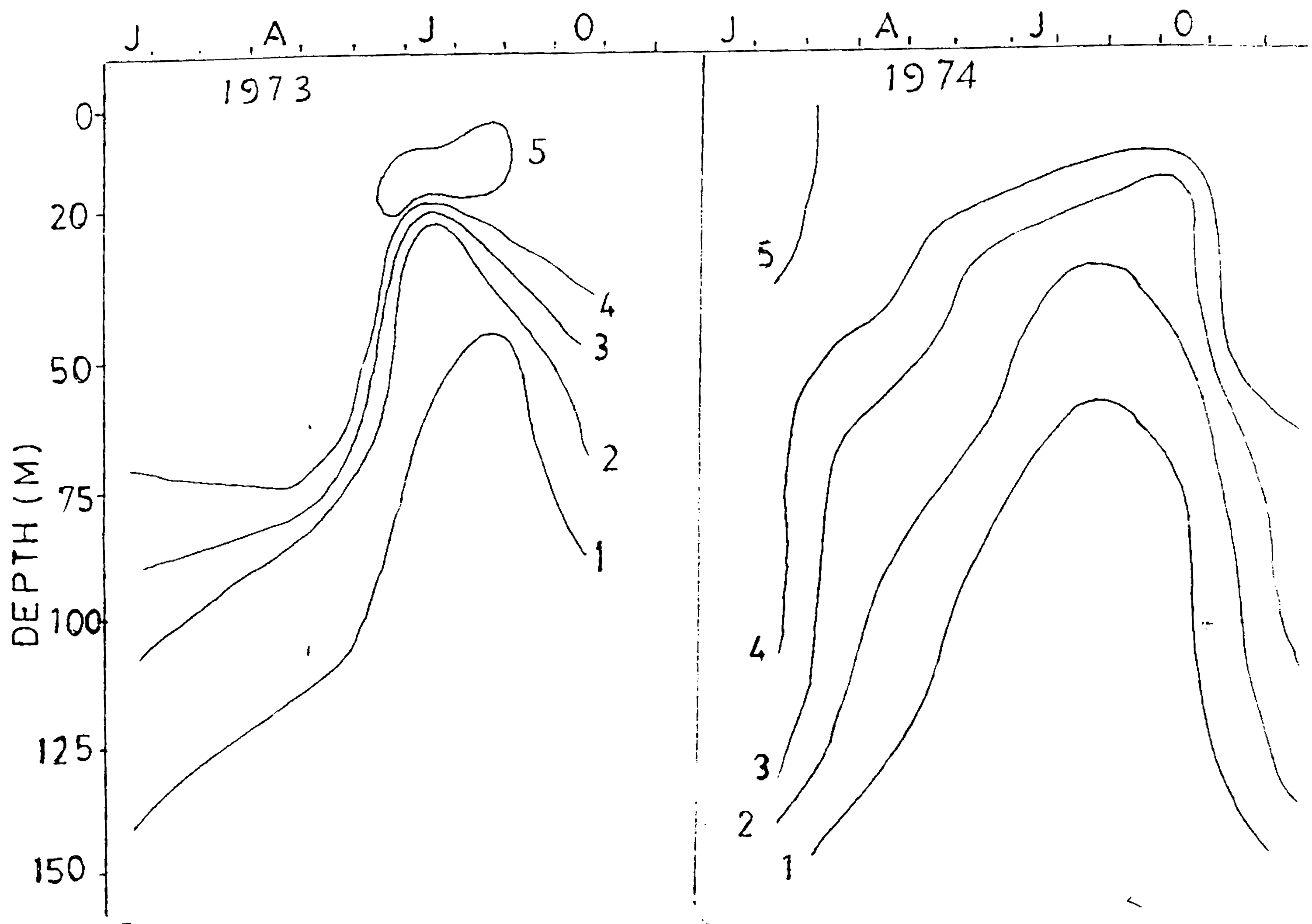
Fig.2 Vertical time section for dissolved oxygen(ml/l) off Quilon(1973,1974)

Fig.3 Vertical time section for dissolved oxygen(ml/l) off Cochin during (A) 1973,1974 (B) 1975,1976 (C) 1977,1978

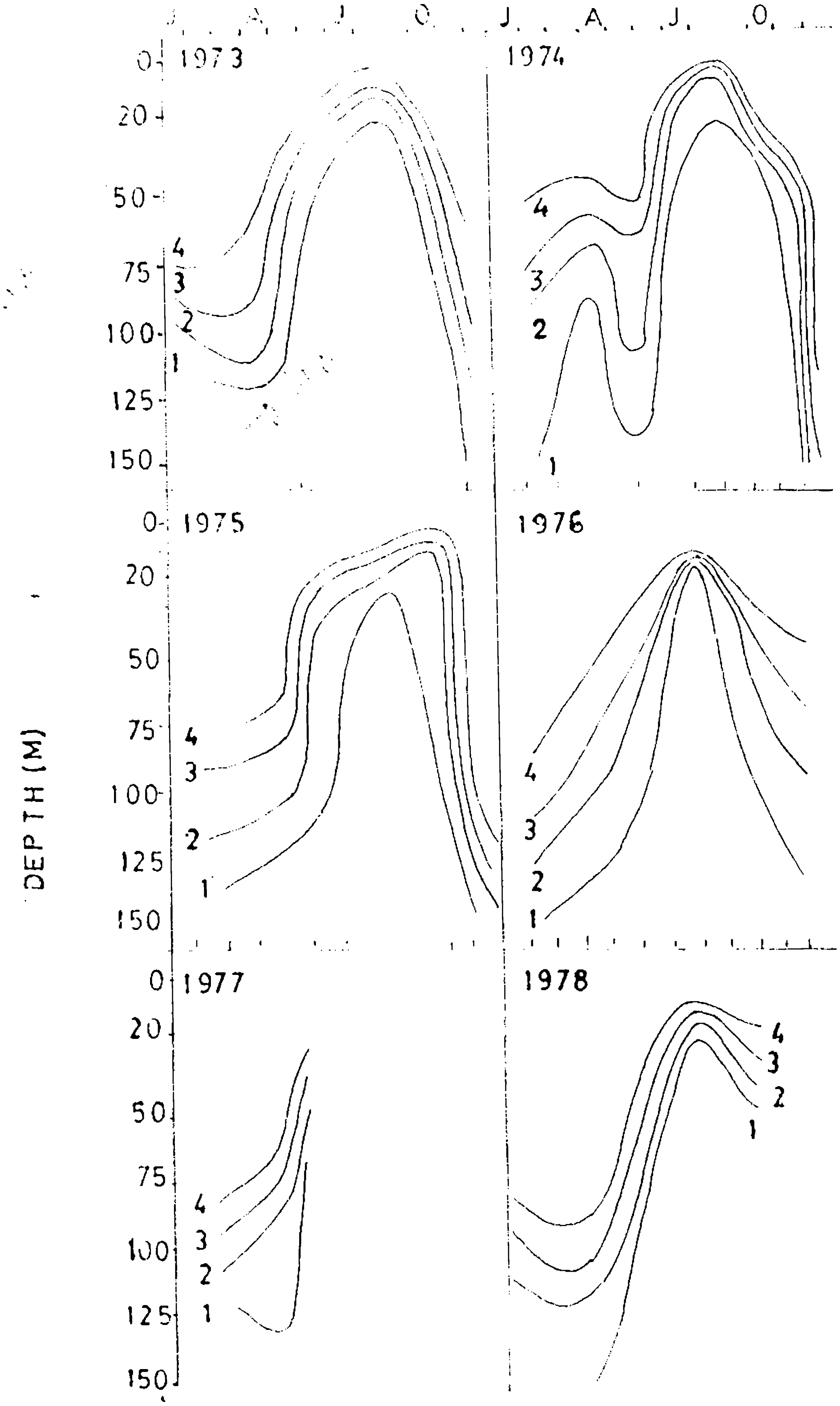
Fig.4 Vertical time section for dissolved oxygen(ml/l) off Kasaragod during (A)1973,1974 (B)1975,1976

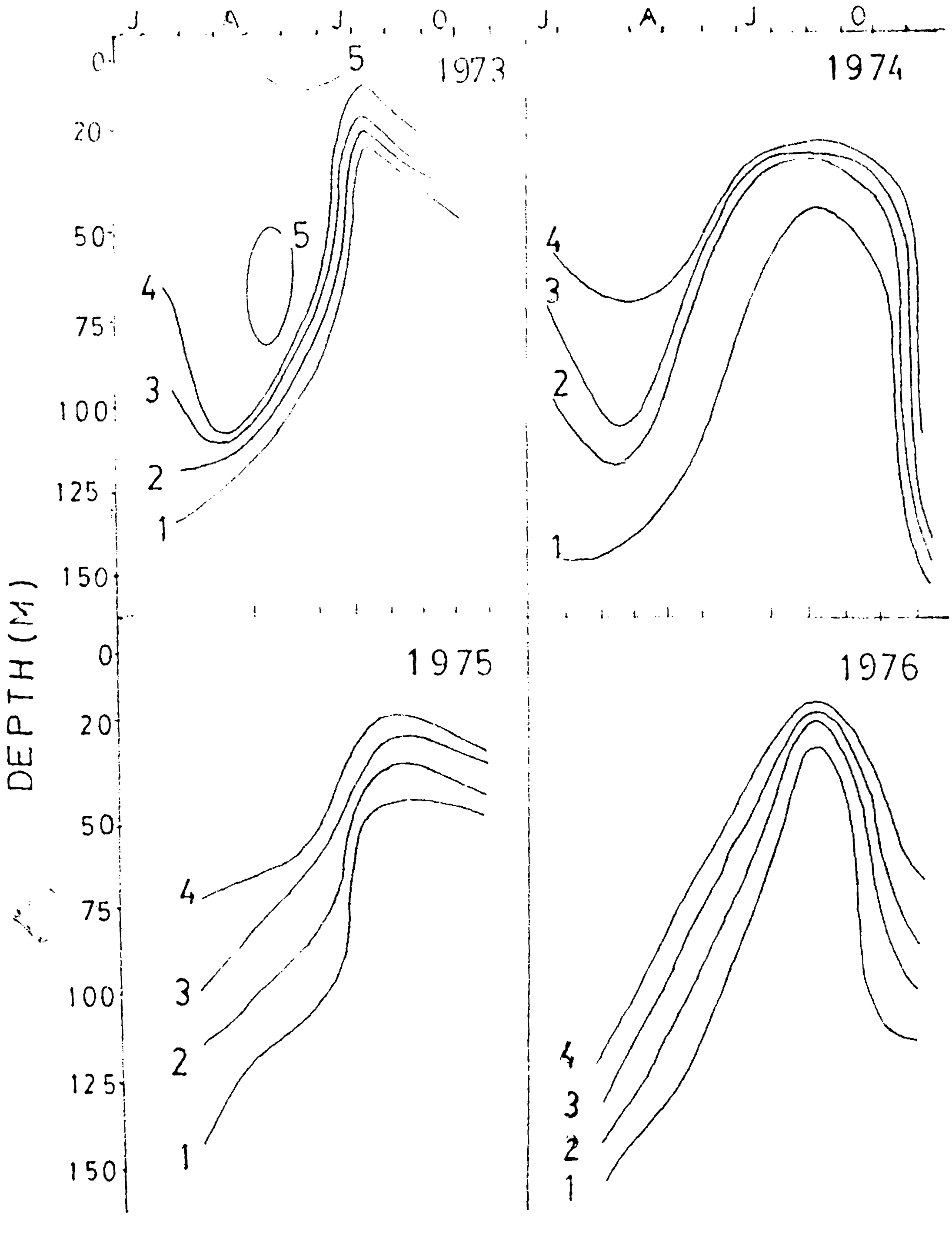
Fig.5 Vertical time section for dissolved oxygen(ml/l) off Karwar during (A)1973,1974 (B) 1975,1976


E 73°
75°
77°
N
16°
14°
12°
10°
8°
RATNAGIRI
INDIA
KARWAR
KASARAGOD
ARABIAN SEA
COCHIN
N
OUILON
CAPE
COMORIN



J
A
J
O
J
A
J
O
1973
1974
DEPTH (M)
0
20
50
75
100
125
150
1
2
3
4
5


J. A. J. O. J. A. J. O.
1973
1974
1975
1976
1977
1978
0
20
50
75
100
125
150
DEPTH (M)
4
3
2
1



J
A
J
O
J
A
J
O
1973
1974
1975
1976
DEPTH (M)
0
20
50
75
100
125
150
1
2
3
4
5

FIG. 1

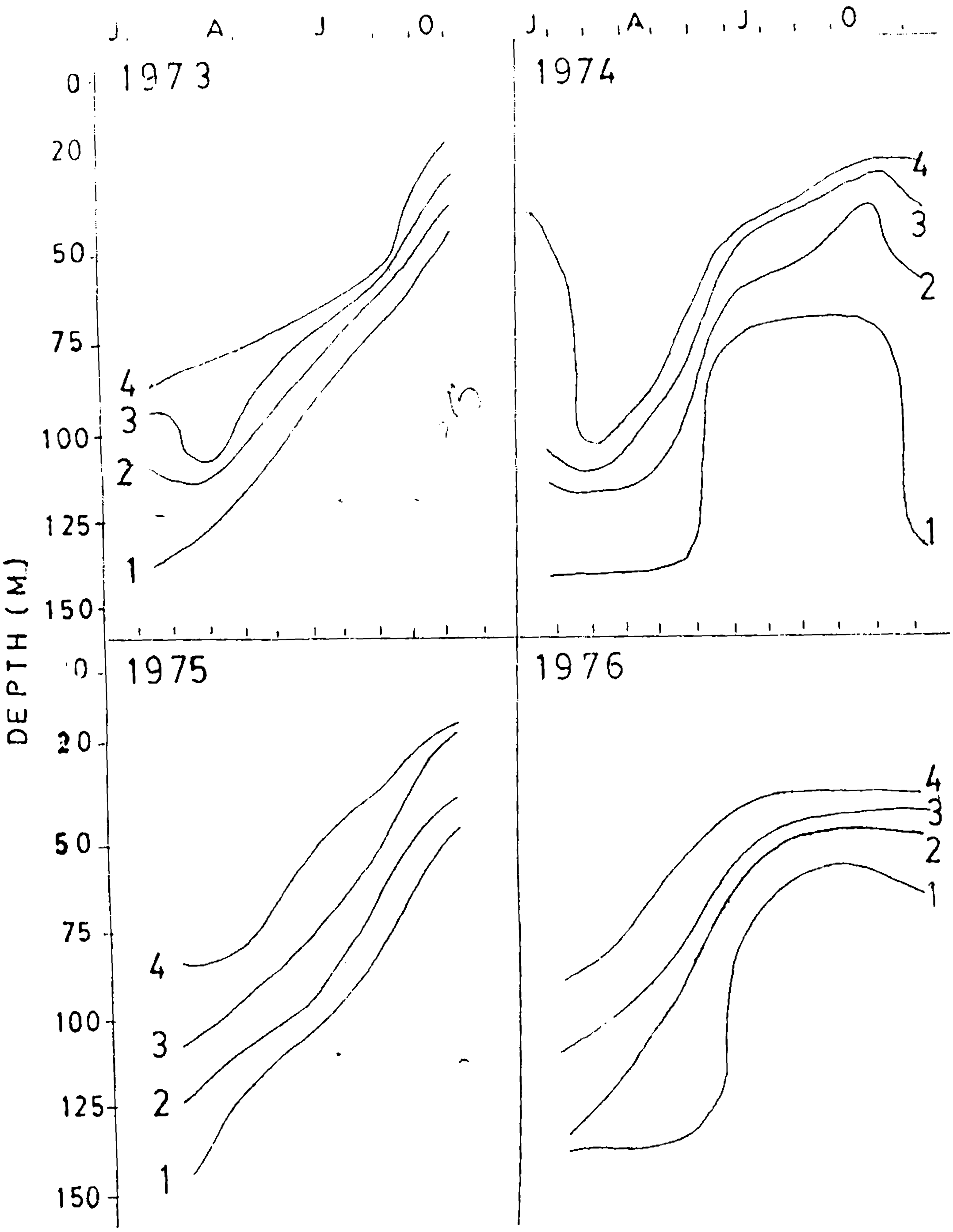


FIG. 5

. biol. Ass. India, 1991, 33 (1 & 2) : 115-133

SALINITY AND THERMAL CHARACTERISTICS OF THE COASTAL WATERS OFF SOUTHWEST COAST OF INDIA AND THEIR RELATION TO MAJOR PELAGIC FISHERIES OF THE REGION*

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Central Marine Fisheries Research Institute, Cochin 682 031

ABSTRACT

A study of the sea water temperature and salinity of the coastal waters along the southwest coast of India between Cape Comorin and Ratnagiri based on observations made along 6 sections for a period of 8 years is made use of for the study. The variations in the monthly mean sea surface temperature and salinity, the position of the thermocline and depth of salinity maxima were studied. Vertical time series sections were used to compare the variations noticed in the vertical oscillation of various isotherms in space and time. An attempt is made to identify the isotherm which exhibits maximum vertical oscillation. The net vertical movement of the water masses, was estimated based on the vertical oscillation of selected isotherm. Possible existence of convergence zones in the area under study was established with the help of horizontal salinity distribution maps. An attempt is also made to examine possible correlations of sea water temperature and salinity with the occurrence of oilsardine, mackerel and whitebait in the area under study.

INTRODUCTION

OF LATE it has been accepted that a reasonable solution to the problems of stock and recruitment, interaction between different species and inherent variability of natural systems will help us to manage the fisheries in a better way rather than basing the entire concept on Maximum Sustained Yield (Gulland, 1977). As in the case of terrestrial animals, the marine fauna including fishes also respond in varying degrees to changes in the oceanographic and climatological conditions. The valuable contributions made by Hela and Laevastu (1970) in this field assume great significance in this context.

The present study is aimed at observing the variations in space and time of sea water temperature and salinity within the coastal waters upto a depth of 150 m along the southwest coast of India between Ratnagiri (17°00′ N, 73°20′ E) and Cape Commorin (08°10′ N, 77°30′ E) (Fig. 1). The study also attempted possible correlations between the observed parameters and the occurrence and migration of the major pelagic fishery resources such as sardine, mackerel and anchovy in the area under study.

A number of investigations were reported from the area selected for the study and adjacent waters with major contributions from Devanesan (1943), Chidambaram and Menon (1945), Bhimachar and George (1950), Banse (1959), Ramamirtham and Jayaraman (1961), Edelman (1960), Pradhan and Reddy (1962), Patil and Ramamirtham (1963), Patil *et al.* (1963, 1964), Murty (1965), Murty and Edelman

* Presented at the 'Symposium on Tropical Marine Living Resources' held by the Marine Biological Association of India at Cochin from January 12-16, 1988.

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(1966), Sharma (1966, 1968), Darbyshire (1967), Banse (1968), Anand *et al.* (1968), Prabhu *et al.* (1972), Noble (1972), Rao *et al.* (1973) and Antony Raja (1974).

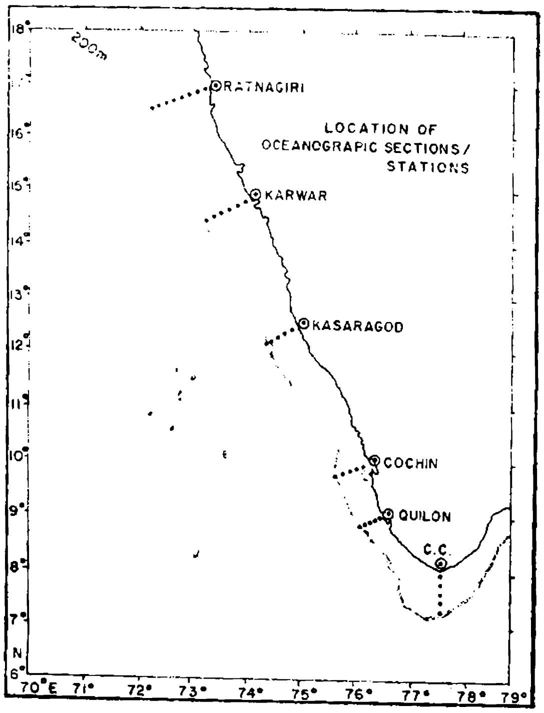


Fig. 1. Location of oceanographic sections/stations.

Some detailed studies were made in the coastal waters of the southeastern Arabian Sea using Research Vessels '*Kalava*', '*Conch*', '*Varuna*' and '*Gaveshani*'. The relevant departmental reports (classified) brought out by the Naval physical and Oceanographic Laboratory (erstwhile Indian Naval Physical Laboratory), Cochin (Sundararaman *et al.*, 1963, 1964), the various reports published by UNDP/FAO Pelagic Fishery Project, Cochin (Anon., 1973, 1974, 1976), relevant reports pertaining to the International Indian Ocean Expedition, the reports/bulletins by the Central Marine Fisheries Research Institute, Cochin, the Fishery Survey of India, Bombay, Integrated Fisheries Project, Cochin and the National Institute of Oceanography, Goa are worth mentioning in this context.

The author wishes to express his sincere gratitude to Dr. P. S. B. R. James, Director, CMFRI, Cochin for his encouragement and to Dr. A. V. S. Murty, CMFRI, Cochin for going through the manuscript and offering valuable guidelines and corrections.

Data and Methods

The basic hydrographic and fishing data collected during 1971-1978 on board the fishery research vessels 'R. V. *Rastrelliger*' and 'R. V. *Sardinella*' of UNDP/FAO Pelagic Fishery Project, Cochin and 'R. V. *Varuna*' of Integrated Fisheries Project, Cochin were utilised.

Most of the sections cover only the continental shelf within a distance of approximately 80 km which constitute the environment for a significant part of the Indian fisheries. Considerable seasonal variations are also characteristic of this environment.

Salinity values upto 150 m depth alone were considered in the present study. The stations within the continental shelf were fixed at an interval of 16 km. Before the arrival of the large vessel '*Rastrelliger*', '*Sardinella*' and '*Varuna*' worked the sections parallel to the latitudes (1971 to 1972) and from 1973 '*Rastrelliger*' sections were worked at right angles to the coast line. Special care was taken to ensure that the different sections were covered within the shortest possible time to get synoptic picture of the hydrographic conditions during each survey. During 1971-'72 salinity estimations were made by the standard titration method. However from 1973 onwards a salinometer was used. A quality analysis of temperature and salinity data resulted in too large a scatter in the salinity determination done by titration method in 1971 and 1972. Therefore salinity values estimated during 1971 and 1972 are excluded in this report.

Nansen reversing thermometers were used in irs to minimise possible errors. Bathythermo- ph observations, using a shallow, medium d deep bathythermographs were also made all the stations except the shallowest stations cated near the coast. The top depth and idth of the main thermocline were determined om the bathythermograms. In order to inimise the fluctuations in the various nvironmental parameters, which are likely o arise out of coastal processes and also iurnal influence, it was decided to consider rameters at the second station from the oast at a depth of 10 m as representative of he conditions characteristic of the surface ayers.

Acoustic surveys and fishing experiments for identification and sampling were under- aken on board '*Sardinella*' and '*Rastrelliger*', when the smaller vessel '*sardinella*' surveyed the shallow parts of the shelf upto 40 m depth at 12 km cruise track intervals, the larger vessel '*Rastrelliger*' covered the deeper parts of the shelf and continental slope with the cruise track interval at 24 km. Both the vessels were fitted with SIMRAD scientific sounders EK 38 (deep) EK 120 and with QM Echo Integrators. On the basis of the patterns of recording and the results of relevant fishing experiments the integrator readings were allocated to different groups of fishes.

'*Rastrelliger*' used 4 types of bottom trawls *viz*. High opening bottom trawl, Hard bottom trawl, Large high opening bottom trawl and a Lobster bottom trawl. The vessel also used a standard pelagic trawl as well as mid water trawl. '*Sardinella*' used two types of high opening bottom trawls and one type of pelagic trawl. This vessel also operated the purse-seine and the gill-seine. Fishing was always carried out based on recordings of the echo sounder and the sonar. Depth of operation in the case of pelagic trawl was decided by operating the trawl sonde. Usual trawling speed was about 3 knots.

RESULTS AND DISCUSSION

Hydrography

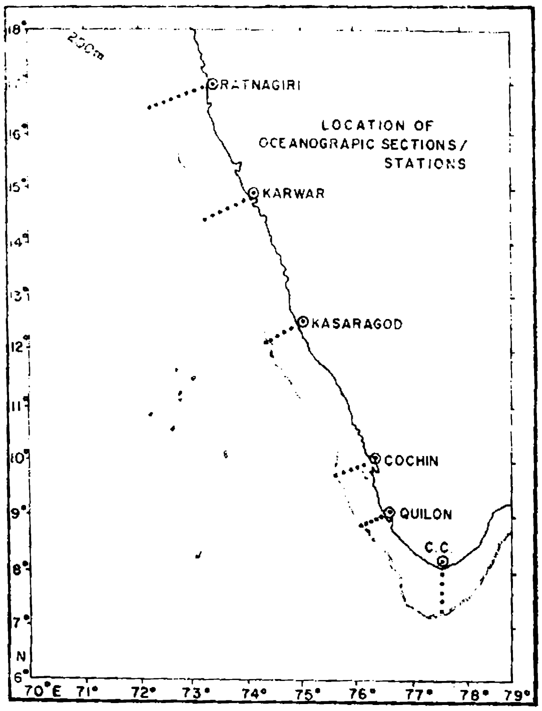
Hydrographic data collected from the oceanographic sections off Ratnagiri, Karwar, Kasaragod, Cochin, Quilon and Cape Comorin (Fig. 1) provided fairly good information on the seasonal fluctuations noticed on the shelf.

Ratnagiri section

The mean monthly sea surface temperature (at a depth of 10 m at the second station from the coast) ranged between 26.50°C and 30.03°C. The maximum was observed in May and minimum in February. The surface mixed layer, on an average, extended to a depth of 39 m during December-February. The mixed layer became non-existent or comparatively very shallow with a minimum thickness (11 m) during October and November. Positive inversions were characteristic of the surface layers (40-150 m) during the period December-March.

The mean monthly surface salinity varied between 34.78‰ and 36.02‰ with the maximum in May and the minimum in October. Salinity was found to be closely related to the influence of the low saline equatorial waters in the northerly current and the advection of the high saline northern Arabian Sea waters in the southerly current. The salinity maximum observed at the surface during May has possibly resulted out of the influence of high saline north Arabian Sea water reaching the area in the southerly flow. Similarly the surface salinity minimum in October is possibly related to the influence of low saline equatorial waters being carried towards Ratnagiri area in the northerly flow. The salinity maximum characteristic of tropical oceans was observed between the depths 30-50 m and 100-150 m during the southwest monsoon and post-monsoon season respectively.

(1966), Sharma (1966, 1968), Darbyshire (1967), Banse (1968), Anand *et al.* (1968), Prabhu *et al.* (1972), Noble (1972), Rao *et al.* (1973) and Antony Raja (1974).



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Salinity values upto 150 m depth alone were considered in the present study. The stations within the continental shelf were fixed at an interval of 16 km. Before the arrival of the large vessel '*Rastrelliger*', '*Sardinella*' and '*Varuna*' worked the sections parallel to the latitudes (1971 to 1972) and from 1973 '*Rastrelliger*' sections were worked at right angles to the coast line. Special care was taken to ensure that the different sections were covered within the shortest possible time to get synoptic picture of the hydrographic conditions during each survey. During 1971-'72 salinity estimations were made by the standard titration method. However from 1973 onwards a salinometer was used. A quality analysis of temperature and salinity data resulted in too large a scatter in the salinity determination done by titration method in 1971 and 1972. Therefore salinity values estimated during 1971 and 1972 are excluded in this report.

Nansen reversing thermometers were used in pairs to minimise possible errors. Bathythermograph observations, using a shallow, medium and deep bathythermographs were also made at all the stations except the shallowest stations located near the coast. The top depth and width of the main thermocline were determined from the bathythermograms. In order to minimise the fluctuations in the various environmental parameters, which are likely to arise out of coastal processes and also diurnal influence, it was decided to consider parameters at the second station from the coast at a depth of 10 m as representative of the conditions characteristic of the surface layers.

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Hydrography

Hydrographic data collected from the oceanographic sections off Ratnagiri, Karwar, Kasaragod, Cochin, Quilon and Cape Comorin (Fig. 1) provided fairly good information on the seasonal fluctuations noticed on the shelf.

Ratnagiri section

The mean monthly sea surface temperature (at a depth of 10 m at the second station from the coast) ranged between 26.50°C and 30.03°C. The maximum was observed in May and minimum in February. The surface mixed layer, on an average, extended to a depth of 39 m during December-February. The mixed layer became non-existent or comparatively very shallow with a minimum thickness (11 m) during October and November. Positive inversions were characteristic of the surface layers (40-150 m) during the period December-March.

The mean monthly surface salinity varied between 34.78‰ and 36.02‰ with the maximum in May and the minimum in October. Salinity was found to be closely related to the influence of the low saline equatorial waters in the northerly current and the advection of the high saline northern Arabian Sea waters in the southerly current. The salinity maximum observed at the surface during May has possibly resulted out of the influence of high saline north Arabian Sea water reaching the area in the southerly flow. Similarly the surface salinity minimum in October is possibly related to the influence of low saline equatorial waters being carried towards Ratnagiri area in the northerly flow. The salinity maximum characteristic of tropical oceans was observed between the depths 30-50 m and 100-150 m during the southwest monsoon and post-monsoon season respectively.

Karwar section

The mean monthly sea surface temperature ranged between 23.86°C and 30.15°C. The minimum was in October and the maximum in May. The mixed layer, on an average, extended to a depth of 61 m during December-February. The mixed layer became very shallow with minimum thickness (10 m) during October-November. Positive inversions were present at the surface layers between the depths 40-150 m during December-March.

The mean monthly sea surface salinity varied between 32.90‰ and 36.12‰. The maximum was in May and the minimum in January. The salinity characteristics of the surface layers were found to be influenced by the southerly and northerly seasonal current systems which carried high saline Arabian seawaters southward and low saline equatorial waters northward. The salinity maximum was found between the depths 30 m (southwest monsoon) and 150 m (post-monsoon).

Kasaragod section

The mean monthly surface temperature ranged between 21.78°C and 29.70°C. The minimum was in September and the maximum during April. The minimum value was associated with the upwelling of subsurface waters to surface levels during the Southwest Monsoon and maximum during the summer season. The mixed layer, on an average, extended to a depth of 56 m during December-February and became very shallow with minimum thickness (13 m) during June - September. Positive inversions were characteristic of the surface layers during the period December-March.

The mean monthly surface salinity varied between 32.71‰ and 35.55‰. The minimum value was during January and the maximum during May. The salinity maximum characteristic of tropical oceans, was found at depths between 30 m (southwest Monsoon) and 150 m (Post-monsoon).

Cochin section

The mean monthly sea surface temperature varied between 23.57°C and 30.01°C. The minimum was during September associated with the process of upwelling and maximum in April.

The mixed layer, on an average extended to a depth of 61 m during December-February. The mixed layer became very shallow with minimum thickness (10 m) during June-September. Positive inversions were present at the surface levels during December-March between the depths 50-150 m.

The mean monthly surface salinity varied between 32.50‰ and 35.22‰. The minimum was observed in December and the maximum in September associated with the presence of high saline upwelled water at the surface level. The salinity maximum was at depths between 30 m (southwest monsoon) and 150 m (Post-monsoon).

Quilon section

The mean monthly sea surface temperature varied between 24.26°C and 29.82°C. The minimum was in September associated with the presence of cold upwelled waters at the surface level and the maximum in April. The surface mixed layer, on an average, extended to a depth of 66 m during December-February. The same became very shallow with minimum thickness (16 m) during June-September. Positive inversions were present at the surface levels during December-March period.

The mean monthly surface salinity varied between 33.34‰ and 35.34‰. The minimum value was in February and the maximum in October associated with the presence of high salinity Arabian Sea waters at the surface. The salinity maximum was between depths 30 m (Southwest monsoon) and 150 m (Post-monsoon).

Cape Comorin section

The mean monthly sea surface temperature varied between 21.13°C and 28.73°C. The minimum was during August and the maximum in April. The mixed layer, on an average, extended to a depth of 63 m during December-February. The same became very shallow with minimum thickness (20 m) during June-Sept. Positive inversions were present at the surface levels during December-March period.

The mean monthly surface salinity varied between 33.03‰ and 35.25‰. The minimum value was during December and the maximum during October.

Seasonal and spatial variations of major hydrographic features in the area under observation

Watermasses: According to Darbyshire (1967) there are three major watermasses present on the shelf *viz.* (1) the Indian Ocean equatorial water (temperature 17°C with a minimum of 34.9‰ salinity) present at the deeper levels on the continental slope, (2) the Arabian Sea water (temperature between 17°C and 27°C associated with maximum salinity of 35.5‰ to 36.3‰) and (3) the equatorial surface water (temperature between 27°C and 30°C and a wide salinity range of 30‰ to 34‰). Banse (1968) indicated that during the peak of southwest monsoon a watermass is formed by the mixing of low salinity surface water and the denser upwelled water. The resulting sub-surface water has a lower salinity when compared to the Arabian Sea water and a wide temperature range down to a minimum of around 20°C.

Convergence zone : The existence of convergence zone in the study area is evident from the horizontal salinity gradients observed during the period January-March (Figs. 2, 3, 4). In 1974, the surface salinity increased from 33‰ to 35‰ between Karwar and Ratnagiri. This difference was less pronounced in 1975. In 1973 a similar zone was observed between Kasaragod and Calicut sections. The variations observed in the surface salinity suggest that the convergence zone exhibit seasonal variations spreading northwards with the intensity of the northerly

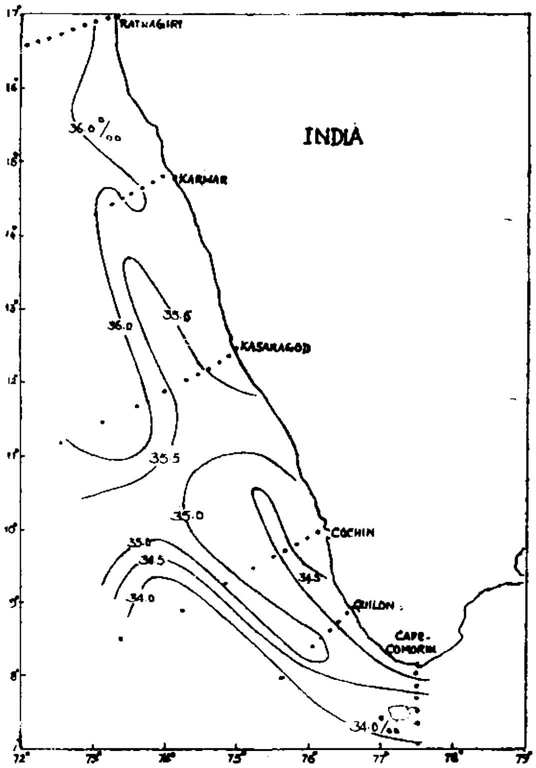

Fig. 2. Horizontal distribution of sea surface salinity (Jan.-Mar. 1973) (Source: PFP Progress Report, 16).

flow which carried equatorial waters towards northern latitudes (Darbyshire, 1967). During the southwest monsoon season the salinity distribution at the surface levels is not indicative of the convergence zone mainly due to the effect of rainfall and river runoff.

Sea water temperature : The monthly mean surface temperature for the period 1973-1978 shows large variation in space and time. In general comparatively low values were observed during January - February and July-October, the lowest being in August

(21.13°C) off Karwar. The high values ware associated with the summer season, just prior to the onset of the southwest monsoon. A steady increase in the highest monthly mean temperature (1973-'78) from south to north was and two minima (July-August and December-January). Off Ratnagiri the maxima occurred in March, June and October and minima in September and December-January.

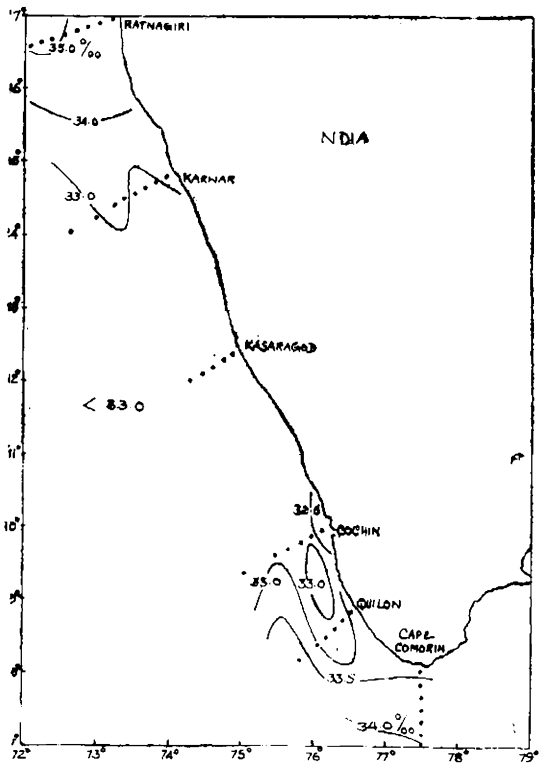

Fig. 3. Horizontal distribution of sea surface salinity (Jan.-Mar. 1974) (Source: PFP Progress Report, 16).

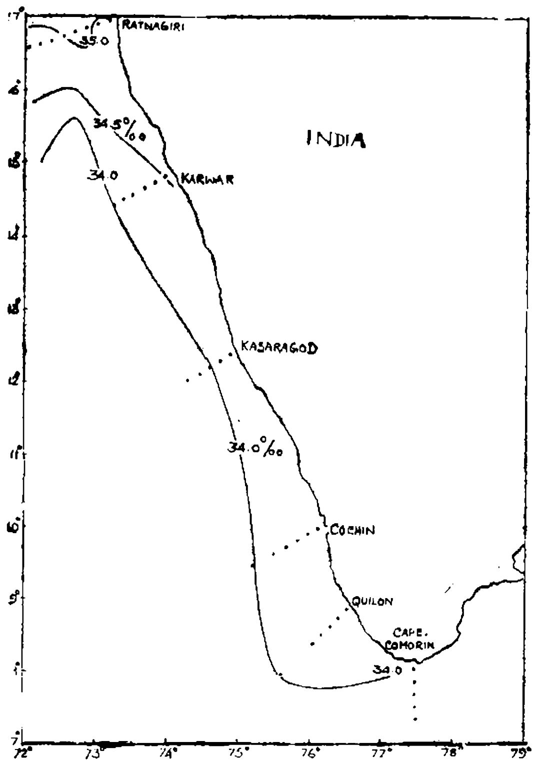

Fig. 4. Horizontal distribution of sea surface salinity (Jan.-Mar. 1975) (Source: PFP Progress Report, 16).

noticed between Cape Comorin and Karwar (28.73-30.15°C). The low values were noticed during January-February and also during the peak upwelling season (July-October). The lowest values were observed in those areas where the intensity of upwelling was comparatively high (between Cape Comorin and Kasaragod). A comparison of mean surface temperature for the period 1972-1978 for Cochin and Cape Comorin sections revealed two maxima (April-May and October-November)

The mean depth of the top of the thermocline shows large variations from season to season (Table 1). The top of the thermocline was deepest during the period December to February and the same reached the surface layers during June-September (south of Cochin) and October-November (north of Cochin).

The vertical time series sections of water temperature for sections representing the southern region (Cape Comorin and Quilon) (Figs. 5, 6) Central region (Cochin and Kasaragod—Figs. 9 and 10) were made use of

TABLE 1. *Mean depths of top of thermocline at different oceanographic sections* (1973-1978)

Section	Shallowest (m)	Period	Deepest (m)	Period
Ratnagiri	11	Oct.-Nov.	39	Dec. to Feb.
Karwar	10	Oct.-Nov.	61	Do.
Kasaragod	13	June to Sep.	56	Do.
Cochin	10	Do.	61	Do.
Quilon	16	Do.	66	Do.
Cape Comorin	20	Do.	63	Do.

to compare the variations noticed in the vertical movement of the various isotherms in space and time. The net vertical movement of isotherms was estimated along different sections plane (Table 2). A comparison of the upward movement of the isotherm for the period 1973-'78 indicated the maximum (110 m) off Quilon and minimum (79 m) off Cape Comorin. During 1977 (July), the isotherm reached the very surface both off Quilon and Cape Comorin.

Thermal inversions : A positive thermal inversion can result in the presence of a surface current where some of the water in the thermocline may also move in the direction of flow overriding the deep water Pillai *et al.* (1977) observed positive inversions in the northern Arabian Sea during March-April and their absence in May was attributed to the comparatively weak circulation system prevailing in this region during the transition period between the northerly and southerly currents.

A careful examination of the bathythermograms pertaining to different stations/

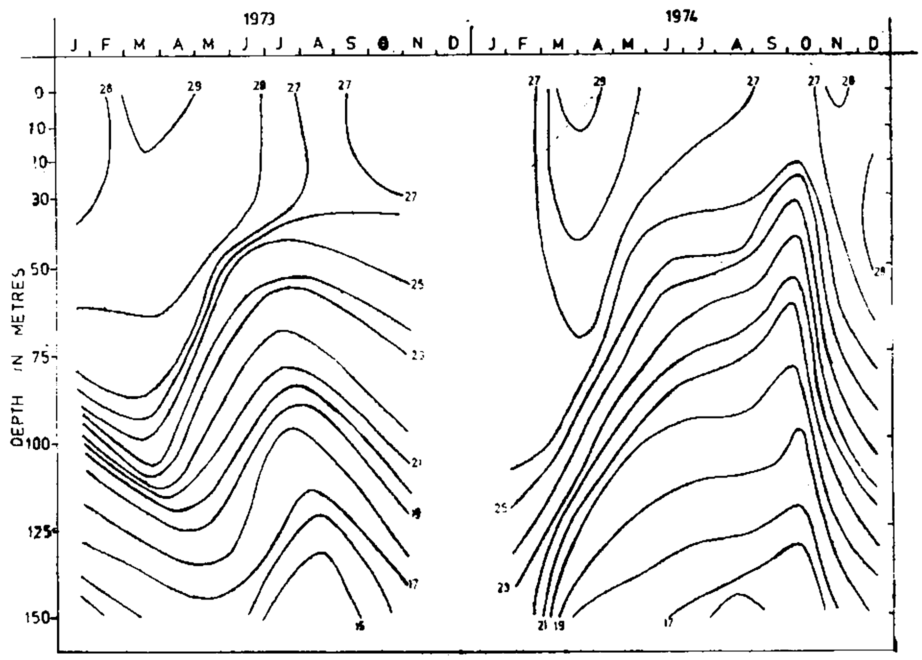

Fig. 5 a. Vertical time section for sea water temperature off Cape Comorin (1973, 1974).

and it was found that the 23°C isotherm exhibited maximum movement on the vertical sections for the period 1971-'78 indicated that positive inversions generally associated with the bottom of the thermocline, were characteristic of all the stations except during May, June and September (Cape Comorin); April and September (Quilon); August and September (Cochin); May, June and July (Kasaragod) and June, July and September (Ratnagiri). The positive inversions were mostly found at the surface levels during the southwest monsoon/upwelling season and the depth of occurrence was maximum during the winter season. Their absence was noticed during the transition between the northerly and southerly currents.

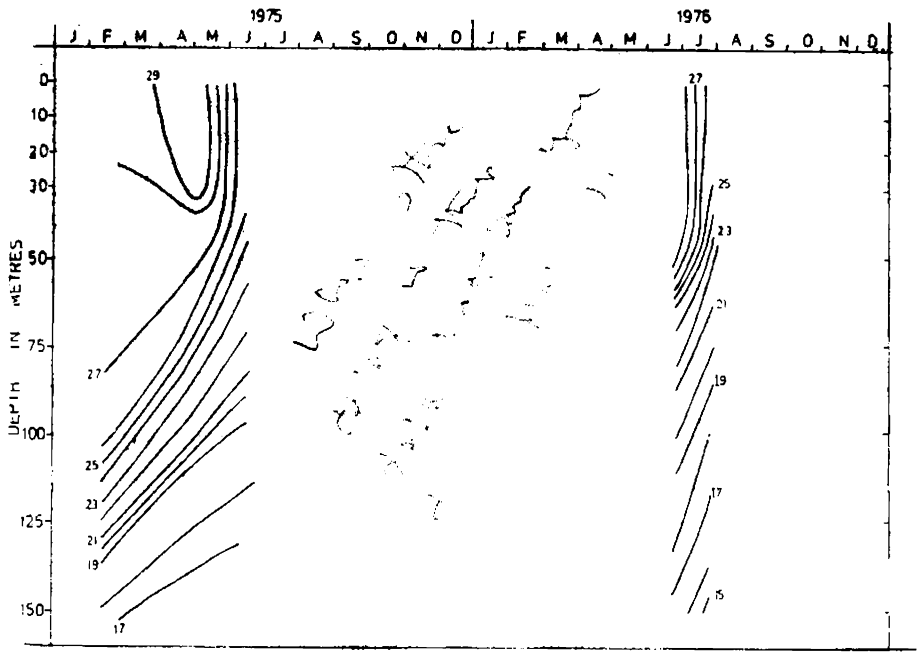

Fig. 5 b. Vertical time section for sea water temperature off Cape Comorin (1975, 1976).

TABLE 2. *Position of 23°C isotherm (sectionwise/yearwise) within the area under observation*

Section	1973 Max.	1973 Min.	1974 Max.	1974 Min.	1975 Max.	1975 Min.	1976 Max.	1976 Min.	1977 Max.	1977 Min.	1978 Max.	1978 Min
Cape Comorin	Mar.	July	Feb.	Oct.	Feb.	July	Feb.	July	Feb.	July	Feb.	July
Depth in m.	110	57	140	43	120	45	115	42	115	0	115	53
Quilon	Jan.	July	Feb.	Oct.	Feb.	Sept.	Feb.	Oct.	Feb.	July	Feb.	July
Depth in m.	115	20	140	23	132	15	127	15	127	0	127	32
Cochin	Jan.	Aug.	Jan.	Aug.	Feb.	Sept.	Feb.	Aug.	Mar.	July	Feb.	July
Depth in m.	110	17	130	16	113	17	124	16	110	7	112	24
Kasaragod	Feb.	Aug.	Jan.	Aug.	Mar.	Aug.	Jan.	Aug.	Jan.	July	Jan.	Aug.
Depth in m.	128	27	110	32	122	30	144	17	144	27	144	27
Karwar	Feb.	Sep.	Jan.	Nov.	Mar.	Oct.	Jan.	Aug.	Jan.	July	Jan.	Aug.
Depth in m.	128	16	120	34	138	35	134	48	134	22	134	15
Ratnagiri	Feb.	Nov.	Jan.	Nov.	Feb.	Oct.	—	—	Feb.	Sep.	Feb.	Oct.
Depth in m.	125	50	122	56	170	45			170	70	170	70

Salinity: The monthly mean surface salinity for 1973-'78 for the different sections also indicated two peaks, one during May-June just before the onset of the southwest monsoon and another during September-October immediately after the southwest monsoon. The lowest values were associated with the monsoon rain and the river run off which showed lot of variations from one section to the other in different years. The monthly mean surface salinity at 10 m from the coast varied between 32.50‰ and 36.12‰. The salinity maximum characteristic of tropical oceans was found at the depths 100 to 150 m during the northeast monsoon and between 30 to 50 m during the southwest monsoon. The variations in salinity which are mainly brought about by the rainfall, river run-off and the prevailing seasonal surface currents are characteristic of the surface layers above the salinity maximum layer.

The surface salinity was highest at Karwar and Ratnagiri sections during May/June (35.6‰ to 36.12‰). Comparatively low saline water (33.03‰) was observed at the surface off Cape Comorin in December when the equatorial surface water was advanced northwards. Sewell (1929) attributed the lowering of salinity during December and January in the Palk Bay and the Gulf of Mannar to the southerly current along the east coast. During this month the salinity value at the surface showed a steady increase from 33.03‰ off Cape Comorin to 35.08‰ off Karwar and Ratnagiri.

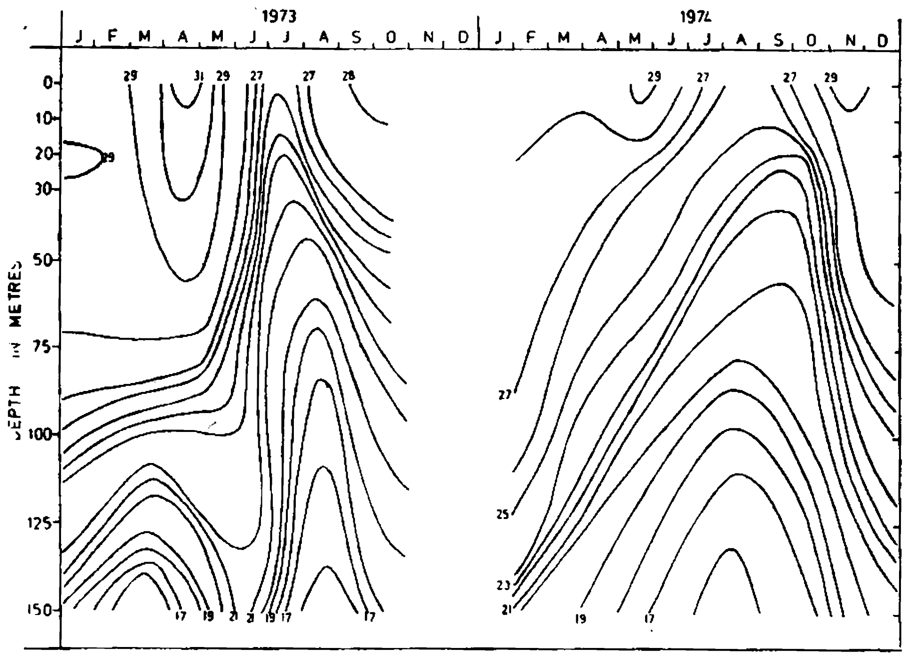

Fig. 6 a. Vertical time section for sea water temperature off Quilon (1973, 1974).

A comparison of monthly mean surface salinity values for the period 1973-'78 indicated the presence of two maxima (April and December) and one minima (July) for Ratnagiri, two maxima (April and October and two minima (July and December) for

Cochin and two maxima (May and October) and two minima (February and December) for Cape Comorin. The maxima occurred comparatively late in the southern sections (during April off Ratnagiri and during October off Cape Comorin) and these were mainly associated with the advection of the high salinity Arabian Sea water in the southerly flow and the presence of high salinity bottom water brought upward to the surface levels in areas where upwelling activity was observed. conditions than the southern sections. At greater depths beyond 100 m there is a decreasing trend in salinity from north to south. It is quite likely that the comparatively high saline north Arabian Sea water is spreading southwards slowly losing their high salinity characteristics. This is in agreement with the general circulation in the upper layers in tropical and subtropical waters. (Sverdrup *et al.*, 1942 ; Wyrtki, 1973 ; Darbyshire, 1967). The salinity maximum associated with the

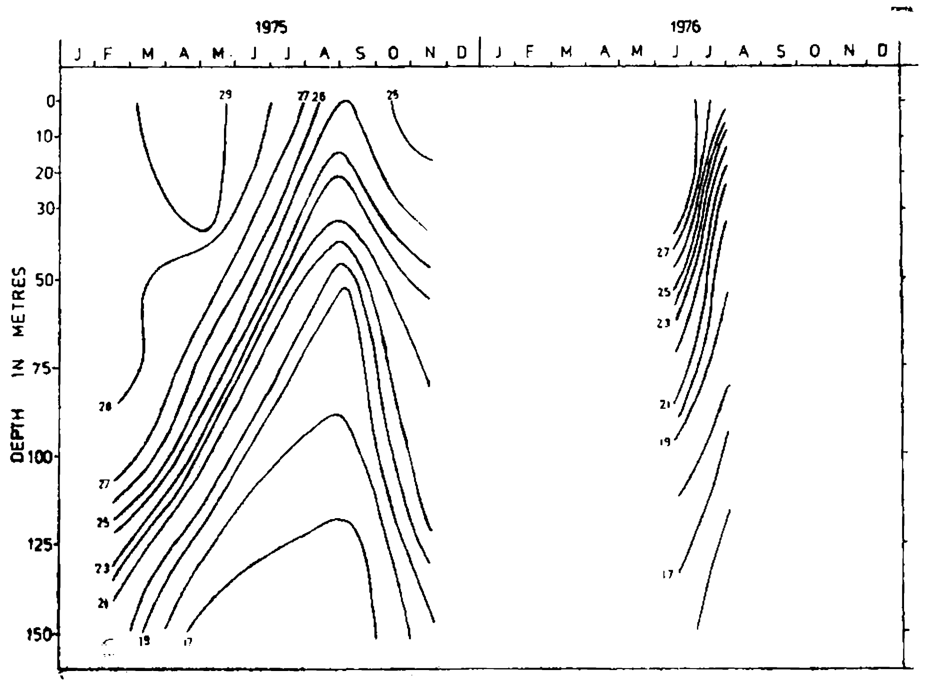

Fig. 6 b. Vertical time section for sea water temperature off Quilon (1975, 1976).

main thermocline probably represents an intrusion of high saline waters below the less saline surface layers towards the Equator.

The minima were associated with the monsoon rain and the resultant river run-off and also the incursion of the low saline equatorial surface waters in the northerly flow. The minima occurred first in the southern region and progressively moved northwards following the trend in monsoon rainfall and the development of the northerly flow.

In general the sections north of Kasaragod exhibited comparatively higher salinity

Possible correlations between oilsardine, mackerel and whitebait fishery and observed oceanographic/biological parameters

Oilsardine and mackerel : The oilsardine *Sardinella longiceps* contributes a major commercial fishery yielding about 15 to 20%

of the total marine fish landings in India. Its fishery is characterised by wide fluctuations both seasonal and annual. The highest abundance and large scale shoaling have been observed off Kerala and Karnataka Coasts (CMFRI, R & D series, 1986). The findings of the erstwhile FAO/UNDP Pelagic Fisheries Project confirmed that 'sardines spawn in shallow water mainly in the near shore areas between latitudes 11°30′ N and 15°30′ N. During the peak of southwest monsoon patchy remains more offshore on the shelf throughout the year consisting mainly of adult fish.'

High concentrations of Indian mackerel *Rastrelliger kanagurta* occurred along the southwest coast. Contribution of mackerel to the marine fish catches of the country during 1965-'84 increased from 2 to 20 per cent with an average of 6 per cent. Mackerel is migratory in habit and its fishery is seasonal. High catches occur during September-November along the

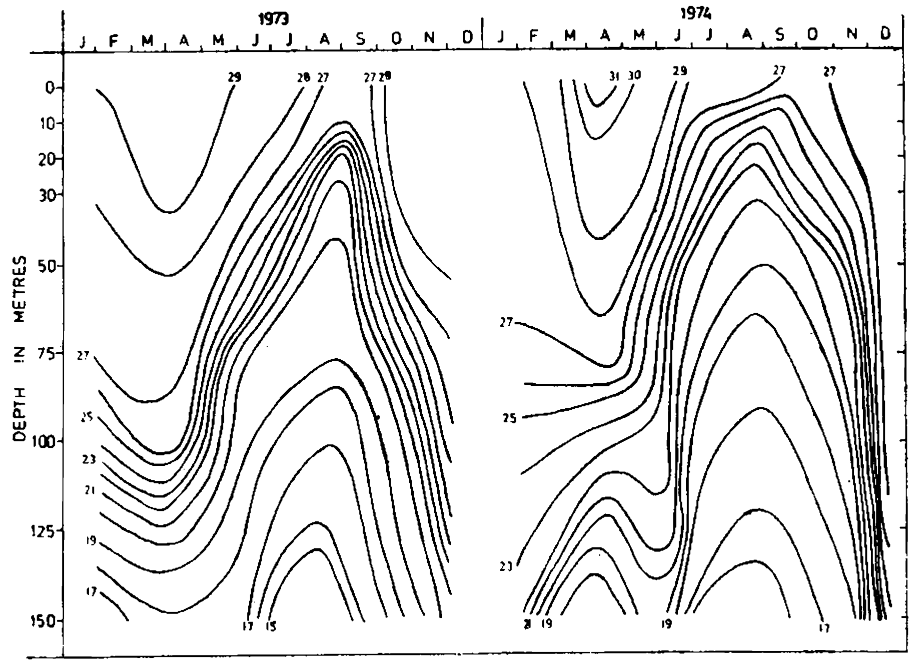

Fig. 7 a. Vertical time section for sea water temperature off Cochin (1973, 1974).

concentrations of oilsardine larvae were observed in the central part of the southwest coast. Oilsardine is a typical schooling species which occurred in a band along the southwest coast mainly within 40 km off shore. It's schooling pattern was found to be associated with upwelling on the shelf. After the monsoon when the upwelling ceases, the school starts to disperse. The oilsardine then moved closer to the coast and become available to the shore based fishery. However part of the stock southwest coast. It is known to breed on the shelf outside the conventional area during Pre-and Post-monsoon months (CMFRI, R & D series, 1986). The observations made by PFP indicated that mackerel spawn during most of the year, particularly from April to October, the peak spawning being observed during April-May. Larvae and juveniles were most frequently observed between 09°00′ and 13°00′N at depths of about 13 m. Mackerel occur in schools at or near the surface depending on

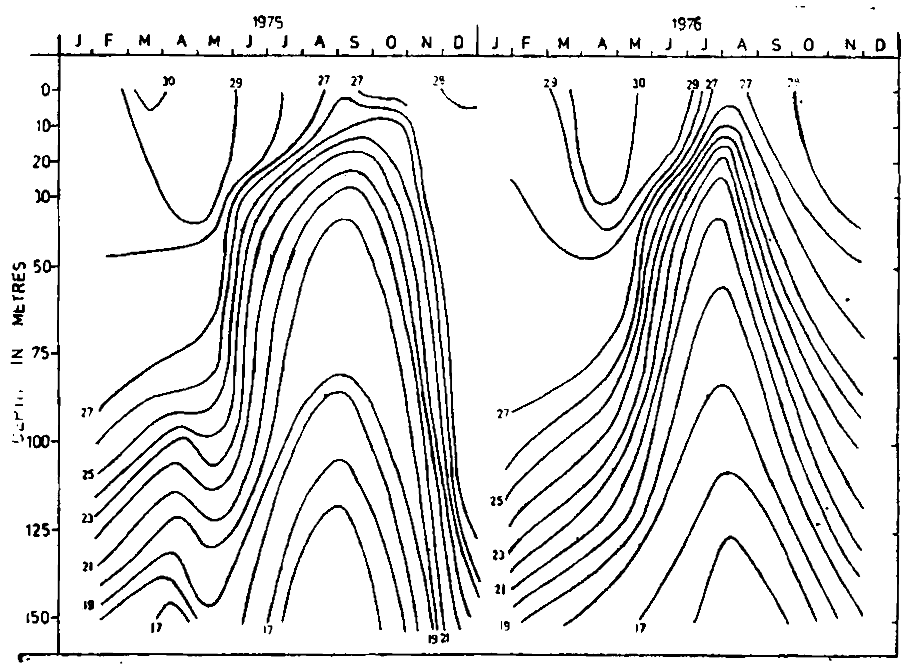

Fig. 7 b. Vertical time section for sea water temperature off Cochin (1975, 1976).

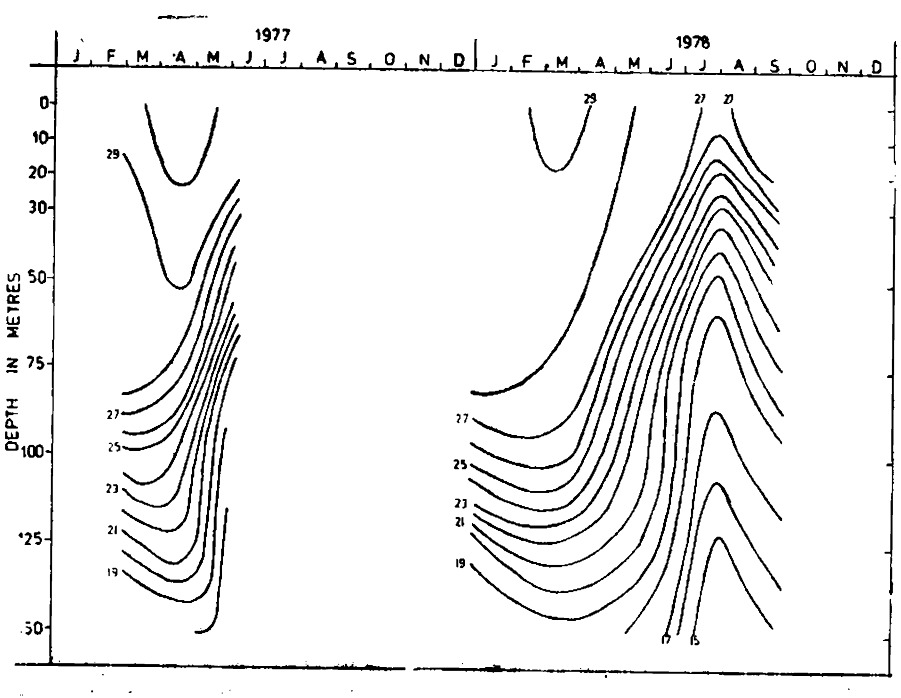

Fig. 7 c. Vertical time section for sea water temperature off Cochin (1977, 1978).

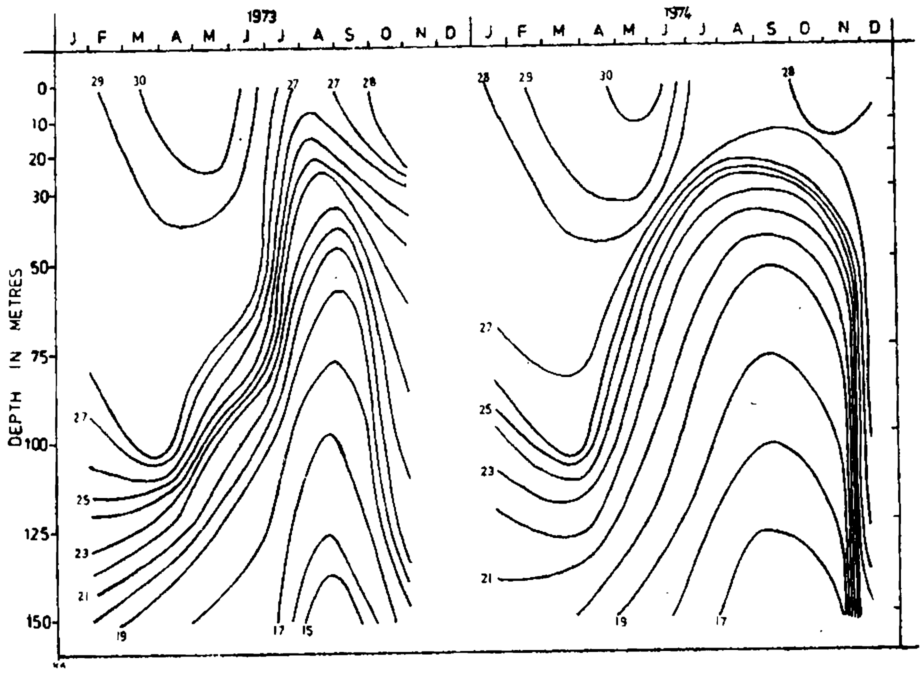

Fig. 8 a. Vertical time section for sea water temperature off Kasaragod (1973, 1974).

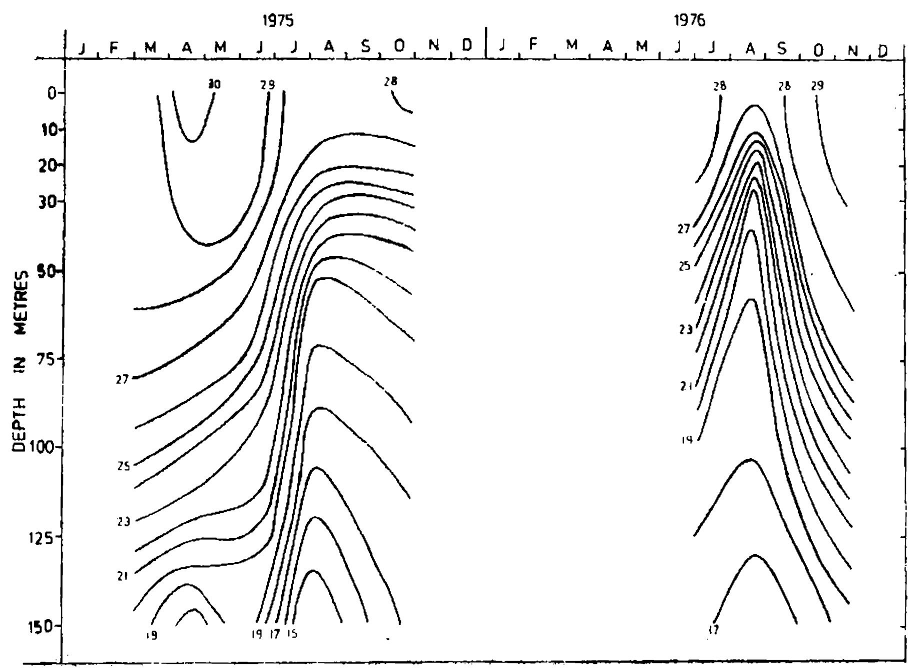

Fig. 8 b. Vertical time section for sea water temperature off Kasaragod (1975, 1976).

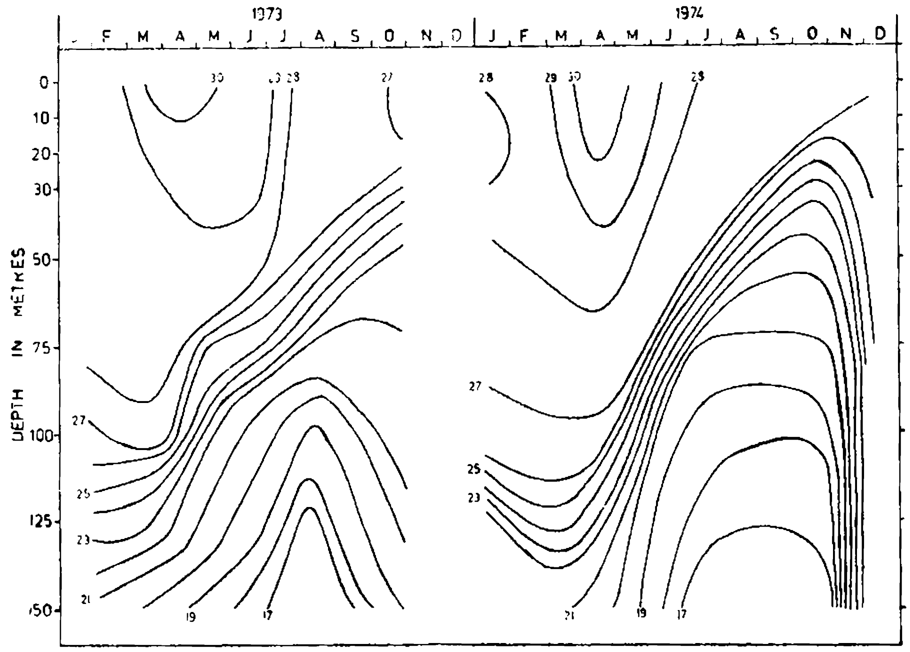

Fig. 9 a. Vertical time section for sea water temperature off Karwar (1973, 1974).

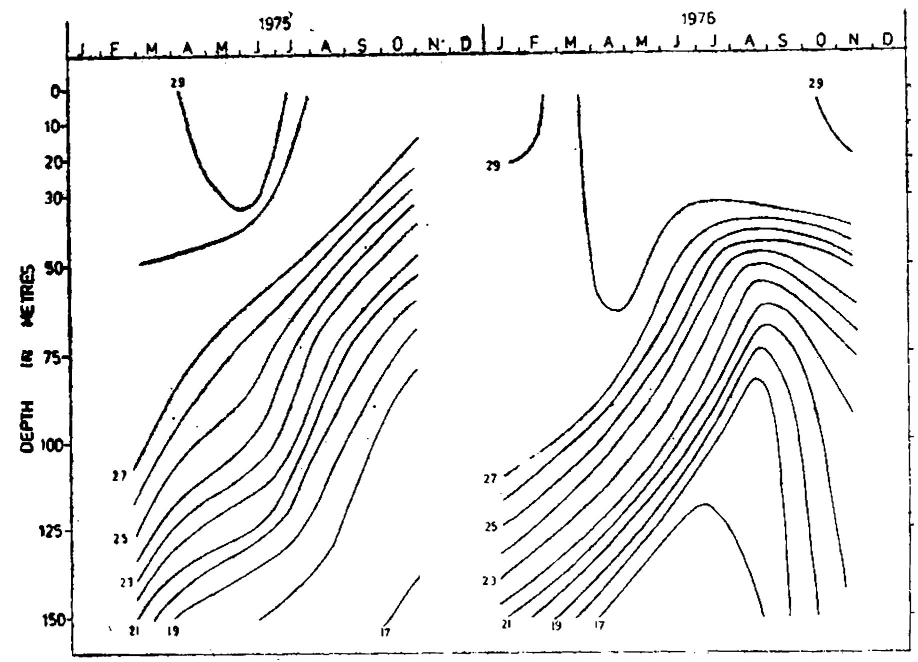

Fig. 9 b. Vertical time section for sea water temperature off Karwar (1975, 1976).

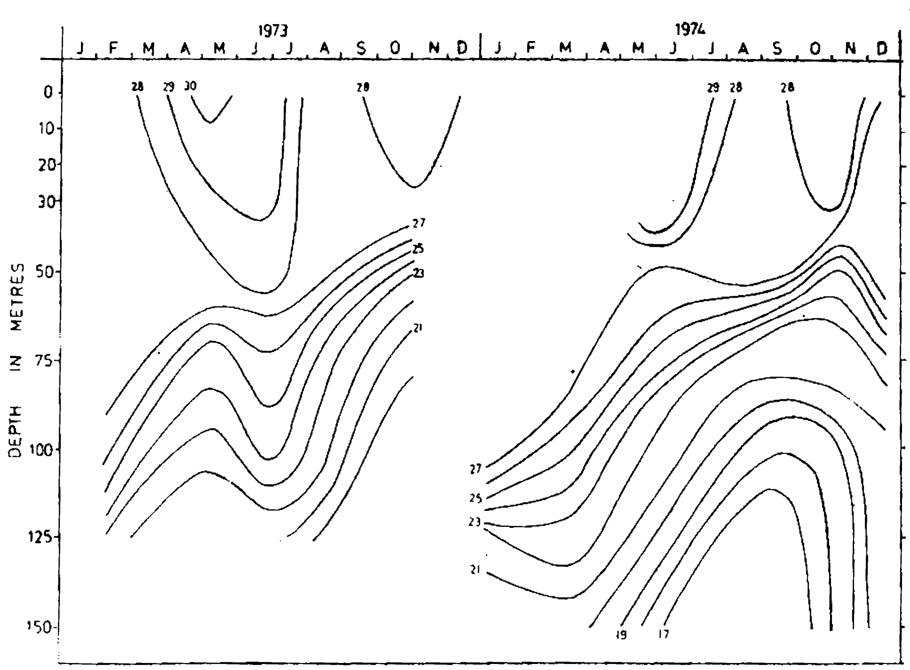

Fig. 10 a. Vertical time section for sea water temperature off Ratnagiri (1973, 1974).

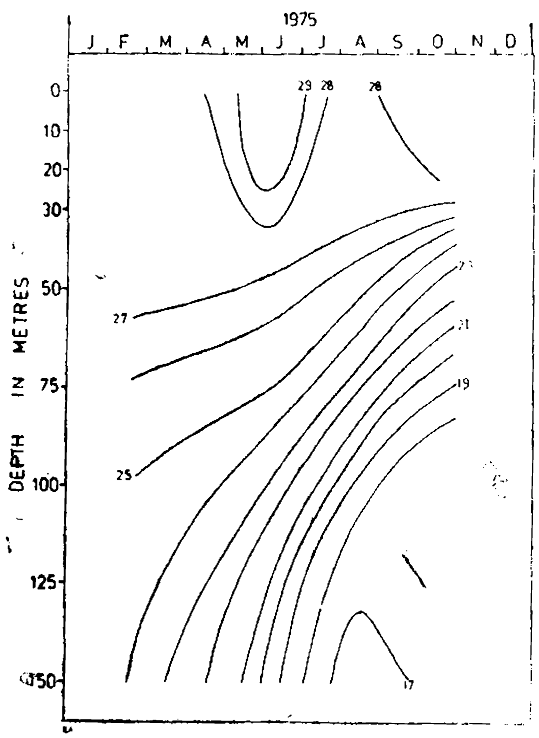

Fig. 10 b. Vertical time section for sea water temperature off Ratnagiri (1975).

local environmental conditions. The congregation of fish in the surface layer is more pronounced in the upwelling season. After the monsoon when the upwelling ceases and plankton become less abundant, the mackerel stock disperses. The juveniles move closer to the shore, but evidently much of the adult stock remains in offshore waters. Mackere was generally most abundant in the aree between Cochin and Mangalore, but in 1972 and 1975 they were evenly distributed along the southwest coast (Anon., 1976).

Panikkar (1949) observed that delays in the onset of monsoon on the Indian Coast are often followed by delays in the fishing seasons for mackerel as well as oilsardine. Bhimachar and George (1952) observed that the mackerel landings show their peak and coincide with or follow the abundance of plankton.

Noble (1972) reported an inverse correlation existing between surface temperature and duration of mackerel fishery off Karwar. During 1955-1956 and 1956-1957 the minimum surface temperature during the southwest monsoon period decreased with a corresponding increase in the duration of the mackerel fishery. During 1958-1959 the minimum temperature once again dropped to the lowest value for the previous 11 year period and the mackerel fishery season was the longest. During 1961-1962 the surface temperature recorded an increase during the southwest monsoon period and the duration of the fishery was the shortest. According to Murthy (1965) the clue for a seasonal and regional variations of both sardine and mackerel fishery has to be found partly, if not wholly, in the variations of the pattern of the coastal currents. According to him catches are maximum during winter season when the northerly drift gets established along the coast.

According to Rao *et al.* (1973) the oil sardine fishery dominates between Alleppey and Malpe and mackerel fishery between Calicut and Malwan. The northern areas appear to be more favourable for mackerel fishery probably due to a sudden increase in salinity occurring northwards from the region off Mangalore. December appears to be the peak season for oil sardine and October for mackerel. In December sinking of the offshore waters (coastal convergence) occurs over the shelf and a well defined thermal layer of about 75-100 m thickness is present along the west-coast (Ramamirtham and Jayaraman, 1961). It is well known that convergence brings in concentration of zooplankton (Hela and Laevastu, 1970). It was observed that zooplankton dominates in the food of oilsardines (Noble, 1972). Hence the abundance of oilsardines may be related to the phenomenon of the convergence along the coast. Rao and Rao (1957) have observed that Juvenile mackerel is selective in its food habit and adult ones are planktonic feeders. Hence it is probable that areas, where plankton productivity is high, constitute a favourable environment for mackerel.

Pradhan and Reddy (1962) reported that high temperature affected the mackerel fishing adversely off Calicut. According to Ramamurthy (1965) the mackerel season in North Kanara Coast coincided with the transition period from the low salinity and low temperature condition during the southwest monsoon to the high salinity and warmer conditions in summer.

Pradhan and Reddy (1962) found an inverse correlation between annual rainfall and mackerel catches off Calicut. The sardine fishery at Ullal was lowest (52.1 t) in 1963-1964 when the rainfall was heaviest (306.5 cm). The catches were better during 1965-1966 and 1966-1967 (283.7 t and 385.6 t respectively) *i.e.* when the annual rainfall was comparatively low (274.1 cm and 283.6 cm respectively) (prabhu *et al.*, 1972).

During the peak of southwest monsoon rainfall, the surface salinity falls substantially along the coast due to rain and river run-off. The influence of the southward spreading of high salinity Arabian Sea water during this season is nullified by the rainfall and river run-off. But the situation is reverse with the northward spreading of upwelling. Experimental fishing conducted by '*Rastrelliger*' and '*Sardinella*' revealed that both mackerel and oilsardine move along with the northward spreading of the upwelling condition. The northward migration of these fishes is confined to the northern limit of the region of upwelling *viz.*, Karwar. It is possible that the comparatively higher salinity and low temperature of upwelled waters favoured both oilsardine and mackerel.

During March-April it was found that the surface temperature increased and the shelf was occupied by comparatively high temperature and high saline waters. Possibly to avoid this high temperature, both oilsardine and mackerel were found migrating away from the coast into deeper water during March-April. The results of fishing operations conducted by the project vessels clearly indicated this position. A comparison of the monthly mean temperature (10 m depth and 2nd station from the coast) for the period July-October for the upwelling area between Quilon and Karwar indicated a mean temperature range of 23.4 to 26.4°C. In the Ratnagiri section the same varied between 27.5°C and 28.3°C during the same period. From these contrasts in the spatial variation of sea water temperature and the northern limit of the fishery for oilsardine and mackerel, it could be inferred that these fishes have less tolerance for temperature above 27.0°C. After March when the sea surface temperature increased much about the limit of tolerance (27.0°C), the fishery gradually subsided and by April-May these fishes moved away from the coast to deeper waters of comparatively favourable conditions.

During 1976 (June-July) some of the densest concentrations of breeding oilsardine were located off Mt. Delli where the temperature gradients were comparatively less (26° to 27°C). ɩerhaps it would mean that oilsardines prefer ɽeas with comparatively less vertical tempera- ɽe gradients for breeding purposes and ɮrmally they moved away from the coast in ɩrch of suitable environment once they in the required stage of gonadal maturity.

hen the process of upwelling intensifies ɑratively lower temperature and higher y subsurface waters slowly rises along the ental shelf towards shallower areas. e of the comparatively low oxygen of deep waters it was observed that the fish population moved in front of ɩhallow surf mixed waters and part fshore away from the centre of strong It was found that the upwelled oxygenated within a short time due with atmosphere and also due to ɩn. These nutrient-rich bottom ɩide a very good habitat for the growth of phytoplankton followed by zooplankton. The plankton bloom attracts the plankton feeding fishes which slowly move behind the northward spreading of the upwelling to take advantage of the plankton bloom. There is always a time lag between the arrival of subsurface water at surface levels through the process of upwelling, the subsequent plankton bloom and the movement of oilsardine and mackerel schools to take advantage of the plankton bloom. The immediate effect of the upwelled water reaching the surface is the expulsion of fishes like oilsardine and mackerel from the vicinity since the same is highly oxygen deficient.

Whitebait

The studies conducted by the erstwhile Pelagic Fisheries Project revealed that the whitebait stock along the southwest coast of India consisted of several *Stolephorus* spp. of which *S. heterolobus* and *S. bataviensis* were the most abundant. *S. zollingeri* may be quite abundant, particularly in the northern part of the project area. It was found that the main spawning was confined to the period before and after the southwest monsoon season. Greatest abundance of whitebait larvae was observed in the Premonsoon period. Whitebait was recorded mostly in areas with bottom depth between 10 and 50 m and only occasionally in deeper waters. They exhibited a typical diurnal migration. During day time the concentrations were distributed close to the bottom while during night they were found dispersed in mid water. Distinct seasonal migrations were observed. In November-December the whole stock is spread along the southwest coast. In April a southwest movement begins and by July-August the stock is accumulated in the Gulf of Mannar. After the Monsoon the whitebait again dispersed along the coast north of Quilon in September-October.

It is possible that whitebait makes the southerly migration during June-July mainly to avoid the comparatively high temperature (above 28°C) prevailing in the Ratnagiri-Karwar region. When they reach further south the effect of the low temperature upwelled water possibly drives it further south and later towards southeast where comparatively favourable temperature (between 24° and 27°C) prevailed. The fishing results of the '*Sardinella*' and '*Rastrelliger*' revealed that during the period June-October the fish remained in the area between Cape Comorin and Tuticorin in dense concentration extending from the surface to the bottom. The setting up of the northerly current with the Post-monsoon conditions prevailing along the southwest coast namely the plankton bloom which followed the upwelling and the gradual rise in temperature resulting from the recession of the upwelling process provided the fish with favourable environmental conditions to commence their northward spreading along the southwest coast (PFP Report 1976).

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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 km^2. 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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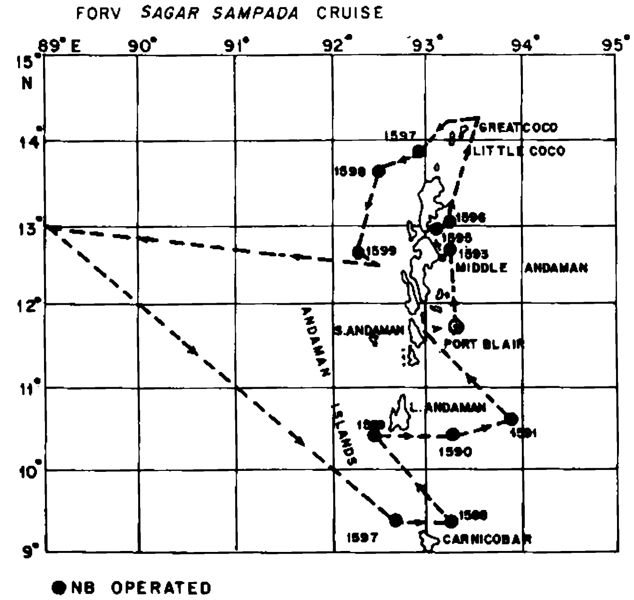

Fig. 1. Cruise Track of Cruise No. 56 of FORV *Sagar Sampada*.

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.

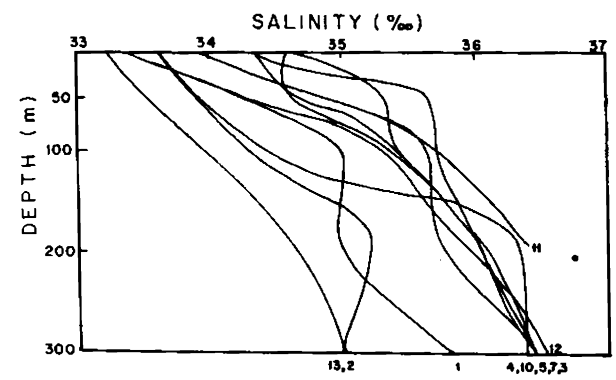

Fig. 2. Distribution of salinity with depth.

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).

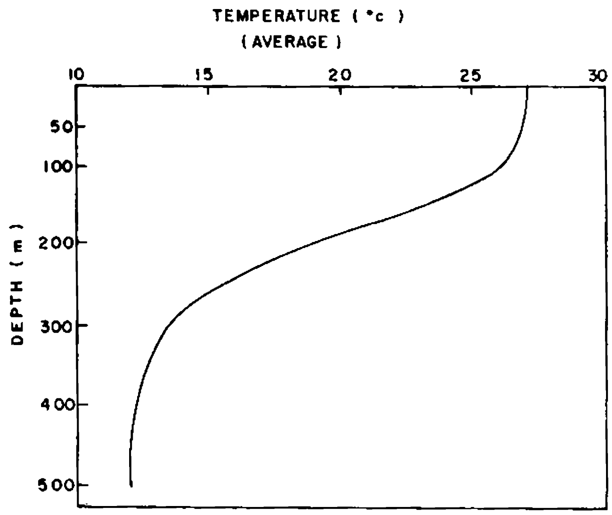

Fig. 3. Distribution of temperature with depth.

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.

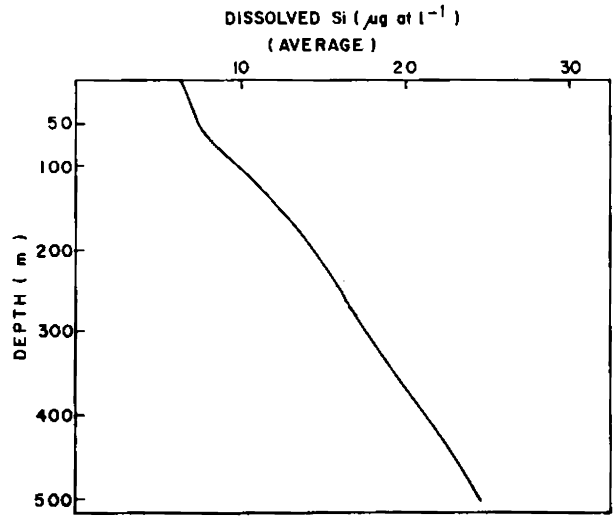

Fig. 4. Distribution of dissolved silicon with depth.

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) 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.

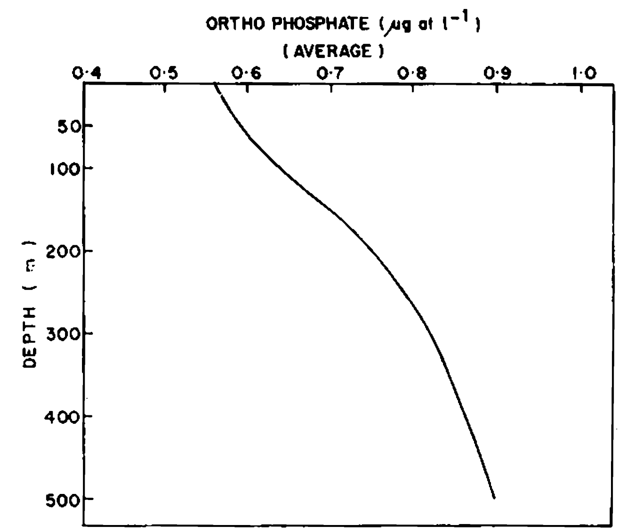

Fig. 5. Distribution of orthophosphate with depth.

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).

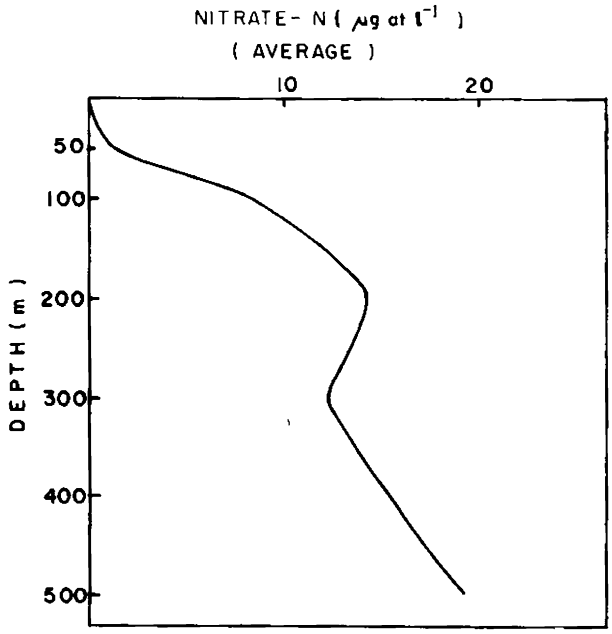

Fig. 6. Distribution of nitrate - N with depth.

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.

Acknowledgement

The authors wish to express their sincere thanks to Dr. P.S.B.R. James, Director, CMFRI, Cochin for the encouragement received for undertaking the present study.

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VERTICAL STABILITY CHARACTERISTICS OF THE CONTINENTAL SHELF AND SLOPE WATERS ALONG THE SOUTH WEST COAST OF INDIA AND IT'S POSSIBLE RELATIONSHIP WITH UPWELLING AND SINKING

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Introduction

The various mixing processes within a waterbody are, to a great extent, controlled by the vertical stability conditions which in turn makes a particular region of the sea fertile or barren. As pointed out earlier by Cooper (1960), the replenishment of the surface waters of the oceans by nutrients from below is dependent on the vertical stability of the water column and hence the proper assessment of the parameter will help us to find out probable areas of upwelling and sinking.

Some work along these lines have been earlier attempted by Sastry (1957), Ramamirtham and Nair (1964) at selected areas in the Arabian sea and Bay of Bengal and certain conclusions have been drawn, based on variations observed in the parameter and correlating the same with meteorological and hydrographic parameters. According to Sastry (1957) when conditions are not stationary and in the presence of intense mixing, as he observed at two neighbouring stations off

Obsèrvations were made first (1971-73) on board the research vessels 'Sardinella' and 'Varuna' and later (1974-78) on board 'Rastrelliger'. Water sampling for salinity estimations and seawater temperature observations were made at standard depths upto a maximum of 500 m using Nansen Reversing Water bottles. [redacted] The stations within the continental shelf were fixed at an interval of 10 n.miles. Before the arrival of the large vessel 'Rastrelliger', 'Sardinella'and 'Varuna' worked the sections parallel to the latitudes (1971 to 1972) and from 1973 'Rastrelliger' sections were worked at right angles to the coast line. Special care was taken to ensure that the different sections were covered within the shortest possible time to get synoptic picture of the hydrographic conditions during each survey. During 1971-72 salinity estimations were made by the standard titration method. However from 1973 onwards a salinometer was used. A quality analysis of temperature and salinity data unfortunately resulted in too large a scatter in the salinity determination done by titration method in 1971 and 1972. Therefore salinity values estimated during 1971 and 1972 are excluded in this report.

Nansen reversing thermometers were used in pairs to minimise possible errors. Bathythermograph observations, using a shallow, medium or deep bathythermograph, were also made at all the stations except the shallowest station located near the coast. The top depth and width of the main thermocline were determined from the bathythermograms. In order to minimise the fluctuations in the various environmental parameters, which are likely to arise out of coastal processes and also diurnal influence, it was decided to consider the parameters at the second station from the coast at a depth of 10 m as representative of the conditions characteristic of the surface layers.

In order to obtain a general picture of stability conditions prevailing within the continental shelf area necessary computations were made for 18 stations (first one representing the coastal conditions, second one the mid-shelf conditions and the third one the conditions at the edge of the continental shelf) along the sections located off Cape commorin, Quilon, Cochin, Kasaragod, Karwar and Ratnagiri upto a maximum depth of 300 m.

Vertical stability parameter in the sea is denoted by the expression "E" = $10^{-3} \frac{d\sigma_t}{dz}$ (Hesselberg, 1918) where $\frac{d\sigma_t}{dz}$ is the individual change in density with depth. When "E" is positive, the stratification along the vertical plane is stable and when it is negative, the stratification becomes unstable. Between positive and negative stability layers there is always a surface where "E" = 0 (neutral stability). The order of magnitude of the different terms in the equation has been computed by Hesselberg and Sverdrup (1914-1915) and it was shown that $\frac{d\sigma_t}{dz}$ is an accurate expression of the stability up to a depth of 100 m.

In general, in the absence of large scale vertical mixing caused by upwelling and sinking, the vertical stability increased at the top of the thermocline probably due to the effect of sudden lowering of temperature with depth. In order to have a general comparison, the stability values pertaining to the year 1974, for the different months/sections are presented in Table 1 A to F. Some work along these lines has been attempted by Sastry (1957) and Ramamirtham and Nair (1964) at selected areas in the Bay of Bengal and Arabian Sea. Sundararamam et al (1963) observed that the instability noticed in the upper layers in the northern and central Arabian sea during the post-monsoon season is the consequence of the transition between the south-west monsoon and the north-east monsoon.

According to Sastry (1957), when conditions are not stationary and in the presence of intense mixing, as he observed at two neighbouring stations located off Visakhapatnam, the stability criterion gives divergent results. He has also concluded that off Visakhapatnam over the continental shelf the changes in the vertical stability with depth are due to mixing in the offshore drift produced by upwelling. More or less similar divergent results have been obtained for the shelf stations occupied during the south-west monsoon period when the offshore drift gets established in areas where

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upwelling becomes intense. The vertical stability conditions off Cape Commorin (May-August), Quilon (July-August), Cochin (July-August) and Kasaragod (July-August) clearly indicated the effect of the offshore drift during the south-west monsoon period. Comparatively low values of stability/instability were observed at 11 stations during the period of survey viz. December-February (Cape Commorin), December (Quilon), November-January (Cochin), November (Kasaragod), December-February (Karwar) and January-April (Ratnagiri). The negative values of stability observed at the surface levels during the months April-May-June-July off Karwar and Ratnagiri might possibly be associated with the effectiveness of evaporation in these latitudes. The resultant increase in salinity and decrease in temperature (evaporation causes cooling) leads to an increase in density and to a reduction in stability. Ramamirtham and Nair (1964) while studying the stability characteristics of the surface waters off Cochin during the different seasons observed vertical turbulance near the bottom during the monsoon and early post-monsoon seasons. Existence of comparatively less stable conditions at the bottom levels during the south-west monsoon period, resulting out of the upwelling process, is evident from a uniform decrease in the stability conditions below a depth of 50 m.

The author feels that the unstable conditions resulting out of the sinking process during the winter season (November -

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February) results in comparatively low values of stability/instability conditions at the surface levels. In fact the reduction in stability at the surface levels could very well be indicative of the existence, duration and intensity of the process of sinking. In the case of the upwelling process, the unstable conditions are more revealed at the bottom levels with uniform decrease in the vertical stability values below a depth of 50 m. The effect of the offshore drift resulting out of the process of upwelling give rise to divergent stability values at the neighbouring stations both on the vertical and horizontal plane.

Fig. ~~12~~ 2A-F gives the variation of vertical stability below the thermocline(s), thermocline intensity in terms of 0°C/10 m (I), vertical spread(width) of the thermocline (T) and top depth of the thermocline (D),. From the general trend of the figures, the following conclusions may be drawn.

When the water column below the thermocline exhibits comparatively low values of stability, the top depth of thermocline is shallow and at the same time the vertical spread of thermocline is large. When the intensity of thermocline is high, its vertical spread is minimum.

Below the thermocline, the vertical stability is comparatively low during the south-west monsoon period all along the coast. However, the strength of thermocline does not vary uniformly

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along the coast. It's strength is more during the south-west monsoon period in the waters south of Kasaragod and during post-monsoon in the waters north of Kasaragod. With regard to the intensity of thermocline, Kasaragod demarcates the border line. During the south-west monsoon the stability below the thermocline is the least and correspondingly the top depth of thermocline also occurs at comparatively shallower waters. But the vertical spreading of the thermocline during this season is large.

During the south-west monsoon, the waters south of Kasaragod indicate least stability below the thermocline. (FIG. 3) The effect of low stability bring the top depth of thermocline closer to the sea surface with a large vertical spread of thermocline. ~~During the same season the effect of increased intensity of thermocline tends to push the thermocline to the deeper depth with the lowest vertical spread.~~ The extent of vertical spread of thermocline could be taken as an index of upwelling. Therefore, upwelling during this season, in these waters, is mainly effected by comparatively weak stabilities below the thermocline. Since the top depth of the thermocline is shallowest during this season, it may be said that the effect of intensified thermocline is negligible when compared to that of low stability below the thermocline.

In spite of the high intensity of the thermocline in these waters during this season, because of the strong effect of the low stability occuring below the thermocline, the waters are upwelled.

North of Kasaragod the stability below the thermocline is high and the intensity of thermocline relatively low during the south-west monsoon period. Thus the conditions of stability are not favourable for promoting upwelling in the waters north of Kasaragod during the south-west monsoon season.

Conclusions

Comparatively low values of vertical stability parameter observed at the surface levels during the winter season could very well be indicative of the existence, duration and intensity of the process of sinking. In areas where upwelling activity was moderately high the unstable conditions were more revealed at the bottom levels with a more or less uniform decrease in the vertical stability values.

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guidelines and corrections.

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LEGEND TO FIGURES

Fig. 1. Location of Oceanographic sections/stations

Fig. 2.a. Relationship between the depth of thermocline, width of thermocline, intensity of thermocline and the vertical stability immediately below the thermocline (average upto 500 m depth) off Cape Commorin (1974)

" 2.b. Relationship between the depth of thermocline, width of thermocline, intensity of thermocline and the vertical stability immediately below the thermocline (average upto 500 m depth) off Quilon (1974)

" 2.c. Relationship between the depth of thermocline, width of thermocline, intensity of thermocline and the vertical stability immediately below the thermocline (average upto 500 m depth) off Cochin (1974)

" 2.d. Relationship between the depth of thermocline, width of thermocline, intensity of thermocline and the vertical stability immediately below the thermocline (average upto 500 m depth) off Kasaragod (1974)

" 2.e. Relationship between the depth of thermocline, width of thermocline, intensity of thermocline and the vertical stability immediately below the thermocline (average upto 500 m depth) off Karwar (1974)

" 2.f. Relationship between the depth of thermocline width of thermocline, intensity of thermocline and the vertical stability immediately below the thermocline (average upto 500 m) off Ratnagiri (1974)

Fig. 3. Relationship between the spread of thermocline (M) and the stability below the thermocline in the area between latitude 08°00'N & 17°00'N along the southwest coast of India during June-July-August (1974)

TABLE 1. A. Vertical stability characteristics of the shelf waters (0-500 m depth) along the south-west coast of India (1974 - Values) (expressed as $10^8 E$)

1. Coastal Stn. 2. Mid-shelf Stn. 3. Outershelf stn.

\- Negative stability
\+ Positive stability
0 Neutral stability

CAPE COMORIN

Depth interval (M)	FEBRUARY 1	FEBRUARY 2	FEBRUARY 3	APRIL 1	APRIL 2	APRIL 3	MAY 1	MAY 2	MAY 3	AUGUST 1	AUGUST 2	AUGUST 3	NOVEMBER 1	NOVEMBER 2	NOVEMBER 3	DECEMBER 1	DECEMBER 2	DECEMBER 3
0-10	+200	-300	-300	+500	+600	+1800	+1900	+900	-300	+400	+800	+1100	+1500	+1000	+ 400	-0-	-0-	-2000
10-20		-0-	-0-		+2700	+2100		+800	+400	+4600	+1700	+2200	-1100	+2200	+600			-0-
20-30		-0-	-0-		+1700	+1000		+2200	-0-		+2300	+4500		+1600	+1600			+4000
30-50		-0-	-0-		+4900	+1800		+4900	+4600		+3700	+4000			+900			+6000
50-75			+80			+3300			+3000			+2000			+1300			+3000
75-100			+2500			+4000			+4200						+2000			+3500
100-125			+4000			+4100			+1500			+1700			+3000			+3200
125-150			+1500			+2000			+1000			+1000			+2500			+1000
150-200			+1800			+1200			+1000						+1500			
200-250												+300			+900			
250-300												+300						
300-400												+100						

TABLE 1 B. Vertical stability characteristics of the shelf waters (0-500 m depth) along the south-west coast of India (1974 - values) (expressed as $10^{8}E$)

1. Coastal Stn. 2. Mid-shelf Stn. 3. Outershelf Stn.

\- Negative stability
\+ Positive stability
0 Neutral stability

QUILON

Depth interval (m)	FEBRUARY 1	2	3	MARCH 1	2	3	MAY 1	2	3	AUGUST 1	2	3	NOVEMBER 1	2	3	DECEMBER 1	2	3
0-10	+1000	-0-	+500	+4600	-0-	+1400	+8900	+1100	+1300	+7400	+700	+2300	+5000	+7300	+400	-300	+200	+300
10-20		+4900			+1400			+2700	+10200		+5500	+9300		+2400	+500		+1200	
20-30		+950	+2800		+800	+4250		+7300	+2100		+8600	+2000		+1200	+2100		+7600	-0-
30-50		+2800	+1550		+1000	+4000		+3800	+2200		+1650	+6500		+1050	+2200		+1450	+4500
50-75		+1300	+3000		+240	+3300		+1100	+2600		+1000	+3900		+1080	+2800		+400	+1800
75-100		[illegible]	+600		+8100	+4700		+410	+2800			+2600		+1400	+2600			+1600
100-125			+1300			+3040			+430			+1080						+400
125-150			+2700			+1440			+2700			+808			+800			+800
150-200			+5000			+880			+1200			+880			+1540			+3180
200-250			+1960			+340												+1580
250-300			+ 820			+340			+470			+270			+760			+1060
300-400			+240			+200			+180			+160			+270			+270
400-500			+130			+120			+120			+120			+170			+160

TABLE 1 C. Vertical stability characteristics of the shelf waters (0-500 m depth) along the south west coast of India (1974 - values) (expressed as 10^8 E)

1. Coastal Stn. 2. Mid-Shelf Stn. 3. Outershelf Stn.

\- Negative stability
\+ Positive stability
0 Neutral stability

COCHIN

Depth interval (m)	JANUARY 1	JANUARY 2	JANUARY 3	FEBRUARY 1	FEBRUARY 2	FEBRUARY 3	APRIL 1	APRIL 2	APRIL 3	MAY 1	MAY 2	MAY 3	JULY 1	JULY 2	JULY 3	AUGUST 1	AUGUST 2	AUGUST 3
0-10	-	+600	-100	+5300	+700	+300	+2200	+2700		+2500	+200	-0-	-	+9800	+4400			+20500
10-20		+500			+1800			+3000	+2770		+400	+400		+6200	+6700	+6200	+7200	+ 3400
20-30		+1900	+1700		+1600	+2150		+7500	+500		+6900	+1100		+4300	+3800		+10100	+2400
30-50		+4450	+200		+700	+5350		+2550	+7700		+1650	+5450		+900	+3000		+2300	+1450
50-75			+2100			+2800			+3800			+2500			+1100			+810
75-100			+3040			+1400			+1800			+2200			+1600			+1320
100-125			+1200			+2800			+3600			+1700			+1700			+1100
125-150			+1300			+3600			+2000			+2300			+1300			+1200
150-200			+4200			+1340			+980			+1320			+800			+1040
200-250			+740			+1040			+550									
250-300			+380			+340						+560						+310
300-400			+200			+160			+240			+290			+380			+160
400-500			+60			+140			+100			+170			+220			+130

TABLE 1. C.

Depth Inter-val (m)	NOVEMBER 1	NOVEMBER 2	NOVEMBER 3	DECEMBER 1	DECEMBER 2	DECEMBER 3
0–10	+17900	+800	–100	–	–	+600
10–20		+4000	+3200			
20–30		+3700	+1300		+11800	+3250
30–50		+700	+4000		+7200	+1350
50–75		[illegible]	+1600			+2000
75–100			+1700			+800
100–125			+1200			+800
125–150			+1700			+1000
150–200			+840			+4180
200–250						+1240
250–300			+640			+640
300–400			+220			+100
400–500			+140			–

TABLE 1 D. Vertical stability characteristics of the shelf waters (0-500 m depth) along the south-west coast of India (1974 - values) (expressed as $10^8 E$)

- Negative stability
+ Positive stability
0 Neutral stability

1. Coastal stn. 2. Mid-shelf stn. 3. Outershelf Stn.

KASARAGOD

Depth inter-val (m)	JANUARY 1	JANUARY 2	JANUARY 3	MARCH 1	MARCH 2	MARCH 3	MAY 1	MAY 2	MAY 3	JULY 1	JULY 2	JULY 3	AUGUST 1	AUGUST 2	AUGUST 3	NOVEMBER 1	NOVEMBER 2	NOVEMBER 3
0-10	+800	+400	+1600	+3000	+2100	+2300	+11300	+600	+3300	-	-500	+800	-	+30100	+500	+10900	+8600	-100
10-20		+100	+2300		+300			+100	+3500		+5500	-0-		+3000	-0-		+13000	+1900
20-30		-0-	+7500		+5800	+5800		+3900	+6200		+11600	-0-		+300	+2800	[illegible]	+3300	+900
30-50		+13800	+4400		+4450	+200		+8700	+2800		+1600	+5700		+1300	+3800		+400	+6900
50-75		[illegible]	+2000			+3700		+600	+5400			+2700		+700	+1700		-0-	+3000
75-100		[illegible]	+4000			+2000			+2600			+2700			+1700			+700
100-125			+3000			+4000			+1000			+1000			+1600			+1200
125-150			+2600			+2500			+300			+1200			+1700			+1200
150-200			+1700			+1800			+1200			+8800			+600			+700
200-250						+800												
250-300			+690			+400			+470			+390			+360			+500
300-400			+240			+240			+330			+220			+170			+200
400-500			+100			+150			+150			+160			+130			+150

TABLE 1´ D (Contd.)

Depth interval (m)	DECEMBER 1	2	3
0–10	–0–	+300	+200
10–20		+400	+4900
20–30		+700	+2400
30–50		+100	+600
50–75			+400
75–100			[illegible]
100–125			+1400
125–150			+280
150–200			+800
200–250			–
250–300			+970
300–400			+540
400–500			+180

TABLE 1 E. Vertical stability characteristics of the shelf-waters I0 - 500 m depth) along the south-west coast of India (1974 - values) (expressed as 10^8E)

1. Coastal Stn. 2. Mid shelf stn. 3. Outer shelf stn.

\- Negative stability
\+ Positive stability
0 Neutral stability

KARWAR

Depth interval (m)	JANUARY 1	JANUARY 2	JANUARY 3	MARCH 1	MARCH 2	MARCH 3	APRIL 1	APRIL 2	APRIL 3	JULY 1	JULY 2	JULY 3	AUGUST 1	AUGUST 2	AUGUST 3	NOVEMBER 1	NOVEMBER 2	NOVEMBER 3
.0-10	-0-	+400	+200	+1100	+3400	-200	+700	+1900	+200	-	-900	-0-	-	+400	+400	+17700	+20000	+300
10-20		+600	+4300		+2300	+1400		+900			+4100			+8200	-0-		+10100	+1600
20-30		+5500	+7200		+4100	+1700		+7000	+2950		+18500	+100		+20000	+100		+3800	+2700
30-50		+4030	+3900		+4850	+4800		+5450	+5600		+2200	-0-		+2500	+4700		+600	+5600
50-75			+1000			+3600			+2500			+5700			+1500			+2100
75-100			+2400			+1300			+3600			+2900			+2040			+1000
100-125			+3400			+3300			+2900			+1200			+1300			+810
125-150			+3000			+2400			+2350			+1100			+1600			+100
150-200			+1340			+3300			+1800			+920			+860			+1140
200-250									+840			+500						
250-300			+670						+400			+360			+690			+500
300-400			+190						+230			+190			+160			+220
400-500			+100						+200			+100			-			+160

TABLE 1: E (Contd.)

Depth interval (m)	DECEMBER 1	2	3
0-10	-200	-400	+100
10-20		+300	-0-
20-30		+300	+100
30-50		+2800	+2650
50-75			+810
75-100			+700
100-125			+1500
125-150			+2300
150-200			+1680
200-250			
250-300			+930
300-400			+250
400-500			+170

TABLE 1 F. Vertical stability characteristics of the shelf waters (0 - 500 m depth) along the south-west coast of India (1974-values) (expressed as $10^8 E$)

1. Coastal Stn. 2. Mid shelf stn. 3. Outer shelf stn.

- Negative stability
+ Positive stability
0 Neutral stability

RATNAGIRI

Depth interval (m)	JANUARY			MARCH			APRIL			JUNE			AUGUST			NOVEMBER		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0–10	+200	+800	-300	-100	-100	+1900	-200	-100	+200	+2200	+1000	-300	-	+300	+400	+4800	+600	+400
10–20		+200	+2200		+3000	+2700	+700	-100			+300	-0-		-0-	-100		+19800	+1400
20–30		+2300			+4200	-600		+5900	+4400		+900	+100		+13800	-0-		+2300	+7400
30–50		+500	+1200		+1400	+2950		+3900	+2600		+6800	+7500		+4300	+350		+150	+4300
50–75			+2600			+1100			+2400			+1700			+760			+360
75–100			+1200			+2040			+5700			+2500			+1200			+2600
100–125			+2600			+720			+1700			+2700			+1500			+1040
125–150			+2800			+1640			+1100			+2800			+1200			
150–200			+800			+2360									+5400			+1040
200–250						+1040			+2160									
250–300						+480			+440						+1220			+470
300–400									+260						+170			+230
400–500									+160						+60			+130

TABLE 1: F (Contd.)

Depth interval (m)	DECEMBER 1	2	3
0-10	+3300	+300	+200
10-20		-	-0-
20-30		+2000	-0-
30-50		+4200	-0-
50-75		+120	+4500
75-100			+2100
100-125			+1100
125-150			+400
150-200			+1180
200-250			
250-300			+720
300-400			+370
400-500			+130

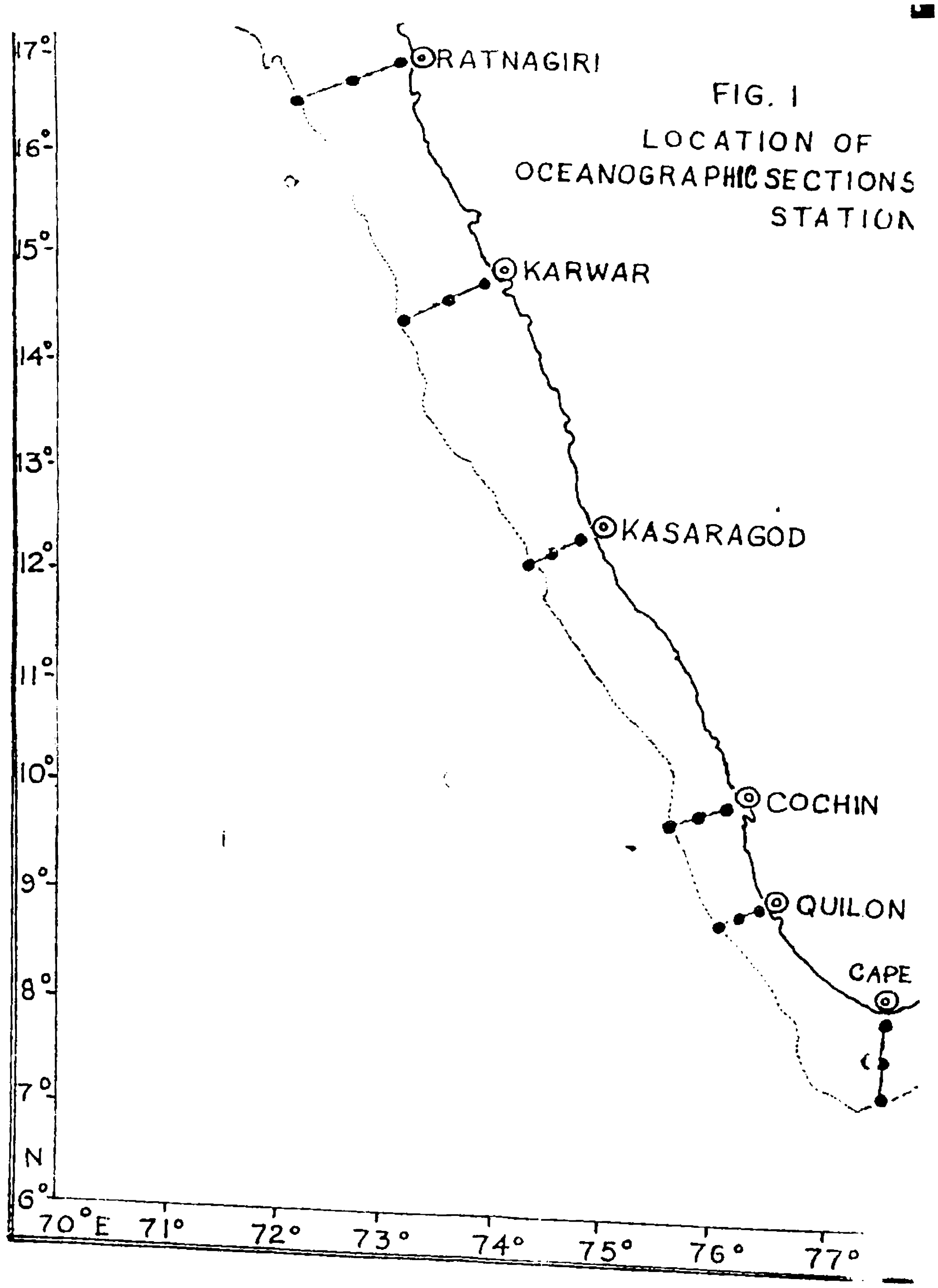
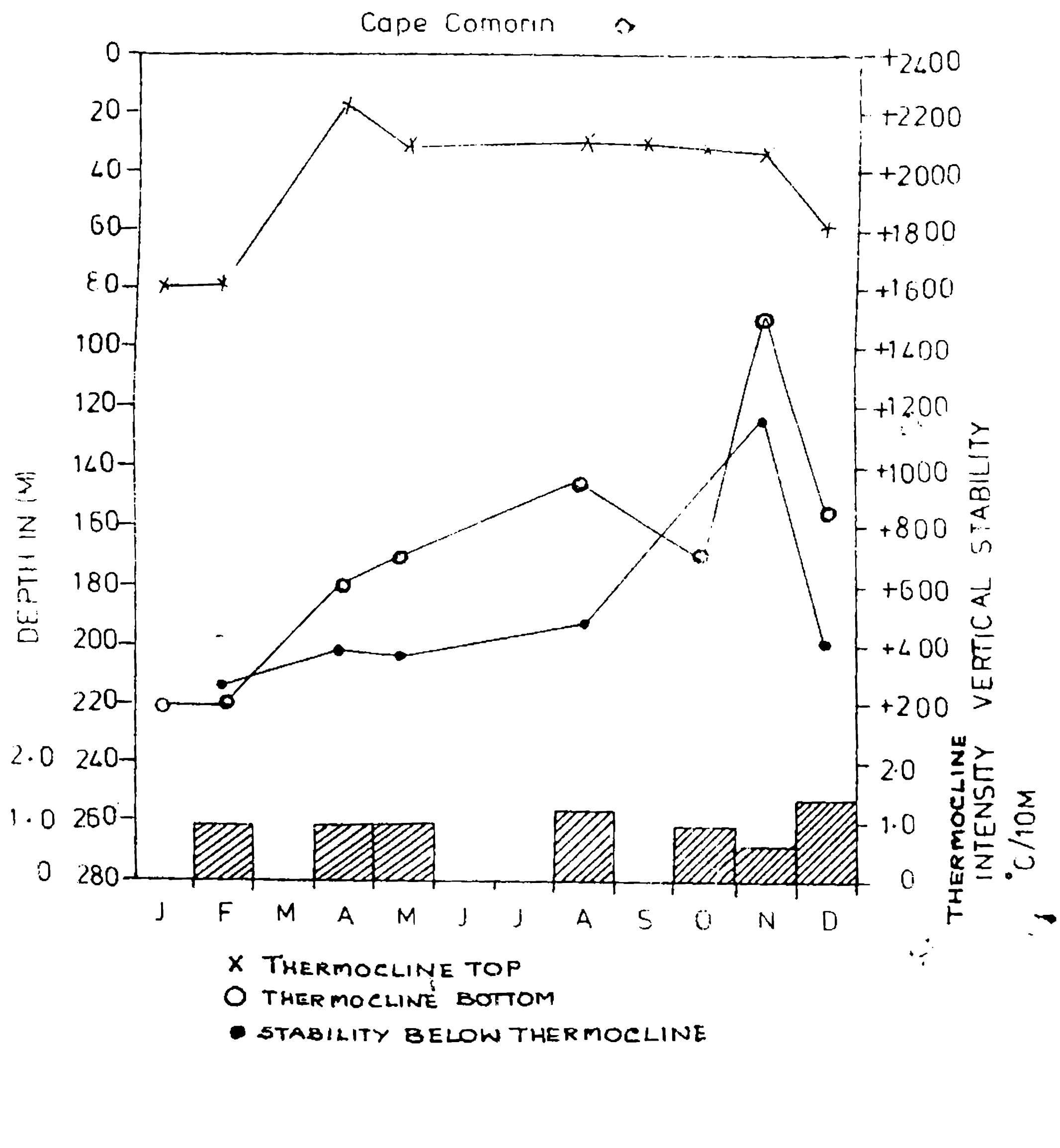


FIG. I
LOCATION OF
OCEANOGRAPHIC SECTIONS
STATION
RATNAGIRI
KARWAR
KASARAGOD
COCHIN
QUILON
CAPE
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
N
6°
70°E
71°
72°
73°
74°
75°
76°
77°

FIG. 2A



Cape Comorin
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
2.0
1.0
0
DEPTH IN (M)
+2400
+2200
+2000
+1800
+1600
+1400
+1200
+1000
+800
+600
+400
+200
VERTICAL STABILITY
2.0
1.0
0
THERMOCLINE INTENSITY °C/10M
J F M A M J J A S O N D
X THERMOCLINE TOP
O THERMOCLINE BOTTOM
● STABILITY BELOW THERMOCLINE

FIG. 2 B

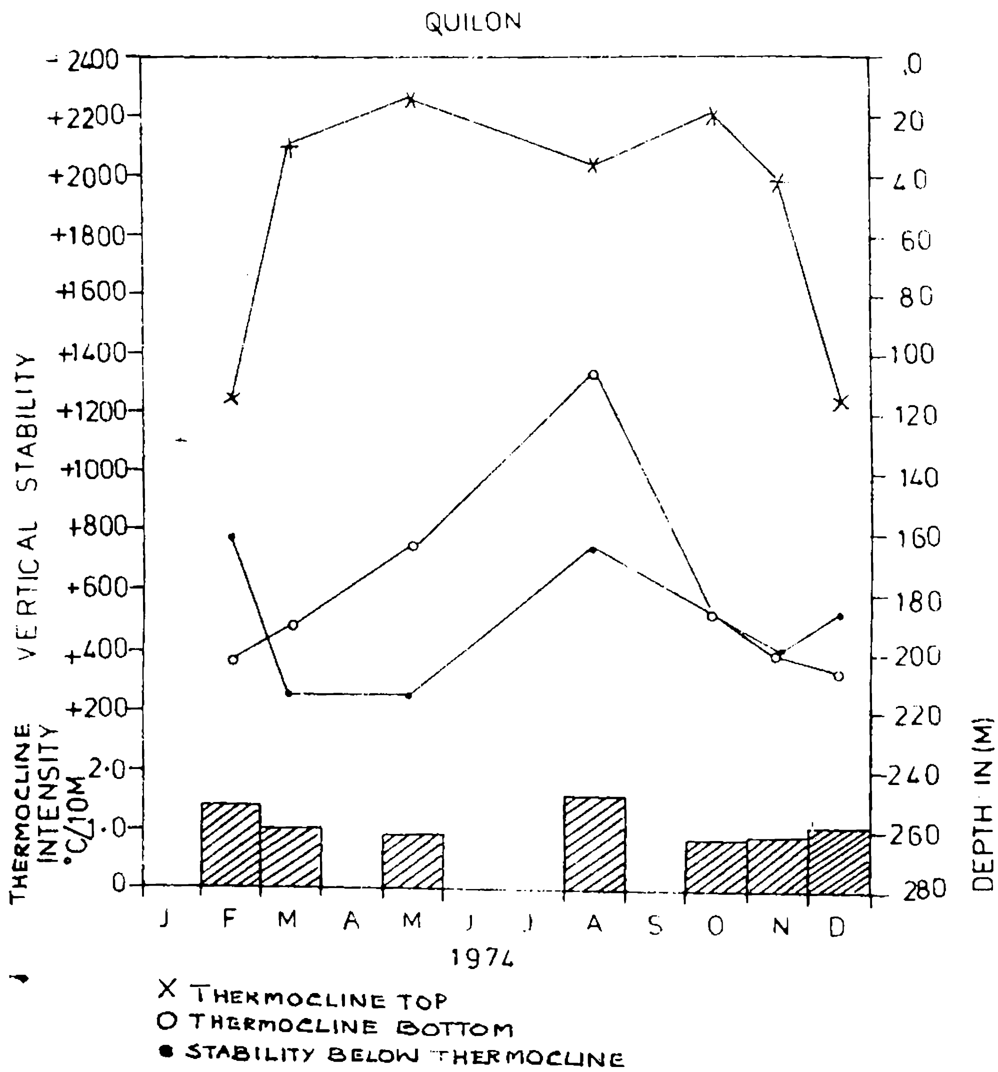
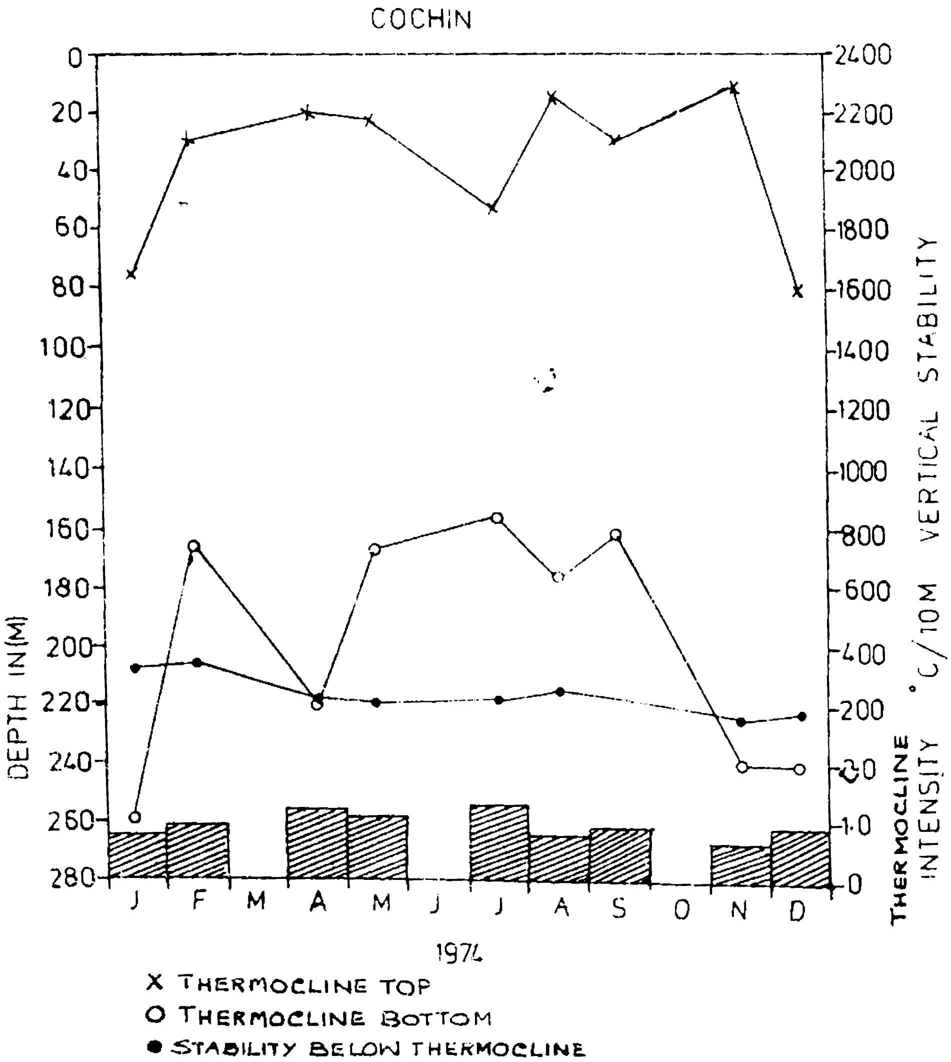
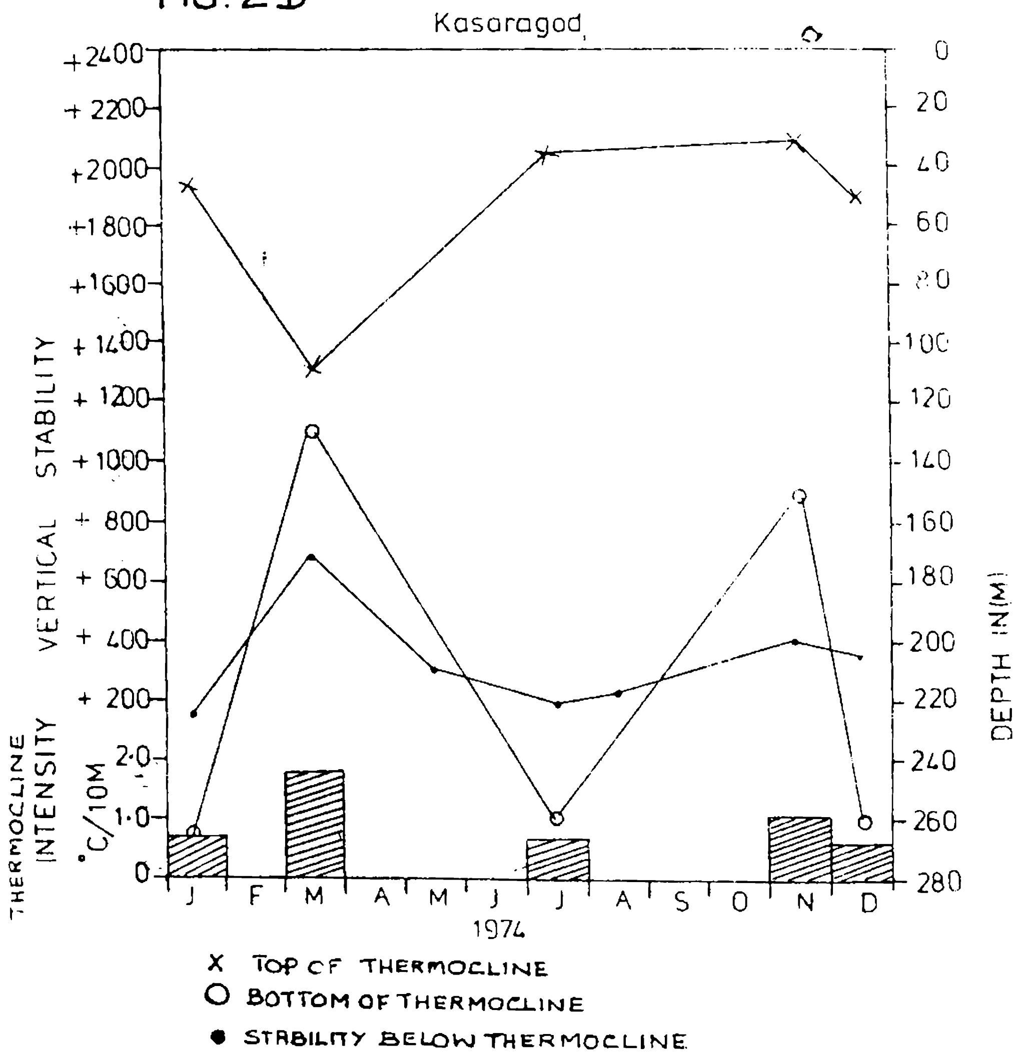

QUILON
VERTICAL STABILITY
THERMOCLINE INTENSITY °C/10M
DEPTH IN (M)
-2400
+2200
+2000
+1800
+1600
+1400
+1200
+1000
+800
+600
+400
+200
2·0
1·0
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
J F M A M J J A S O N D
1974
X THERMOCLINE TOP
O THERMOCLINE BOTTOM
● STABILITY BELOW THERMOCLINE

FIG. 2c



COCHIN
DEPTH IN (M)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
2.0
1.0
0
VERTICAL STABILITY °C/10M
THERMOCLINE INTENSITY
J F M A M J J A S O N D
1974
X THERMOCLINE TOP
O THERMOCLINE BOTTOM
● STABILITY BELOW THERMOCLINE

FIG. 2D



Kasaragod
+2400
+2200
+2000
+1800
+1600
+1400
+1200
+1000
+800
+600
+400
+200
VERTICAL STABILITY
THERMOCLINE INTENSITY °C/10M
2·0
1·0
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
DEPTH IN(M)
J F M A M J J A S O N D
1974
X TOP OF THERMOCLINE
O BOTTOM OF THERMOCLINE
● STABILITY BELOW THERMOCLINE

FIG. 2E

KARWAR

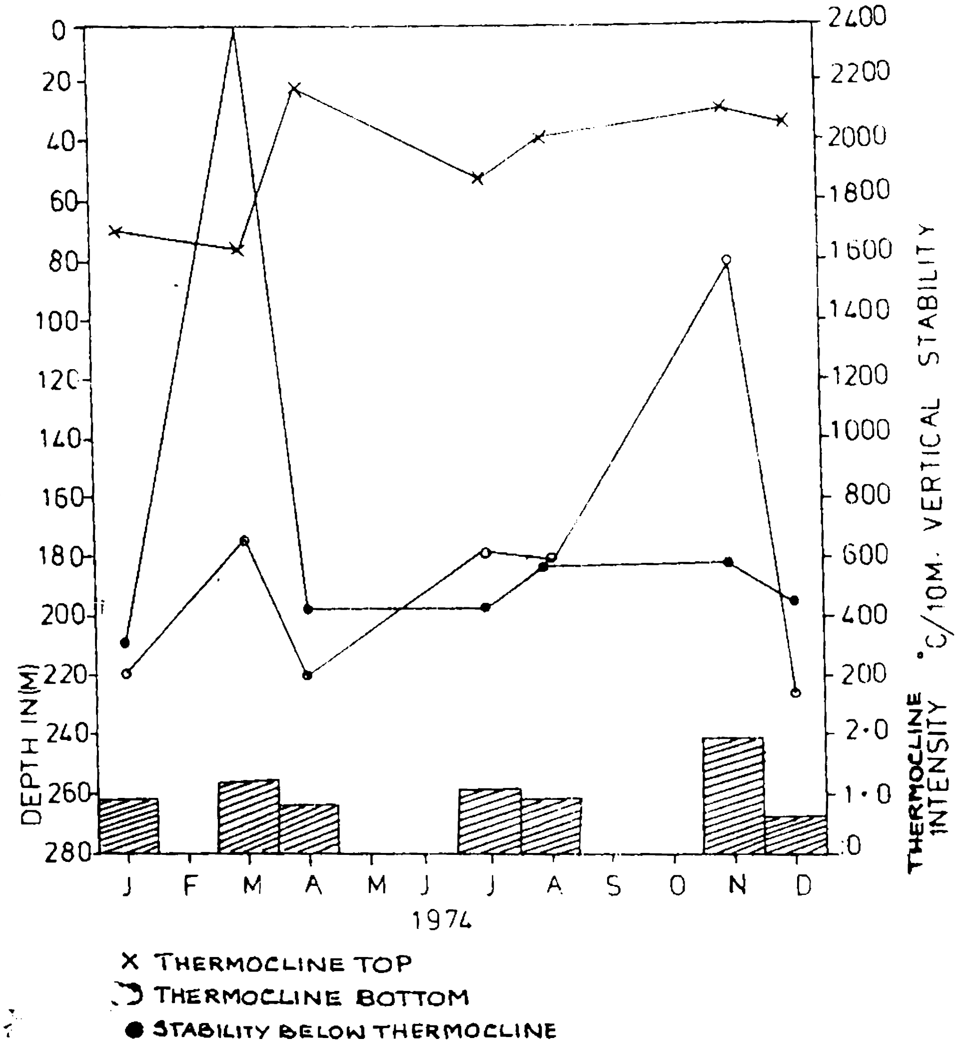
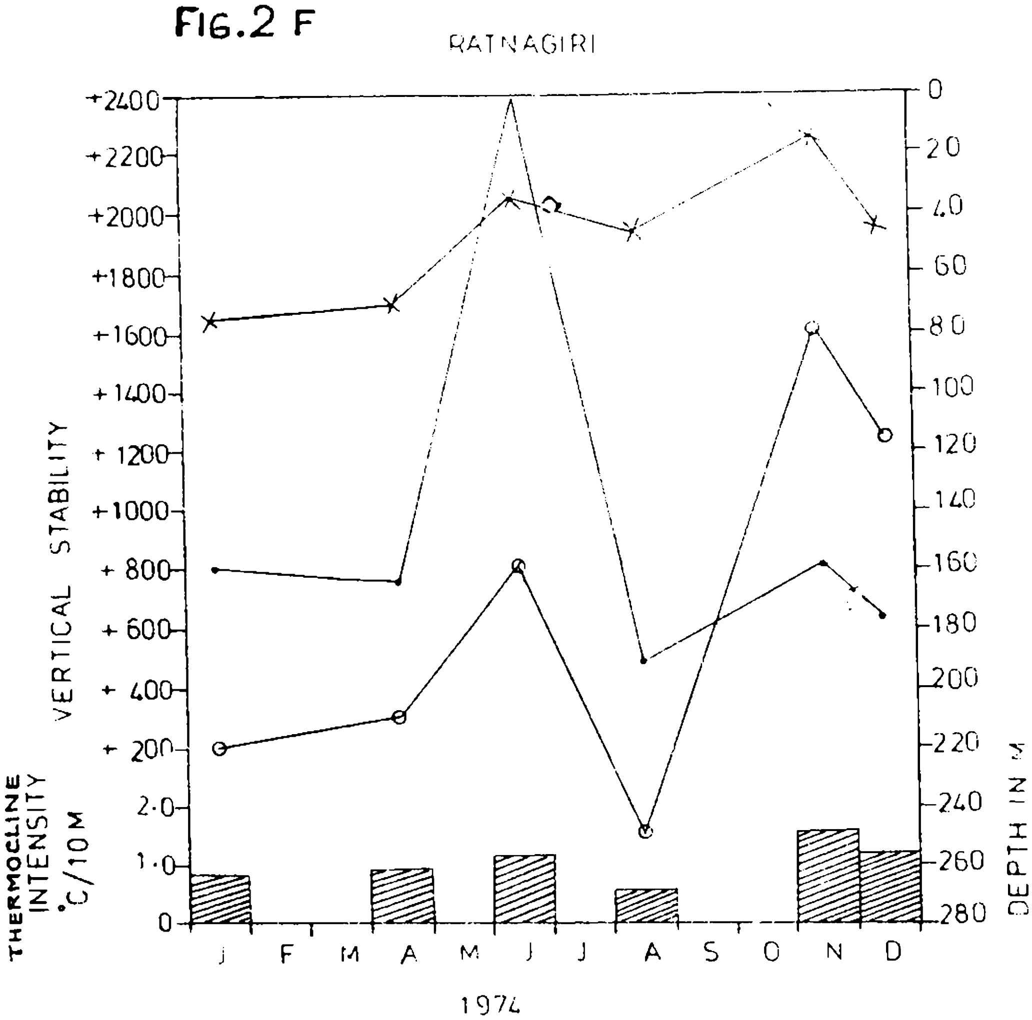
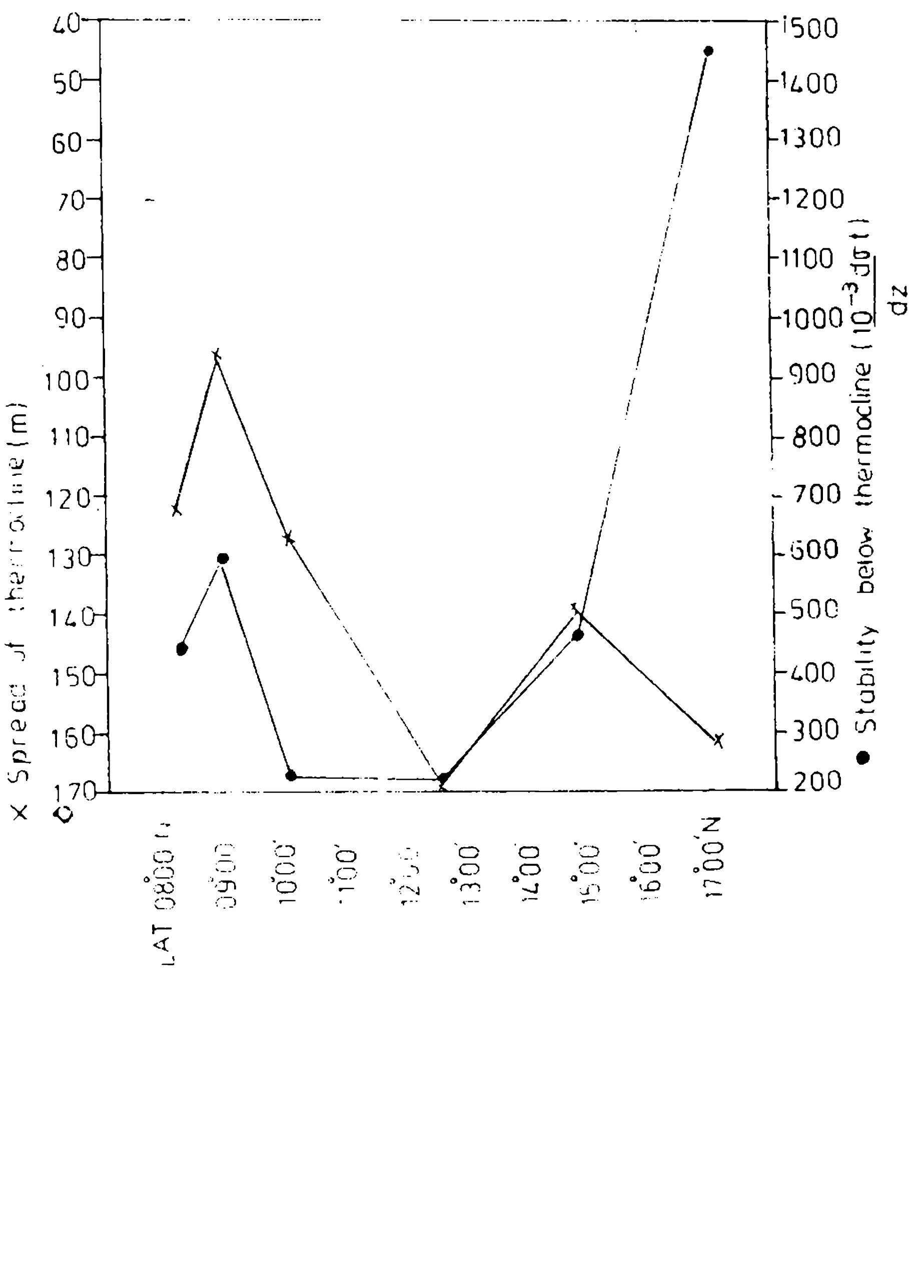


FIG.2 F



X THERMOCLINE TOP
O THERMOCLINE BOTTOM
● STABILITY BELOW THERMOCLINE

FIG. 3


40
50
60
70
80
90
100
110
120
130
140
150
160
170
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
× Spread of thermocline (m)
● Stability below thermocline ($10^{-3}\frac{d\sigma t}{dz}$)
LAT 0800
0900
1000
1300
1400
1500
1600
1700 N

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Satellite Evidence of Enhanced Upwelling Along the European Continental Slope

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17 October 1979 and 18 January 1980

ABSTRACT

TIROS-N AVHRR imagery is used to describe a persistent but localized band of upwelling which follows the contours of the European continental slope from the Porcupine Seabight (southwest of Ireland) to the Bay of Biscay. Its persistent occurrence, its close association with the upper part of the slope, and the northward broadening of the upwelling region are shown to be consistent with recently published theory (Killworth, 1978) concerning the enhancement of upwelling by interaction between slope topography and Kelvin (or other) waves propagating along the slope. Some limited evidence of enhanced biological productivity is also described.

The launch of the TIROS-N Satellite in October 1978 gave the possibility of much improved thermal imagery of the ocean surface via its Advanced Very High Resolution Radiometer (AVHRR), resolving delicate features of the ocean's thermal field which were only dimly glimpsed by previous imagery.

This report describes one such feature—upwelling along the continental slope of the eastern Atlantic—based on AVHRR images at 11 μm for three cloud-free days in the Bay of Biscay (Table 1). Visual and infrared prints of each at 4.5× magnification were obtained from the Department of Engineering and Electronics, University of Dundee.

The visual and infrared images of print B are representative of all three and are shown as Figs. 1a and 1b. The chief feature of interest here is the narrow band of cold water (light grey tone) which slants northwest to southeast across the center of Fig. 1b, though it is inevitably shown here with much less clarity than in the original print. In Fig. 2 the outline of the cold water band and the axis of maximum cooling (dashed line) have been super-

[1] Visiting scientist at Lowestoft Laboratory.

0022-3670/80/050813-07$05.75

TABLE 1. Orbit characteristics of the three images examined.

Print	Date	Orbit	Time (GMT)
A	14 May 1979	3006	1443
B	19 June 1979	3514	1507
C	5 July 1979	3740	1540

imposed on a gridded chart of the area, drawn from these photographs, and with the continental slope indicated by the position of the 250, 500 and 1000 fathom contours. (The most accurate depth chart of the area—Admiralty chart C 6568—is in fathoms and since a precise plotting of the slope contours is important to this report, no attempt has been made to interpolate to meters.) Because the features of interest are so closely superimposed, Fig. 2 is presented in two parts: Fig. 2a shows the outline of the coldest surface water together with a dashed line representing the central axis of the cooling, while Fig. 2b shows this axis in relation to the selected slope contours.

In Fig. 2 a number of features are evident. First, the narrow ribbon of cool water is aligned almost exactly with the continental slope, curving northward west of 11°W as the slope curves north to form the Porcupine Seabight, meandering at 9–11°W where the continental slope is itself indented by two major canyons (Whittard Canyon and a second unnamed canyon some 50 km to the east) and changing slightly in alignment at 47°N, 6°W approximately, where the edge of the Armorican Shelf trends a little more directly southeastward. Second, it is evident that in general terms the cooling increases in extent and intensity northwestward along the slope; on none of the photographs examined was the cooling traced south of 45°N.

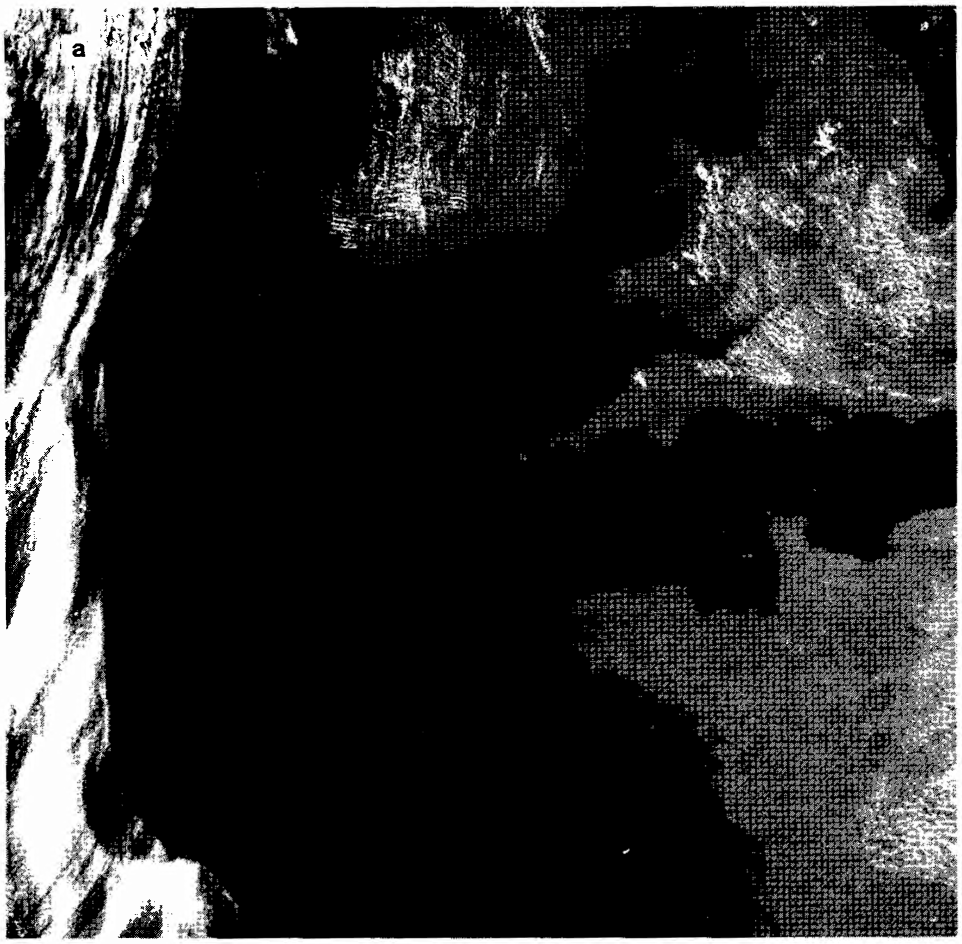

FIG. 1. (a) Visual and (b) infrared AVHRR imagery of part of the European shelf and Bay of Biscay at 1507 GMT 19 June 1979 (TIROS-N orbit 3514). The presence of cool surface water along the continental slope is indicated by the light grey tone slanting from northwest to southeast across the center of Fig. 1b.

b

FIG. 1. (*Continued*)

Third, although there is bound to be some imprecision in plotting the latitude-longitude grid and depth contours, Fig. 2b nevertheless appears to show that the narrow ribbon of cool water is aligned over the *upper* part of the continental slope, being most closely associated with the 250 fathom contour. As will be shown below all of these features conform with recently published theory concerning the enhancement of upwelling along indented continental slopes.

Although cloudless conditions in Biscay are by no means common, these three features of the cold water band do appear consistently on other cloud-free images from this area. The infrared image for 1443 GMT 14 May 1979 (Fig. 3a) shows a similar alignment of the cooling over the continental slope, although in this case sea fog obscures the Porcupine Seabight. Once again the cooling appears to broaden and intensify northwestward from an origin near 45°N, 2–3°W (where the alignment of the slope abruptly changes), and the close link with slope ridges and canyons is clear from the meandering of the cooling around 47–48°N, 7–9°W. When the axis of the cooling and the slope contours are superimposed (Fig. 3b) these particular meanders are shown to overlie Shamrock and Blackmud Canyons and the intervening spur at the "root" of Meriadzek Terrace.

Some limited ground truth for Fig. 2 is provided by surface thermograph records obtained by RV *Cirolana* (Ministry of Agriculture, Fisheries and Food), which made two transects of the cool water band in June 1979. The position of both transects is shown in Fig. 2a. The northern record (not shown) coincides with a lateral spreading of the cold water around 49–49°30′N, 10–13°W where the slope contours spread out, and the cooling is therefore poorly defined. On the southern transect to Brest, however, the narrowness of the cool water band is more typical of conditions on the northern part of this slope. The uncorrected thermograph record for the period from 1500 GMT 27 June to 0200 GMT 28

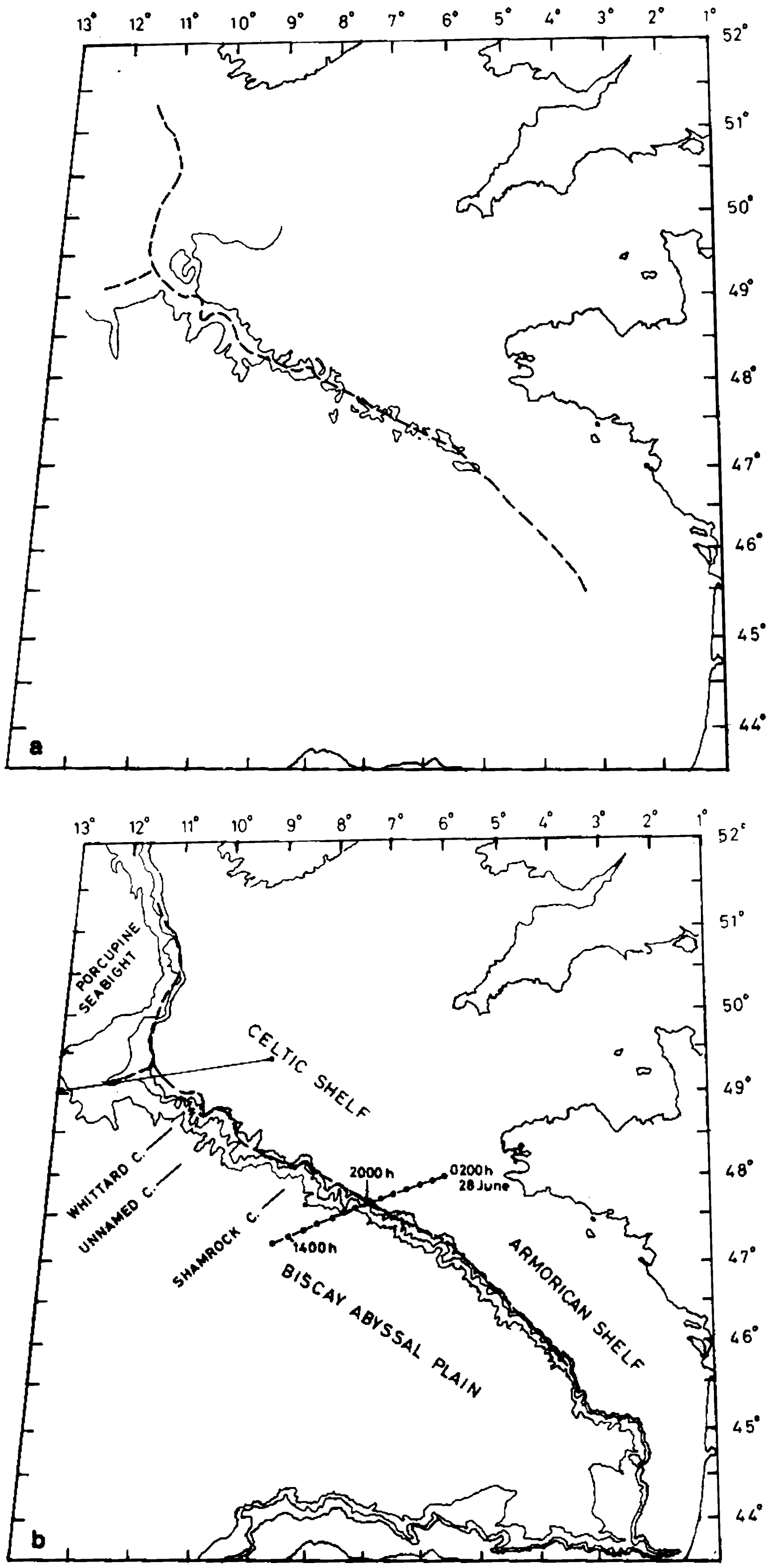

FIG. 2. (a) Outline showing the distribution of coldest surface water at 1507 GMT 19 June 1979, together with the principal axis of the cooling (dashed line). The axis of cooling alone is shown where the cold water belt is narrow and its margins indistinct. (b) Location chart showing the relationship between the axis of the cold water belt (dashed line) and the 250, 500 and 1000 fathom slope contours. Two surface thermograph transects of the slope by RV *Cirolana* in June 1979 are indicated (● —— ●), and hourly positions on the southern transect are shown.

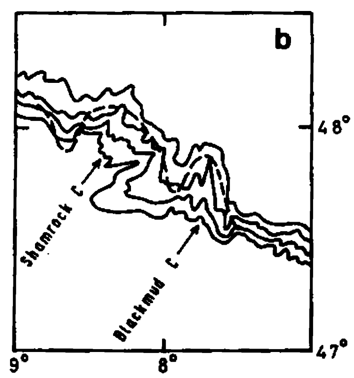

FIG. 3. (a) Infrared (AVHRR) image of the Bay of Biscay at 1443 GMT 14 May 1979 (TIROS-N Orbit 3006). (b) Detail showing the main axis of cooling (dashed line) in relation to the 250, 500, 750 and 1000 fathom slope contours in the area 47–48°30'N, 7–9°W.

June is shown in Fig. 4. Applying an instrument-correction of +0.6°C, this record indicates that surface temperatures decreased from offshore values of 17.5–18.0°C to a minimum of 14.8°C on crossing the slope and then rewarmed to 17.0–17.5°C as the vessel continued inshore. (Hourly positions of the ship during this period are plotted in Fig. 2b for comparison.)

While the existence of cooling at the continental slope was known from earlier NOAA-5 imagery (Pingree, 1978, 1979), its origin has remained obscure. However, the detailed distribution of the cooling along the slope does appear to be consistent with a recent theoretical study by Killworth (1978) which demonstrates that ridges and canyons running down a continental slope can be important in locally enhancing upwelling, through their interaction with Kelvin waves propagating along the slope. [For simplicity Killworth used a vertical coastal wall in his model, but the principal

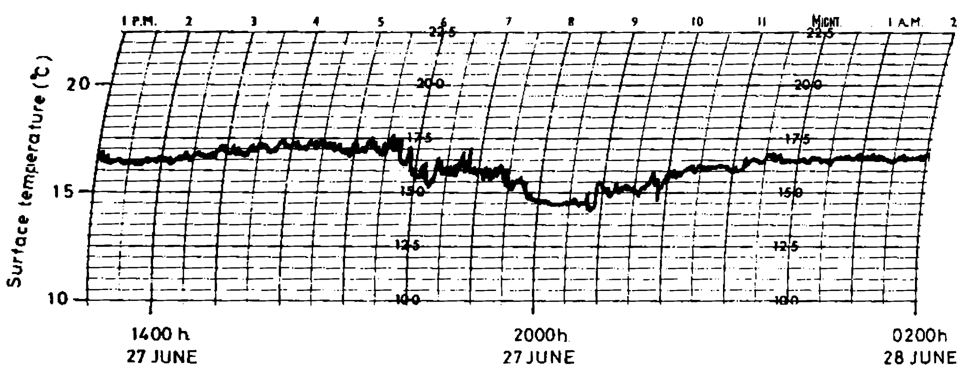

FIG. 4. Surface thermograph record for the period 1500 GMT 27 June to 0200 GMT 28 June during the southern transect of the slope by RV *Cirolana*.

conclusions are thought equally applicable to slopes (Killworth, personal communication)]. The necessary scaling conditions are met if $\epsilon \ll S \ll S^{1/2} \ll 1$, where $\epsilon = u/fL$ is the Rossby number and $S = (NH/fL)^2$ is the square of the ratio of the radius of deformation to the length scale of the topography (for definitions, see Table 2).

The applicability of this theory to the locality in question was tested using the parameters in Table 2; these reflect the apparent water depth along the axis of the cooling (~500 m) and take account of the much larger scale of ridges and canyons on the northern part of this slope (L = 50–100 km assumed) than along its southern part (L = 15 km assumed).

Although these figures are necessarily approximate, largely because the topographic scale cannot be characterized with any great precision, there seems little doubt that Killworth's main theoretical condition for enhanced upwelling on the slope is satisfied in this area. Further, the theory itself shows that so long as this condition is satisfied the ocean's response to a curved shelf line will be the same as for a straight coast, merely shifting east and west to follow the boundary. Some small northward broadening of the upwelling region (width $\propto S^{1/2}$) is also theoretically predicted through the increase in the Coriolis parameter with latitude, but along this particular stretch of the slope, it is evident from theory that this effect will be greatly reinforced by the accompanying increase in topographic scale toward the north. Finally, the theoretical scaling condition that $(NH/fL) \ll 1$ only holds on the shallower upper part of the slope where the upwelling is observed. Thus although other possible mechanisms exist for the general presence of cooling at the shelf break [e.g., enhanced mixing through tidal interaction with the continental slope (Rattray, 1960); geostrophic tilting of isopycnal surfaces by longslope currents and countercurrents; etc.], Killworth's theory also appears to account satisfactorily for certain *details* in the observed distribution of cooling. Though Killworth's report deals specifically with Kelvin waves we may expect any shelf-edge wave propagating northward to act in a similar manner.

From the TIROS-N images examined and from Pingree's study of about 40 images from the NOAA-5 Satellite in 1976–78 (Pingree, 1979), it appears that surface cooling is a general feature of

TABLE 2. Parameters used in the estimation of ϵ (Rossby number) and s (ratio of radius of deformation to topographic length scale) for the European continental slope between 45 and 49°N. For explanation see text.

	Latitude				
	49°N	48°N	47°N	46°N	45°N
Topography scale L (km)	100	50	15	15	15
Brunt-Väisälä frequency N (s^{-1})	4.0×10^{-4}	4.0×10^{-4}	4.0×10^{-4}	4.0×10^{-4}	4.0×10^{-4}
Coriolis frequency f (s^{-1})	1.75×10^{-5}	1.72×10^{-5}	1.69×10^{-5}	1.67×10^{-5}	1.64×10^{-5}
Scale depth H (m)	500	500	500	500	500
Scale speed U (cm s^{-1})*	0.91	0.93	0.94	0.96	0.97
Rossby number ϵ	5.2×10^{-3}	1.1×10^{-2}	3.7×10^{-2}	3.8×10^{-2}	3.9×10^{-2}
Radius of deformation ratio S	1.3×10^{-2}	5.4×10^{-2}	0.62	0.64	0.66
$S^{1/2}$	0.11	0.23	0.79	0.80	0.81

* The scale speed U is calculated from the wind stress τ_0, scale depth and Coriolis parameter by $U = \tau_0/(\rho_0 f H)$.

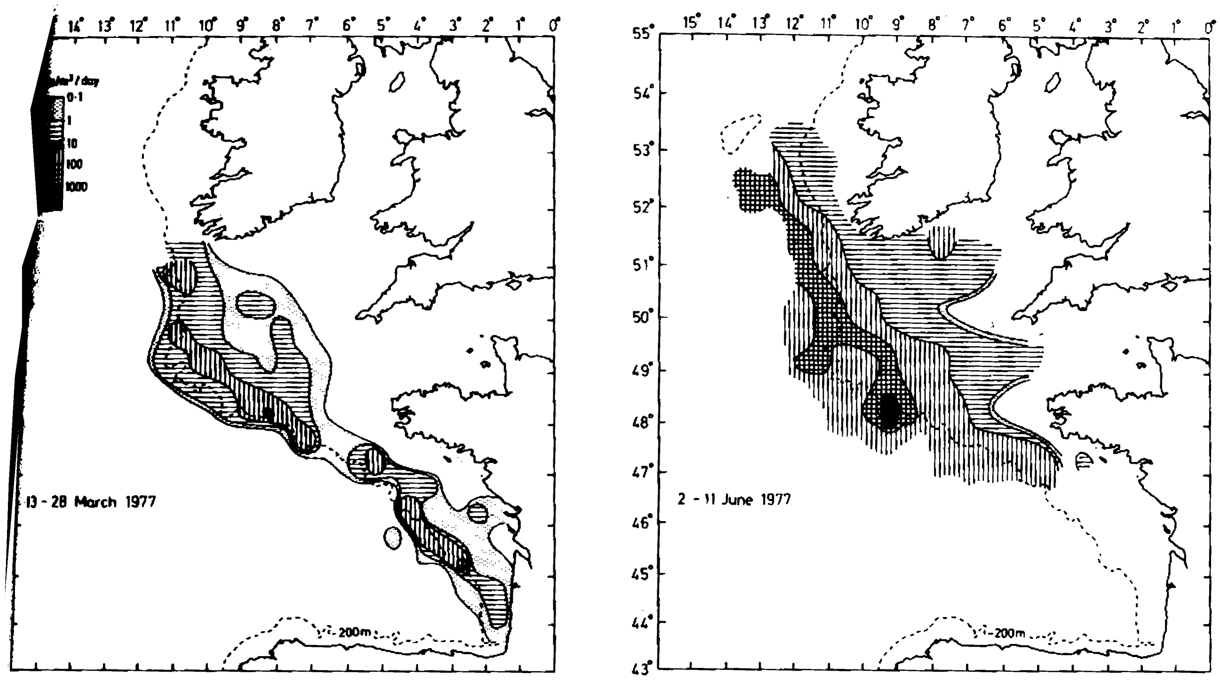

FIG. 5. Production of Stage I mackerel eggs (numbers m^{-2} day^{-1}) during the periods 13–28 March and 2–11 June 1977 (from Lockwood, 1978).

ıs slope in summer, persisting even through :riods of very light winds. While its thermal ɔntrast with surrounding waters is naturally most vident during the summer months May–Septemıer, the process responsible for the cooling may well operate at other times of year also. If due to upwelling the question arises as to its possible importance to biological productivity. The distribution of Stage I mackerel eggs in the area over the period March–July 1977 (e.g., Fig. 5 from Lockwood, 1978) certainly suggests that mackerel spawning mainly occurs in a narrow band which closely follows the alignment of the continental slope. Continuous surface chlorophyll *a* transects by RV *Cirolana* in June 1977 also suggest higher levels of phytoplankton standing stock over the slope than elsewhere (unpublished data, S. Lockwood, personal communication). It remains to be demonstrated, however, whether these indications of high productivity are attributable to the upwelling under discussion or to some other feature of this complex slope region.

Acknowledgments. We thank Peter Killworth and John Huthnance for helpful comments on the manuscript.

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AN INVESTIGATION INTO THE POSSIBLE RELATIONSHIP BETWEEN WOODHEAD SEA-BED DRIFTER RETURNS AND OFFSHORE/ONSHORE WINDS ALONG THE NORTH-EAST COAST OF ENGLAND DURING THE PERIOD AUGUST 1976-JANUARY 1977

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D. G. Hughes*

INTRODUCTION

During 1976 as a complement to measurements made by anchored recording current meters, a study of the residual trends from Woodhead sea-bed drifters released along the north-east coast of England revealed certain interesting trends in the bottom circulation of the region (Ramster and Jones, 1978). Up to about 40 miles offshore, the returns from both inshore and offshore releases consisted principally of drift in the south-westerly quadrant. The beach returns from all the releases at inshore stations tend to be largest within the first three weeks. The release retrieval interval suggested that near-bed residual drift is either more onshore or faster, or both, or that the beaching process is easier in May-October than in the remaining segment of a 12 monthly cycle. The results indicated distinct summer and winter regimes. The main tidal axis in this area runs parallel to the coast and tides are comparatively strong within the first 40 miles. The patterns of returns from inshore stations were very different to those from offshore stations, thereby indicating distinct offshore and inshore regimes. During summer a clear-cut two-layer circulation with onshore flow at bottom levels, especially within the inshore region, was typical of the area under study. During winter a less prominent two-layer regime with more variability existed.

In some coastal areas it is found that bottom onshore drift is associated with offshore winds, particularly in upwelling regions

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(e.g. Halpern, Smith and Mittelstaedt, 1977). The aim of the present study is to examine possible relationships between returns of Woodhead sea-bed drifters and onshore/offshore wind regimes to see if similar relationships exist off the north-east coast of England.

METHODOLOGY

The data used for the study are those pertaining to the period 24 August 1976 to 11 January 1977, the period during which the maximum number of beach returns were recorded. Daily mean wind observations at Tynemouth were taken as representative of the area covered (Figure 1). The 'north' and 'east' wind components were converted into components parallel and perpendicular to the coast, and the offshore/onshore velocities plotted against time (Figure 2). The number of beach returns during days of onshore and offshore wind were then compared (Table 1). In order to check the role played by the duration of wind, periods of persistent offshore and onshore wind were sorted out and the number of beach returns in each period compared.

RESULTS

Out of a total of 1 249 beach returns which occurred during the period, 710 arrived at the beach on days with offshore wind (87 days) and the balance, 539, were beached on days with onshore wind (52 days). This gives a daily average figure of 8 returns during the offshore regime and 10 during the onshore regime.

A closer examination of the duration of offshore and onshore wind components revealed the fact that only offshore winds were persistent. During the persistent offshore regime a total of 298 drifters was beached in 46 days showing an average figure of 6 drifters per day. During the remaining period without either offshore or onshore persistent winds a total of 951 drifters was beached in 93 days showing an average figure of around 10 drifters per day.

Both the above daily averages indicate a smaller number of beach returns per day during the offshore wind regime (Table 2).

DISCUSSION AND CONCLUSIONS

The results of this study lend no support to the hypothesis that offshore winds are more favourable to beach returns of sea-bed drifters. There is in fact some indication that beaching is more likely during other wind regimes. This could be due to the wind having more direct influence upon drifters once they enter the nearshore area where drifters may move higher up the water column due to stronger tides (Dickson, 1976) and where depths are smaller. It seems likely that a nearshore region will exist where drifters will accumulate until wind regimes occur which are favourable to beaching.

An earlier study of this data set (Ramster and Jones, 1978) postulated the existence of a similar accumulation zone in the summer months further offshore, in the transition zone between thermally stratified and mixed waters. While drifters await the chance to beach in these accumulation zones they will be more influenced by local water conditions and in the nearshore zone direct wind influence, and this may account for the increased southerly component of drifters as compared to current meter records reported in Ramster and Jones.

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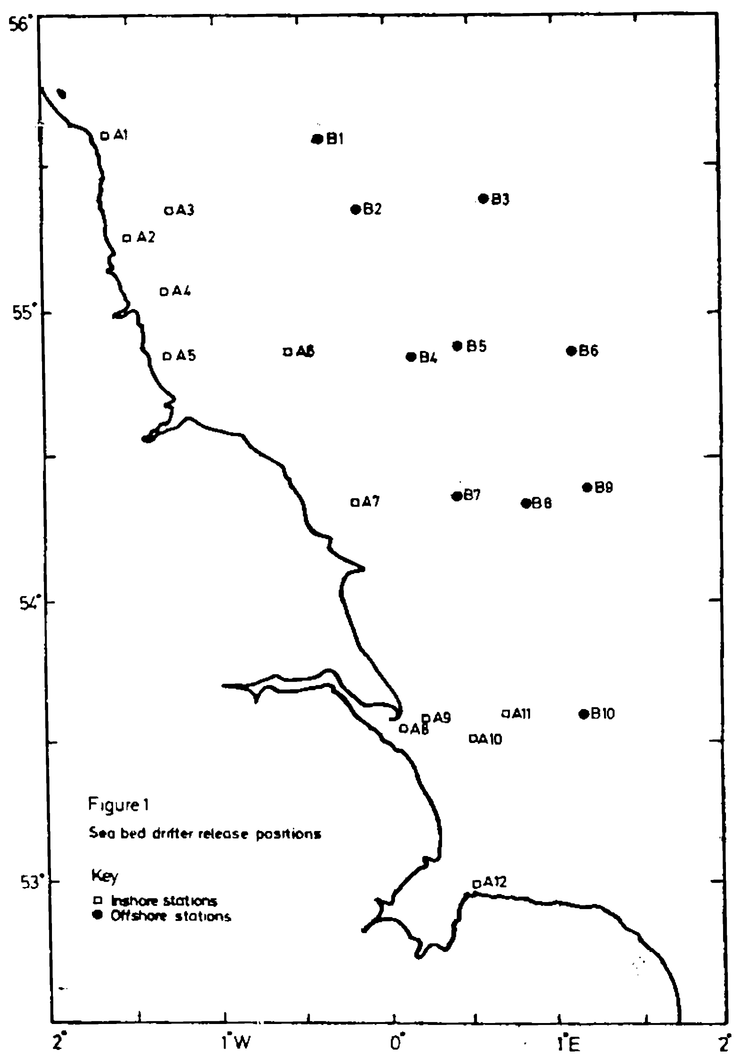

Figure 1
Sea bed drifter release positions

Table 1A Sea-bed drifter-beach returns, wind offshore

Ref.	25 Aug 1976	28 Aug 1976	31 Aug 1976	3-8 Sep 1976	13 Sep 1976	20 Sep 1976	3-8 Oct 1976	10-13 Oct 1976	16 Oct 1976	21-24 Oct 1976	26 Oct 1976	31 Oct-15 Nov 1976	17 Nov-16 Dec 1976	22 Dec 1976	26-31 Dec 1976	2-9 Jan 1977	11 Jan 1977
1/76	0	0	0	0	1	0	0		0	0	0	0	1			0	
2/76	3	3	1	4	0	0	5	5	0	1	0	9	16	0	0	7	0
3/76	0	3	0	6	0	1	4	2	3	0	0	4	5	0	2	2	0
4/76	0	1	1	0	0	1	1	0	1	1	1	1	4	0	1	6	0
5/76	0	0	0	1	0	0	4	1	0	0	0	0	0	1	0	1	0
6/76	0	1	0	1	1	0	1	1	1	0	0	1	6	0	0	1	1
8/76	0	0	1	4	0	0	1	4	0	1	0	3	12	0	2	5	2
9/76	1	2	2	9	0	1		7	2	1	1	5	11	0	1	4	0
10/76	0	0	0	2	0	0	1	0	1	0	0	8	9	0	0	4	1
11/76	1	6	1	7	2	0	9	5	1	1	0	7	14	2	2	14	0
12/76	0	12	0	9	1	0	3	2	2	2	2	14	38	1	5	14	1
13/76	0	0	0	0	0	0	16	6	3	7	0	5	47	0	10	17	7
14/76	0	0	0	0	0	0	5	14	13	11	1	22	41	0	4	16	2
15/76	0	0	0	0	0	0	0	0	0	0	0	6	14	0	3	22	3
16/76	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	3	0
Total	5	28	6	43	4	3	55	44	27	26	5	79	219	4	34	116	12

Table 18 Sea-bed drifter-beach returns, wind onshore

Ref.	24 Aug 1976	26-27 Aug 1976	29-30 Aug 1976	1-2 Sep 1976	9-12 Sep 1976	14-18 Sep 1976	21 Sep-2 Oct 1976	9 Oct 1976	14-15 Oct 1976	17-20 Oct 1976	25 Oct 1976	27-30 Oct 1976	16 Nov 1976	17-21 Dec 1976	23-25 Dec 1976	1 Jan 1977	10 Jan 1977
1/76	0	0	1	0	3	3	0	0	0	1	0	0	0	0	0	0	0
2/76	2	0	5	1	3	4	4	0	1	1	0	1	1	0	2	1	1
3/76		0	5	1	5	3	5	1	1	1	0	2	1	0	1	0	1
4/76		1		0	3	5			3	1	0	0	0	1		0	0
5/76		0		2	2	3	1		1	0	0	0	0	0	5	0	0
6/76			1		2	1	2		2	2		1	0	2	0	0	0
7/76		2		5	5	4	4		3	4		3	0	2	2	1	1
9/76									3	3	0	4	0	1		0	1
10/76	2	1	2	4	10	3	5	0	1	1	1	5	0	1	1	1	1
11/76		5	3	7	10	16	10	0	4	1		5	1	1	3	1	3
12/76			12	2	3	5		1		7		5	0	5	2	1	3
13/76				0	4			1		4	1	15	1	12	6	0	1
14/76						0			[illegible]	21	2	3	2	10		1	0
15/76				0	0	0	0		0	0	0	0	0	4	1	1	4
16/76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Total	12	17	30	30	78	57	55	10	54	52	4	49	9	37	21	10	16

Table 2A Sea-bed drifter-beach returns during onshore wind regime

Date/period			No. of days	No. of drifters beached	Average/ day
1976	Aug	24	1	12	12
		26-27	2	17	8
		29-30	2	30	15
	Sep	1- 2	2	30	15
		9-12	4	76	19
		14-19	6	57	9
		21-			
	Oct	2	12	55	4
		9	1	10	10
		14-15	2	54	27
		17-20	4	52	13
		25	1	4	4
		27-30	4	49	12
	Nov	16	1	9	9
	Dec	17-21	5	37	7
		23-25	3	21	7
1977	Jan	1	1	10	10
		10	1	16	16
Total			52	539	Average/ day ∿ 10

Table 2B Sea-bed drifter-beach returns during offshore wind regime

Date/period	No. of days	No. of drifters beached	Average/ day
1976 Aug 25	1	5	5
28	1	28	28
31	1	6	6
Sep 3- 8	6	43	7
13	1	4	4
20	1	3	3
Oct 3- 8	6	55	9
10-13	4	44	11
16	1	27	27
21-24	4	26	6
28	1	5	5
31- Nov 15	16	79	5
17- Dec 16	30	218	7
22	1	4	4
26-31	6	34	6
1977 Jan 2- 9	8	116	14
11	1	12	12
Total	89	710	Average/ day ∿ 8

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March 1980

INDIA

OCEANOGRAPHIC INVESTIGATIONS ALONG THE SOUTHWEST COAST OF INDIA (1976-78)

A report prepared for
Pelagic Fishery Investigations on the Southwest Coast
Phase II - Project

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1980

ABSTRACT

The description of the oceanographic conditions of the shelf waters off the southwest coast of India between Ratnagiri in the north and Tuticorin in the south for the period 1976-78 is based on observations carried out along oceanographic sections located off Ratnagiri, Karwar, Kasaragod, Cochin, Quilon, Cape Comorin and Tuticorin. In accordance with the objectives of Phase II of the Project, more emphasis was given to improving our knowledge of the behavioural characteristics of the oil sardine and mackerel and also to evolving methodologies for fishery forecasting appropriate to Indian conditions. Hydrography/plankton/fishing surveys were conducted during the southwest monsoon to assess the intensity of upwelling and to establish possible correlations between the behaviour of commercially important pelagic fishes and the variations of environmental factors observed in space and time. Data related to the process of upwelling were collected mainly to evaluate the extent and intensity of upwelling and also to verify the variations of certain physical parameters noted during the Phase I.

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SYMPOSIUM ON ENVIRONMENTAL MODELLING OF PHYSICAL OCEANOGRAPHIC FEATURES AS APPLIED TO INDIAN OCEAN

23 - 24 February 1978, at Cochin

NAVAL PHYSICAL AND OCEANOGRAPHIC LABORATORY
COCHIN

Proceedings of the Symposium on environmental modelling of Physical Oceanographic factors as applied to Indian Ocean. NPOL, Cochin (1978)

SOME ASPECTS OF THE OCEANIC THERMOCLINE IN THE BAY OF BENGAL DURING THE PERIOD MARCH - MAY.

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SENIOR OCEANOGRAPHER

UNDP/FAO PELAGIC FISHERY PROJECT, COCHIN-682016

SUMMARY The period March-May represent the post winter monsoon(NE) and also the pre-summer monsoon(SW) in the Bay of Bengal. The former is effective in the Western Bay along the east coast of India and the latter in the eastern Bay bordering the West coast of Burma and Thailand. The resulting hydrographic conditions are reffected in the vertical extend of the surface mixed layer and also the depth and width of the main thermocline which in turn is interpreted as an indicator of vertical mixing processes active in the region under study. Bathythermograph data form the basis of the study.

INTRODUCTION

Variations in temperature with depth is more or less a typical feature observed on the thermal structure of the oceans in the tropics and sub-tropics. As has been pointed out earlier by several authors, three general regions of water based on temperature characteristics in the vertical plane are traceable vis. the top mixed layer which is more or less isothermal followed by a region with strong vertical thermal gradients, the thermocline, with an average value of not less than 0.5°C for every 10.m. depth (Defant, 1961) and the deep water which extends from the bottom of the main thermocline to the ocean bottom, once again characterised by compartively weak thermal gradients. The main thermocline prevents the mixing of the surface water with sub-surface layers along the vertical axis and thus acts as a barrier to mixing processes like upwelling and sinking. A strong thermocline can influence the productivity of the surface layers which in turn may have an important bearing on the local fishery. The vertical movement of some of the pelagic fishes such as Tuna are restricted by the presence of a strong thermocline. In fact the very success of a purse-seine fishing operation in the tropics would, to a great extent depend on the top depth of the thermocline and

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the vertical hanging of the fishing gear beyond this depth. In the functional design of an oceano outfall sewer the presence or absence of a strong thermocline is of great importance in determining whether the sewage effluent will reach the surface or not (Weigel, 1964) Eventhough three different types of thermoclines exist in the ocean, viz. the permanent (main), the seasonal and the daily thermocline, only the first one is of importance while undertaking a similar study in the tropics.

The aim of the present study is to evaluate the characteristics of the surface mixed layer and the main thermocline in the Bay of Bengal and to bring out their possible relationships with the existing hydrographic conditions leading to the phenomenon of upwelling.

Previous work in this region by Prasad(1952) based on about 27 bathy thermograms taken between Ceylon and Calcutta deals with the relative depths of thermoclines Lafond(1954) 1955, 1957) has undertaken an extensive study of the environmental factors affect in the vertical temperature structure of the upper layers off the east coast of India. Theoretical and physical aspects of the upwelling phenomenon, off Waltair have been studies by Varadachari (1958). A few reports

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on upwelling are also available for the coastal waters of Madras (Lafond, 1954), Sastry 1954; Varma and Reddy, 1959) Studies conducted by Murthy and Varadachari (1967) and Rao and Jayaraman (1967) deal with the probale cases for the differences in upwelling along 3 selected sections on the former case and the variations noticed in the different hydrographic parameters in the Southern and Central Bay in the latter case. Among the references cited above, most of the work deals with specific regions during a particular season and the observations have been mostly based on hydrographic data.

DATA AND METHODS:

As has been pointed out earlier, certain limitations are to be bornein mind while using hydrographic data collected using reversing thermometers at specific depths for vertical temperature studies because while doing so, continuity of the parameter with depth is absent especially at depths below 100 m. in which case the possibility of commiting an error while extrapolating the exavt position of the thermocline is bound to occur.

Inorder to eliminate this type of error I have made use of the author has made us of around 900 bathythermograms collected by the U.S.Research vessel ''ANTON BRUUN'' during a series of traverses in the Bay of Bengal during March-May (1963)

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The deep Bathythermograph which was in use in the aboves said cruises had a maximum range of 270 m. which in the normal case was expected to cover the region of the main thermocline in the area under observation. The distribution of Bathythermograph motions choses for the study is given in Fig. 1. The number indicated in each grid represents the total number of observations made within the area. The specific data had the advantage that it was collected by the same research vessel utilising more or less same type of equipment over a wide area within a short period of time. On an average temperature data was collected at a minimum interval of 10 nautical miles in the specific areas chosen for the study. The time of observation more or less corresponds to the pre-monsoon (S.W) season in the eastern bay and post-monsoon (NE) season in the western bay.

Each bathythermogram was analysed in such a manner so as to give the exavt value of temperature at 10 m. depth interval after applying the necessary corrections for temperature and depth. Distribution charts of sea surface temperature and the top depth of the thermocline (mixed layer depth) have been prepared based on grouping of data over reasonably small sized grids (one degree squares) and treating the entire period March-May as a single season. (Fig. 2 and 3) However, since such graphical representation may not be meaning-

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ful for the second and third thermoclins, in view of their limited number, they are simply discussed at the appropriate places. Since inversions occur only in a limited number of occasions, the discussions of the same is held in the main body of the paper with a brief mention of this thermal feature.

DISCUSSIONS

Sea surface temperature: The surface temperature, in general, decreases towards north, the minimum values being observed above 19° N.Lat. and also near the Burmese and Thailand coast. Temperature, on an average, varied between 26.2 °C and 31,2°C. In general, it is found that the surface water temperature increases towards southern latitudes, especially towards south west. (Fig.2)

Surface mixed layer and thermocline

The main thermocline is seen to start at a mean depth of about 110 m. in the south western part of the bay. Towards north and east the thermocline climbs towards shallower waters. Above 19°N. latitude the top depth of the thermocline is flund at 20 m. Along the west coast of Burma and Thailand the surface mixed layer is almost non existent associated with comparatively low surface temperature values. The gradual tilting of the Thermocline top towards surface layers noticed in the northern and eastern Bay indicate the possibility of the existence of negative vertical stability conditions in these areas and the resultant upwelling of cold bottom waters to comparatively shallower depths. The comparatively low sea surface temperature values also may point to the same reasoning. The ~~top~~ depth of the main thermocline also indirectly indicate the vertical extent of the surface mixed layer which has a maximum thickness of 110 m. on the south western Bay and almost non-esistent in the northern and eastern part of the Bay.

Thermal inversions:

A positive thermal inversion can result in the presence of a surface current where some of the water in the thermocline may also more in the direction of flow overriding the deeper water. Similar inversions are roughly 'S' shaped (La fond, 1964) Occurrence of positive thermal inversions at Majority of stations covered in the southernmost part of the Bay during this period between depths of 15 and 70 m. might have originated from the comparatively strong north equatorial current systems prevailing in this region.

Double thermoclines were observed at a few stations located in the central Bay at depths of 90-200 m.

CONCLUSIONS:

It is more or less an accepted fact that the circulation of waters in the Bay of Bengal is greatly influenced by the wind pattern associated with the

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Prevailing monsoon systems. The coastal circulation is governed more by the physical features like bottom troporgraphy. coastal cofiguration, influence of river run off etc. The surface drift observed in the Bay of Bengal is found to have a north-easterly direction with an occasional easterly component between February and July. A study conducted on the magnitude and direction of mean surface circulation in the Bay of Bengal (Veradachari and Sharma (1967) indicate a clock wise circulation pattorn with a northerly component in the western Bay bordering the east coast of Burma, during the months March and April. The pattern slowly changes during the latter half of May. As in the case along the west coast of India, along the west coast of Burma and Thailand, and also part of the continent bordering the head of the Bay, there is every possibility of upwelling due to dynamical factors associated with a southerly current during the late monsoon (NE) and premonsoon (SW) seasons. The comparatively low sea surface temperatures and the upward migration of the thermocline top are indicative of a similar upwelling process active along the west coast of Burma and Thailand also along the continent bordering the head of the Bay during the months March-May.

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Some aspects of the Oceanic Thermocline in Relation to Fisheries

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Variations in temperature with depth is more or less a typical feature observed in the thermal structure of the oceans in the tropics and sub-tropics. As has been pointed out earlier by several authors, three general regions of water based on temperature characteristics on the vertical plane are traceable viz. the top mixed region which is more or less isothermal followed by a region with strong vertical thermal gradients, the thermocline, with an average fall in temperature of not less than 0.5° C for every 10 m. depth (Defant, 1961) and the bottom water which extends from the bottom of the thermocline to the ocean bottom, once again characterised by weak thermal gradients. The main thermocline prevents the mixing of the surface waters with sub-surface layers along the vertical axis and thus acts as a barrier to vertical mixing processes like upwelling and sinking. A strong thermocline, which is also known as the discontinuity layer, can to a certain extent influence the productivity of the surface layers in the sea at a particular area which in turn may have an important bearing on the local fisheries. In the functional design of an ocean outfall sewer, the absence or presence of a strong thermocline is of great importance in determining whether the sewage effluent will reach the surface layers of the sea or not, (weigel, 1964). In the absence of strong thermoclines, especially at times when the vertical mixing processes become active, the possibilities of the sewage effluent polluting the surface waters in the sorrounding area, are very high. Wherever the effluent is of a toxic nature as is sometimes thrown out by chemical and fertilizer plants, the absence of a strong discontinuity layer may, in some cases, lead to the pollution of the surface waters and result in fish mortalities. This is especially true in those areas where the circulation processes along the horizontal plane, especially at the bottom levels, near the coast are weak. From the fisheries point of view, a strong thermocline can be advantageous and at times disadvantageous to a fisherman as it may prevent vertical movement of sub-surface waters to the euphotic zone which in turn can affect the

'Temperature' is perhaps one of the most easily measurable parameters in the sea. The bathy-thermograph as well as the modern expendable B. T. which gives a record of temperature against depth enable us to make vertical thermal observations in the sea easy and reliable. In developed countries like Japan and United Kingdom, temperature charts supplied by a central agency have become an accepted tool of the fishermen for the rational exploitation of the fishery resources. Let us hope, that in the near future, we will also be in a position to correlate information already collected with the occurrence and movements of commercially important fishes and other marine life so as to enable us to predict, sufficiently in advance probable productive fishing grounds.

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The author wishes to express his sincere thanks to Dr. M. S. Prabhu, Project Director, Pelagic Fishery Project, Cochin for his encouragement and for according the necessary permission to publish this note.

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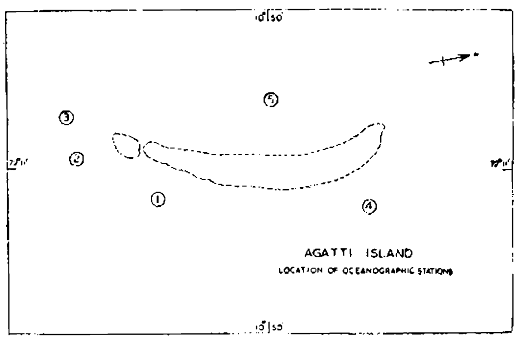
A NOTE ON TUNA FISHERY AROUND AGATTI ISLAND (LAKSHADWEEP) IN RELATION TO HYDROGRAPHIC CONDITIONS LEADING TO THE PHENOMENON OF UPWELLING

HYDROGRAPHIC studies conducted by Rao and Jayaraman (1966) around Minicoy islands indicated the presence of upwelling during late November and suggested that this phenomenon may have considerable impact on the peak tuna catches in this region.

The present observations are based on meteorological, hydrographic and fishing data collected by the training-*cum*-fishing vessels 'Blue Fin' and 'Masterfisherman I' attached to the Central Institute of Fisheries Operatives. Both the vessels were on a 10 day cruise to Lakshadweep islands during the 2nd week of December (1973).

Being the only island in the group from where moderate to good fishing for skipjack tuna (*Katsuwonus pelamis*) was reported during the season, both meteorological and hydrographic data were collected from 5 fixed oceanographic stations around the Agatti island, side by side with pole and line fishing operations.



Large shoals of skipjack tuna were observed especially on the southern and south-western side of the island. The fishes caught by the pole and line fishing boats were more or less of the same size group (approximately 18" in length) and weighed on an average between 2 kg and 2·5 kg. The fishing was moderately good and on an average each pole and line fishing vessel could catch a minimum of around 100 numbers of tuna within a period of one hour. The catch per hour for the above-mentioned individual species of tuna worked out to approximately 250 kg especially of those boats which were fishing on the southern and south-western side of the island.

The prevailing surface currents were north-westerly to north-north-westerly and the velocity of the flow was moderately high. The surface water temperature varied between 28·0° C and 28·1° C and on an average the isothermal layer was found to extend to depths of 50 mtrs. to 55 mtrs. from where the thermocline was found to extend to depths of 90–95 mtrs. at more or less all the stations. The surface salinity varied between 34·799‰ and 35·028‰ with the maximum concentration of the shoals at regions of comparatively higher salinities.

It was observed that the surface currents which head towards the island on its southern tip diverge into two branches one on the eastern side and the other on the western side. The comparatively higher salinity values and low temperature values observed at the surface levels on the southern side of the island indicate the possibility of upwelled water in this area brought from sub-surface levels through the process of upwelling.

It is known that tuna gather around areas of upwelling and in areas where the thermocline is shallower (Nakagome, 1973). Studies conducted in the Caroline and Marshall islands have revealed that better catches of Big eye tuna was brought in during the season when the sea surface temperature was comparatively lower (Nakagome, 1958, 1965). Uda and Nakamura (1973) have observed that the region of maximum hook rate appears to be localised either in the marginal area, water boundaries or along oceanic fronts.

Thus the concentration of large shoals of tuna on the southern side of the island may perhaps indicate a possible relationship between the occurrence of tuna shoals and upwelling zones. It is worth mentioning in this context that in the year 1966 in the presence of diverging currents and the resulting upwelling a good fishery for skipjack tuna flourished around Minicoy island. It seems quite likely that the divergence zone which leads to a favourable environment is shifting from one area to another possibly depending on the velocity and direction of the prevailing current system, geographical location of the islands, bottom topography of the atolls, etc. It may be possible that probable fishing grounds for skipjack tuna in the Lakshadweep area of the Arabian Sea could be predicted sufficiently in advance by keeping a constant watch on the formation and shifting of divergence zones around the islands during the period September to April, the season for the skipjack tuna fishery. Further investigations in this line are worth taking up.

The authors wish to express their sincere thanks to Dr. A. V. S. Murthy, Fishery Scientist (Oceanography), Central Marine Fisheries Research Institute

(ICAR), for the helpful discussions, Shri George Varghese, Director of Fisheries, Lakshadweep, for making available the facilities in the form of tuna pole and line fishing vessels and gear and to the skippers of the training vessels, Capt. K. Balan and Capt. R. Velayudhan and the crew for their sincere cooperation.

Government of India,
Central Institute of
Fisheries Operatives,
Cochin-16, *April* 10, 1974.

V. Narayana Pillai.
M. C. Perumal.

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Vertical Stability Characteristics of the Surface Layers of the Sea in Relation to Environmental Factors

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Introduction

The different process which result in comparatively higher productivity values at a particular region in the sea are governed by the prevailing hydrographic conditions which in turn are dependent on the changing weather conditions. Thus the stability of the water column in the sea is dependent on the variations observed in the different meteorological parameters and also its secondary effect on the waterbody. The various mixing processes within a waterbody (Pillai 1973) are to a certain extent controlled by the stability conditions which in turn makes a praticular region of the sea fertile or barren.

As pointed out earlier by Cooper (1960), the replenishment on the surface waters of the oceans by nutrients from below is dependent on the stability of the water column. Upwelling of nutrient rich bottom waters to the surface layers helps in the replenishment of the upper layers by nutrients from below. As the various mixing processes in the sea would be governed by the vertical stability parameter observed within a water column, a proper assessment of the parameter will help to find out probable areas of upwelling and diverging currents which in turn enrich the waters of the euphotic one. This might help the prediction of probable fish concentrations, especially the commercially important plankton feeders in the area under observetion during a specific period. Moreover a systematic study of the variation of this parameter assumes special significance especially at a time when our country is on the threshold of entering the commercial exploitation of fishable concentrations of the pelagic and columnar waters around the country. Steps initiated for a rational exploitation of tuna, sardine, mackerel, pomfrets etc. which are concentrated in the pelagic and columnar waters and for which certain specific fishing methods are adopted with the help of suitable craft and gear is worth mentioning in this context.

Vertical stability parameter

Vertical stability parameter in the sea is denoted by the expression $E: 1\rho/dz$ (Hesselberg, 1914) where

Ip / dz is the individual change in density with depth. When "E" is positive the stratification in the vertical plane is stable and when it is negative, the stratification becomes unstable. Between positive and negative stability layers there is always a surface where E=O (neutral stability). As shown by Hesselberg and sverdrup, the vertical stability in the top 100 m. can be approximately expressed by the term $E=10^{-3}\frac{d\sigma_t}{dz}$.

Hesselberg and Sverdrup have also shown that the values for "E" using the expression above agree fairly well down to a depth of 1400 m. Usually for similar calculations the parameter, $10^{-3}\frac{d\sigma_t}{dz}$ is calculated from the surface to a maximum depth of 1400 m. using insitu values of temperature and salinity.

Discussions

In the tropics and subtropics under normal conditions within the surface 25 m. there is usually found a weak ~~negative~~ stability and below this the value of "E" slowly increases in the density transition layer where the stratification is extremely stable. Underneath the stability decreases and at the greatest ocean depths approaches neutral equilibrium. Towards the polar latitudes the positive values in the surface layers disappear and are replaced by uniform stability conditions as only the surface waters can be disturbed by seasonal variations in temperature and salinity.

The frequent occurrence of negative stability values within the upper 25 m. or so in the tropics and subtropics is believed to be associated with the effectiveness of evaporation in these latitudes. The increase in salinity and the decrease in temperature (evaporation causes cooling) leads to an increase in density and to a reduction in stability.

Some work along these lines have been attempted by Sastry (1957), Ramamirtham and Nair (1964) and the author himself (1970) at selected regions both in the Arabian Sea and Bay of Bengal and certain conclusions have been drawn based on the variations observed in the parameter and correlating the same with the observed meteorological and hydrographical parameters. According to Sastry (1957) when conditions are not stationary and in the presence of intense mixing, as he observed at two neighbouring stations located off Visakhapatnam, the stability criterion gives divergent results even at two close-by stations. He has also concluded that off Visakhapatnam over the continental shelf the changes in the vertical stabitity with depth are due to mixing on the offshore drift produced by upwelling. In the absence of large scale vertical mixing (such as due to upwelling and sinking) vertical stability of the sea water increases at the top of the thermocline. For a region over the "swatch of no ground" he has observed an alternate change in the sign of stability which, according to him, is associated with large scale turbulance.

Similarly Ramamirtham and Nair (1964) while studying the stability characteristics of the surface waters off Cochin during the different seasons observed vertical turbulance near the bottom during the monsoon and early post-monsoon seasons and brought out the effect of the process on the productivity of the region. During winter good stability conditions were restored and during summer maximum positive stability values were noticed which according to them is sufficient to immobilise the bottom nutrients during these seasons.

The author while undertaking a detailed study of the abovesaid parameter at selected oceanographic stations located in the eastern Arabirn Sea during the south-west monsoon period of 1963 found that the existing meteorological and hydrographical conditions reveal a close relationship with the vertical stratification of the water column. It was noticed that at majority of the stations, the stability increases at the top of the main thermocline probably due to the effect of the sudden lowering of temperature bringing about a uniform increase in density with depth. The instability noticed in the surface waters off Mangalore along with comparatively low temperatures and high salinity values indicated the presence of upwelling along the coast in the month of June. Sharma (1968) also arrived at more or less the same conclusion that off Mangalore the discontinuity layer reaches the surface layers by the month of July. In a vertical section the isotherms were found to slope upwards towards the shore. All the above features suggested a certain amount of upwelling of bottom waters to the shallower regions of the continental shelf off Mangalore towards the end of June (1963). The presence of low oxygen cells associated with upwelling along the Central part of the west coast of India (Anand et. al. 1968) also supports the above said phenomenon. At stations located off Bankot, Goa, Karwar, Beypore and Cape Comorin the depth-wise increase and decrease of positive values of stability indicated the presence of lateral mixing in the shallower regions of the shelf in close conformity with the observations made by Ramamirtham and Nair (1961) at selected number of stations located off Cochin. The same authors have also pointed out that the cell-like structures in the temperature distribution often give rise to unstable water columns. This was true of almost all the stations located off Cape-Omorin where a uniform decrease in stability conditions below a depth of 50–100 m. was also noticed indicating unstable conditions.

Thus it could be noted that a thorough study of the variations observed in the vertical stability characteristics in the surface layers of the sea at a selected region will enable us to predict, sufficiently in advance, the intensity, duration and the extent of the different mixing processes on which is dependent the animal resources of the pelagic and columnar waters. There is every possibility that in the absence of accurate temperature and salinity values, erroneous conclusions with regard to the vertical stratification would be arrived at which in turn would make the predictions, below average, if not totally wrong. Hence special attention should be paid while collecting the basic data and if possible, any kind of extrapolation may be avoided.

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The author wishes to express his sincere thanks to Shri M. C. Perumal, Director, Central Institute of Fisheries Operatives for permitting him to publish this note and also for his encouragement in the course of the above study.

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MIXING PROCESSES IN THE SEA IN RELATION TO FISHERIES

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Mr. V. Narryana Pillai, presently Instructor in Oceanography and Marine Meteorology at the Central Institute of Oceanography, took his Master's degree in Oceanography with a first class and a first rank in 1961 from the Kerala University. Joining the Indian Naval Physical Laboratory at Cochin as a Research Fellow, he studied Hydrographical aspects of the Arabian sea and the Bay of Bengal in 1961-62. From 1962 to 1966 he served the Indian National Committee on Oceanic Research during the International Indian Ocean Expedition as a Research Fellow and participated in several scientific cruises on board both Indian and foreign research vessels. As a senior Research Fellow he served the National Institute of Oceanography from 1966 to '70, conducting his studies on Physical and Chemical aspects of the seas surrounding India. In 1970 Mr. Pillai joined the Central Institute of Fisheries Operatives as Instructor.

Fisheries Oceanography, Fisheries and Fishing Biology are Mr. Pillai's fields of special interest. He has about 15 published papers to his credit.

The productivity of a particular area of the sea is dependent on the replenishment of the waters by nutrients either along the vertical or horizontal plane. Within the euphotic zone the availability of nutrients such as phosphates, nitrates, silicates etc. is perhaps one of the most important factors controlling phytoplankton production which in turn affects the zooplankton community and subsequently the entire animal community in the sea including fishes. As most of the commercially important fishes and other marine life are either directly or indirectly dependent on the phytoplankton production, replenishment of the surface layers (euphotic zone) by plant nutrients either along the horizontal or vertical plane is perhaps the most important factor which controls the availability of sea food in a particular region in the sea.

The abovementioned replenishment of the surface waters by nutrients from elsewhere is possible only by the horizontal or vertical transport of the water masses. The same is more or less true of the essential dissolved gases which promote plant and animal life in a particular area of the sea. The various mixing processes within the waterbody which helps in the replenishment of the surface layers by nutrients from elsewhere and transport of other physical and chemical parameters such as temperature, dissolved gases, salinity etc. can make a particular region of the sea highly fertile.

(a) Mixing along the horizontal plane

(i) **Ocean currents**: Currents in the sea contribute to the distribution of water which in turn affects the productivity of a particular region in the sea. In addition, they maintain living conditions required by fishes and other marine life. They may be conveniently divided into three different categories.

(i) Currents that are related to the distribution of density in the sea: The well known large scale permanent currents in the oceans such as gulf-stream, Kuro-shio, Oyashio, Benguela, cromwell and the equatorial currents belong to this category. In the sea, the pressure increases downwards and hence the pressure gradient that is directed against decreasing pressure is directed upwards. It is so nearly vertical that it practically balances the acceleration due to gravity per unit mass. If it exactly balances the acceleration due to gravity, the isobaric surfaces (imaginary surface along which thepressure remains constant) would coincide with level surfaces — (imaginary surface along which no component of gravity acts) and perfect static equilibrium would prevail. If an isobasic surface slopes relative to a level surface, a component of gravity acts along the surface and the water cannot remain at rest and hence it must move down the sloping surface.

(ii) Currents that are caused directly by the stress of wind at the sea surface (wind-generated currents): The effect of wind at the sea surface is two-fold. It leads directly to the development of a shallow wind drift and subsequently the transport of water by the wind drift leads to an altered distribution or density and the development of corresponding currents. The depth of wind current penetration increases with increasing wind velocity and decreasing latitude.

(iii) Tidal currents and currents associated with internal waves: Near land, currents that are caused by tides are most effective in that they cause sufficient mixing within the coastal waters during the periodic "ebb" ann "flood" of the tide. In deep water, tidal currents are weak and are of negligible importance as they only move water forward and backward. Theoretically the tidal currents should run in the same direction and with the same velocity from the surface to the bottom except in the lowest 20–30 metres where they are influenced by bottom friction. Tidal currents contribute greatly to the mixing of the water layers especially in the coastal areas where these currents can attain velocities upto several knots (especially in narrow estuaries and barmouths).

Currents that are related to the internal waves vary in direction and speed with depth. In the open ocean, they can attain higher velocities than the tidal currents. They can be considered as being maintained by rhythmic variations in the distribution of density. In an internal wave one or more isobaric surfaces above or below a level surface are in opposite directions. The corresponding currents are also in opposite directions.

(b) Mixing along the vertical plane

The various mixing processes in the sea which act along the vertical plane are governed by the vertical stability characteristics of the water column. The vertical stability parameter in the sea can be denoted by the expression E=dp/dx (Hesselberg, 1914), where dp/dz is the individual change in density with depth. When "E" is positive, the stratification in the vertical plane is stable and when it is negative, the stratification becomes unstable. Mixing along the vertical plane can take effect only when the startification is unstable.

(i) Mixing caused by evaporation and subsequent cooling : This type of mixing is most effective in the tropics where, in certain regions excess evaporation causes slight cooling of the surface waters. This cooling coupled with the slight increase in salinity causes an increase in density resulting in the slow sinking of the surface waters to subsurface levels and subsequent replacement by subsurface water masses.

(ii) Mixing caused by winter cooling : This type of mixing takes place in those areas where the surface waters are cooled during the winter season and hence is seasonal. In order to replace the denser surface waters, water from subsurface levels slowly move up and occupy surface levels.

(iii) Convergences and divergences: The former refer to regions where water masses of differing nature meet from opposite directions at the surface layers either in the presence of moderately strong water currents or surface waters rising to the surface layers because of the presence of physical features such as submarine Ridges or rises. In general, shoal areas deflect the movement of water in an upward direction over the shoal. In areas where surface ocean currents branch off, there is every possibility for the sub-surface waters to be induced upwards towards the surface layers. Along the equator, divergences are very common as the wind generated currents are deflected in opposite directions, due to the rotation of the earth, slightly north and south of the equator.

Convergence is the reverse process where an occasional meeting of two surface currents from opposite directions results in the intensive mixing of water masses at the surface levels and probably owing to an altered density (positive) slowly sinks towards subsurface layers. Sub surface waters which are comparatively lighter slowly move up to fill in the gap. In general convergences are found to be good fishing grounds as the resulting physical and chemical characteristics of mixed water massses enable concentration of planktonic organisms in the area which subsequently attracts large shoals of pelagic fishes especially plankton feeders.

Convergences are of common occurrence along ocean current boundaries and also on the leeward side of oceanic islands where the wind removes the surface waters away from the coast thereby enabling the sub-surface waters to slowly penetrate layers.

(iv) **Upwelling:** This is one of the most important mixing processes in the sea which induces the colder, low oxygenated, high saline and nutrient rich subsurface waters to move up towards the surface layers against the force of gravity. The upwelled water makes the stratification of the water column highly unstable.

There is a lot of controversy over the actual mechanism of upwelling. The basic concept is that a wind generated surface current is deflected by about 45° to the right of the wind in the N. hemisphere and 45° to the left in the S. hemisphere. The deflection is caused by the rotation of the earth which is otherwise termed coriolis force. Depending upon the direction of the prevailing wind, especially its orientation with respect to a coast line, in some coastal areas the surface water will be carried away from the coast (if the coast is lying north-south and the prevailing wind northerly — along the western coasts of continents in the N. hemisphere / along the eastern coasts of continents if the prevailing wind is southerly) thereby inducing the sub-surface waters towards surface layers nearer to the coast. Others are of the view that it is not the wind that plays an important role, but the prevailing current system. The basic concept is that in the N. hemisphere the denser water will always occupy the left hand side of the current and in the S. hemisphere, the reverse is true. In order to fulfil this basic requirement, the comparatively denser sub-surface water would be induced upwards in order to occupy the left hand side of the current, nearer to the coast line. A third group believes on a combined effect of the wind system and the resulting current system.

Sub-surface waters, rich in plant nutrients, once brought to the eupholic zone give rise to a favourable environment for a phytoplankton bloom which in turn leads to concentration of zooplankton and ultimately results in a good fishery. The dissolved oxygen content of the upwelled water increases as soon as it reaches the surface layers by contact with the atmosphere. Upwelled water can contribute towards productivity of a particular region in the sea only when the same is brought up from sufficiently deeper layers where the nutrients were not at all utilised due to want of sufficient amount of sunlight. Addition of freshwater at the surface levels, either through rainfall or land drainage which results in a stable stratification at the surface levels, will put an end to the process of upwelling. Moreover, in the presence of a strong thermocline the possibilities of deeper waters upwelling towards the surface layers, are quite remote.

Relation to fisheries : Among the different processes which promote the productivity of a particular region in the sea, the most important are upwelling, divergences and convergences as they result in the concentration of phyto/zoo plankton which form the food of some of the commercially important pelagic fishes like sardine, mackerel, anchovy etc. Along the coast of peru, the upwelling areas of the peru current support one of the richest fisheries in the whole of the world. Other areas viz. california coast, gulf of Aden, off the coast of somalia and S. Arabia, zones of equatorial divergences, current boundaries along the kuroshio and oyashio current systems along the Japanese coast (Hela and Laevastu, 1970) parts of the western and eastern coast of the Indian sub-continent also belong to this category.

Along the Indian coast the process of upwelling has been studied by various workers viz, Lafond (1954), Banse (1959. 1968), Ramamirtham and Jayaraman (1960). Varadachari (1961), L. V. G. Rao and Jayaraman (1966), Darbyshire (1967) and Sharma (1968). According to Banse, the prevailing current system and not the wind is to be regarded as the main reason for the upwelling off the S. W. coast of India. Even if a uniform current velocity is considered all along the coast, the rise of denser deep water will be stronger in the north further away from the equator. He is of the opinion that off the S. W. coast of India upwelling starts with the onset of the S.W. monsoon and reaches the maximum intensity during the months July-August. L. V. G. Rao and Jayaraman reported upwelling around Minicoy waters during the last week of November and attributed the same to the divergence of current systems in the visinity of Minicoy. They have also indicated the possible relationship between upwlling observed during late November and the peak seasons for tuna fishing (December to March) in this region. Ramamirthan and Jayaraman have stated that off Cochin upwelling starts by mid August, establishes by late September and ends by mid October. Darbyshire indicated that along the west coast of India the dense bottom waters approach the surface because of the immediate interplay of the current with the tilting of the sea surface and the thermocline. According to Sharma, upwelling along the west coast of India starts earlier in the south and slowly extends towards North. He is of the opinion that the process commences at deeper depths earlier in the month of February and reaches the surface by May. The process comes to an and by July-August when the thermocline in this area reaches the surface layers. Moreover the influx of run off and rain water stratify the surface layers from July onwards thereby opposing the process. Varadachari (1961), Stommel (1966) and Byther and Menzel (1966) stressed the need for considering coastal currents as a factor in inducing upwelling. Theoretical and physical studies by Varadachari (1958, 1961) show that a northerly current along the east coast of India is favourable for upwelling. During the south west monsoon period both the wind and currents are favourable for upwelling along the Waltair and Madras coasts (June-July). Studies conducted by Lafond on the process of upwlling along the Waltair coast showed that the process is a very slow one. Vertical upwlling velocity observed off Andhra coast ranges between 10 and 40 metres per month when compared to a rate of 20 metres/month recorded off the California coast. According to him the postulation of upwelling on the eastern and northern sides of the Bay of Bengal were confirmed by maasurements made by the Research vessel "Anton Bruun", which revealed a high rate of organic production in this region.

Thus the relationship between mixing processes like upwelling and the resulting high organic production rates clearly indicate the importance of similar processes in the organic cycle, especially from a fisheries point of view. It is needless to emphasise the importance of oceanographical studies relating to these phenomena as in the long run the results will enable us to predict, sufficiently in advance, the probable areas of good fisheries.

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Ocean Tides

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Tides are long ocean waves (with great wavelengths) which are motivated by the differential attraction of the sun and moon. The distance between the centre of the earth and the centre of the moon is determined by a balance between the gravitational force which attracts each other to bring them together and the centrifugal force which tends to make them separate. The tidal forces are initiated by the relatively small differences in the distance between the moon and the various points on the surface of the earth. When compared to the centre of the earth, water in the oceans nearest to the moon is comparatively nearer to the moon. Hence it is slightly more strongly attracted towards the moon by gravity and slightly less strongly repelled by the centrifugal force thereby resulting in a slight bulge of the waters towards the moon.

TIDAL FORCES

All the bodies in the solar system exert a gravitational pull among each other and also on earth. The other planets, because of their greater distance relative to that of the moon and their small size relative to that of the sun, have a negligible effect on the tides. The moon revolves around the earth in an elliptical orbit just like the earth revolves around the sun. Eventhough the sun has a greater mass, because of its immensely greater distance from the earth, it can exert only 2/5 as much gravitational pull as that of the moon. Thus moon may be regarded as the major tide producing force eventhough the effect of the sun is by no means negligible. Similarly tidal forces act on the land masses as well as the larger water bodies with the same intensity. Since the land masses are rigid, it is only less affected when compared to water bodies which are in the fluid state and mobile. Due to the above reason the latter responds more to a tidal pull.

TIDAL CURRENTS

Eventhough the tidal rhythm acts along the vertical plane, (up and down movement) the resultant tidal currents move in the horizontal plane (backward and forward). In deep water, tidal currents do not assume much significance as they are weak and only help in moving water to and fro. But near land they are more noticeable and can even become dangerous to small boats especially in narrow estuaries and barmouths. Perhaps the most important aspect of the tidal currents is that they contribute greatly to the mixing of the different water layers in coastal areas thereby influencing the occurrence and distribution of the representative fauna and flora. The periodic ebbing and flooding of the waters from and to a narrow estuary will enable some of the marine fauna to migrate into the estuary during the flood and also some of the fresh water / brackish water forms to move out into the sea during the ebb. This migratory habit of some of the marine and brackish water fauna especially fishes and crustaceans is being made use of in the exploitation of these forms using certain specific types of fishing gear which takes advantage of the above said temporary migrations.

There is a general belief that tidal currents move foreward and backward reversing their direction once in every six hours or twelve hours according to the nature of the tide. In effect these currents reverse through 36° and hence change their direction every now and then. As an uninterrupted passage is made available only in two directions viz. in the direction of the sea and the estuary, movement of water in these two directions alone attract our attention and hence the above wrong conclusion. The velocity of a tidal flow varies with the stage of the tide. It is generally observed that the velocity of the flow is comparatively higher at the surface levels during ebb and the bottom levels during flood because of the differences in the density of sea water which will try to occupy the bottom levels and fresh / brackish water which will remain at the surface layers. The velocity of the tidal flow will show variations depending on the bottom configuration in shallow areas, geographical distribution of the land masses surrounding the enclosed water body (River, estuary, fjord etc.) and also on the size, shape and location of islands, if any, within the waterbody. The author while studying the tidal current system at a selected number of stations in the Cochin backwater (Pillai et al, 1971) arrived at the following conclusions:

(1) The influence of sea water is felt more at the bottom levels during the flood tide, the magnitude of which decreasing towards the upper reaches of the estuary. During flood, sea water slowly penetrates through the bottom towards the head of the estuary as a tongue of varying thickness.

(2) Even one hour after low tide started at the surface, sea water was found penetrating along the bottom showing the effect of flood at the bottom levels even after the commencement of ebb at the surface. The reverse is also true where even one hour after the high tide started at the bottom levels fresh water was found flowing towards the sea at the surface levels.

(3) The most important agent that controls the variation of hydrographic parameters within the estuary is the tidal flow which does not follow the predicted pattern. This irregularity in the flow pattern may perhaps be attributed to the periodic changes brought about in the bottom topography of the channels due to dredging geographical location of the islands in the vicinity of the barmouth and also the seasonal variations in the fresh water flow.

TIDAL BEHAVIOUR

The tide, due to the gravitational pull of the sun, is repeated at intervals of 12 hrs. and that caused by the moon at intervals of 12 hrs. and 25 minutes. During the course of 24 hrs., the tide caused by moon will occur 50 minutes late when compared to that caused by the sun corresponding to the fact that moon rises 30 minutes later each night. When these two forces coincide, it results in the maximum total effect, a *Spring tide.* During the course of rather more than a week the high tide caused by moon will occur 6 hrs. later than the sun high tide resulting in the slightest total effect, a *Neap tide.* If the sun and the moon always moved along the equatorial plane, tides would be as simple as above. However, they are at constantly changing distances from the equator, the sun during the course of $365\frac{1}{4}$ days and the moon in about 28 days. Since the orbits of earth and moon are elliptical, the tide producing force of the sun is greatest when the earth is nearest the sun, i.e. in its perehelion and that of the moon greatest when it is nearest the earth i.e. in its perigee. During the maximum declination of the moon the resulting tides are asymmetrical with reference to the equator and hence in both the hemispheres one high tide would be slightly higher than the other. This explains why the two tides of a single day (either flood or ebb) are usually not alike. As the moon moves back to the equator this dissimilarity slowly disappears. When both the sun and the moon are on the earth's equator as it occurs around the spring and autumn equinoxes and also in June and December when briefly the sun and moon are both at their greatest declination, one can expect the highest tides of the year.

The highest tides of the month do not occur precisely on full and new moon day, but a day or two later due to the fact that friction between solid earth and water and different layers within the water column slows down the movement of the tide creating a lag between the tide and the force that produces it. Moreover the tidal bulge cannot run freely around the earth because the land massess will slow down its progress.

If a body of water has a natural period of oscillation corresponding to the period of the tide producing forces, large tides will result and if such a relationship is lacking the two oscillations will interfere and the resulting tides will be small. This concept also helps us to understand why some places have a diurnal tide, others a semi-diurnal tide and still others a mixed tide. A diurnal tide is characterised by one high water and one low water during the course of 24 hrs. and a semi-diurnal tide by two high waters and two low waters during the same period. Along the Indian coast, the tides are mostly of the semi-diurnal type.

TIDAL RANGES

The greatest tides in the world are recorded in the Bay of Fundy which lies between Nova Scotia and New Brunswick where a range of 50 feet is not uncommon. The most important reason for these large variations seems to be due to the fact that in the above said region the normal period of oscillation of water corresponds almost exactly to the oscillation of the tide producing forces. Along the Alaskan and British coasts a range of 36-40 feet between the high and low water is noticed.

Around the Indian sub-continent the tidal ranges vary from place to place. It is generally observed that towards south the ranges are comparatively low. Both at Cochin and Madras the recorded range is around 3 to 4 feet. Towards north both at Bombay and Calcutta the ranges are somewhat higher viz. around 15 ft. at Bombay and 18 ft. at Calcutta. The maximum tidal ranges around the Indian sub-continent is observed at Bhavnagar along the Gujarat coast where a variation of approximately 38 to 40 ft. has been recorded. Bay of Fundy in Canada (59'), Gulf of San Jose in Argentina (43'), Severn River in Great Britain (42'), Mont Saint Michael Bay in France (38'), Estuary of Rance in France (34') and Gulf of Cambay along the Indian coast 38–40') are some of the regions where comparatively large tidal ranges are observed around the globe.

TIDAL RECORDINGS

Tide gauges are fixed at all important ports around the world which continuously record the tidal oscillations for every 24 hrs. The tidal ranges expected at different places are predicted and given in the tide tables published by the respective countries. The 'Indian Tide Tables' published annually by the Surveyor General of India is one among them.

EFFECT/USES OF TIDES

Apart from effecting a general mixing of the different layers of the sea in shallow areas, the tides also control the variations observed in some of the important hydrographic parameters such as salinity, dissolved oxygen content, temperature etc. and thereby influence the distribution and migration of both marine and estuarine fauna and flora. They assume importance in narrow estuaries, barmouths, fjords etc. where they can often be dangerous to small vessels. In areas where tidal currents are sufficiently strong they act as important agents in transporting bottom material including sand and gravel. In many important harbours they are responsible for building up sand bars which obstruct navigation. Certain types of fishing gear particularly the stake nets and dol nets (bag nets with fixed mouth) are operated taking advantage of the tidal currents.

It is quite obvious that a tremendous amount of energy is involved in the tidal mechanism. Many men over many years have dreamed of exploiting the tides as a source of power and of late a few of them have succeeded in their attempts. The credit of installing the first tidal power plant goes to France where they have built a power station across the Rance estuary near Saint Malo. The turbines are reversible so that they will operate both during flood and ebb. Britain as well as U. S. S. R. have come forward with similar plans and other nations are also likely to experiment on tidal projects in the near future.

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THE EFFECT OF TIDAL CURRENTS ON THE HYDROGRAPHY OF THE BACKWATERS AROUND COCHIN BARMOUTH DURING POST AND PRE-MONSOON SEASONS

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ABSTRACT

Hydrographic and current observations at eight selected stations located in the Cochin backwater in the vicinity of the barmouth during the post and pre-monsoon period has shown that the important hydrographic parameters especially the salinity and dissolved oxygen content are influenced mostly by the circulation caused by the changing tidal currents. The variation observed in the surface temperature more or less follow a typical diurnal pattern and the tidal circulation is found to have little or no influence on the variations observed in the temperature structure in the vertical plane. The salinity and dissolved oxygen content show a clear-cut variation between flood and ebb both at surface and sub-surface levels. In general, the average surface velocity during ebb is comparatively higher than the corresponding flood velocity whereas during flood a reduced flow is observed both at surface and sub-surface levels.

INTRODUCTION

The present study is based on hydrographic and current observations at eight selected stations situated in the region surrounding the Cochin barmouth. The estuarine system is connected with the Arabian sea throughout the year and hence one can expect a free flow of sea water into the estuary and a counter flow of fresh water into the sea during all the seasons. Since two large rivers flow into the system at its northern and southern extremities, a large quantity of fresh water is added to the system especially during the monsoon season. The influx of saline water is most felt around the entrance channel to Cochin Harbour.

Earlier work in the region by Balakrishnan (1957) Ramamirtham and Jayaraman (1963), George and Kartha (1963), Qasim and Gopinath (1969), and Sankaranarayanan and Qusim (1969) deals with the distribution of the various hydrographic parameters in space and time, their seasonal fluctuations and also their relationship with the existing tide. No previous account has appeared correlating the tidal circulation pattern with the changes in the different hydrographic parameters.

An estuary is a semi-enclosed coastal body of water having a free connection with the open sea and containing a measurable quantity of sea salt (Pritchard, 1952). This definition of an estuary is more or less applicable to the Cochin estuarine system. According to the present status, in terms of geomorphological structure, the Cochin estuarine system could be considered to be of the bar built type. Two rivers (Periyar and Pamba respectively) flow into the system at its southern and northern extremities (upper ends). The system in general is shallow relative to its width and has a dendritic shoreline. The tidal range around the barmouth is about 1 m. The surrounding coast is relatively low. In terms of fresh water flow and evaporation, the system is of a positive type with the fresh water inflow and precipitation exceeding evaporation.

The predominant physical agencies which cause water movement and mixing within the system come under the following heads viz. Meteorological, Tidal and Hydtrological. Since it is obvious that in most estuaries of a positive nature the tidal mixing dominates over the other two especially in the region nearer to the mouth of the estuary, (Stommel, 1953) the effect of tidal circulation on the diferent hydtrographic parameters is being taken up first and dealt with this paper. Eventhough one is able to draw general conclusions as regard to the circulation caused by tides in a similar estuarine system, one should be extremely careful while doing so because each estuary has got it's own characteristics which cannot be compared with any other estuary (Pritchard, 1952).

DATA AND METHODS

The data is collected using the Institute's Research Vessel 'NEENDAKARA' which is well equipped for work in the shallow backwaters. The stations are chosen in such a way so as to get a representative coverage of the region under study. Geographical location as well as depth to the bottom is given due importance in fixing the position of stations. The parameters are observed at one hour interval (at half-an-hour interval where ever a rapid change is observed) covering the two phases of the tide at all the stations where tidal influence is noticeable. Currents are measured using Ekman current meters both at surface and sub-surface levels, keeping the boat at anchor. The current at each level is measured for a minimum period of 15 minutes. Special precautions are taken to see that the boat is stationary. Surface temperature is recorded using a Bucket thermometer (special type supplied by UNESCO) and also a thermal probe which gives a continuous record of temperature against time. Sub-surface temperature is measured using Reversing thermometers. The values are always checked against readings obtained at the same depth using the Temperature-Salinity bridge (E.S.G. London Type - MC 5).

Samples for the determination of salinity and dissolved oxygen are collected using either Reversing water bottles or Hytech water samplers. The salinity values obtained by the temperature-salinity bridge are always compared against values obtained by titration method by a process of random checking so that the correction chart for the Temperature-Salinity bridge is always uptodate. Samples for the determination of dissolved oxygen are analysed using the standard Winkler method.

LOCATION OF STATIONS:

Stations are uniformly distributed to give full coverage for the area under study. Station-A is representative of the conditions prevailing outside the barmouth which separates the estuarine system from the open sea by an opening of about 450 m. width. Stations B? C, D, E, F, G and H are located within the estuarine system in such a way so as to give a representative coverage of the region under study. Station 'C' and 'E' represent conditions prevailing in the Mattancherry and Ernakulam channels respectively whereas stations 'D' and 'B' are located so as to study the influence of fresh water inflow (through southern region) and penetration of saline water from the sea respectively. Station 'F', 'C' and 'H' are located at the northern extension of the backwater system to study the effect of saline water at the bottom levels and the effect of fresh water flow (through the northern region) at the surface levels. The average depth at the above said stations ranges between 3.5 and 10 m.

PERIOD OF OBSERVATION

The stations were visited during the period December to May. Since the period represents post and pre-monsoon seasons, it eliminates the effect of fresh water through reinfall facilitating a realistic study of the effect of tidal circulation an the hydtrography of the region.

RESULTS AND DISCUSSION

(1) Temperature:

It is seen from observations that the oliurnal variation of temperature is the predominant feature of temperature distribution. There is always a certain time lag for bottom waters to attain maximum temperature. Almost at all the stations the maximum temperature occurs between 1300 and 1500 hrs. at the surface. The variation noted in the surface temperature during the twelve-hour observations at all the stations is of the order of 1 to 2.5°C. The range of temperature observed at individual stations between surface and bottom layers during the same interval is between 1.60°C and 2.45°C. Tidal-controlled changes in temperature are not conspicuous at any one of the above said stations during the period of observation.

(2) Salinity:

Salinity shows a clearcut variation between flood and ebb both at surface and bottom levels at all the stations. This is in agreement with the findings of Qusim and Gopinathan (1969) for the same region. During ebb, the influence of fresh water is most felt at the surface and during flood the high saline sea water is found to penetrate the bottom layers at almost all the stations. This is quite evident from the surface and bottom salinity values given in Table I, for representative stations.

TABLE I

Station	Date of Obser-vation	SALINITY ‰ Surface		Bottom	
		Flood Max.	Ebb Min.	Flood Max.	Ebb. Min.
A	3.12.68	33.32	26.47	33.22	26.82
B	6.12.68	27.18	18.46	31.18	27.09
C	17.12.68	29.88	24.02	32.86	26.82
D	4.1 .69	29.70	22.77	32.00	28.12
E	9.1 .69	30.41	19.18	32.18	29.00

(3) Oxygen:

In general it is found that there is an increase in the dissolved oxygen content of surface waters with the advancing ebb. A difference of about 3 ml/L has been observed at stations D and E at the surface. The

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variations observed at the bottom levels are comparatively negligible showing the effect of high saline sea water at the bottom layers with lesser oxygen cont.

(4) Currents:

The tides observed at Cochin are predominantly of a mixed semidiural type. As one goes away from the barmouth towards the head of the estuary, the variation of the different hydgrographic parameters caused by tidal currents progressively decreases which presumably is the causative factor for the time lag in attaining the maxima and minima.

As could be seen from current observations at representative regions of the estuary, the observed current pattern suggest slight variations from the typical backward and forward tidal oscillations in the form of a secondary circulation interfering with the regular oscillatory movement of the tidal flow. The prime reason for this complexity may probably be due to the geographic location of the islands in the vicinity of barmouth, shoaling caused by dumping of dredged meterial and also the periodic changes in the bottom topography due to the dredging of the channels.

At Station A outside the barmouth, the bottom velocities vary between 0.72 - 1.02 knots during ebb where as the flood velocities are found to be between 0.68 and 0.76 knots. From observations it is found that the average surface velocity during ebb in the Ernakulam channel (3.6 knots) is higher than that in the Mattenchery channel where the flow is comparatively weak (1.7 knots) showing a lesser effect of freshwater at station C. Simultaneous observations at the bottom levels show a higher average velocity (3.25 knots) during ebb in the Mattanchery channel as against a relatively week flow (1.5 knots) in the Ernakulam channel. This difference in the flow pattern may be due to the difference in the orientation of the two channels. During flood there is not much variation for the surface and subsurface currents at Station C, whereas at Station E a considerable weakening in the flow (0.5 knots) is observed. Surface velocities are always high irrespective of the phase of the tide at Station D (2.1 to

2.23 knots) when compared to that observed at the bottom (0.75 to 1.13 knots). Station F is characterised by very weak currents of the order of 0.38 - 0.43 knots which may perhaps be due to the presence of the newly reclaimed island on the seaward side of the station. The surface and subsurface flows are found to have comparatively high velocities (2.95 and 2.0 knots respectively) during flood at Station G. The ebb velocities in this region are slightly less (0.75 to 1.7 knots) as evidenced by observations at station H.

CONCLUSIONS

It has been observed that the influence of fresh water on some of the important hydrographic parameters is more experienced at the southern stations when compared to stations located at the northward extension of the estuarine system. This effect is found to have more influence at the surface than at subsurface layers. This is quite evident from the results obtained from station D on 4.1.1969 where, as ebb continues the salinity values at the surface layers decrease from 29.7‰ to 22.77 ‰ within a period of four hours. The variation of salinity at the bottom layers during the same interval is found to be negligible. This again explains the fact that the different hydrographic parameters in the southward extension of the estuary are more influenced during ebb tide due to fresh water inflow.

One conspicuous feature noticed during the observation is that the effect of fresh water is more felt in the Ernakulam channel compared to that in the Mattanchery channel. This is evidenced by both salinity and current data at these stations. The surface salinity values show a variation of 11 ‰ at Station 'E' located in the Ernakulam channel while the corresponding variation is only 5‰ at Station 'C' located in the Mattanchery channel.

The influence of sea water is felt more at the bottom levels during flood tide, the magnitude of which decreases towards the upper reaches of the estuary. During flood, the sea water slowly penetrates through the bottom towards the head of the estuary as a tongue of varying thickness.

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Even one hour after low tide started at the surface, the sea water was found penetrating along the bottom showing the effect of flood even after the commencement of low tide at the surface. Station D also exhibits more or less similar characteristics where the effect of ebb at surface was felt one hour after the commencement of flood at the bottom levels.

At all stations variation in the salinity values has been noticed with changes in the tidal flow. Thus the important agent that controls the various hydrographic parameters within the estuary near the barmouth is the tidal flow which does not follow the scheduled predicited pattern. This irregularity in the flow pattern may perhaps be attributed to the periodic changes in the bottom topography of the channels due to dredging, geographical location of the islands in the vicinity of the barmouth and also the seasonal variation in the fresh water inflow.

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INDIAN NAVAL PHYSICAL LABORATORY

COCHIN-4.

DEPARTMENTAL REPORT NO.8/64.

A STUDY OF THE HYDROGRAPHIC CONDITIONS IN THE ARABIAN SEA DURING POST-MONSOON SEASON(1962)

Part.III Discussion of T-S diagrams and the water masses in the Arabian Sea in the upper 500 m. during the post-monsoon season(1962)

By

K.V.Sundara Ramam,JSO; V.Narayana Pillai

and M.G.Seshagiri Rao.

I.N.PHYSICAL LABORATORY,COCHIN-4.

DEPARTMENTAL RESEARCH REPORT NO. 8/64.

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ABSTRACT

A discussion of the T-S diagrams and the water masses in the Arabian sea during the post-monsoon season is presented.

A. INTRODUCTION

The water masses in the Arabian sea are influenced by the prevailing monsoons,and proximity to the Red sea and Persian Gulf and by discharge from rivers.For instance,on account of the arid zone in the North the water masses in the northern Arabian sea have different characteristics from those in the southern Arabian sea.In this part the different water masses in the Arabian sea during this season are discussed.The Arabian sea is divided into three regions viz;Northern Arabian sea,Central Arabian sea and the southern Arabian sea.It is found that these three regions have different characteristic water masses,especially in the surface layers.The latitude south of Bombay is considered as the southern limit of Northern Arabian sea.Similerly the latitude north of Cochin is considered as the boundary between the central and southern Arabian seas.For the study of water masses T-S diagrams are used and the method given by Sverdrup[1] is followed.The temperature salinity values up to 30 m,up to where the local effects are prominent are not included.T-S diagrams are drawn for all the 101 stations,but only representative diagrams are for the three regions are shown in figures 1-3.Also the three regions represent the conditions towards the end of South-west monsoon,transition period and the beginning of the North-east monsoon.

B.<u>DISCUSSION OF WATER MASSES IN THE ARABIAN SEA</u>

1.<u>Northern Arabian Sea</u>(Fig.1)

Out of the three regions,the Northern Arabian Sea is subjected to the maximum influence of waters from the Persian Gulf, Gulf of Oman and the river Indus.Since this region is bounded in the north by an arid zone,the high rate of evaporation increases the surface salinity to a large extent.Thus the water of high salinity and moderately high temperature is present in the form of one water mass extending up to a depth of about 75 m.The range of temperature and salinity are T=26.5°C,S=36.6°/oo and T= 22.0°C,S=35.6°/oo Between 75 and 150 m the waters are characterised by the low temperature and low salinity.This water is the Intermediate water between the upper subsurface water and subsurface deep water.The ranges of temperature and salinity are T=22.0°C,S=35.6‰ and T=18.5°C,S=35.7‰ This water has almost uniform salinity with slight variations in temperature. The water below 150 m has low temperature and high salinity.This water shows large variations in salinity as well as temperature.The ranges pf temperature and salinity in this water fall between T=18.00°C,S=35.7‰ and T=15.00°C,S=36.7‰.The extension of this water is seen up to a depth of 300 m.Further extension of this could not be traced since the observations do not extend beyond this level in this area. This water does not appear to be Red Sea water but rather to be formed in the Arabian Sea itself. Thus it may be called Arabian Sea water surface water. The formation of different layers of water masses in this region is reported in John Murray Expedition Reports by Moller.[2]

2. <u>Central Arabian Sea</u> (Fig. II)

In the surface layers up to 75 m the water has high temperature. The salinity is not as high as in the Northern Arabian Sea. The salinity is low and uniform. The range of temperature and salinity is T=27.5°C, S=35.8‰ and T=24.00°C, S=35.45‰. The maximum salinity occurs at a depth of about 50 m. The upward shift in the zone of maximum salinity is the result of the divergence present during the transition period in the Central Arabian Sea. The extension of this water is up to 75 m. Below this depth is found another water mass in which the temperature variation is considerably high with little variation in salinity. The ranges of temperature and salinity are T=23.5°C, S=35.5‰ and T=13.[illegible]0°C, S=35.4‰. The main difference from the corresponding water mass in the Northern Arabian Sea is that the range in temperature is high in the Central Arabian Sea. Also the vertical extension is higher than in the Northern Arabian Sea. The same phenomena are observed in the water masses of the Southern Arabian Sea. The presence of this water mass below the Thermocline is particularly noticed. The upper water mass is noticed above the Thermocline. The presence of these two water masses just above and below the Thermocline may be explained by considering that the upper water mass is influenced by the prevailing winds while the lower water mass is the result of mixing in those layers during the transition period. This has been confirmed by comparing the charts showing the horizontal distribution of salinity at 150 and 200 m, where the isohalines are more or less uniform.

The third water mass exists below 200 m. The study of the vertical extension of this water falls beyond the scope of the present paper. But however it can be stated that this water extends beyond 400 m. The ranges of temperature and salinity are T=16.00°C, S=35.4‰ and T=12.00°C, S=35.6‰. This water may be the result of mixing of the 'I' water discussed by Thompson.[5] This mixing takes place with waters of high temperature and high salinity.

3. Southern Arabian Sea (Fig. I..)

In general the characteristic water masses in this region resemble those in the Equatorial Indian Ocean. Between 0 and 50 m the variations in temperature and salinity are from T=28.5°C, S=36.25‰ and T=27.5°C, S=35.9‰. The surface water posses high temperature and high salinity. The maximum salinity is found at about 50-75 m. The upper subsurface layer is reduced very much in layer depth. As has been indicated by Ramasastry,[4] the typical Arabian Sea water forms in winter with rapidly increasing salinity depth with with nearly uniform temperature. This water mixes with subsurface water of high salinity. Thus the maximum salinity is found at about 50-75 m depth. This mixing eliminates the slow rate of decrease of salinity in the lower levels and makes the subsurface water below the Thermocline more uniform and less saline. Thus the hitherto seen upper subsurface water is considerably reduced in the vertical plane with the result that the characteristic up to 300 m appears more or less vertical. This is the second water mass present in this region. The extension of this water is up to 300 m. The variation of temperature is from T=27.00°C to T=16.00°C and the variation in the salinity from S=35.9‰ to S=35.35‰.

Below 300 m the waters have both uniform temperature and salinity. The variation in temperature is from T=14°C to 11°C and salinity from [illegible] to 35.2‰. The lower limits in temperature and salinity closely resemble the characteristic of 'A' water described by Thompson and reported by Ramarastry in the SE. Arabian sea. This water extends northwards along the coast. (Fig. A IV)

The important feature noticed in the SE Arabian sea around Minicoy Island is the decrease in salinity to very low values (33.2‰) in agreement with the observations made by Schott[5] and Frantskevich.[6] The possible explanations for the formation of such low saline waters are:-

(1) Heavy precipitation due to SW and NE monsoons in this region.

(2) Formation of a divergent line and the associated circulation bringing the low saline waters in this region.

(3) Transport of low saline waters from Bay of Bengal into this region through the Palk strait.

The main characteristics of the different water masses in the three regions are given in Table-I.

TABLE-I
CHARACTERISTICS OF THE WATER MASSES

Northern Arab. Sea			Central Arab. Sea			Southern Arab. Sea		
Depth range in M.	Temp. Range in °C	Sal. Range in ‰	Depth Range in M.	Temp. Range in °C	Sal. Range in ‰	Depth Range in M.	Temp. Range in °C	Sal. Range in ‰
0-75	26.5 / 22.0	36.6 / 35.6	0-75	27.5 / 26.8	35.8 / 35.45	0-50	28.5 / 27.0	35.25 / 35.30
75-150	22.0 / 18.5	[illegible] / 35.7	75-200	23.5 / 16.0	35.3 / 35.4	50-300	27.00 / 14.00	35.30 / 35.40
150to 300	18.0 / 15.0	35.7 / 36.7	200	16.0 / 12.0	35.4 / 35.6	300	14.00 / 11.00	35.50 / 35.25

C. CONCLUSIONS

From the above discussion the following conclusions are made:-

(1) Three main water masses can be discerned in the Arabian Sea:

(a) Upper subsurface Arabian Sea Water

(b) Lower subsurface Arabian Sea Water

(c) Deep Arabian Sea Water

(2) The above water masses are formed in the Arabian Sea itself.

(3) In the upper 500 m the presence of Equatorial water or Central water is not seen.

(4) At about 400-500 m transformed Red Sea water is observed as traces.

(5) In the southern and SE Arabian Sea the presence of 'I' water is clearly seen at depths of about 400 m.

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INDIAN NAVAL PHYSICAL LABORATORY

COCHIN

DEPARTMENTAL REPORT

RR 10/63

VERTICAL THERMAL STRUCTURE ALONG THE KERALA COAST DURING THE MONTHS AUGUST-DECEMBER

K.V.Sundara Ramam & V.Narayana Pillai.

INDIAN NAVAL PHYSICAL LABORATORY

COCHIN

DEPARTMENTAL REPORT -RR 10/63

VERTICAL THERMAL STRUCTURE ALONG THE KERALA COAST DURING THE MONTHS AUGUST-DECEMBER.

K.V.Sundara Raman & V.Narayana Pillai.

ABSTRACT

The vertical distribution of temperature in the Arabian Sea along the Kerala Coast during the period August to December is presented. It is found that the isothermal layer extends up to a greater depth during the winter than during the monsoon season.

INTRODUCTION:

Temperature is an important property of sea water which influences many phenomena such as availability of fish, propagation of sound, transport of waters etc. The sea temperature at different depths may be obtained either as a continuous record with the Bathythermograph or at selected depths by using reversing thermometer. The importance of BT data in anti-submarine warfare is a well known fact and hence a systematic study of BT data in Indian waters is essentaial. Such collection of BT data are specially necessary in coastal area as large fluctuations of temperature occur frequently both in space and in time.

Some studies of BT conditions in the Bay of Bengal have been reported by E.C. LaFond, C.Balarama Murthy and Ramasastry and D.Bhavanarayana Rao, but no published literature is available on BT conditions on the west coast. In the present paper the authors have made an analysis of the BT conditions along the Kerala Coast (from Calicut to Trivandrum) during the period August to December.

Treatment and Analysis of BT Data.

Thirteen sections have been considered along the Kerala Coast extending from Trivandrum to Calicut. Almost all the sections run perpendicular to the coast and extend to some distant beyond the continental shelf. The data were collected by I.N. Ships between the years 1956 and 1959. A month-wise analysis of this data has been made on the assuption that there is no large scale fluctuation from year to year in any selected region in the same month.

The vertical temperature structures were drawn after applying the usual temperature depth corrections to the observed data in accordance with the procedure suggested by E.C.LaFond. Fig: 1 shows the geographic positions of the different stations and Fig:2 to Fig:16 represent the vertical thermal structures of the sea in the various sections.

A general description of the temperature structure along the various eections month by mont is given in the following paragraphs.

Discussion of the Vertical Temperature Structures

August

The surface temperature in general shows a slight increase towards north with a maximum of 27.2°C off Cochin. The slight difference in surface temperaute of 0.6°C which is observed along the two sections off Cochin is due to the rain fall on one of the days. As one proceeds along the Coast towards the south one observes a decrease in the surface temperaturewhich can be attributed to the prevailing winds. Off Cochin and in the north the wind is from due west carrying the surface waters towards the coast

coast. But off Trivandrum the wind is from the north north-west producing a surface drift towards the south. This in turn removes the surface waters near the coast to a direction away from it resulting in the upwelling of bottom waters which are at a lower temperature. Off Alleppey the wind is from the north west resulting in a similar phenomenon though of less intensity.

The 26.5^{0}C isotherm is bent upwards in almost all the sections at a distance of about 40 miles away from the coast except off Cranganoor where the isotherms are parallel to the surface. The thermocline is at a depth of 25 ms. off Alleppey whereas off Shertalai and Cochin it lies at a depth of 15 ms. and lo ms. respectively. The thermocline also shows an upward bending at about 4o miles away from the coast. Below the thermocline there is a reversal in the bending of the isotherms at the middle portion of the sections indicating the existence of mixing. The width of the thermocline varies from 20 -25 ms. off Alleppey to 15 -20 ~~miles~~ off Cochin. The compression of the isotherms in the thermocline region may be due to the presence of homogenous waters and is dependent to a certain extent on the factors acting above and below the thermocline.

September.

The coastal waters have slightly higher temperatures than the offshore waters. The thickness of the isothermal water increases as we go away from the shore. This indicates that near the shore the conditions are favourable for the formation of iso-thermal water-namely the presence of winds and consequent mixing and the absence of upward lift of bottom waters. In the offshore regions the thermocline is very sharp and rises to the surface indicating the existence of monsoon conditions in the offshore regions. Near the shore the influence of monsoon weather is considerably reduced.

The depth of isothermal waters is generally small during this month. As one proceeds from the North to the South along the coast, one observes that the isothermal layer depth increases towards south eccepting at one station off Shertalai, where the thermocline is very sharp and is found near the surface.

The variation of surface temperature is not uniform along the coast. The surface temperatures off Ponnani and Quilon are fairly low (25.5°C) whereas at the other places both north and south it lies between 26.0°C and 27.0°C. The bottom waters are characterised by weak thermal gradients as was suggested by Sastry(1959).

October.

The surface temperature in general goes up reaching a maximum of 28.5°C off Cochin. The peculiar feature in this season off Cochin is the convergence of the isotherms off the coast at a distance of about 30 miles. The divergence of isotherms near the coast and the convergence away from the coast shows the existence of stable conditions in the offshore waters. At the middle portion of the section the thermocline lies at a depth of 5-10 ms. whereas it is shifted downwards to a depth of 30 ms. at the soffshore station. At the two stations which are nearer to the shore the thermocline is not well defined and is very narrow. 25.0°C, 24.5°C and 24.0°C isotherms are seen sloping towards the bottom, near the shore.

The above features clearly indicate the onset of post monsoon which is considered to be a turning point from the unstable monsoon conditons to the stable winter season.

November.

There is practically little difference in the surface temperature recorded off the coast at various sections. The whole region is associated with isothermal waters upto a depth of 20 ms. The thickness of the osothermal layer increases as as we go away from the coast indicating the characteristic distribution in the winter season. Accordingly the thermocline occurs at deeper levels in the off shore waters.

December.

The surface temperature increases towards the off shore waters. Isothermal waters exist upto 40 ms. except off Alleppey and Ponnani. The thermocline is shifted to a deeper level of about 80 ms. The isotherms are almost paraller except off Ponnani and Manakkodam where the isotherms exhibit the characteristic " doming and depressions" which may probably due to the intensive circulation.

Conclusion.

Summing up the BT Characteristics of the Kerala coast during the months August to December can be broadly stated as follows:-

(1) During the south-west monsoon the temperature on the north Kerala coast are generally higher than those in the south possibly due to wind action and the associated upwelling.

(2) During the monsoon the thermocline is very near to the surface and descends to greater depths as the winter sets in. In other words, the depth of the isothermal layer is larger in winter than in the monsoon.

(3) The isothermal layer depth increases as one proceeds away from the coast.

(4) As the sonar range is primarily determined by the isothermal layer depth starting from the surface one can expect poor ranges during the monsoon period and better ranges during the winter.

Acknowledgement.

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INDIAN NAVAL PHYSICAL LABORATORY

COCHIN

DEPARTMENTAL REPORT

RR 13/63

A STUDY OF THE HYDROGRAPHIC CONDITIONS IN THE ARABIAN SEA DURING POST-MONSOON PERIOD

PART-I VERTICAL DISTRIBUTION OF TEMPERATURE, SALINITY AND DENSITY IN THE UPPER 500 ms.

K.V.Sundara Ramam, Miss M.Girija,

V.Narayana Pillai and M.G.Seshagiri Rao

INDIAN NAVAL PHYSICAL LABORATORY

COCHIN

DEPARTMENTAL REPORT --- RR/63

A STUDY OF THE HYDROGRAPHIC CONDITIONS IN THE ARABIAN SEA DURING POST-MONSOON PERIOD

PART I- VERTICAL DISTRIBUTION OF TEMPERATURE, SALINITY & DENSITY IN THE UPPER 500 ms

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ABSTRACT

A discussion of the vertical distribution of temperature, salinity and density in the Arabian sea during the post-monsoon season is presented.

INTRODUCTION

In connection with the International Indian Ocean Expedition; the Naval Frigate I.N.S.KISTNA whose description as a research vessel is given by Panikkar[1] made 4 cruises and collected data in the Arabian sea during post-monsoon season 1962. With the data collected, one can obtain detailed information regarding the various water masses of the Arabian sea, circulation of waters, changes of ocean currents and also changes of temperature salinity and density due to monsoons. Among earlier works in this region, mention may be made of the works of Sewell[2], "John Murray Expedition[3] ", " Discovery II[4]", " Valdivia [5]", " Dana[6]" and " Snellius[7]". More recent works in the Arabian sea which are of special interest are those of " Vityaz"(USSR)"Anton Bruun" (USA), " Atlantis II"(USA) " Discovery III"(UK) " Zulfikar"(Pakistan) etc. Besides, some detailed studies were made in the coastal waters of the Arabian sea using research vessels like"KALAVA", "VARUNA"(CM.F.R.I.) and "CONCH"(University of Kerala). In this part of the paper an analysis of temperature and salinity data has been done and the vertical distribution of temperature, salinity and density in the Arabian sea during the post-monsoon period, 1962 are discussed.

COLLECTION OD DATA

During the period September to December 1962 four cruises were made covering 12 sections occupying 101 stations. The map showing the track of the cruises along with the various sections is shown in Fig.1. The stations are names as surface (upto 500 ms) and major (upto 3000 ms) depending on the depth of collection. Some stations where the depth of the bottom is less than 3000 ms are also considered as major stations since they are touched by other ships taking part in the expeditions. Out of these 101 stations occupied, 16 stations are major stations.

Nansen Reversing water bottles along with the reversing thermometers were used to collect the samples from the predetermined depths as a series machine to be operated simulataneously. A series of samples were collected and brought back together with the temperature measurements at each station. The operations were carried out by an electically operated winch. The station positions were determined by Celestial Navigation and dead reckoning. Where the depth is more than 500 fathoms the charted depth is taken at every station. At stations where the depth is less than 500 fathoms the depths are sonic depths. The temperatures were measured by the reversing thermometers to an estimated accuracy of $\pm$ 0.01°C. The depths of the bottles are based on readings of paired unprotected and protected thermometers (Sverdrup 1942[8]). The salinities were determined using ordinary burette to an estimated accuracy of $\pm$ 0.1 percent.

ANALYSIS OF THE DATA

While doing the analysis, the temperature depth and salinity depth curves were drawn following the procedure given by E.C. LaFond[9] and the interpolated values at the standard depths were used in preparing the charts of vertical distribution. The vertical scale for the diagrams showing the vertical distribution of temperature; salinity and density is expanded with respect to the horizontal by the factor 2000.

DISCUSSION

(a) VERTICAL DISTRIBUTION OF TEMPERATURE(Fig.2)

Section-1.

This section runs along the coast from Bombay to Karachi. The average depth of the shelf area is about 40 metres. Along the coastal region the temperature has cellular formations. Cells of high and low temperatures are formed in the vertical. The cause for such formation may be the effect of local heating of the region. In this area, the thermocline is not clearly developed. From station 8 onwards the thermocline happens to be present. It forms at a depth of about 50 meteres at station 8 and rises to 20 metres at station No. 10. The thermocline is very steep since the isotherms in the thermocline are spaced closely. Below the thermocline the isotherms slope upwards towards station 9 from a depth of about 100 metres to about 60 metres.

Section 2

In the surface layers two tongues of high temperatures meet in between stations 11 and 12. Below these tongues, the thermocline is present at a level of about 30 metres and extends to a depth of about 40 metres. Below the thermocline the isotherms show the oscillatory behaviour upto a depth of 200 metres. below this level, the isotherms run upward from stations 10 to 15.

Section.2.

In the surface layers two tongues of high temperatures meet in between stations 11 and 12. Below these tongues, the thermocline is present at a level ofabout 30 metres and extends to a depth of about 40 metres. Below the thermocline the isotherms show the oscillatory behaviour upto a depth of 2oo metres. below this level, the isotherms run upward from stations 10 to 15.

Section.3.

The concentration of high temperature (27.9°C) cell is seen in the surface layers. This section runs along 60°E at the Persian Gulf and Gulf ofOman. At a depth of about 20 metres, the thermocline appears to have formed. Below the thermocline, which has a width of about 20 metres,the isotherms are spaced uniformly upto a depth of about 80 metres. At 80 metres depth a closed cell of high temperature is enclosed between the isotherms. Also a tongue of high temperature is seen at a depth of 200 metres at station 16. The explanation for the presence of such high temperature at those levels is rather difficult. On examination, it may be said that since this station is near the shore at the entrance of Persian Gulf, the water of such high temperature might have been present even in the deep layers. This feature is visible even in the trace of the Bathythermograph.

Section.4.

This section is the first long zonal section running from 60°E to Bombay along almost 20°N. In this section, in the surface layers, concentrations of high temperatures are seen in the eastern part of the section. In general the temperature in the surface layers decreases towards west. Below these levels the thermocline is seen. In general the thermocline runs almost parallel upto station 24. It ascends towards the surface at station 20 and again descends to about 40 metres at station 19. Belwo the thermocline the isotherms are oscillatory with a general upward movement westwards. In the eastern part the isotherms seen to move upwards towards the surface along the continental shelf. But, however, this movement is restricted by the presence of thermocline. In the deeper levels, the oscillatory behaviour of the isotherms is predominant very much.

Section.5.

This section runs almost parallel to the previous one from Bombay to 60°E along latitude 18°N. In this section also in the surface layers the temperatures are confined to the eastern part of the section. At station 35 the thermocline is pushed downwards and again the thermicline rises upwards towards the surface along the continental shelf. In the remaining part the thermocline runs almost horizontal. This upward motion may either be due to the upwelling or due to internal waver. A definite explanation is not possible to be given here. But an attempt is made depending on the distribution. This distribution is modified by the presence of continental shelf which extends upto 200 miles in section 4 and upto 70 miles in section 5. In both sections the crests and troughs are found below a depth of 60 metres. The trough in section 4 is at 315 miles from Bombay whereas in section 5 a crest is found at the same distance. Again a crest in section 4 and trough in section 5 at the same distance from Bombay may indicate the existance of internal waves.

Section.6

This section is the meridional section along 60°E from 18°N. In the surface layers a small core of high temperature is seen. Below this core the thermocline appears at a depth of about 60 to 80 metres. The isotherms in the thermocline are almost horizontal. The isotherms below the thermocline are inclined upwards towards station 47. Below a depth of 200 metres the isotherms bend in the opposite direction(i.e.)downwards towards station 47 from station 46. This behaviour extends upto 500 metres throughout the section between these two stations.

The fact that the slope of the isotherms is same at all the stations upto 200 metres depth and that below 200 metres, the slope changes from station 46 to 47 indicates the reversal of flow in this section.

Section.7.

This section is again zonal section running from 60°E to 70°E along latitude 17N. It represents the middle part of the Arabian sea. The distribution in this section resembles almost the distribution in the previous zonal sections. In the surface layers upto the level of the thermocline a tongue of high temperature moves westwards. This tongue on its way towards the west thermocline ascends towards the surface from a depth of about 100 metres at station 57 to a depth of about 60 metres at station 47. Below the thermocline the isotherms as in the previous sections have the oscillatory behaviour and also there is a general sloping of the isotherms towards the surface layer. This behaviour extends down to 500 metres level. In the deeper levels the general upward bending towards station 47 is absent.

Section.8.

This section runs from 70°E towards Bombay. In the surface layers a high temperature belt moves south-westward towards station 57 upto the depth of the thermocline. The thermocline at station 57 is at a depth of about 80 metres at station 60 towards Bombay. The sotherms just below the thermocline also show this upward movement towards station 60. But the curvature of the isotherms below 200 metres depth shows the reversal from that in the upper levels. The isotherms from a depth of about 350 metres show steep slopes indicating the possible presence of cold water of temperature(11°C)at 400 metres depth.

Section.9.

This section may be taken as the southward extension on the previous section. The existence of warm water ($29^{o}C$) at the surface at station 61 is noticed. Also at station 62 comparatively, water of low temperature ($27.98^{o}C$) at a depth of about 20 metres is present. The thermocline ascends to a level of 100 metres towards north. The thermocline is uniform and all the isotherms upto ($17^{o}C$) isotherm are uniformally spaced. In the deeper layers as in the previous section the isotherms posses little sloping starting from a level of 400 metres. But this slope is not very prominant compared to the previous section.

Section. 10.

This section is one of the lengthy zonal sections. The distribution in the surface layers is that high temperature is pushed to the surface by water of low temperature present at a level of about 30 metres. This water of low temperature extends towards west and rises to the surface in the middle part of the section. In the western side of the section also low temperature is present. The thermocline is found at a depth of about 80 metres at the western side. In the middle portion the thermocline ascends to the top levels. As in the previous section the isotherms are uniformally spaced. They are not associated with any ramarkable steep slopes except at station 74. There is no reversal of the slope of the isotherms also indicating that the water flow due to the temperature change is small in this section.

Section.11.

In the surface layers ahigh temperature(28.4) is found to be present. This may be considered as the result of the movement of water of high temperature from the coast in the previous section towards the sea in this section, The thermocline is almost horizontal at a level of about 60 to 80 metres depth.

In the thermocline region the isotherms are spaced regularly. Even below the thermocline the isotherms are very uniform and regular. The major difference ofthe vertical distribution in the deeper layers is the uniformity in the isotherms in this region. As will be shown later, the density in this region is mainly controlled by salinity distribution.

Section.12.

Near the shore the temperatures arehigh and also throughout the section in the surface layers the temperatures are rather higher than the previous sections. The thermocline exists at a depth of about 80 to 100 metres. The isotherms in the thermocline are almost parallel and uniformly spaced, except at the eastern end where the thermocline rises at station 82 and dscends again towards station 83. At about 300 metres depth just below the thermocline whereas at the western end they slope in the same direction. In themiddle portion of the section the isotherms in deeper layers run almost horizontal. The bending at the two ends may be as a result of the effect of bottom topography on the flow of the water.

(b)VERTICAL DISTRIBUTION OF SALINITY(Fig:3)

Section.1.

The surface layers upto a depth of about 300 metres are associated with cells of high and low salinity. Below the depth of the thermocline high salinity is seen. This sub-surface high salinity has been divided into two by an isohaline of low salinity running vertically in the middle part of the section. With this exception the salinity in the lower layers increases with depth.

Section.2.

The isohalines in the surface layers enclose a high salinity water. This high salinity water extends from the surface at station 15 to a depth of about 20 metres at station 13 and then again ascends to the surface at station 11. This high saline water is confined only to the top layers above the thermocline. In the thermocline region the isohalines run almost parallel. Below the thermocline a tongue of low salinity below which again a high salinity cell is present, is found. These formations of high and low salinities at depths of about 100 to 200 metres indicate that mixing at these levels is not very prominent. This may be result of high stability in this region This phenomenon showsthat the character of the water is controlled more by salinity than by temperature in this region.

Section.3.

In the surface layers upto the depth of the thermocline two high saline water cells are present throughout the section. In the thermocline region the ishohalines run almost parallel and horizontal. Below the thermocline, two different waters, one of low salinity just below the thermocline and the other of high salinity in the lower layers are seen. The upper low saline water extends at a level of 100 metres from station 15 to station 19, Below this low salinity, the water of high salinity is found to be present. Both these high and low salinity waters converge towards station 15 at the level of the thermocline. This region may be called as halocline region. The halocline in this section is well formed only at station 15 while at station 19 there is a weak development.

Section.4.

This is one of the longest sections. The top layer upto the thermocline are, as in the previous sections, associated with high and low salinities. The halocline is not clearly developed. But a weak to moderately intense halocline is is seen at stations 19, 20, 28 and 29. Below the halocline alternate cells of high and low salinity are also seen. However the salinity gradient is not as steep as in the surface layers. The existence of the alternate high and low salinities even in this section indicates that the deeper waters do not mix very much with the result that they exist as a separate body of water in the Northern Arabian sea upto a depth of about 300 metres. Near the shore the isohalines have an upward bending towardsthe surface. This may be thought as due to upwelling as has been indicated in temperature distribution and also by Jayaraman et al[10]. But, however, until further evidence is found from the distribution of other properties like nutrients and also from the study of the wind field in relation to the boundary conditions, it is difficult to lay much stress on the phenomenon of upwelling. As is indicated in the disussion of temperature distribution this may be due to the action of internal waves.

Section.5

The distribution of salinity in this section has the same major features as in the previous section. But the concentration of cells of high and low salinities is less in the surface layers. The halocline runs almost vertical at station 35 upto a depth of about 100 metres and then appears horizontal upto station 38 and again ascends to the surface. This halocline encloses a high saline waterat the surface. On either side of this halocline high salinity waters are present. Thus it may be said that the tongue of high salinity in the subsurface layers in the Arabian sea as reported by many workers (like, carruthers[11] Jayaraman[10] etc.)is interrupted by the halocline. Below these levels the salinity is more or less uniform as reported by Jayaraman[10]. Another noteworthy feature is the existence of low saline water along the continental slope.

Section.6.

Section.6.

In the surface layers cells of high and low salinity are less prominant. A high saline water is present in the region of thermocline. The halocline follows thermocline in this section except where the high saline water is present. In deeper levels at about 200 metres depth water of high salinity is seen. This high saline water is more uniform and spread throughout the section at those levels. This indicates that the waters in the deeper levels are associated with uniform salinity distribution while surface layers are associated with different salinities. The possible explanation for such a distribution may be since that the observations were taken in the transition period.

Section.7.

The surface layers do not have many closed cells of high and low salinities. In themiddle part of the section the salinity values are comparatively low. In the eastern and western parts, the cellular formations are seen. The important difference in this section fom the previous sections is the presence of low saline water from the surface down to deeper layers in the middle part of the section. The presence of this low saline water indicates the presence of homogenous water in thecentral Arabian sea as a result of vertical mixing. On either sides of this section in the deeper levels alternate high and low salinities are found. The explanation for the presence of high and low salinities in the deeper levels at the eastern and western parts may be due to the absence of vertical mixing in those regions.

Section.8.

In general the surface salinity is low. No cells are formed in the central part of the section. Only at a depth of about 10 metres high salinity is seen at both ends of the section. At a level of about 40 metres a tongue of high salinity is observed in conformity with the observations of other workers(Carruthers[11], Jayaraman[10]). Below this tongue of high salinity, the halocline is present. The halocline has a convex beinding downwards. Below the halocline the isohalines are straight and parallel at a depth of 100 metres. At station 59 these straight running isohalines bend vertically downwards upto a depth of 500 metres. The vertically running ishalines indicate the presence of uniform water. At station 57 the deeper levels are associated with high and low salinities. Also since this section extends from 70°E to Bombay in the north-easterly direction the upward bending of the isohalines which is limited upto a depth of about 100 metres towards Bombay may indicate the limitation of upwelling. This limitation shows that upwelling may not be present in the surface levels.

Section.9.

As has been said earlier, this section may be considered as the south-westward extension of section 8. In this section only one cell of high salinity is seen at station 62 at a depth of 40 metres. There is a weak development of the halocline. In the deeper levels the isohalines run vertically indicating the possibility of uniform water. The vertical extent does not reach the surface layers, but confines ony below the halocline regions. Thus it may be seen that the properties in the surface layers are different from those in the deeper levels.

Section.10.

In this section waters of high salinity are present in the surface layers from station 64 to station 67. This high saline water extends upto a depth of about 80 metres at station 65. At station 74 low salinity water of range 35.4 to

35%o is seen near the surface. As in section 7, the central portion of this section also is influenced by the presence of low salinity water from sub surface levels. The salinity variation is considerable upto a depth of about 150 metres upto station 71. Beyond that level the salinity is uniform throughout the section.

Section.11.

Very low saline water (32.2%o) is seen at station 101 at the surface. From station 99 to 96, high salinity is present at the surface. This high saline water(36.40%o) extends downwards from the surface to the deeper levels and meets with low saline water present at station 101 at sub surface levels. This is noticed from the presence of specific tongues of high and low salinity waters extending right from the surface down to the sub surface levels upto about 300 metres near station 101. The absence of cells of high and low salinities in this section may be the result of the setting up of the winter conditions.

Section.12.

The distribution in this section resembles that in the previous section. Here also the low saline water is present at the surface layers from station 81 to station 83. A tongue of high saline water typical of equatorial regions (Défant)[12] is present at a level of about 60 metres. The halocline is presnet from a depth of about 100 metres to 150 metres. The salinity is fairly uniform between 300 and 500 metres.

(c) VERTICAL DISTRIBUTION OFDENSITY(Fig:4)

(The density in terms of is taken)

Section.1.

In this section the surface density varies from 22.81 to 23.95. From Bombay to the Gulf of Cutch, the surface density is unifrom of value 23.5 and it is constant upto the bottom whereas at station No.7 high density water is found at a depth of 10 metres and at station No.6 this high density is found at the bottom i.e. at about 40 metres. From this it can be inferred that this may be the result of movemeht of high density water into the shelf area. The density discontinuity layer slopes gently towards the surface from station No.7 to station 10, the density gradient is rather weak, but below the slope of 25.2 isopycnal is rather steep indicating the existence of moderatley strong flow.

Section.2.

The region above the discontinuity layer is associated with relatively high density water at station No.11 and low density waters on either side. The density discontinuity layer isalmost uniform in thickness and is horizontal. In the deeper levels the isopycnals have oscillatory nature and it is more predominant at a level of about 200 m.

Section.3.

The surface layer upto a depth of about 20 m is uniform in density. The discontinuity layer is inclined and penetrates to the deeper layers. the absence of oscillatory behaviour in isopycnals in this section. In the deeper levels the orientation of isopycnals is similar to that of discontuity layer. This direction of flow is same from the discontinuity layer to the bottom.

Section.4.

The top layer upto 30 m has regions of low and high density waters. Near 70° and 63°E Long low density waters (values 23.44 and 23.o7 respectively) and at 61°E high density waters(24.8) are present. This high density has on its either side steep vertical isopycnals and it shows the possible indication of strong currents in that region. This high current seems to be responsible for maintaining high density waters above the low density at depths of 75 and 30 m at station Nos.20 and 21 respectively. The region between stations 27 and 25 may be considered as a region of instability in the surface layers, since high density water lies above the low density water.

The density discontinuity layer is well defined only between stations 31 and 28. In the region between stations 27 and 25 this layer is pushed downwards because of the unstable conditions prevailing in that region. Due to this unstability, the discontinuity layer has taken a typical shape. Again it rises to the surface levels at station 22 where it divides tnto two branches one ascending to the surface and the other decending to the deeper levels. The branching of the discontinuity layer may be attributed to the vertical flows associated with the unstable conditions.

In the deeper levels between 100 and 200 m the isopycnals exhibit an oscillatory structure with the possible indication of either internal waves or the effect of bottom topography.

Section.5.

The surface density in this section increases from the shore towards 60°E. As in the previous section, the unstable condition do not exist in the upper levels. The density discontinuity layer decends along the continental shelf from station 33 to station 35 from where it ascends to a level of 40 m at station 36. From station 36 upto station 45, this layer is amost uniform and horizontal with an exception at station 37, where it descends to a level of 100 m. This may be the result of the outflow of the low dense water from the shore and inflow of high dense water along the continental shelf.

Section.6.

A relatively high density compared to stations on both sides is found at station 46 near the surface. Thetransition layer is not well defined. At station 45 at a depth of 100 m low density region is existing (which shows the fnflow of low density water in this region) indicating that instability is existing below the discontinuity layer. High density water(27.95) exists at about 400 m at station 47 and it moves downwards from station 47 to station 45 (along the isopycnals). This type of slope of the isopycnals indicates that the flow in the deeper waters is more intense than at the surface.

Section.7.

Along the coast, the xistence of alternate high and low density in the surface layer may be due to the transition period. Low density water is existing between stations 49 to 53 upto a depth of about 70 m. This may be due to the rain fall in the south west monsoon and the low rate of evaporation. The discontinuity layer is not well defined but exists at a depth of 80 m. The isopycnals below 150 m have different curvatures lowering at stations 52 and 53 and rising at stations 48 and 55 on both sides. Besides, regions of high density at 300 m and low density at 500 m at station 57 and highdensity at stations 54 and 55 at 500 m are seen. Similarly high density at 200 m and low density at 300 m at stations 47 are also observed. Since these observations are taken in the transition period the existence of the high and low density water at the extreme ends of the section may also be explained ue to the unstable condition prevailing.

Section.8.

Very low density(21.79) is existing at station 59 near the surface. The discontinuity layer near the coast(i.e. at station 60) is at 40 m depth and it diverages as it goes away from the coast, Low density water is found in the discontinuity layer at station 58 at 40 metres depth. This section being near the coast, it experiences unstable conditions in the upper layer during the transition period. Below 100 metres the high density water moves downwards from station 58 towards the coast.

Section 9.

Low density is found at 30 metres at station 63. The discontinuity layer in this section is well defined and shows an oscillatory behaviour. Below 100 metres the isopycnals are almost parallel with one rising up at station 62 and lowering at station 63. Below 400 metres the curvature is changed. The important difference of this section from other sections is that the surface layers do not have alternate high and low density waters.

Section 10.

In this section also the low density water is found in the central part. The discontinuity layer shows oscillatory behaviour. It has been depressed too much at station 72 indicating the possibility of convergence. These convergences and divergences extend to deeper levels also from below the discontinuity layer. This section has been covered in the month of October when the period of transition becomes over and the winter conditions starts namely the setting up of the north-east monsoon. This may be the reason for the absence of the alternate high and low density waters. But the oscillatory behaviour of the isopycnals in the deeper levels is the indication of the existence of unstable condition due to the transition period in this month also.

Section.11.

In the surface layers, a tongue of low density water extends from Monávoy Islands towards west. At station 97 moderately high density water sinks from the surface, thus modifying the low density tongue. The discontinuity layer is clearly seen without any oscillatory behaviour as in the previous sections. Only in the deeper layers a gadual rise of the isopycnals occur from station 101 to station 99. This uniformity may be due to the stable conditions during the onset of winter.

Section 12.

The density wedge is confined only to a very small region. The dicontinuity layer seems almost horizontal and extends from 80 metres to 150 metres. In the deeper levels, the sloping of the isopycnals is not very prominent. Only towards the onshore regions the discontinuity layer shows upward bending towards the offshore region. Also a reverse slope is meen in the deeper layers at the on-shore regions. This may be due to the reversal of the flow of the water.

CONCLUSIONS.

The salient features of temperature, salinity and density distribution can be summed up as follows.

1. TEMPERATURE.

i. The surface temperature decreases westwards.

ii. The depth of the isothermal water increases towards the equator.

iii. Three different water masses appear to be present in the northern Arabian sea during this period. This type of distribution was also reported in he John Murray Expedition.[3] The distribution of temperature observed in this region resembles that described by Writky[13] in the Indonesian waters. The three different water masses are as follows:-

(a) Surface layers with cells of high and low temperatures and salinities can be attributed to the influence of waters from the Persian Gulf and from various rivers like the Indus and also to the local convective heating.

(b) The high salinities in the surface layers may be due to the high rate of evaporation. The low temperature and low salinity which are observed just below the thermocline shows possibility of sinking of the waters from the Persian Gulf.

(c) The third water mass with low temperature and high salinity is noticed at deeper levels and can be attributed to horizontal mixing of various deep waters. This shows that the waters from the Persian Gulf sinks to the appropriate levels and move southwards while the surface waters move northwards as in the Red sea.

The presence of high temperature and high salinity in the meridional section off the Arabian cost has already been explained in the previous sections.

iv. The vertical distribution of temperature indicate the oscillations of the thermocline and the isotherms below. This phenomenon may be due to one or a contribution of the following factors.

(a) The presence of internal waves of tidal character in the boundary layers as observed during Michael Sars Expedition[14].

(b) Effect of bottom topography(Sverdrup)[8] influencing the vertical distribution in the layers above the ridges or valleys.

(c) The sloping of the isotherms or isopycnals may indicate or rather exaggerate the intensive circulation as suggested by Deacon[15] and confir- by Jayaraman et al[10].

(d) The presence of upwelling along the coast during this season may be the cause for the observed distribution as reported by Ramasastry [16], Banse [17] Jayaraman [18] etc.

It is not possible to ascertain the main factors which are respensible for this phenomenon, due to the follow-wing reasons.

(a) Since continuous bathymetric charts were not taken the influence of bottom topography could not be determined.

(b) The effect of internal waves could not be confirmed since repeated observations were not available to find out the period and length of internal waves.

(c) The sloping of the isotherms or isopyenals may be partly due to the vertical exagggeration of the diagrams.

(d) Since the observations were taken only at a few sections along the coast and as also the wind field is not avaiable the presence of upwelling along the coast could notbe confirmed.

In these circumstances, however, the most plausible explanation would be that the internal waves are present at these depths and the upward tilt of the isotherms, isohalines and isopycnals is the result of the modification brought about by continental shelf on the internal waves. A detailed analysis of the wind field in this region and its contribution to upwelling on the lines of Hidaka [19] will form the subject of another.paper.

II.SALINITY.

In the central and southern Arabian sea high salinity is observed (Defant[12], Carruthers[11], etc.). This high salinity is influenced by the presence of low salinity in the central part of the Arabian sea. A tongue of low salinity is seen from the surface to the deep levels indicating the presence of homogeneous water. The running of isohaline in the vertical direction has also been observed by Jayaraman et al[10]. The salinities in this region during winter are general low. The distribution of salinity in the surface layers is in close agreement with those given by Sverdrup[8], Defant[12], etc. The presence of alternate high and low salinities in the deeper levels is the result of a little vertical mixing in the deeper levels.

III. STABILITY.

The instabilities noticed in the upper layers in the Northern and Central Arabian sea are the consequence of the transition period between South-West monsoon and the North-East monsoon. This is confirmed by the disappearance of the instabilities in the Southern Arabian sea where observations were taken at the onset of winter. A greater degree of stability is observed at deeper levels indicating practically no vertical mixing except in the central Arabian sea where the isopycnals rise to the surface. Instabilities are also observed in the eastern and western sides of the sea upto a depth of 300 metres.

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The authors wish to record their thanks to Dr. D.Srinivasan, Officer-in-Charge, I.N.P.L., Cochin, for his kind guidance and helpful discussions during the preparation of this paper. Thanks are due to Dr.S.S.Srivastava, for his keen interest in this studies and kind encouragement. They wish to acknowledge the assistance of the Indian National Committee on Oceanic Research under whose sponsorship the cruises were conducted.

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COCHIN-4

DEPARTMENTAL REPORT -RR 14/63

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ABSTRACT

A discussion of the horizontal distribution of Temperature, Salinity and Density in the Arabian Sea during the Post-monsoon season is presented.

A. INTRODUCTION

In Part I of this paper[1] the vertical distributions of temperature, salinity and density in the Arabian sea during the post-monsoon season were discussed. A study of the spatial distribution of these parameters is best achieved by drawing the horizontal charts showing their distribution at different levels. The data collected during the cruises of I.N.S. KISTNA during the post-monsoon season of 1962 were used in preparing the horizontal charts which represents a transition period between the SW monsoon and the NE monsoon.

B. ANALYSIS OF THE DATA

The data have been plotted at each level on a horizontal chart(Fig:1) for temperature, salinity and density. The levels considered are surface, 50m, 75m, 100m, 150m, 200m and 300m. Using this data the contours were drawn for all the three parameters. In the case of temperature distribution the contour interval is is 0.2°C and in the case of salinity and density it is 0.2%° and t 0.2 respectively.

C. DISCUSSION

I. HORIZONTAL DISTRIBUTION OF TEMPERATURE

1. Surface (Fig.II)

The temperarure distribution at the surface mostly resembles the general distribution of surface temperature in this region during this period as given by Sverdrup et al[2], Defant[3] and Von Arx[4]. Since the observations are based on a large number of stations it is possible to study the distribution in detail over the Arabian sea. This may be the main reason for certain deviations from the general distribution.

The eastern Arabian sea is warmer than the middle and Western Arabian seas and high temperatures exist near the Persian Gulf and Gulf of Oman. But near the mouth of Indus the waters have low temperature of the order of 25°C. In the middle Arabian sea concentrated cells od low and high temperatures are found to be present. In general the isotherms run along the meridions with high temperatures (29°C) towards the eastern side and low temperatures (27°C) on the western side. A concentrated cell of high temperature is found on the SE side also. The cellular distribution of temperature in the middle part of the Arabian sea may be the result of the clockwise circulation, the Equatorial circulation and also the recedinf SW monsoon and the onset of NE monsoon. The temperatures at the Equator are higher than those inthe northern Arabian sea. The deviation seen in the present investigation may be due to the detailed observations made since the observations are taken from September to December, 1962

2. 50m (Fig:III)

The distribution at this level closely resembles the surface distribution. At this level also the closed vertices are formed which are however less pronounced. The difference between the surface chart and this chart is that in the North the temperature is much lower (23°C) than in the south (28°C) and the East-West gradient is reduced very much. This phenomenon is clearly seen where the isotherms are found to run throughout the Arabian sea from West to East. The nature of the isotherms indicates that warm waters exist up to 20°N latitude. In the north Arabian sea, at this level, the temperatures are very low in dicating the water flow to be in the NE direction. The range of temperature is from 28°C to 21°C.

3. 75m (Fig: IV)

At the upper levels the temperature of the water ranges from 27°C in the south to 19°C in the North. Closed cells of high and low temperatures are also present. The isotherms converge off Bombay and off Minicoy. The 25°C isotherm particularly runs from West to East converging the greater part of the sea. At this level also the water flows in the NE direction.

4. 100m (Fig: V)

At this level the isotherms tend to become parallel to the latitudes but still the previous pattern is maintained. The convergence of isotherms off Bombay and off Minicoy is clearly seen. But the main difference lies in that there do not exist many concentrated cellular formations of low and high temperature waters indicating uniformity in distribution. Further the temperature gradient from south to north is very much reduced, the values falling from 24°C to 19°C. An interesting observation at 60°E and 12°N is the presence of remarkably very low temperatures (17°C) while in the upper levels this feature is not so prominent. The absence of very low temperature in the northern Arabiab sea is particularly to be noted since at all the upper levels this region is associated with low temperatures. The 22°C isotherm represents the envelope of the entire Arabian sea separating the high temperature waters in the middle Arabian sea from the low temperature waters in the north.

5. 150m (Fig: VI)

At this level the temperature range is from 21°C to 16°C. As in the previous levels high temperature is found to be present inthe middle Arabian sea. off Bombay. On both eastern and western sides of the sea the temperatures are of the order of 16°C and also the isotherms in the north and south become almost parallel to the latitudes. This phenomenon is clearly seen in the case of 18°C isotherm in the north and 17° and 16°C isotherms in the south- The presence of high temperatures at these depths in the middle part of the Arabian sea may be brought about by the vertical mixing due to turbulance of the waters. caused by wind action.

6. 200m (Fig: VII)

At this level the range of temperature is from 19°C to 14°C. The temperatures are found both in the north and middle Arabian sea. The isotherms tend to become parallel to the latitudes indicating the uniformity of temperature from east to west. The lower temperatures are found at the Equatorial regions. The ~~re~~ enclosed cells become less prominent. The isotherms inthe middle and northern Arabian sea have ~~so~~ southward bending whereas in the previous levels they show a northward bending. The convergence of isotherms off Bombay and off Minicoy is also less pronounced. At this level also the middle Arabian sea is warmer than the rest of the sea. In the regions north of Bombay and off Minicoy high temperatures are found. The main difference in distribution from other levels is the absence of a single isotherm running throughout the Arabian sea.

7. <u>300m</u> (Fig:VIII)

The range of temperature is 16°C to 12°C. The main feature of this pattern is the absence of cellular formations. The isotherms have become more flat, uniform and run parallel to the latitudes. At this level also high temperature of the order of 14°C and 15°C are found to be present in the northern latitudes at about 20°N latitude. This may be considered to be the shift of warmer waters from south to north as the depth increases.

II. <u>HORIZONTAL DISTRIBUTION OF SALINITY</u>.

1. <u>Surface</u> (Fig:IX)

The salinity variation is from 30.81‰ to 37.04‰. Low saline waters of 30.81‰ salinity are found in the Minicoy region. The high saline waters of 37.81‰ salinity are found in the vicinity of Bombay at about 20°00'N. and 70°00'E. East of thisrigion comparatively ~~fxmm~~ low saline waters are found. The isohalines from 37.00‰ to 36.40‰ show the southward bend indicating the extension of high saline waters from North to South. At 15°00'N. and 60°00'E again, low saline waters of the value of 35.60‰ exists. This water extends from south to north. Another tongue of low salinity (35.00‰) passes from North to South at the Gulf of Oman. This tongue of low salinity seems to be penetrating into the high saline waters at about 20°00'N. This may be the reason why the water at 20°00'N and 60°00'E has high values of salinity.

2. 50 ms. (Fig:X)

The salinity ranges from 36.98‰ to 33.75‰. The salinity of 33.75‰ is found near Minicoy and salinity 36.98‰ is found at 20°00'N. and 68°00'E. This high saline water at this level also extends towards south meting a northward moving low saline water from 12°00'N and 60°00'N. This high saline water at the northern end meets another low saline water coming from the north. The whole distribution may be broadly divided into three categories.

(a) East of 70°00'E.- The waters in this category have low salinity.

(b) Middle Arabian Sea - The waters in this category have high salinity.

(c) The third category contains low saline waters extending in a North-Easterly direction. However, deviations from this general distribution are seen at the North-Western regions near Arabia where high saline waters are found to be present.

3. 75 ms. (Fig.XI)

At this level the range of salinity is from 34.55‰ to 37.23‰. Again, as in the upper levels the low saline waters are found in the region off Minicoy and the high saline waters are found around 20°00'N and 70°00'E. The extent of this high saline water into the southern region is increased. This the western low saline water belt is reduced. Around Minicoy Islands the low saline waters extend towards west. Around Bombay the influence of high saline waters reduces the presence of low saline waters. The high saline water present at 18°00'N and 60°00'E extends in a North- Easterly direction as a tongue of high saline water, North and South of which the low saline waters are present.

Again, near the Persian Gulf the waters have high salinity (36.55%°).

4. 100 ms. (Fig:XII)

The range of salinity at this level is from 34.84%°) to 36.86%°). The low salinity waters ~~was~~ are found near Minicoy and south west of Bombay. The whole Arabian Sea at this level is much influenced by high saline waters. This the extent of low salinity water is reduced very much. The presence of low saline water is seen only at very few places viz. (1) At 15°00'N and 65°00'E. (2) At 18°00N. and 60°00'E (3) Off Karachi (4) Near the Gulf of Oman (5) Near Minicoy (6) South-West of Bombay. This level may be considered as the level where the salinity reaches its maximum throughout the Arabian.Sea. This is seen clearly by the nature of 36.00%° Isohaline. This isohaline almost runs throughout the Arabian Sea.

5. 150 ms. Fig;XIII)

The range of salinity at thislevel is from 34.91%° to 36.63%° The low saline waters exist in the vicinity of Minicoy Island and at 19°N and 70°E.The main difference from the previous level is that the whole Arabian sea consists of many cells of low and high salinity waters. This feature is clearly seen along 17°N and 21°N where alternatively high and low saline waters are present.The general feature of distribution is the reduced influence of high salinity in the vicinity of low salinity.In other words the low saline water penetrates as a tongue ~~of~~ into the region of high salinity water.This can be clearly seen around Minicoy and Bombay and also at the NW Arabian sea where alternate streaks of low and high saline waters are present.

6. 200m (Fig:XIV)

The range of salinity is from 34.99‰ to 36.69‰. At this level also the low saline waters are found near Bombay. Such very low saline waters are not found around Minicoy. The alternate high and low salinity cells are found both along 17°N and 20°N. But they are not very close as in the 150m level. The high salinity cells have less salinity than that observed at 100m level and the low salinity cells show higher values than at 50m level. The high saline water present at the Persian Gulf may be the water formed in the Gulf itself. The long streaks of high and low saline waters are not present at this level.

III. HORIZONTAL DISTRIBUTION OF DENSITY

1. Surface (Fig:XV)

The surface density varies from t 21.8 to t24.3. The minimum density occurs at two places; one off Ratnagiri and the other in the neighbourhood of Minicoy Islands. The maximum density is observed near Arabia and near the Gulf of Oman. The density distribution is not uniform throughout the Arabian sea since this period represents the transition between SW and NE monsoon seasons. Thus the whole distribution comprises of small tongues of different densities. In the N. Arabian sea, north of 20°N two tongues of high and low density waters appear. In the region south of 20°N latitude alternate high and low densities are found. In the central Arabian sea a closed cell of high density (t 23.6) is seen. Adjacent to this high density region exist on either side low density regions. Thus the flow in the eastern and western Arabian sea are in the opposite directions. In the southern Arabian sea the isopycnals run almost parallel to the latitudes. This uniformity in he density indicates the onset of NE monsoon in that area. Also this distribution is similar to that in the Equatorial counter current.

2. 50m (Fig:XVI)

At this level the density ranges from t25.68 to t21.37.The maximum density is observed south west of Bombay.But mostly the dense waters are found in the northern Arabian sea.The orientation of the isopycnals in western Arabian sea is such that the flow is northerly to north-easterly.The isopycnals from 24.6 to 24.2 run southward along 60°E and turn NE upto 20°N.They turn eastward along 20°N almost parallel to that latitude and finally turnssouthwards off Bombay. These isopycnals indicate that the flow is NE along 60°E,easterly along 20°N and finally southerly along the west coast of India. Thus an anticlockwise circulation is set up.Off Bombay the isopycnals are closely spaced indicating farely moderate currents off Bombay. This current pattern mainly resembles the surface circulation given in the H.O.Publication No.556.In the central Arabian sea the isopycnals are indicative of somewhat complicated circulation due to the transition period.The orientation of the isopycnals 23.6 and 23.8 is such thatboth clockwise and anticlockwise circulations are present inthis region.The isopycnals 23.6 and 23,4 are run almost parallel to to 10°N up to 65°E from where a northerly bend especially for 23.6 is seen.The 23.4 isopycnal turns back towards 10°N and continue to move eastwards.Around Minicoy,again,closely spaced isopycnals are seen. The flow along 10°N is mainly easterly.Around Minicoy the flow is north-easterly.

3. 75m(Fig:XVII)

The density varies from t22.37 to t 25.96.The lowest density is present around Minicoy Islands while the highest density is found near the Persian Gulf.The isopycnals 25 and 24 occupy most of the northern and central Arabian sea.Cells of low density (t 23.3 and 23,6)are seen in he central Arabian sea.The presence of these low and high density cells indicates the complicated picture of the currents during the transition period.North of 20°N the flow is NNE. In the central Arabian sea the flow is NE around 60°E and turns eastwards and south-eastwards and finally goes towards Bombay as a NE current.Along the coast the data is not sufficient to draw any conclusions; but it can be said that along 70°E off Bombay the flow is southerly.Off Cochin to the east of 70°E the flow is northeasterly to northerly.This northerly current is fairly strong.In the region between 70°E and 60°E the flow along the 10°N is south-westerly to westerly and meets the north-easterly flow along 60°E.

The northern Arabian sea possess the characteristics of the S-W monsoon. The central Arabian sea possess the characters of the transition period and the southern Arabian sea starts possessing the characters of the N-E monsoon.

4. <u>100 ms</u>.(Fig XVII)

The sensity variation is from 22.89 to 26.30. The major high density region is the northern Arabian sea. All the isophycnals in thisregion have high values above 25.00. As in the previous level the 25.00 isopycnal moves north-eastwards turning towards east and then towards south and finally eastwards at 70°00'E longitude. Low density (24.2) isopycnal is formed into a closed cell in the central Arabian sea. South of 10°00'N. latitude the density again increases. Off Cochin upto 70°00'E a large density gradient is present.

The flow in the northern Arabian sea is mainly south-casterly to easterly. North-easterly flow is seen in the central Arabian sea around 60°00'E. A clockwise circulation is prevalent in this region. The clockwise moving current joins the westerly flow around 10°00'N. and 65°00'E. This flow continues to be intensified towards Socotra Islands. The main difference from the previous levels is the existence of a south-easterly to easterly current north of 20°00'N and a north-easterly clockwise circulation in the central Arabian sea.

5. 150 ms. (Fig:X1X)

The density variation is from 26.09 to 24.51. The high densities are confined to the northern Arabian sea and also at 60°00'E and 15°00'N. The low density is seen near Minicoy islands and in the central Arabian sea. The cellular formations are seen at this level also. South of 10°00'N the density again increases. The presence of high density in the eastern parts of the central Arabian sea may be explained as due to the influence of the Red sea water.

The currents off the Arabian coast are southerly and the flow is into the Red Sea. At about 15°00'N and 60°00'E the flow is northerly and easterly at 20°00'N. Thus a clockwise current is set up in the central Arabian sea. But this current again turns northwards current off Cochin. The clockwise current in the central Arabain sea joins the westerly current at about 10°00'N.

6. 200 ms. (Fig:XX)

The density variation isfrom 27.52 to 25.61. The high density water is found near the Persian Gulf and also at 60°00'E and 15°00'N. The 26.20 isopycnal almost runs northwards along 65°00'E. The low density cell (25.40) is considerably reduced in size and a steep gradient is present around this reduced cell. In the remaining part of the central Arabian sea the density remains uniform. Again, the density increases sotuh of 10°00'N. The presence of high density water at 60°00'E and 15°00'N is the result of mixing with the Red sea water.

The flow along the Arabian coast is southerly, meeting a northerly to northeasterly flow to the east of this current. In the central Arabian sea the flow is northerly to north-easterly. It branches off into northerly and easterly and runs as an intensive clockwise circulation aroundthelow density cell. This clockwise current meets an anti-clockwise current at about 65°00'E and 17°00'N and ultimately merges with the westward flowing current around 10°00'N and 68°00'E. The anticlockwise curcualation starts off Cochin and moves northwards almost parallel to 70°00'E longitude. Another branch moves along 10°00'N latitude towards west. This current meets another westwards flowing current at about 68°00'E and together they move as a westerly current.

D. CONCLUSIONS.

In conclusion the following salient features can be summarised.

1. Highest temperatures are observed in the central part of the Arabian sea except at deeper levels.
2. Lowest temperatures are found in the northern Arabian sea.
3. There is a shift of warmer waters from south to north as the depth increases.
4. Concentrated cells of low and high temperature are found to be characteristic of the surface layers and they become less prominant as the depth increases, indicating the uniformity in distribution.
5. The salinity is always high in the middle Arabian sea and near the Persian Gulf.
6. ~~East~~ In general, the maximum salinity is observed at a level of 100 metres.
7. East of 70°00'E longitude the waters are characterised by low salinity values especially around Minicoy islands and as the depth increases the high saline waters ~~the~~ from the central Arabian sea penetrate more into this region.
8. During the post-monsoon period the northern Arabian sea possesses the characteristics of the S-W monsoon, the central

Arabian sea that of the transition period and the southern Arabian sea starts possessing the characters of the N-E monsoon.

9. Low densities are found in the central Arabian sea and near Minicoy islands.

10. High densities are observed in the eastern parts of the central Arabian sea, near Arabia and in the Gulf of Oman.

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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 mid-water 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 of the same size range as *Sagar Sampada* through the III 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.

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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 km^2 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 km^2. 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

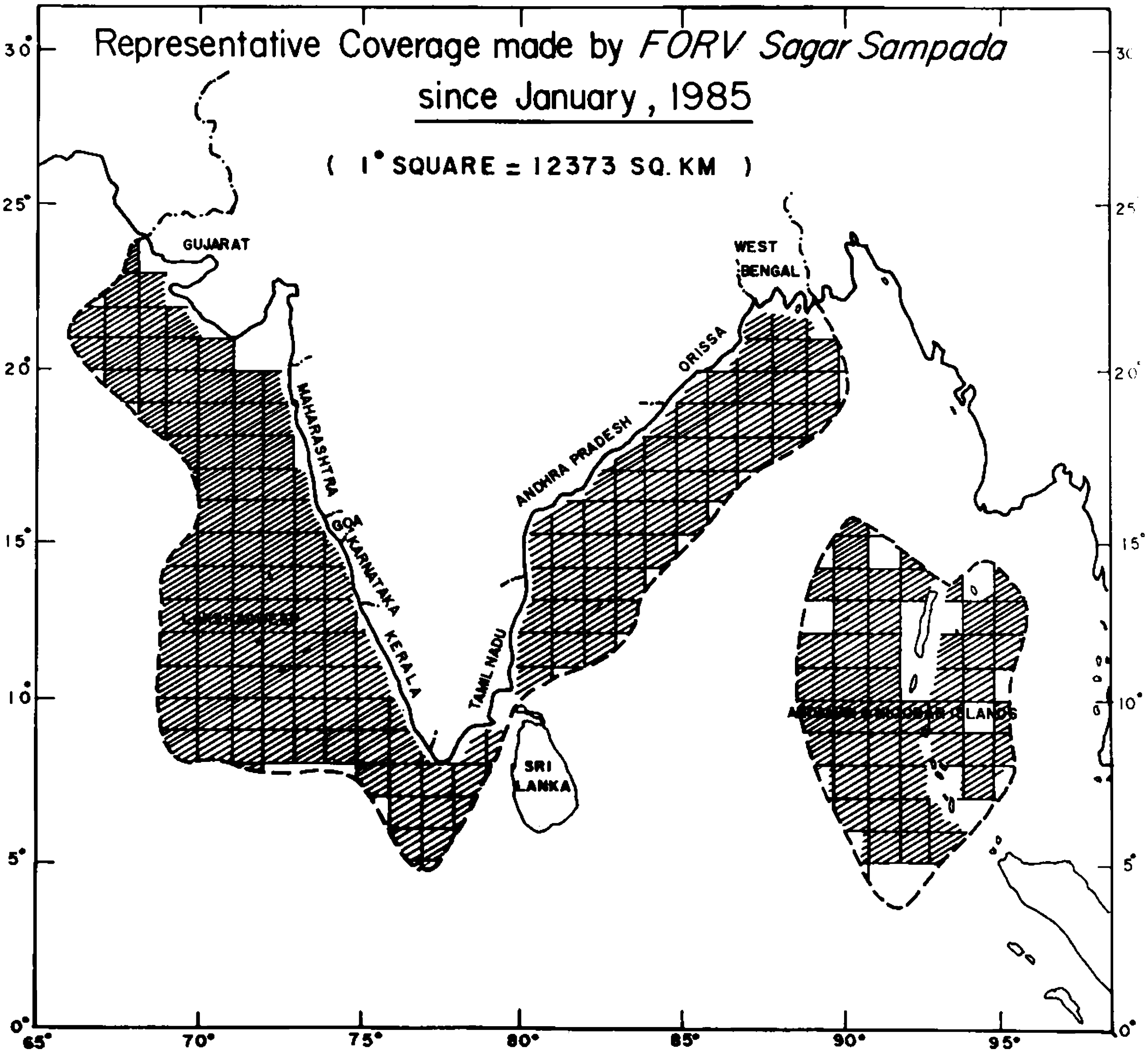


Fig. 1. Representative coverage made by FORV *Sagar Sampada* since January, 1985.

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.

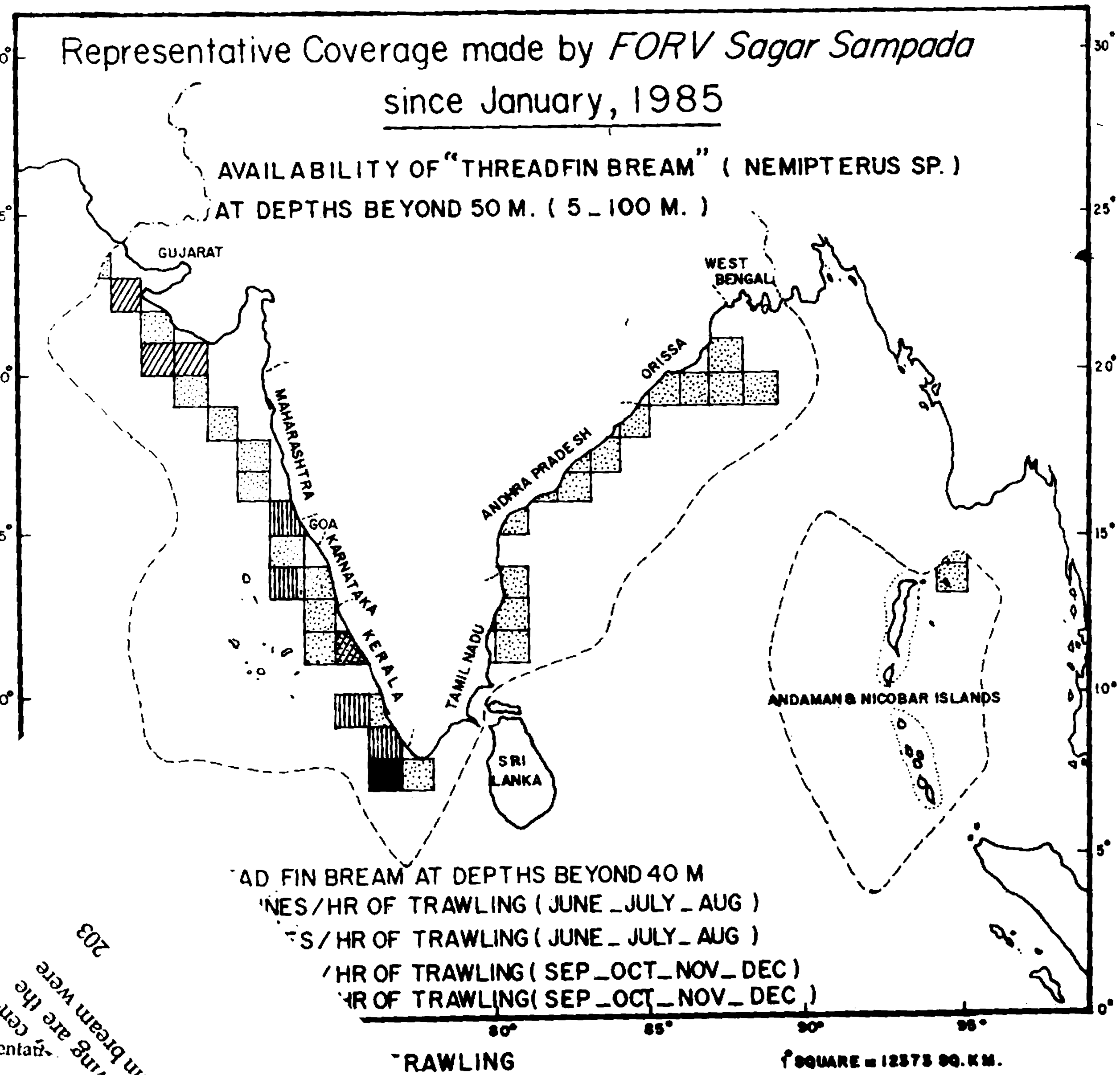


Fig. 1. Representati... at depths beyond 50 m (5-100 m).

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).

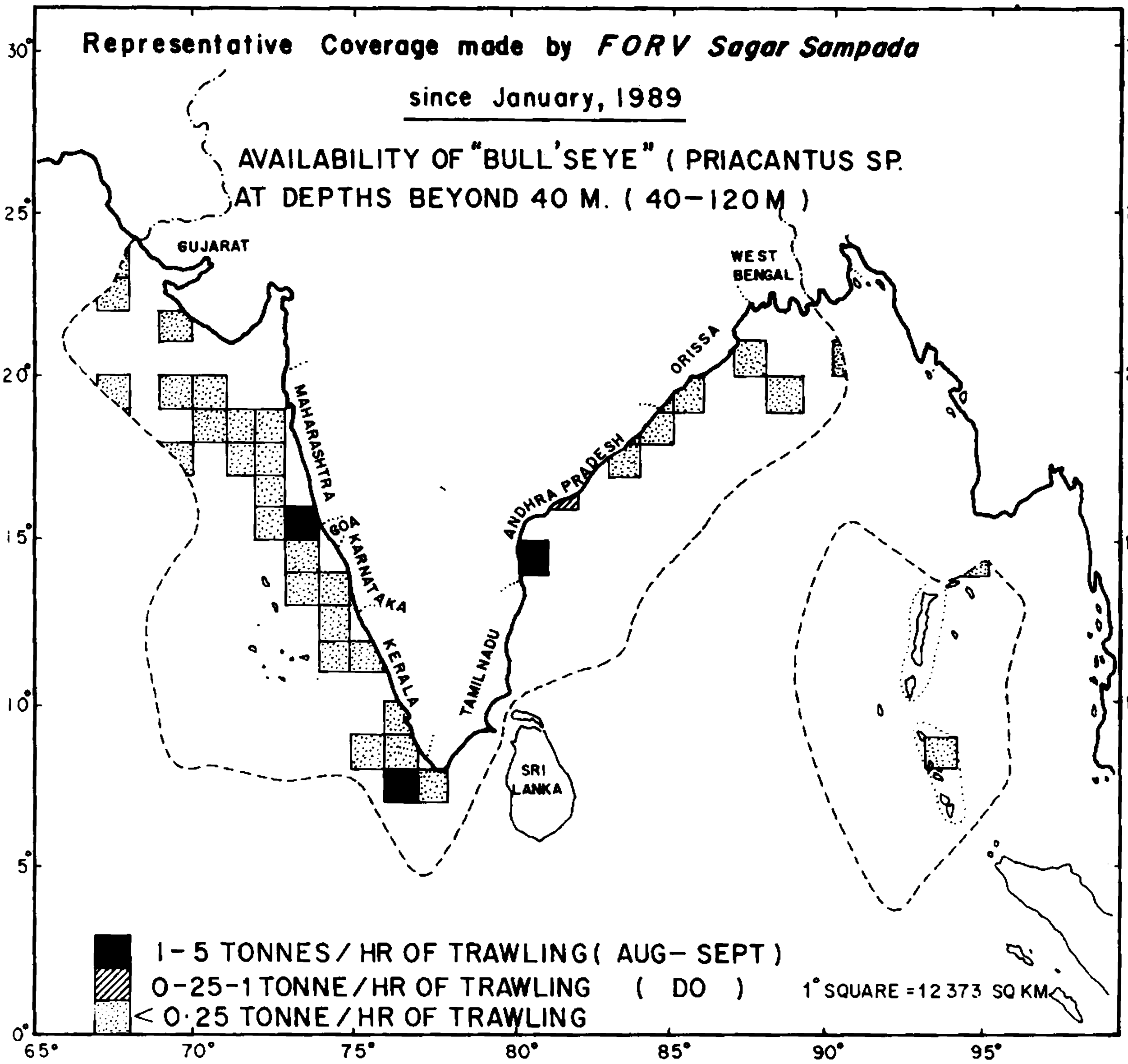


Fig. 3. Availability of Bull's eye (*Priacanthus* sp.) at depths beyond 40 m (40-120 m).

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-

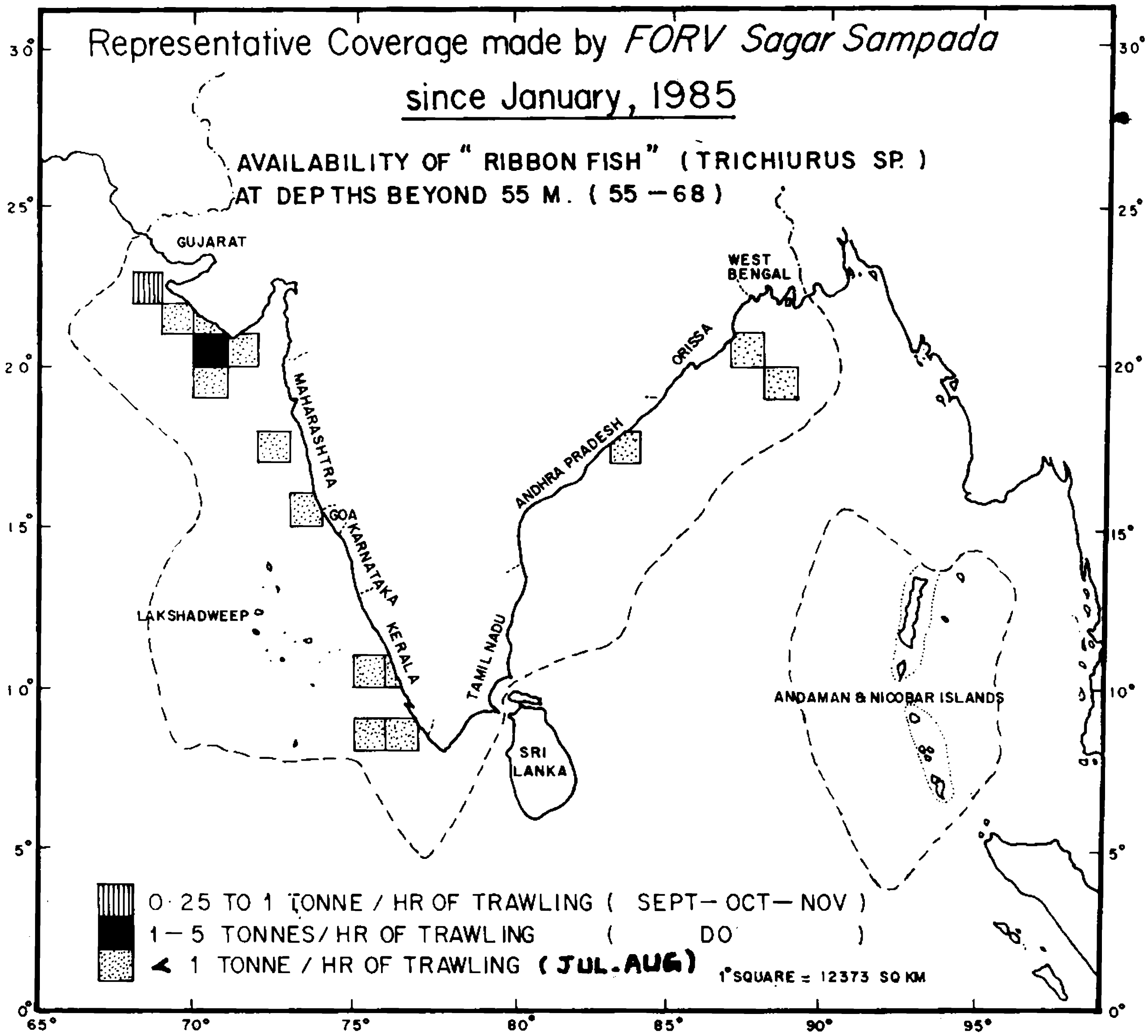


Fig. 4. Availability of Ribbon fish (*Trichiurus* sp.) at depths beyond 55 m (55-68 m).

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).

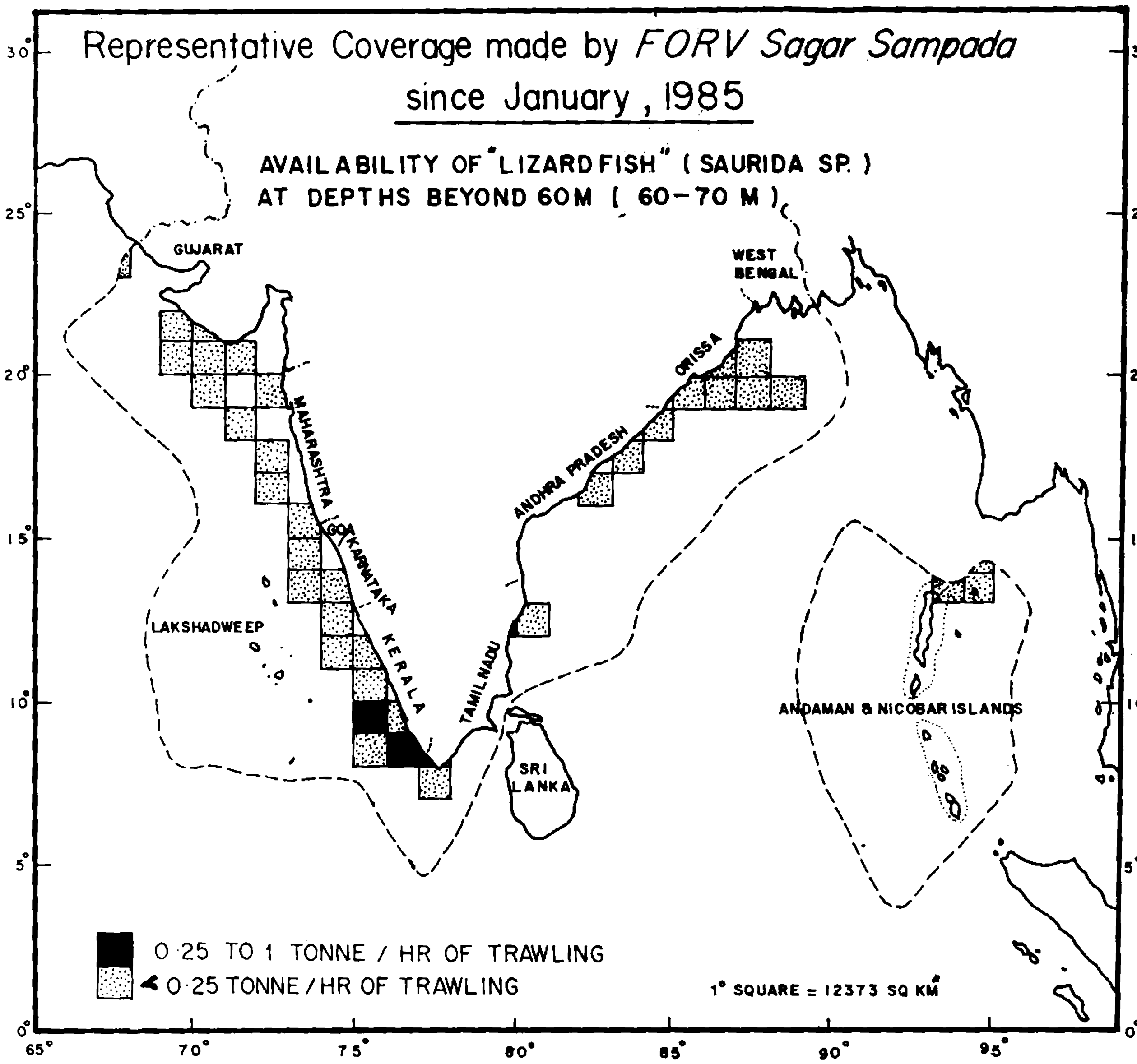


Fig. 5. Availability of Lizard fish (*Saurida* sp.) at depths beyond 60 m (60-70 m).

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).

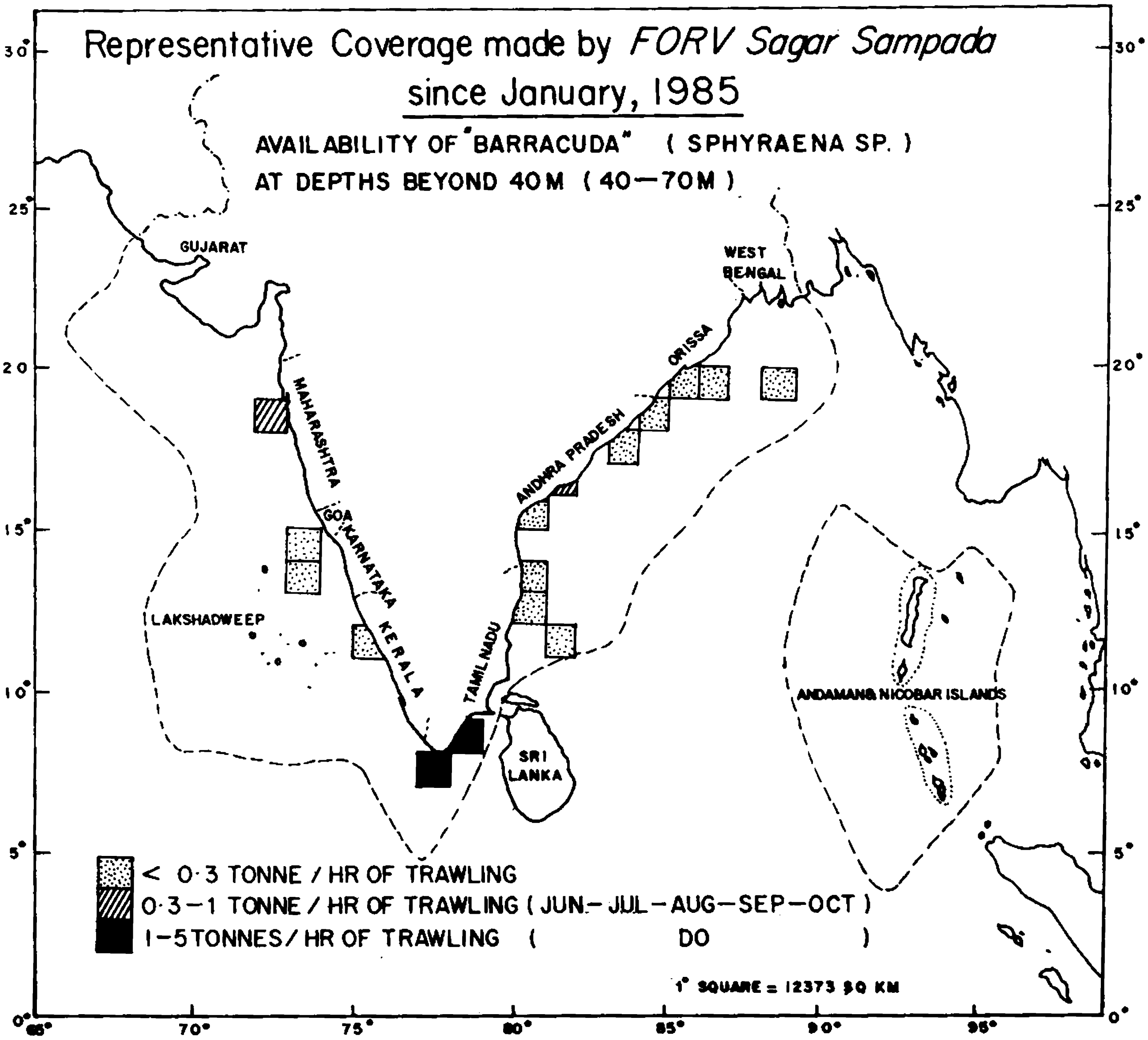


Fig. 6. Availability of Barracuda (*Sphyraena* sp.) at depths beyond 40 m (40-70 m).

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

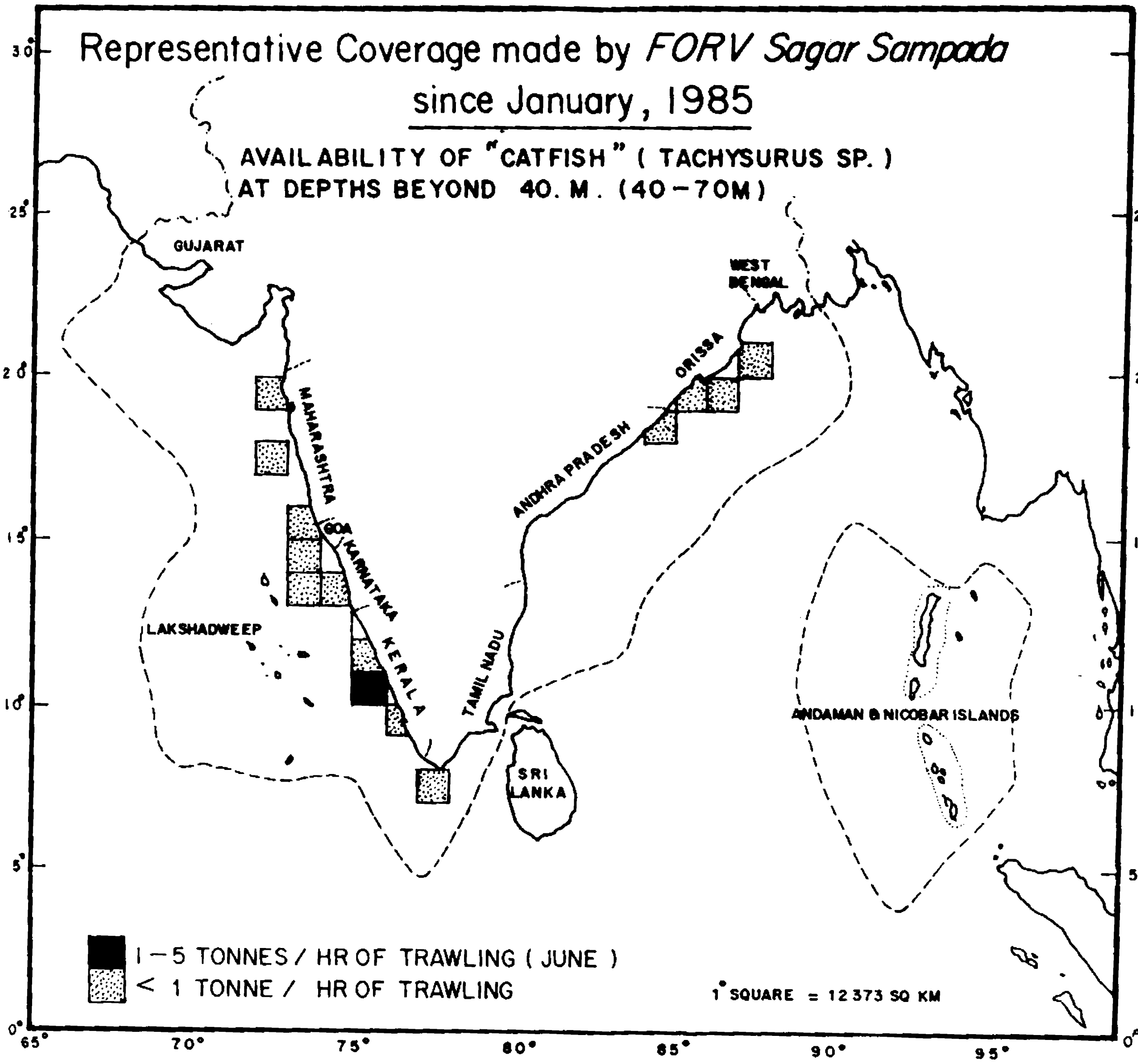
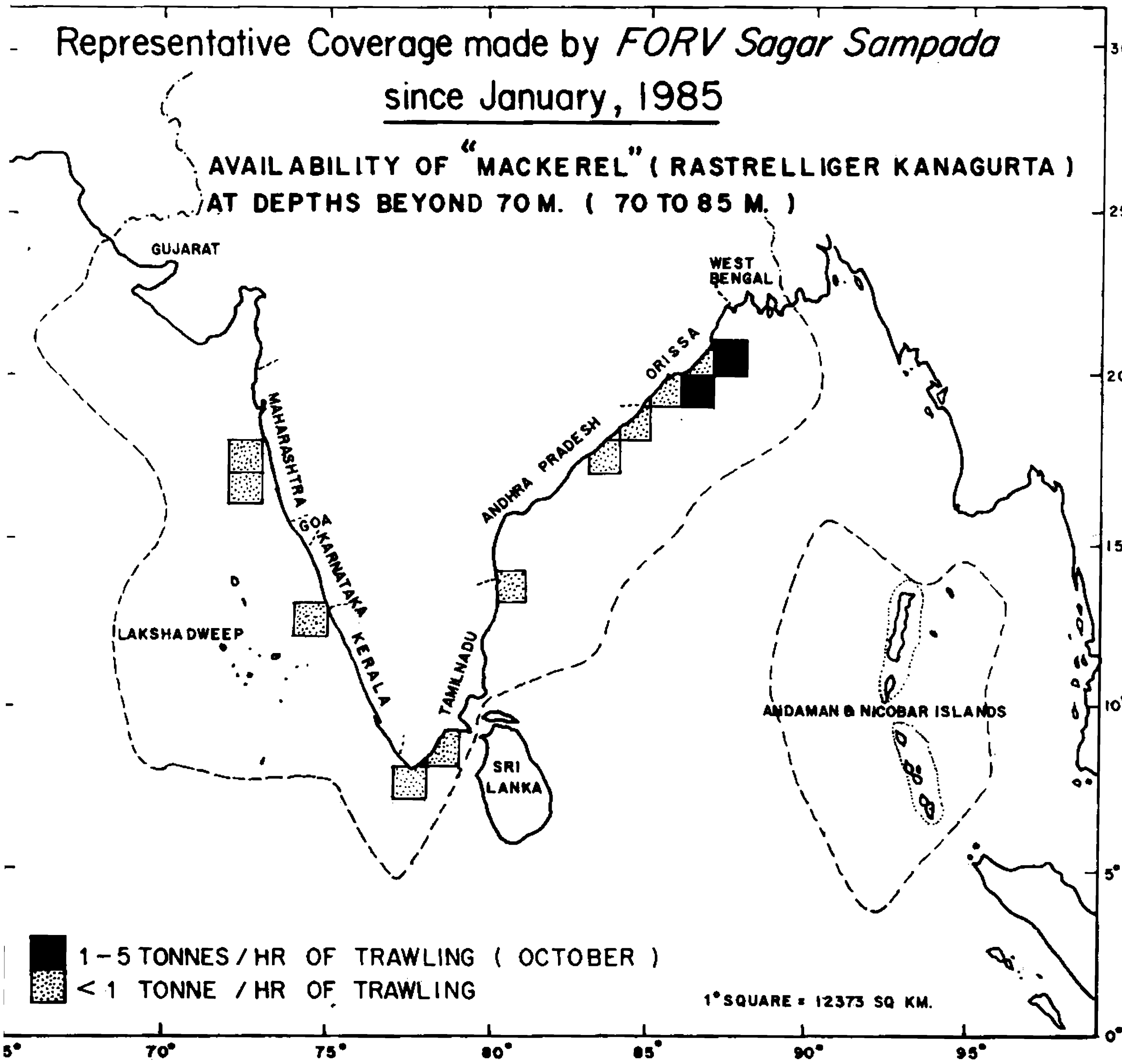


Fig. 7. Availability of Cat fish (*Tachysurus* sp.) at depths beyond 40 m (40-70 m).



;. 8. Availability of Mackerel (*Rastrelliger kanagurta*) at depths beyond 70 m (70-85 m).

ıt. 7° to 13°N) as 8,136 t. Out of this hardly 4 to 5% being exploited at present.

1. *Bull's eye*: Average CPUE obtained was be- /een 800 kg and 4.9 t/hr of trawling. Compara- /ely rich grounds were located in the Wadge Bank ıugust), off Goa (September) and off Andhra 'adesh (September). Maximum CPUE was found a depth of 120 m. The fishing squares where ;hable concentrations of bull's eye were observed :PUE above 250 kg/hr of trawling) are listed below: ig. 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

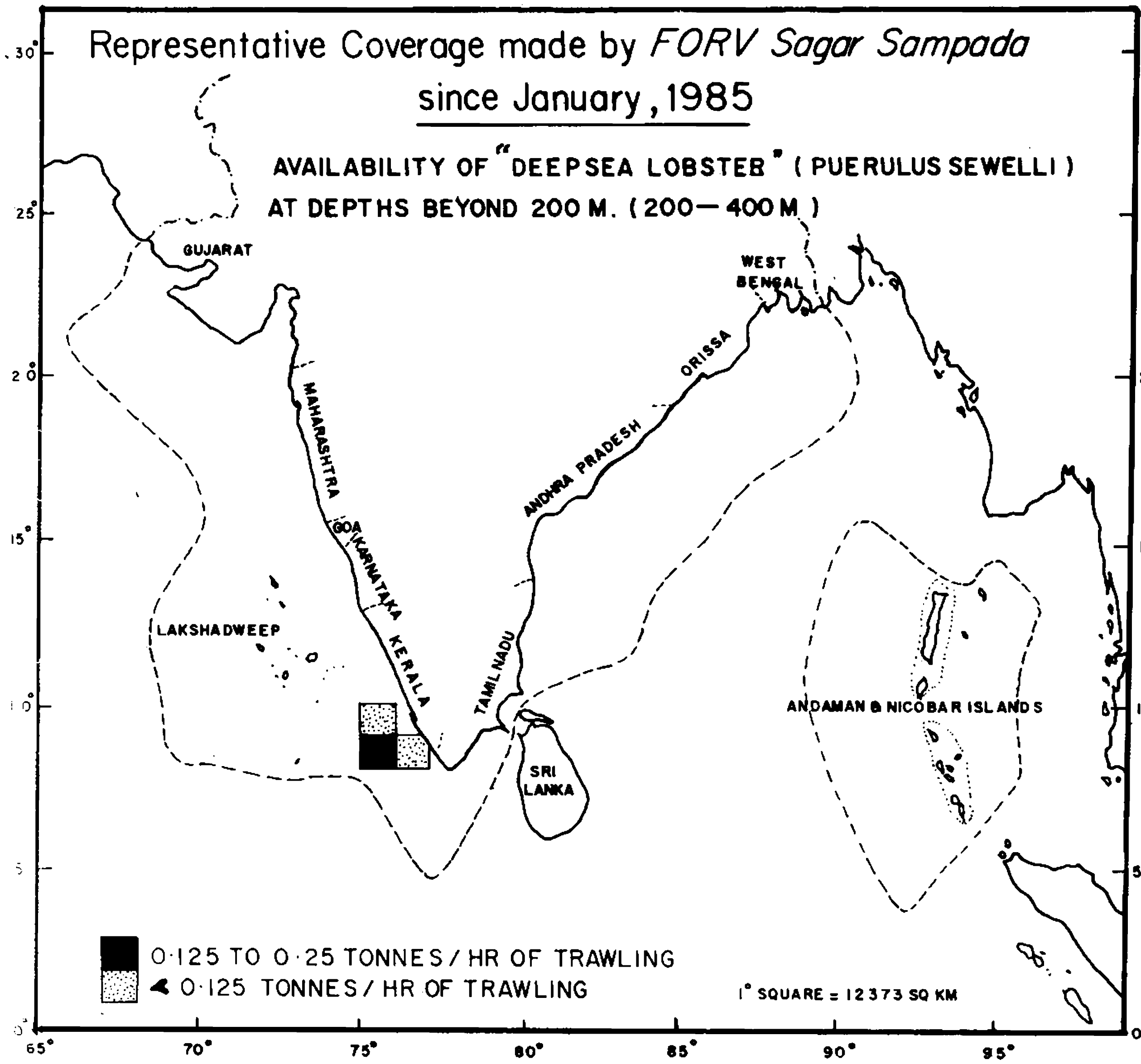


Fig. 9. Availability of deepsea lobster (*Puerulus sewelli*) at depths beyond 200 m (200-400 m).

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:

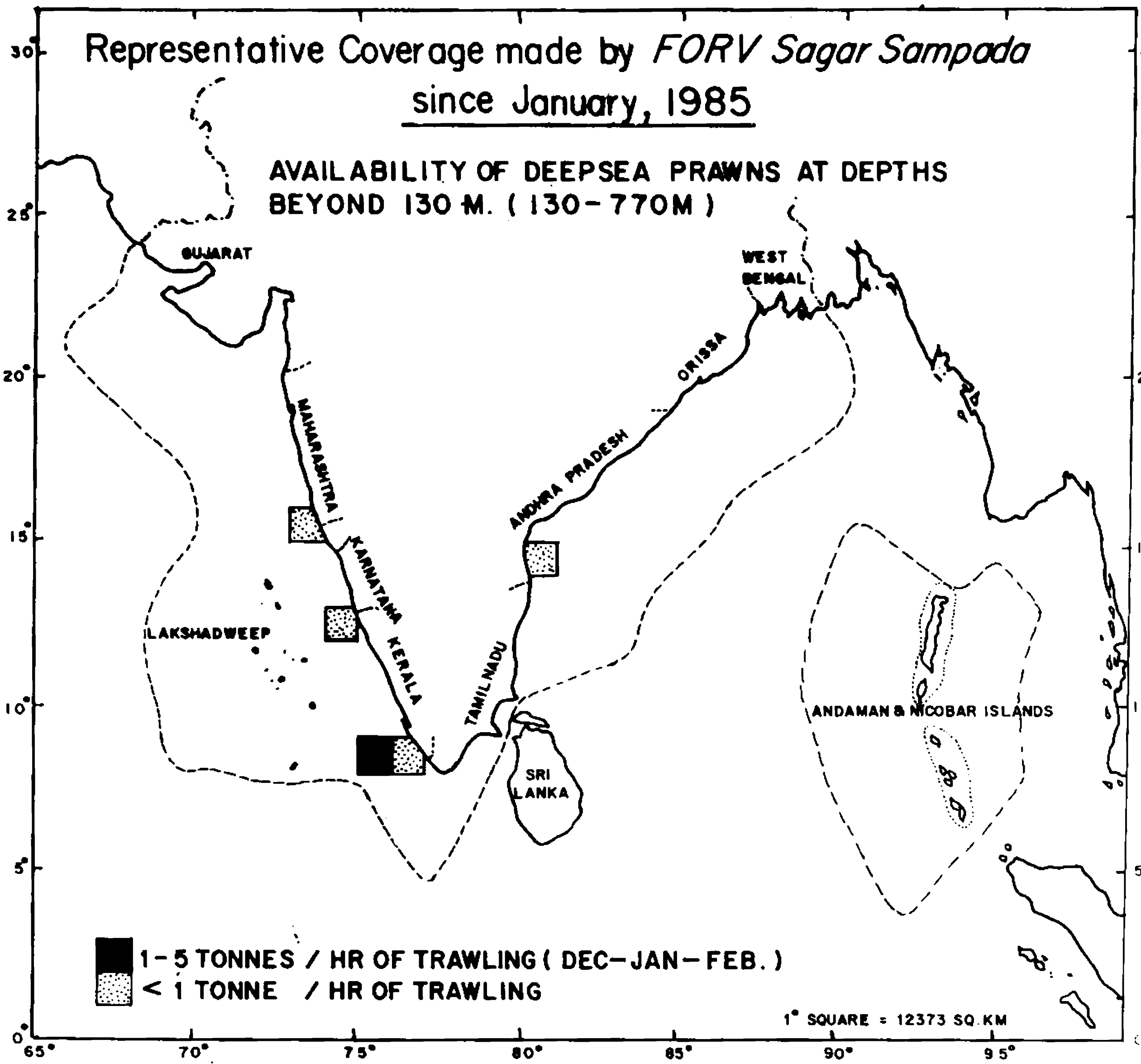


Fig. 10. Availability of deep sea prawns at depths beyond 130 m (130-770 m).

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 ishery 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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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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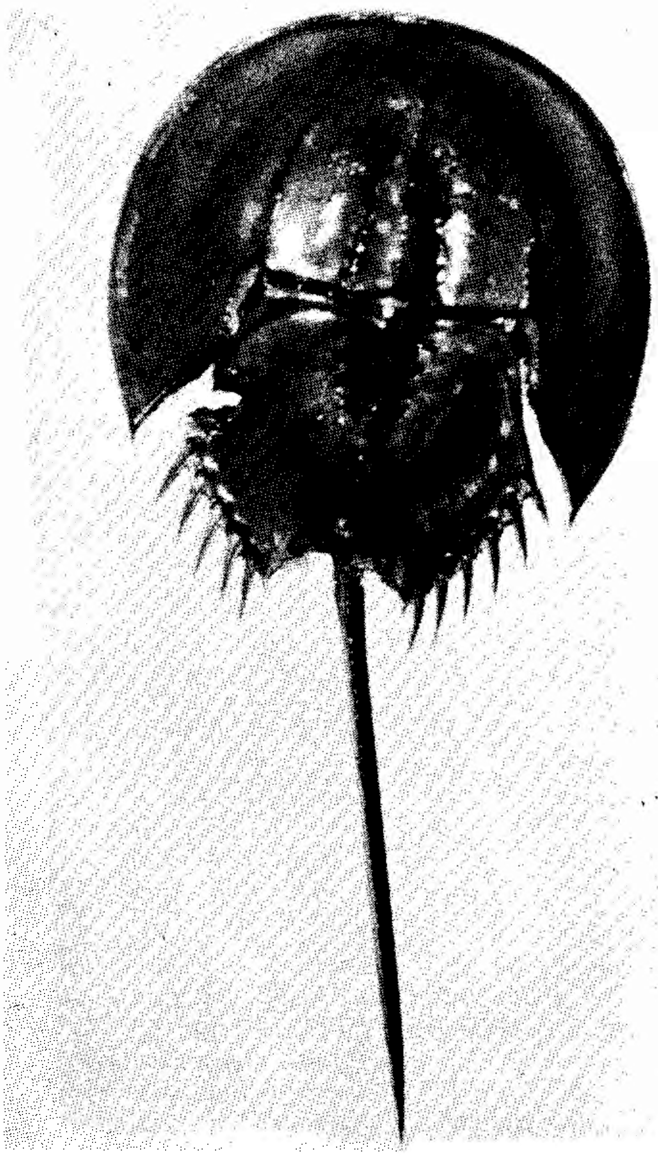

Fig. 1. *Tachypleus gigas* (Muller) - dorsal view.

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) a higher in Station 1206 (5.46 ml/l)and 1207 (5.37 m l). Thus , the animal seems to tolerate wide rang of salinity and oxygen. The water temperature corded at the stations ranged narrowly : 30.5° C 1205 and 1207 and 29.6° C and 29.4°C respectiv at stations 1204 and 1206 . The fish fauna land along with the king crab were : *Rastrelliger nagurta, Ariomma indica, Decapterus russelli, Upene vittatus, Lutianus malabaricus, Nemipterus metopi Priacanthus hamrur, Johnius dussumieri, Saurida dosquamus, Ilisha megaloptera, Trichiurus leptur* skates, rays, *Leiognathus bindus*, and *L . lineolat* The prawns, *Penaeus canaliculatus* and *P. semisul tus* and the weaving mussel *Modiolus* sp. w 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.

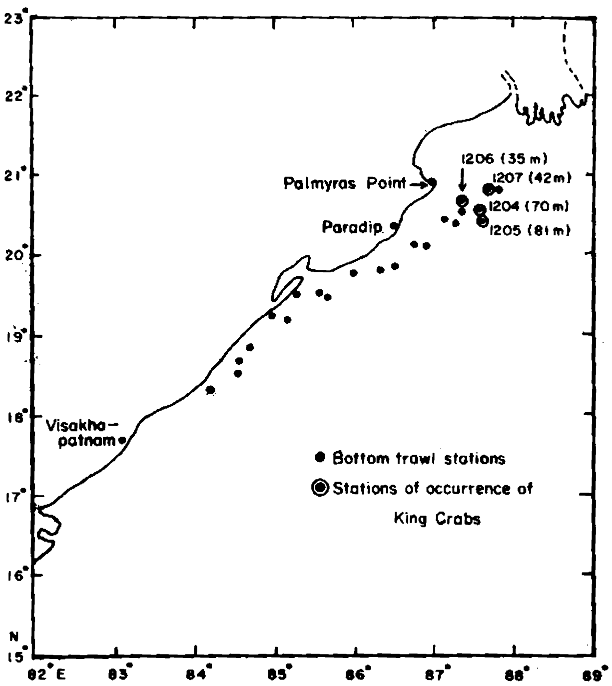

Fig. 3. Map showing the stations where bottom trawl was operated and locations of occurrence of king crab.

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.

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OBSERVATIONS ON THE FISHING POTENTIALITY OF THE SHELF AND SLOPE WATERS ALONG THE S. W. COAST OF INDIA BASED ON THE FISHING RESULTS OF IFP VESSELS

By

V. N. PILLAI * And R. SATHIARAJAN **

1 INTRODUCTION

Availability of resources is perhaps the most important factor which determines the success of any Industry. In the case of fishing industry, the availability of fishable concentration of fishes and other marine life assumes great significance since the success of the fishing operation is entirely dependant on the availability of resources which can be effectively exploited with the fishing equipment carried on board.

1.1. BACKGROUND :

Earlier observations on experimental trawling along the south west coast of India at a depth range of 55-70 m conducted by "Lady Goschen" (Sunderraj 1930) and an account of experimental trawling carried out in Indian waters before the Second World War (Chidambaram 1953) made a beginning of systematic studies along these lines. Results of trawling operations conducted off Cape-Comorin between 70-100 m by the vessels "Kanyakumari" and "Sagarkumari" (Gopinath 1954), "Taiyo Maru" (Srivasta 1952), vessels of the erstwhile Indo-Norwegian Project (Per Sandevan 1955), 'Ashok" and "Pratap" of the erstwhile Deep Sea Fishing Station of Govt. of India showed the existence of productive fishing grounds within the continental shelf area along the south west coast of India. Jayaraman *et al.* (1959), Nagabhushanam (1964), Tholasilingam *et al* (1964), Virabhadra Rao (1968), Perumal *et al* (1972), the relevant Reports of the Central Marine Fisheries Research Institute, Fishery Survey of India, Integrated Fisheries Project, erstwhile FAO/UNDP Pelagic Fishery Project, Central Institute of Fisheries Nautical and Engineering Training, Central Institue of Fisheries Education etc. have thrown light on the total landings and catch rate of important types of fishes, their distribution and abundance in relation to depth and other environmental factors.

1.2. EXPERIMENTAL FISHING OPERATIONS CARRIED OUT BY INP/IFP VESSELS :

The Integrated Fisheries Project; the erstwhile Indo-Norwegian Project came into existence in the year 1953 as an area/community development programme. The project, as early as 1954, initiated experiments in diversified fishing techniques employing newly designed gear. One of the important objectives of the Project was to implement the programme of "increasing the fish production by improving the methods". Towards achieving this very important objective, the Project initiated the programme of mechanisation, introduction of new methods of fishing and also imparting training in diversified fishing techniques.

It is estimated that an area of approximately 21, 31, 318 Sq. km around the Indian subcontinent including the Islands situated in the Arabian Sea and Bay of Bengal lie within the Exclusive Economic Zone. Out of this, about 5, 86, 017 sq. km falls within the south west sub division and another 2, 46, 385 sq. km within the south-east sub division. The total coverage by the vessels attached to the Project since inception is estimated as under.

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	CONTINENTAL SHELF AREA (Approximately within 200m depth)		OCEANIC AREA (beyond 200m depth extending upto the limit of EEZ)	
	Total Area available (sq. km)	Total Area covered by IFP Vessels (sq. km)	Total area available (sq. km)	Total area covered by IFP vessels (sq. km)
South West Sub-division	71,389	64,489 (90.33%)	5,14,628	25,300 (4.9%)
South East Sub-division	54,358	16,100 (18.38%)	1,92,027	9.200 (4.8%)

Between 1952 and 1985 fishing was carried out mostly within the continental shelf between Goa and Cape Comorin on the south west coast and between Cape Comorin and Mandapam along the south east coast. During the above period a total fishing effort of 68,380 Hrs. were expended in an area of approximately 1,15,000 sq. km.

The following is a summary of observations on the results of fishing activity with special reference to the fishing techniques adopted. The details regarding the type of craft and gear employed for conducting the fishing operations are also given.

2. DATA AND METHODS :

The details regarding the fishing vessels operated by the Project are given in Table-I. Broad specifications of Fishing Gear and accessories designed, operated and found successful by the Project are listed in Table II.

The fishing and allied data pertaining to this study were collected by the Project vessels and presented in standard fishing data sheets, the format of which was updated from time to time to meet any additional requirement. The Skippers in charge of individual vessels were entrusted with the responsibility of maintaining the data sheets on board which in turn was submitted to the shore officer on completion of each cruise. The fishing programme drawn out by the shore officer was implemented in the presence of scientific staff who remained on board during each cruise. Since early sixties the Project started using Fishing Square charts. On the admirality chart each 1° square was sub-divided into 36 equal divisions each smaller square covering an area of 100 sq. nautical miles or 256 sq. km. Each 10' square was also serially numbered both alphabetically (from A to F) and numerically (1-6) on the x and y axis respectively to identify each of the smaller squares,

In general, fishing operations commenced at 0530 hrs. and were continued till sunset except in operations, where a particular operation required fishing during night time. The duration of fishing (during each haul/set) was decided by the Skipper in consultation with the Scientific Staff present on board. Supporting meteorological / oceanographic data were gathered simultaneously on board larger vessels like "Samudradevi", "Varuna" etc. An on the spot comparision of echograms with the fish catch was made and recorded separately, for attempting possible quantitative / qualitative correlations.

3. DISCUSSIONS:

The results are presented fishing technique wise; since evolving new fishing techniques, experimenting, improving the design and dissemination of results of successful fishing gear to the end users formed one of the major objectives of the Project. Moreover it would also enable the end users to know how best the technology developed and proved by the Project has been accepted by the Industry, in stages over the past 3 decades.

3.1. SHALLOW WATER TRAWLING:

All the vessels operated by the Project since inception were engaged in shallow water trawling operations at one time or other.

Trawling was conducted in 103 fishing squares covering an area of approximately 26,000 sq. km located within the continental shelf (up to 200m depth.)

3.1.1. Catch per unit effort :

Out of a total of 103 fishing squares covered by Project vessels (located within a depth range of 20 to 200m) *3* squares viz. 12-74/5E, 12-74/4E and 7-77/4B yielded average fish catches of 500 kg and above per hour of trawling, the maximum being 750 kg/hr. in fishing square 12-74/4E. *3* fishing squares viz. 12-74/2F, 10-75/1F & 9-76/1A yielded average catch per unit effort of 400-500 kg. *6* fishing squares 11-75/5B, 11-75/6A, 9-76/6B, 9-76/3A, 8-76/4C and 9-74/3B yielded values between 300-400 kg./hr. *25* fishing squares 14-73/6F, 5F, 12-74/1F, 11-75/5C, 10 75/5F, 3F, 5E, 3E, 10-76/1B, 2A 9-76/5B, 4B, 5A, 4A, 8-76/2F, 4E, 3E, 6D, 7-77/6F, 3C, 6A, 5A, 9-79/4B. 2B and 3A yielded values between 200-300 kg/hr. 49 squares yielded between 100-200 kg/hr. and the balance *17* squares yielded an average catch/hr. of less than 100 kg.

Maximum effort was expended in the fishing square 9-76/5A located off Cochin (approximately 6500 hrs). The total fishing effort expended in all the 103 fishing squares for shallow water trawling alone works out to about 48000 hrs.

3.1.2. Catch composition:

The dominant varieties of fishes represented in the shallow water trawl catches were Horse mackerel (*Megalapsis cordyla* and *Decapterus Spp*). Silver bellies (*Leiognathus bindus, L. splendens*), Cat fish (*Arius thalassinus, A. dussumieri*), *Lizard* fish, (*Saurida tumbil*), Ribbon fish (*Trichiurus haumela, T. savala*), Threadfin bream (*Nemipterus japonicus*), Perches (*Epinephelidae*, Lutianidae, Lethrinidae etc). Elasmobranchs (sharks, rays, skates etc.) (*Scoliodon* spp, *Carcharinus* spp., *Rynchobatus* spp., *Rhinobatus* spp.), Balistids (*Odonus niger, Sufflamen capistratus*), oceanic crabs (*Charybdis edwardsi*), Flying gurnards (*Dactyloptena orientalis*) etc.

Less dominant varieties of quality and miscellaneous fishes were pomfrets (*Pampus* spp), Carangids (*Caranx* spp), Barracuda, white fish (Lactarius spp), Sciaenids, Seerfish (Cybium spp) etc. Prawns (*Penaeus indicus, Metapenaeus affinis, Parapenaeopsis stylifera, Metapenaeus dobsoni*) were caught mainly from shallow water fishing grounds between 10-40 m depth ranges by the smaller vessels of the Project.

In recent years (since 1982) *Priacanthus* spp. started appearing in the shallower areas of the continental shelf especially in the depth range of 35 to 75 m.

During the period 1954-59, the Project employed small mechanised vessels of 10.97 m OAL to exploit the shrimp resources in the shallower areas of the continental shelf between Goa and Cape Comorin on the south west coast and upto Mandapam on the south east coast. Shrimp trawls with comparatively higher horizontal opening were specially designed and deployed for the purpose. As a result, productive shrimp grounds were identified off Karwar (9-33 m), Mangalore (16-29 m), Cannanore (9-25m), Cochin (9-37m), and between Alleppey and Quilon (9-37 m).

During late sixties and the earlier part of seventies upto 1975, the dominant varieties in the fish catches were cat fish (15%), Threadfin bream (7%), Elasmobranchs (13%), Lizard fish (3%) and Ribbon fish (1%). It was generally observed that during the period 1965-75 either cat fish or kilimeen dominated the catches. An overall analysis of the fish catches for the period under review showed that approximately 50% of the total catch was formed of miscellaneous fishes which were not of much economic value.

During late seventies horse mackerel and silver bellies formed dominant varieties in the fish catches from the depth zone 30-50 m. Catches from the shallower areas predominantly consisted of Scads. During September 1978 one of the bottom trawl operations from 47 m depth south west of Cochin yielded 1750 kg of horse mackerel/hr. They were found in significant quantities from July to September in the Southern grounds and from November to January in the northern grounds.

Silver bellies were dominating in depth ranges of 30-40 m mainly between 9° and 10°N lat. and also between 11° 30' and 13°N (20-35m) and around 15°N lat. (20-25m). During January (1977) 700kg/hr. was obtained from 20 m depth off Karwar.

Cat fishes were found to dominate depth ranges of 30-60 m, mainly north of 9°N lat. Large concentrations of the fish were observed during November-April between 9° and 11°N lat. Very dense concentrations were observed during May July in 9°N lat. area. During the south west monsoon period (July-Oct.) cat fish is found to be shoaling in the mid -water column, thereby showing poor results in bottm trawling.

Ribbon fishes were found dominant in the catches in the gulf of Mannar in July from 25-40 m depth ranges. Concentration of the fish was seen within 13° and 15°N lat. during May-June at 25-30 m depth range. During October-January, the distribution of the fish was widespread mainly between 13° and 15°N lat. at 25-40 m depth ranges.

Threadfin bream is known to occur in wide depth ranges from 20m to 100m. They form the dominant variety in the catches during August-October mainly between Quilon and Goa.

Trawlable perch grounds are mainly located in the Wadge Bank, South of Cape Comorin, known to be one of the best grounds for perches. Perches being inhabitants of rocky bottom are generally found throughout the year. The catches from the large vessels of the Project showed good returns in January-February (upto 560 kg/hr) in the depth range 20-55 m. On the Wadge Bank out side 50m depth contour maximum catches of 200 kg/hr. were obtained in June. Most of the trawlable perch grounds lie between 20m and 80m depth contour. South west of Karwar (14° 40'N. lat.), during September catch rates upto 170 kg/hr. have been obtained from a depth of 75 m. Bobbin trawling for perches was undertaken by the Project Vessel "Velameen" during 1970 using a 316 mesh fish trawl with steel bobbins in the fishing squares 10-75/3E, 4D, 5C, 4C, 6B and 5B. A total fishing effort of 32 hrs. yielded catches between 195 and 732kg/hr. in the depth range of 80 to 200m.

Good catches of Elasmobranchs have been recorded by Project vessels during December-June period, the peak season being January and February. The shelf area south of 10°N lat. particularly between 9° and 10°N. lat. was found productive, also the areas between 12°N and 13°N lat. between depth ranges of 20-50 m. Leave alone rare catches of individual large sized sharks, Rays and Skates in the trawl catches, the average catch/hr. for the fish remained at 50 kg with maximum catches of 560 kg/hr. during January south west of Quilon between 40-45 m depth.

3.2. DEEP SEA TRAWLING FOR LOBSTER:

Deep Sea Lobster *Puerulus sewelli* was recorded in about 46 fishing squares, mostly lying between 180 and 270m depth range. The highest catch per unit effort of 327 kg/hr. was obtained from the sub square 8-79/5D located off Mandapam in the depth range 200-270 m. Values above 150 kg/hr. were obtained from the sub squares 8-75/6F, 5F, 8-76/6A, 8-79/6B and 9-79/1B. Maximum catch/unit effort was obtained during the months February-June. Pandalid and penaeid prawns were also caught along with Deep Sea Lobster in the above mentioned area. A comparative study of the catch/hr. of trawling for deep sea lobster at the different grounds shows a decreasing trend towards north and south of Quilon. This is in conformity with the earlier findings of Joseph (1972), Pillai (1972) and also for the grounds located on the south east coast (Sathiarajan 1974).

In general and particularly in the grounds located off Quilon (squares 8-75 and 8-76), the catch was predominantly constituted of *Puerulus sewelli* (50 to 97%) with a small percentage of deep sea prawns and fishes such as *Emmelichthys* spp., *Chlorophthalmus* spp., *Centropristis* spp., *Cubiceps* spp. *Epinula* spp. and *Bemprops* spp.

The catch/hr. recorded by the Soviet Research Vessel "Academic Knipovich" for deep sea lobster in the southern part of the slope along the south west Indian shelf at depths of 200-320 m was 100 kg. It is quite evident from the present study that the catch/hr. of trawling for deep sea lobster for the project vessels was comparable with the above results In specific locations the catch rate was comparatively high during the February-April period

3.3. SINGLE BOAT PELAGIC TRAWLING:

The Project commenced single boat pelagic trawling as early as 1973 using the vessels, *"Varuna", 'Klaus Sunnana" "Velemeen", "Tuna"* and *"Norind-2"* mainly in the area between 8°30'N lat. and 10°30'N lat. with a few cruises covering northwards upto Karwar, employing the vessel *Sardinella*. A total of about 1200 fishing hours were expended in about 25 fishing squares. The catch per unit effort showed wide variations with a maximum of 200 kg/hr. Silver bellies, Golden scad, lesser Sardines and horse mackerel dominated the catches in the northern latitudes. During May-August Catches above 500 kg/hr. predominantly of white baits have been made east of Cape Comorin at 25-30 m depth, white bait (*Anchoviella*) spp. at the rate of 100-500kg/hr. have also been recorded south of Goa, Karwar, Coondapur, Mangalore, Kasaragod, Cannanore and also east of Cape Comorin at 27-35 m depth during May-August. Operations on the south west coast in the shallow areas (20m) yielded mostly shallow water mixture composed of silver bellies, golden scad etc., while those in deeper waters (30m) north of 13°N Lat. yielded cat fish and Ribbon fish with small quantities of white bait. On a few occasions good catches of Balistids (300 kg/hr.) were obtained from the fishing square 7-77/4D at 39m depth during September - December. Off Goa, Mangalore and between Cochin and Quilon in deeper waters (28-60 m) Ribbon Fish was common in October. In shallow areas (10-30 m) Silver-bellies, white baits and small sized Carangids were common. It is found that the period May-August is most suitable for single boat pelagic trawling which yield comparatively high catches of white bait. Catch rate of more than 500 kg/hr. consisting of oil sardine and mackerel has been recorded off Cochin from 20 m depth.

Flying gurnards were recorded in the fishing squares 9-76/3A and 8-76/4C in significant quantities in September.

3.4. PAIR TRAWLING :

In mid water trawling operations, the vertical and horizontal mouth opening of the trawl net is an important decisive factor. In this respect the pair trawlers have a big advantage over singele boat trawlers. In pair trawling since no otter boards are used, the towing power of the boat is abosorbed by the warps and netting only. The Project vessels M-11, M-12, M-13 & M-14 (all 9.75m OAL) took up pair trawling operations as early as 1973. During 1979-80 two larger identical vessels "Velameen" & "Tuna" (23.8m OAL) also joined the experiments. A total fishingeffort of more than 2000 hrs were expended on experiments conducted with 9.75 m OAL vessels. On an average the catch per unit effort varied between 66kg and 85 kg/hr. in the fishing squares 9-76 and 10-76. Experiments with 23 8 m OAL vessels in the area 9-76 yielded 490 kg/hr. for pair bottom trawling.

3.5. PURSE SEINING :

The Project initiated Purse seining experiments as early as 1954. Project vessels M2, M3, Kalava-2, Norind-2, Tuna and Samudradevi (9.75m OAL to 28m OAL size) were deployed for conducting purse seining mainly for the exploitation of Pelagic shoaling fishes like Oil Sardine, Mackerel, Tuna and Anchovies. A total of 36 fishing squares were covered by the above mentioned vessels employing Purse seine gear designed and fabricated by the Project. A total fishing effort of about 5000 hrs. have been expended for perfecting the methodology and demonstrating the same for the benefit of end users. The average catch/set showed wide variations, the maximum recorded being 5832 kg/set. (11-75/4D), 4344 kg/set (11-75/3C) 2450 kg/set (10-75/5F), 1408 kg/set (9-75/6F) (9-76/5B) and (9-76/3A). The catches were predominantly of a single variety of fish eithet oil sardine, Mackerel, Anchovy or small Tuna.

Purse seining with light attraction was also tried from the Project vessels Norind-2 and M-13 during the period 1974-75 expending a total fishing effort of about 36 hrs. The highest catch/hr. recorded was 332 kg. It was noticed that better results were obtained on dark nights and also during peak tides.

3.6. HAND LINING AND TRAPPING FOR ROCK CODS :

A systematic survey of the Perch fishing grounds was taken up by the Project during 1956. Due to the uneven nature of the sea bottom and occurrence of Rocky patches trawling is not possible in the narrow belt of the shelf where rock cods thrive. The fishing gear employed for hand lining is very simple and inexpensive. The hand line equipment consists of a main line having 5-7 branch lines with hooks. The efficiency of hand lining depends on the ability of the vessel to remain stationary just above the ground without much drifting for a considerable period. Hand lines were operated on board *Kalava* (1956-66) *Varuna* (1968, 1976-84) *Tuna* (1976) and *Kalava-2* (1975-76). When the wind and surface currents gather strength, hand lining will become very difficult. To over come this difficulty, the Project developed Traps for catching rock cods. Rock cods have a natural tendency to remain in crevices on the rocky ground. Once they are out they tend to move in small shoals. This behaviour pattern makes them more amenable for trapping. The collapsible nature of the trapes also makes it convenient to carry more of them even in small vessels of 13.5m OAL. Traps were operated on board the vessel *Kalava-2* (1975-76), *Tuna* (1976) and *Varuna* (1976-84).

Trapping and Hand lining were tried at a total of 34 fishing sub squares. Catch per unit effort of more than 100kg/hr. was obtained from a total of 9 sub squares *viz.* 8-76/6A, 9-75/1F, 2F, 10 75/4C, 11-75/1A, 1B, 11-74/2F, 5E and 6E in the depth range of 80-100m with a maximum of 269kg/hr. from the sub square 11-74/5E located off Mahe, during the months February-May.

3.7. SQUID JIGGING :

Hand lining for squid was tried during 1974-75 on trial basis with the help of simple pole and line gear consisting of a jig, line and pole. During 1978-79 squid jigging with two automatic jigging machines with 25-30 jiggs each was tried onboard the vessel *Varnua*. 4 Nos. of 1000 w. lamps with shades were arranged in a single row along side the bulwark over the deck, side by side with the jigging machines.

Squid jigging operations which were mainly concentrated on the continental shelf between Cochin and Trivandrum yielded 3-6 Nos. of squids per hour of fishing.

4. CONCLUSIONS

Over a period of 3 decades (1954-1985) the Project conducted experimental fishing operations employing diversified fishing techniques with a view to find out the fishing potential in these waters areawise / seasonwise/specieswise. The results were disseminated to the end users from time to time. Experiments on those of the fishing techniques which were accepted by the fishing industry were discontinued and the effort was diverted on new resources which were hitherto not exploited on a commercial scale.

Mechanised trawl fishing for prawn resources in the shallwoer areas of the shelf was discontinued by the Project during the early sixties consequent on the acceptance of this fishing technique by the Industry during the early sixties. Similar is the case with bottom trawling operations for deep sea lobster, Bobbin trawling operation in the wadge bank, Pelagic trawl operations for the commercial exploitation of *Anchoviella* spp., Purse seining for oil sardine, mackerel and *Anchoviella*, Trap fishing and Hand lining for Rock cods etc.

The results, in general, could be summarised as follows:

Productive shrimp grounds were identified off Karwar (9-33m), Mangalore (16-26m) Cannanore (9-25m) Cochin (9-37m) and between Alleppey and Quilon (9-37m) The shallow water mixture consisting of silver bellies, golden scad, glass perches etc. is a common constituent of shallow water trawl catches in the area between Quilon and Karwar. During the south west monsoon period (June-September) Cat fish, Ribbon fish and Lizard fish occured in large quantities. Off Tuticorin in the Gulf of Mannar, bottom trawl operations yielded silver bellies, balistids and perches. During January-April trawling in the Wadge Bank yielded perches (40-50m) North of lat. 9°N Cat fish and thread fish bream were well represented in the catches, especially in the depth range 20-50m.

During September – December period, the important varieties in the shallow water catches would be perches, balistids and porchpine fishes (wadge Bank area 40-45m) Cat fish, Ribbon fish and Thread fin Bream (between 9° and 16° lat. N) (30–40m depth range). Lizard fish, *Saurida* spp. Flat head (*Platycephalus* spp.) goat fishes (Mullidae), Bull's eye (*Priacanthus*) spp. are normally caught in deeper water 70-80m. But during the past 3 years or so *Priacanthus* spp. is available in large shoals in comparatively shallower water (35-75m) especially during the post monsoon period (September–October).

Approximately 1-5% of the catches is composed of less dominant varieties of quality fishes like pomfrets, carangids, Barracuda, white fish, sciaenids, seer fish etc. There were a few instances, where large shoals of (8-to 10 tonnes) consisting predominantly of pomfrets were caught mainly between Quilon and Mangalore in Depth of 30 to 70m. Pomfrets form one of the major constituents in the catches during the post monsoon period (September - December) between Quilon and Mangalore.

Elasmobranchs were dominant in the catches during December–June period between 20 and 50m depth range. This is especially so in the area between 9°N and 13°N lat.

Out of a total of 103 fishing sub squares covered by Project vessels expending a total fishing effort of 48,000 hrs, 86 sub squares yielded and average catch of more than 100kg/hr.

For deep sea trawling for Lobster, highest catch rates were obtained during the months February-June from grounds located off Quilon and off Mandapam between 180 and 270m depth range. The average catch rate for Deep Sea Lobster (single species *viz. Puerulus sewelli*) varied between 150 and 327kg. Deep sea prawns were also caught along with Deep sea lobster at the above grounds.

For pelagic trawling, encouraging results were obtained during the monsoon and post monsoon period (May–September) with the average catch reaching values of 150-200kg/hr Silver bellies golden scad, lesser sardines and horse mackerel dominated the catches in the northern latitudes (above 10°N lat.) During May–August catches above 500kg/hr. have been made east of Cape Comorin at 25-30m depth consisting predominantly of white bait.

White bait at the rate of 100-500kg per hour has also been recorded south of Goa, Karwar, Coondapur, Mangalore, Kasargod and Cannanore during May-August (27-35m).

Operations in the shallower areas (20m) yielded mostly shallow water mix composed of silver bellies, golden scad etc. While those in deeper water (30m) north of 13° N lat. yielded cat fish and Ribbon fish with small quantities of white bait. Off Goa, Mangalore and between Cochin and Quilon in deeper water (28-60m) Ribbon fish was common during October.

Purse-seining was introduced by the Project for the first time in this region. By expending a total fishing effort of nearly 5000 hrs. the Project could perfect the technology and demonstrate the same for the benefit of the private industry as an efficient fishing methodology for catching of oil sardine, mackerel, anchovy and tuna. The industry accepted this methodolgy and introduced a sizeable number of purse-seiners to exploit the pelagic resources during the seventies. Consequent on the implementation of Marine Fishing Regulation Act by the Govt. of Kerala, the Project continued the experiments in deeper waters, exploring the possibility of deep water purse seinieg for the same pelagic shoaling fishes. Even though the results are encouraging, more work is required to draw conclusions.

Hand lining and trapping for Rock cods got acceptance as an ideal fishing techniqe for the commercial exploitation of rock cods in the rocky patches of the continental shelf mainly between Alleppey and Ponnani, where no other fishing method can be employed. The fishing gear employed is very simple and inexpensive. Perhaps the only additional requirement onboard would be an echo sounder of suitable range to locate the fishing ground and to retain the vessel above the ground for a certain duration of time. Catch rate above 100kg/hr was obtained from 9 sub squares in the depth range 80-100m with a maximum of 269kg/hr. from the sub-squares 11 74/5E located off Mahe during the period February May.

Preliminary investigations on squid jigging conducted by the Project in the area between Cochin and Trivandrum revealed the presence of squid resources in this region. More intensive work is planned to be carried out during the VII Plan period for proving the commercial viability of squid jigging operation in these waters.

Among the major varieties of commercially important fishes caught from this area, cat fish and ribbon fish exhibit the widest distribution. They were mainly caught between 30m and 80m all along the south west coast, practically throughout the year with the exception of post monsoon period (September-October) when these fishes migrated to inshore waters.

For horse mackerel, the main concentration was found in the southern waters near Cape Comorin, close to the shore between 50m and 80m and towards north they were caught mostly in deeper water beyond 90m In general horse mackerel was found concentrated in shoals during day time. They disperse during the night and can be effectively caught with the help of midwater trawls.

The "shallow water mix", the group of fishes which are normally found within the 20m depth zone is composed of lesser sardines, rainbow sardine, silver bellies, golden scad, butter fish, glass perch and quite often the younger ones of cat fish and ribbon fish. During the day they form small shoals close to the bottom and at night they disperse in the entire water column. They are found all along the coast in shallow water. During the period July-October in areas where upwelling is pronounced, they form surface shoals which can be effectively caught with the help of mid-water trawls.

Other commercially important fishes caught in this area, usually found in deeper waters, but rarely in large shoals are pomfrets, seer fish, travelly, barracuda, anchovy, small sharks, rays and squids. In deeper waters, beyond 50m depth the commonest forms which are available in dense concentration are thread fin bream and lizard fish. They are found through out the year in a wide area on the middle and outer shelf but there is a tendency for southward migration during south-west monsoon period.

Demersal fishes of good commercial quality found in the area are perches, snappers, pig head breams etc., which are caught in bottom trawls on the Wadge Bank, Quilon Bank, Pedro Bank and also on the narrow rocky patches found at depths of 70-120m between Cochin and Ponnani.

Since the availability of "fishable concentration" form the basis of commercially oriented fishing operations, a systematic monitoring of the availability of different types of commercially important fishes, their distribution and movement from place to place in time and space assume great significance. Experiments on evolving suitable fishing gear to exploit a particular fishery should also continue side by side with reference to the size and type of vessel to be employed for economic operation. The catchability expresed by the term catch per unit effort should form the basic criterion in commercial fishing operations. Care should be taken to choose the right type and size of the vessel, optimum size to be decided, since the economics of operation depends to a large extent on the size of the vessel employed for the operation. Adoption of diversified fishing techniques will help the operator to catch a particular variety of fish which is available within the fishing capability of the vessel in different depth ranges/distances from the coast, It will also ensure a steady supply of commercially important varieties of fishes in sizeable proportions so as to make commercial operations economically viable.

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Table-1 * Details of fishing vessels of the Project

Sl. No.	Vessel	OAL (m)	B. H. P.	G. R. T.	Type of fishing performed
1.	Varuna	28.00	400	160.34	Trapping and Hand lining, squid jigging, Long Lining
2.	Samudradevi	27.31	750	193.86	Trawling and Purse-seining
3.	Velameen	23.85	480	117.21	Trawling
4.	Tuna	23.80	480	115.62	Trawling, Trapping, Purse seining
5.	Klaus Sunnana	19.81	220	61.28	Trawling
6	Norind-2	17.50	233	47.25	Trawling, Purse seining,
7.	Kalava-2	13.17	72.5	19 27	Trawling, Purse seining, Trapping and Hand lining
8.	M - 3	10.97	48	12.00	Purse seining
9.	M - 12	9.75	48	7.00	Trawling

* Selected number of vessels which were utilised for diversified fishing alone are included in this list.

Table 2 List of important Fishing gear designed, operated and found successful on board Project Vessels :

1. BOTTOM FISH TRAWLS:

700 mesh, 650 mesh, 600 mesh, 500 mesh, 450 mesh, 400 mesh, 360 mesh and 316 mesh.

(For details please refer to IFP Bulletin No. 8, January, 1984)

2. MID WATER FISH TRAWLS ;

SINGLE BOAT : 25.8 m, 31.0 m (Diamond Type)
33.1 m (Star Type), 38.3 m.,
19.4 m (Sputnik type)
22. 4m, 31. 6m, 32.35m (High opening trawl nets)

(For details please refer to IFP Bulletin No. 9, June, '84)

3. SHRIMP TRAWLS :

32m, 34m, 37m, 42m, 41m

15.2m, 22.5m, 25.5m, 37.5m (Flat trawls)

10.85m (Out rigger type)

16. 5m (Mexican type)

18. 2m, 24. 0m, 54. 6m (Four seam type)

22. 0m, 29. 0m, 37. 2m (Norwegian type)

21. 2m, 35. 0m, 46. 2m (Kuwait type)

14. 0m, 12. 6m (Otter type)

5. 6m, 4.45m (Try nets)

(For details please refer to IFP Bulletin No. 10, February, 1985)

Table - 2 Contd.

PURSE SEINES :

1.	366m x 27.5m	(M-1)
2.	384m x 27m	(M-1, M-4)
3.	550m x 68m	(Tuna)
4.	370m x 64m	(Tuna)
5.	550m x 64m	(Tuna)
6.	550m x 91m	(Tuna)
7.	366m x 36.5m	(M2, M3)
8.	293m x 29m	(M2, M3)
9.	292m x 25.65m	(M2, M3)
10.	366m x 46m	(Norind -2)
11.	502m x 72m	(Samudradevi)
12.	350m x 31.8m	(Kalava-2)

(For details please refer to IFP Bulletin No. 3, 1980)

4. KALAVA TRAPS :

1.86m x 0.86m-Rectangular-Collapsible.

5. LONG LINE:

80 Baskets each containing 5 hooks
Length of each basket-270m

6. SQUID JIGGING EQUIPMENT:

Automatic squid jigging machine with 35-50 jigs-2 sets,

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OBSERVATIONS ON THE TRAWL FISH CATCHES IN THE SHALLOW WATERS OFF THE SOUTH WEST COAST OF INDIA 1969 - 1972

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Introduction

Knowledge regarding the occurrence, distribution and seasonal variations of some of the commercially important fishes is essential for an effective exploitation of the same at the appropriate time. Eventhough a certain amount of work has been done in the past in the survey of the various regions along the south west coast of India mainly with a view to assess the potential resources available in these areas, adequate attempts on the assessment of the stock and its variations has not been done along the areas going to be described in this paper.

As early as 1928, experimental trawling along the south west coast of India between a depth range of 31–35 fathoms were conducted by the vessel "Lady Geschen" of the Madras Government (Sundarraj 1930) and Chidambaram (1953), has given a comprehensive account on experimental trawling carried out on the Indian waters before the second world war. Trawling operations were conducted off Muttom at depths ranging between 38 and 60 fathoms by the vessels of the "west coast fisheries, Travancore Ltd."; 'Kanyakumari' and 'Sagarkumari' and the results were published by K. Gopinath (1954). During September 1952 the vessel 'Taiyo Maru' of the New India Fisheries Co. made some trial fishing between depths of 13–26 fathoms and the results were not very much encouraging. A start on the further development of trawl fishing along the Kerala coast was initiated by the exploration of the Indo Norwegian Project (Per Sandeven 1955) vessels during the year 1955 when the foundation was established. The results showed that there are productive areas both South and North of Cochin. Reliable statistics were not collected as to the potential resources of fish in relation to fishing areas. Later in the year 1959 the results of the trawling operations conducted by the vessel 'Ashok' and 'Pratap' of the Deepsea Fishing Station, Bombay and 'Taiyo Maru No. 17' of the Taiyo Fishing Company off the Bombay and Sourashtra coasts (Srivatsa 1952) (Jayaraman et al 1959) have thrown some light on total landings and catch rate of the important types of fishes, their distribution and

TABLE I

Catch composition of the major fish groups for the different periods (1969-72)

Period	Total catch* (Kg)	Cat fish (Kg)	Percentage %	Kilimeen (Kg)	Percentage %	Lizard fish (Kg)	Percentage %	Ribbon fish (Kg)	Percentage %	Elasmobranch	Percentage %	Miscellaneous and others %
1969 April to 1970 March	68899	10462	15.2	4838	7.02	1430	2.07	235	0.34	8516	12.4	62.97
1970 April to 1971 March	121879	16080	13.2	26856	22.03	2089	1.71	825	0.67	9299	7.62	54.77
1971 April to 1972 March	135723	25676	19.00	8257	6.08	4077	3.00	3616	2.66	20588	15.2	54.06
Total (Kg.)	326501	46218	14.15	39951	12.2	7596	2.33	4676	1.43	38403	11.76	58.13

The following varieties of quality fishes were also landed during the periods under study in proportionately smaller quantities:

a) Pomfrets
b) Perches
c) Carangids
d) Barracuda
e) White fish
f) Sciaenids
g) Seer fish.

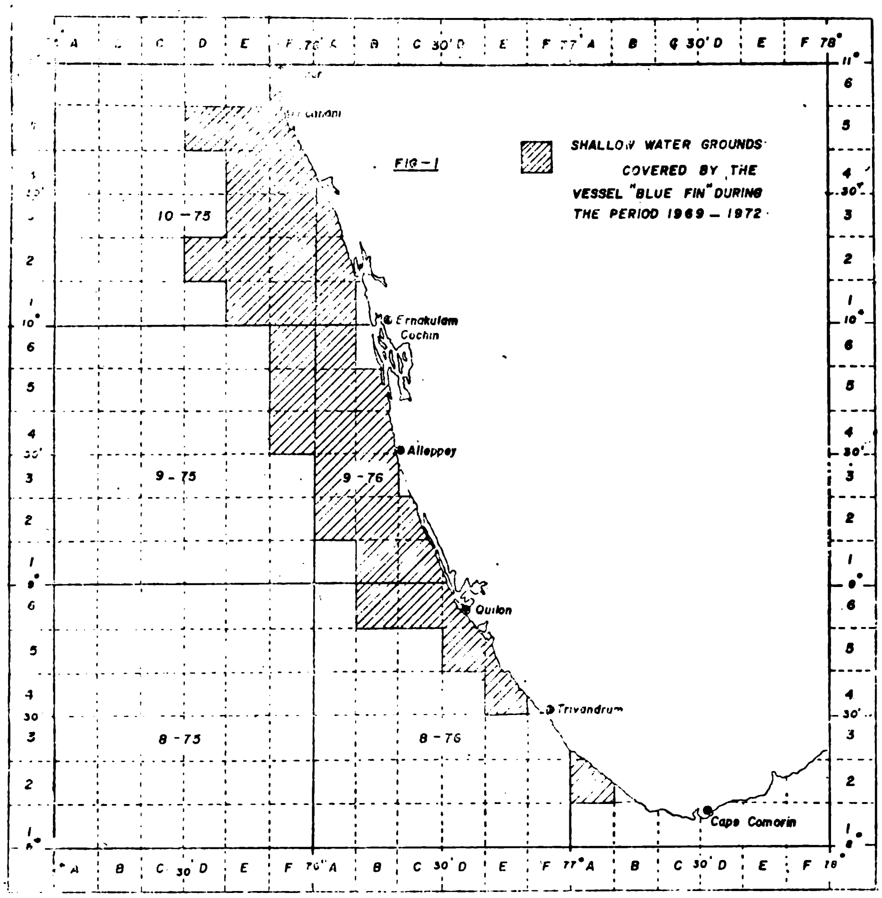
The balance is grouped under the head 'miscellaneous'. The details of catches of the above groups and miscellaneous fishes during the three year period is given in Table II.

TABLE II

Details of catches of less dominant varieties of quality fishes and miscellaneous fishes (1969-72)

	1969–70 (Kg)	1970–71 (Kg)	1971–72 (Kg)
Pomfrets	11399	135	248
Perches	734	165	1513
Carangids	580	272	370
Barracuda	—	467	487
White fish (Lactarius sp.)	143	—	495
Scianide	30	65	—
Green fish	75	—	—
Other miscellaneous	30457 (44.2%)	65626 (53.84%)	70396 (51.86%

It is observed that during the period 1969-70 a record catch of pomfrets (Pampus argentius) was obtained during the month of November 1969 at a depth of 14 fathoms off Alleppey. A total of 9774 kg. was caught in 18 hauls (23 hrs. 15 mts.) during a three day trawling. The catch / trawling hr. for this species alone was 420 kg. (Perumal and Alagarswami 1970). This accounted for mostly 16.54% of the total fish catch of the vessel for the year 1969-70 and also could be considered as the highest record for this species by bottom trawling along the Indian coast.



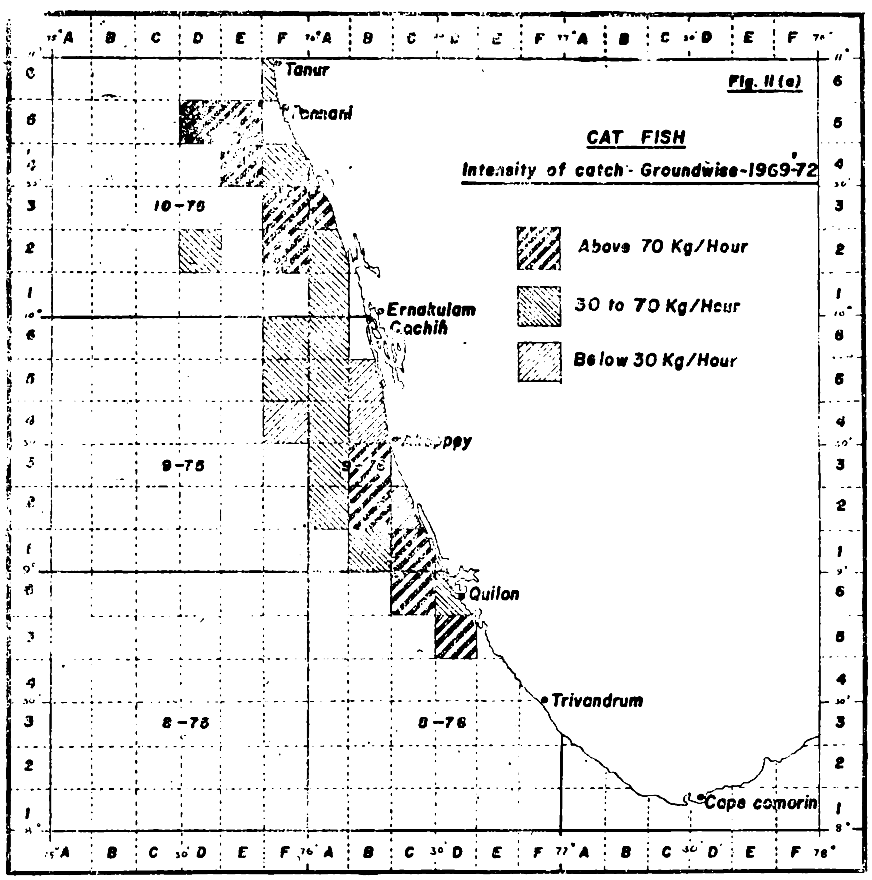
In the case of perches a shoal consisting of 170 numbers and weighing 1141 kg. of Red Snapper (Lutianus argentinaculatus) was caught off Cochin in the month of January 1972 in a single haul. This is perhaps the first time that a similar shoal of Red Snapper has been caught by the vessel in this region. (Narayana Pillai & Ramachandran 1972). Among the catches two specimens of Kalawa (Epinephelus tauvina) weighing approximately 150 and 170 kgs. respectively are worthy of notice. (Joy et el-1974)

An overall analysis of the fish catches of the vessel during the three year period shows that approximately 5% of the total catch was formed of miscellaneous fishes which was not of much economic value. The yearwise % composition of the catches reveal the fact that the % of miscellaneous fishes constitute 44.2%, 53.84% and 51.86% respectively for the periods 1969-70, 1970-71 and 1971-72.

Groundwise distribution

The shallow water fishing grounds covered by the vessel 'Blue Fin' during the period 1969-72 is given in fig. I. The vessel has conducted regular trawling operations at 37 fishing grounds distributed between Tanur and Cape Comorin within a depth range of 10 to 35 fathoms. An attempt was made to cover all the above grounds during the different seasons so as to make studies on seasonal variations possible.

A comparative study of the shallow water grounds in general indicates that the grounds 8–76/60, 9–76/2A, 9–76/8A, 9–76/33, 9–76/6A, 8–76/6D, 8–76/5D, 8–76/5E, 10–76/2A, 10–75/4E and 10–75/3F are comparatively more potential with an average catch/hr. of 70 kg. for the dominant varieties.

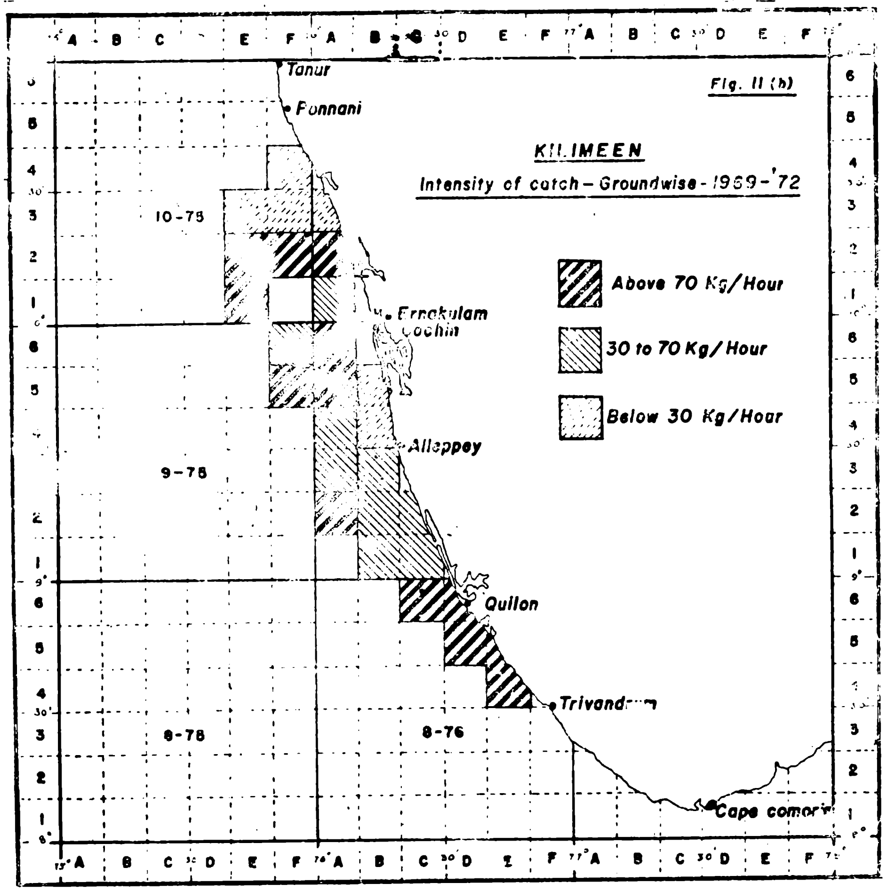


Groundwise intensity of the fish catches

a) *Catfish :* The groundwise distribution of catfish is given in Fig. II (a). The distribution pattern as analysed by comparing the intensity of catch (catch/hr.) is represented in three different grids. viz. 70 kgs./hr., between 30 and 70 kg./hr. and 30 kg./hr. so as to make comparison of catches easier. As is evident from the figure the grounds 10–75/5E, 5D, 4F, 3F, 2F and 10–76/3A located in the region between off Ponnani and Cranganore and grounds 9–76/3B, 2B, 1C, 8–76/60 and 5D located in between off Alleppey and Quilon have yielded more than 70 kg./trawling hour. Out of the above grounds, the maximum catch / hr. (503.5 kg.) was obtained from the ground 10–75/5E located off Ponnani. Grounds 10–75/5D, 4E and 8–76/5D yielded more than 100 kg. / trawling hour. (100 kg., 121.48 kg. and 160 kg./hr. respectively).

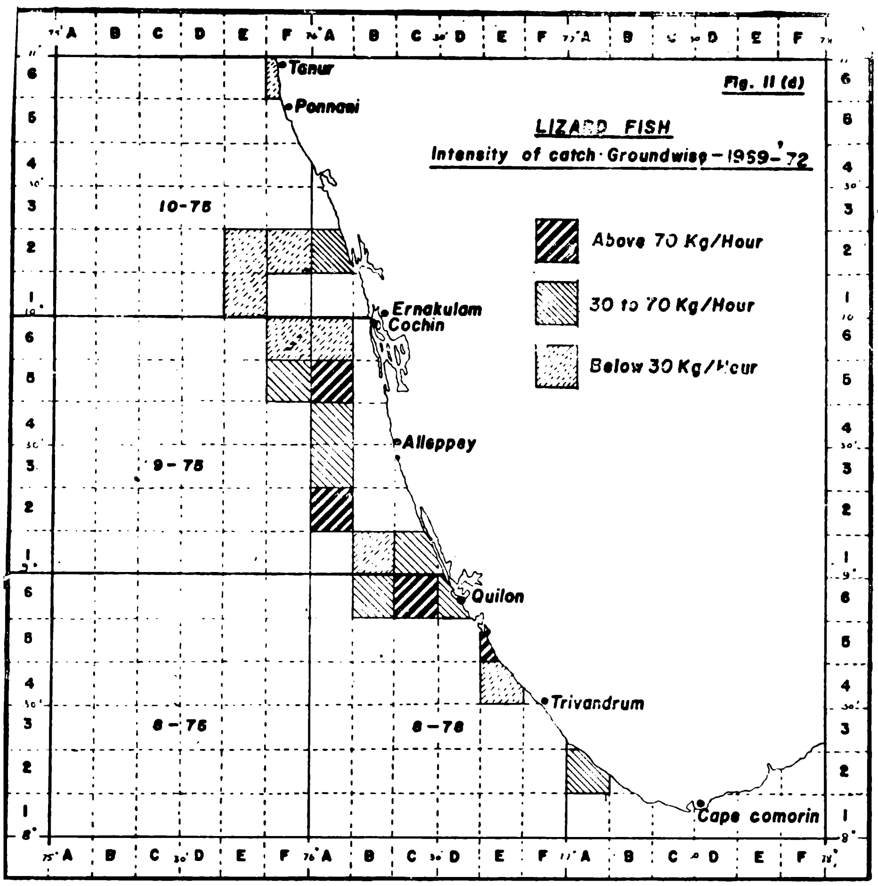
If individual catches at the different grounds for catfish are considered it is found that from the ground 10–75/5E at a depth of 21 fathoms a maximum catch of 1000 kg./trawling hr. was obtained.

b) *Kilimeen:* The groundwise distribution of Kilimeen is given in fig. II (b). The representation of intensity of catch is the same as that for catfish. It is seen that grounds



10–75/1E, 2E, 2F and 10–76/2A located off Cranganore, 9–76/6A, 5A and 9–75/5F located off Cochin, 9–76/2A located off South west Alleppey, and 8–76/60, 6D, 5D and 4E located off Quilon, have yielded an average catch of Kilimeen above 100 kg./hr. Among these the grounds 10–75/2E, 2F, 8–76/4E and 5E yielded more than 500 kg./hr. of trawling (600 kg., 533.3 kg., 666 kg. and 640 kg. / trawling hour respectively). If individual catches of Kilimeen are considered it is observed that from the ground 8–76/5A at a depth of 24 fathoms a maximum yield of 3000 kg./hr. of trawling was obtained.

c) *Elasmobranches :* The groundwise distribution of elasmobranchs (sharks, skates and rays) is given in Fig. II c. It has been observed that grounds 10–75/4E, 3E, 0–76/3F and 1F located between Ponnani and Cochin and 9–76/5B, 4B, 3B, 2B, 4A, 3A and 2A located between Cochin and south west of Alleppey yielded an average catch of more than 70 kg. of elasmobranchs./hr. of trawling. From 9–76/2B and 10–75/1F an average maximum catch/hr. of 138.88 and 117.11 kg. respectively were obtained. When individual catches of elasmobranchs are considered, a maximum catch of 358 kg./hr. was obtained from the grouud 0–76/4A at a depth of 22 fathoms. In this connection the landing of



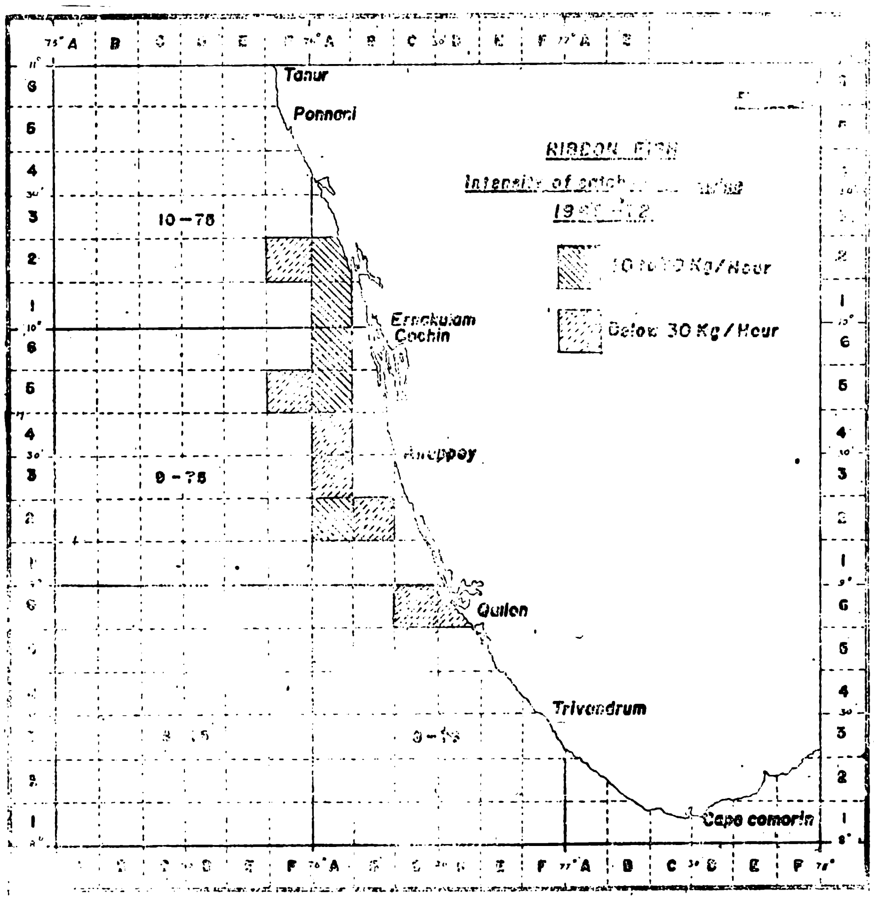
(a) *catfishes :* The average maximum catch/hr. of trawing during the period 1969-70 was 115.11 kg. between the depth range of 16-20 fathoms and the maximum individual catch/hr. of 1000 kg. was obtained from the ground 10-75/5E at about 21 fathoms depth. During 1970-71 the average catch/hr. from all the depth ranges covered were comparatively low and the maximum individual catch/hr. (666.6 kg.) was obtained from 9-76/2B at a depth of 20 fathoms. During 1971-72 also the trend of average catch/hr. between 10-30 fathoms was almost the same as that of the previous period with a maximum individual catch (463.5 kg.) at ground 9-76/6A at about 16 fathoms depth.

Depthwise distribution of the major varieties of fish

Four different ranges have been demarcated for the sake of analysing the distribution of the above fish groups with respect to depth.

Table III (a), (b), (c), (d) and (e) represents the average catch/hr. for the three year period in these four depth ranges.

An analysis of the catch for all the five depth ranges as indicated in table III (a), shows that the catfish concentrations were maximum between the range of 16-25 fathoms and the intensity of catch was found to decrease as depth increases and towards the shallow depths the catch intensity was found



paratively less, the same is not considered).

During the period 1970-71 the average maximum of 1972.73 kg. was obtained at a range of 21-25 fathoms with the individual maximum of 2355 kg./hr. from 9-76/5A at a depth of 23 fathoms. In 1971-72 the maximum average catch was obtained at a depth range of 26-30 fathoms with the individual maximum of 450 kg./hr. from 9-76/4A at 29 fathoms and a single catch of 160 kg./hr. was obtained from 9-76/2A at a depth of 31 fathoms.

to be comparatively better than the deeper zones beyond 25 fathoms.

(b) *Kilimeen:* The average maximum catch/hr. for Kilimeen for the period 1969-70 was 188.61 kg. between 21 and 25 fathoms depth with the individual maximum of 893 kg./hr. at ground 8-76/6C at a depth of 21 fathoms. (Eventhough the average maximum catch/hr. during the above period (225.2 kg.) was obtained from the range 26-30 fathoms, as the number of observations were com-

The depthwise catch intensity for Kilimeen indicates that intensity is comparatively high between the depth range of 16-25 fathoms. It is also observed that the catch intensity increases as the depth increases, but from the depth range of 26-30 fathoms onwards a reverse effect is noticed as evident from table III (b).

TABLE III (a)

Details of catch/hr. at different depth ranges — CATFISH

Period	Depth range	Average catch/Hr.	Maximum catch/Hr.	Ground and depth (in fathoms)
1969–70	10-15 Fath	10.3 Kg/Hr. (only-2)	75 Kg/Hr.	9–76/3A (14)
	16–20 „	115.1 Kg/Hr.	500 Kg/Hr.	9–76/3B (16)
	21–25 „	202.50 Kg/Hr.	1000 Kg/Hr.	10–75/5E (21)
	26-30 „	—	—	—
	30 „	—	—	—
1970–71	10–15 Fath	40.43 Kg	250 Kg/Hr.	9–76/6A (14)
	16–20 „	57.67 Kg	666.66 Kg/Hr.	9–76/2B (20)
	21-25 „	55.64 Kg	333.33 Kg/Hr.	8–76/60 (25)
	26–30 „	30.85 Kg (only-1)	33.33 Kg/Hr.	9–76/4A (27) 2B 1B
	30 „	20.0 Kg	46.1 Kg/Hr.	9–76/6A (31)
1971–72	10–15 Fath	50.40	400 Kg/Hr.	9–76/6A (14)
	16–20 „	39.74	463.5 Kg/Hr.	9–76/6A (16)
	21–25 „	50.13	200 Kg/Hr.	10–75/3F (24)
	26–30 „	27.92	100 Kg/Hr.	9–75/3E (26)
	30 „	—	—	—

TABLE III (b)

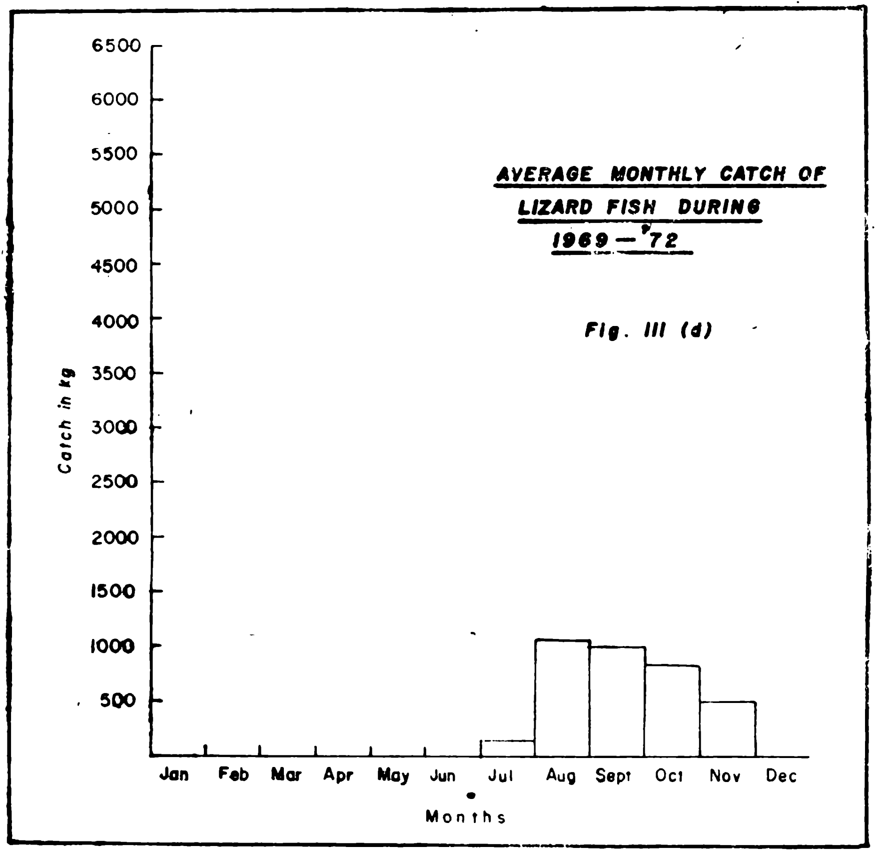
Details of Catch/Hr. at different depth ranges — KILIMEEN

Period	Depth range	Average catch/Hr.	Maximum catch/Hr.	Ground and depth (in fathoms)
1969–70	10–15	61.64 Kg/Hr.	160 Kg	10–76/1A (5)
	16–20	42.75 „	644 Kg	8–76/6C (20)
	21–25	188.61 „	893.3 Kg	8–76/6C (21)
	26-30	30.00 „	200 Kg	9–75/5F (32)
	30	225.22 „	600 Kg	10–75/2E (35)
1970–71	10–15	118.10 „	1500 Kg	10–75/2F (15)
	16–20	147.07 „	1450 Kg	9–76/6A (17)
	21–25	192.73 „	2305 Kg	9–76/5A (23)
	26–30	—	—	—
	30	—	—	—
1971–72	10–15	20.55 „	266.6 Kg/Hr.	9–76/1C (15)
	16–20	48.20 „	210.0 „	8–76/6D (18)
	21–25	31.50 „	236.0 „	8–76/6C (21)
	26–30	112.52 „	450 „	9–76/4A (29)
	30	160.00 (only one)	160.00 „	9–76/2A (31)

Period	Depth range	Average catch/Hr.	Maximum catch/Hr.	Ground and depth (in fathoms)
1970–71	26–30	19–58 ,,	20 ,,	9–76/1B (26)
	30	—	—	—
1971–72	10–15	—	—	—
	16–20	44 ,,	300 ,,	9–76/4A (19)
	21–25	69.49 ,,	210 ,,	8–76/6C (21)
	26–30	61.51 ,,	142 ,,	9–76/4A (29)
	30	66.66 (only one)	96 ,,	9–76/2A (31)

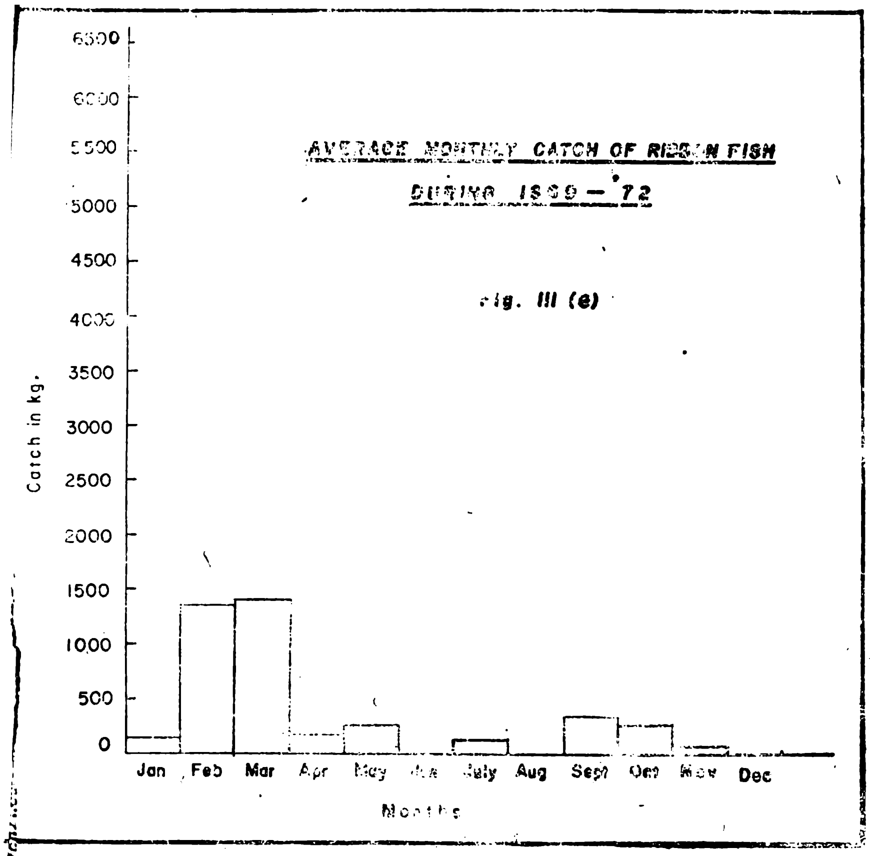
the average catch/hr. were the maximum between the depth ranges 21–25 fath. (76.37 kg.) with an individual maximum of 358.5 kg./hr. at 22 fathoms from the ground 9–76/4A.

In the case of elasmobranchs also, as in the case of catfish and Kilimeen, the catch intensity was high between 16–25 fath. range. Table also confirms a gradual depthwise increase upto 25 fath. from where it decreases.



(d) *Lizard fish:* Table III (d) gives the depthwise analysis of average and individual lizard fish catch/hr. during the three year period.

During 1969-70 a maximum average catch/hr. of 167.11 kg. was obtained from a depth range of 21-25 fath. with the individual maximum of 333.33 kg./hr. from 8-76/6c at 21 fathoms depth. During 1970–71 also the maximum catch/hr.



(83.63 kg.) was observed at a depth of 21–25 fath. with an individual maximum of 870 kg. from 9–76/5A at a depth of 24 fathoms.

During the next year period also the catch/hr. was comparatively high (69.49 kg.) within 21–25 fath. range with an individual maximum of 300 kg. from 9–76/4A at 19 fathoms depth.

The depth wise intensity was observed to be of the same pattern as in the previous fisheries, and the intensity of lizard

TABLE III (e)

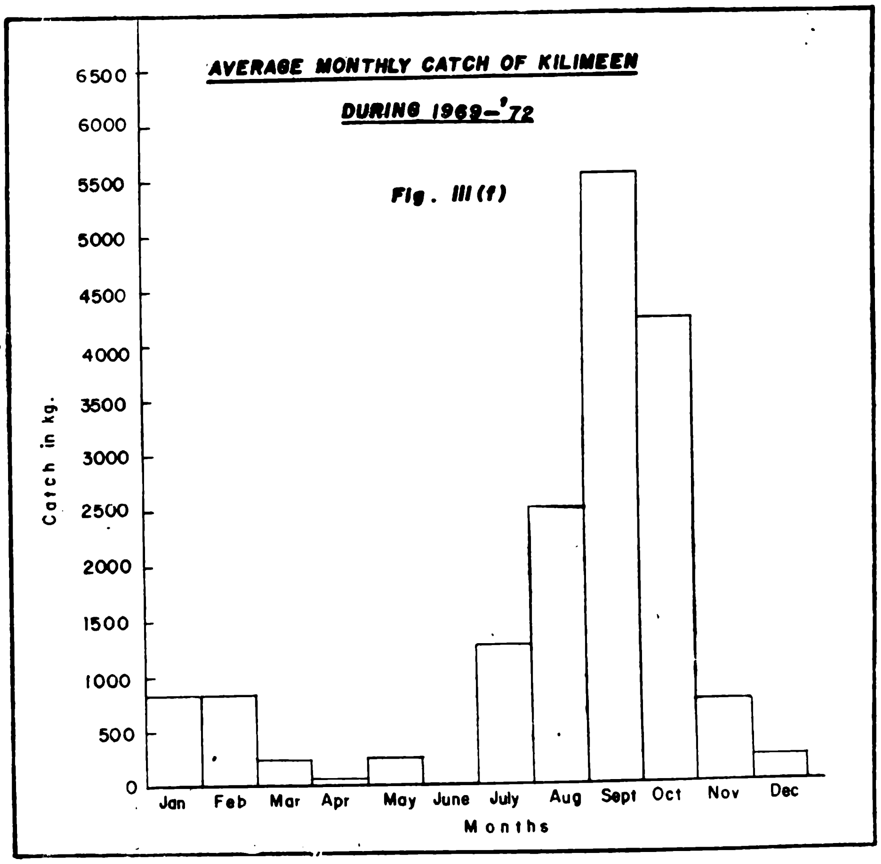
Details of catch/Hr. at different depth ranges — RIBBON FISH

Period	Depth range	Average catch/Hr.	Maximum catch/Hr.	Ground and depth (in fathoms)
1969–70	10–15	40 Kg	40 Kg/Hr.	9–76/3A (14)
	16–20	25.52 ,,	75 ,,	9–76/2B (20)
	21–25	10 ,,	10 ,,	8–76/6C (21)
	26–30	—	—	—
	30	—	—	—
1970–71	10–15	39.48 ,,	80 ,,	9–76/5A (13)
	10–15	43.9 ,,	228 ,,	10–76/2A (14)
	16–20	14.18 ,,	42.66 ,,	9–75/5E (16)

Period	Depth range	Average catch/Hr.	Maximum catch/Hr.	Ground and depth (in fathoms)
1970–71	21–25	10.01 ,,	30.5 ,,	9–76/6A (23)
	26–30	18.00 ,,	38.4 ,,	9–75/5F (27)
	30	60.00 (one value)	72 ,,	9–76/2A (31)

fish as observed from the catch rate was high between the depths 16-25 fathoms.

(e) *Ribbon fish :* The depthwise average and individual catch/hr. values of Ribbon fish catches at different ranges during the period 1969–72 is given in Table III (e). The depthwise analysis of the ribbon fish is not possible as it is not represented at all the ranges by way of catch. An overall observation indicates that catches were comparatively better in the shallow depths. (10-20 fathoms).

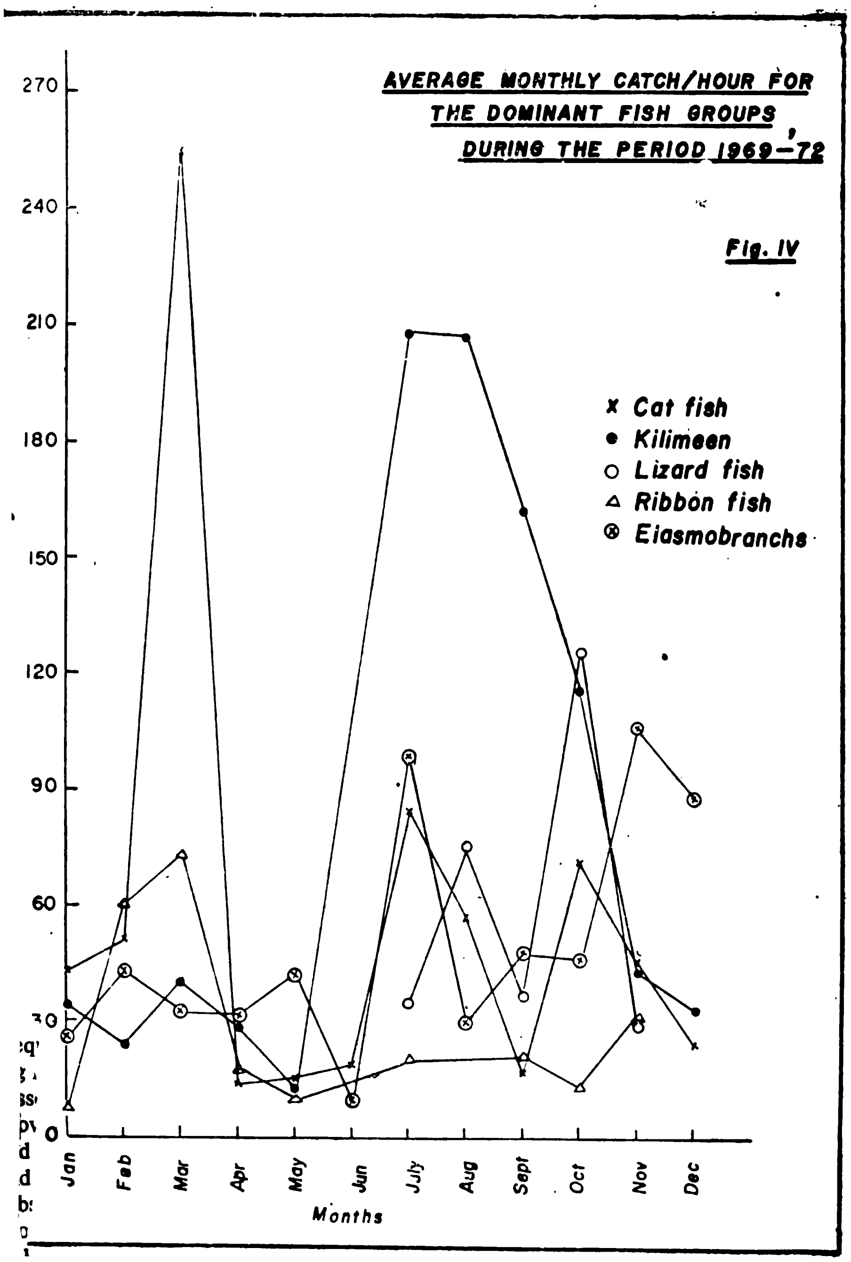


IV. Yearwise/monthwise variations in catches

The average monthly catch for the year 1969–72 for catfish, Kilimeen, Elasmobranchs, Lizard fish and Ribbon fish are shown in figures III 'a' 'b' 'c' 'd' ~ d 'e' and the average monthly catch/hr, for all the above fish groups in fig. IV.

(a) *Cat fish :* Th catfish catch was th maximum (25,676 kg which constitutes abou 19% of the total fis catch during the perio 1971-72. An analys of the average month catches for the thr year period from 1969-

indicate two maxima, one during the period February-March (3300–5200 kg.) and another during October-November (2325–3000). The average monthly catch/hr. indicates a maximum of 255 kg./hr. during the month of March and a minimum of 14 kg./hr. in the month of April.



AVERAGE MONTHLY CATCH/HOUR FOR THE DOMINANT FISH GROUPS, DURING THE PERIOD 1969–72

Fig. IV

(b) *Kilimeen :* The yearwise catches for the three year period shows a maximum of 26,852 kg. (22% of the total fish catch) for the year 1970-71. The average monthly catches indicate a maximum of 2500–5550 kg. during August-October with the maximum in the month of September. The average monthly catch/hr. during the 3 year period shows a maximum of about 208 kg./hr. during the months July and August and a minimum of 13 kg./hr. in the month of May.

(c) *Elasmobranchs :* The yearwise catches for the three-year period shows a maximum of 20,588 kg. (15.2% of the total fish catch) for the year 1971–72. The average monthly catches indicate a maximum of 5400 kg. during the month of November. The average catch/hr. during the 3 year period shows a maximum of 99 kg./hr. in the month of July and a minimum of 10 kg./hr. in June.

(d) *Lizard fish :* The yearwise catches for the period 1969-72 shows a maximum of 4077 kg. (3% of the total fish catch) for the year 1971–72. The monthwise average chatches indicate a maximum of 1080 kg. in the month of August. In general the maximum catches were observed during the months August, September and October.

The maximum average monthly catch/hr. was observed in the month of October (125 kg./hr.) and a minimum of 35 kg. in July. No appreciable quantity of Lizard fish was observed during the months January to June.

(e) *Ribbon fish :* The yearwise catches for the period 1969–72 shows a maximum of 3616 kg. (3.66% of the total fish catch) during the year 1971–72. Maximum average monthly catches were obtained during the months February and March (about 1400 kg.).

The maximum average monthly catch per hour also indicates that the peak period is March (73 kg./hr.), The minimum (10 kg.) was observed in the month of May.

Catch variations in relation to time

Catch composition of the various dominant species of every haul was observed from morning to evening. Fishing operations were commenced in the early hours of the day (between 0500 and 0530 hrs.). From these observations at least in two fish groups (catfish and Kilimeen) specific variations were observed. A definite trend in the variation of quantity of catch of catfish was found in the different times of the day. Fishing operations in the areas where catfish catches were more, show a maximum between 1000 to 1400 hrs. with minima on both sides. The early morning hauls fetch lesser catches of catfish which was found to increase gradually towards midday. Similarly during the late hours of the day, also a gradual decline was observed. A correlation of these catches was attempted with that of the echo recordings of the different hauls at different periods. Interpretations of echoes of catfish was made by this correlation and from the echograms the traces of individual cat fish was observed to be of "spot" or "fingernail" shape. These traces more or less closely resemble the individual echo traces of cod in European waters.

Observations on echo grams : Cushing (1952) observed that in the light of the knowledge of the biology of the different species and the distribution and characteristics of their fishery, some degree of specific identifications of species in any area is often possible by a careful analysis of the echogram. A similar observation was tried in the case of the dominant fish groups during this study particularly along areas where these species dominate in the catches. The echosounder employed for the study was a SIMRAD-SKIPPER sounder operating at a transmission frequency of 38.5 kc/s. Interpretation of the echotraces obtained during each haul was made for its size and shape. This was carried out in a similar line as has been done by Cushing (1971). Cushing has classified four types of echoes, the spot, the comet, the "plume" and the "layer" traces depending upon the interruption of the sound beam by the fish Our observations of the echo traces indicat the presence of the "spots", "fingernails" a "layers" close to the bottom. Echotraces the midwater except for the individual con traces, indicating a specific fish group, w difficult to identify since data pertaining to t pelagic fish groups were not available alo with the echograms. Comparison of the dominant fish catches of individual haul with that of the echo traces observed close to the bottom showed that "spot" or "fingernail" traces were formed of cat fishes of different sizes. The "layer" trace which indicates a scattered shoal is found to be formed of Kilimeen (Fig. IV (a)).

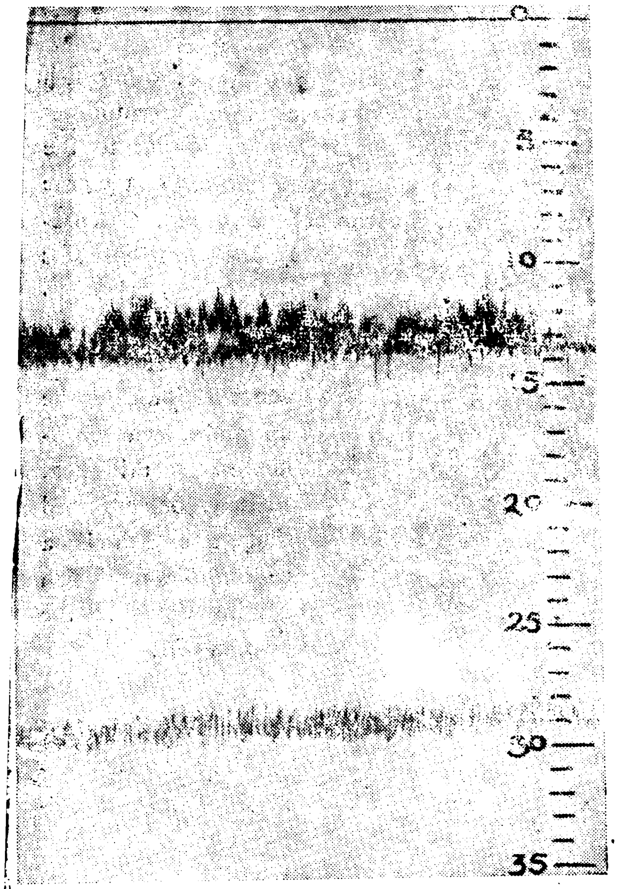


FIG. IV (a) : Echogram showing the 'layer' type trace of a dense shoal of *Kilimeen* recorded on 24.9.'70 at a depth of 15 fathoms at ground 10-74/2F during morning hours (0845). Approximately 500 Kg of *Kilimeen* was caught in 20 minutes time.

Requirement of trawl gear and accessories for stern trawling for the 23m. vessels are similar to that of the 17-5m. vessels. For out rigger trawling the 23m. vessels should be provided with 2 pairs (4 Nos.) of trawl gear fully rigged and 2 pairs (4 Nos.) of trawl gear in parts (without rigging) and 4 pairs (8 Nos. of OB during the 1st year. During the subsequent years 2 pairs of trawl gear will have to be provided. Two pairs of otter boards (1 set) will have to be provided during the 3rd year.

Dense shoals of catfish were not observed very often along these areas as against those found in the east coast. Observations on the intensity of catch of the dominant fish groups and the position of the identified traces relative to the seabed were made. It is found that catfish is making a diurnal vertical migration. The fishes are found to descend from the midwater during the early hours of the day and then they get scattered over the bottom (Fig. IV (b)). The depth at which they remain during the day time vary between 2–3 fathoms from the bottom. Catch intensity increases when they are within "fishable limit". Studies have been made on the effective vertical opening of the trawl net employed for the present study (Perumal etal 1974). They found that the predicted and observed values of vertical opening of a 31 m. trawl net was 1.725 m. and 1.80 m. respectively. Since a good % of catfish concentrations are not always found within this limit (1.80 m. above the bottom) it is not likely that all the fishes distributed close to the bottom will come within the vertical limit of the net mouth. Observations on the vertical opening of the 25 fath. net was also not very encouraging as to the catchability of the catfish. Observations with a net recorder indicated that the vertical opening of a 25 fathom net also does not exceed 1.5 fathom. The irregular vertical distribution of this fish can be a probable reason for the low catches in certain hauls during the expected time of the day. It is of interest to note that shoaling tendency is seldom noticed in the case of catfish when they are at the bottom. This is evident from the echograms as the catfish s represented as scattered individual "spot or finger nail" traces near the bottom. It is also tempting to believe that downward migration of catfish during the morning hours, other than light, is also influenced by its feeding habits. Similarly the upward movement during the evening hours may be because the bottom living organisms also move up and spread during night. Laevastu and Hela (1970) described a similar type of diurnal virtical migration in the case of marine organisms. Catfish can be grouped as a demersal fish with daytime occurrence on or close to the bottom, migration and dispersal into the water mass above during sun set and discend to the bottom during sun rise.

Regarding the identification of other fish groups, except for Kilimeen it was very difficult to arrive at any definite conclusion as to the exact nature of the echo traces. In the case of Kilimeen, layer traces indicating less densely packed fish shoals were found close to the bottom. There was no definite evidence to indicate the up and down movements of this fish. It may be assumed that this fish is a column water fish coming down to the bottom often.

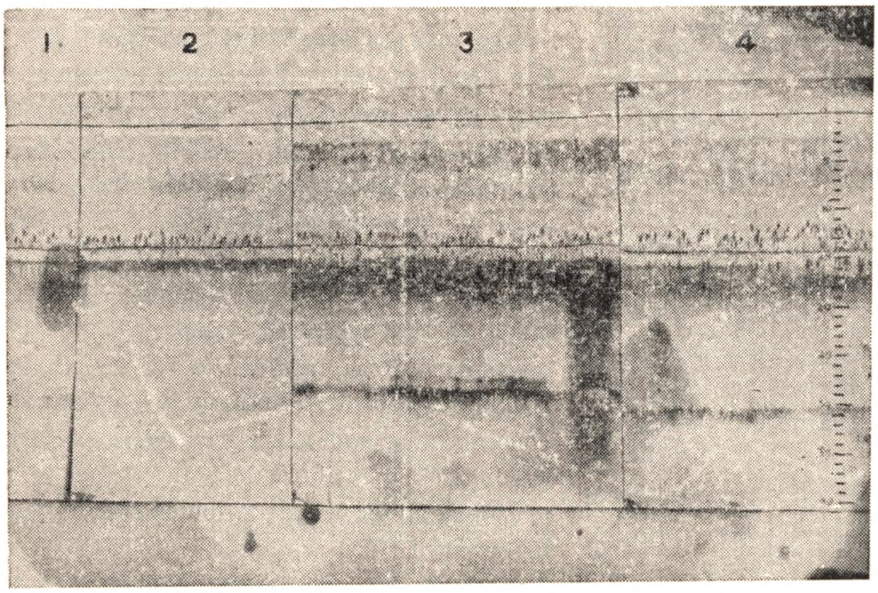


Fig. IV (b): A series of echograms taken in a single day at different hours to indicate catch variation in time of Cat fish.
Date of recording : 31 . 1 , '72
Ground : 9-76/6A
Depth : 14 fathoms
Nature of the Trace : 'Spot' and 'Finger nail'

(1) At 0800 Hrs. — Fish is scattered well off the bottom and showing tendency of setting down - Catch 100 Kg. in 1 hour and 45 minutes.

(2) At 1100 Hrs. — Fish has settled down on the bottom - Catch 200 Kg. in 30 minutes.

(3) At 1400 Hrs. — Movement of the fish at random - Catch 150 Kg. in 1 hour and 45 minutes.

(4) At 1700 Hrs. — Gradual movement of the fish away from the bottom - Catch 200 Kg. in 1 hour and 45 minutes.

Conclusions

The detailed analysis of the data collected from the Training/Fishing vessel 'Blue Fin' obtained during her trawling operations from 1969-72 is presented and discussed. The total landings of fishes with special reference to the dominant fish groups like catfish, kilimeen, elasmobranchs, lizard fish and ribbon fish are presented. Average catches — yearwise/monthwise/areawise and depthwise intensity of catch, variation of catch in relation to time, interpretation of echo traces of dominant fish groups and a comparative study of this with the catch intensity/haul were made to arrive at certain conclusions as to the behaviour of fish.

(1) During this three-year period out of the total fish catch (3,26,501 kg.) excluding the prawn and deep sea lobster fish catches, the cat fish catches were more than any other fish groups. Other dominant fish groups in the order of intensity were Kilimeen Elasmobranchs, Lizard fish and Ribbon fish. When the Kilimeen catch increased the catfish catch is found to decrease. The period 1971–72 showed the maximum in total fish catches. Approximately 51% of the total catches were composed of miscellaneous fishes including smaller quantities of quality fishes like Pomfrets, perches, carangids, barracuda, white fish, sciaenids and seer fish. Exceptional catches of pomfrets (9774 kg.) during 1969–70, Red Snapper (141 kg. obtained in a single haul), two individual specimens of Kalava weighing 150 kg. each, were also obtained.

(2) Out of the 37 fishing grounds between Tanur and Cape Comorin, about 11 grounds are comparatively more potential for the dominant fish groups considering the average catch/hr. A groundwise analysis shows 6 grounds located between off Ponnani and Crangannore and 5 grounds located between off Alleppey and Quilon have yielded comparatively better catches for catfish. For Kilimeen 4 grounds located off Cannanore 3 grounds off Cochin, 1 located s. w. of Alleppey and 5 located off Quilon have yielded the maximum. 4 grounds between Ponnani and Cochin and 7 located between Cochin and Alleppey were better for Elasmobranchs. For lizard fish, 4 grounds between Cochin and Trivandrum yielded the maximum. Regarding Ribbon fish catches, above 70 kg./hr. of trawling was not obtained from even a single ground. Altogether five gronnds proved to yield between 30 and 70 kgs./hr. of trawling all along the area under study.

(3) Analysis of the catch for the five depth ranges for all the species except Ribbon fish was observed to be between the depth range of 25–30 fathoms. For ribbon fish, comparatively better catches were obtained from the shallow depths of 10–20 fathoms.

(4) An analysis of the average monthly catch/hr. of trawling for the entire period indicates a maximum during March for catfish, July-August for Kilimeen, July for Elasmobranchs, October for Lizard fish and March for Ribbon fish.

(5) Echotraces of individual catfish close to the bottom were identified to be of "spot" or "fingernail" shape and Kilimeen to that of "layer" type. Identification of these traces is made by a long term comparative analysis of the echogram with that of the intensity of dominant fish catch.

(6) Analysis of the echotraces with catch/individual haul indicates an up and down diurnal migration of catfish. This fish may be grouped as a species, migrating down at sunrise, distributing over the bottom during day time and again ascending towards column waters at sun set. The vertical distribution

range of catfish over the botton during day time points to the fact that trawl nets having a high vertical opening may increase the catch rates. Kilimeen is identified as "layer" trace close to the bottom. Evidence is lacking as to the movements of this fish.

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INTERPRETATION OF FISH SHOAL INDICATIONS IN THE ARABIAN SEA

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Operatives, Cochin.

Introduction

Availability of resources is perhaps one of the most important factors which determines the success of any industry. In the case of the fishing industry, at the basic production level, the availability of fishable concentrations of fishes and other marine life is the decisive factor which controls the economy of the whole system. Even when well equipped vessel, fishing gear and trained personnelare available, the success of the industry is dependent on the availability of fishable concentrations of commercially important marine life at the appropriate time. By the word' fishable concentrations', the implication is availability of sizeable quantities of fishes which could be definitely caught using a particular type of craft and gear in a particular area at a particular time. Naturally, with the availability of fishable concentrations of commercially important marine life, the chances of getting a good catch are always high. Hence it assumes great significance at the basic production level of the industry.

Some knowledge regarding the presence of similar fishable concentrations of fish and other marine life is of great importance to the technical skill working on board fishing vessels. Their technical knowledge in fishing could be put to use more effectively when positive indications with regard to the availability of shoals are known to them. The correct and quick interpretation of these indications would place them in a better position from where they can use their judgment towards achieving great success in this endeavour.

In India, only very little work seems to have been done along these lines especially to arrive at a positive correlation between certain natural indications and presence of fishable concentrations of commercially important marine life, especially the shoaling fishes. The work done by Balan (1961) is worth mentioning in this context where the author has made certain observations on the shoaling behaviour of the oil sardine off Calicut along the Kerala coast.

Fish shoals

Fish shoals are naturally accumulated group of fishes which under normal conditions show a tendency to remain together. The commercial feasibility of operating certain specific types of nets (Purse seines, Cast net, Ring nets, Rampani nets, Patta bala, Mari bala, Colli vala etc.) is dependent on the availability of fishable concentrations of commercially important shoaling fishes. The necessary knowledge regarding the behaviour of similar shoaling fishes will enable us to use the specific type of fishing gear more effectively, thereby increasing the catches. Absence of such knowledge can result in wastage of valuable time, labour and above all money. The behaviour of a fish shoal is certainly decided by the variations observed in the various environmental factors both meteorological and hydrographic, such as direction and force of wind, amount of cloudiness, phase of the moon and tide, temperature, salinity, dissolved oxygen content, currents, presence of organic and inorganic particles and their intensity and the like. Eventhough, in general, fishes are known to swim against the prevailing currents during day time, at night many of them are found to drift along with the current, sometimes evidently in the midst of food items on which they feed.

Fish shoals common around Indian waters could be broadly divided into two major groups, viz.,

1) Surface shoals
2) Submerged shoals.

In the case of the first category, the shoal itself or rather individual fishes (of sufficiently large size) would be visible from the deck of a fishing vessel. Among the second category there can be two types viz, those which are visible and those which are not visible. The visibility is usually governed by factors such as amount of light and transparency of the water column and above all the depth at which the shoal moves. Based on their habits, shoaling fishes give different types of indications suggesting their presence in a particular area/depth of the sea. The correct interpretation of these indications is of great importance as otherwise there is every possibility of losing the chances of a good catch, by employing a particular type of fishing method.

Indications and Interpretations

(A) *Movement in the surface waters :* When the shoal moves up in the surface waters small sized ripples are created depending upon the size of individual fishes. It is presumed that the distance between two successive waves is more or less equal to double the thickness of individual fishes. They can be spotted from a distance of 7 to 8 km. and are usually dark in colour. Fishes which are found in similar shoals are mostly cat fishes, sciaenids, seerfish, anchovies barracuda, carangids, mackerel, sardines. gray mullets, etc.

(B) *Taking water through the mouth while moving :* During winter when sea water temperature shows a sudden fall, certain fishes move towards the sea surface and while moving they keep their mouths open half above the water surface. Cat fishes sciaenids, Otolithus sp., gray mullets, carangids etc. belong to this category and can be easily spotted.

(C) *Showing the dorsal fin above the water level while moving :* This is a typical characteristic of Cat fishes and carangids.

(D) *Flying movements above the water level :* Certain fishes when they get frightened or when chased by other fishes exhibit flying movements above the water surface, covering distances of 20 to 30 m. at a time. The typical examples are the flying fish (Exocoetus sp.) and fishes like Hemiramphus sp. etc.

(E) *Keeping the gills open while moving:* While moving in a shoal, fishes like mackerel and sardines are known to keep their gills wide open and move sideways.

(F) *Splashing movements :* According to the law of nature, bigger carnivorous fishes feed on smaller fishes. These carnivorous fishes usually take advantage of fish shoals. When the shoal is suddenly attacked the smaller fishes show a tendency to move faster to escape the predators and while doing so cause a certain amount of splashing of water at the sea surface. Eg. sardines, mackerel, silver bellies, prawns etc. The common predators encountered are Sharks, seer, fish dolphins, saw fish, leather skins etc.

(G) *Jumping movements :* Some fishes are in the habit of jumping above the water line, at certain intervals. Sometimes it so happens that they push the anterior part of their bodies up and before the tail portion leaves the water surface, the head once again plunges back into the water. Sometimes similar movements are repeated at longer intervals of 5 to 6 minutes. Cat fishes, sardines, silver bellies, anchovies etc. belong to this category.

(H) *Individual fishes moving up and splashing the water surface and then going down :* In a fish shoal, sometimes individual fishes come up and go down quickly thereby splashing the water surface. If the movement is slow, the water movement caused by this splashing will resemble the movement caused by rainfall at the sea surface. Similar indications are characteristic of shoals of anchovies, carangids, and Ambassis sp. (near fresh water outlets into the sea)

(I) *Individual fishes cutting the water surface and moving back :* Sometimes from a moving shoal a few of the fishes move up and cut the water surface by their tail and move down to join the shoal. If the shoal is moving nearer to the sea surface, the shoal would be visible. Fishes like Tuna, seer fish, leather skins and carangids give similar indications.

(J) *Shoals which release a thin film of oily secretion :* Oily secretions are characteristic of waters where shoals of cat fish, sharks rays (especially Aetobates sp.), mackerel, sardine and carangids are common. Certain varieties also give a peculiar smell. One cannot always expect the shoal directly underneath these oily patches as these patches are found to move along with the prevailing wind and water currents.

(K) *Changes observed in the colour of surface and bottom waters :* Generally, fishes which exhibit coloured indications do not make other visible signs. The dorsal surface of a large number of fishes in a shoal when seen from the surface reveals specific colourations depending upon the species. In the case of fishes like pomfrets which exhibit sideways motion, the colouration exhibited is that of the lateral side. Bottom fish shoals like those of golden anchovy reveal a reddish tinge, probably brought about by a combination of the dorsal colouration of some of these fishes and also the reflected radiation from the sea bottom. Surface fish shoals, in general, are blackish in colour.

The above said feature is noticed in the following varities of fishes viz. Crescent perches, sharks, soles, prawns, white fish, rays, kilimeen, ribbon fishes, polynemids etc.

(L) *Bubbles appearing at the sea surface :* When certain fish shoals move underneath we are likely to come across either individual or large number of bubbles in the surface layers. In general, bubble forming shoals are found to move rather slowly. Fishes which exhibit this characteristic are sardines, engraulids, cat fishes, carangids, white fish etc.

(M) *Slow movement of surface water above the shoal :* It is rather difficult to differentiate between a similar slow motion of water caused by a moving shoal (submerged) and an ordinary low intensity water current caused by a favourable wind. If the water column is sufficiently clear, part of the shoal itself would be visible.

The following major types of water motion are observed in the case of fishes noted against each :

(1) Formation of a small wave caused by the movement of a shoal from one place to another very near the surface. (Mackerel, sardines etc.)

(2) Surface water moving with low intensity splashing noise caused by a moving shoal. (Carangids)

(3) Formation of a whirling motion caused by the movement of a fish shoal which moves in circles. (Mackerel, sardines, carangids & cat fishes) Sometimes the speed of the shoal and the resulting water motion at the surface can be so high that it can capsize small boats which go nesr the shoal.

(4) When a sufficiently fast moving fish shoal moves at the sea bottom, particularly in shallow areas, muddy water usually comes up towards the surface layers. This is especially the case in areas where the sea bottom is composed of loose mud (Mackerel, sardines, carangids, anchovies, cat fishes, soles & rays).

(N) *Shoals which are visible at night due to phosphorescence :* Certain fish shoals are bioluminiscent. Fishes like Silver bellies (Leiognathids), Bombay duck (Harpodon sp.) etc. will illuminate a large area of the sea and at times one may find it difficult to differentiate these fishes from the bright light reflected back from the sea.

FALSE INDICATIONS : Some of the above said natural indications can also become false indications as the particular indication may not be due to the presence of a fish shoal. For eg. small waves which are caused by a favourable wind, current boundaries where two adjoining current streams form a mixed layer, places of diverging or converging currents, outlets of industrial or any type of naturally or artificially contaminated sewage flow, floating oil which has leaked out into the sea from oil tankers and the like, shadow of low clouds especially when they are moving, presence of swarms of other marine life (eg. Noctiluca sp.) which gives colour to the sea, under water rocks, flock of birds, bubbles released from the bottom mud in areas where emical decomposition is in progress :. can act as false indications. Special re has to be taken while differentiat- g between the above said false indi- tions and the real indications mention- l under the items A to N., before con- ming the presence of a fish shoal and ƙing further measures for exploiting e same.

'FECT OF ENVIRONMENTAL
ICTORS ON FISH SAOALS:

Effect of Wind:

Along the west coast of India, in the ·esence of light easterly wind, the eneral tendency of a fish shoal is to ove down into deeper water. This in rn can produce one of the indications sted under item M. 1 to 4 mentioned ırlier.

When the wind is northerly the eneral tendency noticed in these areas the shoal moving up towards surface aters. When the wind is southerly the fect is just the opposite. With a west- ·ly wind the shoal shows a tendency to ove shorewards. In rough weather sh shoals are generally found to move own into deeper water.

. Effect of Light:

In general, shoaling fishes show a ndency to move towards light. Because : this, during morning hours shoals are kely to face the east and towards vening, the west. A more or less milar tendency is also noticed with the sing and setting moon. Most of the shes, especially Hemiramphus sp. and ertain varieties of prawns are attracted wards artificial light at night. In Ram- ani fishing, artificial lights are com- ıonly used to lure the shoal into smaller ets to be transported to the shore.

III. Effect of variations in temperature:

Every individual species of fish has an optimum temperature eventhough eurythermal fishes can survive within certain variations of temperature. It is generally observed that fishes show a tendency to aggregate together and form shoals when the water temperature falls below a certain optimum limit. When the water temperature rises, the fishes in a shoal are likely to spread out. This might be the reason why we come across more number of fish shoals around Indian waters during the months September to December when the sea water temperature is likely to fall. During the months March to July, when the sea is comparatively warm in these areas, the number of fish shoals observed are less. Certain shoaling fishes show a tendency to float at the sea surface during the peak of winter. During such time, these fishes are found to be comparatively sluggish. Eg. Rays, Crabs and the like.

IV. Effect of currents:

In general shoaling fishes are found to move against currents during the day time. During the night time, especially in the presence of large quantities of food materials, fishes are known to drift along with a particular water body which contains the food item. When the current speed increases beyond a certain optimum limit, even during day time, shoaling fishes are found to drift along with the currents. But while drifting it is observed that individual fishes in a shoal always face the current eventhough they drift along with the stream.

V. Effect of variations in salinity:

In areas where rivers discharge sufficiently large quantities of fresh water into the sea, the tendency noticed is the spreading of fresh water at the surface (due to a low density) in the form of a tongue into the sea. It is generally observed that fish shoals always try to avoid the tongue of fresh water either by diving into deeper water or by occupying the two sides of the tongue where the effect of fresh water is negligible. The same tendency is also noticed in the presence of a sudden shower. especially in localised areas eventhough it is quite possible that some of the euryhaline fishes may be able to withstand a certain variation in salinity.

VI. Effect of variations in the dissolved oxygen content:

Majority of the commercially important fishes require an optimum concentration of dissolved oxygen in the surrounding waters. If due to some reason the quantity of dissolved oxygen falls below a certain minimum, they show a tendency to migrate towards favourable environments. It has been observed that at certain times oxygen depletion can result in more or less complete absence of shoaling fishes in a particular region of the sea. Oxygen depletion is characteristic of enclosed or semi-enclosed water bodies where it is caused by poor vertical/lateral circulation processes. In the open sea the main cause seems to be the putrification of large quantities of dead organic matter coupled with poor circulation processes. An earlier record of a similar phenomenon reported from the shelf waters off Bombay (Banse, 1968) is worth mentioning in this context. This is especially true during the S. W. monsoon period in areas where the process of upwelling is active thereby bringing bottom waters with low dissolved oxygen concentrations to shallower depths. Banse (1959) has also shown that during the S. W. monsoon period off Cochin the decrease in the oxygen content of the nearbottom waters results in the disappearance of demersal fishes especially the dominant variety, Nemepterus japonicus.

Conclusions

The importance of knowing some of the above said indications along with their correct and speedy interpretation need not be stressed again. A fair knowledge regarding the various environmental factors and their effect on the behaviour of shoaling fishes will certainly enable the skipper of a fishing vessel to exploit the resources in a better way. This will also help him to use the right type of gear and other accessories to catch a particular variety of fish under certain specific conditions.

Acknowledgements

The authors wish to exxpress their sincere thanks to Mr. M. C. Perumal, Director, Central Institute of Fisheries Operatives, Cochin for his encouragement and keen interest in the present study and also permitting them to publish this note.

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On the occurrence of two specimens of Giant Greasy Reef cods, 'Epinephelus tauvina', (Forskal), off Cochin

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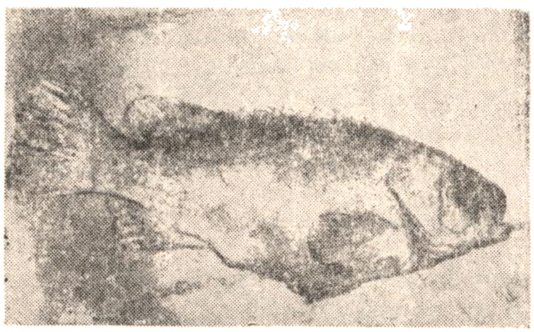
During the regular training cum fishing programme of the Swedish gift vessel 'BLUE FIN' of the Central Institute of Fisheries Operatives, collections were made of fishes and other aquatic forms of biological and commercial importance, as a part of the regular training programme of the Institute. Among the



Epinephelus tauvina (Forskal)

collections thus made, two giant greasy reef cods, locally known as "Pannikavala" are noteworthy to mention in view of their notable size.

The specimens under study were caught by the 93' training cum fishing vessels, equipped with modern sophisticated electronic and navigational equipment and is fitted with diesel motor of B & W Alpha main engine, capable of developing 600–650 H. P. at 400 RPM. The name 'BLUE FIN' is named after one of the well known species of the Tuna family found abundantly in the Arabian Sea known by the Scientific name *Kishinoella tonggol*.

The giant sized Reef Cods were caught on 7-1-71 and 19-1-71 at a depth of 25 and 32 meters respectively, off Cochin when the vessel was trawling on bottom, north-west coast of 150°. The area from where the specimens are caught were Latitude 9° 40′ to 9° 50′ and Longitude 76° to 76° 10′ and Latitude 10° 50′ and 11° and Longitude 75° 40′ to 75° 50′ respectively. The nature of bottom from which the fish were caught was sand mixed with shells. The sky was clear and the sea was calm. The specimens weighed 150 and 170 Kgs. and were having a length of 250 cms. approximately. They were hauled on board the vessel with great deal of difficulties, they were later identified as "*Epinephelus Tauvina*" (Forskal). The colour of the specimens was dark brown throughout the body and prominent black spots were present on the body, second dorsal, pectoral, anal and caudal fins. Both the specimens were found to be females.

The gear used by the vessel during his operations was 31 m. garfil Trawl net and the otterboards were rectaugular type, weighing 410 Kgs. The trawling speed during the operation was 3 knots. The other major varieties of fish caught along with the Reef cods were sharks Rays, white fish, cat fish, Barracuda and miscellaneous fishes.

One of these specimens (caught on 7-1-'71) has been preserved by stuffing and lodged in the reference collection museum of Central Institute of Fisheries Operatives, Cochin. To the best of our knowledge no published information seems to be available on the capture of similar giant rock cods, viz. Epinephelus tauvina.

The authors express their grateful thanks to Shri M. C. Perumal, Director, Central Institute of Fisheries Operatives, for his encouragement in this study. The authors also express their appreciation and thanks to S/Shri H. Padmakar, K. Balan and their crew for catching the specimens and bringing them ashore in tact condition.

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MISCELLANEOUS NOTE

9. ON THE OCCURRENCE OF A RECORD SHOAL OF RED SNAPPER *LUTIANUS ARGENTIMACULATUS* FORSKAL OFF COCHIN

Landings of perches are common along the east coast of India eventhough they appear sporadically along the west coast. However, it is of interest to record a shoal of 170 Red Snapper *Lutianus argentimaculatus* Forskal weighing 1141 Kg which were caught off Cochin by the vessel 'Blue Fin 93', training-cum-fishing vessel of the Central Institute of Fisheries Operatives, Cochin.

The fishes were caught by the vessel on 31st January 1972 when she was on her 142nd voyage at a depth of 25 m between 0830 and 1015 hrs in a single haul. The weight of the specimens ranged between 7 to 10 Kg and were 51 to 63·5 cm in length. The most interesting feature which needs special mention is that eventhough the vessel operated the same gear (450 meshes Trawl-Garfil) in the same ground and at the same depth and made five hauls, not a single specimen was caught in the other four hauls. The skipper of the vessel confirmed that this is the first time that such a shoal of Red Snapper was caught by the vessel. There seems to be no record of occurrence of such large shoals of this particular species around Cochin waters.

The sea bottom at the fishing grounds was predominantly muddy with plenty of shells. Other varieties of fishes which were found with the catch were Sharks, Skates and Rays (20 Kg), white fish (2 Kg), small carangids (3 Kg), small jew fishes (3 Kg), flat fishes (5 Kg), Barracuda (3 Kg), Cat fishes (100 Kg) and Sand lobsters (3 Kg).

The catch/hr for Red Snapper, at this ground worked out for this particular haul to 652 Kg/hr.

Acknowledgements

Thanks are due to Shri M. C. Perumal, Director, Central Institute of Fisheries Operatives, Cochin, for his encouragement and permission to publish this note. Thanks are also due to Shri K. Balan, Skipper and crew of the vessel for the keen interest shown for recording the details of operation.

Central Institute of Fisheries Operatives,
Cochin-16,
June 2, 1972.

V. NARAYANA PILLAI
V. S. RAMACHANDRAN

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A NOTE ON DEEP SEA FISHES COLLECTED FROM THE CONTINENTAL SLOPE OFF THE KERALA COAST

By F. V. BLUE FIN

BY
V. Narayana Pillai and **V. S. Ramachandran**
Central Institute of Fisheries Operatives, Cochin.

Introduction

Information pertaining to the deep sea fishes off the Kerala coast is rather scanty eventhough sporadic attempts were made by the Research vessel 'CONCH' of the University of Kerala and some of fhe Indo-Norwegian Project vessels. In this connection the work done by Samuel (1963 & 1966), Thulasilingam et al (1964), Silas and Prasad (1969), Silas (1969) the Indo-Norwegian Project (1971) and Joseph (1972) are indeed worth mentioning. The present communication is an attempt made by the vessel 'BLUE FIN', the 93' training cum fishing vessel of the Central Institute of Fisheries Operatives during fishing operations along the deep water grounds located between Alleppey and Quilon at depths of 173 to 293 m. The vessel has undertaken a total of 152 voyages during the period of 1969-'72 out of which 42 voyages were made in the deep water grounds located between Alleppey and Quilon. As a part of an extensive study made on the availability of deep water lobster resources along the Kerala coast (Pillai and Ramachandran, 1972) an attempt was also made to segregate and record the deep sea fish catches from time to time. As the vessel was operating more or less the same type of gear and accessories throughout the period under observation, it was possible to make a comparative study on the abundance of deep sea fishes in the total catches (deep sea mixture) and also their intensity.

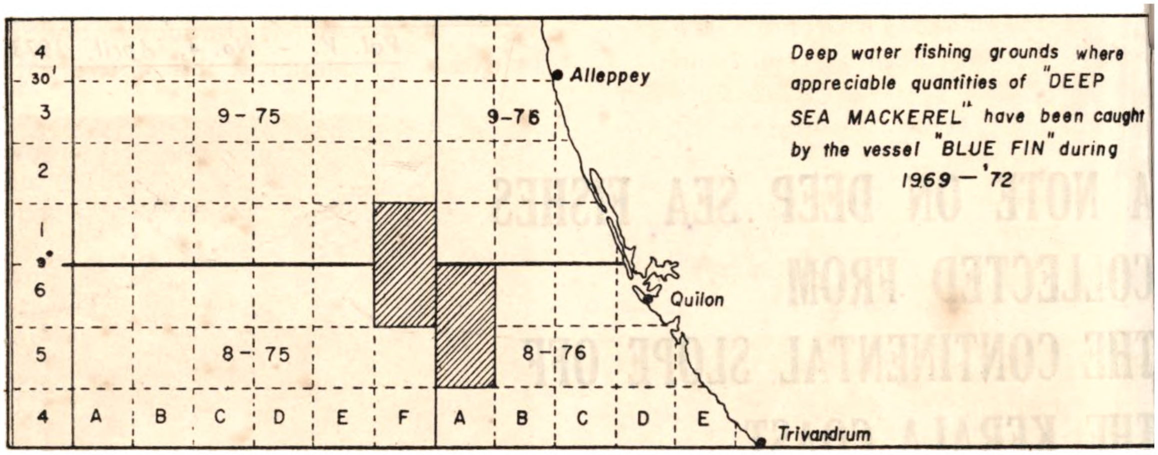

Fig. I.

Data and Methods

Fig. 1 gives the location of deep water grounds covered by the vessel 'BLUE FIN' during the three-year period under study. The catch statistics along with other details such as hauling time, depth of trawling, nature of bottom, catch composition etc. in respect of individual haul are taken from the fishing log maintained by the skipper of the vessel. Special care was taken to see that the respective data is incorporated in the log regularly. The predominant varieties of fish were identified in the Institute laboratory by the authors from time to time.

Craft and Gear

The vessel 'BLUE FIN' is a 93' steel stern trawler fitted up with engines of 650 B. H. P. and equipped with modern sophisticated electronic navigational, communication and fish-finding devices can remain out in the sea continuously for periods of 5 to 7 days. The gear used for the above study fall under the following categories viz.

(1) 600 meshes deep sea trawl (Garfil).

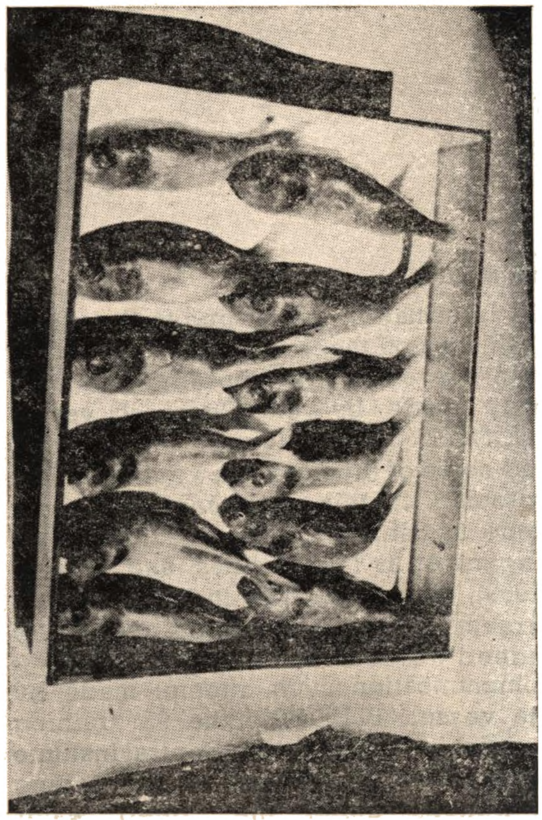

Fig. II. Emeleychthys nitidus

(2) 450 meshes trawl net (Garfil).
Rectangular otter board—
2 . 23 X 1 . 18 m.
weight ≈ 410 Kg.

Observations

A general study of the deep water grounds covered by the vessel shows that only at 4 grounds viz. 8–75/6 F, 8–76/5 A, 8–76/6 A and 9–75/1 F, appreciable quantities of 'deep sea mackerel' identified as *Emmelechthys nitidus* RICH (92 . 92 Kg./Hr. to 463 . 2 Kg./Hr.) mixed with smaller quantities (1 to 2%) of other deep water fishes like Myripristis sp., Peristedion sp., Cubiceps natalensis, Epinnula orientalis, Chlorophthalmus sp., Polymixia nobilis, Bembrops caudimacula, Lophiodes lugubris, Antegonia rubescens, Chascanopsetta lugubris, Saurida undosquamis, Uranoscopus sp., and also deep sea crabs were obtained. The grounds which are located between depths of 183 to 293 m off Quilon were visited by the vessel during the different seasons as a part of the regular training programme. During the period under report the vessel has conducted bottom trawling operations at the above said 4 deep water grounds for a total duration of 77.5 fishing hours which yielded a total deep sea mixture of about 9481 Kg. This forms 5% of the total fish catches from the above grounds which includes the deep water lobster *Puerulus sewelli* (Pillai and Ramachandran, 1972) and deep water prawn catches (Perumal et al, 1972).

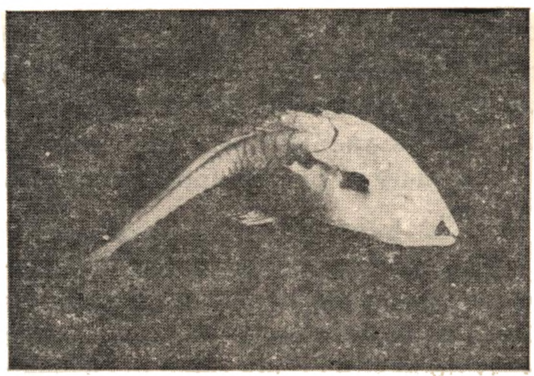

Fig. III. Peristedion sp.

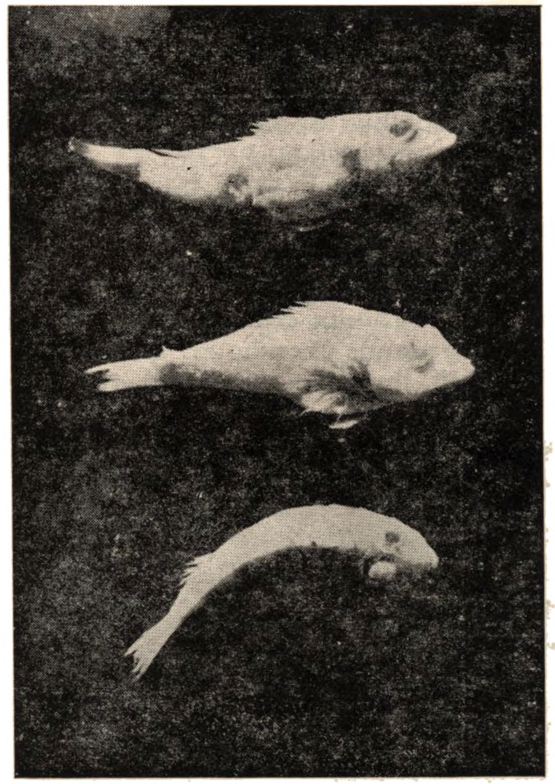

Fig. IV. Centropristis sp.

Eventhough certain indications on the availability of the deep sea mackerel Emmelechthys nitidus' RICH along the continental slope off the SW coast of India have been given earlier by the

Indo-Norwegian Project, it seems that no published work is available on the distribution and seasonal variations of this particular species. (It would not be out of place to mention in this connection that the trade markname 'Deep sea mackerel' was given to this species of Emmelechthys for the first time by the INDO-NORWEGIAN PROJECT.) With a view to achieve this goal, clear cut instructions were given to the skipper of the vessel so as to incorporate details regarding the catches of the predominant varieties of fishes in the deep water grounds eventhough a large % of the fish thus caught were generally thrown overboard inorder to save precious storage space for economically

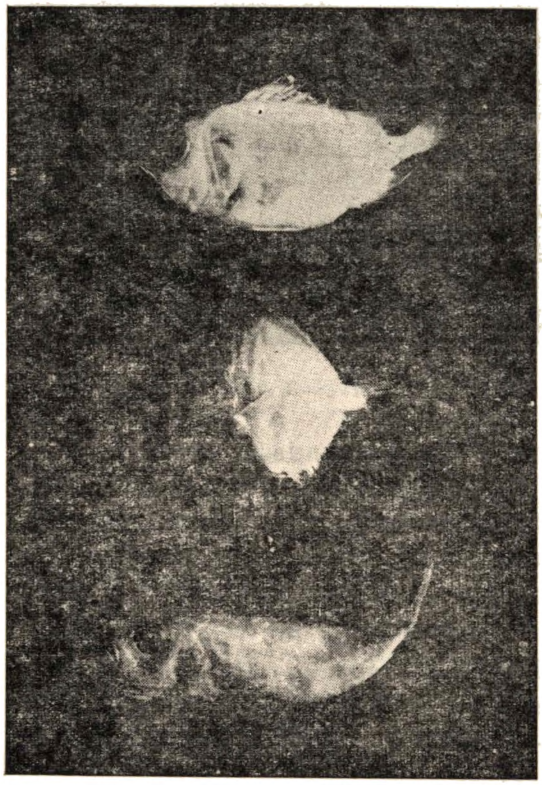

Fig. V. 1. Myripristis kaianus
2. Antigonia rubescens
3. Priacanthus sp.

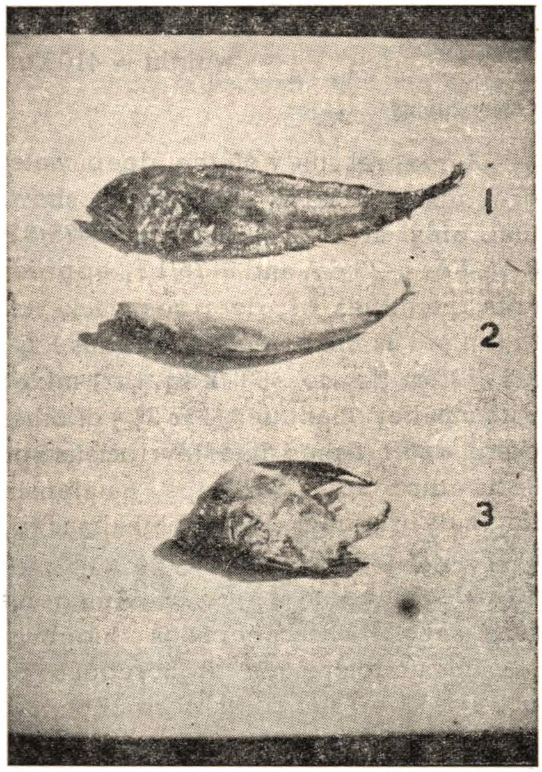

Fig. VI. 1. Chascanopsetta lugubris
2. Saurida undosquamis
3. Histiopterus spinifer

important varieties of fish especially the deep sea lobster. Inorder to explore the commercial possibilities for this variety of fish the catches were filletted on an experimental basis and released in the market by the Indo-Norwegian Project.

The present study more or less substantiates the earlier finding made by the Indo-Norwegian Project that "fish of fairly good size do not seem to be found in deeper waters". It has been observed that the dominant species represented between 100 to 150 fathoms along the upper continental slope covered by the above mentioned grounds are the 'deep sea mackerel' (Emmeleychthys sp.) and the 'Diamond fish' (Myripristis sp.) as also reported earlier by the Indo-Norwegian Project.

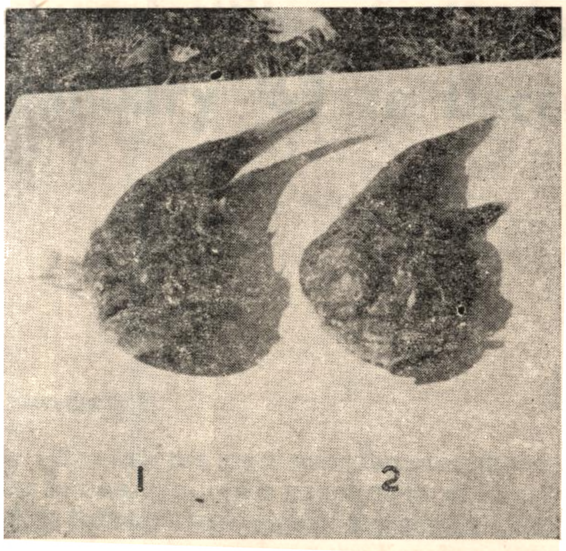

Fig. VII. 1. *Lophiodes lugubris*
2. *Uranoscopus sp.*

It was observed that at all the above mentioned fishing grounds, the sea bottom was predominantly constituted of loose mud mixed with plenty of shells.

Acknowledgement

The authors are grateful to Shri M. C. Perumal, Director, Central Institute of Fisheries Operatives, Cochin for his guidance and helpful suggestions. Thanks are also due to Shri K. Balan, Skipper, 'BLUE FIN' but for whose co-operation the study would not have been possible.

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Some trends observed in the deep-sea lobster catches of the vessel "Blue Fin" during the period January '69 to December '71

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Introduction

During the past two decades there have been sporadic attempts to explore the lobster resources especially the deep-sea lobster along the Kerala coast. Even as early as 1901 (Alcock, A) the occurrence of deep-sea lobster off the Travancore coast has been recorded. This was later confirmed during the year 1959 (John and Kurian) on the basis of data collected by the Research Vessel "CONCH" of the University of Kerala. Later in 1968 the reports of the INP vessels and the Soviet Research Vessel 'ACADEMICIAN KNIPOVICH" (1971) also supported the same view. Certain biological aspects of some of the species were worked out and presented during he Symposium on Crustacea (J. B. Holthuis, 1966) and the symposium on he living resources of the seas around ıd ia (P. V. Rao and M. J. George, 1968), ilas (1969 and Joseph (1972) have in- licated the probable distribution and density of the deep-sea lobster *Puerulus sewelli* Ramadan based on the data of the exploratory survey vessels of Indo-Norwegian Project and Deep Sea Fishing Station.

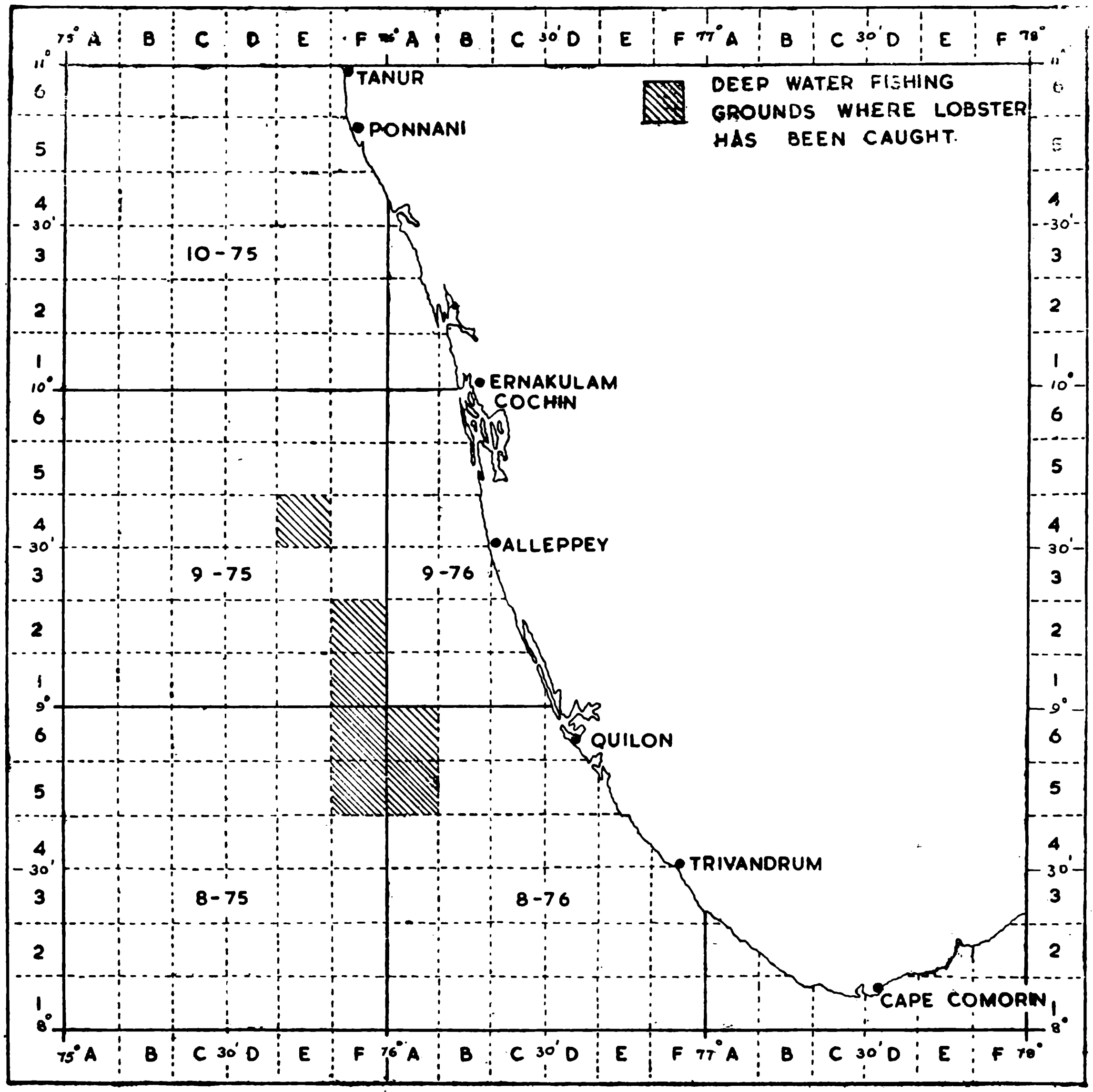
The total value realised from export of frozen lobster tails from India has shown a steady increase from Rs. 2,26,362/- in 1962 to Rs. 1,09,41,746/- in the year 1971. Eventhough the total quantity exported shows a slight fall when compared to that of the previous year, the increase in the value realised clearly indicate the importance of this particular item from the export point of view.

Most of the reports available on the subject are based on limited data pertaining to a particular season and collected by different types of vessels using gear of different specifications. Under these circumstances it would be worthwhile examining certain trends observed in the deep-sea lobster catches of an individual vessel which was engaged in fishing operations during the different seasons at a selected number of fishing grounds using certain standard types of gear and thereby making comparison of catches easier.

Craft and Gear

The vessel "BLUE FIN" operated by the Central Institute of Fisheries Operatives, Cochin was engaged in regular trawling operations during the years 1969, 1970 and 1971 as a part of the training programme. The vessel is fitted up with engines of 600–650 BHP. The trawling winch has a capacity of 1200 metres of 14 mm wire rope. Fitted up with modern electronic navigational

FIG-1



and fish finding devices, the vessel can remain out in the sea continuously for seven days.

The following type of fishing gear was used by the vessel in the fishing grounds under survey:

600 meshes deep-sea trawl net (garfil)
Rectangular Otter board-2.23 × 1.18m.
weight = 410 kg.

Data and Methods

The data used has been taken from the fishing log of the vessel which gives details regarding the operations and also the catch. The catch/Hr of trawling has been worked out for individual hauls on which is based the monthly and yearly averages.

Observations

Out of a total of 68 fishing grounds visited by the vessel during the years 1969, 1970 and 1971, seven grounds yielded the deep-sea lobster *Puerulus sewelli* Ramadan in the depth range 183 to 293m. The catch per hour of trawling based on a monthly average for individual grounds show a comparative maximum of 1430 kg/Hr at ground 8-75/6 F located off Quilon (depth range 192 to 293 m) during the month of February, 1971 and a minimum of 45.4 kg/Hr at ground 9-75/4 E located off Alleppey (depth range 247 to 256 m.) A comparative study of the catch/Hr of trawling for deep-sea lobster *Puerulus sewelli* Ramadan at the different grounds show a decreasing trend both towards north and south of Quilon in confirmation with the findings of Joseph (1972). This trend in catches is quite evident from the catch/Hr based on monthly averages for a three year period for the grounds 8-75/6 F (635.8 kg/Hr) and 8–76/6 A (316 kg/Hr) both located off Quilon. During the three year period the maximum catch/Hr for individual haul (2658.4 kg/Hr) was recorded at ground 8-75/6 F during the month of February, 1971.

An overall review of the catches for the different months in a year show that in the grounds 8-76/6A, 8-75/6F, 8-76/5A and 8-75/F located off Quilon, the maximum catch/Hr for deep-sea lobster was recorded during the months February, March, April, May and October. A survey of the monthly catches for the different grounds during the three year period shows that the catches were comparatively high during the months March, 1969 (26920 kg), April, 1969 (33518 kg), May, 1969 (16237 kg), February, 1970 (14842 kg), March, 1971 (23363 kg.) and April, 1971 (14581 kg). The vessel caught a total of 1,75,994 kg of deep-sea lobster *Puerulus sewelli* Ramadan during the period under review.

The catch composition shows that at grounds 8–75/6F, 8–75/5F, 8–76/5A and 8-76/6A located off Quilon the catch was predominantly constituted of *Puerulus sewelli.* (50% to 97%) Apart from a small percentage of deep water prawns, other varieties of fishes which were found mixed with the deep-sea lobster catches were represented by the following species:

1. Emmelichthys sp.
2. Chlorophthalmus sp.
3. Centripristis sp.
4. Cubiceps sp.
5. Epinulla orientalis.
6. Bemprops caudimacula.

Out of the above the Emmelichthys sp. was the most dominating species in the deep water catches. The sea-bottom at all the above said grounds was predominantly muddy with plenty of shells.

The average catch/Hr of trawling for *Puerulus sewelli* for all the grounds together varies between 103 and 451 kg/Hr. The average catch/Hr for all the grounds together calculated on the basis of monthly and yearly averages comes to about 236 kg/Hr. The catch/Hr recorded by the Soviet Research Vessel "ACADEMICIAN KNIPOVICH" for *Puerulus sewelli* in the southern part of the slope of the west Indian shelf at depths of 200 to 320 m was 100 kg/Hr of trawling. It is quite evident from the present study that the catch/Hr of trawling for *Puerulus sewelli* for the vessel "BLUE FIN" was comparatively high at the above said grounds during the period January, 1969 to December, 1971.

Acknowledgement

The authors wish to express their sincere thanks to Shri M. C. Perumal, Director, Central Institute of Fisheries Operatives, Cochin for his keen interest in the present study and also for his helpful suggestions. Thanks are also due to the skipper and crew of the vessel "BLUE FIN" for making proper records of operation and catch from time to time.

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SOME TRENDS OBSERVED IN THE PRAWN CATCHES OF THE VESSEL 'BLUE FIN'

DURING THE PERIOD JANUARY TO DECEMBER 1971

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Introduction

The value realised from India's export of Marine Products show a rise from Rs. 3 crores in 1960 to Rs. 36 5 crores in 1971, a twelve fold increase during the past decade. If this trend continues, with appropriate development at the different levels, it is envisaged that the same could be raised to Rs. 60.9 crores by the end of the IV Plan period. The value realised from the export of prawns (frozen, canned and dried) accounts for more than 70% of the total export earnings from marine products. This is indeed the major reason for the present dependency of the sea food industry of India on the availability of exportable prawns. Of late there have been reports on certain disturbing trends noticed in prawn fishing, especially at the different fishing grounds located in and around Cochin. At present the Agencies concerned with research, exploration and development are holding discussions in order to make a proper assessment of the present status of the fishery and advise the industry accordingly.

Under the abovesaid circumstances it would be worthwhile examining certain trends observed in the prawn catches of an individual vessel which was engaged in regular fishing operations throughout the year at a selected number of fishing grounds using certain standard types of gear and thereby making comparison of catches easier.

Craft and gear

The vessel 'Blue Fin' operated by the Central Institute of Fisheries Operatives, Cochin, is a 93' modern fisheries training vessel built in Sweden. The vessel is fitted up with a 600–650 H. P. Alpha 406–26 VO type diesel motor. The fishing winch is centrally positioned, trawl cum purse seine winch of Rapp's type STW 2–5 with cargo drum and two gypsies. The capacity of each drum is 1500 m. of 12.4 mm. wire rope. There are two trawl gallows fitted aft on deck. The refrigerated fish hold has a capacity of about 48 tons and is maintained at a temperature of about 0°c. The vessel can undertake continuous fishing upto 7 days. Fitted up with modern electronic Navigation, Communication and Fish finding equipment such as RADAR, RDF, Echo Sounder, Sonar, Radio Telephone etc. the vessel is mainly used for imparting practical training in the different aspects of fishing.

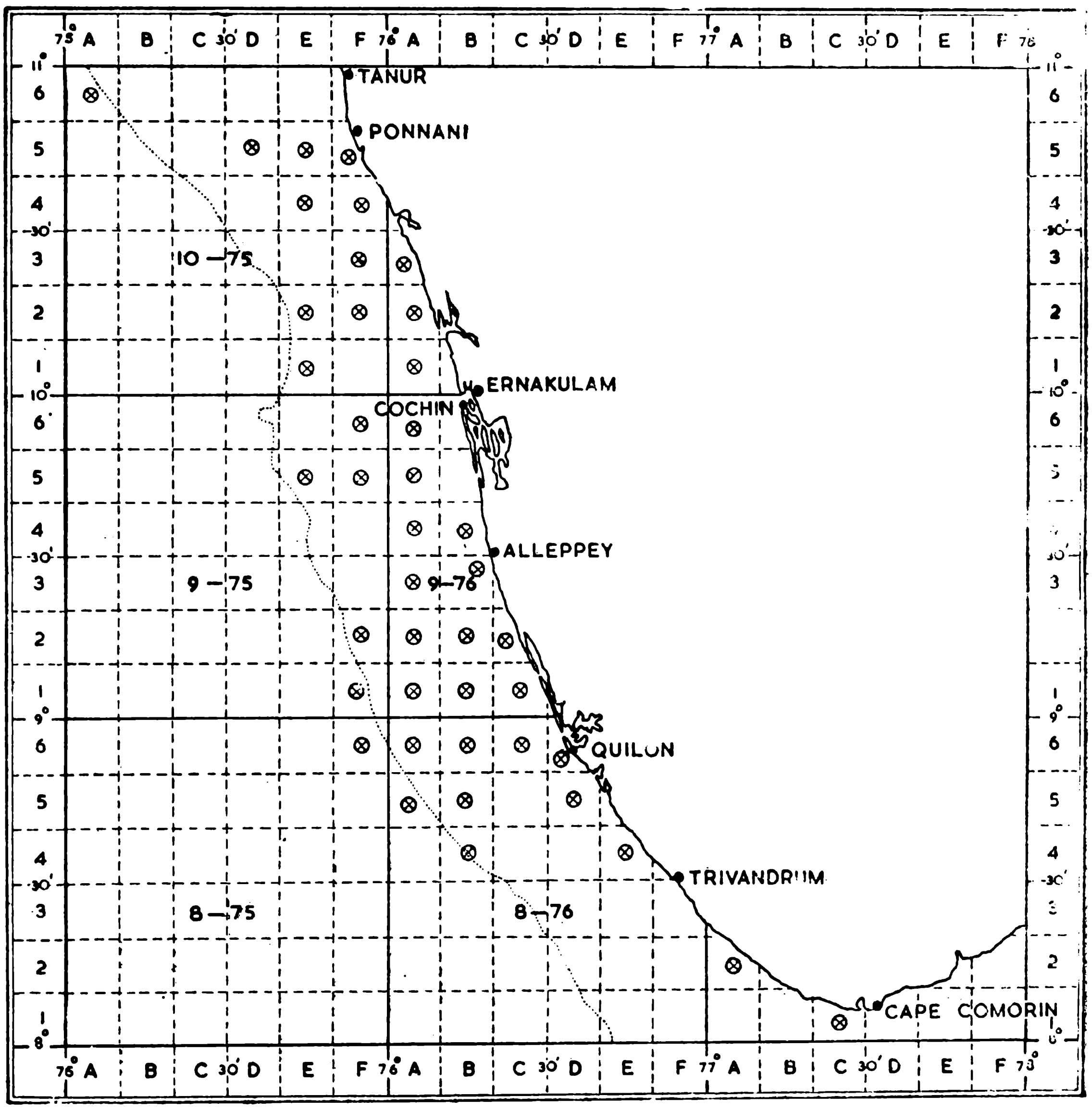
The following types of fishing gear were used by the vessel during the period under review.

1. 45.75 m. shrimp trawl (Nylon)
2. 45.75 m. shrimp trawl (garfil)
3. 31 m. Fish trawl (garfil)
4. 19 m. Aberdeen trawl (garfil)
5. 33 m. Swedish fish trawl (Nylon)
6. 30.4 m. Shrimp trawl (Cotton)

The otterboards used were of the following two types:

1. V–shaped otterboard
   weight = 147.7 kg. 1.88 x 1 08 m.
2. Rectangular otterboard
   Weight = 410 kg. 2.23 x 1.18 m.

FIG – I-A



Data and methods

A separate fishing log is maintained by the vessel wherein the data pertaining to the type of fishing, type of gear used, grounds visited, gear fishing depth, nature of the sea bottom, duration of the hull, catch composition of individual haul etc. are entered as and when the fishing operations are conducted. This paper is based on the data entered in the fishing log of the vessel which is maintained up-to-date. The data has been analysed in a systematic way, first hull-wise then groundwise, monthwise and yearwise and the catch/hour has been worked out with respect to individual hauls. Wherever comparisons have been attempted, special care has been taken to see that the type of gear used and the duration of the hual are more or less the same.

Fig. 1 – A, B & C shows the location of the different fishing grounds covered by the vessel 'Blue Fin' during the period under survey. Out of a total of 68 fishing grounds visited during the years 1969, 1970 and 1971, 58 grounds yielded prawns. Out of these, 5 grounds were located outside the 100 fathom line and the rest within the shelf.

Observations

Total catch: An overall review of the total fish catch shows that approximately 3%, 8% and 3% of the total catches for the years 1969, 1970 and 1971 respectively were made up of prawns. The total prawn catch of the vessel for the three-year period was approximately 25,050 kg. Out of this, deep water prawns (beyond 100 fathoms) constituted only about 380 kg. ie. about 1.56% of the total prawn catch. The maximum prawn catches were recorded during the month of August 1970 (5944 kg.) from shallow water fishing grounds (depth range 16 to 49 m) between Trivandrum and Quilon.

During the year 1969 comparatively better catches were obtained during the months July (2275 kg.), November (3849 kg.) and December (1590 kg.) whereas in 1970, similar catches were obtained during the months August (5944 kg.) and October (2878 kg.). During the year 1971, the prawn catches were poor when compared to the previous two years with maximum catches in the month of May (1143 kg.) and June (1036 kg.)

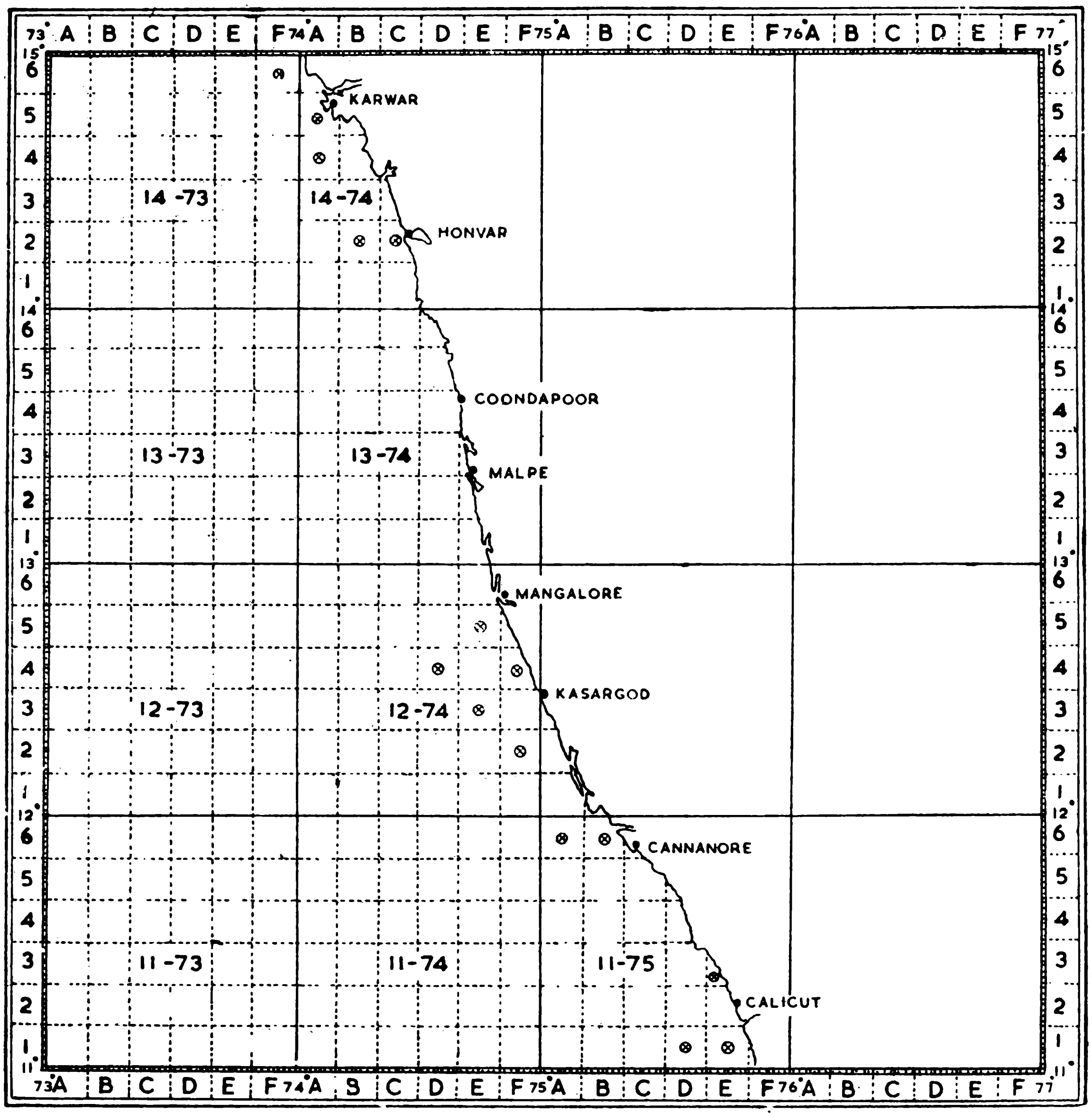
Catch per hour: The prawn catch/hour worked out for individual grounds show large variation from month to month and also from year to year. At ground No. 9–76/2B the yield was rather poor in February (9.2 kg /hr.) whereas in April it started increasing to 24.2 kg./hr. and reached a maximum in August (45 5 – 159.3 kg /hr.). In October once again the catch/hr. showed a sudden fall to 26.4 kg. and slowly started decreasing to 4 4 kg. in November. This is more or less the general trend observed at all the shallow water fishing grounds (16 m. to 46 m) between Cochin and Trivandrum. Catches made during the same month show an increasing trend towards the southern region especially at grounds located nearer to Quilon. During the month of August 1970 during which time comparatively higher catch/hr. was recorded, the maximum catch/hr. (180.3 kg.) was recorded for the shallow water ground (32–36 m.) located north of Quilon. The values show a downward trend toward nothern grounds located nearer to Alleppey (78 kg./hr.)

During the year 1969 the maximum catch/hr (165.15 kg.) was recorded at the shallow water fishing grounds (16–26 m.) located between Ratnagiri and Bombay, during the month of November. In 1970 the shallow water fishing ground (36–40 m.) off Quilon recorded the maximum catch/hr. (181.6 kg.) in the month of August. In 1971 the maximum catch/hr. showed a decline towards 97.7 kg. recorded at the shallow water fishing ground (27 m.) located slightly north of Quilon in the month of June.

In general it is fund that the sea bottom at all the abovesaid grounds was predominantly muddy.

As regards the deepwater grounds (beyond 100 fathoms) the prawn catches were, in general, very poor. The depth range at these grounds which were located between Trivandrum and Quilon were approximately 170–293 m. The

FIG 1-B



catch/hr. recorded for these deep sea prawns were comparatively low varying between 0.75 kg. and 25 kg. The sea bottom at the deep water grounds was found to be composed of a mixture of mud and shell.

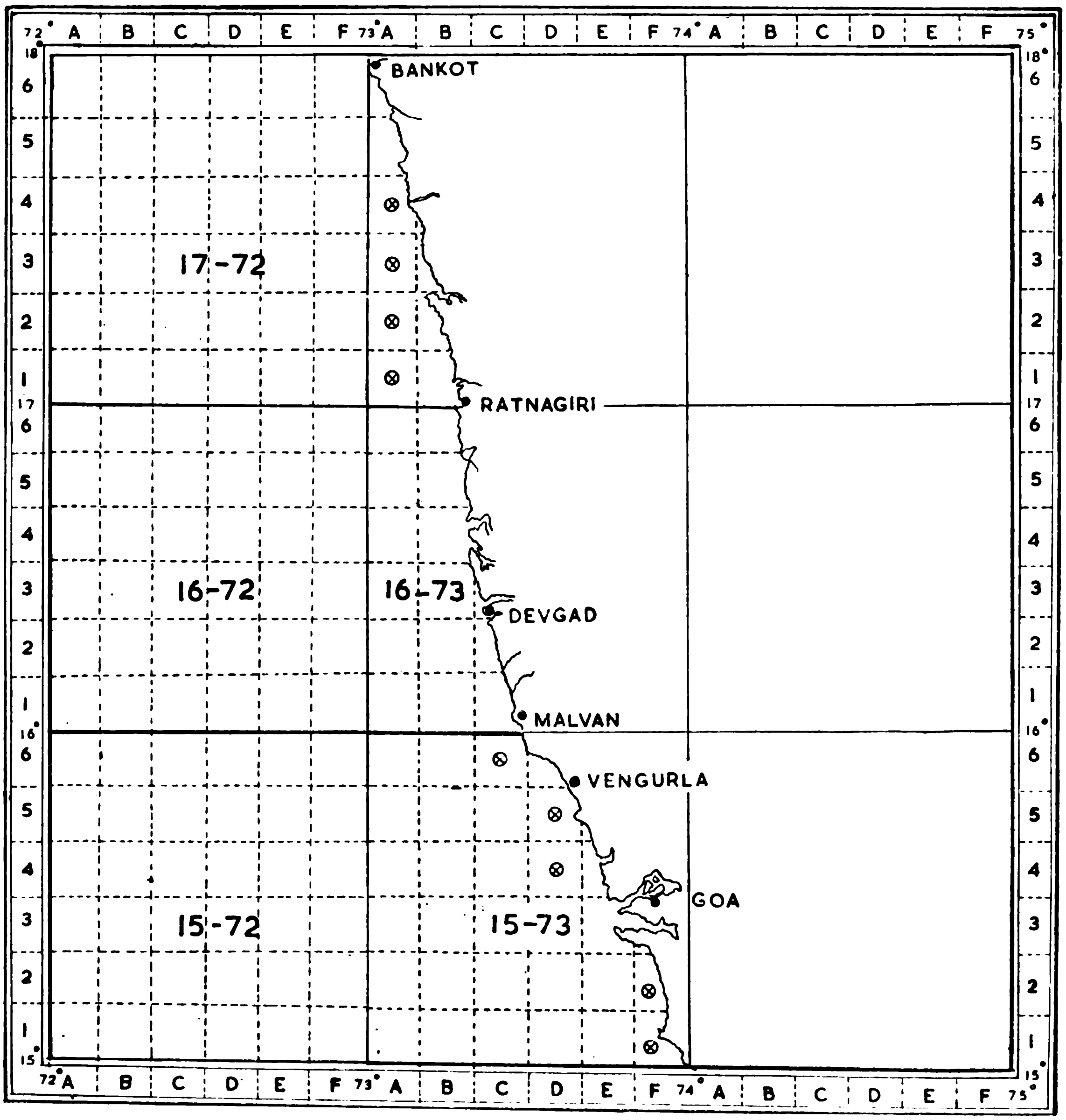
Major varities

The prawn catch in general was found to be composed of the following major vaieties :

Shallow water grounds:

1. Penaeus indicus
2. Metapenaeus affinis

FIG-1-C



3. Parapenaeopsis stylifera
4. Metapenaeus dobsoni

Deepwater grounds:

1. Parapandalus sp.
2. Heterocarpus sp.
3. Solenocera hextii
4. Panaeopsis rectacutus
5. Plesionika sp.

The catch composition of big, medium and small varieties of prawns for the different years is as follows:

Size	Catch composition in kg. in different years		
	1969	1970	1971
Big	245	840	2265
Medium	5025	5380	1575
Small	2675	4939	1134

Conclusions

The average catch/hr. for individual years show a fall during the year 1971. From an average of 35.90 kg /hr. in 1969 the figure for 1970 showed a slight increase viz. 40.29 kg./hr. But a fall in the average catch/hr. for the year 1971 (19.5 kg./hr.) shows that there has been a certain amount of fluctuation of the stock especially because of the fact that most of the grounds visited during the year 1971 and the gear were more or less the same as those operated in the previous two years.

The groundwise catches show that the shallow water grounds between Ratnagiri and Bombay (25-26 m.) and between Trivandrum and Quilon (16–49 m.) and off Ponnani (10 m.) yielded comparatively good catches, especially during the months July to November. The seasonal variations observed in the prawn catches suggest a probable maximum during the months June–September and a minimum from November to February at most of the shallow water fishing grounds along the Kerala Coast. Towards north, between Ratnagiri and Bombay (25–26 m. depth) comparatively good catches were obtained during the month of November. The deep water grounds in general were comparatively less productive.

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EXPLOITATION OF MARINE FISHERIES RESOURCES IN INDIAN WATERS

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Introdnction

According to experts, India can produce about 11 to 13.7 million metric tonnes of fish a year. But the actual production is somewhere around 1.5 million metric tonnes indicating an unexploited quantity of about 9.5 to 12.2 million metric tonnes. The value of marine products exports has risen from Rs. 3 crores in 1960 to Rs. 36.5 crores in 1970-71. According to a recent survey of India's export potential of marine products conducted by the Indian Institute of Foreign Trade under the programme of USAID, with suitable efforts the abovesaid figure can be stepped up to 60.9 crores by 1973-74 and to 118 crores by 1978-79. The report also said that with a vast coast line extending over 5000 kms. and a fishable potential of about 13.7 million metric tonnes, India can surpass some of the leading maritime nations of the world by adopting a systematic exploration of its resources.

Present Exploitation

Most of the fishing operations around Indian waters are being carried out within a narrow belt of about 10 - 15 miles while the offshore and deep sea waters bevond the territorial waters are mostly exploited by the fishing fleet of U.S.S.R., Japan and other countries. In general, the fishing activities, as is evident from records, is mostly concentrated along the west coast particlarly in and around Cochin, which accocnts for about 3/4 of the total marine fish catch of the country. Mechanisation of fishing boats has been one of the methods introduced with a view to increase the range and duration of fishing crafts. Mechanisation was initially introduced during the first Five Year Plan by the commissioning of about 650 fishing boats. The number rose to about 2000 at the end of second plan period and to about 5000 by the end of Third Five Year Plan. The Fourth Plan envisaged a further addition of about 5500 boats thereby raising the total number of mechanised boats to about 13,500 by the end of the plan period.

While the inshore areas are being heavily exploited by the country crafts and the mechanised boats mentioned above, the wealth of the offshore and deepsea waters remain yet to be exploited by employing suitable craft and gear. Partly this could be done by building up a fishing fleet with medium and lsrge vessels equipped with modern navigational and fishing aids and partly by the introduction of diversified fishing methods and suitable gear. We are rightly on the threshold of such a venture.

During the Fourth Five Year Plan, the Government of India has planned to introduce about 300 medium and large vessels for exploiting the offshore and deepsea fishery resources in Indian waters. There are at present a total of about 30 fishing vessels of above 17.5 OAL operated from the different Indian ports engaged in commercial and exploratory fishing around the Indian waters. The small mechanised boats are mainly intended for inshore areas and the medium as well as large vessels for exploiting the offshore waters. The introduction of larger vessels of above 30 m. OAL could be considered only on the basis of positive results to be obtained from the exploratory surveys of the deeper waters.

Although the total marine fish landings have shown an upward trend from 6,84,000 tonnes in 1961 to about 1 million tonnes in 1971, the annual growth rate during the dacade has been rather insignificant. This has been mainly due to the under-exploitation of the offshore and deepsea resources. While reviewing this problem, the following important factors will have to be considered.

Suggestions for the future

In India though mechanisation of fishing vessels is being implemented at a fast rate, we have not introduced any modern methods of capturing fish other than the basic methods of bottom trawling. We have ourselves to organise other methods of catching fish viz. long lining, purse-seining and gill netting in order to diversify this fishing effort. In fact, the pelagic waters were not at all exploited properly due to lack of enthusiasm on the part both of governmental and private agencies in diversifying the present fishing methods. The experience of purse-seiners operated by the Indo-Norwegian Project shows that purse-seining would be ideal for the effective exploitation of the commercially important pelagic fish concentrations. It is indeed disheartening to note that no serious attempt has been made towards finding out the effectiveness of pelagic and mid water trawling in the Indian waters. A large number of small and medium vessels which are at present engaged in bottom trawling can certainly consider a change for one of the above mentioned methods of fishing and thereby making an earnest attempt to increase their present catches.

The majority of private operators may refrain from trying a similar step because of the fact that prawns, which now accounts for more than 70% of the total export earnings of marine products could be exploited only by using suitable bottom trawls. This may be perhaps the most important reason for the fast depletion of the inshore belts which accounts for more than 95% of the total production. Eventhough the country has the largest coast line in the world, it accounts for a total fish production of only around 2 million metric tonnes out of the world total of over 68 million tonnes. As has been already pointed out by the expert committee on prawn fishing under the National Commission on Agriculture, the shrimp fishing boats will have to diversify their activities in catching other commercially important fishes so that the fall in income owing to larger number of boats will be made good by income from other types of fishes. A similar step would certainly require more organised distribution and marketing facilities for the commercially important fishes other than prawns.

In India today about 97% of the total catch is being handled by private traders. It is hightime that effective steps are taken to streamline the marketing of fish in the internal markets. Once a similar set up is worked out and put into operation, the present dependency of the industry on the availability of exportable prawns alone, could be certainly brought down. Let us hope that both governmental and private agencies would appreciate the need for a thorough reorganisation of the internal marketing system, which, to a certain extent, can solve the present crisis with regard to the economics of operation of our vessels. There is no doubt that diversification of the present fishing methods and introduction of more organised distribution and marketing facilities within the country will certainly pave a way to the betterment of the fishing industry as a whole.

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ON TWO LARGE SPECIMENS OF SAW FISH '*PRISTIS MICRODON*' LATHAM CAPTURED OFF COCHIN

Landings of medium sized and large specimens of saw fishes are not uncommon along the Kerala coast. However, the specimens under report seemed to be worth mentioning due to their notable size and weight. They were caught off Cochin by 'Blue Fin', training-*cum*-fishing vessel of the Central Institute of Fisheries Operatives, Cochin, during regular fishing cruises on 16-2-1972 and 21-2-1972 respectively.

The 93' training-*cum*-fishing vessel is fitted with modern sophisticated electronic navigational, communication and fish finding equipment. Fitted up with 600 BHP Alpha engine, the vessel is usually engaged in bottom trawling. The refrigerated fish hold has a capacity of about 48 tons. The vessel which is used for imparting the necessary sea training for the trainees of the institute can remain out in the sea for a period of 7 days at a time.

The specimen number 1 was caught at a depth of 15 fathoms between 0630 and 0830 hrs on 16-2-1972 and the specimen number 2 was caught at a depth of 14 fathoms between 1230 and 1700 hrs, on 21-2-1972. Both these specimens got trapped in the 450 meshes trawl net (garfil). It was reported that both the saw fishes were hauled on board the vessel with considerable difficulty and they were found struggling for a few hours by striking sideways with their formidable snouts. Immediately after the capture they attained a pale red colour which gradually faded. The colour on the back of the specimens was greenish grey. The specimens which were brought ashore intact were later identified as females of *Pristis microdon*. The authors were able to collect the following morphometric characteristics pertaining to individual specimen.

TABLE I

		Specimen No. 1	Specimen No. 2
Total length	..	538 cm	543 cm
Basal lengtn of pectoral	..	62 ,,	84 ,,
Basal length of first dorsal	..	46 ,,	51 ,,
Basal length of second dorsal	..	30 ,,	32 ,,
Height of first dorsal	..	62 ,,	69 ,,
Height of second dorsal	..	59 ,,	63 ,,
Height of caudal (upper lobe)	..	86 ,,	91 ,,
Height of caudal (ower lobe)	..	49 ,,	54 ,,
Distance between filrst dorsal and second dorsal		61 ,,	64 ,,
Distance between eyes	..	29 ,,	31 ,,
Distance between nostrils	..	23 ,,	28 ,,
Length of Rostrum	..	115 ,,	114 ,,
Width of base of Rostrum	..	23 ,,	27 ,,
No. of teeth on Rostrum on each side		17	17
Wt. of Rostrum	..	6 kg	7 kg

The specimens were reported to have estimated weights of 434 kg and 442 kg respectively as estimated and recorded at the Indo Norwegian Project, Ernakulam.

It was observed that numerous spots were pronounced on the rostrum and formed a mosaic-like structure in both the specimens.

The auhors express their deep gratitude to Shri. M. C. Perumal, Director, Central Institute of Fisheries Operatives, for his valuable suggestions and permission to publish this note. We also express our appreciation to the skippes S/Shri K. Balan and K. V. Krishnan Nair and the crew for their active interest and team spirit in catching the specimens and bringing them ashore intact.

Central Institute of Fisheries Operatives, Cochin, *March* 25, 1972.

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DEVELOPMENT OF FISHERIES EXTENSION PROGRAMMES IN INDIA

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Introduction

THE main aim of research and exploratory organisations is to locate resources and find means to gather and distribute them with increasing effectiveness. This aim can be achieved only if there is appropriate machinery to reach or extend the knowledge to the actual operators in the field. Artisanal fishing which is stretched all along the coast accounts for the major share of the fish production. This section of the fishing consists of mostly very small units and are operated by men who in many cases are not very literate. But as the efficiency of a major sector of the fishing depends on these men, need for devising appropriate machinery capable of extending the knowledge on latest techniques to these categories of personnel assumes great importance. Developing means to disseminate knowledge in the latest techniques in production, processing and distribution for the operators of middle, distance and long distance fishing vessels and marketing agencies is of no less importance, though in this case, the machinery can be less complex and a discourse between the research and exploratory organisations can almost be continuous. But all the same need for establishing a means for continuous exchange of information is of equally great importance.

There is no dispute regarding the need for having effective extension service; but developing a suitable type of extension service which will suit the requirements of all sectors of the fishing industry not only to impart information but also to convey their requirements back to the research/exploratory organisations, requires careful and detailed planning. Highly valuable and useful information is being collected by the various exploratory/research organisations both in the public and private sectors. Well organised fisheries extension programmes can play a major role in spreading this valuable knowledge to the operators at different levels. The basic requirement for improving such fisheries is to carefully analyse their production and distribution processes. Special emphasis should be given to problems which are directly connected with the basic production processes and while presenting the results, care should be taken to see that they are spread in a way which is understandable to the common fisherman so as to enable him to put the same to practical use.

Organisation

A research/exploratory organisation and an extension service have to work side by side with maximum co-operation eventhough the two types of work are entirely independent of each other and hence are to be handled by two different and independent agencies. In fact the extension service should be in a position to collect the results of research/exploratory studies, process them and recast them in such a way to suit the respective capacity of small fishery units and individual fishermen working under different environmental and management conditions. The reverse type of passing on the information from the fishermen to the research worker should be also made possible through a well organised extension service. In both these respects an extension agency should be capable of identifying the technical needs of the fishermen and provide them with the required information at the appropriate time.

What should be the relation between the fisheries universities and extension service ? It can differ according to the type of educational institutions and also to a certain extent on the historical background of similar universities in each country. For example in U.S.A., the extension service is directly connected with the Universities which are responsible for research, teaching and extension whereas in Japan the fisheries universities have little direct relation with the extension service.

While organising a fisheries extension service the following points assume special significance:

1. Organisation of the required number of personnel for doing extension work.
2. Training of the extension workers.
3. Planning, programming and supervising/directing the extension service.

In India, although the basic need for a well organised extension system has been widely accepted, lines on which this aim could be achieved are not clearly indicated. The preliminary step seems to have been the creation of 10 regional extension units mainly for demonstrating improved techniques. Somehow or other, it is observed, these units were discontinued towards the end of the III Plan Period. Later a Central Extension Cell has been organised in the Ministry and allied Research Organisations which are at present functioning under I. C. A. R. Similar extension cells have been found necessary for the two exploratory organisations under the Government of India viz. Deep-sea Fishing Station, Bombay and Integrated Fisheries Project, Cochin. In spite of the above developments, the extension work did not gain sufficient momentum. The Government of India have stressed the importance of developing this branch during the V Plan Period and have already given the necessary directives for the reorganisation of the scheme with a view to achieving the very purpose of a fisheries extension programme at the National level.

The following principal methods could be adopted for spreading the required technical know-how to the concerned operative personnel at the basic level especially among the fishermen who form the backbone of an artisanal fishery set up.

1. *Field Extension Services:* This can be carried out with the help of mobile teams equipped with film, slides and demonstration units and display materials. Units of this nature should be well equipped for demonstration of various techniques and should have a compliment of trained staff on a unit basis. The staff should be made responsible for collecting the required information from Research / Exploratory organisations and transmitting the same effectively to the basic level in the most appropriate form.

In India, the ICAR is attempting to implement a similar scheme through the Agricultural Universities which were assigned direct responsibility on extension work. Of late, it is understood that these institutions would be in a position to organise demonstrations etc. in and around the Institute premises, within certain limits. In order to meet the extension requirements throughout the country, fisheries extension centres will have to be organised on a regional basis. While establishing new centres special care should be taken to equip them with mobile extension units in order to cover a wider area. The effectiveness of operating a similar scheme would also depend on the use of visual and demonstration aids such as slide projectors, cine projectors, photographs, working models etc.

2. *Publications:* Publications meant for the above purpose should be easily understandable to the ordinary fisherman preferably in simple regional language with supporting diagrams wherever possible. Special care should be taken to include only matter relating to the practical aspects of specific problems which concern individual fishermen or small groups who have common problems. These may be released in the form of pamphlets and news letters after taking into consideration the nature of information, whether it is of a periodic nature or otherwise etc. Publications may be also released in the form of Research and Administrative publications, which are basically meant to cover administrators, processors etc.

3. *Consultancy Services:* According to this method of spreading information, experts drawn from the different disciplines would be made available to provide information and guidance to problems faced by small groups or organisations, by a central agency, who will also suggest and advise on the availability of suitable expertise.

In India, based on the recommendations of the Central Board of Fisheries (1970), a proposal to organise a fishery consultancy service was considered by the Ministry of Agriculture and a programme was drawn up by the Ministry along broad specifications, as mentioned above.

Requirements

The prime necessity for the implementation of a well organised Fisheries Extension Service would be the availability of sufficient number of trained technical personnel to supervise / execute the above work at the appropriate time. In India, at present, there is no central agency which has adopted a uniform system of training of extension workers after taking into consideration the requirements of the profession.

Broadly our requirements of trained technical skill to carry out extension work in the field of fisheries could be brought under two important heads: viz. (i) extension workers for the Marine Fisheries, (ii) Extension workers for the Inland Fisheries. A similar classification is necessary because of basic difference in the methods employed at the production level in the two branches of fisheries.

The actual requirement of the above said two categories of personnel would depend on the area to be covered - to be more precise, the number of fishermen or small fishery units to be contacted - under the two broad divisions.

The Report of the Working Group on the Fisheries Fifth Five Year Plan, while estimating the total fishermen manpower available in India, said "The Fishermen manpower available in India had been estimated at one million, some time back. The figures from latest census are not available but it is likely that the number has increased appreciably ". The working group (sub-group) stressed the essentiality of extension services for the fishery industry and recommended "the setting up of an extension wing to the Fisheries Division in the Department of Agriculture and the strengthening of the extension facilities in the States. It is envisaged that the organisation will be of particular service to the 1208 community development blocks in the various states, now implementing intensive fisheries development programme, and to 197 community development blocks operating the fisheries scheme under the "Applied Nutrition Programme".

From the above recommendations it is clear that a total of 1,405 community development blocks located in the various states can act as units of a Central Agency for spreading technical knowledge at the basic production level. Once all these units are established with the required facilities in the form of buildings, transportation facilities and related publicity aids, the most important requirement would be the availability of trained personnel to work as extension workers and also to supervise the work of individual units. A relevant recommendation made by the Working Group (Sub-group) on 'Fisheries Fourth Five Year Plan' is worth mentioning in this context. The Sub Group recommended that "the concerned Central Organisation should have an efficient extension service consisting of experienced officers of suitable status who are receptive to new methods, can acquire the skill in a reasonable period of time and demonstrate the same to the industry". According to the Sub-group, the extension workers should be at three levels viz.

1) Subject matter specialists at the Centre who have distinguished themselves in evolving new techniques.
2) State level specialists.
3) Extension Operatives.

Calculating at the rate of a minimum of 3 extension workers to be attached to a single unit, the total requirement of extension workers who will function as a link between the fishermen and the specialists at the State / Central levels would be around 4215. Taking the total number of personnel engaged in the fishing industry at the production level to be around 1.5 million (approximate figure), the total requirement of around 4200 extension workers mentioned above is only a basic minimum as there would be only one extension worker to serve every 357 Nos. of individual fishermen, who are to be directly benefitted by this programme.

Unless the various state governments get adequate number of extension workers trained in the special technique to a degree of efficiency which can be demonstrated successfully in the field, the abovesaid programme will certainly become ineffective. One important reason for the abovementioned gap is lack of suitable training programmes to get the extension workers trained to the required level. This shows the immediate necessity of starting a centralised training programme through one of the Central Institutions which has the required facilities in the form of staff and equipment. The training of extension workers will have to be organised with a practical bias and in this connection it may be observed that a somewhat similar course is already being conducted at the Central Institute of Fisheries Operatives to provide the required number of trained teachers for the various State Fishermen Training Centres.

As the requirement of trained extension workers is sufficiently large, this training programme will have to be immediately taken up in a phased manner so that the entire scheme could be put into operation during the Fifth Plan period.

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General Principles of Certification Systems For the Crew of Fishing Vessels

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INTRODUCTION

Some type of certification systems for men working on board fishing vessels is now in operation in most of the maritime countries. We have come a long way from the age old methods of catching fish to modern diversified fishing methods using improved types of craft and gear. The duties and responsibilities shouldred by the skipper of a well equipped modern fishing vessel operating well designed gear, using the vessel as a working platform for catching, preserving the catch and as a means of transporting the catch to profitable landing and marketing centres, are far different from the duties and responsibilities normally envisaged for the operation of a small fishing vessel. This would mean that a person who is in charge of a modern mechanised fishing vessel should receive not only the required training in fishing operations using such a vessel but also should have his proficiency in fishing tested and certified. This is perhaps the most important reason for insisting on a proficiency test for those who are to qualify to handle fishing vessels both on deck and engine side. Naturally this would also give the profession the required social status as it happens in every other industry where the proficiency of the concerned skill are tested and levels defined.

Deck Certifications

To obtain a Fishing Vessel Skipper Certificate, in majority of the countries, it is generally necessary for candidates to meet certain conditions with regard to age, professional experience and physical fitness and to pass an examination designed to test the candidate's theoretical and practical knowledge. In computing the sea time required for certification in some countries including the United Kingdom, Iceland, Ireland, France, India and others, the concerned authority allows reduction of the total required period by the amount of time spent in vocational training schools. Thus in the United Kingdom regulations provide that the sea service requirements for all the certificates may be reduced by a maximum of 12 months for a period of satisfactory attendance at a vocational training school approved by the Ministry of Transport. In India a remission of 9 months' qualifying sea service is allowed to those of the candidates who successfully complete the respective training course in the Central Institute of Fisheries Operatives (Ministry of Agriculture & Irrigation).

Most countries including Belgium, Denmark, France, Germany, Ireland, Iceland, India, Italy, Japan, Morocco, the Netherlands, Norway, Sweden, the United Kingdom, the United States and others require some form of physical examination, usually including an eye test before the candidate appears for the respective Competency Certificate examination.

All of the countries with certification systems require the candidate to pass an examination covering appropriate professional, theoretical and practical knowledge. This examination usually covers the knowledge and skills required of the skipper of any sea-going vessel including seamanship, ship handling and navigation. These examinations are usually written or as in the case of Ireland, India etc. both written and oral. However, some countries such as the United States grant certificate on the basis of oral examinations only.

None of the existing certification examinations on which information is available require special knowledge concerning standard procedures and safety techniques to be carried out during fishing operations.

In general, most of the countries with fishing vessel certification systems either apply special rules to fishing vessels or have certificates which are distinct from those required of Merchant Navy Captains. However, some countries such as Brazil, Greece, Vietnam and Venezuela apply Merchant Navy Captains' Certificate requirements to fishing vessel Skippers and in others some Merchant Navy Certificates are the equivalent of certain Fishing Vessel Skipper Certificates. Most of the countries which have this inter changeable certificate provision, however, also provide that the holder of the certificate must have sea-going experience on the type of vessel which he commands (Norway). Japan also has inter-changeable fishing vessel and Merchant Navy Certificate but makes some minor distinctions between fishing and other types of vessels in the Certification regulations.

The United States regulations deal with fishing vessel officer certificates separately from Merchant Navy Certificates, under the category of vessels for which material inspection by the coast guard is not required.

In most of the countries with fishing vessel certification systems, skipper certificates are usually graded according to both tonnage and fishing area. However, there are other criteria in use in several countries. For example, the United Kingdom makes a distinction with regard to certification requirements between the types of fishing in which the boat is engaged and also the length of the vessel. The Israeli certification system is also based on the length of the fishing vessels. Italy bases her certification not only on tonnage and area but also on the propulsion power of the vessels.

In general, the minimum tonnage of fishing vessels to which skipper certification requirements apply in most of the countries, is lower than the 200 G. T. minimum tonnage laid down in I. L. O. convention (No. 531) for Merchant Navy Captain Certificates. Denmark applies Skipper certification requirements to fishing vessels over 20 G. T. and India. Norway and the United Kingdom to fishing vessels over 20 G. T. while the Netherlands apply the same to vessels above 50 G. T. and the United States to vessels above 200 G. T. In the Federal Republic of Germany, regulations concerning the certification of crew of fishing vessels below 75 tonnes are left to the local authorities while the Federal Government lays down regulations for fishing vessels above that tonnage.

Mate certifications;

In the certification systems of most countries there is a classification of fishing vessels on board which only Skipper Certificates are required and of those on which one or more mates are required in addition. For example, in Belgium, all fishing vessels above 30 tons and engaged in fishing in the middle water area also require a certificated mate. In Denmark, fishing vessels navigating outside the limited water area must carry a mate while in Sweden fishing vessels above 35 tons which require a First Class fishing vessel Skipper must also have a certificated Second Class fishing vessel Skipper acting as mate.

Some countries, instead of using Skipper Certificates of a lower class for the certification of mates as in Belgium, Denmark and Sweden, provide for separate mate certificates. In Germany, fishing vessels above 200 tons in middle-water fishing must carry a B-2 certificated mate while all fishing vessels engaged in distant water fishing must carry a B-4 certificated Mate. India, the Netherlands and the United Kingdom require that fishing vessel above 50 G. tons carry a certificated second hand (Mate), In Japan, fishing vessels of over 1000 tones navigating in the smooth water area must carry a B-class second mate, in the minor coasting area of over 200 tons a C-class mate, first major coasting area of above 150 tons a certificated C-class Captain as Mate and those navigating in the ocean going area, a B-class second mate.

In the United Kingdom, for certificates of competency as secondhand, 4 years sea time is required whereas 5 years are required for the skippers certificates. Also, the professional examinations required for certification as Mate are usually similar to those required for Skipper Certificate, but cover fewer subjects. In India, for certificates of Competency as Secondhand of a fishing vessel qualifying sea service of 36-42 months (in terms of actual fishing days) on board vessels of appropriate tonnage is required. In order to qualify for the

Skippers Certificate a candidate should serve at least 5 years at sea of which at least 12 moths must have been as a certificated secondhand.

Engine certifications

In almost all the countries with fishing vessel engineer certification systems, the classes of fishing vessels on board which certificated engineers are required are graded by Horse Power, eventhough classification for other certifications may be based on tonnage, fishing area and other criteria. (Belgium, Greece, Senegal Iceland, India etc.) A few countries however. have categories which are based on both Horse Power and fishing area. (Denmark and Germany). The professional experience required for engineers in most countries is also comparable to the standards for fishing vessel skippers and mates. Thus in the Republic of South Africa., the engineer certificate candiate should have spent one year at sea as Assistant Engineer while the mate candidate must have had one year as boats-wain and the skipper, two years as mate. In Iceland for both third and second class fishing vessels and candidates for the First Class Certificate must have 5 years sea service after completing the required vocational training course.

In the United States candidates for Chief Engineer and Skipper certificates must have 4 years of total sea service, of which one year must have been as licensed Asst. Engine man or Mate and candidates for Mates and Asst. Engineer must have 3 years sea service on deck or in the engine room respectively.

All the countries with Engineer Certification systems require professional examination, usually, covering practical and some theoretical aspects of the operation and maintenance of diesel, gasoline or steam-engines. Some countries like France which have special certificates for some classes of fishing vessel engineers also utilise their Merchant Navy Certificates for other classes of Fishing vessel engineers. Canada also has two fishing vessel engineer certificates for smaller engines, but requires fishing vessel enginemen to hold Merchant Navy Engineer Certificates onboard larger fishing vessels. Engineer Certificates are not required below 10 H. P. Merchant Navy Engineer Certificates are also required on board fishing vessels in Norway. As in Canada, an extensive theoretical and practical technical education is required for certification as a Merchant Navy Third, Second or First Class Engineer. It is reported that eventhough the level of Competency of Norwegian Fishing vessel Engineers is high, it is difficult for operatives to find sufficient number of fully qualified Third and Second Class Merchant Navy Engineers for smaller fishing vessels and that it has become necessary for the Government to grant waivers of the engineer certification requirement to permit fishing vessels to put to sea.

In India, separate Rules for the examinations of Engineers and Engine Drivers of fishing vessels were recently finalised and implemented with effect from 10th February, 1973. A large number of First Class and Second Class certificated engine drivers who are at present working on board sea going fishing vessels under dispensation are expected to qualify for the appropriate certification under the new rules. in the immediate future on completion of the prescribed qualifying sea service/workshop service. In India, if the vessel is of 50 N.H.P. or more, it requires one engineer duly certificated, being an engineer of a fishing vessel who shall be designated as Chief Engineer and if the vessel is of less than 50 N.H.P., it requires at least one engineer duly certificated, being an engineer of a fishing vessel who shall be designated as the Chief Engineer or with at least one engine driver of a Fishig Vessel duly certificated.

Fisherman Certifications:

Only very few countries provide certification for grades below the level of skippers, mates, Engineers and Asst. Engineers. Belgium has the Certificate of apprentice sea man which is awarded to boys between the ages of 14 and 18 who have completed fishermen's vocational training course prior to entering employment onboard fishing vessels. France also has a maritime apprentice certificate for boys completing vocational training courses and entering employment on fishing vessels. This certificate is obligatory for all men under 25 years of age entering employment on fishing vessels over a gross tonnage of 50 tons or more fixed by each maritime district. Italy has a similar obligatory certificate. The Netherlands provides a Certificate, viz. "Certificate of acquaintance with the International Regulations for prevention of collisions at sea" which may be awarded to fishermen over 17 years of age with one year's deck service at sea on board fishing vessels of over 25 tons. This certificate is obilgatory and all seagoing fishing vessels (over 500 tons) must have three fishermen holding this certificate onboard. Poland has 5 certificates for fishermen. The young fisherman certificate which is analogous in function to the apprentice certificate in France and Belgium certifies that the holder has completed fishing vocational training and is ready to begin employment on board fishing vessels. The fisherman certificate may be awarded after 12 months at sea and master-fisherman certificate after an additional period of 12 months. After a third 12 month period the fisherman may take the examination for certification as bosun and after a fourth 12 month period the examination for certification as skipper.

In India, similar courses aim at equipping the fishermen with sufficient knowledge to man a small mechanised fishing boat and fish from the same. The duration of training conducted at the various fishermen training centres varies between 6 months and 12 months in different states.

Radio Operator Certifications:

In Japan, the Radio Operator onboard coastal fishing vessels under 500 G. T. must hold a C-class ship's Radio Operator certificate. Middle water fishing vessels must have a C-class operator if they are below 500 G.T. and B-class operator if they are between 500 G.T. and 1500 G.T. and an A-class operator and a B-class operator if they are above 1600 G.T. The distant water fishing vessel's requirements are the same except that fishing vessels above 5,500 G.T. must carry 3 Radio operators with A, B and C-class certificates respectively. Belgium requires certificated Radio operators in all fishing vessels with Radio Transmitters and France, on all fishing vessels above 250 G.T.

In majority of countries a separate certificated Radio operator is not a requirement on board fishing vessels fitted up with R/T equipment. However, the skippers are given sufficient training in the operation of communication equipment fitted on board who will attend to the same as a part of their duty on board.

General conclusions

The need for a more complete certification system seems especially clear in those countries which require certain types of fishing vessel officer certification and not others. For example, Canada requires certificated engineers on board fishing vessels above 10 G. T. but does not require skippers to be certificated on fishing vessels of any tonnage. Thus on a fishing vessel of 800 tones, a first class engineer is required but the skipper of the vessel may be uncertificated. The reverse is true in the United Kingdom and Ireland where on a similar 800 tons vessel the Skipper must have a first class fishing vessel certiffcate, but the engineers may be uncertificated. In Canada, with incomplete certification standards, it is a common practice for fishing vessel skippers to voluntarily obtain analogous Merchant Navy certificates and the practice is generally encouraged by employers. In the United States, Insurance Companies have also encouraged voluntary certification programme while in the United Kingdom some Insurance Companies provide their own engineering certificates.

In the interest of ensuring that only those who have suitable and adequate proficiency in fishing are placed on board the fishing vessels, so that fishing efficiency may not suffer, it would become essential for us to develop a procedure by which fishing proficiency also could be tested just as the nautical proficiency is tested by the respective authorities. This would be easy in the case of those candidates who pass through institutional training because they could be made to appear for the fishing proficiency examination immediately after completion of the prescribed qulifying sea service and before they appear for the respective competency certificate examinations. Organisational difficulties perhaps may arise when we have to insist that all the candidates who have not gone through the Institutional training also should appear for the fishing proficiency test. This also can be tackled by carefully arranged regional examinations as is being done in some countries, particularly in U.S.S.R.

TONNAGE/H.P./AREA LIMITS FOR VARIOUS FISHING VESSELS CERTIFICATIONS IN DIFFERENT COUNTRIES

S. No.	Certifications	Tonnage-H.P. Limits	Name of the country
I.	**Deck Certifications:**		
1.	Coastal Fishing vessel Master	Upto 30 G.T.	Belgium
		Upto 50 H.P.	Italy
2.	Second Class Fishing vessel Master	Upto 200 G.T.	Belgium
3.	First Class Fishing vessel Master	Above 200 G.T.	Belgium
4.	Small limited water fishing vessel Master	Upto 75 G.T.	Germany
5.	Fishing vessel Master	Above 75 G. T.	–do–
6.	Fishing vessel Captain	In all waters	–do–
7.	Inshore Fishing vessel	Upto 7 G.T.	Spain
8.	Coastal Fishing vessel Skipper	Upto 45 G.T.	,,
9.	Middle water fishing	Upto 300 G.T.	,,
10.	Distant water fishing	Upto 500 G.T.	,,
11.	Fishing Vessel Skipper	Above 50 G.T.	Netherlands
12.	Third Class fishing vessel	Upto 30 G.T.	Iceland, Denmark, France, Ireland, New Zealand, Poland, Sweden, Tunisia, Rep. of S. Africa.
13.	Second Class fishing vessel	Upto 120 G.T.	As above
14.	First Class fishing vessel	Above 120 G.T.	As above
15.	Skipper Fishing Vessel	No limit	India, Argentina, Senegal, Venezuela, U. S. A.
16.	Secondhand Fishing	Above 50 G.T.	India
17.	Skipper Fishing vessel limited	100 ft. in length in limited area	U. K.
18.	Skipper Fishing vessel full	No limit in tonnage and area	,,
19.	Secondhand Special	Below 50 G.T. in limited area	,,
20.	Head Fisherman	Upto 44 ft.	Israel
21.	Junior Skipper	Between 44′ and 75′	–do–
22.	Coastal Fishing vessel Operator	Below 5 G.T.	Italy
23.	Limited Meditarranean Fishing vessel Master	Upto 120 H.P.	–do–
24.	Fishing vessel Master/Deck Officer	Upto 400 H.P.	–do–

S. No.	Certifications	Tonnage-H.P. Limits	Name of the country
25.	Captain	No limit	Italy
26.	Coastal Skipper	Upto 500 G.T.	Norway
27.	Small sized vessel operator/mate	Upto 20 G.T.	Japan
28.	B-class second mate	Depending on tonnage	-do-
29.	First mate/captain	-do-	-do-
II.	**Engine Certifications:**		
1.	Sailor engine man	Upto 180 H.P.	Belgium
2.	Engine man	Upto 400 H.P.	-do-
3.	Distant water fishing vessel engineer	No limit	-do-
4.	Fourth Class engineer	Above 100 H.P. 32 to 50 H.P.	Germany Greece
5.	Third Class engineer	Above 600 H.P. Upto 150 H.P.	Germany Iceland
6.	Second Class engineer	50 to 100 H.P. Between 200 and 600 H.P. 152 to 600 H.P. 100 to 500 H.P.	Greece Germany Iceland Greece
7.	First Class engineer	Upto 200 H.P. Above 600 H.P. Above 500 H.P.	Germany Iceland Greece
8.	Engine Driver fishing vessel	Upto 50 N.H.P.	India
9.	Eengineer fishing vessel	Above 50 N.H.P.	-do-
10.	Motor operator	Upto 100 H.P.	Senegal
11.	Engine man	100 to 300 H.P.	-do-
12.	Engineer	Depending on Fishing area above 300 H.P.	Denmark
III.	**Radio Telephone Certifications:**		
1.	C-class ships operator	Below 500 G.T.	Japan
2.	B-class ships operator	Above 500 G.T.	-do-
3.	A-class ships operator	Above 1600 G.T.	-do-
4.	Radio operator	For all fishing vessels	Belgium
5.	-do-	-do-	France
6.	Certificate of Proficiency General, restricted or Inland maritime	For all fishing vessels fitted up with R/T equipment.	India.

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TRAINING OF FISHERIES OPERATIVES PERSONNEL IN INDIA

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Introduction

The growth and development of any industry is dependent on the availability of trained technical skill. In the case of the fishing industry the technical skill is represented in the two broad categories of personnel viz. the operative personnel who are engaged in the process of catching fish and the supporting shore technicians who cater to the needs of the former by way of looking after the supply, maintenance and repair work of the necessary craft and gear and also the distribution of catches through appropriate channels. Among the first category itself there can be varied types of skill required depending on the size of the vessel, horse power of the engine and also the type of fishing method adopted. There will have to be specialised technical skill available to (1) Navigate the vessel safely and conduct fishing operations using the vessel as a base and also to bring the catch in good condition to the shore base and (2) to look after the running, maintenance and repair work of the ship's engines and other accessories while out at sea including deck equipment and fittings utilised for conducting fishing operations. As has been mentioned earlier, the type of skill required to operate a small, medium sized and large fishing vessel both on deck as well as engine side are quite varied.

In order to meet the above requirements and to safeguard the interests with regard to safe navigation and conduct of economic fishing operations, certain competency certificates came into existence for the different disciplines depending upon the job requirements and were made compulsory by different countries from time to time. Today a varied number of such certifications are available in different countries and were fixed as the basic minimum requirement for taking up the respective positions on board fishing vessels of different tonnage / horse power. There are training organisations all over the world which are engaged in imparting the required theoretical and practical knowledge and also aid the candidate to earn the prescribed qualifying sea service or workshop service by suitable postings on board fishing vessels of the prescribed tonnage/

B. H. P. or recognised engineering workshops. Among these a vast majority offer permanent trainning programmes to a selected number of candidates who fulfil the basic requirements with regard to age, educational qualifications and physique. A large number of these training institutions also offer ad hoc training programmes mostly in the form of refresher courses to inservice personnel employed both in artisanal as well as industrial fishery units. The latter is mainly aimed at making the inservice personnel qualify for suitable certifications and also to ensure that they are introduced to modern improved techniques in fishing and allied subjects from time to time.

Training programmes in India

The Committee on Fisheries Education appointed by the Government of India in 1958 observed that "In India, Fisheries Science is, unlike Agriculture, largely a new and unfamiliar discipline In Japan, Norway, Great Britain and the United States, to mention only a few instances, fishing and fishery industries have been organised and developed by private enterprise in the course of several generation. In these countries governmental intervention followed in response to the needs of industry which have set a pattern for training in and assistance from the public sector. But even among the countries mentioned above, Japan may be cited as an example for "forthright governmental assistance in which establishment of training institutes played a major role in the modernisation of fishery industries....... One of the most fruitful forms of governmental assistance, on natural scale, is to provide facilities for training of personnel at various levels ".

During 1958–59, the Committee observed that training in navigation and seamanship was provided in the Nautical and Engineering College, Bombay for Skippers and Second hands of fishing vessels. There were *eight* fishermen training centres organised jointly by the Union and State Governments which gave 6 months training courses in a uniform pattern. The Indo-Norwegian Project was also providing 6 months training in mechanised fishing to the fishermen of three villages near Quilon in Kerala State since 1953. Training in mechanised fishing was also provided on large boats of the Central Deep-sea Fishing Station, Bombay, Offshore Fishing Station at Cochin and Tuticorin and on the vessels of the Government of West Bengal (Calcutta) and Indo-Norwegian Project (Cochin).

The Committee concluded that a review of the existing facilities "discloses a most unsatisfactory situation with regard to provision in India of training of fishery workers of various categories. The training is largely adhoc with an excessively academic bias and with inadequate facilities for giving practical experience. The existing arrangements are not capable of training personnel in the numbers required nor do they train to the required levels of proficiency ". The Committee was of the view that there is need to extend the period of training in the light fishermen training centres to one year or at least 9 months and to increase the number of centres.

Accepting the recommedations made by this Committee, the Government of India established two training institutions viz. the Central Institute of Fisheries Education, in Bombay during the year 1961, to impart post-graduate instruction in the composite discipline of fisheries science to district level fisheries officers in service, deputed by various State Governments, for implementing development programmes and the Central Institute of Fisheries Operatives established at Cochin in the year 1963 along with its unit at Madras which was established during the year 1969 to train the required number of specialised technicians like skippers, fishing second hands, engineers and engine drivers of medium and large fishing vessels which come under the purview of the Merchant Shipping Act (1958) and also the related Shore Technicians like Fisheries Electronics Technicians, Fishing Gear Technicians, Shore Mechanics, Boat Building Foremen and Teachers required for the various fishermen training centres.

The required number of trained technicians needed for the small mechanised fishing vessels which do not come within the purview of the Merchant Shipping Act (1958) are being trained by a total of about 27 fishermen training centres distributed in the states of Gujarat (2), Maharashtra (4), Mysore (4), Kerala (5), Tamil Nadu (7), Andhra Pradesh (3) and the Union Territory of Laccadives (1) and Goa (1). As in January 1972, a total of 6500 Nos. of Fishermen have been trained by all these Training Centres together and made available to the Industry both in the public and private sectors for the operation of the smaller mechanised fishing vessels. The details of instructions at these training centres include basic lessons in (1) Navigation (2) Motoring (3) Gear Construction and maintenance (4) Different aspects of fishing etc. The duration of training is fixed as 12 months in A. P., 10 months in Gujarat and Tamil Nadu, 6 months in Maharashtra, Goa, Mysore, Orissa and Laccadives and in Kerala the duration of the course is fixed as 38 weeks.

The Central Institute of Fisheries Operatives Imparts training for a selected number of candidates who fulfil the basic requirements with regard to Age, educational qualifications, aptitude and physique so as to enable them to appear for the following Competency Certificate Examinations.

(1) Skipper — Fishing
(2) Secondhand — Fishing
(3) Engineer — (Fishing vessel)
(4) Engine Driver—(Fishing Vessel)

Apart from the above, the Institute also trains the required number of supporting technicians such as shore mechanics, fishing gear technicians, fisheries electronics technicians, boat building foremen, and teachers required for the fishermen training centres. In order to fulfil this requirement, the Institute conducts 7 different courses with duration varying from 6 to 15 months. The qualifying sea service/workshop service (Post-institutional training programmes), prescribed under the existing regulations is also arranged by the Institute for the trainees who successfully complete the respective training courses so as to enable them to appear for the respective competency certificate examinations on successful completion of the total prescribed sea/workshop service requirements.

The training given at this Institute in all the above disciplines is practical biased and aims at making candidates capable of carrying out the practical jobs of their respective specialisations satisfactorily. During the last 10 years the Institute has made steady progress and today it is counted among the leading institutions in the South-East Asia engaged in training of operative personnel for the fishing industry. The progress achieved since inception of the training programme upto April, 1973 is given below.

Course	No. of candidates trained	
	Cochin	Madras Unit
1. Fishing Second hands Course	241	100
2. Engine Drivers Cource	206	98
3. Boat Building Foremens Course	53	Nil
4. Gear Technicians Course	77	5
5. Shore Mechanics Course	45	Nil
6. Radio Telephone Operators Course	46	28
7. Teacher Training Course	20	Nil
	688 +	231

Total trained : 919

Among the above, *43* have obtained the Secondhand Fishing Competency Certificate and 18 have taken the Skipper fishing Competency Certificate. A large number of engine driver candidates who have obtained the required qualifying sea service are eligible to appear for the Engineer/Engine Driver (fishing vessels) Examinations, rules for which have been finalised and implemented in February 1973. Among these, 10 candidates have obtained the Competency Certificate as Engine Driver Fishing Vessel recently.

Facilities for practical training at sea include two 93' and two 57' veasels one each attached to the Institute at Cochin and Madras. One more 43' vessel constructed at this Institute as a part of the training programme will be added to the existing fleet in the near future. With the addition of another 200' OAL multipurpose training vessel with about 30 days cruising range and with a capacity for 40 trainees at a time, a proposal for which is under the active consideration of the Ministry, the Institute will enter a new phase in fisheries Operatives training by way of imparting specialised training in different methods of fishing like purse seining, long lining, pole and line fishing, gill netting, mid-water trawling etc. for which the existing facilities in the form of training vessels would not be sufficient to train the required number of technicians within the prescribed period. Especially with the implementation of the V Year Plan when the country is expected to go into the exploitation of the pelagic waters in a bigger way, let us hope that this Institution will cater to the needs of the industry with regard to the availability of specialised skill in the different disciplines at the appropriate time, and contribute immensely to the economic development of the nation.

"Investment in men" is one of the essential factors in developing any industry. This being a costly and long range programme, this investment has to be done with careful assessment of requirements and utilisation. On this will rest the harvest of the resources for decades to come.

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Management of Technical Personnel in the Fishing Industry*

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INTRODUCTION

Compared with India's traditional jute or tea industry which could reach a figure of Rs. 260-280 crores, the progress made in the export of marine products in the course of 10 years is considered, even in government circles, as phenomenal — Rs. 4 crores earned in 1964 to Rs. 80 crores in 1974. The very existence of any industry is dependent on the availability of the basic resources which are scarce, viz. money, machines, materials and men. Among these, the first three inanimate resources are governed by certain definite laws and hence are predictable within certain limits. As regards the fourth and most important animate resource there are no laws or rules governing the same as human behaviour is highly unpredictable and exhibits individual and circumstantial variations.

It is rather an accepted fact that the growth and development of any industry is to a large extent dependent on the availability of trained technical skill. In the case of the fishing industry the technical skill is represented in the two broad categories of personnel viz. the operative personnel who are engaged in the process of catching fish and the supporting shore technicians who cater to the needs of the former by way of looking after the supply, maintenance and repair work of the necessary craft and gear, distribution of catches through appropriate channels, overall administration and guidance including welfare activities. Both the abovesaid two groups, the former functioning at sea and the latter at shore, eventhough to a certain extent indepenent, are interdependent to such an extent that one cannot exist without the other. Eventhough the captain of a fishing vessel could be rightly called the manager of the group, in effect the management of the group is being carried out from the shore base by a fleet manager. In fact

* From the final study paper submitted in partial fulfilment of the requirement for a Post Graduate Diploma in Business Management.
The views expressed in the present study are the personal views of the author and do not in any way reflect the official opinion or the policy of the organisation where he is serving.

the achievement of the objective viz; catching, transporting, marketing and selling for profit of commercially important varieties of fishes and other marine life is entirely dependent on the extent of cooperation between the two groups and also coordination among individuals in the group. Under the abovesaid circumstances it is rather impractical to visualise these two groups as independent and hence we may consider them as two small sub-groups within a large formal group. This division has been necessitated mainly because of the difference in the functions of the two groups, special characteristics of the organisational set up and above all on the social set up where the two sub-groups are functioning.

Scope of the study:

The scope of the present study is limited to the identification of some of the possible drawbacks of the existing system of management of the abovesaid individual subgroups and suggest possible remedia measures for improvement. By the term 'Crew of fishing vessels' the implication is those categories of personnel working onboard medium and large sized fishing vessels of above 15 gross tons which come under the manning regulations prescribed in the Merchant Shipping Act (1958). The methodology adopted include personal data collected through experience and communi cation and also library references. The study is limited to groups functioning mostly around Cochin so as to enable the author to gather first hand information wherever required. It may also be noted that the views expressed in the present study are the personal views of the author and do not in any way reflect the official opinion on the policy of the organisation where he is serving.

For convenience's sake we may examine the organisational set up, objectives and functions of the two sub-groups separately, identify the probable draw backs and suggest possible methods for improvement.

Discussions

SUB GROUP I: Crew of Fishing Vessels

A fishing vessel is in effect a floating working platform used for catching, storing and preserving fish and other commercially important marine life and transporting the catch to the landing centres. Perhaps one of the major differences between a fishing vessel and an undertaking functioning at shore would be the capacity for the former to move from place to place in search of raw-materials which are alive (animate) in comparison to the sedentary nature of the latter and also the inorganic raw materials which it mostly deals with. In fact in the case of a fishing vessel the organisation as such moves from place to place in search of raw materials which by themselves are scarce and non stationary. Perhaps one of the important features which strikes one is the highly unpredictable nature of of the availability of raw materials in sufficient quantities so as to make the operation an economically viable proposition. This in turn has an important effect on the 'time factor' which forms one of the major physical factors controlling the efficiency of the organisation as a whole.

Organisational set up:

The leader or manager of the sub-group under discussion is the skipper of the vessel who is in command of all operations carried out on board. In general the group consists of two major categories of personnel viz: those working on the deckside and those attached to the engine side. The former include Fishing Secondhands (mates), Bosuns and Deckhands. In rare cases the group also comprises of a junior Skipper. The second category consists of engineers, engine drivers and oilmen or greasers. Among the above categories of personnel, the skippers, fishing secondhands, engineers and engine drivers should possess the respective competency certificates issued by the Mercantile Marine Department (Ministry of Transport). Deck hand and oilman/greaser positions are usually filled up with personnel who fulfil the minimum requirements with regard to physical fitness, age and experience in the field. Persons who have successfully completed the prescribed course of training under a recognised central or state training institution are always preferred because of the necessary educational background, age, physical fitness and standard in the theory and practice of fishing. Such candidates also get an advantage in the total qualifying sea service required to appear for one of the deck/engine certifications in due course as they are eligible for a fixed remission in sea/workshop service by virtue of successful completion of the training programme conducted by the governmental institutions.

Responsibility, Authority and Accountability

Eventhough both the deck as well as engineside crew have specific duties and responsibilities of their own, in actual practice one cannot function effectively without the close cooperation of the other. The functions in this respect are comprable to those of the heart and the brain in the human body. Eventhough both are assigned independent duties, it is well known that one cannot function effectively without the other contributing its share. The functions performed by the engine side crew are more or less similar to the functions of the heart in a human body and those performed by the deck side crew to the brain and connected systems. One cannot establish the superiority or importance of one over the other as both are complementary to each other. Even the actual fishing operation is a cooperative effort where both the deck side and engine side crew will have to take part and contribute their share. It is a joint effort where the cooperation of even a single deckhand or oilman counts a lot when it comes to a question of personal contribution.

The skipper is the manager of the sub-group as a whole and is in charge of all operations carried out onboard including the navigation of the vessel from place to place. As a manager he requires the close cooperation of all the crew members working onboard. He has to coordinate the various activities performed onboard by the different categories of crew towards the achievement of the goal, in this case, to catch and transport sufficient quantities of commercially important fishes and other marine life to meet the requirements of both the internal market as well as the export market. While in charge of the vessel the necessary authority is delegated to him by the promoters of the undertaking through the managing director and the fleet manager. His duties and responsibilities are specifically stated and he is accountable to the fleet manager on all aspects concerning the operation of his vessel including the welfare of the crew members.

While at shore the skipper has to co-ordinate the activities of the shore group with those of the group functioning on-board under the guidance of the Fleet Manager for effectively carrying out unloading of the catches, loading of ice, fuel, fresh water and supplies, repair works, maintenance and observance of statutory regulations prescribed in the Merchant Shipping Act (1958). Over and above looking after the main objective of the enterprise viz: making profit, he is also responsible for the welfare of the crew working on board.

The Engineer is in charge of the engine room including the deck equipment and accessories of a fishing vessel, for its running, maintenance and repairs and is accountable to the skipper. The engine driver on the other hand is responsible for running, maintaining, carrying out repair work and upkeep of the engine and other accessories and is accountable to the engineer. The oilman or greaser helps the engine driver to carry out the routine maintenance of the engine and other accessories including oiling and greasing. He in turn is accountable to the engine driver.

The fishing secondhand or mate assists the skipper in running, maintaining and also conducting fishing operations on board a fishing vessel. He is accountable to the skipper of the vessel. The deckhands under the leadership of the bosun assist the secondhand in fishing operations, general maintenance, attending to watch duties and safety of the vessel and fishing gear. Both these categories of skill are accountable to the secondhand.

Other categories of personnel on board include cook, topass etc. The former helps the crew in deck work, general maintenance, fishing operations and above all looks after the cooking onboard. The latter looks after the general maintenance, cleaning of decks, cabins, bath and lavatory and assists the cook in the galley. Both these categories of personnel are accountable to the secondhand.

Depending on the type of fishing operations carried out and also on the size of the fishing gear employed most of the engine crew very often help the deck crew when the vessel is engaged in fishing operations. Thus there is always a certain amount of overlapping of the work of engine side crew with those on the deck side in order to compensate for the comparatively smaller number of crew posted on the deck. In majority of cases it is observed that there is no decentralisation of power effected from the skipper to the secondhand unless there is an emergency.

The categories and number of persons normally employed on board vary with different sizes of fishing vessels and also on the type of fishing carried out onboard. The medium and large fishing vessels operating from Indian bases broadly fall within the range of 15-150 gross tons. In general it is observed that a total complement of 6 to 13 crew members working both on the deck and engine side over and above the skipper work on board vessels of tonnages varying between 15 and 150. There are a few vessels with tonnage above 150 and engaged in fishing operations along the coast. Two of them are factory vessels with facilities for processing of raw materials on board. Since these vessels employ modern sophisticated electronic and other equipment there is not much of difference in the total number of manpower employed on board when compared to vessels below 150 gross tons which form more or less 99% of the total number. It is upto the skipper to increase the number of a particular category especially on the deckside to achieve maximum efficiency under a given condition.

Operating Radius and its Effect on the Crew:

The cruising range of different sizes of vessels vary greatly. The range under normal conditions increases with increasing tonnage and also the capacity for storing fuel, water and other supplies as also the capacity of the fish hold. Since the fishing grounds are not uniformly distributed the distance from a particular base to the nearest productive fishing ground varies from one place to another and also from season to season. A certain time is always spent by individual vessels while steaming to the fishing ground and returning to the base. The capacity to remain out for longer duration increases with increasing tonnage and this parameter varies from 3 days in the case of 15 G. T. vessels to not less than 15-20 days in the case of vessels around 160 G. T.

Because of the above the crew will have to remain out in the sea for durations of 3 to 20 days depending on the size of the vessels. Of course the time out at sea is also dependent on the possibilities of obtaining a good catch to fill in the storage space. Since the availability of fishable concentrations of fish is a highly variable factor no time limit, except the maximum possible, could be set for each trip. So also, the fishing operations commence and conclude at any time of the day or night thereby making it impossible to fix any kind of effective working hours for each of the above categories of skill including the skipper. As the vessel carries only the minimum required number of crew onboard, it is also impossible to work on a shift system thereby limiting/fixing the effective working hours of individual crew. An increase in the number of crew is almost impossible mainly due to :

(1) Shortage of space on board, the major space being occupied by fish hold and gear store below deck and fishing deck above.

(2) Indefiniteness in locating and catching the required quantify of commercially important varieties of fish (mainly because the latter are not stationary) and the ultimate effect of the same on the economics of operation of individual vessels.

When fishable concentrations of commercially important fish are available, the fishing operations more or less become continuous as the interval between two successive hauls is made use of for sorting, cleaning and storing the fish caught. Thus it could be seen that eventhough the work carried out on board a fishing vessel (extractive industry) is more or less comparable to the routine work in a factory situated on land, the following major differences are worth mentioning in the case of the former :

(1) Both the factory as well as the raw materials are not stationary.

(2) There cannot be any fixed effective working hours as a shift system is almost impossible onboard fishing vessels.

(3) More or less all the crew members will have to contribute their share of work when fishing operations are in progress. This makes individual crew members indispensable especially because any addition in the number of crew over and above the minimum required affects the economics of operation of the vessel adversely. This is also because of the indefiniteness in the availability of raw materials on which the industry exists.

(4) The sub-group as a whole will have to work in complete isolation for periods of upto 20 days at a time, cut off from other groups which are working on land.

SUB GROUP II :

Supporting Personal Working at the Shore Establishment

Organisation set up—Responsibility, Authority and Accountability:

The shore management consists of :

(1) Fleet manager, who is entrusted with the responsibility of controlling and guiding the operation of fishing vessels through the respective skippers. The number of vessels which a fleet manager can effectively control depends on the size of individual vessels. He has to coordinate the activities of the shore group headed by the shore manager with those of the group employed onboard individual vessels with the assistance of the respective skippers. The fleet manager is responsible for the smooth operation of all the vessels and is accountable to the managing director of the firm.

(2) The shore manager who is in charge of the entire technical shore establishment which looks after the fishing gear requirements of individual vessels, repair work and overhauling of engines and other accessories on board, processing section and marketing section of the enterprise. He is responsible for carrying out all the abovesaid activities through the respective section heads viz:

(a) Fishing gear technologist who is responsible for carrying out the designing, fabrication and repair work of various types of fishing gear and accessories for individual vessels. He is assisted by one or more fishing gear technicians and a few net menders.

(b) The shore engineer or foreman who is in charge of the shore engineering workshop which looks after the repair work and overhauling of engines and other accessories of individual vessels in between two fishing trips. He is assisted by one or more shore mechanics.

(c) The refrigeration engineer who is in charge of the entire processing section assisted by one or more processing technicians and employees engaged in peeling work.

(d) The marketing officer who is responsible for the marketing of the processed/fresh raw materials. He looks after both the internal and export marketing of the enterprise assisted by one or more marketing assistants.

The fishing gear technologist, shore engineer, refrigeration engineer and the marketing officer carry out the assigned work as per directive received from the shore manager and are accountable to him.

(3) The administrative officer who is responsible for all the administrative and accounts matters. He is assisted by an office administration, chief accountant on the accounts side and a store superintendent in the stores section at the immediate lower level followed by other categories of personnel like clerical staff, accountants, store keeper and peons, the number of each category depending on the size of the enterprise. The administrative officer is accountable to the managing director of the enterprise.

When compared to the sub-group working on board individual vessels, the work carried out by the shore sub group is more or less similar to the routine work in a factory. Normally they follow a fixed effective working hours. In most of the cases the question of any kind of shift system does not arise as any additional work outside normal working hours is being attended to by the staff on over time allowance basis or compensatory off basis. The effective functioning of both the processing and marketing sections is dependent on the availability of the requird minimum quantity of raw materials having an internal or export market potential. In the absence of a minimum quantity of raw materials, the functioning of the processing unit as well as the marketing section is likely to become infructuous. Both the engineering maintenance and fishing gear technology sections will have to function even in the absence of a minimum quantity of raw materials as the vessels and the gear are to be repaired and maintained periodically. Under the abovesaid circumstances the required number of employees engaged in peeling work in the processing section and fishing gear repair and mending work in the gear technology section are usually employed on casual basis and their number is varied according to the necessity.

Observations and Conclusions

Management of the Sub-Groups:

As is evident from the organisation chart and discussions, the fleet management headed by the fleet manager, the technical shore management headed by the shore manager and the administrative shore management headed by the administrative officer make up the management pattern. In the case of the fishing industry, the management in a single enterprise has to shoulder the responsibility of managing both the above-said sub-groups, one working on board and other at the shore base. Due to differences in the environment where the group works as well as the working conditions the management of the sub-group working on board headed by the skippers of individual vessels very often poses certain problems. The shore management is also left with the task of coordinating the activities of the two sub-groups, on which is dependent the smooth functioning of the organisation as a whole.

Coordination:

One of the senior shore managers, in this case the fleet manager will have to coordinate the work of all the above categories of shore personnel with those of the crew working on board through the respective heads of each section. Lack of coordination will result in delayed unloading of fish catch to the processing plant, loading of ice, carrying out repair work on engines and other accessories including fishing gear which cannot be carried out on board when the vessel is out at sea, loading of fuel oil, fresh water and supplies, replacement of crew etc. and will ultimately affect the economics of operation of the organisation as a whole.

Schedule of operation:

Normally, the fishing vessels belonging to a single enterprise work according to a well planned schedule. A periodical (weekly, fortnightly or monthly) tentative schedule of fishing trips of individual vessels is prepared by the fleet manager in consultation with the shore manager. The fishing grounds to be covered during a particular season are also indicated based on information collected from the various experimental/exploratory fishing organisations operating in the region. Time and date of leaving and returning to jetty in the case of individual vessels will have to be adjusted in such a way as to avoid any kind of overlapping and the resultant delay in unloading of catches, loading of ice, fuel, water and supplies and also carrying out repair work. Similarly a work schedule for the shore staff will have to be prepared on the basis of the fishing trip chart. By adopting a similar method the time spent by an individual vessel at the jetty will be reduced to the minimum thereby increasing the number of effective fishing hours.

When the vessel returns to the jetty after carrying out fishing operations out at sea for a period of few days, one cannot expect all the crew members to remain on board full time and attend to the various works during the period when the vessel remains at the jetty. It is here that the shore personnel can play a vital role which would not only increase the efficiency of operations but also provide a moral support to those of the crew who have come ashore for a brief interval. The shore group is also responsible for arranging the required transport facilities for the crew members and to a certain extent look after the welfare of the crew's families while they are at sea. This in turn creates an atmosphere of perfect harmony thereby making the crew on board capable of concentrating more on their work. Here one has to take into account the mental condition of individual crew at a time when they are secluded and cut off from any other similar group working on land, especially their own counterpart, the sub-group working at shore. Perhaps the only way to compensate for the peculiar environment where the sub-group works, is to provide them with additional amenities, when they remain at shore in between two fishing trips.

Shift system:

In this connection it is worth mentioning that there is no close similarity between crew employed on board Merchant Navy vessels and fishing vessels eventhough the former remain out at sea for longer intervals. Since a Merchant Navy vessel transports men and materials from one place to another, the work performod on board is of a routine nature by following a shift system. The fishing vessel, on the other hand acts not only as a working platform for carrying out fishing operations but also stores and transports the raw materials from the fishing ground to the shore base and hence the work performed on board by individual crew is of a diversified nature. Because of the limited accommodation available on board the total number of crew carried on board is also limited thereby making a shift system impossible. As the availability of raw materials, viz: fishable concentrations of fish is quite indefinite there cannot be any kind of fixed duration for active fishing and hence very often the crew will have to work continuously for long durations without any break. Because of the above the duties and responsibilities of a skipper of a modern fishing vessel which is equipped with electronic fish finding, navigation and communication equipment, operating complicated but well designed fishing gear, using the vessel as a working platform for catching, storing and preserving the catch and as a means to transport this catch to the landing centres are far different from the duties and responsibilities envisaged for a captain of a Merchant Navy vessel. Operations of this nature require, as is very evident, a difinite pattern of proficiency in the disciplines of fishing gear technology, fishing technique, handling and preservation of catches, book keeping and also marketing techniques apart from knowledge in navigating the vessel.

Provision of incentives:

Under the above said circumstances, in order to meet the objectives of the industry as a whole, the necessity for providing the required incentive either in the form of cash or kind in order to compensate for the peculiar working conditions of the crew working on board similar veseels need not be stressed.

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This may be one of the reasons for the comparatively higher pay scales offered to these categories of personnel working on board sea going fishing vessels especially when compared to similar skills employed at shore. There is also the necessary provision whereby an operative who joins the industry as a deck hand is eligible to qualify himself as a second hand fishing and later as skipper fishing by fulfilling the prescribed qualifying sea service requirements. Same is the case with an oilman or greaser on the engine side where he is eligible to rise to the position of an engine driver in the first instance and later as an engineer by passing the respective competency certificate examination. The industry in majority of cases also provides free messing fixed messing allowance per day of effective fishing, payment of insurance premium, free accommodation and transport, free medical facilities etc.

There are certain limitations to be borne in mind for providing increased incentives either as cash or kind in order to compensate for the peculiar working conditions of the crew. It may not be possible for the promoters of the enterprise to increase the incentives beyond a certain limit as it may affect the economics of operation of the enterprise. Moreover the returns by way of fish catches are not at all assured either in terms of quality or quantity. In a similar set up the management is left with only one choice viz. provide the optimum incentives and ensure the effective functioning of the supporting establishment at shore so that the crew members will get maximum relief when the vessel remains at the jetty in between two fishing trips. In order to achieve this the skipper of individual vessel should be asked to submit, immediately on arrival at the jetty, a list of works to be attended to by the different sections at shore to the fleet manager so that only the minimum time is taken by the shore establishment for the completion of the work. Advance information can be always passed on through the Radio Telephone so that the respective sections at shore can make the necessary preparations for carrying out a particular work when the vessel arrives at the jetty. Among the crew members, one person can be asked to take up the watch duty when the vessel remains at the jetty. The coordination between the crew and the shore personnel is perhaps the most important aspect of the management of a similar enterprise. Once this is taken care of, with the optimum incentive it would not be difficult to achieve the objectives.

Necessity for a Manual:

In the fishing industry, personnel employed at the shore establishment fall within the purview of Factory Act. Those employed on board do not fall within the purview of the Act and hence the second aspect to be given due consideration is the implementation of uniform and well defined rules and regulations governing the Sub-group – I viz. skill employed on board fishing vessels. Eventhough the fishing vessels come within the purview of the Merchant Shipping Act (1958) as regards manning regulations are concerned, the working conditions mentioned therein which are generally applicable to Merchant

Navy vessels, cannot be applied to fishing vessels because of the basic difference in the type of work performed on board, In the light of the above, the immediate requirement would be framing of separate rules and regulations governing the working conditions of operative personnel employed on board sea-going fishing vessels in the form of a manual. This would enable the industry to apply a set of uniform and well defined rules and regulations and would help both the employers and the employees of the industry to settle the disputes, if any, in a systematic and cooperative manner. While preparing a similar manual difficulties may arise while deciding on a definite period as working hours each day as is being done in the case of similar skill employed at shore. As there are limitations with regard to the maximum number of personnel who could be taken on board a fishing vessel at a time, this difficulty can be eliminated only by way of providing alternative compensation in the form of incentives (fringe benefits) and also by providing relief when the vessel remains at jetty in between fishing trips. The manual should take care of all the abovesaid aspects taking into consideration the requirements of both the crew working on board as well as those who are employed at the shore base. A similar manual should also contain standard proformae and procedures to carry out the various functions in the organisation in the most effective manner, responsibility, authority and accountability of each category of personnel etc. Variations from the normal can be noticed only when a reference standard is available. in this case, the reference standard which could be employed is an exhaustive manual and a code of conduct delineating clear-out duties and functions of all executives and operatives.

Training of personnel:

Another important aspect to be given due consideration is the periodic training of both on board and shore personnel in the respective disciplines so as to enable them to keep abreast of modern development in the respective fields. This could be achieved by sending them periodically to attend refresher training programmes arranged by competent governmental or private agencies.

Maintenance of vessels:

While planning the fishing programmes of individual vessels, the periodic maintenance and overhauling including drydocking of the vessel for carrying out under water repairs, painting etc. can be postponed and got done during the off season. In the case of smaller craft, the off season can be the peak monsoon season when comparatively rough sea conditions prevail. The medium and large sized vessels are capable of operating during the monsoon season and hence the off season for the raw materials as the medium and large sized vessels are capable of moving towards productive fishing grounds located away from the base. The annual repairs and overhauling including the drydocking of individual vessels is planned sufficiently in advance especially in view of the limited facilities available in the country for dry docking. Normally the leave period of the major categories of crew should coincide with the off season when individual vessels will remain at the jetty or dry dock. Otherwise the alternative left would be to keep the required number of leave reserve personnel handy so that the fishing programme will not be affected in case a particular crew member is unable to report for duty due to genuine reasons. But in the case of certificated skill, a similar arrangement is also difficult because of the shortage in the number of unemployed certificated personnel.

In the fishing industry, as in any other industry there are certain definite laws governing the behaviour of inanimate resources such as money and machines. But the behaviour pattern of the two animate resources viz: materials (raw materials in the from of fishable concentrations of fish) and men (represented in the category of crew of fishing vessels and supporting shore staff) are highly unpredictable and hence there are no definite laws governing the behaviour of both these resources. As such management of there two animate resources assume special significance in the fishing industry. One of the major aspects to be borne in mind is the highly perishable nature of the raw materials (dead fish and other marine life). The quickness with which the raw materials are transferred from the fishing gear/deck to the fish hold and the efficiency with which these raw materials are preserved decide to a large extent the sucdess of the operations. Delay or inefficiency at any one stage can make a valuable fish catch completely useless thereby affecting the economics of operation of the enterprise as a whole. Let us hope that the present day managers in the industry would fully realise the importance of the above factors and act accordingly towards a betterments of the enterprise and also the industry as a whole. ● ● ●

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Environmental Monitoring and Forecasting Services for Indian Fisheries Possibilities and Prospects

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INTRODUCTION:

It is estimated that by 1985 it would become necessary to step up the present world fish production of 80 million tonnes to about 145 million tonnes to meet the minimum requirements of fish for the world population. Of late it has been accepted that a reasonable solution to the problem of stock and recruitment, interaction between different species and inherent variability of natural systems will help us to manage thei fisheries in a better way rather than basing the entire concept on maximum sustained yield (Gulland, 1977). Considerable amount of data has been gathered on the life histories of various species and also their environmental requirements and behaviour and several attempts have been made in the past to translate the results into practictal applications for the economic benefit of fisheries. This resulted in the recognition of a separate branch of fisheries environmental services with the basic objective of assisting fishermen in better planning for fishing operations and also in searching for fishable concentrations. Such a service will help to minimise the searching time, thereby reducing the running expenses for the craft and the crew. The net result would be a proportionate lowering of prices which in turn would make cheaper fish protein available to low income groups of developing countries.

POSSIBLE RELATIONSHIPS: As in the case of terrestrial animals, the marine fauna including fishes also respond, in variying degrees, to changes in the environmental conditions. The physical parameters such as sea water temperature, density, hydrostatic pressure, horizontal and vertical movements of water masses, the intensity of solar radiation and chemical parameters such as the saltiness of sea water dissolved gases and biological factors such as the availability of food, occurence of predators etc. decide the occurence, distribution, abundance, reproduction and mortality of individual species in space and time. "Perhaps the ultimate objective would be to predict, to a satisfying extent, meaningful relations between:

(1) Fishable fish concentrations and one or more of the easily observable environmental parameters.

(2) Changes occuring in the availability of fish and the respective environmental changes.

(3) Effect of these changes on the reeproductive success and fluctuations in the number of recruits."

(Tomczak, 1977)

Japan was one of the first countries which recognised the importance of synoptic information on oceanagraphic and marine meteorological conditions and also their application for the improvement of fishery efficiency. The valuable compilations prepared by Leavastu and Hela (1970) assume great significance in this context.

In due course the need for similar services has been accepted by several other nations such as Australia, France Republic of South Africa, U. S. A., U. S. S. R., U. K. etc. These services which are established for the benefit of the respective national fisheries provide oceanographic analyses and "stress the need to establish intelligent collaboration between services, research scientists and the end users in such a manner that all of them could considerably profit from such a collaboration. On the one hand this will result in a greater accuracy of environmental analyses and predictions and vice versa the need for better prediction may additionally justify governmental support for basic research and on the other hand fishermen will be more willing to provide the required environmental observations if the scientists conducting these services are in a position to interpret the analyses in terms understandable and usable for them." (Tomczak, 1977)

WORK CARRIED OUT BY THE EXISTING ENVIRONMENTAL SERVICES IN OTHER COUNTRIES:

(1) **Analyses/Short term forecasts:** "Analyses demonstrate the present state of it environmental condions and are taken as a basis to draw conclusions regarding the behaviour of a given fish population, also making limited extrapolations of the environmental conditions for a short time period." (Tomczak, 1977).

(2) **Mid-term and Long-term forecasts:**

These are mostly "based on climatic considerations and corresponding changes in the heat content of oceanic regions. From such environmental forecasts conclusions may be drawn concerning the behaviour of commercial species, eg. reproduction, changes in migration routes" (Tomczak, 1977)

Most of the existing services are mainly working with the first categorv of products. The analyses cover the following oceanographic and marine meteorological parameters:

(1) Temperature (2) Currents (3) Plankton (4) Wheather analyses (5) Sea state.

Satellite observations for environmental analyses and forecasts:

"Besides the direct assistance given to fisheries by visual air spotting of fish schools, remote sensors are used successfully onboard aircraft to assess environmental conditions and to monitor fish distribution. Techniques have been developed to measure the sea surface temperature with high accuracy and space resolution and, connected with it, the heat flux thermal fronts and the upwelling intensity and variability, the ocean colour (chlorophyll and plankton) and bioluminiscence of plankton. At present remote sensors from space craft observations are available for surface temperature measurements, temperature gradients and anomalies showing upwelling areas and current boundaries (Infra red and micro wave radio meters), for measurements of circulation patterns and eddies of water masses (Colour and multi spectral cameras) and for the dynamics of sea ice Great success has also been achieved in measuring chlorophyll and plankton." (Tomczak, 1977).

The following are some of the more important existing fishery environmental services:

(1) The CSIRO Service (Divn. of Fisheries and Oceanagraphy) Australia.

(2) The ISTPM, Nantes, France.

(3) The CNEXO, Brest, France.

(4) The Japan Fisheries fnformation Service Centre (JFIC), Tokyo, Japan.

(5) South-West Fisheries Centre, La Jolla, California, U.S.A.

(6) National Environmental Satellite Servicess, California, U.S.A.

(7) Marine Meteorological Fishary Services, U.S.S.R.

The following are some of the more important proposed fishery environmental services:

(1) Icelandic Herring Search and Information Services.

(2) Analyses and forecasts for North sea - surface temperature (SST) and Bottom water temperature (BWT).

EXISTING FACILITIES IN INDIA:

Two of the major fisheries in India viz. that for Oil sardine and Mackerel show large scale fluctuations in their occurence, distribution and abundance. More or less same is the case with the White bait fishery which also exhibit large scale migrations from one season to another. The above mentioned fluctuations assume great significance especially because of their impact on the total marine fish catches of the country as a whole. The average annual catch (1973-1977 figures) indicate a total catch of 1,45,000 tonnes of Oil Sardine, 57,000 tonnes of Mackerel and 32,000 tonnes of White bait. As regards Oil Sardine, 99% of the catches are landed along the Kerala and Karnataka Coasts. The fishery starts some time in August and continues up to April/May with a peak during October-January. The average potential standing stock of the fish has been estimated to be about 400,000 tonnes (PFP) of which at least 50% could be harvested. The Mackerel fishery is mainly concentrated along the coast of Goa, Karnataka and Kerala during the period August-April May. The estimated average standing stock is about 300,000 tonnes (PFP). The White bait fishery which exhibits large scale seasonal migrations is mainly concentrated between 14°N and 8°N Lat. from October through May and there after in the area between 13° and 10° N Lat. on either side of Cape Comerin during June-August. The standing stock for White bait has been estimated to be around 400,000 tonnes (PFP).

Realising the importance of proper assessment and rational exploitation of Pelagic fishery resources, particularly Mackerel and Oil Sardine, the Govt. of India organised the Pelagic Fishery Project at Cochin in the year 1971 in collobration with the United Nations Development Programme (UNDP) and Food and Agriculture Organisation (FAO) of the United Nations. The Norwegian Agency for Inernational Development (NORAD) was a collaborator during the first phase of the Project from 1971 to 1975. The Project commenced it's second phase of operation in 1976.

One of the important objectives of the Project was to study the relation between environmental factors and the distribution and migration of pelagic fish in the project area. The project document has emphasized the importance of investigating such factors which might influence the availability of fish to the existing fisheries. With the above objective in mind, the Project has put into operation a relatively extensive programme for environmental monitoring since 1971. The various other institutions currently engaged in marine fisheries research and connected aspects, no doubt, are also working on related problems, but emphasis on field operations have been limited due to various reasons. The Project has two research vessels, one 54' fibre glass boat, R. V. SARDINELLA and one 152' steel stern trawler, R. V. RASTRELLIGER, both equiped with the latest elecronic devices like SONAR, Echo Sounder, Echo Integrator etc. Both the vessels are rigged for purse-seine and trawl operations at varying depths. Regular surveys with the vessels are conducted for resources survey, environmental survey and estimation of fish abundance. The Project mainly used the recently developed acoustic techniques for the surveys and the assessment of the resources. This pioneering effort has brought forth a vast amount of information related to several aspects of the pelagic fish stocks in the area. However the efforts of the Pelagic Fishery Project have been limited to a study of selected resources in a restricted area. A country like India, with about 5000 km of sea coast and large extent of fishable areas on the shelf and beyond, requires a permanent set up to monitor the various parameters connected with fish resources, environmental data governing distribution of these resources and such others which influence the fluctuations in stock sizes. To clarify such situations and to make fairly accurate fishery forecasting, continued surveys and data monitoring are needed.

ENVIRONMENTAL SERVICE FOR INDIAN FISHERIES:

In a developing country like India with a vast potential of fishery resources, the importance of organising a fishery environmental monitoring, analyses and prediction service need not be emphasised. This assumes greater significance especially in the light of the proposed extension of the economic fishing zone to 200 miles limit. Taking into consideration the existing facilities available in the country for a rational exploitation of these resources and also the limitation by way of the number and location of operating bases, the cruising range for different types of fishing crafts, the wether conditions, availability of suitable fishing gear, width of continental shelf and bathymetry for trawling purposes, storage / processing facilities both on board and ashore, infra structure for loading of fuel, water and ice, unloading of catches and marketing facilities, and reduction of searching time to the bearest minimum, assume great significance. This is especially the case with the non-machanised boats whose operating ranges are comparatively smaller. Perhaps the first step towards organising a similar service would be to set up a facility for collection of synoptic oceanographic and marine meterological data, the analysis and interpretation of this data and to predict, within reasonable limits, the availability of fishable concentrations in specific areas. Of course, the collection of synoptic data with the co-operation of fishing vessels will, to a large extent, depend on how best one can convince the boat operator the usefulness of the processed information which is supplied in return. The nucleus of a similar facility could be any one of the already existing organisations engaged in fisheries resources survey, fisheries environmental studies and assessment of the stocks. As the work mentioned above is highly field work oriented, special emphasis should be laid on the available facilities with regard to suitable vessels, fishing gear and equipment and above all trained personnel in the respective disciplines.

The Pelagic Fishery Project of the Government of India functioning from 1971 at Cochin has already set up a stage for carrying out the types of programmes envisaged in a fishery forecasting service. The work of this project has already indicated several guidelines for attempting studies in this direction. It has been made clear that the seasonal upwelling in the Indian water would be an important phenomenon to be studied in detail every year. Temperature and current patterns are other physical aspects to be considered equally important. From the biological angle the density and distribution of plankton are likely to throw light on the migratory patterns of the commercial fish populations. Young fish survey, with special reference to the major commercial species, is also to be carried out year after year. Fishery forecasting services in the country may make a start with studies on the above indicated lines particularly with the aim of forecasting the major pelagic fisheries like oil sardine and Mackerel.

The dissemination of processed information as well as the predictions at a level, easily understandable and usuable for the basic operator, require special consideration. Different types of audio-visual media such as Radio broacasts, Radio telephone / Wireless, telegraphy messages, movie filims, notices and news letters could be tried to find out their suitability and effectiveness for different groups whose basic education and capacity to understand and assimilate the information vary within wide ranges. The effectiveness and purposeful functioning of a similar service would greatly depend on the speed with which the predictions can be transfered to reach the appropriate levels.

Field demonstration of the suitability of specific types of fishing gear to harvest the different fisheries also will have to rest with the same organisation. Once the usefulness of the service is established and the fishing community is convinced of the utility of such a service, the organisation may find it easier to induct some of the commercial fishing boats, by stages, for the collecton of certain primary data with simple instruments. Provision of some of the simple oceanographic and meterological instruments for use on board and necessary training to selected numbers of crew, in the collection, proper recording and quick transmission of such information to the interpretting agency may be necessary for working this system. A similar management has been proved effective in some of the developed countries such as Japan, Australia, U. S. A., U. S. S. R. and U. K.

In order to convince the fishermen of the usefulness of a similar service, short-term forecasts/analyses are found most effective and hence such forecasts are suggested as a first step while initiating fishery environmental monitoring and forecasting service. Later, once the effectiveness of such forecasts are proved, we can consider possibilities of organising mid-term or long-term forecasts. It is worth mentioning in this context that such predictions assume great significance with reference to those of the fishery resources which exhibit large scale seasonal fluctuations, especially the shoaling fishes found in the pelagic waters which are more influenced by the seasonal changes brought about by the variation of some of the meterological parameters and their secondary effect on the sea. The subcontinent, with the Arabian sea on the west and the Bay of Bengal on the east and the northern Indian ocean on the south, is situated in a belt where the monsoon wind system is most effecive both during the summer (SW) and winter (NE) monsoon seasons. The resulting changes in the wind systems, the accompanying current systems and the effect of the associated rain fall and river run off give rise to large scale fluctuations of the various environmental conditions which affect the existing fishery to a varying degree every year.

Let us hope that a much needed fishery forecasting service would be created in the country by continuing, developing and streamlining the existing Pelagic Fishery Project established and operated for the past 8 years with U. N. assistance. Perhaps one of the very objectives of the Project *Viz.*, "to set up a stage to continue the work of monitoring and forecasting the pelagic fish resources on a regular basis" would be achieved by developing such a national service from the already existing nucleus of the Project which is scheduled to complete it's term by the end of the fifth Five Year Plan period,

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