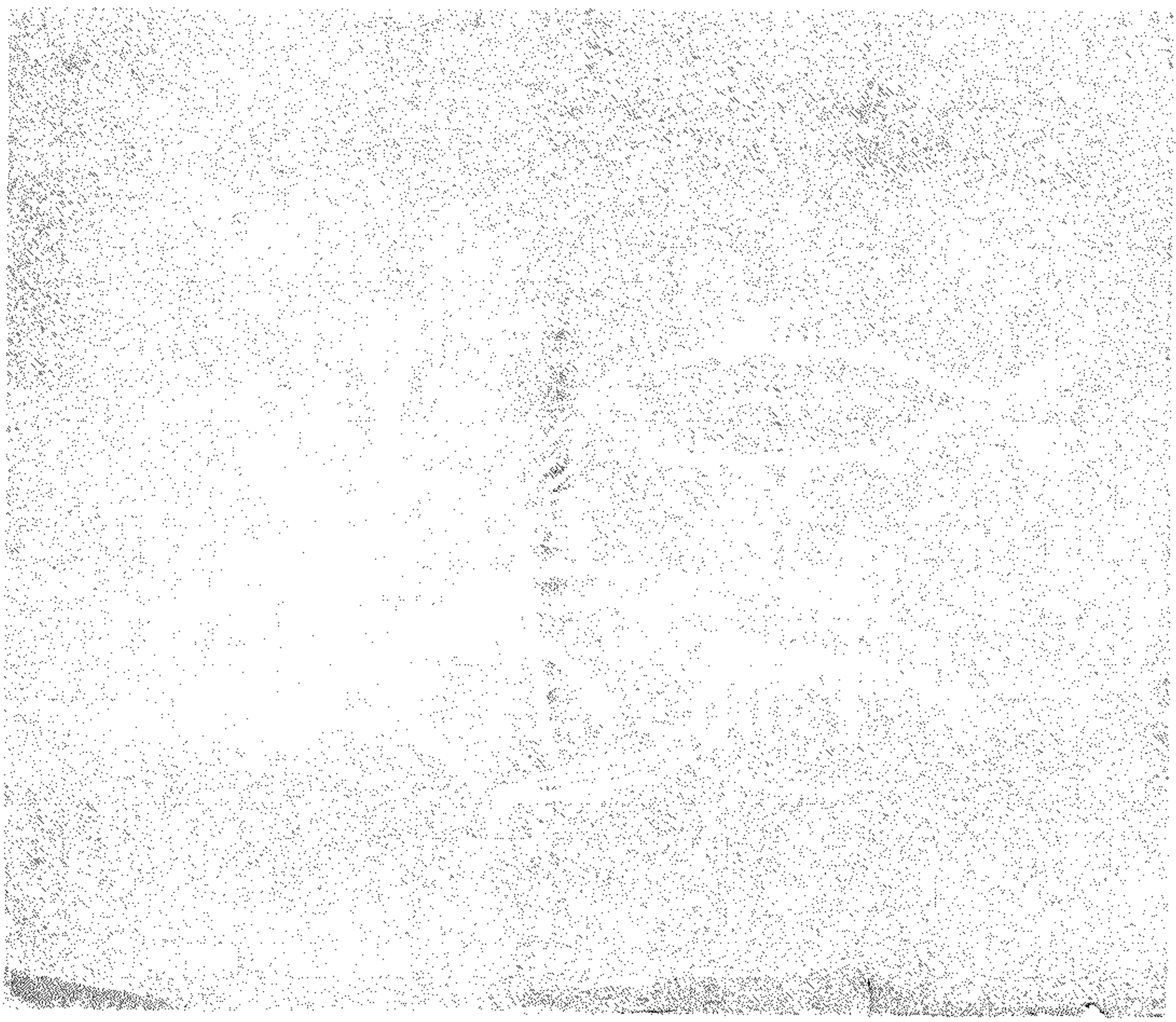
PROCEEDINGS OF THE SYMPOSIUM
ON
LIVING RESOURCES *of* THE SEAS AROUND INDIA



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METHOD OF ESTIMATION OF FISH ABUNDANCE IN THE INDIAN SEAS AND STEPS TO BE TAKEN FOR MANAGEMENT OF THE COMMERCIAL FISHERIES

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ABSTRACT

The present state of our knowledge of resources in the Indian seas, *i.e.*, the Arabian Sea and the Bay of Bengal is very limited. Exploration of demersal fisheries has been done with some intensity upto a depth of 40 fathoms only, but this does not even cover the entire coastal belt. The data available on deeper grounds are sporadic and do not lead to conclusions. On pelagic fisheries our assessment as to the quantities available is yet to be done and since the fishing fleet in the Indian Ocean is being increased considerably it is desirable to take up speedier methods of assessing the fish abundance both for demersal and pelagic stocks. Side by side it is also necessary to encourage sound fisheries management practices as the resources picture becomes clearer. The paper suggests an approach to these problems under Indian conditions.

INTRODUCTION

THE Indo-Pacific Fisheries Council of FAO had engaged a group of experts to make a review of the existing knowledge of the resources of the Indian Ocean. Their findings indicate that there are a number of areas or particular fisheries which show promise of increased yield. It has been suggested that the bottom fish on the coasts of Pakistan, West Coast of India, Bay of Bengal and Thialand is a major resource and there may be a potential between $1\frac{1}{2}$ to 1 million metric tons from this area. Another area is the Gulf of Aden and adjacent waters where productivity figures indicate enormous potential. They have recommended exploration with sonars to obtain broad estimates of yield. The oceanic islands and Banks of Western Indian Ocean are also said to have very good potential, the estimate being 2·8 million metric tons. The major difficulties here are the nature of the bottom which is rocky and markets are not organised. The prawn fisheries of the African East Coast and Madagascar in the expansive mangrove areas are under-utilised; so also the prawns and bottom fishes of the North Western Coast of Australia being poorly known.

Dr. W. M. Chapman in his address to the Advisory Committee on Marine Resources Research (ACMRR) in 1967 on the state of Ocean Use Management pointed out that ocean research over the last decade has indicated existence of large under-utilised resources in the sea and could feed the developing countries which suffer from malnutrition. The ocean was producing more animal protein per year than several times the present world population could consume and the protein malnutrition problem arose from socio-economic reasons and not from supply problems. Developing nations have found out by hard experience that while there is plentiful resources, at least in some parts of the world, it was quite a different matter to have the protein in the hands of the people who need it most. In some areas detection of abundance of fish has led to a very rapid expansion of a fishing industry which has not benefitted the consumer from the point of view of obtaining more protein for himself.

What actually happens when an area of abundance is detected near the coast of a developing country is that local fishing effort develops rather slowly and the pioneers get much more fish for less effort. The build-up of capital takes time and it may be quite some time before the fishing effort reaches the danger level. It is, therefore, necessary for developing nations to adopt a policy that intensive exploitation of areas of fish abundance should be attempted through Government incentive in the beginning. Meanwhile it is obligatory on the part of research scientists to form an idea of the sustainable stocks and devise regulatory measures as the situation warrants. Many biologists might contest this approach but it has to be conceded that for getting adequate information on the stock to enable the biologists to make a somewhat reliable assessment of the stock, there must be an additional source of information from commercial fishing and unless this is taken up at some magnitude as soon as the abundance is located the results of assessment of stocks may not have any meaningful value.

The present production of fish in the Indian Ocean has been estimated at 2·5 million tons annually of which the marine fish production of India is of the order of 9,00,000 tons per annum. Nearly 3/4 of this is landed from the Arabian Sea and the rest from the Bay of Bengal, the Arabian Sea and the Bay of Bengal constituting the northernmost part of the Indian Ocean. The broad features of this area are a high water temperature of 20°–29° C and salinity of 32–35 parts per mille. A clock-wise circulation of current is established during the south-west monsoon and gets reversed during the winter monsoon being more pronounced in the Arabian Sea. The intensive evaporation in the northern part of the Arabian Sea contributes to its high salinity.

The Bay of Bengal has warmer waters with pronounced estuarine influence on account of a large in-flow of freshwater through the major rivers. The upwelling which results on account of strong wind in the Somali coast affected by a strong current coming northwards of East Africa in a clock-wise direction has its effect even upto the Indian west coast. Large-scale upwellings occur during south-west monsoon in the south-west coast of India. In addition, there are small upwellings in some of the coastal areas of the south coast specially in the central zone. As a sequence of the monsoon circulation increased nutrients are brought to the surface. Mass mortalities in highly productive areas have been attributed to invasion by oxygen minimum layers and azoic areas have been recorded in various parts of the Arabian Sea and probably created desert conditions in the sea bottom. In a cruise between Visakhapatnam to Madras, the author came across such a desert spread over a large area. Our knowledge about the Arabian Sea and Bay of Bengal regarding productivity, etc., is limited. The following table indicates the information now available :

		Arabian Sea	Bay of Bengal
Phosphate mg/m^2	..	75–153	40–48
Primary production Mg C/M^2 per day	..	50–120	10–30 (Average for Indian Ocean)
Chlorophyll Mg/sq. meter	..	100–320	Less than 10 observations not conclusive
Phytoplankton	..	High concentration	Low concentration
Zooplankton	..	do.	do.
Benthos	..	Rich	4 to 6 times lower than Arabian Sea
Contribution to coastal landings	..	75%	25%
Catch per hour per horse-power	..	2	1

The last column in the table, *i.e.*, catch per hour per horse-power has been calculated by the author in order to arrive at a rough estimation of the fishing efficiency as the 20 to 25 vessels which were operated for exploratory survey were of different horse-power using different sizes of gear. This method has its obvious limits, but it has given, as stated above, a rough indication of the fishing efficiency. Catch per hour per horse-power in areas of different bases is indicated below:

Base		Catch/hour/H.P.	No. of hours fished
West Coast:			
Veraval	..	3·38	2186
Mangalore	..	3·24	1113
Bombay	..	1·21	6062
Cochin	..	1·21	4371
East Coast:			
Tuticorin	..	1·12	1728
Visakhapatnam	..	0·69	5166

Various estimates have been made on the fish production potential of the Indian Ocean most of these being based on studies on base line production and primary productivity. Panikkar estimates a production of 20 million tons by 2000 A.D. and thinks that the scope for development of fisheries in the Indian Ocean is moderately optimistic. The estimates are considered to be conservative by Chapman.

India's immediate concern is to obtain optimum production from the adjoining seas, *viz.*, Bay of Bengal and the Arabian Sea as the operations are more economic in areas nearer the shore. The observations in the article are confined mainly to these parts of the Indian Ocean.

Present State of Our Knowledge of the Fisheries of the Arabian Sea and Bay of Bengal

The major fisheries are the sardines including oil sardines. Sardines mainly *Sardinella longiceps* constitute 26%, Indian mackerel, *Rastrelliger kanagurta* 11%, prawns 15% of the catch, the rest being mixed fish like perches, Bombay duck, sciaenids, etc.

Oil sardine Fisheries

The oil sardine, *Sardinella longiceps*, has a rather limited geographical distribution. The range extends from Arabia to Philippines through Seychelles, India, Ceylon, Andamans and the Malay Archipelago. Based on proportion of the head in total length and also the length of the tail, it has been suggested that there is more than one race in this species in the West Coast. The current belief is that shoals migrate *en masse* from the offshore area to the inshore area simultaneously in the west coast towards the end of the monsoon but during the end of the fishery in summer the shoals move back into the offshore waters gradually from northern areas ending with the southern centres. The surface shoals display flipping, pattering, rippling, leaping, and luminescent shoaling characteristics. The bottom shoals do not appear to have been studied and the characteristics are not known. The shoals are found to be scattered by predators particularly dolphins. The fluctuations in the occurrence of sardines in the inshore area have been considerable. The landings in Kerala were as high as 281,548 tons in 1964–65 as against only 12,000 tons in 1950–51. The reasons for such enormous variations have not been elucidated.

Mackerel Fisheries

The Indian mackerel, *Rastrelliger kanagurta* is widely distributed in the tropical Indo-Pacific. In the Indian Ocean it has been recorded from the Persian Gulf, Somalia, Seychelle Islands, Mozambique in Delagoa Bay, coast of South Africa around Durban, Pakistan, coasts of India, Andaman and Nicobar Islands, Ceylon and Burma. In the Central Indo-Pacific it has been recorded from Malaysia, Thailand, Cambodia, Philipplines, Indonesia, Australia along the coast of Queensland, New Guinea, Melanesia, Micronesia and Polynesian areas, islands of Bougainville, Solomon, New Hebrides, Fiji, Samoa, coast of People's Republic of China, Taiwan, Hong Kong, Ryuku and Hawaiian Islands. Although as important as *Rastrelliger kanagurta*, *R. brachysoma* is also known to be a fishery in some parts of the Indian Ocean and Central Indo-Pacific. The distribution of this species appears to be confined to the waters of South Africa, around Durban; Andaman Islands, Malaysia, Thailand, Philippines, Indonesia, New Guinea, Fiji and Solomon Islands. As yet the racial studies have been found to be inconclusive. It has been observed that in the northernmost part of the west coast the shoals enter into inshore waters when north-easterly wind starts. The shoals usually move along the current of water at high tide. When there is a strong easterly wind they come close to the shore moving in semicircular or arrow-head formation. The shoals appear as dark patches with ripples during day from a distance and are phosphorescent during night. They scatter when boats approach them or predators chase them. When sinking downwards they do so in a compact mass. The speed has been observed to be about 8–10 nautical miles per hour but the normal speed appears to be only 3 to 4 knots. It has been estimated that nearly 10% of the total marine fish production is attributed to the mackerel. The main fishery is confined to the west coast of India from Ratnagiri to Cape Comorin but sporadic shoals are seen near Mandapam, Nagapattinam, Madras, Kakinada, Visakhapatnam and some parts of Orissa. It is extremely interesting to note that a small number of mackerels has been taken in trawl catches from Bombay and Saurashtra coasts as well as from the deeper regions of the Bay of Bengal; the size was around 30 cm and the depth of the fishing area 30–73 metres. Obviously this factor has to be taken into consideration while trying to study the abundance of occurrence of mackerels. Mackerel yields also fluctuate considerably. Against 1,34,000 tons in 1960 only 16,000 tons were landed in 1956. Some studies have been conducted on the effect of temperature and salinity on mackerel catches. It has been found that mackerel is more susceptible to changes in temperature than salinity and different degrees of toleration are evinced by different sizes of fish, *e.g.*, 19–21 cms. fish appear to tolerate increase in temperature and salinity whereas smaller fish shoals in large numbers at lower levels of temperature and salinity. It has also been observed that there is an inverse relationship between the landings and the rainfall. The effect of wind force has not been elucidated fully. An interesting fact is that mackerels have been known to enter estuarine waters and tolerate low salinity even down to 2·04‰. Recent experiments of Alikunhi indicate that mackerel survives without difficulty in running sea-water and tagging mortality, when mackerel has been kept under such conditions, has been nil.

Shrimp Fisheries

Several species of shrimp are caught in India including: *Metapenaeus dobsoni*, *Metapenaeus affinis*, *Metapenaeus monoceros*, *Parapenaespsis stylifera*, *Penaeus indicus*, *Penaeus carinatus* and *Penaeus monodon*. India is the world's second largest producer of shrimp exceeded only by the United States. In 1966 the catch was 90,900 metric tons representing 15% of the world shrimp catch, the major producing area being the south-western coast. The exploratory survey of the shrimp grounds has been confined to about 25 fathoms contour of the continental shelf and the bulk of the catch has come from a depth approximately 10 to 15 fathoms. The survey has been conducted with shrimp trawl nets from small boats of 32 to 36 ft. Improved gear like double rigger nets, etc., have not been tried on a large scale as yet. Recent developments have taken place in locating shrimp beyond a depth of 100 fathoms in the Indo-Norwegian Project in Kerala and this will be an interesting aspect of the exploratory survey if deep water shrimp grounds are located in the seas around India.

Abundance in Coastal Waters

The average landings of marine fish in the East and West Coasts of India in 1964, 1965, 1966 in tonnes is indicated below :

	Pelagic	Bottom	Total
East coast ..	93,802	83,806	177,608
West coast ..	366,662	150,705	517,367
TOTAL ..	460,464	234,511	694,975

It is interesting to compare the present yield of fish per sq. mile of fishing areas in the inshore and offshore waters as indicated in the following table. While the figures in the last column have been computed by extensive exploratory operations by the deep sea fishing vessels of Government of India, inshore figures are based on computations from the multi-types of gear used in traditional fishing.

Catch per sq. mile of pelagic and bottom fish in inshore area and bottom fish in offshore area

	Catch per sq. mile in tonnes		
	Pelagic fish 0–10 fms.	Bottom fish 0–10 fms.	Bottom fish 10–40 fms.
East coast zone			
Visakhapatnam	46·80	32·19	5·20
Tuticorin ..	29·21	30·80	9·94
West coast zone			
Cochin ..	242·31	55·00	4·49
Mangalore ..	153·46	11·82	5·32
Bombay ..	23·33	78·30	8·77
Veraval ..	6·68	6·16	9·60

Tiews (1966) estimated a yield of 12·3 tons of demersal catch from 1 square nautical mile to a depth of 50 fathoms. The estimates presented by the author in the following table are on the basis of 3 years sampling and the potential yield has been presumed to be the catch on the assumption, that in view of the rapid growth of fish in tropical waters and the age of the fish contributing to commercial catch being mainly between 1 to 3 years, sufficient stock is left behind to maintain a fishery at this level of exploitation. According to this table a potential yield of about 0·6 million tons can be expected from the coastal belt between 10–40 fathoms.

Potential yield of demersal fish from offshore areas

Base	Total area in square metres	otal computed yield in tonnes	Yield per sq. mile in tonnes
East coast			
Visakhapatnam	5,180	26,936	5·20
Tuticorin ..	8,400	83,496	9·94
West coast			
Cochin ..	7,560	36,969	4·89
Mangalore ..	9,240	49,157	5·32
Bombay ..	11,840	130,147	8·77
Veraval ..	28,300	268,800	9·60

Methodology of Exploratory Fishing

The sampling of fishing grounds has been done at random in squares to which our fishing areas have been divided. This is usually called as grid sampling system. The samplings have been conducted from suitable bases with various types of vessels using various types of gear. The author had attempted to analyse some of these data for 3 years and was able to form some broad conclusions regarding the availability of exploitable stock in our coastal waters upto a depth of 40 fathoms by using the " swept area method ". It was, however, quite clear as the analysis was going on that the technique adopted was not the one to yield a rapid estimation of fish abundance nor was it adequate to enable investment of capital by the industry. Some of the vessels were engaged in capture of all bottom fish and some had special gear for shrimps. Pelagic survey was limited to use of certain types of purse seining without adequate experiments having been conducted on the most suitable type of gear for a particular fishery. Furthermore there had been very little co-ordination between the occurrence of fish and the environmental factors in the fishing grounds, not to speak of the study of fish behaviour.

The ACMRR of FAO had set up a Working Party on Direct and Speedier estimation of Fish Abundance which reported to the Committee its findings in 1967. The party stated that while the traditional methods of sampling by fishing gear and marketing the fish were likely to continue to be important for estimating abundance of fish stocks particularly in the areas where there was organised collection of fisheries statistics, catch sampling and other scientific investigations, these were inadequate and time-consuming for obtaining initial estimate of abundance of unexploited resources. The Working Party was dealing, however, not only with areas of fish abundance but also the assessment of total stock. The first acoustic technique was echosounding which came into use towards end of the 19th century. Sonars for fish detection came broadly into use in Norway in early post-war years. While pelagic stocks could be assessed somewhat more easily, difficulties were faced regarding the demersal stocks but with greater technological developments in production of special equipment these are gradually being overcome. The use of narrow beam and high resolution has facilitated detection of bottom fish particularly the shrimp. It is well known to persons using echosounders or sonars that it has not yet been possible to identify the targets acoustically in most cases. The targets may consist of different species but it is also possible that they can be distinguished by their habits of shoal formation or by their known habits of dispersal. In most cases, however, identification by either direct underwater observation or by using suitable sampling gear is necessary. A counting system has also come into use by increasing transmission frequency and by shortening pulse length in case of smaller fish. The targets have also been counted in a scanned beam of a sector scanner.

The broad recommendations of the Working Party are that the details of survey plan should be decided upon with regard to local conditions and should include those of the operational grid in surveying an area by echosounder or sonar. For sonar transmissions it has to be borne in mind that these are modified by thermal layers and the range is affected but this can be determined after studying the hydrographic conditions. Under favourable conditions a sonar can search a band of water as much as 5 Km wide, while the echosounder searches a much smaller volume of water, very often not more than 30 metres wide. The survey plan has to take into account these limitations. For demersal fish it has also to be noted that the effective volume is limited to a region near to the axis of transmission. There should be good co-ordination between detection and capture for identification purposes. Navigational aids are necessary for good fixing of positions in any survey. Advanced countries are now adopting use of calibrated equipment for counting surveys of individuals and/or multiple targets aimed at estimating absolute abundance. They are using high resolution sector scanners and other equipments which make the echosounder more effective. The other method which is being rapidly developed is the direct underwater optical method and there is considerable hope that underwater vehicles which will combine acoustic and optical method will come into increasing use.

For surface schooling fish aerial surveys have been used profitably for assessing the abundance of a stock in a well-defined area. It is well known that a natural follow-up has been utilisation of the spotting surveys by the fishing vessels. Aerial surveys also make its own contribution for estimating relative abundance. Bearing in mind these recommendations and leaving aside the detailed techniques adopted for each equipment it is necessary to devise a broad pattern of procedure for locating fish abundance of the Indian coast as quickly as possible. On the research side the world is trying to develop such equipment as would indicate the size and the species in the shoals using acoustic methods of determining the size of fish and frequency ratios on methods based on air-bladder resonance. Research is required to discriminate fish target from bottom reverberation and identification by photographic method of fish detected by the acoustic equipment. The role of electronics has been diversified for utilisation in the fishing industry by utilising different frequencies, *e.g.*, frequencies from 14 to 200 KHz are used by fishermen to observe conditions of fish schools and also for underwater television, sonar, fish finder and net sonde. For fixing the position of vessels, frequencies from 100 to 2,850 KHz are used by receivers. Extremely high frequencies are used by radars, *e.g.*, 9,375 MHz with the help of which fishermen keep their boats safe from other boats or gear when operating on a fishing ground in fog or snow or in the dark at night. Telecommunications are used utilising approximately frequencies from 1,600 KHz to 150 MHz. A new use is being found for frequencies from $4 \cdot 3$ to $7 \cdot 3 \times 10^6$ GHz for fish-luring or fish trapping. Similarly it has been found that some of the fish schools do not like low frequencies and these are being utilised to partition an enclosed water area from the outside zone in lieu of a partition net. Buoys with arrangements for giving out a specific signal have been used, in addition, by attaching them to lines and nets scattered over a wide range and this has enabled the nets to be located by the fishing vessels. The development of single side-band communication system has enabled fishing boats to communicate directly with other boats upto a distance of 1,000 Km using very small quantity of power. It may not be a distant date when electronic equipment will be installed at major points in the sea and convey information on temperature, current, plankton and fish school to their control stations. This information in turn will be utilised by fishing boats. The present trend has been that more sophisticated electronic equipment is being used in increasing number by boats of smaller tonnage which hitherto had been content at best with a small echosounder and a portable radio telephone.

The word exploratory fishing has been sedn to cover various activities connected with fisheries resources. In many places it is confined only to resource assessment whereas in some others it is comprehensive, *i.e.*, it takes care of resources assessment, development of process of exploitation and also training of the personnel required for fabricating the gear and all other activities leading to exploitation. The general specifications for an exploratory vessel as indicated by Alverson of the U.S. Bureau of Commercial Fisheries, Seattle, are that they be equipped with a good white line type echosounder and horizontal ranging equipment. They should include a small hydrographic winch and the vessels should have multi-purpose capabilities, *i.e.*, having the ability to operate gill nets, long lines, purseseiners, trawls, etc. He does not think that it is not possible to utilise all these methods on one boat but what may result is that all the equipment will not be utilised with optimum efficiency which actually is not required in an exploratory vessel. According to him planning should include a thorough evaluation of the area to be explored, the physical and chemical oceanography features of the region including topography, meterology and general oceanographic data as well as data on existing commercial fisheries. An assessment has to be made of the results of biological and exploratory surveys already carried out and correct identification of the fauna is of utmost importance. A decision has to be taken on the right type of sampling gear, which has to be evolved again by preliminary experiments for specific purposes. Alverson has identified three techniques (1) the general survey which follows a specific trackline which fixes specified stations and this is used in areas where there is little information concerning the fauna. Various types of gear are used for sampling and this operation yields qualitative information on occurrence of different species of fish. (2) To obtain information on seasonal distribution and abundance the survey is planned for species groups or for individual species. The sampling programme has to be stratified taking into account the distribution patterns with reference to hydrographical conditions. (3) The third type is specific for demersal fishing gears.

In all the three types of survey considrable use is made of acoustic equipment making detailed plots of the bottom topography, the nature of the sediment at the bottom followed by subsequent investigations with chain drags and gear prepared on commercial lines. Demersal investigations are kept separate from pelagic fish studies in detailed survey, the operations involved in surveying pelagic fish being more complicated. Knowledge of oceanography and utilisation of various such equipment like aircraft, sonar, birds, etc., are essential for a comprehensive pelagic fisheries survey. The data retrieval system is standardised on the basis of standardised observations and recording techniques. The system also takes care of arrangements by which relevant information can be passed on to the industry very quickly. Establishment of a sampling schedule for fishery exploration have led to considerable discussions as to the pattern. There is an intrinsic desire for the grid pattern but results obtained from sampling of this type have been found to be generally poor even though the purpose is only a qualitative survey. Alverson feels that if an unexploited bottom area has to be surveyed first acoustic survey of the area will be required prior to sampling and stations must be established with regard to bathymetry and substrate features. He feels that without a stratified sampling a fair idea of the fish abundance will not be obtained. For pelagic explorations basic oceanography must be considered and may indicate the pattern of sampling to be followed. A selection of gear must be made for specific purposes and even for specific species and size group. These remarks are worth serious consideration under Indian conditions. With some experience of exploratory fishing in the East Coast from Paradeep by the author it has been felt that keeping a somewhat limited end in view, *i.e.*, introduction of commercial fishing through Government incentive within a short time of the location of fish abundance in particular areas, the grid system of exploratory fishing followed is not suitable to Indian conditions. The grid system requires, in order to have adequate sampling intensity, a large number of vessels which could be minimised by resorting to stratified sampling both with respect to the ground as well as with respect to the species involved. Further stratification can also be made according to the age group of the species important in commercial fisheries. Another difficulty that was faced in exploratory fishing was lack of preliminary knowledge on the fishing ground which had not been surveyed acoustically and chartered prior to starting sampling operations. It is worthwhile charting the bottom grounds of the area selected and stratifying the same according to depth and nature of the ground. This should be followed by a sampling operation to locate the species qualitatively and have an idea of the percentage composition of each species. Upto this point it is not necessary to have highly specialised boats for specific purpose. But when the grounds are broadly known and the likely commercial species located it becomes absolutely necessary to have a type of gear which is suited to the type of bottom and also to the type of fish as well as the age of the fish. Knowledge of fish behaviour in India being extremely limited it is necessary to try out several types of gear suited to the species from the same ground and to determine the type of gear that gives the optimum catch under the existing bottom conditions. In an interesting experiment in which 5 vessels of comparable size and horse-power were used by the author to trawl simultaneously on a ground side by side the variations in the catch were found to be considerable from vessel to vessel which indicated that there was need for considerable intensive sampling to arrive at predictable results. Unfortunately the author did not have at that time an echosounder specially suited to bottom grounds at comparatively shallow waters.

As indicated previously the major resource for commercial fisheries appear to be shrimps, miscellaneous bottom fish, sardines and mackerels and skipjack tuna. The major problem before exploratory fishing units is not only to locate areas which have abundance of these species of a sufficient concentration to make commercial fishing economic but also to determine the type of eco-system which is likely to harbour these species. The eco-system cannot be studied in detail but at least temperature, dissolved oxygen, current and a few other factors need co-relation with the quality and quantity of fish located. For the medium size vessels it is necessary to use the electronic integrator to integrate the observations quantitatively, followed by sampling either from the mother boat or accompanying boats to determine the species and the size composition of the shoals.

STEPS FOR MANAGEMENT OF FISHERIES

Taking into account the existing information on the fish abundance the following would need prior attention :

(i) Stratification of bottom area according to depth, current, nature of bottom and temperature.

(ii) Study of occurrence of prawns in relation to environmental conditions differentiating the species and their behaviour with reference to migration both horizontal and vertical.

(iii) Stratification of pelagic area with reference to depth, current, oxygen, upwellings and temperature. Production areas have to be specially studied with reference to plankton and its role in fish occurrence.

Exploratory survey data if collected accurately and according to carefully framed programme provide the basis for management of fishing grounds and fisheries. Continuous scouting operations are required to determine movements of stock with reference to environmental conditions. The minimum effort required for continuing exploratory surveys after intensive survey has been conducted would depend on the degree of variation observed in the relevant parameters. In India, fishing effort has developed in scattered areas not merely because fish resources were good in the area but also on account of various factors like facilities of landing, berthing, handling and distribution of fish, etc. With the development of a chain of fishing harbours with accompanying facilities a trend of dispersal of fishing effort is already visible. Unless an exploratory survey programme speedily estimates the fish abundance and provides the guidelines management of the fisheries cannot be effective.

Summarising the observations :

(1) In a developing country like India where it is not possible to put in adequate fishing effort in grounds newly discovered, it is desirable to orientate the survey programme to location of commercial grounds and focus the available fishing effort on the same

(2) Instead of having sampling on grid system, it is necessary to prepare charts showing areas of convergence of current and isobaths. Occurrence of fish, nature of bottom and other relevant information have already been collected by various agencies during the last two decades. Commercially important fishing grounds have to be located and exploitable stock assessed.

(3) The exploratory fleet for demersal fish selects likely areas of abundance and conducts trial operations regarding the species composition and catch per effort. It is essential that evolution of effective sampling gear must precede the trial operations.

(4) In case the catch is over 500 Kg per hour, the position is marked by a marker buoy and intensive fishing operations are conducted on various anchors to the isobaths, to determine the extent of area, the quantity of catch that can be expected and the number of boats that could be used usefully at a time.

(5) In case it is possible to increase the fishing effort, exploratory vessel has to continue sampling and keep watch on the fishing effort in the ground and when it has reached the peak point, fishing has to be stopped. It is needless to emphasise that equipment of specialised type for a particular type of fish and the depth at which it is abundant are absolutely necessary for exploratory activities.

(6) The data may have to be subjected to analysis by computers so that information is passed on to the industry within a very short time.

(7) The parameters in survey will be surface temperature, mid-water temperature, bottom temperature, salinity, turbidity, colouration, plankton, benthos, bottom samples, sea conditions, waves, flourscence, floating sea-weeds, marine birds, schools of pelagic fish, etc.

(8) Studies on fish behaviour in specially constructed test tanks and aquaria are essential for guiding the gear technologist in evolution of suitable gear.

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