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I N D I A

PELAGIC FISHERY INVESTIGATION ON THE SOUTH-WEST COAST

Report on Project Results,
Conclusions and Recommendations

by

The Norwegian Agency for International
Development (NORAD)/Institute of Marine Research, Bergen

on behalf of

The Food and Agriculture Organization of the United Nations (FAO)

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1. INTRODUCTION

1.1 PROJECT BACKGROUND

1.1.1 Broad national objective

The Pelagic Fishery Project was established in response to an official request made by the Government of India to the United Nations Development Programme(Special Fund) in July 1967.

The broad national objective of the project was to facilitate the development of the fishing industry by gaining a more steady yield from the presumbly rich fish resources in the area. This is reflected in the background information given in the Government's request:

"The stretch of coast from Goa to Cochin is known to be one of the richest fishing grounds in the world. The fish production from this area averaged 273 000 tonnes during the last 16 years, roughly half of which is attributable to the two most important pelagic fishes, oil sardine and mackerel. The landings of these species, however, have shown violent fluctuations. Their occurrence in the inshore waters within the reach of indigenous craft (6-8 miles from the shore) is restricted to a few months in the year. Enormous shoals appear in these waters in some years, while no major inshore migration occur in some other years.

During good fishing seasons, when fish are extremely abundant, difficult problems are created with respect to the handling, processing and marketing of fish, particularly in the case of oil sardine. The fishermen have to stop fishing during the period of glut, since such facilities as oil extracting plants, fish meal plants, etc, are not adequate. During poor fishing seasons, on the other hand, there is little raw material available. Without a steady yield of fish, the industry based on these rich resources could not adequately be developed.

It is generally believed that the introduction of offshore fishing vessels would assure a steady supply of fish, which is required for the expansion of the industry. As a first step, however, it is necessary to operate exploratory fishing vessels to determine the abundance, distribution and migrations of these species.

Although studies have been made on the various aspects of the biology of oil sardine and mackerel by Indian fishery research agencies, much of the information on the breeding and migrations of these species is still to be obtained. An exploratory survey is required from this point of view also.

The need for such a survey has been emphazied by the Indo Pacific Fisheries Council, as well as the FAO Committee on Fisheries.

With the assistance of the UNDP (Special Fund) the Government wishes to carry out an exploratory fishing project to survey the stocks of important pelagic species in waters off the south-west coast of India".

1.1.2 Preparatory mission

In February 1968 UNDP/FAO fielded a preparatory mission to study the question of what impact the project would have on the fisheries development in the region, and to have consultations with relevant institutions.

The mission recommended that the project should conduct resource assessments based on acoustic survey methods. For this purpose it was recommended that two survey vessels be used, one relatively small for nearshore surveys and a larger vessel for offshore work.

1.1.3 Objectives of the project

At the time of preparing the Plan of Operation only the stocks of mackerel and sardine were known to be of major commercial importance. Accordingly the purpose of the project was defined

as: " - to assist through resources surveys in the development of sardine and mackerel fisheries on the south-west coast. In particular the project will:

(a) assess the abundance of the sardine and mackerel stocks and their fluctuations, and study their spatial and temporal distribution in relation to the environment and consequential changes in the availability of fish to the fisheries.

(b) study the life-history of sardines and mackerel including migration, reproduction, growth and mortality.

(c) study the behaviour of these species with special reference to the efficiency of tactics and methods of fishing.

(d) conduct fishing experiments for the purpose of finding efficient methods and gear".

1.2 OFFICIAL ARRANGEMENTS

1.2.1 Approval, working arrangements and budgetting

The Governing Council of the UNDP approved the project at it's seventh session in January 1969. FAO was designated as Participating and Executing Agency.

Many kinds of equipment and installations of importance for the operation of the project were available from the Indo-Norwegian Project at Cochin, therefore this institution was designated as Counterpart Agency. To facilitate cooperation with the Indo-Norwegian Project, the major UNDP components of the project were sub-contracted to the Norwegian Agency for International Development (NORAD). The Institute of Marine Research, Bergen was responsible for the technical operation of the project on behalf of NORAD.

The Plan of Operation and the sub-contract were signed in October 1970, and three amendments to these were introduced during the project period. The total Government contribution consisted

of the equivalent of US $ 867 000 in kind and US $ 126 000 towards local operating costs. The UNDP allocation to the project was US $ 1 898 700. In the sub-contract the funds were detailed in Norwegian Kroner (NKr): 4 407 945 as expences towards personnel services and NKr. 6 969 425 for equipment, materials and supplies.

The project manager arrived at Cochin in December 1970, and UNDP declared the project operational as from 3 February 1971.

1.2.2 Planning and building of project vessels

In view of the long time required to plan and build the project vessels, UNDP had already authorized FAO to enter into a sub-contract for this purpose. The planning of the project vessels was, therefore, already initiated in 1969.

A considerable increase in ship building costs occurred in the period 1968-1970 and the amount allocated for the vessels in the project budget was not sufficient. To meet this difficulty NORAD assisted the project with a sum of NKr. 2.000 000 and in December 1970 UNDP made an extra allocation of US $ 70 000 for equipment.

A sub-contract was also arranged with the suppliers of the acoustic equipment, SIMRAD A/S, for preparatory work on acoustic surveying. A sum of US $ 15 000 was allocated for this purpose.

1.2.3 Mid-term review

The general inflation at the beginning of the project period together with the devaluation of the US dollar caused severe difficulties in the economy of the project and it soon became clear that with the available funds it would not be possible to complete the project as planned.

The lack of funds became one of the major items for the mid-term mission which reviewed the project in January-February 1974. The result of the negotiations was that the Government of India made available US $ 160 000 from the I.P.F. in addition

to US $ 120 000 and US $ 200 000 which had previously been allocated in November 1972 and June 1973 respectively.

NORAD made an extra allocation towards 120 man months of expert services and besides this about 20 man months for the assignment of a fishing technologist.

The mission recommended a continuation of the work programme with emphasis on surveys and studies of sardines and mackerel. However, the studies of other pelagic and semi-pelagic species such as whitebait (Anchoviella spp.) should also be continued.

The mission also recommended that the increased emphasis provided for in the Plan of Operation in the field of experimental fishing during the final years of the project should be followed and strengthened where possible. However, experience had shown that the project vessels and staff would remain fully occupied with the survey work and it would be impossible to devote adequate time and effort to items (c) and (d) of section 1.1.3.

In realization of this situation, the Pelagic Fishery Project worked out a follow-up programme for the Government of India which would essentially be implemented by national institutions.

The project should contribute with consultants and the fishing technologist provided for in the revised project budget.

1.2.4 Prolongation of the project

In December 1974 the Government of India announced it's intention to follow up the findings of the project with a second phase.

Accordingly, FAO arranged a review and formulation mission which visited India in May 1975. This mission recommended that a phase II of the project should be implemented and continue until the end of March 1979. A bridging arrangements was made to permit vessel operations to continue from October through December 1975 at which time the new project should come into

effect. In connection with this an amendment to the sub-contract brought the expenses for personnel services to NKr. 3 818 496 and the expenses for equipment, materials and supplies to NKr. 8 859 476.

1.2.5 Personnel

The project manager designate was appointed as from 1 January 1970, and recruitment of other international staff was initiated later in the year.

Also procedures for recruitment of national project staff were started during 1970. The national project director was appointed in April 1971 and five scientists were appointed in August 1971 from the Central Marine Fisheries Research Institute under the Indian Council for Agricultural Research. Names of staff members with dates of starting and eventual termination of their appointments are entered in Appendix 1.

Though some delays occurred in recruitment and clearance, most of the international staff were appointed as planned. The strained economy of the project caused much of the delay.

The national recruitment system worked fairly well in the beginning of the project period, but later on it created some difficulties in providing substitutes for personnel who were transferred.

1.2.6 Training

Funds for training abroad were not provided for in the project budget, but NORAD offered special fellowships to four of the national scientists for studies of modern survey methods at the Institute of Marine Research, Bergen. A fellowship was also granted to the electronic engineer of the project. More details on the fellowships are entered in Appendix 2.

The project also gave some training to candidates from the Central Institute of Fisheries Operatives who served their prescribed sea duty as deck hands and greasers on RASTRELLIGER.

1.2.7 Reporting

A series of technical reports have been issued from the project, the titles of which are given in Appendix 3. This also includes a list of all cruise reports and other publications related to the project. Abstracts of the technical progress reports are given in Appendix 4.

1.2.8 Major equipment

The most important items of equipment in the project are the two project vessels.

The small project vessel SARDINELLA which came to India in May 1971, is a 54 ft survey vessel built in fibreglass reinforced polyester. She is equipped with a hydraulic winch for the operation of trawls and a power block for purse seining. SARDINELLA and her equipment was described in Technical Progress Report No. 1 and her main data are given in Appendix 5.

The large project vessel RASTRELLIGER came to Cochin in December 1972. This is a 152 ft stern trawler type survey vessel equipped for operating a mid-water trawl, bottom trawl and purse seine. She is also rigged for working hydrographic stations and collecting plankton samples. Data for RASTRELLIGER are also given in Appendix 5.

The acoustic instruments are important pieces of equipment on both vessels. Each vessel has two scientific echo sounders, an echo integrator and sonar. RASTRELLIGER also has equipment for testing and calibration of the echo sounders.

2. RESULTS AND CONCLUSIONS

2.1 METHODS

2.1.1 Acoustic surveys

The results and findings described in this chapter are all based on certain methods which remained more or less the same throughout

the project period. Though these methods are described in detail in the technical reports, a brief description is also given here.

The most important part of the sea operations was the acoustic surveying for which purpose the project area was covered six to eight times a year. The normal procedure on these surveys was to cover the area with a grid of survey tracks. An echo sounder was kept continously working and the recordings were constantly under observation. Trawling was carried out for identification of the recordings and for biological sampling. Repeated surveys were occasionally carried out in order to check on the relative accuracy of the method.

Connected to the echo sounder was an echo integrator which sums the echo signals received. The sum of echo signals received per nautical miles steamed is an index of the amount of fish recorded, and therefore a measure of the fish density in the area.

The integrator values were divided into main groups of species after examination of the records together with the data from the trawl catches. These values were plotted along the survey tracks on charts and isolines for distribution were then drawn. Stock assessments were made on the basis of these maps.

2.1.2 Aerial surveys

Pelagic species such as sardines and mackerel often occurred in dense schools in the surface layer and the standard acoustic metodology described above was not suitable for observation under these conditions. An aerial survey was, therefore, arranged once a year for the assessment of the size of these stocks. For this purpose an aircraft covered the area and visual as well as photographic observations were made.

At the same time the area was surveyed by vessel. Visual observations were made for identification of schools and echo sounders were used to determine their vertical extent. Fishing experiments were carried out for identification, sampling of biological data

and for sizing of schools. The packing density of the schools was obtained on the basis of the fishing data together with visual observations.

The horizontal extent of the schools was determined from the aerial photos and their distribution was calculated on the basis of combined aircraft and vessel data.

During the two latest surveys sonar proved very useful with the transducer fixed to one side. Since the aircraft was grounded with technical defects in 1975, the survey of that year was to a great extent based on sonar observations.

Observations were plotted along the course tracks of the aircraft and vessels. Distribution charts and stock assessments were made on the basis of these plots.

2.1.3 Hydrography and plankton observations

Hydrographic observations of temperature, salinity and dissolved oxygen were made in standard sections off Ratnagiri, Karwar, Kasaragod, Cochin, Quilon, Cape Comorin and Tuticorin. Observations were made with Nansen bottles at standard depths to the bottom, or down to a maximum of 500 m.

Plankton hauls were also made in these sections, a 20 cm Bongo net being used as standard for this purpose. Continous oblique hauls were made to 100 m depth, or to the bottom when shallower.

2.2 HYDROGRAPHY

2.2.1 Background

The environmental conditions were considered an important factor in the study of fish resources since it was generally known that considerable local seasonal fluctuations occur in the project area. Collection of environmental data as described in 2.1.3 was, therefore, taken up by the project as soon as the sea operations

started. In 1971 and 1972 only the area between Karwar and Quilon was covered, but when both project vessels became operational the programme was expanded to include 7 sections, covering the whole project area. The sections were worked 7 to 8 times yearly and a total of 1449 hydrographic stations were worked. These data are the first comprehensive series of frequent oceanographic observations in the region continuing throughout all seasons during several years.

2.2.2 North-east monsoon season

As generally found in tropical waters there was a well developed transition layer (thermocline) between the surface waters and the deeper water masses. The temperature decreased rapidly with depth in this layer, which from November to March is observed at 100 to 130 m. Connected to this temperature drop there was also a pronounced transition layer in density and oxygen content at about the same depth.

In the upper waters, above the transition layer there was relatively intense mixing which originated at the surface. These waters were, therefore, warm and well aerated, with temperatures generally between 26 and 30°C and oxygen contents close to saturation.

The water masses below the transition layer were only moderatly mixed with the upper waters. The temperature was below 20°C, decreasing slowly with depth. The dissolved oxygen content was quite low, less then 1 ml/l.

During the north-east monsoon season the current generally flowed north along the coast, its velocity was, however, relatively low. Low salinity surface waters were transported by the current. This water originated from the Bay of Bengal and the equatorial regions south-east of India. This Bengal type water was present along the coast in the project area. It's presence was indicated by a decrease in salinity to around 32 °/oo from December or January onwards.

2.2.3 South-west monsoon season

The most important and predominant feature in the seasonal fluctuations was probably the variations in the current system. The current direction varied during the year, responding to the main wind field in the north-western India Ocean, including the Arabian Sea. As a result of this the current reversed in the March-April and October-November periods. During the south-west monsoon season the current,therefore, flowed southward along the coast with a much higher velocity than that of the northward current during the north-east monsoon.

The southward current carried highly saline waters to the project area from the northern Arabian Sea of salinities up to 35.5 $^{o}/oo$. In the later part of the monsoon there was, however, a thin, brackish surface layer close to the shore which was produced by run-off from land resulting from the monsoon rains.

Due to the passage of the southbound current, the stratification in the water masses including the transition layer sloped upwards towards the shore, and the oxygen deficient water from below started ascending the shelf. Because of its relatively great density this water mixed slowly with the less dense water above and its characteristics were preserved relatively well. As the upwelling developed, the characteristics of the upwelling water could be observed along the bottom almost in to the shore. While these conditions were prevalent, the entire shelf northward from Quilon was covered by oxygen deficient water with a dissolved oxygen content less than 1 ml/l near the bottom.

2.3 PLANKTON, FISH EGGS AND LARVAE

2.3.1 Background

Collections of plankton, fish eggs and larvae were made routinely at all hydrographic stations worked by the project. This was done in order to establish a general monitoring of the zooplankton biomass and of the distribution of fish eggs and larvae.

In addition, collections were made in nearshore waters on several

special cruises during the monsoon seasons. The purpose of these cruises was mainly to locate spawning oil sardines.

2.3.2 Plankton

The zooplankton biomass was at very low levels during the season from January to April. Afterwards it increased to reach a peak sometime during the July-September period soon after the upwelling during the south-west monsoon. The upwelling along the coast seemed to trigger primary production which was followed closely by secondary production of zooplankton. The timing and intensity of the upwelling to a great extent influenced the pattern of plankton production year after year.

2.3.3 Fish eggs and larvae

Particular attention was paid to the study of larvae of commercially important pelagic species. Sardines, mackerel, whitebait,carangids and coastal tuna were observed to spawn on the shelf, mainly in the areas where they are of commercial importance. The spawning was, however, apparently spread over wide areas without any sharply defined spawning grounds. In the total larval collection clupeidae represented 21 %, scombroidae 16 %, carangidae 7 % and the rest consisted of miscellaneous varieties.

Larvae of the different Sardinella species are very similar, but oil sardine larvae were the most numerous. This type was identified by the project on the basis of its numerical dominance, the myotome numbers in combination with the pigmentation characteristics and the locatities of occurrence.

Sardine larvae were met with almost throughout the year and over the entire project area, but only in abundance during the period from April to August. The sardines spawned close to the shore and spawning was most frequently noted between $11^{o}30'$ and $15^{o}30'$N. Also the Wadge Bank and the coastal stretch from Cape Comorin to Tuticorin appeared to be important spawning areas.

Mackerel larvae were collected from all over the project area in most months of the year. The mackerel spawning occurred over the

inner area of the shelf, but generally farther offshore than in the case of oil sardine. The whole coastal area between Cape Comorin and Karwar was of importance as a spawning area, particularly the southern part.

The period from April to September appeared to be the main spawning season, with a main peak before the monsoon and a secondary peak afterwards.

The whitebait stock consisted of several Anchoviella species all having extended spawning seasons. Whitebait larvae were observed during most of the year all over the project area and form the major component of the clupeoid larval population. The March-July period was, however, observed to be the season with greatest larval abundance.

The most important species of carangidae in the project area were golden scad (Caranx kalla), horse mackerel (Megalaspis cordyla) and scad (Decapterus spp.). Larvae of carangidae were found throughout the year, but spawning seemed to be most frequent in the February-September period. The Cochin-Cape Comorin region was observed to be the major spawning area for these species.

Coastal tuna, especially Auxis spp., spawned mainly between Cape Comorin and Calicut with the most intense spawning season from May to August.

2.4 MACKEREL

2.4.1 Background

Mackerel (Rastrelliger kanagurta), being one of the most important pelagic species in the area, have always contributed considerably to the fishery which has been tradionally carried out only a few miles from the shore or with beach seines.

Mackerel schools were recorded throughout the year, but surface schools have been observed particularly after the south-west

monsson. The seasonal formation of surface schools was evidently not only related to the upwelling, but also to the rich bloom of plankton which itself was a result of the upwelling. In October the upwelling ceased, and the fish were no longer restricted in their range of vertical distribution. A considerable proportion of the stock, particularly the juveniles, then moved close to the shore and became available to the traditional shore based fishery.

2.4.2 Distribution

The mackerel schools were mainly observed in a belt extending along the coast usually between 10 and 25 n.mi offshore. Sonar observations showed that schools were present in this area throughout the year, indicating that only part of the stock moves closer to the shore after the monsoon season.

The mackerel schools were to a great extent distributed in the same area as the sardine schools, and they were often difficult to distinguish from these. In some of the technical reports the mackerel distribution is,therefore, presented together with that of the sardines.

The mackerel distribution was generally found to be the same during the main spawning season of April-May as during the rest of the year. The mackerel juveniles were to a great extent similarly distributed to the adults, and were found along the entire shelf between Tuticorin and Ratnagiri. Maximum concentrations were, however, found in the south, particularly off the coast from Quilon to Calicut.

The annual aerial surveys in September-October indicated some distributional fluctuations from year to year. In 1972 it was not possible to depict the separate distribution of mackerel, but about 60 % of the combined mackerel/sardine stock was observed south of 10^{o}N. In 1973 and 1974 most of the stock was observed on the shelf between 10^{o} and 13^{o}N. In both years about 95 % of the stock was observed in this area. The observations from SARDINELLA in 1971 suggested that mackerel schools were in September-October mainly distributed north of 11^{o}N.

In 1975 the mackerel and sardine schools were mixed very much within the same area and separate distribution charts could therefore, not be drawn. The resources were, however, more or less evenly distributed along the coast, though with concentrations off Cochin an Mangalore where 26 % and 16 % of the biomass were located respectively. The data from the cruises indicated that about a third of the schools consisted of mackerel, and these were also evenly distributed in the area.

2.4.3 Life history

The observations made by the project indicate that the mackerel spawned on the inner shelf over an extended period, particularly from March to October. The most intensive spawning was observed from March to May and in September - October.

Mackerel are relatively short-lived and the stock is consequently affected by high natural mortality.

The progression of modal lengths showed a rapid growth up to 22 - 23 cm from the main spawning before the south-west monsoon until the end of the year. Mackerel spawn when one year old and few appear to survive for a second spawning.

2.4.4 Assessments

Yearly stock assessments were made after the south-west monsoon when the schools were visible at the surface. These assessments were based on the aircraft and vessel data from during the aerial surveys.

In 1972 the observations were too few to allow calculation of separate assessments for mackerel and sardines. A combined assessment was made, indicating a stock of 75 000 tonnes of mackerel and sardines. This first aerial survey was conducted on a trial basis and was supported by one vessel only. Due to this the sea observations were too few and fragmentaric and the resulting assessments were unreliable and most probably an underestimate. Evidently, however, the stock was at a re-

latively low level.

In 1973 the mackerel stock was relatively large and assessed to be 450 000 tonnes. This assessment was based on more data than that of 1972 since seven vessels supported the aircraft in making observations under more favourable weather conditions.

In 1974 six vessels participated in addition to the aircraft. The visual observational work was restricted by unfavourable weather conditions, but the use of sonar enabled a relatively reliable estimate. The stock was at a rather low level and assessed to be 100 000 tonnes.

In 1975 the aircraft was not operated and only three vessels participated in the survey. The whole area was, however, surveyed with sonar in the course of eight days, and an assessment was made on the basis of the sonar data alone. Since the mackerel and sardine schools were mixed in the area a combined assessment was made. The magnitude of the resources was relatively large and assessed to be about 1 million tonnes, of which one third was apparently mackerel.

2.4.5 Fishing Experiments

Adult mackerel are fast swimming fish which are difficult to catch with towed gear. They easily avoided the numerous trawl hauls made by the project vessels so that only stray specimens were caught. This was experienced on many occasions throughout the project period and it can, therefore, be concluded that any commercial exploitation of the mackerel stock is unlikely to be based on a trawl fishery.

Being a schooling fish, the mackerel is more suitable for purse seining. Small and shallow purse seines can, however, also be avoided by adult fish. The purse seines on the project vessels proved too shallow out in the open sea, and it was repeatedly observed that schools escaped below the net. Only in turbid, shallow water was it possible to take commercial sized catches.

A 90 ft vessel from the counterpart agency of the project, IFP,

took commercial catches with a 300 x 40 ftm purse seine.

The project vessel SARDINELLA carried out some experiments with gill nets drifting near the surface as well as set at the bottom during the night. She took catches which might be profitable for small craft such as 32 and 36 footers. This fishery could apparently be carried out throughout most of the year.

2.5 SARDINES

2.5.1 Background

The sardines (Sardinella spp. and Dussumeria spp.) were very similar to mackerel with respect to distribution and behaviour. Together with mackerel the sardines, particularly the oil sardine, have traditionally been of great importance to the coastal fishery of the project area. Sardines occurred mainly in schools which were often visible at the surface during the upwelling season. The survey techniques were,therefore, the same as those for mackerel.

2.5.2 Distribution

The sardines are, similarly to the mackerel, distributed in a band along the coast between about 10 and 25 n.miles offshore. After the upwelling season part of the stock came close to the shore and contributed to the shore-based fishery. However, sardine schools were also observed further out on the shelf throughout the year.

Juveniles were found distributed on the inner shelf southward from Karwar. In general they occurred very dispersed but dense patches were occasionally observed between Karwar and Alleppey.

Annual fluctuations in distribution were observed during the aerial surveys, similar to those of the mackerel stock.

In 1971 the SARDINELLA observations in September-October indicateted that most sardine schools were distributed north of 11^{o}N.

In 1972 it was not possible to decide the distribution of sardines separately, but the observations made indicated that this year most of the schools were sardines. Schools were observed along the coast south of Ratnagiri, but about 60 % of the combined mackerel and sardine biomass was located south of 10^{O}N.

In 1973 as well in 1974 more than 75 % of the sardine stock was concentrated between 10^{O} and 13^{O}N.

In 1975 schools of mackerel and sardines were mixed and found distributed along the coast between Ratnagiri and Trivandrum. The data available suggest that about two thirds of the schools were sardines.

2.5.3 Life history

The sardines spawned close to the shore over several months, the main spawning for the oil sardine being from May to July.

Modal sizes of the oil sardine indicated a rather fast growth up to about 16 cm length. At this size the fish were mature and they spawned in their first year of life. Oil sardines are short-lived and second time spawners are seldom observed.

2.5.4 Assessment

Assessments were based on aircraft and vessel data from the aerial surveys, and considerable year to year fluctuations were observed in the stock size. The 1972 estimates indicated a combined stock of sardined and mackerel of about 75 000 tonnes.

In 1973 the sardine stock had increased considerably and was assessed to be between 350 000 and 400 000 tonnes.

In 1974 the stock was relatively small, and assessed to be only about 50 000 tonnes.

In 1975 the combined assessment for mackerel and sardines amounted to 1 million tonnes. Probably two thirds of this large biomass

were sardines.

2.5.5 Fishing experiments

Sardines were generally difficult to catch by trawl, so only a few catches of commercial importance were taken by the project vessels when using this gear.

However, when purse seines were used they were easier to catch than mackerel, and even with small purse seines sizeable catches were taken.

2.6 WHITEBAIT

2.6.1 Background

Traditionally, whitebait (Anchoviella spp.) are of little commercial importance in the project area. Only in a few places along the coast have there been any fisheries for them. Whitebait was, therefore, not considered as an important resource when the project started. However, the initial cruises of SARDINELLA indicated that this resource was quite abundant, which deserved full attention from the project. The subsequent surveys fully confirmed these early observations and more over proved that this is one of the major pelagic resources in the area. Accordingly the project work was gradually also oriented towards investigation of this important potential fisheries resource.

The whitebait stock in the project area was found to consist of several Anchoviella species, of which A.heteroloba, A. bataviensis and A.zollingeri were the most important.

2.6.2 Distribution and behaviour

Whitebait were most frequently observed at depths between 25 and 35 m. They also occurred in quite shallow water close to the shore, particularly in the southern area. Towards deeper water whitebait concentrations were very rarely found beyond 50 m depth. Though whitebait were observed in dense schools during

daytime, they were mostly found in dense layers at or near the bottom. During nighttime they came higher up in the sea and dispersed.

Throughout most of the year, from about October to May, the whitebait concentrations were spread out along the south-west coast. Before the south-west monsoon season there was a southward migration, and during the monsoon they were concentrated in the Gulf of Manaar, particularly on the shelf off Cape Comorin and eastward to Manapad.

This migration was apparently related to the oceanographic conditions. The southbound migration followed the current which flows southward from March or April. In shifting southwards the whitebait also avoided the oxygen deficient water which started ascending the shelf north of Quilon at that time.

When the monsoon was over the whitebait migrated northward along the west coast, again following the current which had now reversed its direction of flow. The whitebait attained their most northern distribution in the January-March period.

Juvenile whitebait were distributed more or less along the whole shelf from Tuticorin to Ratnagiri. They were most abundant from April to July and from Otober to February and the best concentrations were found between Cape Comorin and Mangalore.

2.6.3 Life history

The three most abundant species apparently did not differ much with regard to life cycle. Spawning took place during most months of the year with one pre-monsoon and one post-monsoon peak. The growth rate was high and adult sizes of 8 to 9 cm were reached after about six months. Spawning took place in the first year of life and after spawning the fish probably suffered a high natural mortality.

2.6.4 Assessment

As a result of the seasonal migrations there were considerable local fluctuations in the availability of whitebait. Before September 1973 whitebait were grouped together with catfish and ribbon fish. However, when the stock was concentrated in the Gulf of Manaar the influence of other species was negligible and the stock could relatively easily be assessed. The assessments made in 1973 and 1974 indicated that the abundance was greatest during this period.

In July 1973 the stock was assessed to be about 500 000 tonnes.

In 1974 the stock was assessed two times while it was congregated in the Gulf of Manaar and found to be 780 000 tonnes in August and 810 000 tonnes in October.

In 1975 the assessments made in July and September indicated a stock of 880 000 and 670 000 tonnes respectively. However, the greatest abundance was assessed in April-May when the stock was distributed over almost the whole project area and assessed to be about 1.5 million tonnes. In general A.heteroloba and A.bataviensis were the most dominant species in the stock. However, A.zollingeri was quite important in the northern part of the area in April-May when about 850 000 tonnes were located north of 15°N. The migratory range of the whitebait stock stretches northward beyond the project area and it is likely that particularly A.zollingeri may be quite abundant north of Ratnagiri.

2.6.5 Fishing experiments

Numerous fishing experiments on whitebait with various types of gear were tried. The general conclusion was that whitebait are easy to catch.

It was observed that in many cases whitebait occurred in concentrations dense enough for purse seining. Experiments showed also that they were easily attracted by light to form concentrations suitable for this gear.

The whitebait were easily caught by trawl. A mid-water trawl proved most suitable since the concentrations most often occurred at some distance from the bottom.

The project vessels obtained quite encouraging results, and catches averaging about 1800 kg per trawl hour were taken in the Gulf of Manaar with 6x6 ftm trawls. Several catches exceeding 10 tonnes per trawl hour were taken with a larger mid-water trawl (20 m vertical opening) by RASTRELLIGER, the largest being about 40 tonnes.

Good results were also obtained with the 6x6 ftm mid-water trawl off the south-west coast with catch rates averaging about 1000 kg per trawl hour.

Promising results were also obtained with a small high opening bottom trawl operated as a pair trawl by two 32 footers.

2.7 OTHER FISH

2.7.1 Background

A considerable biomass of other pelagic resources was observed along with the main groups mentioned above. This biomass included some species of commercial importance which were dealt with as separate groups in the technical reports. The species confined to the nearshore zone were grouped as "shallow water mix". Catfish and ribbon fish were observed to be relatively abundant and contributed to the catches on the whole shelf along the south-west coast. The horse mackerel group was mostly observed on the outer shelf, particularly in the southern part of the project area. The rest of the biomass, which included a variety of species, is grouped here as "miscellaneous" fish.

2.7.2 Horse mackerel

The important species in this group were horse mackerel (*Megalaspis cordyla*), scad (*Decapterus kurra*), Russel's scad (*D.russeli*) and travally (*Caranx* spp.).

These species occurred in characteristic schools mainly on the outer and middle shelf, but occasionally also dispersed. Schools occurred in the whole project area, but the abundance was greatest south of 9°N. No distinct seasonal distribution pattern was observed during the year. However, due to the schooling pattern of horse mackerel the assessment of this group was considered uncertain. Separate estimates have been prepared since September 1973, indicating an average stock of about 180 000 tonnes. A general increase was observed after the monsoon season in 1974 and a maximum of about 550 000 tonnes was recorded in May 1975.

Horse mackerel were difficult to catch by trawl and only small catches were taken by the project vessels with such gear. Better catches were taken by purse seine, but such fishing required a deep seine since the schools often occurred at some depth. Catches taken with gill nets were of sizes which may be profitable for smaller fishing vessels.

2.7.3 Catfish and ribbon fish

This group consisted of several species of catfish (Tachysurus spp.) and ribbon fish (Trichiurus spp.) and has been assessed separately since 1975.

They were found distributed along the whole south-west coast, most abundant around 50 m depths. Only small seasonal variations were observed in the distribution pattern, but the stock had apparently a more southerly distribution during the south-west monsoon than during the rest of the year. These species represented about 20 % of the total fish biomass and can consequently be considered as an important resource. In 1975 the stock was on average assessed to be about 475 000 tonnes.

The pelagic trawl seemed to be suitable gear for catching these species. In August 1975 catch rates of up to 2800 kg per trawl hour were obtained.

2.7.4 "Shallow water mix"

This group of fish consisted mainly of silver bellies (Leio-

gnathus spp. and Gaza minuta), golden scad (Caranx kalla), butterfish (Lactarius lactarius) and glass perch (Ambassis sp.). The proportions of the different species in the group varied from place to place and from period to period.

During the day they were located near the bottom and dispersed up in the water column during the night. Most of the year the species of this group dominated in the nearshore zone along the entire coastal stretch of the project area. During the south-west monsoon season they were in the area where upwelling occurs, distributed in the upper layers farther offshore.

The average biomass of "shallow water mix" was assessed to be about 50 000 tonnes and the maximum stock size of 185 000 tonnes was recorded in May 1975.

These species were easily caught with various types of trawl and catch rates of up to one tonne per trawl hour were obtained during daytime as well as during nighttime.

2.7.5 Miscellaneous species

The project concentrated on the main groups of pelagic species which have already been dealt with in previous reports. However, in addition to these there was a great variety of miscellaneous fish which contributed to the survey recordings all along the coast. Though these species occurred in varying quantities, none of them contributed greatly to the biomass of the shelf area. Some of them were, however, high quality fish and fetched good prices on the local market. The most important of these were pomfret (Stromateus spp.) and seerfish (Scomberomorus sp.) which are pelagic species often occurring near the sea surface. They were caught with trawls as stray individuals by the project vessels. The other pelagic and semi-pelagic species that contributed to the biomass were lizard fish (Sphyraena spp.), threadfin bream (Synagris sp.), Indian anchovy (Thrissocles mystax), sharks and rays. Concentrations of cuttlefish and squid (Cephalopoda) were also occasionally encountered, often occurring in the zone near the bottom.

The species mentioned above were mostly recorded on the middle and outer shelf, and their distribution pattern was more or less uniform throughout the period. Due to the variety of species, it was difficult to draw a comprehensive picture of their overall migratory behaviour. Nevertheless, the general trend seemed to be that they are found in abundance on the northern shelf during post-monsoon months and are concentrated on the southern shelf during the monsoon period.

The lantern fish group, consisting mainly of the two genera Myctophum and Vinciguerria may become commercially important because of their relatively great abundance. Echo recordings og this type were made in oceanic waters, particularly in a belt just beyond the edge of the shelf. This group exhibited pronounced diurnal vertical migrations rising from deep scattering layers during nighttime and forming a layer near the surface. Swimming crabs (Charybdis sp.) were often recorded in considerable quantities together with the lantern fish.

The typical demersal fish which contributed to the echo recordings were: snapper (Lutjanus spp.), rock cod (Serranus spp.) and pig-faced bream (Lethrinus sp.).

2.8 CONCLUSIVE REMARKS

The extensive resources information provided by the project in less than 5 years were the result of intensive, all-seasons survey work at sea. Modern acoustic instrumentation and methodology were applied combined with frequent fishing for identification and sampling. This activity required intensive utilization of both project vessels and took up a considerable proportion of the working capacity of the project staff. It was, however, to a great extent also possible to work up the observations and, thereby, follow the trends in abundance, migration and behaviour without much delay. The general knowledge about the resources was, thereby, gradually broadened and utilized in the current planning of the field activities as appropriate.

The assessments made for the various species gave figures for total biomass of each group. These pelagic species are, however,

short-lived with rapid growth and most of them spawn within their first year of life. Generally, the spawning takes place over extended periods with the pre-monsoon and post-monsoon periods as the most important seasons. There is almost certainly a high natural mortality after spawning and the stocks are, therefore, susceptible to annual variations in recruitment. On the other hand, however, the maximum sustainable yields are taken at high rates of fishing.

The monitoring based on the frequent surveying gave particularly good information on trends in the abundance of the fish stocks during the project period. In general the biomass was at its lowest seasonal level in the December-January period. As regards more long-term trends the observations indicate that the total resources were at a low level of abundance from the middle of 1973 till the beginning of 1975. From late 1974 there was a pronounced increase in the biomass which reached a maximum in the beginning of the south-west monsoon in 1975. It is worth nothing that this fluctuation had effect on various types of biomass, assessed from integrator values as well as from counts of schools.

Though the surveying and monitoring of the pelagic resources have revealed the occurrence of considerable fluctuations in stock sizes from year to year, the existence of major under-exploited resources of small pelagic fish off the south-west coast is now proved beyond any reasonable doubt.

3. RECOMMENDATIONS

The project findings are evidence of comprehensive potentials for fisheries development in India. Most recommendations generated by these findings are evidently related to the follow-up activities required for transforming the resource information produced by the project into fisheries development. These would include: scope, organization and execution of continued surveying and monitoring of the fisheries resources and associated activities; experimental and exploratory work required to try out and introduce efficient harvesting methods suitable for local

conditions; establishing appropriate methods for fish handling and processing, developing new products; and finding market and distribution routes and facilities for the products which can be made.

However, since a decision has already been made to extend the project with a phase II, and a project document has been made which specifies activities to be undertaken in all relevant fields of work, detailed recommendations of a specific nature at this stage would in most cases be rather redundant. Accordingly only some few general recommendations are her put on record, as well as some concerning practical arrangements for future survey work.

3.1 ORGANIZATION OF ACTIVITIES

For the purpose of developing a lasting fishery based on the resources identified by the Pelagic Fishery Projet, major efforts are required in the fields of resources surveying and monitoring, experimental and exploratory fishing, fish handling, product development and processing, and marketing and distribution. All these are interdependant and the various follow-up activities required will be most efficiently coordinated in a fully integrated project.

3.2 FUTURE SURVEY WORK

The intensive survey work which was carried out during the project period gave comprehensive information on the overall picture of the fish resources in the area.

It is recommended that adequate surveys be conducted to monitor the current abundance of the resources in the area also in the future. The survey frequency can, however, be reduced since the general picture is now known. The time saved can be used for special investigations where appropriate.

3.3 AERIAL SURVEYS

The use of an aircraft for surveys of schooling mackerel and

sardines proved efficient under favourable conditions, but was susceptible to bad weather. As soon as some choppy sea grew up the schools left the sea surface and could no longer be observed visually. However, the use of sonar proved efficient under varying conditions.

For future surveys of this kind it is, therefore, recommended that the use of sonar is given higher priority than the use of aircraft.

3.4 EXPERIMENTAL FISHING

Since the behaviour of the various types of fish are different, a commercial fishery would have to diversify with regard to fishing techniques and gear. Mackerel and sardines are best caught by purse siene, whereas a fishery on whitebait can be carried out with trawls. Trials on such a diversified fishery should be made by various types and sizes of vessels.

During the second phase of the project it is, therfore, recommended that a selection of suitable vessels be operated and administrated by the project for fishing experiments. These vessels could be chartered from Government agencies or private firms. To begin with a 90 ft vessel would be suitable for purse seining of mackerel and sardines while 57 and 72 ft craft with mid-water trawls could cary out trials on the whitebait fishery. Smaller vessels with pair trawls could also be tried on this fishery.

3.5 ENVIRONMENTAL MONITORING

On the basis of the information the project acquired on the environmental conditions, future monitoring may require fewer observations.

It is recommended that the number of surveys covering the whole project area be reduced to four per year and to work one or two sections more often. One of these sections could appropriately be the section off Cochin.

3.6 CATCH STATISTICS

The project established 13 centres along the coast to collect samples and catch statistics from the commercial fishery of mackerel and sardines. It is recommended that this programme eventually be reduced and that the activities should be concentrated at the most successful centres.

APPENDIX 1

PROJECT STAFF

1.1. International staff

		Arrival	Departure
S. Olsen	Project Manager	4.12.70	23.1.74
J. Blindheim	" "	19.1.74	18.1.76
S. Tveite	Biologist	4.9.71	10.6.73
T. Monstad	"	21.2.74	18.12.75
H. Bjørke	"	12.4.74	12.7.75
O. Chruickshank	Acoustic Expert	9.4.71	10.5.73
K.A. Hansen	" "	3.10.72	3.8.75
V. Torsvoll	" "	21.8.73	7.7.74
I. Svellingen	" "	2.9.74	14.12.75
Y. Ellingsen	Skipper	10.5.71	31.5.72
B. Hansen	"	27.7.72	12.10.73
O. Kristensen	"	11.12.72	27.10.73
M. Ødegaard	"	9.11.73	14.12.75
H. Henriksen	Marine Engineer	1.5.71	24.4.74
R. Øksnes	" "	21.2.72	20.7.74
H. Lenes	" "	2.8.74	14.12.75
S.G.Klepp	" "	2.8.74	31.1.76
R. Skåtøy	Masterfisherman	11.12.72	21.11.73
A. Hermansen	"	26.6.74	31.1.76

1.2. Concultants

O.J.Østvedt	Project planning Plankton and pelagic resources	5.11.71	13.12.71
O. Nakken	Acoustic Programming and assessment	11.2.72	23.3.72
J. Blindheim	Oceanography	21.2.73	1.4.73
O. Nakken	Acoustic surveying	26.6.73	7.8.73
O. Nakken	" "	23.4.74	24.5.74
S. Olsen	Aerial survey	10.9.74	29.9.74
J. Schärfe	Fishing Technology	10.9.74	2.10.74

(1.2. Consultants continued)

		Arrival	Departure
G. Pajot	Light fishing	8.9.74	27.9.74
S. Tveite	Fisheries biology	27.8.75	15.12.75
T. Jacobsen	" "	31.10.75	19.12.75
O.M.Johannessen	Oceanography	14.11.75	19.12.75

1.3. FAO Administrative support personel

N. Sivaramyan	Administrative Asst.	12.4.71	31.1.76
T.P.Shanmugham	Driver	1.9.71	31.1.76

1.4. National staff

M.D. Menon	Project Director	Mar. 71	Jan. 76
N.Radhakrishnan	Biologist	Aug. 71	May 74
D. Chakraborty	"	Aug. 71	June 75
K.V.N. Rao	"	Aug. 71	Jan. 76
K.C. George	"	Aug. 71	Jan. 76
V.N. Bande	"	Aug. 75	Jan. 76
M. Kumaran	"	July 75	Jan. 76
G. Subbaraju	Oceanographer	Aug. 71	Jan. 76
R.Krishnaswamy	Engineer Electronics	June 72	Aug. 74
P.M. Sadanandan	Skipper	July 71	Jan. 76
N.G. Karkara	"	July 72	June 73
A.J. Paul	"	Nov. 73	May 74
M.P. Hamza	"	Dec. 73	Jan. 76
K. Koyamma	"	Nov. 74	Jan. 76
J.A. Eappen	Marine Engineer	Aug. 72	Sep. 74
V.G. Antony	" "	Jan. 72	Aug. 72
P.B. Nair	" "	Dec. 72	June 74
J.J. Panikulam	" "	Jan. 75	Feb. 76
E. Zacharia	" "	June 75	Jan. 76
G.Ramamurthy	Admin. Officer	Apr. 72	Jan. 76

APPENDIX 2

FELLOWSHIPS

In order that the scientists engaged with the project should obtain an opportunity to study the sampling procedures and survey methods applied by the Institute of Marine Research, Bergen, NORAD granted 40 man months fellowships. The scientists visited the Institute as entered below:

Name	:	D. Chakraborty
Subject	:	Modern methodology for stock assessment and collection of field data in fishery.
Duration of fellowship	:	9 months, August 1971 to May 1972.
Name	:	K.C. George
Subject	:	Survey of pelagic fishery resources with special reference to eggs, larvae and juveniles.
Duration of fellowship	:	8 months, February to September 1972.
Name	:	R. Krishnaswamy
Subject	:	Use and maintenance of acoustic equipment used in fishery research.
Duration of fellowship	:	6 months, July - December 1972.
Name	:	K.V.N. Rao
Subject	:	Theoretical and practical methods of pelagic fishery resources survey.
Duration of fellowship	:	9 months, August 1971 to May 1972.
Name	:	G. Subbaraju
Subject	:	Oceanography in relation to fisheries.
Duration of fellowship	:	6 months, January - August 1972.

APPENDIX 3

LIST OF DOCUMENTS

Reports and publications issued by the project and important reports related to the project.

3.1 Technical progress reports issued by the project

PROGRESS REPORT NO. 1 (1971)
R/V SARDINELLA and her work from June to October 1971.

PROGRESS REPORT NO. 2 (1972)
Results of the first year's survey with the SARDINELLA.

PROGRESS REPORT NO. 3 (1973)
Hydrographic investigations - June 1971 - January 1973.

PROGRESS REPORT NO. 4 (1973)
Report of aerial survey 3 - 10 October 1972.

PROGRESS REPORT NO. 5 (1973)
Biological sampling data and catch statistics of mackerel and oil sardine from different fishing centres during the seasons 1971/72 and 1972/73.

PROGRESS REPORT NO. 6(1974)
Survey results 1972-73.

PROGRESS REPORT NO. 7 (1974)
Plankton, fish eggs and larvae studies.

PROGRESS REPORT NO. 8 (1974)
Report of aerial survey, September - October 1973.

PROGRESS REPORT NO. 9 (1975)
Report of aerial survey, September 1974.

PROGRESS REPORT NO. 10 (1975)
Young fish studies.

PROGRESS REPORT NO. 11 (1975)

Survey of mackerel and sardine schools in 1975.

PROGRESS REPORT NO. 12 (1976)

Survey results 1973/74.

PROGRESS REPORT NO. 13 (1976)

Survey results 1974/75.

PROGRESS REPORT NO. 14 (1976)

Catch statistics, growth and sexual maturity of mackerel and oil sardine as analysed from data collected at fishing centres on the south-west coast of India.

PROGRESS REPORT NO. 15 (1976)

Oil sardine larvae.

PROGRESS REPORT NO. 16 (1976)

Physical oceanography on the south-west coast of India based on investigation by the UNDP/FAO Pelagic Fishery Project.

PROGRESS REPORT NO. 17 (1976)

Report on fish eggs and larvae.

PROGRESS REPORT NO. 18 (1976)

A synopsis of the information on pelagic resources along the south-west coast of India. (Under preparation).

PROGRESS REPORT NO. 19 (1976)

Fishing results in the pelagic resources off the south-west coast of India. (Under preparation).

3.2 Cruise reports issued by the project

UNDP/FAO - Pelagic fishery Project. 1971. Cruise reports covering the cruises S/71/1 through 28. 27 reports.

(3.2 Cruise reports issued ..... Continued)

UNDP/FAO - Pelagic Fishery Project. 1972. Cruise reports covering the cruises S/72/1 through 51. 42 reports.

UNDP/FAO - Pelagic Fishery Project. 1973. Cruise reports covering the cruises R/73/1 through 31 and S/74/1 through 24. 14 reports.

UNDP/FAO - Pelagic Fishery Project. 1974. Cruise reports covering the cruises R/74/1 through 23 and S/74/1 through 38. 12 reports.

UNDP/FAO - Pelagic Fishery Project. 1975. Cruise reports covering the cruises R/75/1 through 17 and S/75/1 through 29. 9 reports.

3.3 Various publications issued by the project or related to the project.

NAKKEN, O. 1972. Acoustic abundance estimation, UNDP/FAO - Pelagic Fishery Project, IND 69/593, Report given as consultant in acoustics.

OLSEN, S. 1973. Role of acoustics in pelagic fishing, Financing Agriculture. Vol V. No 2-3. 37-39 pp.

OLSEN, S., TVEITE, S. and CHAKRABORTY, D. 1973. Acoustic surveying in tropical waters. ICES Symposium on acoustic methods in fisheries research, Bergen, 1973. Doc. No. 45.

OLSEN, S., CHRIUCKSHANK, O. and HANSEN, K. 1973. Target strength of porcupine fish - an outstanding deviation from the established target strength/length regression. ICES Symposium on acoustic methods in fisheries research, Bergen, 1973. Doc. No. 46.

UNDP/FAO - Pelagic Fishery Project. IND 69/593, 1973. Programme of follow-up of the Pelagic Fishery Project's findings.

(3.3 Various publications issued ....Continued)

NAKKEN, O. 1974. Report on calibration of echo integrator on board RASTRELLIGER. UNDP/FAO Pelagic Fishery Project, IND 69/593, Report given as consultant in acoustics.

SHÄRFE, J. 1974. Report of travel for consultancy on fishing technology to the Pelagic Fishery Investigation on the south-west coast (IND/593) Project. FAO Fisheries Travel Report and Aide Memoire No. 965.

PAJOT, G. 1974. Experiment in small boat purse seining with light attraction. Report to the Pelagic Fishery Project, IND 69/593, September 1974.

MENON, M.D. and GEORGE, K.C. 1975. Whitebait resources of the south-west coast of India. Seafood Export Journal, VII, 1 January 1975.

BLINDHEIM, J., CHAKRABORTY, D. and MENON, M.D. 1975. Pelagic Fishery resources of the south-west coast of India. Symposium on fish processing industry in India. Mysore 1975.

MENON, M.D. 1975. The handling and processing of pelagic fish in India. Symposium on fish processing industry in India. Mysore 1975.

Report of the UNDP Fishery Mission to India (Request for a pelagic fishery investigation, Goa - Cochin area) IND/93. Rome, February 1968.

IND 69/593 - Pelagic Fishery Investigation on the south-west coast. Report of the Mid-Term Review Mission. Rome, February 1974.

IND 69/593 - Pelagic Fishery Investigation on the south-west coast. Report of the Review and Formulation Mission. Rome, June 1975.

APPENDIX 4

ABSTRACTS OF TECHNICAL PROGRESS REPORTS

ANON, 1971. The R/V SARDINELLA and her work from June to October 1971. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 1, 16 pp.

As the first technical report issued by the project this report is introductorily describing the objectives of the project and the plans for its implementation, particularly with regard to sea operations.

The small project vessel SARDINELLA had been in operation for sometime, and this vessel is described. A description is also given of her equipment and performance.

The survey methods are dealt with in some detail, and some preliminary survey results are given based on the initial field work from June to October.

Observations of surface schools of mackerel and sardine are reported, particularly in the area north of $11^{\circ}30'N$, generally located 6 to 20 miles offshore.

In June-July accumulations of whitebait (Anchoviella spp.) were also recorded off Cochin.

The collection of hydrographic data in standard sections was initiated.

ANON, 1972. Result of the first year's survey with the SARDINELLA. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 2, 40 pp.

This report reviews the survey work done by the project during its first year of sea operations, i.e. up to the end of September 1972.

The first annual cycle of hydrography and plankton as observed by the project is described.

The seasonal upwelling of cold, oxygen deficient water is demonstrated and this phenomenon is also reflected in high values of zooplankton.

Preliminary studies indicated two periods of egg and larvae abundance i.e. April-July and September-November.

Abundance and distribution of the fish resource during the year is described and the most important species such as sardines, mackerel and whitebait are dealt with separately.

It is indicated that the main mackerel spawning occurs on the south-west coast in the pre-monsson period.

A more offshore fishing of mackerel and sardines is suggested. This will probably also extend the fishing season at both ends.

ANON, 1973. Hydrographic Investigations - June 1971-January 1973, UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 3, 13 pp.

The report reviews the hydrographic data collected by the project before February 1973, dealing mostly with the seasonal fluctuations on the shelf.

The data comprised observations of temperature, salinity and dissolved oxygen in standard sections established in the project area.

A brief general description of the hydrography in the area is given based mainly on sections worked by RASTRELLIGER in January and February 1973. One of the main features is the termocline at depths of 100 to 125 m. This thermocline coincides with an oxycline under which the content of dissolved oxygen is less than 1 ml/l.

The longest series of observations was worked in the sections off Quilon, Cochin, Kasaragod and Karwar. These sections revealed distinct seasonal fluctuations

in temperature and dissolved oxygen content. In connection with the south-west monsoon season there was upwelling of cold, oxygen deficient water, giving rise to an annual amplitude amounting to 7 to 8°C and about 4 ml/l of dissolved oxygen in the middle of the shelf.

ANON, 1973. Report of Aerial Survey 3-10 October 1972, UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 4, 16 pp.

Based on frequent observations of surface schools of mackerel and sardines along a considerable part of the coast after the south-west monsoon in 1971, it was decided to conduct an aerial survey in early October 1972.

The survey procedures are described, a Dacota aircraft was chartered and surveyed the area along east-west flight tracks 7.5 n.miles apart. Standard altitude was 3000 feet.

Observations were made visually and photographically from the aircraft.

The project vessel SARDINELLA was directed to the locations with best school concentrations in order to identify them either visually or by fishing. School volumes were based on echo sounder recordings from SARDINELLA.

Based on combined aerial and vessel observations distributions of school concentrations and school densities were worked out and plotted on charts.

For the sardines a mean length of 10-12 cm and an average weight of 10 g were observed. A packing density of 25 fish/m^3 was anticipated. Applying these figures to the total volume assessments give a total figure of 73 000 tonnes.

ANON, 1973. Biological sampling data and catch statistics of mackerel and oil sardines from different fishing centres during the seasons 1971/72 and 1972/73. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress

report no. 5, 11 pp.

A sampling scheme was established for collection of catch statistics and biological data from commercial catches of mackerel and oil sardines. Sampling was made at 13 centres along the south-west coast between Panaji, Goa and Vizhinjam near Trivandrum.

The trend of the fishery during the season from October to May-June is described for mackerel.

The maturity data indicated a major pre-monsoon spawning in April-May with a secondary less important spawning after the monsoon in September-October.

Monthly length frequency distributions were used to produce a growth curve which indicates a rapid growth from about 145 mm in August to 200 mm in November. It is concluded that these are fish from the pre-monsoon spawning.

Similarly, the fishery for oil sardine is described.

The maturity stages in catches taken during July to September indicated that spawning was taking place.

The growth of this major brood of the oil sardine was clearly traced from 65 mm in August to about 115 mm in November. After 1 year the length was 145-150 mm.

The data collected show that the fishery is largely supported by juveniles and that both mackerel and sardines have a rapid growth and a rather restricted longevity.

ANON, 1974. Survey results 1972/73, UNDP/FAO Pelagic Fishery Project, IND 69/593. Progress report no. 6, 141 pp.

This report gives the results of the survey conducted from October 1972 to August 1973.

The two research vessels made 8 complete coverages of the project area during 1972/73. The details of surveys and the methods of assessment are outlined.

Stock assessments, distribution and abundance of fish resoruces during the period are given and important resources such as mackerel, oil sardines, whitebait,

"shallow water mix" and other pelagic resources are dealt with separately.

It is indicated that the aggregation of sardines and mackerel into surface schools just after the south-west monsoon is related to the special environmental conditions resulting from the upwelling of cold, oxygen deficient waters and to the associated plankton bloom.

It is suggested that the development of a purse seine fishery in more offshore waters will extend the duration of the fishing season and lead to a greater exploitation of the older year classes of the oil sardine and mackerel stocks.

The resources of whitebait in the project area were in June/July concentrated in the Gulf of Manaar area and were estimated to be more than half a million tonnes, while the average for the period was 0.34 million tonnes.

The resources of "shallow water mix" were estimated to vary from 25 to 142 thousand tonnes with an average for the period of 90 thousand tonnes.

The biomass of other pelagic fish resources comprising mainly horse mackerel, ribbon fish, lesser sardines, rainbow sardines, catfish etc., were estimated to vary from 150 to 430 thousand tonnes.

No separate precise estimate of the horse mackerel resources (including scad) was made, but it is suggested that it would be in the order of 100 thousand tonnes.

Incidental observations on tunas, squid and cuttle fish, and meso-pelagic species such as lantern fish indicate that they were widely distributed in the area and were probably of quite large abundance.

The most practical and efficient types of fishing gear and craft are discussed as well as fishing methods in harvesting the resources.

ANON, 1974. Plankton - fish eggs and larvae studies, UNDP/FAO Pelagic Fishery Project, IND 69/593. Progress report no. 7, 21 pp.

Plankton studies in the project area from September 1971 to August 1973 indicated a fairly dense belt of zooplankton in August-September nearly all along the coast from Quilon to Ratnagiri, generally some 10 miles from the shore. Thereafter until December the plankton became rather patchy and a period of very low abundance was observed in January and February. From March onwards plankton densities increased with the concentrations a little off the coast, reaching the peak in September. Plankton production was seen to be high during or immediately following the time of upwelling. The standing crop of zooplankton was found to be of lower magnitude in 1971/72 than in 1972/73.

The distribution of mackerel, oil sardine and whitebait schools generally coincided with the observed high density areas of plankton.

Isolated cases of oil sardine spawning in the near-shore waters (12 m) were recorded off Kasaragod in July 1972 and off Cochin in July 1973, when numerous eggs and newly hatched larvae of the species were collected.

Evidence of mackerel spawning over an extended period and area was given by the occurrence of larvae and from April to September and in November all along the coast from Tuticorin to Ratnagiri.

Clear evidence of a major spawning of frigate mackerel (Auxis spp.) during June-July in the Quilon - Cape Comorin area was given by the presence of considerable numbers of larvae of the species.

Post-larvae and early juveniles of mackerel (2-10 cm) occurred on the shelf from March to August in fairly considerable quantities within latitudes 8^{o}-16^{o}N, at 15-50 m depths and these appear to be the nursery grounds of the fish.

ANON, 1974. Results of the 1973 aerial survey, UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no.8, 11 pp.

A relatively successful aerial survey was carried out

in October 1972 and it was decided to conduct a similar survey in September 1973. In the planning of this survey the experience from the 1972 aerial survey was taken into consideration. The aircraft was this year supported by seven vessels placed in sectors along the coast.

The aircraft surveyed the area with east-west flight tracks. Visual and photographic observations were made from the aircraft.

The vessels covered their sectors twice and observations were made visually as well as with echo sounders. Fishing experiments were made to obtain samples and estimates of school sizes.

Distribution charts for mackerel and sardines were made. The magnitude of the sardine stock was assessed to be 350 to 400 thousand tonnes whereas the mackerel stock was assessed to be about 450 thousand tonnes.

ANON, 1975. Results of the 1974 aerial survey, UNDP/FAO Pelagic Fishery Project,IND 69/593, Progress report no. 9, 10 pp.

This was a continuation of the work taken up in the aerial surveys in 1972 and 1973 for assessing the stocks of mackerel and sardines in the project area. It was considered an advantage to conduct the survey as early as possible after the south-west monsoon and the survey was implemented from 17 to 22 September.

The aircraft surveyed the area following more or less the same procedure as in 1973 and observations were made visually and photographically.

Six vessels were placed in sectors along the coast and made observations visually and with echo sounders. Fishing was carried out to collect samples.

During this survey RASTRELLIGER surveyed the most abundant areas with her sonar with the transducer fixed 90° to the starboard side. The observations made with the sonar proved very useful for the assessments

of the mackerel and sardine resources. The assessments indicated that the magnitude of the stocks was relatively small. The mackerel stock was assessed to be about 100 thousand tonnes and the sardine stock about 50 thousand tonnes.

ANON, 1975. Young fish studies, UNDP/FAO Pelagic Fishery Project, Progress report no. 10, 14 pp.

Along the south-west coast of India over 800 pelagic trawl hauls were made during the period June 1971-December 1974. In this report the material is analysed with regard to occurrence of juveniles of dominant species.

The most abundant young fish were: whitebait, mackerel, scad, rainbow sardines, lesser sardines, ribbon fish and silver bellies.

The predominant periods of occurrence were from April to August and November to February. This is in agreement with the sequence of egg and larval abundance in the area. The periods also coincided with seasonal changes in the hydrographic conditions.

Due to long spawning periods and many broods, much effort is required to arrive at reliable estimates of the oncoming adult stocks.

ANON, 1975. Survey of mackerel and sardine schools in 1975. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 11, 6 pp.

Aerial surveys were conducted by the Pelagic Fishery Project in 1972, 1973, 1974 and in 1975 for assessing the stocks of mackerel and sardines along the south-west coast of India. Every year these surveys were conducted during the end of September and the beginning of October.

In 1975 the survey was conducted without an aircraft. The results were, therefore, based on the data obtained by the sonar onboard RASTRELLIGER which was transducing 90° to the starboard side. The

vessel covered the area from Ratnagiri to Trivandrum with east-west tracks 7.5 n.mi apart extending 30 n.mi out from the coast.

The distribution of school areas and densities together with biomass estimates are given. The biomass estimates arrived at were approximately 700 000 tonnes for sardines and 300 000 tonnes for mackerel.

Experience from these surveys shows that the usefulness of the aerial observations is dependent of weather conditions. The sonar was only used in 1974 and in 1975 and proved useful in such studies.

The least reliable factors in calculating stock sizes are the vertical extension and packing density of the schools. The estimates are, therefore, best improved by obtaining more reliable data on these two parameters.

ANON, 1975. Survey results 1973/74. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 12, 32 pp.

During the period from September 1973 to October 1974, ten coverages of echo surveying, fish sampling and hydrographic observations were conducted along the south-west coast of India.

The geographical distribution and abundance of mackerel and sardines, whitebait, horse mackerel, "shallow water mix" and "other fish" are given for each coverage. The corresponding assessments of their biomass are also presented. Species composition and catch rates are discussed toghether with length distribution and maturity condition of the most important species.

The biomass of mackerel and sardines is estimated spearately. The rest of the fish biomass, consisting on average of 35% whitebait, 9% horse mackerel, 2% "shallow water mix" and 54% "other fish", amounted to 775 thousand tonnes. The highest estimate was made in September/October 1974 with 1.5 million tonnes.

Observations made on mackerel and sardine schools throughout the year indicate that these species may never leave the shelf waters.

The whitbait resource was found to be of great magnitude, amounting to more than 0.8 million tonnes in the August-October period. During this time the whole stock was found in the Gulf of Manaar, where catches up to 40 tonnes per hour were taken with a pelagic trawl.

Species of the horse mackerel group were recorded both as dense schools and in scattered layers. Since these species are fast swimmers and easily avoid the net, only stray individuals were caught by trawl.

"Shallow water mix", located within the 20 m bottom depth zone, is the resource having the least biomass, with an average estimate of 17 000 tonnes. However, average catch rates of 275 kg per hour were obtained with a pelagic trawl.

The "other fish" group consists of many different species and contributes to more than half of the biomass. Catfish and ribbon fish comprised the predominant elements. This group was found more or less along the whole shelf throughout the year.

ANON, 1976. Survey results 1974/75. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 13, 21 pp.

From October 1974 to October 1975 the project area along the south-west coast of India and in the Gulf of Manaar was covered 6 times with echo surveying, fish and plankton sampling and hydrographic observations. Geographical distribution of the various fish group and their biomasses assessed on basis of the echo integrator values are given for each coverage. An outstanding increase was observed in the biomass from 1974 to 1975.

The fish biomass, excluding the stocks of mackerel and sardines, was assessed to be in order of 2 million

tonnes on average. Of this whitebait contributed 36%, horse mackerel 16%, ribbon fish and catfish 22%, "shallow water mix" 4% and "other fish" 22%. The lowest estimate was made in November/December with 669 thousand tonnes and the highest in May/June with 3.7 million tonnes.

Growth pattern and maturity stages are given for some of the species while length frequencies are given for most of them.

Visual and acoustic observations of mackerel and sardine schools indicate that these species remained in the shelf waters the year around.

The best recordings of whitebait were made in April/May when the stock was assessed to be 1.5 million tonnes. Half of it was located within the area between 16^{o} and 17^{o}N. In august and September the whitebait stock was concentrated in the Gulf of Manaar and relatively good pelagic catches were taken.

The resource of the horse mackerel group was mostly recorded as schools scattered over wide areas. On an average the biomass was estimated to be 320 thousand tonnes with the best recordings in the southern region.

Recordings of catfish and ribbon fish were observed throughout the period. In 1975 when these species were considered as a separate group, their average biomass was estimated to be 475 thousand tonnes. The maximum concentrations were observed north of Cochin and good catches were taken with pelagic trawl.

"Shallow water mix" was by far the smallest group, and their biomass within the 20 m bottom depth zone was assessed to be only 75 thousand tonnes on average. However, relatively good recordings of typical shallow water species were also made more offshore.

The "other fish" group consisting of a great variety of species, were recorded more or less along the whole coast within the project area. Their average biomass

was estimated to be of the same magnitude as the catfish/ribbon fish group.

ANON, 1976. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 14, 12 pp.

During the four fishing seasons from 1971/72 to 1974/75 a sampling program was carried out in Goa, Karnataka and Kerala on commercially landed mackerel and oil sardines. The sampling, which was designed by the Pelagic Fishery Project, included catch statistics, length measurements and biological sampling. The present report deals mainly with the data collected in 1973/74 and 1974/75.

The sampling covered 8.7 % and 9.5 % respectively of the total landings of mackerel and oil sardines which were estiamted by CMFRI. The reliability of the PFP estimates of the total catches is apparently not very high, but they probably reveal the major fluctuations in the fisheries.

The mackerel landings increased in 1973/74, but dropped severely in 1974/75. The oil sardine landings increased slightly from 1972/73 to 1973/74. The CMFRI data indicated a further increase in 1974/75, whereas according to the PFP data there was a severe decrease in the landings.

The data on sexual maturity of mackerel indicated spawning throughout the year except in November and December. However, the major spawning seemed to take place 2-3 months during the pre-monsoon season. On an average first-time spawning seemed to occur at one year of age and at a length of 220 - 225 mm.

ANON, 1976. Oil sardine larvae. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 15, 18 pp.

The larval sardines collected by the project were examined to identify oil sardine larvae. Relevant published information on Sardinella species of the project area, sardine spawning and eggs and larvae are

briefly reviewed. General characteristics of early larvae of Sardinella species are given.

Several growth stages from 3.4 mm to 17.7 mm length are described and illustrated. The oil sardine larvae were isolated primarly on the basis of their higher myotome numbers and numerical abundance of the type over the other sardine larvae. The usefullness of pigmentation appears rather limited in the specific identification of the different Sardinella larvae.

ANON, 1976. Physical oceanography on the south-west coast of India based on the investigation by the UNDP/FAO Pelagic Fishery Project. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 16, (in press).

The oceanographic condition is described in the period 1971-1975 based on a total of 200 sections from Ratnagiri in the north to Tuticorin in the south. This area was surveyed 7-8 times per year. In general the seasonal variation was very repetitive from year to year. During the south-west monsoon period, April-October, the current flowed southwards, causing a lifting of the isolines for the different oceanographic parameters near the coast. This lifting generated upwelling of intermediate water with very low oxygen content. This effect was most developed in August/September when water with oxygen content of less than 0.5 ml/l was observed to cover the whole shelf area over the bottom. The upwelling was more pronounced north of Quilon than in the area around Cape Comorin in the south. During this season the effect of the strong runnoff was traced to a considerable distance from the coast.

In the north-east monsoon period, November-March, the current system reversed, thereby transporting low salinity water from the equatorial region northwards. The low salinity water from the Bay of Bengal was traced northwards along the coast.

It is believed that the upwelling process which brings nutrient rich water to the surface as well as spreading

low oxygen content water over the shelf area is very important both for the fisheries development and fish distribution in the area.

ANON, 1976. Report on fish eggs and larvae. UNDP/FAO Pelagic Fishery Project, IND 69/593, Progress report no. 17, 19 pp.

Up to September 1975 about 1300 standard plankton hauls were taken at all the hydrography stations. Continuous oblique hauls with the Bongo net was the standard pattern and depths of collection varied with depth of grounds, but the maximum depth was normally restricted to 100 m. Several special collections were made during the monsoons from the nearshore waters with the aim of locating spawning oil sardines.

The zooplankton biomass tended to increase after April towards a peak sometime before December and fell to low values subsequently; the January - April period being lean. Upwelling along the coast appeared to trigger the primary production which was followed closely by secondary production of zooplankton. The timing and intensity of upwelling was to some extent reflected in the annual pattern of plankton production.

The larval material collected was considerable and particular attention was paid to the study of larvae of species contributing important pelagic fishery resources.

Sardines, mackerel, whitebait, carangids and coastal tuna were observed to spawn on the shelf - mainly in the area where they are fished. No sharply defined spawning grounds were observed. Of all the larvae collected Clupeidae contributed about 21%, Scombroidae 16%, Carangida 7%, Vinciguerria 4%, Bregmaceros 4%, flat fish 3% and the rest constituted miscellaneous varieties.

Nine species of sardine (Sardinella spp.)were reported from the project area and three were commercially important, the oil sardine being the most important. The larvae of different sardines

look very much alike. Sardine larvae were observed throughout the year but their abundance was especially noticable during the April-August period. Patches of spawning of oil sardines were noticed during the south-west monsoon period and spawning was largely restricted to the Quilon-Karwar region.

Mackerel larvae were collected from all over the project area in most months of the year. The main spawning period appeared to be in April-September.

The southern sector of the project area from Calicut to Cape Comorin was found to be the major spawning ground of the coastal tuna, especially the frigate mackerel (Auxis spp.). The May-August period was the time of intensive spawning.

Significant contributions to the fisheries in the project area were made by at least 4 species of Anchoviella. These fish are known to be prolonged breeders. Whitebait larvae occurred throughout the project area in almost all months of the year and formed the major component of the clupeoid larval population. The March-July period was found to be a period of major abundance.

Golden scad (Caranx kalla), the horse mackerel (Megalaspis cordyla) and scad (Decapterus spp.) were the most important of the several species of Carangidae occurring in the project area.

Larvae of one or other Carangidae were met with throughout the year. The major period of occurrence of larvae and hence of spawning was from February to September. The Cochin - Cape Comorin region was the major spawning ground for the species.

APPENDIX 5

MAJOR ITEMS OF EQUIPMENT

5.1 Project vessels

R.V. RASTRELLIGER: stern trawler type combination trawler/ purse seiner.

LOA	46.45 m
Breadth	9.00 m
Depth	6.50 m
Draught	4.35 m
Hold capacity	210 m^3
Cold storage capacity	43 m^3
Gross tonnage	390 tonnes
Fuel oil capacity	124 m^3
Fresh water tanks	46 m^3
Fresh water production	3 m^3/day
Main engine power	1320 Hp
Speed	12.2 knots
Accommodation	24 men
Duration at sea	3 weeks

R.V. SARDINELLA: combined trawler/purse seiner built in glass fibre reinforced polyester.

LOA	16.34 m
Breadth	4.50 m
Depth	2.45 m
Draught	2.12 m
Fuel oil capacity	5 tonnes
Fresh water capacity	1.4 tonnes
Main engine power	153 Hp
Speed	9.5 knots
Accommodation	9 men
Duration at sea	7 days

The vessels were equipped with fishing gear, acoustic instruments and other research equipment, all of which was not specified separately when the vessels arrived at the project. Inventory lists of fishing gear and all kinds of spare parts are kept at the project quarters.

5.2 Vehicles

1 station wagon, 1 car (on loan from UNDP N. Delhi).

5.3 Equipment in project quarters

Photo copying machine (1), typewriters (2), calculators (3), air conditioners (3), binocular (1), microscopes (2), camera (1), multimeter (1), diving equipments(2) with air compressor (1).