J. mar. biol. Ass. India, 1989, 31 (1 & 2) : 172-119

RESULTS OF ICHTHYOPLANKTON SURVEYS ALONG THE SOUTHWEST COAST OF INDIA WITH SPECIAL REFERENCE TO PELAGIC FISH RESOURCES*

K. C. GEORGE
Central Marine Fisheries Research Institute, Cochin-682 031

ABSTRACT

A well planned and systematic Ichthyoplankton survey programme was carried out by the UNDP/FAO Pelagic Fishery Project, Cochin (1971-79) along the southwest coast of India. These surveys were part of the Project's programmes for assessment of the Pelagic fish resources of the Project area extending from Ratnagiri to Tuticorin. Major part of the field work was conducted from 1971 to 1975 over the shelf and adjacent waters.

The survey results indicated that all the dominant pelagic species spawned over the shelf in the entire range of their distribution in most months of the year. The peak of spawning in almost all cases was aligned to the Southwest Monsoon period with a secondary peak in the Northeast Monsoon in some species; including the mackerel. The larval distribution showed a southward drift and concentration in areas south of 12° N, spreading over oceanic waters in this sector.

No consistent and positive relationship between the abundance of larvae of a particular species with the magnitude of its fishery in the area was evident. However in cases like the whitebaits the larval abundance gave corroborative evidence supporting the findings of simultaneous acoustic surveys on the very high potential of these fishes. On the other hand the predominance of the larvae of frigate mackerels, compared to those of Indian mackerel is not supported by commensurate fishery for the former species or potential in the surveyed area.

The paper critically reviews the findings of the surveys on the spawning, distribution and abundance of the larvae of the major pelagic fishes and their resources along the southwest coast of India.

INTRODUCTION

IT IS well known that apart from identifying spawning areas and spawning seasons one of the valuable application of egg and larval suvevys is to measure stock size of adults and relative changes in stock from year to year. Till recently studies on the quantitative aspects of fish eggs and larvae in the Indian seas were limited to studies on their taxonomy, seasonal abundance based on material from the inshore plankton and postlarval fish collections from restricted localities. A comprehensive bibliography on earlier studies on this subject is available (Jones and Bensam, 1968). In the late fifties and early sixties, the erstwhile Indo-Norwegian Project, in collaboratioon with the Central Marine Fisheries Research Institute played a vital role in the survey of ichthyoplankton, off the SW coast of India, particularly in the Lakshadweep Sea (Jones and Kumaran, 1964 a, b; Silas, 1974).

The *Dana* Expedition of the Carlesberg Foundation (1928-'30) (Jones and Kumaran, 1963, 1964 a, b) and the International Indian Ocean Expedition (IOBC, 1970 a, b) made valuable contributions to our knowledge of the

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

Also formed part of the Ph. D. Thesis, Cochin University of Science and Technology, Cochin.

fish eggs and larvae from a wide area of the Indian Ocean (Ahlstrom, 1968 ; Peter, 1969, 1974, 1977 ; Nellen, 1972 , 1973 ; Panikkar and Rao, 1973 ; Shomura, 1970 ; Panikkar, 1968. Raju and Ganapathi (1969) dealt with the distribution of fish eggs and larvae in the Bay of Bengal.

The most intensive and systematic effort in ichthyoplankton surveys in recent times in Indian waters has been put in along the south-west coast of India by the UNDP/FAO Pelagic Fishery Project, Cochin (Anon., 1974, 1976) The present paper critically reviews the results of this survey with reference to the distribution and abundance of fish eggs and larvae particularly the latter and the pelagic fisheries of the area.

The author acknowledges his indebtedness to Prof. C. V. Kurian, former Head of the Department of Marine Sciences of the Cochin University of Science and Technology for guidance in this work.

Material and Methods

The material dealt with in the present study has been collected from the Project area extending from Ratnagiri on the west coast of India (17°N) to Tuticorin (8°48'N) on the east coast and relates to the period from September 1971 to December 1975.

In 1971 and 1972, two vessels R.V. *Sardinella* (Length 16.34 m, 153 HP) and R.V. *Varuna* (Length 28 m, 400 HP) were used by the Project for the cruises. From 1973, a larger vessel R.V. *Rastrelliger* (46.5 m, 1320 HP) was used. The twin cone ' Bongo 20 ' net with a calibrated flow meter was the principal gear used. The continuous oblique hauls at a vessel speed of 2-3 knots sampled the water column, down and up. The depth of collection was adjusted to ground depths in shallow waters usually to 100 m in deeper areas.

Seven transects, namely Ratnagiri, Karwar, Kasaragod, Cochin, Quilon, Cape Comorin and Tuticorin were considered as standard sections in the present study. Data from Vengurla, Coondapur and Calicut sections covered only occasionally have also been included in the studies (Fig. 1).

Along each section 5-10 stations were worked depending on the width of the shelf. Stations were 10 miles apart on the shelf and 15 or 30 miles apart beyond the shelf. 68% of all stations worked were on the shelf. Altogether 1318 standard stations were worked during the period. Distribution of the standard stations on the shelf and oceanic region on the basis of sounding depths are presented in Table 1. While material from the standard stations (1318) only have been considered for density mapping, those from 91 ' special stations ' worked on the shelf, between the sections have also been included for computing occurrence indices of certain categories of larvae and correlation with hydrographical factors. The special stations were worked with a single cone net of ring dia. 60 cm and without flow meter.

The plankton samples were preserved immediately after collection in 4% formaldehyde solution in sea water. All the fish eggs and larvae were later sorted out of the sample.

For purposes of standardising the densities of eggs and larvae, an index of their numbers occurring below one square metre of the surface was computed based on the formula $\frac{N \times D}{V}$, where N is the mean number of egg/larvae caught in the two net cones at the station, V the volume of water filtered in m^3 and D the depth of collection (Dragesund, 1970). The eggs were dealt with on an unclassified basis except those of the oil sardine, when observed in significant numbers.

The distribution and abundance of fish eggs and larvae are illustrated by drawing density contour lines on the basis of standardised numbers (No/m^2).

Results

Abundance and distribution of fish eggs

The general picture of the distribution of fish eggs showed that during the pre-monsoon season, typically, the indices of abundance of fish eggs were low over the entire SW coast, with some localised concentrations both in the north and south sectors of the area or sometimes only in the southern sector.

During the monsoon season high indices of abundance were noticed with consistently high concentrations in the area south of 13° N. Dense pockets in nearshore waters or high value offshore patches were characteristics of this season.

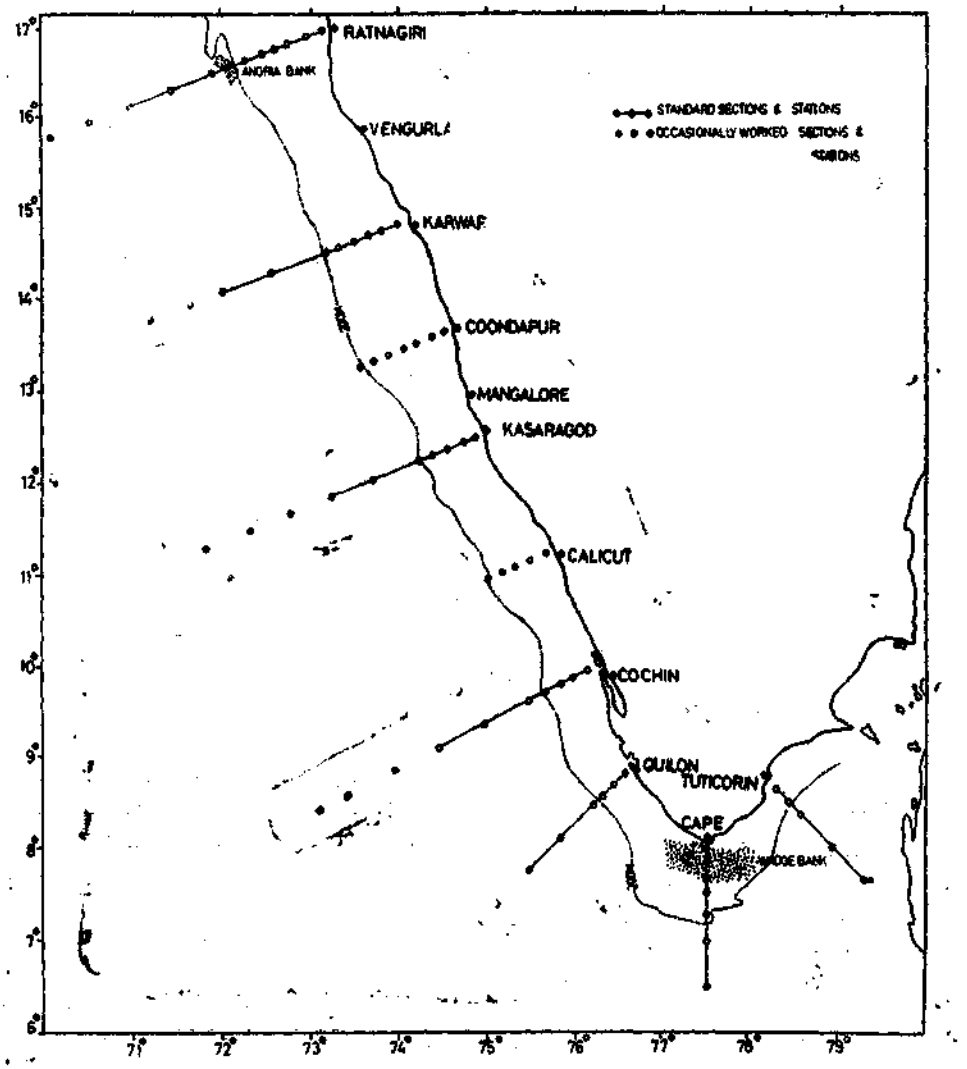

FIG. 1. SW Coast of India and contiguous waters upto Tuticorin on the SE Coast with station positions.

During the post-monsoon season, abundance of fish eggs were generally moderate to high over the shelf, decreasing steadily towards

offshore, with pockets or narrow stretches of high concentrations, usually near the shore or over mid-shelf. However, these generalised patterns varied in details in different years.

The overall picture of abundance of fish eggs of the SW coast of India indicated that the highest fish spawning activity in the area took place during the SW monsoon season and the least during the pre-monsoon season.

Oil sardine eggs

During the present studies, eggs of oil sardine (with the characteristic large perivitelline space, segmented yolk, single oil globule about 0.1 mm diameter and egg diameter range of 1.1-1.4 mm) were collected within 9° 30'-12°30' N, over grounds less than 25 m depth. However, only on few occasions during the SW monsoon period they were taken in very large quantities (more than 5000 eggs/m^2), usually from nearshore stations.

Abundance and distribution of fish larvae

The picture of distribution of fish eggs as well as larvae are derived out of the same samples and hence is a simultaneous picture.

The distribution and abundance of fish larvae point to the same conclusion arrived at from the distribution of fish eggs, that the major spawning activity of the fishes along the SW coast of India is during the monsoon period, which partly spreads on either side; the pre-monsoon and post-monsoon periods. The distribution of eggs and larvae does not overlap strictly in density gradients. It is seen that there is a wide dispersal of larvae from the points of spawning of offshore waters and to the southern sector particularly during the monsoon and post-monsoon periods, when the surface current flows southwards in the area.

Distribution and abundance of 'all clupeoid' larvae

Large majority of the clupeoid larvae collected from the surveyed area were of Whitebaits (*Stolephorus* spp.). Next in importance were the larvae of *Sardinella* spp. of which *S. longiceps* was the most dominant. Other types of clupeoid larvae met with in lesser numbers in the collections were those of the white sardine (*Kowala coval*), the rainbow sardine (*Dussumieria* sp.) and the anchovies (*Thrissa* spp.).

The higher density of clupeoid larvae were on the shelf and seaward areas south of Kasaragod. In the areas north to Kasaragod clupeoid larval densities were generally less, with only some pockets of high densities.

Reports of the Pelagic Fishery Project (Anon., 1974, 1976 a) presented preliminary information on the distribution of clupeoid larvae along the SW coast of India, on a cruise-wise basis from April 1972 to August 1975 period.

Sardine larvae

The sardine larvae with a predominance of *Sardinella longiceps* occurred throughout the year, mainly from March to September, with the maximum abundance from April to August and the peak in July. The lean months for sardine larvae were from December to February, as was the case with most fish larvae in the area. Sardine larvae were practically restricted to the shelf areas, spilling beyond in any significant manner, only off Cape Comorin and in the Gulf of Mannar (Fig. 2). However, in the Gulf of Mannar, the maximum concentration was seen over the narrow shelf. Best concentrations of sardine larvae were recorded with in the inshore shelf between Cannanore and Vengurla (11°30' N to 15°30' N). Fifty per cent more sardine larvae were caught in night hauls than during the day. The

larvae occurred in a wide range of surface temperature from 24°C to 31°C with their dominant occurrence in the 26°-28°C range. Similarly a wide range in salinity toleration was also noticed ; from 29‰ to 36‰ S with predominant occurrence in the 33‰ to 35‰ range.

to July period and with a secondary dominance around November. The distribution of these larvae showed relatively dense concentration in the area south of Kasaragod to the Gulf of Mannar, with the high value core mostly over the outer shelf from 07°30' N to 11°30' N. A northern concentration was noticed over the seaward half of the shelf, approximately

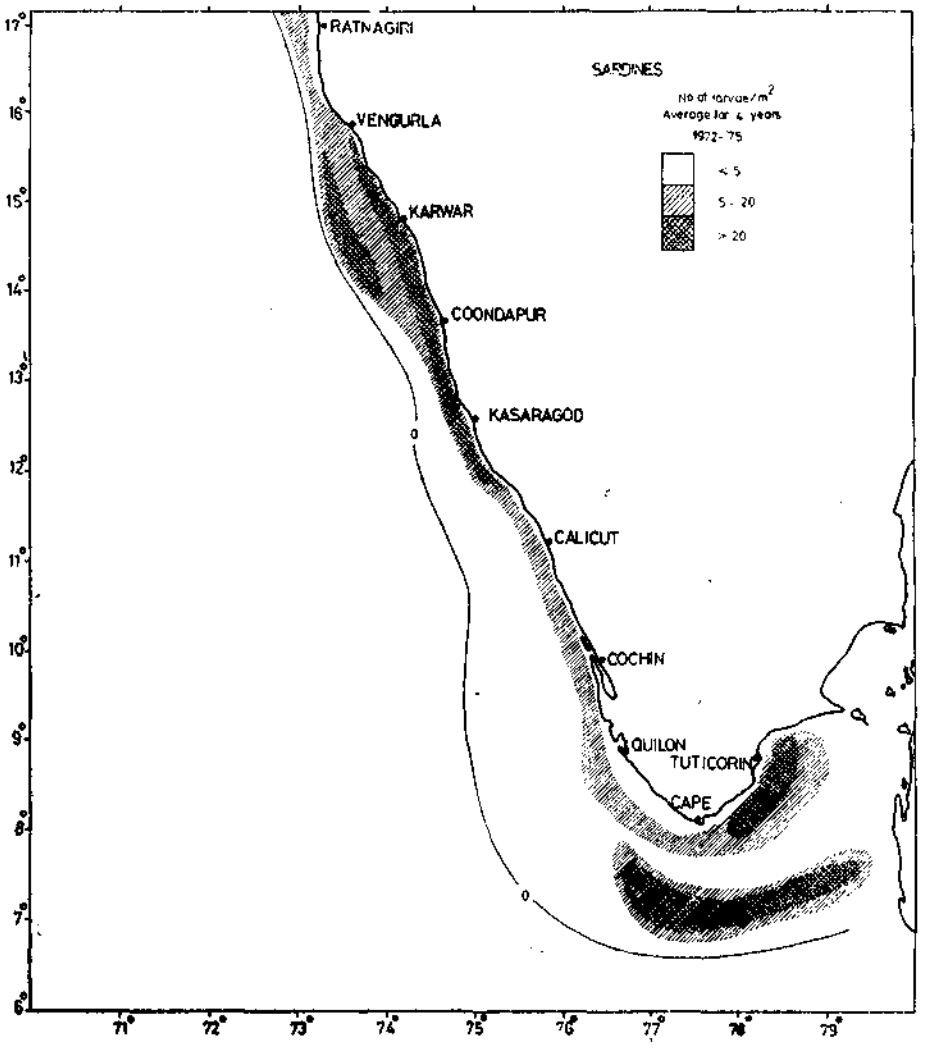

FIG. 2. Average picture of the distribution and abundance of sardine larvae during 1972-75. (The figure is reproduced from the Progress Report of the Pelagic Fishery Project, No. 17, Anon., 1976 a).

Whitebait larve

Stolephorus spp. larvae occurred in all the months with their major occurrence in March

between 13°30' N and 15°30' N. The larval concentrations were found to be of rather light densities outside the shelf, diminishing further

seaward. A synoptic picture of the distribution of whitebait larvae for 1972-75 period are presented in Fig. 3.

Scombroid larvae

The scombroid larvae in the present collections included mostly those of frigate (*Scomberomorus commerson*), Swordfish (*Xiphias gladius*) and the Sailfish (*Istiophorus gladius*) were found in the collections. Larvae of the bonito (*Sarda orientalis*) and the Wahoo (*Acanthocybium solandri*) have not been found in the collections, eventhough adults of both the species occurred in the area, with the former

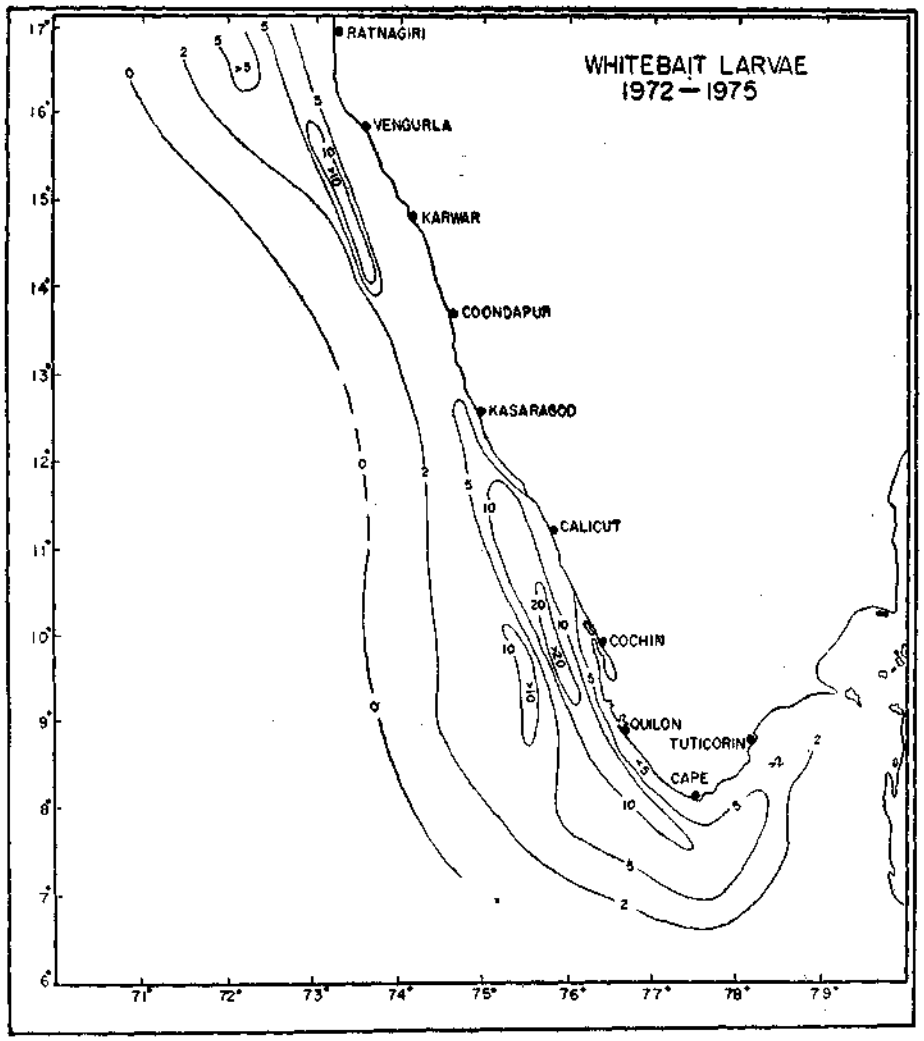

FIG. 3. Average picture of the distribution and abundance of Whitebait larvae during 1972-75.

mackerels (*Auxis* spp.), Indian mackerel (*Rastrelliger kanagurta*), Skipjack (*Katsuwonus pelamis*), little tuna (*Euthynnus affinis*) and *Thunnus* spp. One postlarva each of Seerfish supporting a seasonal coastal fishery. The larvae of *Auxis* spp. (*A. thazard* and *A. rochei*) and *Thunnus* spp. have not been identified to specific level in the present study.

Looking at the relative frequencies of occurrence of the major scombroid larvae in the collections (Table 1), it is seen that larvae of *Auxis* spp. dominated followed by those of *Rastrelliger kanagurta*. Among the major tunas, the larvae of *Katsuwonus pelamis* were available more than those of *Euthynnus affinis* and *Thunnus* spp. In terms of the number of larvae caught also, *Auxis* spp. by far dominated all the other scombroid.

oceanic waters except in the nearshore belt, the major concentration being beyond 50 m depth, over the continental slope and oceanic waters in a belt of an average width of 30 miles from Kasaragod to Tuticorin.

Mackerel larvae

Larvae of *Rastrelliger kanagurta* occurred in about 9% of all stations worked. They were only next in abundance to larvae of *Auxis*

TABLE 1. *Relative frequencies of the occurrence of some larval scombroids during 1972-75 period*

*Type of larvae	Pre-monsoon					Monsoon				Post-monsoon			Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Auxis sp.	2	3	11	13	22	32	36	29	5	9	2	2	166
Rastrelliger kanagurta	2	3	11	11	16	13	33	14	7	3	12	4	129
Katsuwonus pelamis	—	10	9	7	3	11	1	3	—	—	1	—	45
Euthynnus affinis	—	—	2	2	9	11	2	3	—	—	—	—	29
Thunnus spp.	—	6	7	2	2	6	—	—	—	—	—	—	23
	4	22	40	35	52	73	72	49	12	12	15	6	392

* Specimens from some tows whose identity could not be confirmed due to damage or other reasons are not included here. However, such instances are less than 5% of the total number examined.

The general picture of distribution of all scombroid larvae showed two area of concentration, one south of Calicut to east of Cape Comorin and another smaller concentration off Ratnagiri. A dissimilar picture of this average pattern was seen in 1975, when the major concentration shifted to a large central patch, between 10°30' and 13°30' N in the offshore waters. An inshore belt, about 10 miles wide along the surveyed area was often devoid of larvae.

In the present collections, the larvae of tunas were recorded from about 19% of the total plankton stations. The larvae of *Auxis* spp. the most abundant of all scombroid larvae were found over most part of the shelf and

spp. and occurred in all the months with dominance from March to August and in November with the peak occurrence in July. Relatively dense distribution of the larvae was found mostly over the mid shelf, beyond 30 m depth from 8° to 15°N, with maximum concentration south of 10°N. While the larval occurrence spilled beyond the shelf south of Mangalore it was restricted to the inner third of the shelf in areas north of Mangalore. The nearshore areas north of Karwar and of the Gulf of Mannar were devoid of mackerel larvae. In the Gulf of Mannar the mackerel larval occurrence was mostly in the offshore waters. Silas (1974) observed the distribution of *R. kanagurta* larvae mostly between 9° and 10°N in 30-80 m depth zone in May.

R. kanagurta larvae showed a marginal increase in catches at night. The more favourable surface temperature range for the larvae was found to be 27° to 29°C. The larvae occurred in the surface salinity range of 31 to 36‰ with dominant occurrence in the 33 to 35‰ S

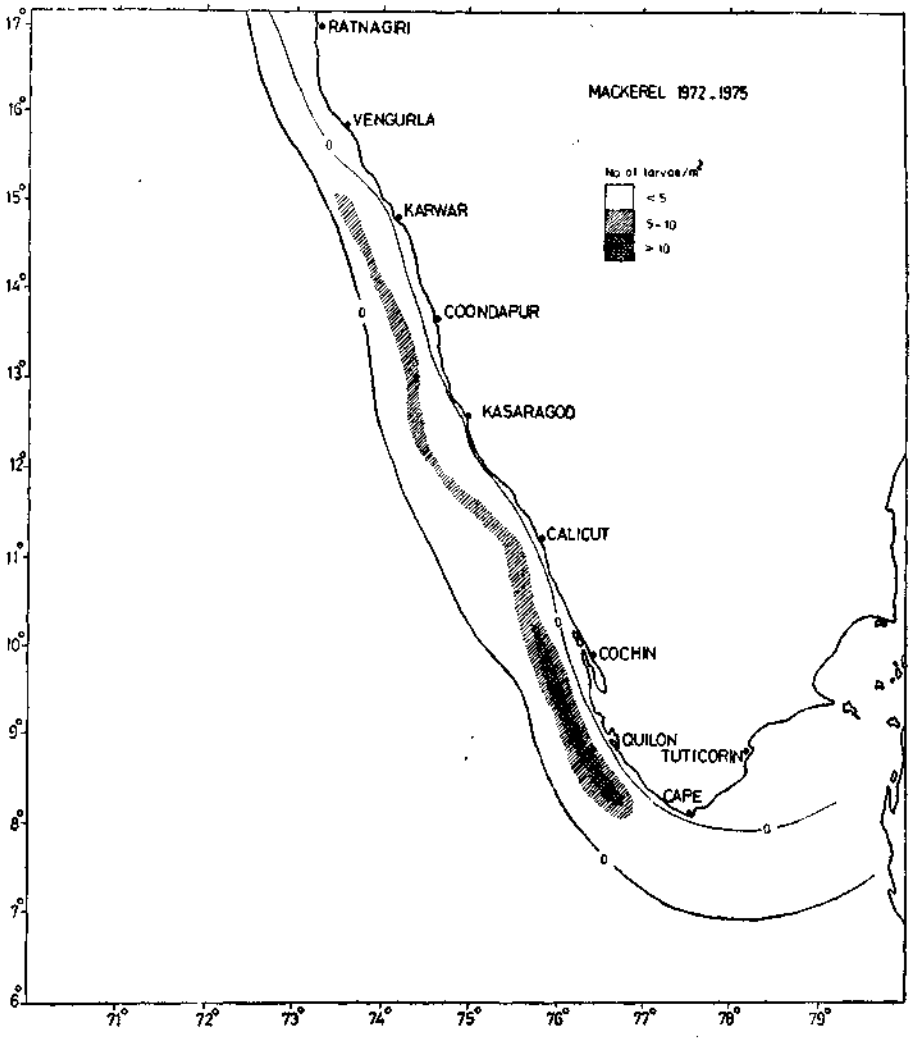

FIG. 4. Average picture of the distribution and abundance of mackerel larvae during 1972-75. (The figure is reproduced from the Progress Report of the Pelagic Fishery Project, No. 17, Anon., 1976 a).

range. Larvae of 2 to 4 mm length groups dominated in the catches. Fig. 4 shows the average larval densities (No/m²) for the entire period of observation, taking into consideration all the coverages made during the period.

Larvae of the frigate mackerels

Auxis larvae were the most numerous of all scombroid larvae in the present collections. The stout *Auxis* larvae (*A. thazard* type, Matsumoto, 1959) have been more common in the present collections. However, some

elongate larvae *A. thynnoides* type have also been encountered along with the former. In view of the uncertain specific identity of *Auxis* larvae, all the *Auxis* larvae are treated together in the present study. The abundance and distribution of *Auxis* larvae for the 1972-'75 period have been charted (Fig. 5) based on the average number (No/m^3) of the larvae collected at the different stations during the period.

The larvae were encountered over most part of the shelf and outwards in the oceanic waters upto a distance of about 1200 miles from the shore, all along the surveyed area. However, the inshore area varying in width from 4 to 20 miles was found to be devoid of the larvae.

The concentraions of the larvae were found over the outer shelf and slope of the shelf and

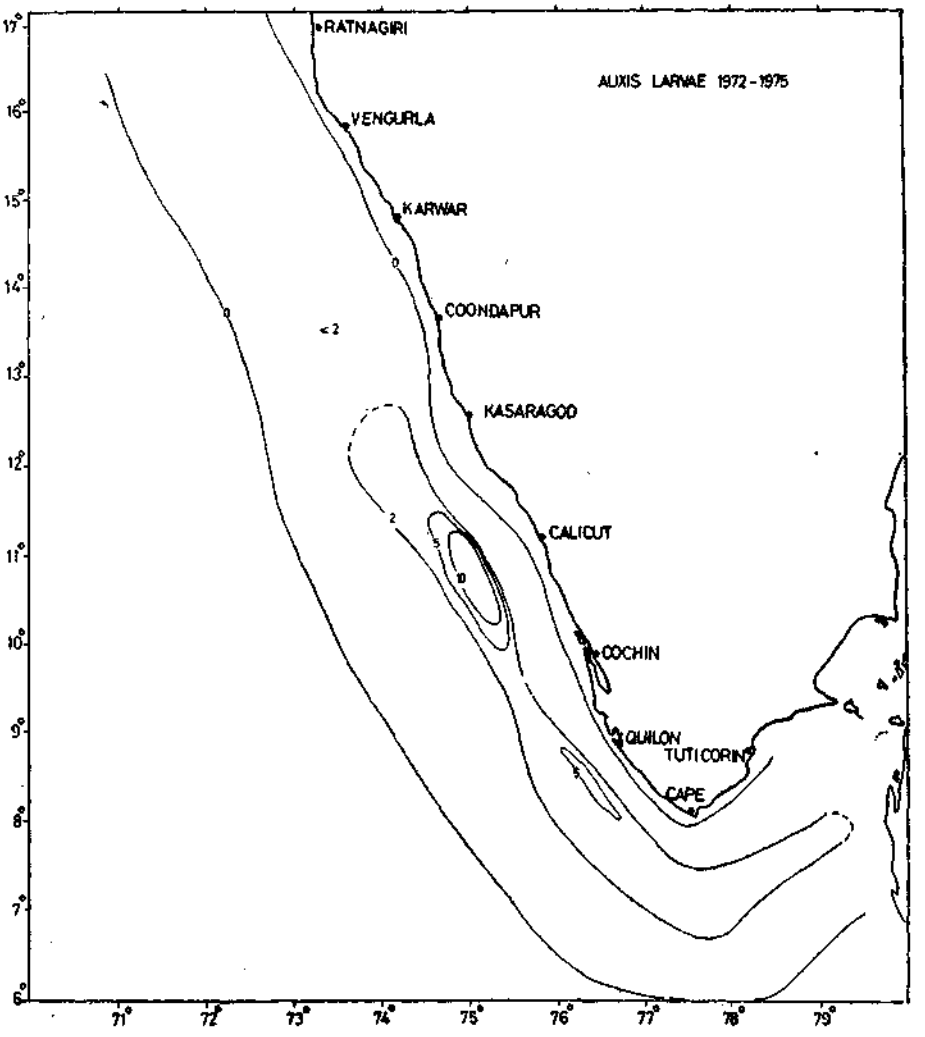

FIG. 5. Distribution and abundance of *Auxis* larvae during 1972—75.

even beyond, in a belt of an average width of 30 miles from Kasaragod to Tuticorin. There was a gradual increase in the number of positive stations beyond 50 m depth. Relatively high core densities were located between 10° and 11°30' N and also off Quilon.

size of larvae caught was 2.1 mm and the maximum size 13.6 mm, with 3 to 6 mm length groups dominating the catches. No significant day/night variation in the catches was noticed. The larvae occurred in a wide range of surface temperature (25°C to 31°C), but were more

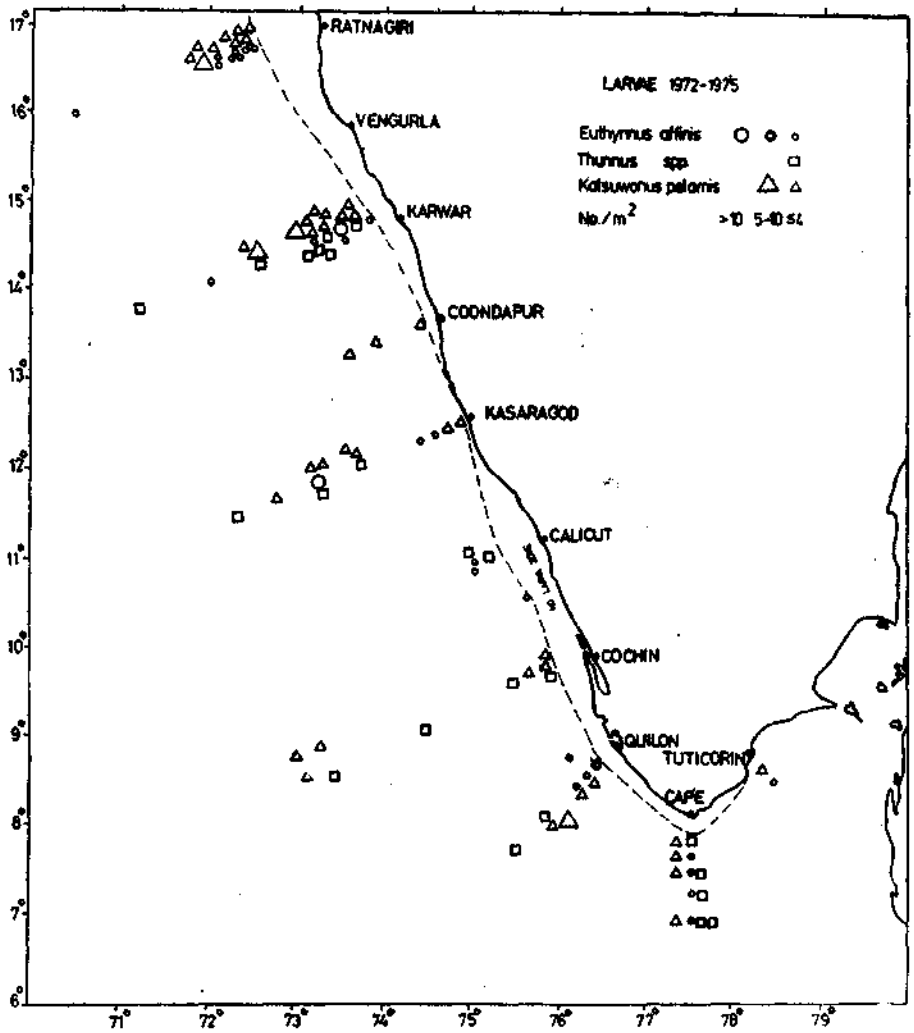

FIG. 6. Stations of occurrence of the larvae of *Euthynnus affinis*, *Katsuwonus pelamis* and *Thunnus* spp. indicating also their abundance during 1972-1975.

Auxis larvae were collected in the present study in all the months of the year, more abundantly from March to August with the peak in July. They were least available during November to February period. The minimum

often caught in 27°C to 29°C range. They were found in surface salinity range of 32—36‰, but the dominant occurrence was noticed in 34-36‰ S (Fig. 7).

Larvae of other tunas

It would be seen (Fig. 6 and Table 1) that the maximum frequency of occurrence was for *K. pelamis* larvae (45), followed by *E. affinis* (29) and *Thunnus* spp. (23). It was also noticed that most of them were caught from all the sections, mainly during February - August period. This is in contrast to the occurrence of the larvae of *Auxis* spp. and *R. kanagurta* in all months of the year (Table 1). The northern sections off Karwar and Ratnagiri and the Cochin and Quilon sections showed relatively more incidence of tuna larvae. The lesser frequency of occurrence in Coondapur and Calicut could be attributed to the infrequent coverage of these sections as well as their limited seaward extension. However, the Tuticorin section eventhough covered adequately from the beginning of 1973 showed only 2 occurrences.

Skipjack tuna larvae

Larvae of *Katsuwonus pelamis* were caught from 45 stations accounting for 93 larvae.

These larvae occurred during February to August period, with dominant occurrence from February to April and in June. The present and the past observations (Raju, 1963, 1964; Jones, 1959) put together show that *K. pelamis* spawns throughout the year off the SW coast. During the present survey, more larvae were caught north of 12° N, but were fairly well represented in the south also, particularly in the Cape Comorin region. The previous northern-most record of the larvae from the Arabian Sea appears to be by Jones (1959) (11°40'N, 42° 35' E) and from the Bay of Bengal by Gorbunova (1963) (13°30' N), whereas the present collections extend the distribution of the larvae upto 16°40'N in the Arabian Sea. *K. pelamis* larvae have been encountered in the nearshore, as well as oceanic waters, more of them having been caught beyond 75 m depth areas. However, the Lakshadweep particularly the Minicoy waters where a good fishery for the species exists have not been covered regularly during the present studies. The larvae showed a marginal increase in catch in the night hauls. The surface temperature range in which the larvae occurred was 27°C to 31°C with predominant occurrence in the 28°C to 30°C range. The favourable surface salinity range was 34 to 36‰ (Fig. 7). The smallest larvae caught was 2.8 mm in total length and the largest 12.7 mm with 3 to 6 mm length group dominant in the catches.

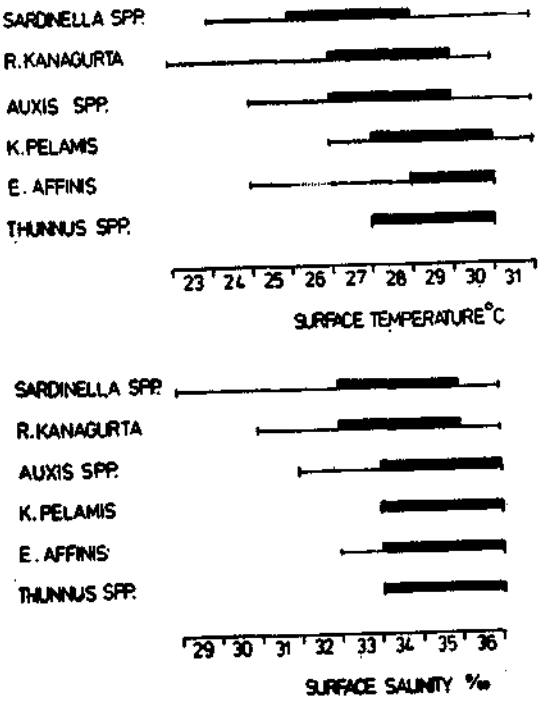

FIG. 7. Surface temperature and salinity ranges in which different larvae occurred. (The total range — entire bar and the more favoured range — thick bar are indicated).

Little tuna larvae

Euthynnus affinis larvae occurred in the present collections from March to August, with their dominant occurrence in May-June period. They were represented in all the sections, except Cochin. Karwar and Ratnagiri sections yielded more larvae (Fig. 6).

These larvae were caught more in offshore waters beyond 50 m depth contour. Fifty percent more *E. affinis* larvae were caught in night hauls than in the day. The favourable surface temperture for occurrence of the larvae was however, 29°C to 30°C, they were found at temperature as low as 25°C. The larvae occurred in 33 to 36‰ surface salinity range with dominant occurrence in the 34 to 36‰ range (Fig. 7). The minimum length of the larva caught was 3.0 mm and the maximum 12.8 mm, with the dominant length groups at 3 to 6 mm.

The present collection of *E. affinis* larvae came from 29 stations of the surveyed area and accounts for a total of 89 larvae.

Thunnus spp. *larvae*

Thunnus larvae in the present collections are classified to generic level only and it is likely that the material contains more than one species. In all, 23 positive stations were observed for *Thunnus* spp. accounting for 36 larvae.

Larvae of *Thunnus* spp. were the least abundant of all tuna larvae, occurring in relatively restricted period from February to June. They were not observed in Ratnagiri and Tuticorin sections, but recorded from Karwar to Cape Comorin with significant occurrence off Karwar as well as Cape. More of these larvae were caught in offshore waters beyond 100 m depth. The smallest larva caught was 3.2 mm in total length and the largest 10.4 mm. There was only marginal increase in the catches of *Thunnus* larvae at night. The larvae occurred in relatively restricted range of surface temperature (29°C to 30°C) and surface salinity (34 to 36‰ S) (Fig. 7)

The occurrence of *Thunnus* larvae in the present collections from February to June indicates a relatively shorter spawning period or it may be that the full range of the spawning area of this oceanic species was not accessible in the present survey.

Larvae of Carangids

Carangid larvae occurred almost throughout the year with a predominance of *Decapterus* spp. Maximum numbers of larvae were noticed over the shelf waters in May-June period, with a secondary abundance around the month of October. Carangid larval concentrations were mostly seen in the southern sector of the SW coast, between Cochin and Cape Comorin.

Larvae of lantern fishes

The larvae of lantern fishes were most common and wide spread in occurrence than all other fish larvae in the present collections. Sorting of these larvae beyond the family level has not been attempted in this study. The larvae occurred in about 45% of the stations sampled during the entire period.

The larvae were collected as far as 200 miles offshore, upto which distance the surveys were extended a few times. However, they were found only in small numbers in a large part of shelf waters from Ratnagiri to Tuticorin. The major larval concentration (10 larvae/m^2) were found in a belt 30-40 miles wide, outside the shelf, south of 9°30' N. This strip of larval concentration at about 50-60 miles, away from the coast, extended as far as south of Cape Comorin. The next best concentrations (75 No/m^2) was in the northern part in a narrow belt over the outer shelf and the continental slope from north of Coondapur to Ratnagiri. The larval abundance showed gradually increasing trend towards oceanic waters upto an average distance of 120 miles from the shore and decreased further seaward.

Myctophid larvae were collected in all months from the area, but their abundance was more during February to August period with the peak in July.

Larvae of 'light-fishes'

The gonostomatid larvae commonly met with in the present collections were those of

Vinciguerria spp. Silas and George (1969) who described in detail several stages in the early life-history of *Vinciguerria nimboria* from the SW Coast of India found them more in the oceanic area, than in the neritic waters. The average pattern of distribution of the larvae of *Vinciguerria* spp. showed wide distribution all over from Ratnagiri to Tuticorin. The larvae clearly showed increase in their numbers seawards upto about 100 miles and declined further off. The oceanic regions off Karwar - Ratnagiri and Quilon - Cape Comorin Coasts were richer in larvae compared to the area in between. Few pocket concentrations of larvae were noticed over the mid-shelf, off Cochin and Ratnagiri.

The larvae of *Vinciguerria* spp. were collected in varying numbers in all the months, but relatively more in February to May period and least during September and October. *R.V. Varuna* collection from the SW coast of India in 1962 and 1963 showed relatively large numbers of *Vinciguerria nimbaria* larvae during November to January and April-May periods (Silas and George, 1969). Spawning in these fishes appear to be more active in the pre-monsoon period than during the monsoon.

Larvae of Bregmaceros sp.

Bregmaceros macclellandi is the most common adult species recorded from the Indian waters. The existence of other species in Indian waters cannot be ruled out in view of the reports of the larvae of *B. nectabanus*, *B. rarisquamosus*, *B. japonicus* and *B. arabicus* from the Indo-Pacific (D' Ancora and Cavinato, 1965 ; Day, 1869, 1878).

In the present collections, larvae of *Bregmaceros* sp. occurred throughout the year mostly over the mid-shelf. More larvae were encountered during the monsoon season than before or after it. November to January was generally the lean period for the larvae. With regard to the geographical distribution it is seen that the larvae are distributed in the entire area of the survey from Tuticorin to Ratnatgiri, the Quilon-Ratnagiri area being denser in larval distribution with the maximum abundance in the Karwar - Ratnagiri stretch. There is a gradual reduction in abundance towards the south from Ratnagiri downwards. 68% of all positive stations for the *Bregmaceros* larvae were located over the midshelf between 30-150 m depths, 10% in the inshore area within 30 m and about 22% in the oceanic region.

General Observations

Day and night variations in larval catches

Knowledge of the diurnal variations in the catches of larvae are important while planning spawning surveys.

In the present study larval catches from 1280 stations were considered for day (0601-1800 hrs) and night (1801-0600 hrs) variations and the larvae caught per station (larvae/m^2) estimated. Similarly the trend in day and night catches of some classified larvae have been considered, based on several positive hauls for which time of haul has been registered. Details are presented in (Table 2).

It is seen that the night catch rate per station for 'all larvae' exceeded that of day catches, the night/day ratio of average number (larvae/m^2) being 1.4. On the classified basis, it is seen that the maximum increase in night catch rate is seen in the larvae of *Vinciguerria* spp., the night/day ratio being 2.15 and the least in the case of *Auxis* spp., where the night/day ratio being only 1.01 indicating nearly equal catches during day and night, which agrees with the observation of Richards *et al.* (1971) from the Gulf of Guinea and off Seirra Leone, where the collections have been made by an ICITA (International Co-operative Investigations of the Tropical Atlantic) 1 m plankton net towed at the surface.

Fifty per cent more sardine larvae and little tuna larvae are caught at night than in day

hauls. The increase in larval catch rates at night though consistent in all types of larvae; in the case of mackerel, whitebait and *Thunnus* spp., it is only marginal (Table 2).

Variations in larval catches during different times of the day could happen due to the larvae avoiding the net or due to their reactions to light intensities, causing aggregations at different levels. Avoidance rate will be influenced by the type of gear and method of haul. In the present case the continuous oblique Bongo net haul at a vessel speed of 2-3 knots is expected to reduce avoidance compared to slow speed vertical hauls from stationary ships.

tage frequencies of occurrence of the larvae of sardines, mackerel and tunas against temperature and salinity ranges have been presented as histograms (Fig. 7).

It is seen that larvae of *Sardinella* spp. and *Rastrelliger kanagurta* occur in a wider range of temperature and salinity than those of tunas. The temperature range for *Sardinella* larvae is observed to be 24° to 31° C with their predominant occurrence in the 26° to 28° C range. The mackerel larvae preferred slightly warmer waters, the temperature range being 20° to 30° C with their abundance in 27° to 29° range.

TABLE 2. *The proportion of different types of larvae caught during day and night hauls*

Type of larvae	Day (0601—1800 hrs)		Night (1801—0600 hrs)		
	No. of stations considered	No. of larvae/m²/ positive station	No. of stations considered	No. of larvae/m²/ positive station	ratio
All larvae ..	696	32	584	45	1.40
Whitebaits ..	263	13.21	254	15.34	1.16
Sardines ..	68	15.03	59	22.61	1.50
Mackerel ..	50	5.68	48	6.37	1.12
Auxis sp. ..	66	16.86	78	17.18	1.01
Katsuwonus pelamis ..	13	1.46	32	1.78	1.22
Euthynnus affinis ..	13	2.23	16	3.50	1.57
Thunnus spp. ..	10	1.10	13	1.23	1.12
Vinciguerria spp. ..	162	4.26	173	9.16	2.15

Majority of the observations cited in the chapter show that more fish larvae are caught at night than during day eventhough varying results have been reported in some cases like *Auxis* and Jack mackerel larvae, where they have not shown increased rates of catches at night.

Temperature and salinity on the distribution of larvae of sardine, mackerel and tuna

In the present study the surface temperature and salinity values of the positive stations for different larvae have been considered. Percen-

Among the tunas, the larvae of *Auxis* sp. and those of *Euthynnus affinis* occur in relatively wider range of temperature; 25° to 31° C in the case of *Auxis* and 25° to 30° C in the case of *E. affinis*. Dominant occurrence of *Auxis* is found in the range of 27° C to 29° C and *E. affinis* is it restricted to 29° and 30° C range.

Larvae of *Thunnus* spp. show relatively very restricted temperature range in their occurrence; 28°C to 30°C.

As regards the tolerance of salinity it is seen that *Sardinella* larvae show the widest range from 29‰ to 36‰, with their predominant occurrence recorded in the 33‰ to 35‰ range. The mackerel larvae show a slightly smaller range from 31‰ to 36‰, with the same predominant occurrence range (33-35‰) as sardine larvae. All the tuna larvae show 34‰ to 36‰ salinity range for their dominant occurrence, with *Auxis* and *E. affinis* showing a wider tolerance down to 32‰ and 33‰ respectively.

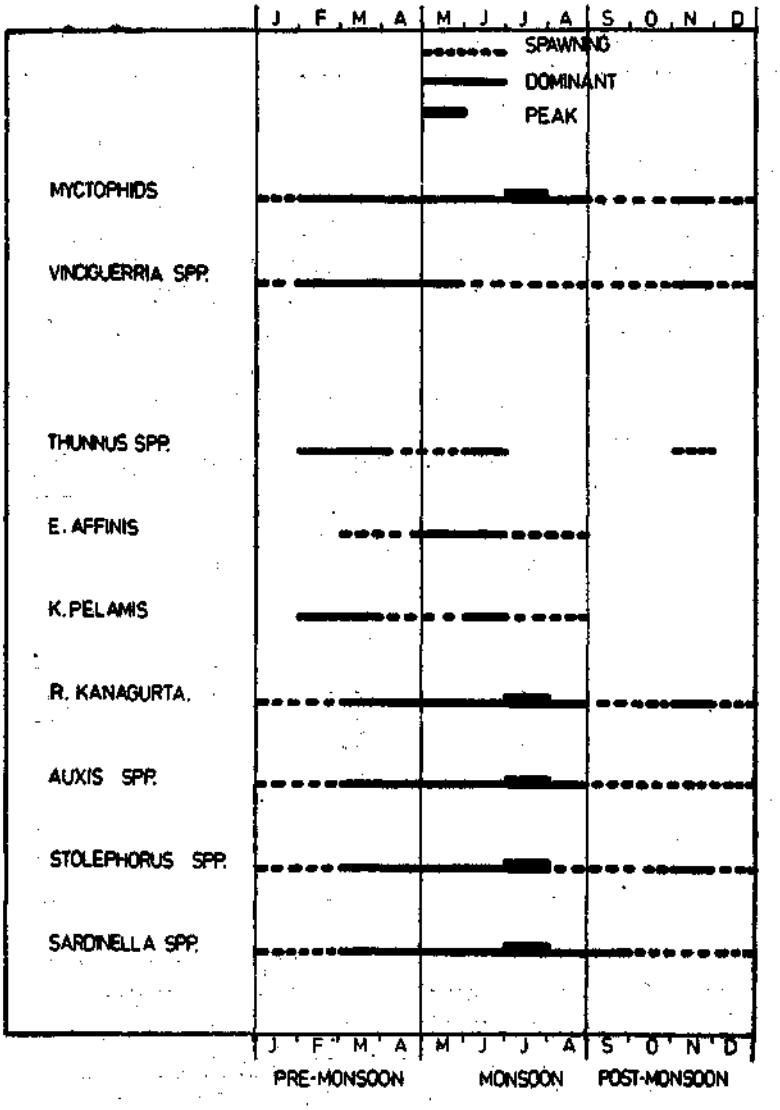

FIG. 8. The spawning periods of different fishes.

DISCUSSION

In the past, indications of spawning seasons and spawning grounds of fishes in Indian seas have been based mainly on the occasional collections of eggs and larvae from inshore

localities or on the basis of gonad studies, The concept of well defined spawning ground and seasons in temperate water fishes influenced the surmises based on very partial coverage of the spawning of the concerned fish, in time and space. A comprehensive review of information of spawning periods of several marine teleosts of the Indian seas has been made by Qasim (1973). He has come to the conclusion that fishes along the west coast of India 'largely spawn during the monsoon (June to September) and post-monsoon months (October to January). Many species appear to be continuous breeders with prolonged spawning, lasting 7-9 months during the year'.

It is seen from the present studies that several pelagic fishes of the SW coast of India, namely *Sardinella longiceps, Rastrelliger kanagurta, Auxis* spp. and *Stolephorus* spp. spawned almost throughout the year, in the entire range of their distribution, mostly on the shelf. The tunas other than *Auxis* spp. showed shorter spawning period from February to August. The planktonic larvae showed in general a southward drift and concentration in areas south of 12°N spreading over the oceanic water in this sector. The highest spawning activity of most of the commercial species, especially the pelagic ones was observed during the SW monsoon season (Fig. 8). Short periods immediately prior to and after the monsoon season also showed significant spawning. December-January period recorded least spawning activity. The drifting of the fish larvae to the southern sector of the SW coast appeared to be due to the southward surface current during the major part of the spawning period indicated.

The present survey has in a reasonable measure achieved the delineation of the spawning seasons and areas of the important commercial pelagic fishes of the SW coast of India as evidenced by their larval distribution in time and space.

Majority of the clupeoid larvae collected from the surveyed area consisted of those of *Stolephorus* spp. and *Sardinella* spp. Among *Sardinella* larvae those of *S. longiceps* were more common than others. It was observed that higher density of clupeoid larvae were on the shelf and seaward areas south of Kasaragod. *Stolephorus* larvae were relatively much more abundant than *Sardinella* larvae, while the exploited fishery showed much less *Stolephorus* spp. in the catches than *Sardinella* spp. At the same time there was clear evidence from the acoustic surveys conducted concurrently that *Stolephorus* spp. accounted for the largest clupeoid fish biomass in the project area (Anon., 1976 b) showing that the larval abundance of the species is reflected in the high potential stocks of the species.

TABLE 3. *Catches of sardines and mackerel (t) in the project area and the indices of abundance of their larvae (no. of larvae/positive haul) during* 1972-75

	1972	1973	1974	1975
Oil sardine	1,27,568	1,44,395	1,26,676	1,59,240
Lesser sardines	44,629	1,08,523	83,921	1,12,117
Total catch	1,72,197 (2.11)	2,52,918 (3.86)	2,10,597 (2.78)	2,71,357 (7.76)
Mackerel	1,08,971 (6.7)	79,423 (4.6)	37,462 (6.1)	45,947 (4.6)

Of all the Scombroid larvae collected during 1972-75 period 75% were those of *Auxis* sp., 15% of the Indian mackerel and the rest of tunas ; those of *Thunnus* spp. being the least represented among the tunas. The high abundance of the larvae of *Auxis* spp. is again not consistent with the small magnitude of the exploited fisheries for the species, nor was there any evidence of large biomass of the species in the project area from the acoustic surveys. It could be that the coastal fishery

for *Auxis* spp. in the area is only a fringe of the total stock, while the major part of the stock retreated to the oceanic waters.

A comparison of the sardines (*Sardinella* spp.) and mackerel landings in the project area for 1972-75 period and the indices of abundance of their larvae (No. of larvae/positive haul) have shown generally a positive relationship particularly in the case of sardines (Table 3).

With regard to mackerel larvae this relationship has been less consistent, though in the year of best catch of mackerel (1972) the larval index was also the highest.

Thus the larval abundance indices in these cases appear to be broadly indicative of the fishery of the year. However this picture can be vitiated by the varying strengths of older year classes contributing to the fishery in any year.

Also from a practical point of view, adequate coverage in time of the spawning of these fishes stretches into many months and subsequent final analysis of construction of larval abundance indices might be arrived at only when the year's fishery is well through the season. The element of mortality of larvae and the survival rate will remain unaccounted unless detailed studies are possible within a short time. This situation depreciates the value of the larval surveys for forecast of fisheries, in tropical conditions. The cost of vessel time and man power involved on recurring icthyoplankton surveys are quite high and commensurate results to make precise forecasts of the fisheries, sustained largely by the 0 year and 1 year class fishes cannot be expected. In comparison, surveys for young fish or acoustic and aerial surveys for shoreward migrating surface schools prior to fishing season may be more profitable exercises, yielding quicker results for the forecast of the fisheries.

REFERENCES

AHLSTROM, E. H. 1966. Appraisal of the IIOE larval fish collection at IOBC, Cochin, India. *UNESCO Inform. pap.*, 137 : 1-10.

ANON. 1974. Plankton — Fish eggs and larvae studies. UNDP/FAO, Pelagic Fishery Project, Cochin. *Progress Report*, 7.

——— 1976 a. Plankton — Fish eggs and larvae studies. *Ibid.*, 17.

——— 1976 b. A Synopsis of the information on pelagic fish resources of the southwest coast of India. *Ibid.*, 18.

D'ANCONA, U. AND G. CAVINATO 1965. The fishes of the family Bregmacerotidae. *Dana Report*, 2 (64) : 1-92.

DAY, F. 1878. *Fishes of India.* William Dawson and sons Ltd., London.

——— 1869. Remarks on some fishes in Calcutta Museum. *Proc. Zool. Soc. London.* pp. 511.

DRAGESUND, O. 1970. *Recruitment studies of Norwegian spring spawning herring* Clupea harengus (*Linnaeus*). 554 pp.

GORBUNOVA, N. N. 1965. The spawning seasons and conditions of Scombroid fishes (Pisces, Scombroidei). *Trudy Inst. Okenol.*, 80 : 36-61 (In Russian with English summary).

——— 1970. Distribution of fish eggs and larvae in the Indian Ocean. In : N. K. Panikkar (Ed.) *International Indian Ocean Expedition Plankton Atlas* 2 (2). NIO, CSIR, New Delhi.

JONES, S. 1959. Notes on eggs, larvae and juveniles of fishes from Indian waters III. *Katsuwonus pelamis* (Linnaeus) (Temminck and Schlegal). *Indian J. Fish.*, 6 (2) : 360-373.

——— AND M. KUMARAN 1963. Distribution of larval tuna collected by the Carlseberg, Foundation's Dana Expedition (1928-1930) from the Indian Ocean. *Proc. World Sci. meet. biol. tunas and rel. sp.*, 1962, *FAO Fish. Repts.*

——— AND ——— 1964 a. Distribution of larval billfishes (*Xiphiidae* and *Istiophoruidae*) in the Indo-Pacific with special reference to the collections made by the Danish Dana expedition. *Proc. Symp. Scombr. fishes, MBAI*, 1 : 483-498.

——— AND ——— 1964 b. Eggs, larvae and juveniles of Indian scombroid fishes. *Ibid.*, **1** : 343-378.

——— AND P. BENSAM 1968. An annotated bibliography on the breeding habits and development of the fishes of the Indian region. *Bull. cent. Mar. fish Res. Inst.*, **3** : 1-154.

MATSUMOTO, W. M. 1959. Descriptions of *Euthynnus* and *Auxis* larvae from the Pacific and Atlantic oceans and adjacent seas. *Dana Rep.*, **50** : 1-34.

NELLEN, W. 1972. Fish larven des Indischen ozeans. *Meteror Forsch. Engebnisse, Reihe* D, **14** : 1-66.

——— 1973. Kinds and abundance of fish larvae in the Arabian Sea and the Persian Gulf. In : B. Beitzschel (Ed.) *Ecological studies. Analysis and synthesis*, **3** : 415-544.

PANIKKAR, N. K. (Ed.) 1968. Maps of total zooplankton biomass in the Arabian Sea and the Bay of Bengal. *IIOE Plankton Atlas*, **1** *Fasc.* 1 & 2.

——— AND T. S. S. RAO 1973. Zooplankton investigation in Indian waters and the role of the Indian Ocean Biological Centre. IOBC *Handbook*, **5** : 111-162.

PETER, K. J. 1969. Preliminary report on the density of fish eggs and larvae of the Indian Ocean. *Bull. Nat. Inst. Sci. India*, **38** : 854--863.

——— 1974. Seasonal variation of Ichthyoplankton in the Arabian Sea in relation to Monsoons. In : J. H. S. Beaxter (Ed.) *The early life history of fish*. Springer-Verlag, Berlin, pp. 263-264.

——— 1977. Distribution of tuna larvae in the Arabian Sea. *Proc. Symp. on warm water zooplankton. Spl. publication*, NIO, Goa : pp. 36-40.

QASIM, S. Z. 1973. On an appraisal of the studies on maturation and spawning in marine Teleosts from the Indian waters. *Indian J. Fish.*, **20** (1) : 166-181.

RAJU, G. 1963. Spawning of the oceanic skipjack *Katsuwonus pelamis* (Linnaeus) in the Laccadives sea. FAO *Fish. Rep.*, **3** : 1582-1669.

——— 1964. Studies on the spawning of the oceanic skipjack *Katsuwonus pelamis* (Linnaeus) in Minicoy waters. *Proc. symp. Scombroid Fishes*, MBAI, **2** : 744-768.

RAJU, N. S. AND P. N. GANAPATI 1969. Distribution of fish eggs and larvae in Bay of Bengal. *Bull. Nat. Inst. Sci. India*, **38** (2) : 797-804.

RICHARDS, W. J. AND C. DAVID 1971. Distribution of tuna larvae (Pisces, Scombroidae) in the northwestern Gulf of Guinea and off Sierra Leone. *U. S. Fish. Bull.*, **69** (3) : 555-568.

SHOMURA, R. S. 1970. Indian Ocean coastal waters. *In* : J. A. Gulland (Ed.) *The Fish Resources of the Ocean*. FAO *Fish. Techn.*, Pap. **97** : 115-129.

SILAS, E. G. 1974. Larvae of the Indian mackerel. *Rastrelliger kanagurta* (Cuvier) from the west coast of India. *Indian J. Fish.*, **21** (1) : 233-253.

——— AND K. C. GEORGE 1969. On the larval and postlarval development and distribution of the mesopelagic fish *Vinciguerria nimbaria* (Jordan and Williams) (Family Gonostromatidae) off the west coast of India and the Laccadive Sea. *J. mar. biol. Ass. India*, **11** (1 & 2) (1971) : 218-250.