STUDIES ON SOME FISH LARVAE OF THE ARABIAN SEA AND BAY OF BENGAL

THESIS
SUBMITTED TO THE UNIVERSITY OF COCHIN
IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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JANUARY, 1982

D E C L A R A T I O N

I hereby declare that this thesis entitled "Studies on some fish larvae of the Arabian Sea and Bay of Bengal" has not previously formed the basis of the award of any degree, diploma, associateship-fellowship or other similar title or recognition.

ERNAKULAM,
29th JANUARY, 1982.

(K.J. PETER)

C E R T I F I C A T E

This is to certify that this thesis is an authentic record of the work carried out by Shri K.J. Peter, under my supervision at the Indian Ocean Biological Centre and the Regional Centre of National Institute of Oceanography, Cochin and that no part thereof has been presented for any other degree in any University.

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P R E F A C E

Though several scientific expeditions surveyed the Indian Ocean, their findings on larval fishes were fragmentary and incomplete. During the International Indian Ocean Expedition (1960-1965) zooplankton samples were collected from vast area of the Indian Ocean adopting standard procedures by the participating vessels. These plankton samples provided an opportunity for a general study of the zooplankton as well as their taxonomy, abundance and distribution. Realising the importance of the analysis and classification of fish larvae at the family level being one of the most immediate information required then for the Indian Ocean region, the fish larval portion sorted out from the above zooplankton samples was allotted to the author by the UNESCO Consultative Committee for the Indian Ocean Biological Centre. In spite of the emphasis laid on the study of the family Scombridae, owing to the paucity of the scombrid material in the collection, much could not be done about it. However, the record and description of the very early stages of mackerel larvae made in 1967 as part of this study was the first of its kind. The present study on the distribution aspects of fish larvae of such large area in the Indian Ocean is also unique and first of its kind.

The identification of fish larvae was the most difficult and time consuming task necessitating considerably long time especially due to the large amount of material and the different degrees in the quality of their preservation. The present thesis is the outcome of such an assignment. The main objectives are to present a general picture of abundance, distribution and seasonal variation of fish larvae along with the larval characters at the family level in the Arabian Sea and Bay of Bengal. Also the present state of biological and oceanographic knowledge of this region has been summarised for studies on their interaction with fish larvae.

K.J.P.

A C K N O W L E D G E M E N T S

I wish to express my deep sense of gratitude to Dr. C.V. Kurian, D.Sc., Emeritus Scientist (ICAR) and former Professor and Head, Department of Marine Sciences, University of Cochin for his valuable suggestions, supervision of the work and critical reading of the manuscript.

I am thankful to late Dr. N.K. Panikkar and Dr. S.Z. Qasim, former Directors of the National Institute of Oceanography, Dr. V.V.R. Varadachari, Acting Director, Dr. T.S.S. Rao, Head, Biological Oceanography Division and Dr. M. Krishnankutty, Scientist-in-Charge, Regional Centre, National Institute of Oceanography, Cochin for the encouragements and facilities given during the course of this work.

I am greatly indebted to late Dr. E.H. Ahlstrom, Senior Scientist, Southwest Fisheries Centre, La Jolla, California; Dr. T.S. Rass and Dr. (Madam) Gorbunova, Institute of Oceanology, Moscow for their useful suggestions and the help rendered in the identification of some of the fish larvae.

I take this opportunity to acknowledge with thanks UNESCO and SCOR for the funds provided in 1967, 1970 and 1973 which enabled me to visit several laboratories and examine the identified collections stored at the Plankton Laboratory, Charlottenlund Slott, Denmark; British Museum (Natural History), London; Far Seas Fisheries Laboratory, Schimuzu and Fisheries Laboratory, Kyushu University, Fukuoka, Japan.

Thanks are also due to the participants of the IIOE for collecting the samples, my colleagues of the erstwhile Indian Ocean Biological Centre and Regional Centre of National Institute of Oceanography, Cochin, for processing them, particularly Smt. C.B. Lalithambika Devi, Smt. P.P. Meenakshi Kunjamma and Dr.(Smt.) V. Santhakumari, who collaborated with me in the analysis and processing of the Ichthyoplankton. The statistical analysis of the data rendered by Smt. K.V. Jayalakshmi and the overall helps extended by Dr. T. Balachandran during the preparation of this thesis are gratefully acknowledged. I also thank Shri K.K. Gopinathan for the secretarial assistance.

1. INTRODUCTION .. Pages 1 - 14

1. INTRODUCTION

1.1. Scope and purpose of the study.

Fish fauna of the Indian Ocean is reported to comprise of about 3,000 to 4,000 species of tropical shore fishes (Cohen, 1973). The number of shelf, slope and abyssal species are comparatively less when compared to the shore fish fauna. Fowler (1956) recorded about 235 species from Red Sea and southern coast of Arabia and Smith (1965) recorded more than 1,000 species from the South African waters. Parin (1968) stressed the diversity of epipelagic fish fauna of the Indian Ocean and classified its ecological origins. Rass (1969) estimated that out of the 1,500 deep sea oceanic fishes, less than 300 are known for the Indian Ocean in comparison with 725 species for the Atlantic and 800 for the Pacific. Of the total 300 deep sea species of the Indian Ocean, 150 to 200 species belonging to over 60 families are of commercial importance. In spite of the large fauna of fishes existing in the Indian Ocean, very few have been accorded taxonomic attention sufficient to allow their use in zoogeography for describing distribution patterns.

But for the studies of Rass (1965) and Hida and Pereyra (1966) no well documented qualitative studies are available on the charactèrisation and distribution of species complex.

The survey of eggs and larvae was first made at the beginning of the century to study the early life history of commercially important species. Considering the several advantages in sampling fish larvae during their early larval period rather than juveniles and adults, Ichthyoplankton surveys were conducted at different parts of the world oceans. Most of the marine fishes have pelagic larvae including those that deposit demersal eggs or brood their eggs internally. They have a more or less depth oriented distribution in the upper mixed layer and just below the thermocline including larvae of mesopelagic and bathypelagic species. Because of the feeble swimming ability of the larvae they can be sampled with a simple gear like the plankton net. This with their wide distribution facilitates the possibility of sampling from extensive areas. Ahlstrom (1959, 1971) has observed that maximum number of eggs and larvae could be obtained by sampling a water column down to a depth of 100 - 150 m and that there was no evidence for fish larvae moving through the thermocline while making diurnal vertical migration. Fish eggs and larvae surveys provide interesting and basic data on the location of probable spawning grounds, nature of eggs and larvae. Further, the systematic collection of the sample would also indicate the spawning season and variation in the races and population. The importance of the distribution studies is that it helps to evaluate the entire spectrum of physical and biological environment to which the species are adapted. Many of the pelagic fishes like white baits, sardines, mackerel etc. are caught mainly in the coastal waters.

An attempt to find out how far oceanic these coastal species do occur and which are the areas of spawning concentration of these species as well as other species would be of interest, as similar studies in such magnitude have not been attempted earlier. With the above ideas in mind the fish larvae sorted out from the standard samples collected from 200 - 0 m during International Indian Ocean Expedition (IIOE) were subjected to detailed studies in combination with the other environmental parameters available. In view of the difficulties experienced in the analysis of samples, identification of fish larvae and processing of data in respect of such large number of collections, the present study was limited to the larval material of the Arabian Sea and Bay of Bengal.

1.2. Historical account.

Until towards the end of the last century little was known about the eggs and early larval stages of marine fishes. As early as 1865 the eminent Norwegian Planktonologist Sars observed that the eggs of cod, haddock and gurnard are planktonic. It was this important discovery that stimulated the interests of Ichthyologists in Europe to take up the study of the life histories of species of commercial importance during the period 1885 to 1900. But the active work was centered in England, Italy and Germany. The greatest contribution was first made by the British Marine Biologists Holt, MacIntosh and Cunnigham during the period between 1885 and 1900. The other scientists in the field were Ehrenbaum in Germany and Guitel in France. Initially most of the work was in the laboratories. By means of artificial fertilisation the research workers succeeded in describing eggs and larvae of several British marine teleosts. Later the invention of young fish trawl by Peterson (1904) helped in describing the post-larval stages too. The description of these stages was done chiefly by the Danish scientists Johannes Schmidt and Peterson. Later the advances in the sea going research vessels and improvement of the plankton sampling gear helped to collect them quantitatively in sufficient numbers. By 1920 several of the planktonic stages of north European fishes were described. The plotting of the spawning areas and movements of larval and postlarval stages of certain important food fishes such as herring, cod and plaice wasthe next stage in this field of study.

In the year 1901 Hjort conducted an Ichthyoplankton survey in 'Michael Sars' and succeeded in locating areas of cod spawning in Norwegian waters. Schmidt investigated certain parts of Atlantic and waters around Iceland in 1905. Since 1898 the International Council for the Exploration of the Seas (ICES) could initiate several Ichthyoplankton surveys giving information about the spawning areas of several fishes and stimulate research on Ichthyoplankton in a number of countries, especially Denmark. Peterson (1904) studied the complete life history series of flat fishes, and Schmidt (1905, 1906) that of gadoids. Schmidt's (1925) studies on life history and breeding grounds of European eel Anguilla vulgaris based on the leptocephali of the North Atlantic was one of the very important contributions in that field. Taning was another outstanding Danish worker who contributed very much to the studies on Myctophid larvae and adults (Taning, 1918). Vilh Ege dealt with the larvae and adults of meso and bathypelagic fishes such as Paralepididae, Stomiatidae, Chauliodus, etc. (Ege, 1930, 1948, 1953, 1957). Bertelsen (1951) worked on ceratoids. Ehrenbaum published an indispensable reference work, the 'Nordish Plankton', for identifying fish eggs and larvae during 1905 to 1909. Luigi Sanzo and other Italian workers contributed to the Uova, larvae e stadi giovanili di Teleostoi in Monografia 38 in the series Fauna e Flora del Golfo di Napoli published between 1931 and 1956. Hildebrand and Cable (1930, 1938) made one of the largest contributions to life history studies of western north Atlantic marine fishes. Ichthyoplankton surveys to collect sardine eggs and larvae were started in 1929 by the Department of California Fish and Game (Scofield, 1934). Ahlstrom was very actively involved in the studies of eggs and larvae since the last 40 years. U.S. Bureau of Fisheries and Scripps Institution of Oceanography conducted cooperative Ichthyoplankton surveys from 1939 to 1941, for the quantitative collection of eggs and larvae of Pacific sardine ~~(Ahlstrom, 1948)~~ and northern anchovy (Marr and Ahlstrom, 1948). The CalCOFI which started in 1949 is being continued to the present time concentrating on Ichthyoplankton research.

In the Indo Pacific region the pioneer work on fish eggs and larvae was done by the Dutch Scientist Delsman during the period from 1921 to 1938. Contributions by the Japanese scientists in this field are also very valuable. Most important among them are the works on eggs and larvae of the Japanese waters (Uchida et al., 1958; and Mito, 1960-1963). Larvae and juveniles of scombroid fishes particularly tunas and bill fishes have been studied by Ueyanagi (1963, 1964 . 1974) and Ueyanagi and others. Ichthyoplankton surveys for assessing the distribution and abundance of sardine eggs and larvae of Japan have been conducted for several years. Eel leptocephali have been studied by Castle (1965 a, b, c, 1969) from the Newzealand area. The team of Russian Scientists headed by Rass was also studied the early life histories of various groups of fishes such as myctophids, flat fishes (Pertseva - Ostroumova, 1964, 1967, 1974), scombroids (Gorbunova, 1963, 1965 a, b, c, 1967) and exocoetids (Gorbunova and Parin, 1963; Kovalevskya, 1963, 1964, 1965; Kovalevskya and Khrapkova, 1963).

1.3. Work done in India.

The earlier work on the distribution and larval development of marine fishes carried out in India prior to the International Indian Ocean Expedition dates back to 1922, based on the plankton collections of the coastal waters. Hornell (1922) made studies on the fishery and spawning habits of *Cypselurus* sp. of the Coromandal coast. Nayudu (1922) studied the development of *Cypselurus* sp. Hornell and Nayudu (1923) described the life history of *Sardinella longiceps* from the plankton collections off Madras coast. Aiyar (1933, 1935) contributed to the study of eggs and developmental stages of *Acentrogobius neilli*. Aiyar *et al*. (1936) dealt with the plankton record for the years 1929-1930. Nair (1939) described certain early developmental stages of *Hilsa ilisha*.

During the period from 1940 to 1950 fish eggs and larvae studies were conducted mainly from the coastal waters of Tamil Nadu and Maharashtra regions. Devanesan and Chidambaram (1941) described the planktonic eggs and larvae of *Caranx cruminopthalmus* hatched in the laboratory at West Hill in Calicut. Gopinath (1942, 1946, 1950) studied larval and postlarval stages of several speciesof fishesfrom plankton off Trivandrum coast. Chidambaram (1943, 1945) recorded the early stages of species of *Caranx* and larval life of *Cynoglossus semifasciatus* from the plankton off West Hill. Aiyar *et al*. (1944) studied the leptocephalus belonging to *Muraena* and *Ophichthys* of the Madras coast. Bal and

Pradhan (1945 a, b, 1946, 1947) made investigations on the eggs and larvae of Bombay waters. Chidambaram and Menon (1945, 1948) reported the occurrence of eggs and larvae in plankton of the west coast of India. From the Trivandrum area an account of the occurrence of fish eggs and larvae havebeen given by Menon (1945). Panikkar and Nair (1945) and Nair (1946, 1947, 1948) dealt with the fish eggs and larvae from the Madras coast.

The major portion of the larval studies between 1951 and 1960 were also concentrated in the Madras and Bombay waters, mainly by the maritime Universities and State Departments. The south west coast of India and Andhra coasts were also covered partly. Bal and Pradhan (1951, 1952) investigated the occurrence of fish larvae and postlarvae in the Bombay waters. John (1951) studied the pelagic fish eggs and larvae of the Madras coast. Jones and Menon (1951) dealt with the developmental stages of Hilsa ilisha and (1952) of genus Coilia. Pantulu and Jones (1951) published noted on the larval development of Pama pama. Bapat and Prasad (1952) studied some developmental stages of Caranx kalla from Gulf of Mannar. Nair (1952 a, b, 1960) described the eggs and larval stages of Sardinella longiceps and other eggs and larvae from the Madras plankton. Bapat

(1955) made a preliminary study of the pelagic fish eggs and larvae of Gulf of Mannar area. Jones and Pantulu (1955, 1958) described the life history stages of ophichthid species off Kerala, Madras, Orissa and Bengal coasts. Balakrishnan (1957) reported the occurrence of larvae of young mackerel from Vizhinjam near Trivandrum. Kuthalingam (1957, 1958, 1959 a,b,c, 1960 a,b,) studied the prolarvae and post-larvae and their feeding habits of Cynoglossus lingua and several other species collected from the plankton of Madras coast. Nair (1957a) made studies on the early life history of Ambassis gymnocephalus and (1957b) Mugil cephalus. Jones (1958, 1959 a,b, 1960 a,b) studied the larvae and juveniles of tuna, sail fish and sword fish. Balakrishnan (1959) studied the fish eggs and larvae of Cynoglossus spp. from the Kerala coast. Ganapati and Raju (1960) contributed to the study of eggs and larval development of eels from the Bay of Bengal.

During the period between 1961 and 1970, the materials studied were mainly from the oceanic collections of the Arabian Sea and Bay of Bengal. A large scale oceanographic expedition (IIOE) was conducted during the period from 1960 to 1965, organised by the Scientific

Committee of Oceanic Research (SCOR) of the International Council for the Exploration of the Sea (ICES) and UNESCO in the Indian Ocean, since it remained as one of the latest known oceans of the world. The magnitude of this expedition in terms of area surveyed, personnel, ships, money and countries involved made it the greatest oceanographic endeavour to date. The studies on the materials collected by the participating vessels were mainly studied during this period. Balakrishnan (1961, 1963) described the eggs and larvae of Cynoglossus species collected from the Kerala coast and (1969) of Thrissocles sp. Ganapati and Raju (1961, 1963) reported the occurrence of pelagic fish spawn at the coast of Waltair. Kuthalingam (1961) contributed to the life history and feeding habits of Mugil cephalus from the Madras area. Jones and Kumaran (1963) contributed to the geographical and seasonal distribution of tuna larvae collected by the 'Dana' expedition of the Carlsburg Foundation; (1964 a) larval stages of Myripristis murdjan, Holocentrus sp.; (1964 b) Istiophorus, Makaria, Xiphias sp.; (1964 c) scombroids. Jones and Silas (1963) dealt with the larval stages and distribution of Katsuwonus pelamis in the Indian Ocean. Silas (1963 a,b) made studies on the larval stages and distribution of Gramatorcynus bicarinatus and Sarda orientalis in the synopsis of the biological data of these species. Subrahmanyam (1964, 1968) described the eggs and early development of carangids from Madras waters. James (1967 a,b) studied the ribbon fishes of the family Trichiuridae. Jones (1967) studied the larvae of *Pegasus* and *Dactylopterus* sp. Jones and Rosa (1967) have given information on the larvae and juveniles of *Rastrelliger kanagurta* in the synopsis of the biological data of the species. Peter (1967, 1969 b) described the larvae of mackerel from the Indian Ocean and (1970) illustrated the distribution of fish eggs and larvae in the same area. Raju and Ganapati ([illegible], 1969) have given an account of the eggs and larval distribution of *Sardinella* sp., *Bregmaceros artipinnis*, *Stolephorus heterolobus*, *Cynoglossus* sp., *Muraena* sp., *Saurida* sp. and *Myctophum* from Bay of Bengal. Balasubrahmanyam (1966) recorded one larva of *Idiacanthus fasciola* from Bay of Bengal. Bensam (1968 a,b,) made studies on the eggs and early developmental stages of muraenid eel, *Opisthopterus tardoore* and *Cynoglossus semifasciatus* and (1971, 1973) of *Sardinella* spp. Sudarsan (1968a) studied the developmental stages of pipe fish *Syngnathoides biaculeatus* and (1968 b) reported the occurrence of eggs and larvae of a hemirhamphid fish from Mandapam. Balasubrahmanyam *et al*. (1969) described the larval and juvenile stages of *Hirundichthys coromandelensis* and

Exocoetus volitans from Bay of Bengal. Devi (1969) recorded the occurrence of larvae of *Pseudorhombus elevatus* from the southwest coast of India.

Contributions on the developmental stages and distributional aspects of the larval fishes between 1971 and 1980 are mainly from the collections of the southwest coasts of India, Madras waters and certain oceanic regions. Balakrishnan (1971) recorded the larvae of *Bregmaceros* sp. from the southwest coast of India. Peter (1972 to 1979) contributed to the studies on the larval distribution and seasonal variation of fish eggs and larvae in the Indian Ocean based on the IIOE collections. Silas and George (1971) described the developmental stages of *Vinciguerria nimbaria* from the collections made from the above area. Balakrishnan and Devi (1974) made studies on some of the larvae of flat fishes from the Cochin backwaters. Girijavallabhan and Gnanamuthu (1974) recorded one post-larva of *Rastrelliger kanagurta* from the inshore waters of Porto Novo. Silas (1974) contributed to the study of early larval stages and distribution of *Rastrelliger kanagurta* from the southwest coast of India. Venkataramanujam and Ramamurthy (1974, 1977) dealt with the seasonal variation of fish eggs and larvae of the Porto Novo coastal waters. Devi (1977) illustrated the distribution of flat fish larvae in the Indian Ocean based on collections of the IIOE. Dilip (1977) described the life history stages of Saurus tumbil from the collections of the southwest coasts of India made during 1971 to 1975. Premalatha (1977) made studies on the larval stages of Chorinemus sanctipetri from the same area. Sreekumari (1977) recorded eggs and larvae of white baits from the above area. George (1979) made studies on the distribution and abundance of fish eggs and larvae of the continental shelf region of the southwest coast of India. Valsa (1979) studied the larval stages of Diogenichthys panurgus from the collections of the same region. Balachandran (1980) investigated the latitudinal, seasonal and diurnal variations of fish larvae and their distribution in relation to thermocline along the 78°E latitude while studying the Meroplankton of the Indian Ocean.

2. MATERIAL AND METHODS .. Pages 15 - 42

2. MATERIAL AND METHODS

2.1. Material.

The fish larvae dealt with in the present study were collected from the Arabian Sea and Bay of Bengal during the International Indian Ocean Expedition (1960-1965). The collections numbering 935 were made from the upper 200 m area of the northern Indian Ocean. Out of the total samples collected from Arabian Sea and Bay of Bengal, 3.4% were from waters of depth less than 50 m, 5.7% from 50 tp 100 m, 90.9% from 100 and 200 m. The collections made from the area studied included samples collected by 15 research vessels belonging to 8 nations that participated in the biological (zooplankton collection) programme of the IIOE. From the Arabian Sea area 12 research vessels collected 573 standard samples during 29 cruises, whereas 10 vessels collected 362 samples in 23 cruises from Bay of Bengal. The details of zooplankton collections made by various ships are presented in Table 1. The major part of the collections (90%) was made during 1962-'64.

Table 1 : The countries and research vessels which participated in the International Indian Ocean Expedition zooplanktion programme, number of samples collected and cruises carried out.

Country	Vessel	Arabian Sea No. of collections/ cruises*	Bay of Bengal No. of collections/ cruises*
Australia	Diamantina	3/1	4/2
Germany	Meteor	118/1	-
India	Conch	6/1	-
	Kistna	47/7	157/10
	Varuna	70/4	-
Japan	Kagoshima Maru	8/1	9/1
	Kayo Maru	-	18/2
	Oshoro Maru	-	17/1
	Umitaka Maru	10/1	1/1
Pakistan	Zulfiquar	22/1	-
United Kingdom	Discovery	105/2	-
United States	Anton Bruun	97/7	79/2
	Argo	79/2	26/1
	Pioneer	-	34/1
Soviet Union	Vitiaz	8/1	17/2

* Number of collections/cruises.

Geographical coverage: The southern boundary of the Arabian Sea and Bay of Bengal in the present study was limited to 5°S (IOBC, 1969, 1971). From the oceanographic point of view, Schott (1935) bounded the Arabian Sea with the rest of the Indian Ocean at a point approximately 5°S. The density of the distribution of the zooplankton collections in terms of spatial, diurnal, hourly and seasonal coverage showed their hetesogeneous nature due to lack of coordination for the simultaneous observations. The Tables 2 and 3 show the density of observations, volume of zooplankton biomass and number of larvae collected from each 5° square in the Arabian Sea and Bay of Bengal respectively during different seasons. The Bay of Bengal had a slightly higher density of collections in terms of area and number - Bay of Bengal covering 38% area having 362 collections compared to the Arabian Sea covering 62% area with only 573 collections. Many of the stations were clustered along the continental shelf area of the Indian Peninsula, and Arabia. This discrepency in the sampling density may affect the outcome and reliability of biogeographical studies.

Table 2 : Area, number of samples, biomass (volume) and larvae collected from the Arabian Sea.

Marsden square No.	Area in 5° square: Latitude	Area in 5° square: Longitude	Total No. of hauls	Volume of zooplankton (ml)	No. of fish larvae obtained.
332 (2)	35°01' - 40°00'E	05°00'S - 00°00'	2	18.50	138
331 (1)	40°01' - 45°00'E	05°00'S - 00°00'	21	344.00	1863
(2)	45°01' - 50°00'E	05°00'S - 00°00'	5	84.50	259
330 (1)	50°01' - 55°00'E	05°00'S - 00°00'	14	358.75	823
(2)	55°01' - 60°00'E	05°00'S - 00°00'	13	150.60	635
329 (1)	60°01' - 65°00'E	05°00'S - 00°00'	11	126.20	370
(2)	65°01' - 70°00'E	05°00'S - 00°00'	8	51.30	196
328 (1)	70°01' - 75°00'E	05°00'S - 00°00'	4	18.75	50
(2)	75°01' - 80°00'E	05°00'S - 00°00'	21	172.70	753
032 (1)	40°01' - 45°00'E	00°01' - 05°00'N	4	99.25	257
(2)	45°01' - 50°00'E	00°01' - 05°00'N	22	827.10	1379
(4)	45°01' - 50°00'E	05°01' - 10°00'N	6	200.00	472

Table 2 (Contd.)

Marsden square No.	Area in 5° square: Latitude	Area in 5° square: Longitude	Total No. of hauls	Volume of zooplankton (ml)	No. of fish larvae obtained
031 (1)	50°01'- 55°00'E	00°01' - 05°00'N	16	403.00	482
(2)	55°01'--60°00'E	00°01' - 05°00'N	16	254.50	1099
(3)	50°01' -55°00'E	05°01' - 10°00'N	18	533.00	1047
(4)	55°01' -60°00'E	05°01' - 10°00'N	7	112.50	258
030 (1)	60°01' -65°00'E	00°01' - 05°00'N	10	115.50	153
(2)	65°01' -70°00'E	00°01' - 05°00'N	11	119.70	630
(3)	60°01' -65°00'E	05°01' - 10°00'N	3	27.50	86
(4)	65°01' -70°00'E	05°01' - 10°00'N	4	35.80	78
029 (1)	70°01' -75°00'E	00°01' - 05°00'N	8	118.50	361
(2)	75°01' -80°00'E	00°01' - 05°00'N	26	275.50	1113
(3)	75°01' -75°00'E	05°01' - 10°00'N	22	277.50	627
(4)	75°00' -80°00'E	05°01' - 10°00'N	29	516.25	1826

Table 2 (Contd.)

Marsden square No.	Area in 5° square		Total No. of hauls	Volume of zooplankton (ml)	No. of fish larvae obtained
	Latitude	Longitude			
068 (1)	40°01' - 45°00'E	10°01' - 15°00'N	5	112.00	463
(2)	45°01' - 50°00'E	10°01' - 15°00'N	12	340.00	648
(3)	40°01' - 45°00'E	15°01' - 20°00'N	1	6.50	62
067 (1)	50°01' - 55°00'E	10°01' - 15°00'N	36	858.20	2710
(2)	55°01' - 60°00'E	10°01'- 15°00'N	8	137.90	409
(3)	50°01' - 55°00'E	15°01' - 20°00'N	9	269.50	556
(4)	55°01' - 60°00'E	15°01' - 20°00'N	19	968.50	2150
066 (1)	60°01' - 65°00'E	10°01' - 15°00'N	6	59.75	72
(2)	65°01' - 70°00'E	10°01' - 15°00'N	4	15.70	55
(3)	60°01' - 65°00'E	15°01' - 20°00'N	15	363.10	766
(4)	65°01' - 70°00'E	15°01' - 20°00'N	9	123.50	247

Table 2 (Contd.)

Marsden square No.	Area in 5° square		Total No. of hauls	Volume of zooplankton (ml)	No. of fish larvae obtained
	Latitude	Longitude			
065 (1)	70°01' - 75°00'E	10°01' - 15°00'N	22	304.50	2546
(2)	75°01' - 80°00'E	10°01' - 15°00'N	8	184.00	289
(3)	70°01' - 75°00'E	15°01' - 20°00'N	39	412.50	1361
105 (2)	35°01' - 40°00'E	20°01' - 25°00'N	1	7.00	121
103 (2)	55°01' - 60°00'E	20°01' - 25°00'N	5	273.00	902
102 (1)	60°01' - 65°00'E	20°01' - 25°00'N	13	369.00	1453
(2)	65°01' - 70°00'E	20°01' - 25°00'N	39	521.70	1426
101 (1)	70°01' - 75°00'E	20°01' - 25°00'N	19	68.30	803
	Total		573	10434.55	20966

Table 3 : Area, number of samples, biomass (volume) and larvae collected from Bay of Bengal.

Marsden square No.	Area in 5° square		Total No. of hauls	Volume of zooplankton (ml)	No. of fish larvae obtained
	Latitude	Longitude			
327 (1)	80°01' - 85°00'E	05°00'S - 00°00'	7	76.00	424
(2)	85°01' - 90°00'E	05°01'S - 00°00'	17	99.00	559
326 (1)	90°01' - 95°00'E	05°01'S - 00°00'	17	120.80	671
(2)	95°01' -100°00'E	05°01'S - 00°00'	8	27.00	183
028 (1)	80°01' - 85°00'E	00°01' - 05°00'N	8	85.50	249
(2)	85°01' - 90°00'E	00°01' - 05°00'N	17	189.25	558
(3)	80°01' - 85°00'E	05°01' - 10°00'N	7	181.00	449
(4)	85°01' - 90°00'E	05°01' - 10°00'N	8	78.50	290
027 (1)	90°01' - 95°00'E	00°01' - 05°00'N	18	120.80	1038
(2)	95°01' -100°00'E	00°01' - 05°00'N	1	8.00	211
(3)	90°01' - 95°00'E	05°01' -100°00'N	16	199.75	786
(4)	95°01' -100°00'E	05°01' -100°00'N	22	194.50	1488
026 (1)	100°00' -105°00'E	00°01' - 05°00'N	1	4.00	22

Table 3 (Contd.)

Marsden square No.	Area in 5° square		Total No. of Hauls	Volume of zooplankton (ml)	No. of fish larvae obtained
	Latitude	Longitude			
064 (1)	80°01' - 85°00'E	10°01' - 15°00'N	29	425.75	3065
(2)	85°01' - 90°00'E	10°01' - 15°00'N	19	189.75	924
(3)	80°01' - 85°00'E	15°01' - 20°00'N	27	286.70	1851
(4)	85°01' - 90°00'E	15°01' - 20°00'N	45	606.25	3499
063 (1)	90°01' - 95°00'E	10°01' - 15°00'N	51	743.90	2554
(2)	95°01' -100°00'E	10°01' - 15°00'N	19	234.50	650
(3)	90°01' - 95°00'E	15°01' - 20°00'N	20	248.80	1268
(4)	95°01' -100°00'E	15°01' - 20°00'N	1	4.50	95
100 (2)	85°01' - 90°00'E	20°01' - 25°00'N	3	70.00	583
099 (1)	90°01' - 95°00'E	20°01' - 25°00'N	1	25.00	85
		Total	362	4218.95	21492

<u>Monsoon coverage</u>: (Table 9) During the Southwest monsoon period (May to August) 366 collections were made and the transition period that followed (September to October) the number of collections was 125. During Northeast monsoon period (November to February) the number of collections made was 287 and that of the second transition period (March to April) was 157.

<u>Day-Night coverage</u>: Of the 935 collections, 480 were made during day hours and 455 during night hours (Table 10). Cassie (1963) showed that no two samples are comparable unless they are taken at the same time of the day and under the same lighting conditions. Bogorov (1958) found zooplankton undergoing diurnal vertical migration to different depths which varied from species to species. This can introduce a disparity in the estimation of abundance since organisms of diurnal vertical migration have been incompletely sampled. The appa rent absence of species in such areas might be due to the limit of the sampling depth.

2.2. Methods.

Sakthivel (1972) and Sakthivel and Rao (1973) have made a critical study of the methods employed during the IIOE zooplankton collections. Based on the proposals suggested by a team of zooplankton experts who met at Cochin in 1961 that a standard sampling gear was necessary for the uniformity of sampling for quantitative studies. Currie (1963) designed the Indian Ocean Standard Net. Plankton samples collected with this gear were classified into two categories, the standard and nonstandard based on the nature of the sampling. The 'standard samples' were defined as those sampled in the water column under 1 m^2, the stratum sampled being the upper 200 m in deep water, and the entire water column over the continental shelf where the sounding was less than 200 m. The zooplankton samples collected by the various vessels, fixed and preserved in 4% HCHO (usually buffered with Hexamine) were received, logged and processed at the Indian Ocean Biological Centre, Cochin (Hansen, 1966). A large percentage of the samples had undergone deterioration in spite of the precautions taken at various stages.

Prior to the actual sorting of the samples the biomass was determined by the displacement method (Hansen, 1966). The larger organisms, fish eggs and larvae were separated from the sample. The rest of the sample was then subsampled using either the Lea's plankton fractionator (Wiborg, 1951) or Folsom Plankton Splitter (Mc Ewen et al., 1954 and Gopalakrishnan, 1973). Depending upon the volume of the sample only aliquots of 3 - 5 ml or 90% of the sample was taken for the sorting of the various taxa and the rest was left as 'Archive'. All organisms in the sample were sorted in 5% formalin and enumerated using hand tally counters leaving behind the very minute forms in the residue. The fish eggs and larvae when obtained from the subsample, their numbers were also computed for the whole sample and added tothe original number of the respective samples. The entire fish larvae sorted out which formed the material for the present study, were further subsorted at the family level as far as possible. The identification of larvae was mainly done based on the existing literature available on fish larvae of the tropical waters as well as other world oceans, and the identified materials kept at several laboratories. Morphological characters, meristic counts, body proportions, larval pigmentations and nature of fins and alimentary canal were some of the important characters taken into account in fixing up the identity of the larvae. The subsorted catagories were preserved in 5% formalin. The total number of larvae in each sample was estimated, logged and catalogged for deposition at the IOBC, Cochin and World Data Centre, Washington.

Reliability of the samples: The drawbacks noticed in the collection methods were - The Indian Ocean Standard Net with a mesh width of 330 microns was not a satisfactory gear for collecting fish larvae. As no flow meter was used in several cases, the volume of the water filtered could not be correctly measured. The clogging of the net, patchiness, diurnal migration of the larvae, limitation of the depth of haul, undivided vertical haul through a water column of 200 m, fluctuating monsoon, avoidance of the net by the larvae, sampling variations and improper coverage of the inshore areas can introduce errors in the estimation of abundance.

Presentation of data: The total number of larvae in the sample was taken as the number per unit haul. At the stations where the observations were repeated more than once, their average numbers were taken in the presentation of distribution maps and for contouring, stations with fish larvae were indicated by closed circles, while open circles denoted stations without fish larvae. Numerical abundance was used to indicate the main centre of distribution. For distribution and abundance studies it was recommended that samples be compared on the basis of catch per standard haul (IOBC, 1969) and not on the basis of number in volume of water filtered since flow meter was not used and wire angle not recorded in all cases. So the total number of fish larval taxa were estimated per unit standard haul for each station and plotted on maps. Numerical data collected from each station were then plotted on maps against the station positions. The method of presentation was found to be difficult where the stations were closely placed. In such cases the average number for a cluster of stations was plotted. By this method the distribution of larvae as a whole was illustrated. The difference in the degree of abundance was indicated on the maps using four suitable ranges for contouring viz. 1-25, 26-50, 51-100 and above 100 (Fig. 21). The error introduced by the varying depths of haul was almost nullified by this method of presentation. The same procedure was adopted in the contouring of maps showing the seasonal distribution also, but with only 3 ranges, viz. 1-50, 51-100 and above 100 (Figs. 24-27). In the case of the distribution of the various families only presence or absence was indicated on the maps (Figs. 1-19). As the fish larvae undergo diurnal migration it was thought to be more meaningful to show the diurnal variation in abundance. The samples collected during the hours between 0600 and 1800 were considered as day samples and the rest as night samples. The present collections included 480 day samples and 455 night samples. In the Arabian Sea 53.6% of the collections were made during day hours and 46.4% during night, whereas in the Bay of Bengal they were 47.8% and 52.2% respectively (Table 10). The latitudinal and longitudinal distribution of larvae calculated for 5° squares were prepared based on the average values. This was done by plotting average number of larvae for each 5° square against the respective 5° square and making histograms either longitudinally (Fig. 22) or latitudinally (Fig. 23). Since the northern Indian Ocean is subjected to monsoonal changes (Ramage, 1969, Wyrtki, 1973) it was found necessary to split the data season-wise in order to elucidate the seasonal variation in the occurrence and abundance. Eventhough the number of observations were quite insufficient to split the entire data month-wise, maps were prepared for the two monsoons and two transition periods (Figs. 24-27). In addition to these maps showing the distribution of 22 groups of fish larvae (Fig. 1-19), table showing the percentage of larvae collected and their frequency of occurrence in respect of 55 groups (Table 6) was also prepared. Tables (14 and 15) showing the number of zooplankton samples with more than 200 larvae per haul from the Arabian Sea and Bay of Bengal were prepared in order to show the relation between the number of larvae and biomass of the sample. Monthly variation of larvae was expressed by plotting the average number of larvae collected per month against the respective months (Fig. 28). For presenting the distribution of larvae during day and night the number of larvae collected per haul was plotted against the corresponding station position and contouring the different densities (Fig. 29). The relationship between the day and night distribution of fish larvae in the Arabian Sea and Bay of Bengal was compared in Figure 30 by plotting the average number of larvae per 5° square against the 5° interval latitude. Based on the number of larvae in a sample, all the zooplankton samples were grouped into class intervals of 20 larvae each and multiples of that and plotted against their frequency of occurrence to show the relationship for the Arabian Sea and Bay of Bengal areas (Table 13, Figs. 31, 32). Similarly the relationship between the biomass of the sample and the number of larvae were also drawn in Figures 33 and 34.

2.3. Statistical methods.

The coexistence of the 27 common families/groups of fish larvae collected from Arabian Sea and Bay of Bengal areas was studied by means of the correlation coefficient matrix of size 27 x 27. The significance of correlation in each case was tested using critical ratio test. The test statistic used was

$$\frac{r\sqrt{N-2}}{(1-r^2)}$$

r = Correlation coefficent

N = Number of sample units

$$r = \frac{\mathrm{cov}(x,y)}{\sigma x \times \sigma y}, \quad \mathrm{Cov}(x,y) = \frac{\Sigma xy - N\bar{x}\bar{y}}{N}$$

$$\sigma x = \sqrt{\frac{\Sigma(x-\bar{x})^2}{N}}, \quad \sigma y = \sqrt{\frac{\Sigma(y-\bar{y})^2}{N}}$$

$$\bar{x} = \frac{\Sigma x}{N}, \quad \bar{y} = \frac{\Sigma y}{N}$$

A multiple regression model for the prediction of abundance of fish larvae at the family level was developed using the data collected from the Arabian Sea and Bay of Bengal. In the regression model, numerical abundance was correlated with temperature and salinity. The model was $y = b_0 + b_1x_1 + b_2x_2$ where y is the number of individuals for all families for each station, x_1 temperature and x_2 salinity. The constants b_0, b_1, b_2 are regression coeffients. They were calculated to fit the multiple regression model by the method of least squares and the normal equations thus obtained were solved by the Matrix Inversion method.

The significance of the fitted regression was tested using analysis of variance technique. The relative importance of each of the variables mentioned in the prediction equation also was calculated using the formula

$$[|b_i|] \sqrt{\frac{\Sigma x_i^2}{\Sigma y^2}}$$ (Snedecor and Cochran, 1967)

The abundance of fish larvae in nine different areas - the Arabian coast, Red Sea and Persian Gulf, African coast, Central Arabian Sea, west coast of India, east coast of India, west coast of Burma and Thailand, central Bay of Bengal and Equatorial region was studied using Fisher's diversity index α given by the equation

$$S = \alpha \log_e \left(1+\frac{N}{\alpha}\right)$$

where S = the number of groups, α = Fisher's diversity index, N = the total number of individuals for all the groups. Larger the value of α, older will be the environment and smaller the value of α, new or severe or unpredictable will be the environment. The variance of α was calculated using the formula

$$V(\alpha) = \alpha^3 \left[\frac{(N+\alpha)^2 \log_e \left[\frac{2N+\alpha}{N+\alpha}\right] - N\alpha}{(SN + S\alpha)^2} \right]$$

Smaller the value of V (α), more constant will be value of α calculated.

2.4. Identification of fish larvae.

The taxonomy of the larval fishes of the highly complex planktonic world is very closely interwoven with the taxonomy of the adults of the nektonic world. It is dependent on a large measure on the knowledge of the adult fish. Identification of larvae belonging to this highly diverse tropical biotope even to the family level was a very difficult task because of the poor preservative quality of the material studied. Identification was mainly based on the various larval structures, their positions and sequence of appearance, number and shape of melanophores, morphometry, meristic counts and size of larvae when they transform to juveniles. If the eggs can be artificially fertilised under controlled conditions it would be possible to study the development through the embryonic and early larval period. In most pelagic fishes the pigmentation pattern found on the developing embryo is quite different from that seen on the later larval stages. The larval pigmentation after hatching usually undergoes a marked reorientation accompanied by partial or total pigment migration forming definite spots or patches. Tracing the development atleast as far as post-larval stages using the developmental stages obtained from artificially fertilised eggs of known parents is an excellent way to approach the taxonomic studies of younger stages. But in view of the difficulties experienced in the artificial fertilization of eggs, this method could not be adopted. Also in the present case as the materials were preserved the above method was not applicable.

In the present study identification of larvae and assigning them to their respective families were done mainly based on the following 4 characters.

A. Morphometric characters.

Measurements of the body parts and changes in the body proportions over a size range of specimens from just hatched larvae to the postlarval stage. The shape and position of fins, mouth, nature of alimentary canal and location of anal opening also are important larval characters in fixing up the identity of the groups.

A.1. Shape of body: The shape of body though characteristic of several groups is a character of limited use. Some larvae that are found may become long and thin as adult or visa versa. However during the larval stages the characteristic shape and structural peculiarities exhibited by the various groups help to a great extent in fixing up the identity of the families.

1.1. Elongated body:

1.1.1. Elongated slender body: Gonostomidae, Idiacanthidae, Engraulidae, Clupeidae, Dussumieridae, Synodontidae, Syngnathidae, Fistularidae, Blennidae.

1.1.2. <u>Less elongated and less slender body</u>	:	Hemirhamphidae, Sphyraenidae, Sillaginidae, Mullidae, Bregmacerotidae, Labridae, Histiophoridae, Gobiidae, Coryphaenidae.
1.1.3. <u>Elongated ribbon shaped body</u>	:	Elopidae, Albulidae, Megalopidae, Anguilliformes.
1.2. <u>Short body</u>:		
1.2.1. <u>Moderately short body</u>	:	Mugilidae, Holocentridae, Apogonidae, Serranidae, Carangidae, Labridae, Leiognathidae, Sciaenidae, Sparidae, Scombridae, Thunnidae, Stromateidae, Scorpaenidae, Callionymidae.
1.2.2. <u>Short and globular body</u>	:	Ostraciontidae, Diodontidae, Tetraodontidae.
1.2.3. <u>Short and oval body</u>	:	Monacanthidae, Balistidae, Antennariidae.
1.2.4. <u>Short and deeply compressed body</u>	:	Psettodidae, Bothidae, Pleuronectidae, Solidae, Cynoglossidae.
1.2.5. <u>Short and depressed body</u>	:	Platycephalidae, Pegasidae, Dactylopteridae.

A.2. <u>Fins</u>: The number and position of fins especially dorsal and pelvic are very important characters in the identification of various groups of larval fishes. For example, if the pelvic fins are abdominal in position, the larvae will usually belong to one of the groups like Isospondyli, Iniomi or Scomberosex. Fishes with abdominal pelvics have also other characters in common. These are soft rayed fishes lacking spines in the dorsal, anal and pelvic fins.

2.1.	Single short dorsal	:	Gonostomidae, Clupleidae, Engraulidae, Dussumieridae.
2.2.	Single long dorsal	:	Bregmacerotidae, Serranidae, Carangidae, Coryphaenidae, Leiognathidae, Histiophoridae, Stromateidae, Bothidae, Pleuronectidae, Solidae, Cynoglossidae.
2.3.	Two dorsals	:	Mugilinidae, Apogonidae, Mullidae, Gobiidae.
2.4.	Pectorals enlarged	:	Exocoetidae, Scorpaenidae, Platycephalidae.
2.5.	Ventrals enlarged	:	Exocoetidae, Stromateidae, Callionymidae, Platycephalidae, Champsodontidae.
2.6.	Ventrals absent	:	Anguilliformes (apodes), Syngnathidae, Tetraodontidae.
2.7.	Elongated fin rays on the dorsal	:	Bothidae, Soleidae, Cynoglossidae, Bregmacerotidae.
2.8.	Elongated spines on the dorsal and ventrals	:	Serranidae, Balistidae, Alutridae, Brancheostegidae, Acanthuridae.

A.3. Alimentary canal and position of anal opening.

The shape and position of the mouth, nature of alimentary canal and location of the anal opening also are important larval characters in fixing up the identity of the groups.

3.1.	Mouth oblique	:	Hemirhamphidae, Exocoetidae, Bregmacerotidae, Apogonidae, Leiognathidae, Carangidae, Labridae, Serranidae.
3.2.	Wide mouth	:	Clupeidae, Dussumieridae, Apodes, Sphyraenidae, Thunnidae, Scomberomoridae, Histiophoridae, Platycephalidae, Serranidae.
3.3.	Small mouth	:	Labridae, Balistidae, Monacanthidae, Alutridae, Ostrociontidae, Tetraodontidae.
3.4.	Tubular mouth	:	Fistularidae, Syngnathidae.
3.5.1.	Alimentary canal long and straight	:	Majority of Gonostomidae, Stomiatoidae, clupeoids and Synodontidae.
3.5.2.	Alimentary canal bulged or sac like	:	Cynoglossidae, Soleidae.
3.5.3.	Alimentary canal short and coiled	:	Majority of Perciformes.

3.6.1. <u>Position of anal opening in the middle of body</u>	:	Apogonidae, Carangidae, Thunnidae, Scombridae, Gobiidae, Scorpaenidae, Pleuronectidae, Bothidae.
3.6.2. <u>Position of anal opening behind the middle of body</u>	:	Apodes, Hemirhamphidae, Exocoetidae, Fistularidae, Mugilidae, Sphyraenidae, Coryphaenidae.
3.6.3. <u>Position of anal opening far backwards</u>	:	Stomiatoidae, Clupeoidei, Synodontidae.
3.6.4. <u>Position of anal opening far forwards</u>	:	Bregmacerotidae, Atherinidae, Blennidae, Trypauchenidae.

B. <u>Meristic characters</u>.

The larval structures that could be counted such as myotomes or vertebrae, and other postlarval structures like fin rays, brancheostegal rays etc. are of much significance in the larval taxonomy.

B.1. <u>Myotomes or vertebrae</u>.

The number of myotomes on vertebrae, present in fish varies with different families. This meristic character is perhaps the most important among others in confirming the identity of the larvae up to the family level. A good majority of the families are with vertebrae around 24. However there are also larvae of fishes with less than 24 and more than 200 vertebrae.

1.1. Vertebrae less than 24 : Callionymidae, Balistidae, Monacanthidae, Diodontidae, Tetradontidae, Molidae.

1.2. Vertebrae between 30 and 40 : Gonostomidae, Engraulidae, Myctophidae, Coryphaenidae, Labridae, Scombridae, Thunnidae, Sillaginidae.

1.3. Vertebrae between 41 and 50 : Clupeidae, Engraulidae, Chiroventridae, Myctophidae, Scomberomoridae, Bregmacerotidae.

1.4. Vertebrae between 51 and 80 : Elopidae, Albulidae, Megalopidae, Chirocentridae, Beloniformes, Syngnathidae.

1.5. Vertebrae between 100 and 200 : Anguilliformes, Trichiuridae, Gempylidae.

C. Pigmentation.

Pattern of larval pigmentation is very characteristic in certain families. Pigmentation may be dense, partial or limited as bloches, patches or spots.

1.1. Densely pigmented : Exocoetidae, Hemirhamphidae, Holocentridae, Mugilidae, Coryphaenidae, Histiophoridae.

1.2. Partially pigmented : Atherinidae, Bregmacerotidae, Mullidae, Apogonidae, Stromateidae, Theraponidae, Platycephalidae.

1.3. Limited to bloches, patches or spots : Engraulidae, Clupeidae, Synodontidae, Carangidae, Apogonidae, Serranidae, Leiognathidae, Thunnidae, Scombridae, Scomboromoridae, Pleuronectidae, Cynoglossidae.

D. Specialised characters.

Certain characters of the larvae are specialised and typical of the groups. The types of marine larvae that could be easily distinguished by this method are the string type (gonostomids, clupeoids, synodontids), ribbon type (Elopidae, Megalopidae, Albulidae, Anguilliformes), tadpole type, spiny or zoea type, triaxial type or baloon type. Development of stalked eyes is characteristic in some groups of larvae, the best known example being Idiacanthus larvae which have their eyes attached to the ends of long stalks. In the case of most Asteronesthidae, several Bathylagidae and even in some Myctophidae also the eye stalks vary in lengths of different degree. Presence of narrow eyes often with tear drops of underlying choroid tissue are common in Myctophidae. The development of elongated rays in the dorsal or pelvic fins as in the case of some flat fishes and bregmacerotids are typical characters which are of definite use in identifying the larvae even up to the generic lebel. In Trachypteridae the larval rays are very well developed. Another example is the spines and ridges that develop on the head and operculum of some larvae such as Carangidae, Scopaenidae, Triglidae etc.

D.1. <u>Head</u>: Several groups exhibit bony crest and prominent spines on the head or strong or feeble spines on the operculum during the larval stages. Among Perciformes, majority possess spinous structures.

1.1.	<u>Bony crest on the nape</u>	: Helocentridae, Carangidae, Leiognathidae, Coryphaenidae, Scorpaenidae, Platycephalidae.
1.2.	<u>Spines on operculum prominent</u>	: Carangidae, Serranidae, Coryphaenidae, Thunnidae, Scomberomoridae, Histiophoridae, Scorpaenidae.
1.3.	<u>No spines on operculum</u>	: Scombridae, Labridae, Gobiidae, Trachypteridae.
1.4.	<u>Presence of barbel on lower jaw</u>	: Exocoetidae.
1.5.	<u>Elongated tentacle on the operculum</u>	: Champsodontidae.
1.6.	<u>Bony ridge above the eyes</u>	: Carangidae, Stromateidae, Holocentridae, Histiophoridae, Scorpaenidae.
1.7.	<u>Protruded snout</u>	: Holocentridae, Histiophoridae, Pegasidae, Exocoetidae, Hemirhamphidae.

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3. GENERAL FEATURES OF THE ARABIAN SEA AND BAY OF BENGAL.

3.1. Importance of oceanographic parameters.

The role and importance of various biological and oceanographical parameters in the distribution of plankton biomass and their relation to fisheries have been studied by several workers. Approaches to marine ecology involves complexity of animal relationships and their correlation with their organic and physical environment. The parameters of physical environment that can be examined are distribution of water temperature, salinity, dissolved oxygen, density, specific chemical components and their daily, tidal and seasonal variations of weather, sea conditions, water movements, currents, depth and plankton biomass. The dynamics of upwelling, the enrichment of surface layers, the initiation of primary production followed by zooplankton production, the timing of spawning and development of fisheries all constitute a biological unit and the various factors mentioned are interlinked to form a common ecosystem (Cushing, 1971).

Varadachari and Sharma (1964, 1967) have presented results of the investigations on the divergence and convergence and circulation pattern of surface water in the northern Indian Ocean for different months of the year. Since the divergence and convergence occurring throughout the year in open ocean are seasonal and spatial in the nearshore regions, they affect the production considerably in such areas. Along the west coast of India all the interesting observations in regard to the rich biological and fishery productivity have been attributed to the seasonal upwelling along this coast. The importance of upwelling is that they play a prominent role in the fertilisation of the surface waters of the region which include high organic production. The meso-pelagic plankton biomass are also brought to the surface layers due to upwelling. The intensity of upwelling depends on the divergence value. The divergence occurring along the west coast of India and Somali coast during January to September is replaced by convergence during the rest of the year. The convergence causes dynamically a concentration of zooplankton (Hela and Laevastu, 1962) and during divergence a high production of organic matter takes place. Prasad (1968 a,b, 1969) found the distribution of zooplankton broadly agreeing to the vergence pattern of these areas brought about by the seasonal shift of monsoons. A comparison of the plankton density charts with the circulation maps (Varadachari and Sharma, 1967) also indicates close relationship between zooplankton distribution and surface currents which are directly connected with the oceanic circulation. These surface currents are important as they induce upwelling along the Somali and Arabian coasts up to the Gulf of Oman. The winds blowing parallel to the coasts too transport surface waters away from the coast giving rise to upwelling which culminate in the high production of zooplankton standing crop. Thus the high plankton concentration can be seen following the route of surface currents. In this way currents help in the transport of plankton. The low plankton biomass in the central region of Arabian Sea during Southwest monsoon can be accounted for the lack of vertical movements in the areas. Monsoon influences zooplankton distribution in two ways. There is a shift of population either to the east or to the west depending on the prevailing monsoon, and by its reversal, the Somali current transports zooplankton mechanically across the equator both in southern and northern directions.

The most important factor which probably controls the distribution of species over large areas, is temperature, while in sub areas, where temperature variation is small, salinity variation restricts distribution. Zoutendyk (1970) studying zooplankton density in the southwestern Indian Ocean limited its densities with the physical environment using sea temperature as a criterion. The dissolved oxygen content and the density of the water are also equally important factors. Hence the study on the zoogeography of zooplankton and the zooplankton biomass reflects the hydrographical regimes in the different parts of the Indian Ocean environments.

3.2. Topography.

The topographical features of the Indian Ocean are unique as it is land locked in its northern boundary at 25°N. Hence it lacks subtropical, boreal and polar zones in the northern hemisphere. Compared with the broader southern part of the Indian Ocean which is less influenced by the land masses, the northern part which is considerably narrower is affected climatically by the great land masses of Asia and Africa producing monsoonal conditions which are unparalleled in the world oceans. Its southern end is open and extends right up to the Antarctica like the other major oceans. The Red Sea forms an extension of the Arabian Sea, and Gulf of Aden is a deep basin having an extremely shallow sill at about 125 m depth at the narrow southern entrance at the Strait of Bab-el-Mandeb. The Persion Gulf is a shallow basin having an average depth of 35 m, the maximum depth being 150 m. It is connected with the Arabian Sea through the 50 m deep sill at the Hormuz Strait.

The northern part of the Indian Ocean is divided into the Arabian Sea and Bay of Bengal. The Laccadive-Maldive Islands in the Arabian Sea and the Andaman-Nicobar Islands in the Bay of Bengal subdivide these regions again. The Carlsburg-Murray Ridge of the Arabian Sea is a feature of topographical importance due to its role in the upwelling process. In the northern Indian Ocean eventhough the continental shelf area is greater in the Arabian Sea and shallower in the Bay of Bengal, the eastern sector of Arabian Sea and eastern sector of Bay of Bengal have relatively wide continental shelf zones. The prominent shelf off the coasts of Burma, Thailand and Malaysia support rich mangrove swamps.

Along the east coast of India the shelf is narrow. The East African coast has narrow shelf area as the 200 m contour line at many places is within 4 km from the shore. This narrow shelf in the coastal region of Mosambique, Tanzania and Kenya are fringed with coral reefs and mangroves. In the Red Sea the shelf is wide at the central and southern parts.

3.3. Current systems and patterns of circulation.

Of the three distinct circulation patterns reported by Wyrtki (1971) in the Indian Ocean, the Antarctic water with circumpolar current and the sub-tropical anticyclonic gyre are seen in the southern Indian Ocean similar to those in the Atlantic and Pacific. The northern Indian Ocean is characterised by the seasonally changing monsoon gyre. This circulation reflects the wind systems with stronger and steadier currents during the Southwest monsoon compared to those in the Northeast monsoon. This has no close parallel in the other oceans. This gyre is different from the southern subtropical gyre, because it is very characteristic in its chemical features. All the areas north of 10°S fall under this gyral system. The cyclonic and anticyclonic circulation of the Arabian Sea and Bay of Bengal, the North Equatorial Current, the Counter Current of the South Equatorial Current and Somali Current are the major surface components of the monsoon gyre. The circulation patterns of the surface waters of the northern Indian Ocean of different months of the year has been described by Varadachari and Sharma (1967) and Wyrtki (1971).

The onset of the Southwest monsoon in summer develops a seasonal low pressure area over central Asia, causing the wind system to blow persistently from the southwest. This generates the Somali Current (Lighthill, 1969) which flows northwards along the east coast of Africa from south to north as a swift narrow current with speed as high as 7 knots as reported by Swallow (1965). The Somali Current results in a general clockwise circulation in the Arabian Sea which in term develops into a relatively strong southerly current at the surface level along the west coast of India. The southerly currents which develop in May continue until November when the current reverse until April. It reaches its greatest strength in July. At the height of development, the Somali Current reaches as far north as lat. 12°N however most of the water leaves the coast and flows in an easterly direction as monsoon currents south of lat. 12°N. In the Gulf of Aden the flow of surface current is from Gulf to the Arabian Sea from June to August. Along South Arabia the currents are weak and more in the east and northeasterly directions. It flows northerly along the Arabian coast and southerly along the Indian coasts. The southerly current brings comparatively high saline Arabian Sea water southwards and northerly current transports the less saline equatorial water northwards.

In the Bay of Bengal the flow is generally northeast, upon reaching the continental coast most of this water turns southwards and flows along the continental shelf. South of Sumatra, the current flows southeasterly along the coast of Sumatra and merges with southeast Asian water flowing into the Indian Ocean through the Timor Sea. These water forms the basis of South Equatorial Current in the Indian Ocean.

During Northeast monsoon prevailing in winter (November-February) the wind generated from a high pressure source forming over the Tibetan plateau and the neighbourhood move towards the low pressure belt in the Equatorial Indian Ocean from northeast to southwest.

This brings about considerable changes in the circulation pattern in the northern seas. The general circulation in the open ocean is westerly with a counter clockwise circulation along the coasts. The Somali Current reverses direction and flows southerly from December to February. Surface current flow in the Gulf of Aden is from the Arabian Sea into the Gulf. For a brief period (November-December) a weak current flows northwards along the coast of India. In the Bay of Bengal a cyclonic circulation occupies the entire Bay in February, however this pattern does not prevail during the entire Northeast monsoon period.

3.4. Watermasses.

The northern Indian Ocean is characterised by the presence of several layers of watermasses. The surface water of the Arabian Sea and Bay of Bengal generally occupies a layer from the surface to a depth of about 100 to 150 m. Of the water below the surface layer, the subsurface watermasses are the most limited in spatial extent and remain within well defined areas of the ocean. The Laccadive Island Ridge affords a sharp division between equatorial water on the west and the Indo-Australian subsurface water to the east. The

Indo-Australian water is apparently carried west by the South Equatorial Current until it meets the barrier of the ridge and is then reflected southwards. The equatorial water also flows along the ridge towards south for some distance. Farther to the north the equatorial water finds it way across the ridge and proceeds into the Bay of Bengal and parts away along the coast of Sumatra. While the subsurface water of Bay of Bengal extends up to 1500 m, that of Arabian Sea extends up to 400 m only after which Arabian Sea Intermediate water is occurs up to 1500 m. Below this level deep water is present through out. The origin of deep sea cold water found in the northern Indian Ocean has been explained by Gallagher (1966) and Wooster et al. (1967). The movement of the cold Antarctic bottom water (deep water) from the polar region into the Arabian Sea and Bay of Bengal has a bearing on the organic productivity of the region, because of its low salinity, low temperature and high nutrients. This Antarctic bottom water divides into three branches, one going to the east coast of Madagascar, the second touching the Carlsberg Ridge and getting reflected to the surface of the Arabian Sea and the third one again dividing into two, one branch striking the coast of

Sri Lanka which enters the Laccadive Sea, while the other travels northwards between Carpenters Ridge and Andaman-Nicobar Ridge.

3.5. Hydrological properties.

The Arabian Sea differs both seasonally and regionally from Bay of Bengal in several biological and oceanographic parameters associated with their water movements. The fluctuations in average surface temperature are wide in the Arabian Sea between 23°C and 30°C (Gallagher, 1966) and the usual range along the Indian coast is from 23°C to 29°C. Along the Indian coast south of 15°N and coasts of Somalia and Arabia relatively cool surface water is present during June to September as a rêsult of upwelling. In the Bay of Bengal the range of average surface temperature is between 27°C and 29°C except in narrow areas near the coast. Robinson (1966) observed a bimodal temperature cycle at the surface in the Arabian Sea and Bay of Bengal. Regarding vertical distribution pattern there are two important aspects from the point of view of their application to the problem of variations in biological productivity. They are (i) the variation in the thickness of the isothermal or near-isothermal layer and

(ii) the level of thermocline or the discontinuity layer. Because of monsoonal influence, the thermocline depth fluctuates widely in the coastal areas of Arabian Sea which is subjected to upwelling. Off the southwest coast of India the thermocline is usually found at 100 to 125 m depth during winter and during the stable period between the winter and summer months the thermocline level is usually 75 to 90 m. With the progress of the Southwest monsoon in summer thermocline level migrates upwards to 20 to 30 m depth and even surfacing in late summer. In the Bay of Bengal the thermocline is usually below 50 to 55 m and occasionally goes down to 100 to 125 m depth, and except for a small area off the east central coast, the shelf waters are for most of the time isothermal or near isothermal, whereas off the west coast of India the thermocline fluctuates a great deal showing a seasonal trend. Because of the arid climate that prevails in most of the area around northern Arabian Sea it is subjected to evaporation. Compared to the high evaporation rate the amount of precipitation is considerably less. This high rate of evaporation and influx of high saline water from the Red Sea and Persian Gulf cause high salinity in the Arabian Sea, and the high precipitation in combination with river discharge lead to low salinity in the Bay of Bengal. The average salinity values of the Arabian Sea ranges from 34 to 37‰ while that of Bay of Bengal from 30 to 33‰. The salinity of the Arabian Sea decreases from north to south, while in Bay of Bengal it increases from north to south (Gallagher, 1966). The high salinity water of the Arabian Sea spreads southwest into the area off Somalia during Northeast monsoon and is further drawn into the Equatorial Current as a distinct tongue up to 90°E. During Southwest monsoon the high salinity water of the Arabian Sea spreads southwards and is driven along with the monsoon current and is traceable up to south of Sri Lanka, although it does not penetrate into the Bay of Bengal (Wyrtki, 1971). The Arabian Sea also receives high saline water fromthe Red Sea and Persian Gulf forming the North Indian High Salinity Intermediate Water. This subsurface watermass occupies from about 150 to 900 m depth in the Arabian Sea and spreads southwards in different directions in the monsoon gyre including the Bay of Bengal (Rochford, 1964; Wyrtki, 1971).

The dissolved oxygen content in the well mixed surface layers of the northern Arabian Sea down to about 100 m varies between 4.5 ml/l and 5 ml/l. In the lower layers oxygen decreases sharply and the subsurface oxygen minimum layer is formed. The values are less than 0.5 ml/l below a depth of about 150 m and the low values persist up to a depth of about 1500 m (Sankaranarayanan, 1978). At 2000 m depth the variation in dissolved oxygen is between 1.25 ml/l and 2.5 ml/l. But the Bay of Bengal deep water occurring in depths below 1500 m had oxygen content varying from 3.18 to 4.17 ml/l.

The nutrient concentration in the Arabian Sea is of a higher magnitude as compared with that of Bay of Bengal. The inorganic phosphate values in the Arabian Sea vary roughly between 0.2 and 1 ug-at/l with a general increase in the phosphate concentration towards north (from 0.5 ug-at/l to 1.5 ug-at/l). The phosphate concentration increases gradually till a maximum is reached between 1000 m and 1500 m, thereafter decreasing uniformly. Studies on distribution of phosphates between 16°N and 19°N latitudes in the Bay of Bengal showed a phosphate maximum between 600 and 800 m (Sankaranarayanan, and Reddy, 1968).

3.6. Upwelling.

A general review of the upwelling areas of the world and their biological productivity has been reported by Cushing (1969). Compared to the classical wind induced upwelling observed in the upwelling areas of the world, the Arabian Sea upwelling is known to be due to the prevalent coastal currents in those areas. According to Banse (1968) the prevailing current system (and not the wind) is the main condition to generate and maintain the upwelling. Darbyshire (1967) concluded that there was no wind generated upwelling during the Southwest monsoon along the west coast of India and she also indicated that the dense bottom water approached the surface because of the immediate inter-play of current with the tilting of the sea surface and the thermocline. In the Arabian Sea one of the most pronounced zones of upwelling is in the waters off South Arabia from Kuria Maria Bay to Rasal Hadd during Southwest monsoon period. This large scale upwelling makes the Saudi Arabia coast the richest area of zooplankton production in the northern Indian Ocean. The second pronounced area of upwelling is off northern Somalia within 35 km off the coast (Swallow, 1965). Ramamirtham and Jayaraman (1960) stated that off Cochin upwelling starts by mid-August, establishes by late September and ends by mid-October. Banse (1968), Panikkar and Jayaraman (1966) have shown that off the southwest coast of India between 7°N and 16°N strong seasonal upwelling starts with the onset of the Southw monsoon and attains maximum intensity during July-August. Sharma (1966) states that the area between 7°N and 14°N latitudes and from longitudes 73°30'E and 77°30'E shows the upward tilting of thermocline from February to July and sinking after August near the coast, upwelling starts earlier in the south and progressively shifts towards the north. Upwelling has also been noticed in the northwest coast of India off Bombay during October (Carruthers, et al., 1959).

In the Bay of Bengal LaFond (1954, 1957, 1958) reported areas of upwelling along the east coast of India from Madras to Hoogly river. Anand et al. (1968) have confirmed upwelling off Madras and Visakhapatnam. Upwelling is also noticed off the Burma coast and off Andamans (LaFond and LaFond, 1958) during Northeast monsoon. This upwelling has been attributed to the prevailing monsoon winds which cause offshore displacement of surface water from the Burmese coast. The most important upwelling in the eastern Indian Ocean perhaps occurs south of Java. Wyrtki (1962) estimated the extent of the area of upwelling as 400 km wide and 1200 km long.

During upwelling the deep waters with high concentration of inorganic phosphates and nitrates are brought to the surface enriching the surface layers to be used by phytoplankton. This replenishment of nitrate salts controls the magnitude of the annual organic production leading to fisheries.

In addition to the temperature and salinity the other contributing factors to the upwelling phenomenon are dissolved oxygen and nutrients salts particularly phosphates. During the upwelling periods of early August to October the dissolved oxygen occurs in concentrations as low as 0.5 ml/l below 20 m along the west coast between 7°N and 16°N latitudes. The phosphate occurs in high concentrations in the entire water column over the shelf (1.94 to 2.74 mg at/m^3).

In the northwestern Bay of Bengal, coastal upwelling is found as one of the factors governing the distribution of nutrients during January to April.

3.7. Organic production and chlorophyll concentration.

The investigations carried out by Kabanova (1961, 1968), Prasad and Nair (1963) and Ryther *et al*. (1966) reveal a comparative picture of productivity of the Arabian Sea and Bay of Bengal. Usually very high production rate was found over the continental shelf in the tropical regions. The production rate of the entire water column varied from 0.5 $gC/m^2/day$ to 5.0 $gC/m^2/day$, while it was 0.2 $gC/m^2/day$ for the surface waters. The level of organic production in the Arabian Sea which increases to the north and west is estimated to be atleast 3 times that of Bay of Bengal. The average production rate for the Bay of Bengal being 0.19 $gC/m^2/day$ it is 1 $gC/m^2/day$ for the Arabian Sea.

Larid <u>et al</u>. (1964) made chlorophyll measurements and found values greater than 150 mg/m^2 along Somali Coast, whereas the chlorophyll concentrations in the Bay of Bengal was less than 10 mg/m^2. This study supports the higher productivity in the Arabian Sea.

3.8. Zooplankton biomass.

Zooplankton biomass measurements can be used as indices to the amount of living matter present in the form of one or more of the various kinds of organisms comprising of a plankton population. This is an important measure of abundance throughout the history of descriptive studies of biological populations in the sea. The importance of the biomass estimation is that, these values could be converted to the third trophic level and used for the prediction of potential fishery resources of an area as done by Subrahmanyam (1959) and Cushing (1971). The organic content is perhaps the most fundamental property which a biomass measure seeks to measure to gain insight into their nutritional state or their potential value as food. The classical measures of biomass involving several basic properties are grouped under three general headings, the gravimetric, volumetric and chemical. Of the two, direct volumetric techniques, the displacement method in which the space occupied by the plankton is measured in terms of the equivalent volume of liquid that they displace, is used and represented as biomass in the present study. The zooplankton material already fixed and preserved in formaldehyde is used for the purpose. The sample was filtered using a silk gauze of 330 micron mesh size, to remove the interstatial water. After this it was added to a measured volume of dilute formaldehyde in a graduated cylinder and the amount of consequent increase in the formaldehyde level, taken as the measure of its volume. The size of the graduated cylinder used will depend upon the size of the plankton sample.

Prasad (1968 a,b, 1969) made a comprehensive study of the zooplankton biomass in the Arabian Sea and Bay of Bengal and obtained a similar pattern of distribution observed by Bogorov and Rass (1961) and Panikkar and Rao (1973). During the Southwest monsoon period (April to October) in the Arabian Sea the distribution pattern of the plankton biomass was the same during the day and night. Higher plankton biomass ranging from 45 to 60 ml per standard haul occurred towards the western half of the Arabian Sea and about 30 ml per haul along the southwest coast of India. Rest of the areas such as the central zone and Gulf of Kutch to Gulf of Cambay and off Gujarat seemed to have a low plankton biomass especially during day time. In general, the plankton volume decreased from the coastal regions to the open sea. Compared to this the plankton biomass during this period in the Bay of Bengal was considerably less and uniformly distributed having only 10 to 20 ml on the average. During the Northeast monsoon period (October to April) the pattern of distribution of plankton in the Arabian Sea was somewhat diffuse, the day time having 10 to 15 ml of plankton per haul, while that of night having 15 to 30 ml per haul. In the Bay of Bengal the average volume varied from 10 to 20 ml per haul, which was not appreciably different from that of the Southwest monsoon period. However the progressively increasing trend in biomass noted towards the northern region in the day time is reversed in the night time.

To summarise, the distribution of zooplankton biomass in the Arabian Sea showed marked variation during the Southwest and Northeast monsoons, whereas in the Bay of Bengal there was no significant variation. Ryther and Menzel (1965) noticed zooplankton blooms often delineated by extremely clear and unproductive waters in the Arabian Sea. This extremely patchy distribution is characteristic of Arabian Sea.

Chidambaram and Menon (1945), Subrahmanyam (1959), Bogorov and Rass (1961), Prasad and Nair (1963), Sudarsan (1964), Longhurst (1966), Uda (1966), Panikkar and Jayaraman (1966) and Cushing (1971) studied the relationship between plankton production and fisheries. They concluded that invariably high concentration of fish particularly the pelagic species occur in areas of high plankton production, which in turn will be areas of upwelling or local enrichments in the tropical oceans. There was also a correlation existing between the upwelling and zooplankton biomass. Always the higher plankton biomass was found to be coinciding with peak periods of upwelling. At the same time in certain areas in spite of the high velocity of upwelling the plankton biomass did not show proportional increase in volume.

This may be attributed to the rocky bottom of the waters of that area. In contrast to the above, the northern half of the Arabian Sea is characterised by mass mortalities of fish resulting from the very high plankton production. This is an indication of the existence of large populations of fish in the Arabian Sea.

Phytoplankton is more directly linked to the physical and chemical environment than zooplankton. Changes in the chemical and physical environments are reflected in the phytoplankton population. Since zooplankton is dependent upon phytoplankton for food, its derivaties are to a large extent governed by distribution of phytoplankton. Similarly the distribution of zooplankton controls the fish larvae population too. Blackburn (1965, 1969) have concluded that there is a general relationship between zooplankton abundance and tuna catch.

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4. DISTRIBUTION OF FISH LARVAE

4.1. List of families*

The larvae of the following families/groups are represented in the collections. As regards Anguilliformes, which constitutes the leptocephali of the eels and eel-like fishes, identification was done only at the family level.

ORDER CLUPEIFORMES

SUBORDER CLUPEOIDEI

FAMILY ELOPIDAE

FAMILY CLUPEIDAE

FAMILY ENGRAULIDAE

FAMILY BATHYLAGIDAE

OTHER CLUPEOIDS

SUBORDER STOMIATOIDEI

FAMILY GONOSTOMIDAE

VINCIGUERRIA SPP.

CYCLOTHONE SPP.

FAMILY STOMIATIDAE

FAMILY IDIACANTHIDAE

FAMILY CHAULIDONTIDAE

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* Classification followed is that of Berg (1940, 1958)

ORDER SCOPELIFORMES

FAMILY SYNODONTIDAE

FAMILY PARALEPIDIDAE

FAMILY SCOPELARCHIDAE

FAMILY MYCTOPHIDAE

ORDER ANGUILLIFORMES

ORDER BELONIFORMES

SUBORDER EXOCOETIDAE

HEMIRHAMPHIDAE

ORDER GADIFORMES

SUBORDER GADOIDEI

FAMILY BREGMACEROTIDAE

ORDER SYNGNATHIFORMES

FAMILY SYNGNATHIDAE

FAMILY FISTULARIDAE

ORDER BERYCIFORMES

FAMILY HOLOCENTRIDAE

ORDER MUGILIFORMES

FAMILY MUGILIDAE

FAMILY SPHYRAENIDAE

ORDER PERCIFORMES

SUBORDER PERCOIDEI

FAMILY SERRANIDAE

FAMILY APOGONIDAE

FAMILY CARANGIDAE

FAMILY CORYPHAENIDAE

FAMILY SCIAENIDAE

FAMILY LABRIDAE

FAMILY CHAMPSODONTIDAE

SUBORDER TRICHIUROIDEI

FAMILY TRICHIURIDAE

FAMILY GEMPYLIDAE

SUBORDER SCOMBROIDEI

FAMILY SCOMBRIDAE

FAMILY THUNNIDAE

FAMILY SCOMBEROMORIDAE

FAMILY HISTIOPHORIDAE

SUBORDER CALLIONYMOIDEI

FAMILY CALLIONYMIDAE

SUBORDER ACANTHUROIDEI

FAMILY ACANTHURIDAE

SUBORDER STROMATEOIDEI

FAMILY STROMATEIDAE

SUBORDER GOBIOIDEI

FAMILY GOBIIDAE

SUBORDER COTTOIDEI

FAMILY SCORPAENIDAE

ORDER DACTYLOPTERIFORMES

FAMILY DACTYLOPTERIDAE

ORDER TETRADONTIFORMES

SUBORDER TETRADONTOIDEI

FAMILY TETRAODONTIDAE

FAMILY DIODONTIDAE

SUBORDER BALISTOIDEI

FAMILY BALISTIDAE

SUBORDER MOLOIDEI

FAMILY MOLIDAE

ORDER LOPHIIFORMES

FAMILY ANTENNARIIDAE

4.2. Larval characters and spatial distribution.

FAMILY ELOPIDAE
(Pl. I.9)

Larva has elongated ribbon-shaped semi-transparent body with numerous myomeres like the leptocephalus of eels. Pre anal part is about 70% of the total length. Swimbladder is prominent and pigmented. Head is very small and pointed anteriorly. Mouth is terminal, gape reaching middle of eye. Eyes are pigmented. Alimentary canal is long and straight. There is only a single

PLATE I.

1.	Bathylagidae	7.3	mm
2.	*Vinciguerria*	10.9	"
3.	" "	20.3	"
4.	*Cyclothone*	19.2	"
5.	" "	6.1	"
6.	Chauliodontidae	28.6	"
7.	Idiacanthidae	54.7	"
8.	Stomiatidae	10.1	"
9.	Elopidae	19.2	"
10.	Clupeidae	11.8	"
11.	Engraulidae	10.8	"

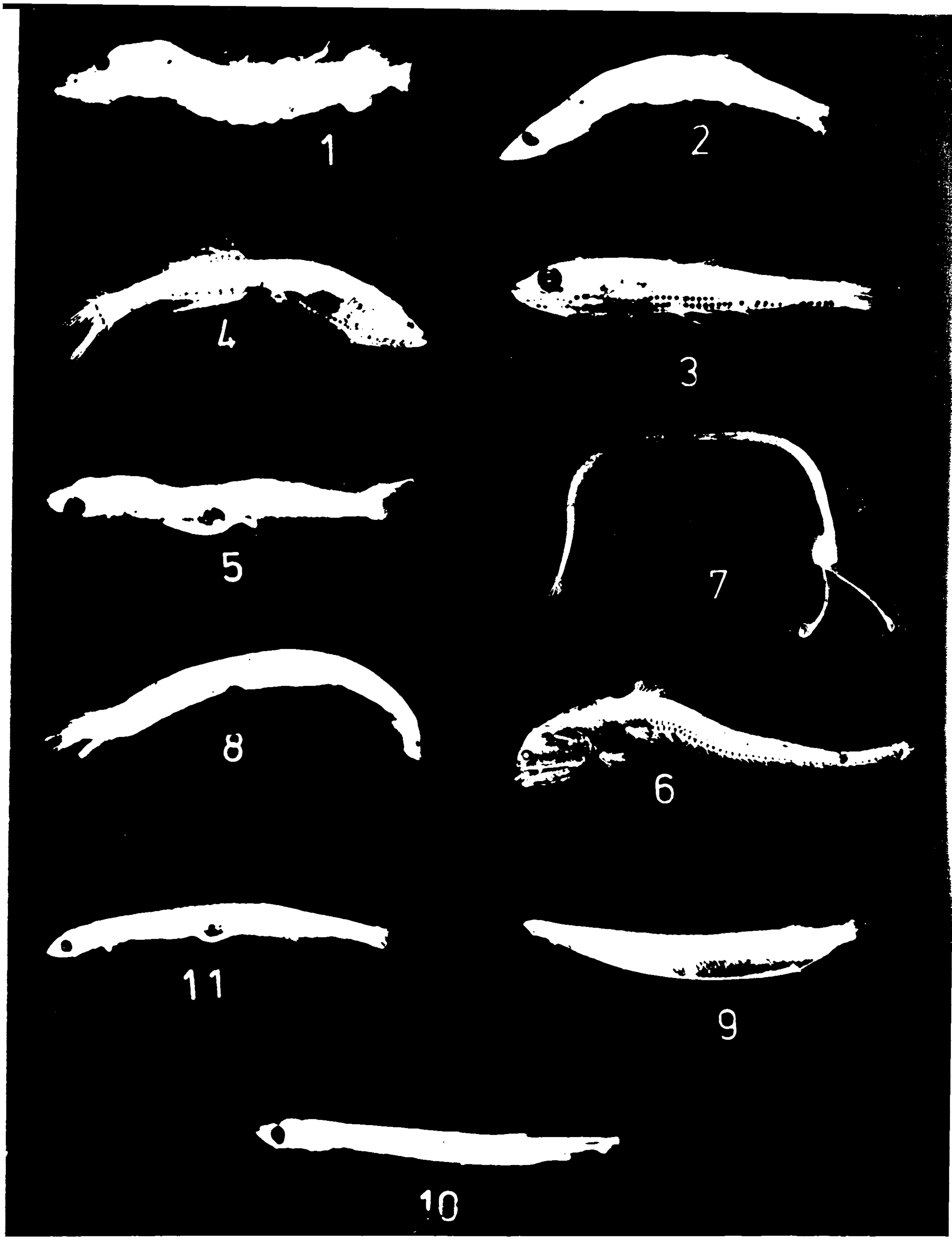


PLATE I

dorsal with soft rays situated far back of the body. Dorsal and anal are opposite in position. Pelvic fin is present. Caudal is broadly forked except in very small larvae. Myomeres are about 70 in number, but always less than 100.

Among the earlier workers on the elopid larvae, Delsman's contribution (1926 b) was on the postlarvae of *Elops hawaiensis* from the Java Sea. Gopinath (1946) made studies on the larvae and postlarval stages of *Elops indicus* collected from Trivandrum coast. Alikunhi and Rao (1951) have given an account on the stages of metamorphosis of *Elops saurus*. Nair (1952 a), and Kuthalingam (1958) studied the larvae of *Elops saurus*. Uchida *et al*. (1958) described the elopid larvae while studying the eggs, larvae and juveniles of Japanese fishes. Gehringer (1959) contributed to the development and metamorphosis of *Elops saurus*. Basheeruddin and Nayar (1962) made preliminary study of the young ones of *Elops indicus* of the coastal waters of Madras. Hildebrand (1963) dealt with the family Elopidae of the western North Atlantic. Whitehead *et al*. (1967) has reviewed the elopid fishes of the Red Sea and the adjacent region.

Out of the 935 hauls made only a nearshore station (10°14'N - 75°54'E) in the Arabian Sea had one larva of the family Elepidae. This was collected during March from a night haul. The surface salinity and temperature of the station were 34.6‰ and 29.6° respectively.

FAMILY CLUPEIDAE

(Pl. I.10, Fig. 1)

Elongated rod shaped larva with long alimentary canal similar to that of engraulids. Gut length is greater than 80% notochord length. Crossed arrangements of muscle fibres are seen on the body. The preanal part is about 70% of total length. Body length is lesser than in engraulids. The head and vertical part of the body are pigmented. Alimentary canal is tubular and straight. Dorsal is single with soft rays only. Dorsal and anal are opposite in position. Origin of dorsal is behind end of dorsal. In the prolarvae dorsal and anal fin folds are continuous. Myomeres number between 40 and 50.

Earlier works on eggs and larvae of clupeids were of Delsman (1926 a,b, 1930, 1933) from the Java

Sea. Chacko (1950) described the features of eggs and larvae of some clupeids from the waters around Krusadi. John (1951) studied the eggs and larvae of some of the sardines of Madras coast. Bapat (1955) made studies on the eggs and larvae of *Dussumieria* and *Sardinella* spp. of the Gulf of Mannar and Palk Bay. Uchida *et al.* (1958) contributed to the study of eggs, larvae and juveniles of clupeids from Japanese waters. Kuthalingam (1960) studied the eggs and newly hatched larvae of *Sardinella longiceps* from the plankton of Madras coast. Hildebrand (1963) dealt with the family Clupeidae from the western north Atlantic. Bensam (1967, 1971 a,b, 1973) made studies on the embryonic and early development of Clupeiform fishes of the Indian waters. The works carried out in the Indian Ocean are restricted to the coastal waters. The present attempt to trace the larvae and distribution of clupeids in the offshore waters showed that they are mainly confined to nearshore waters. As sampling in the coastal waters was very much limited, the number of larvae caught was also very few in number.

From the Arabian Sea this group was recorded only from 5 stations (Tables 4 & 6), the total number of larvae collected being 10. Along the western boundary of the

Fig. 1. Distribution of larvae of Clupeidae, Engraulidae and other clupeoids in the Arabian Sea and Bay of Bengal.

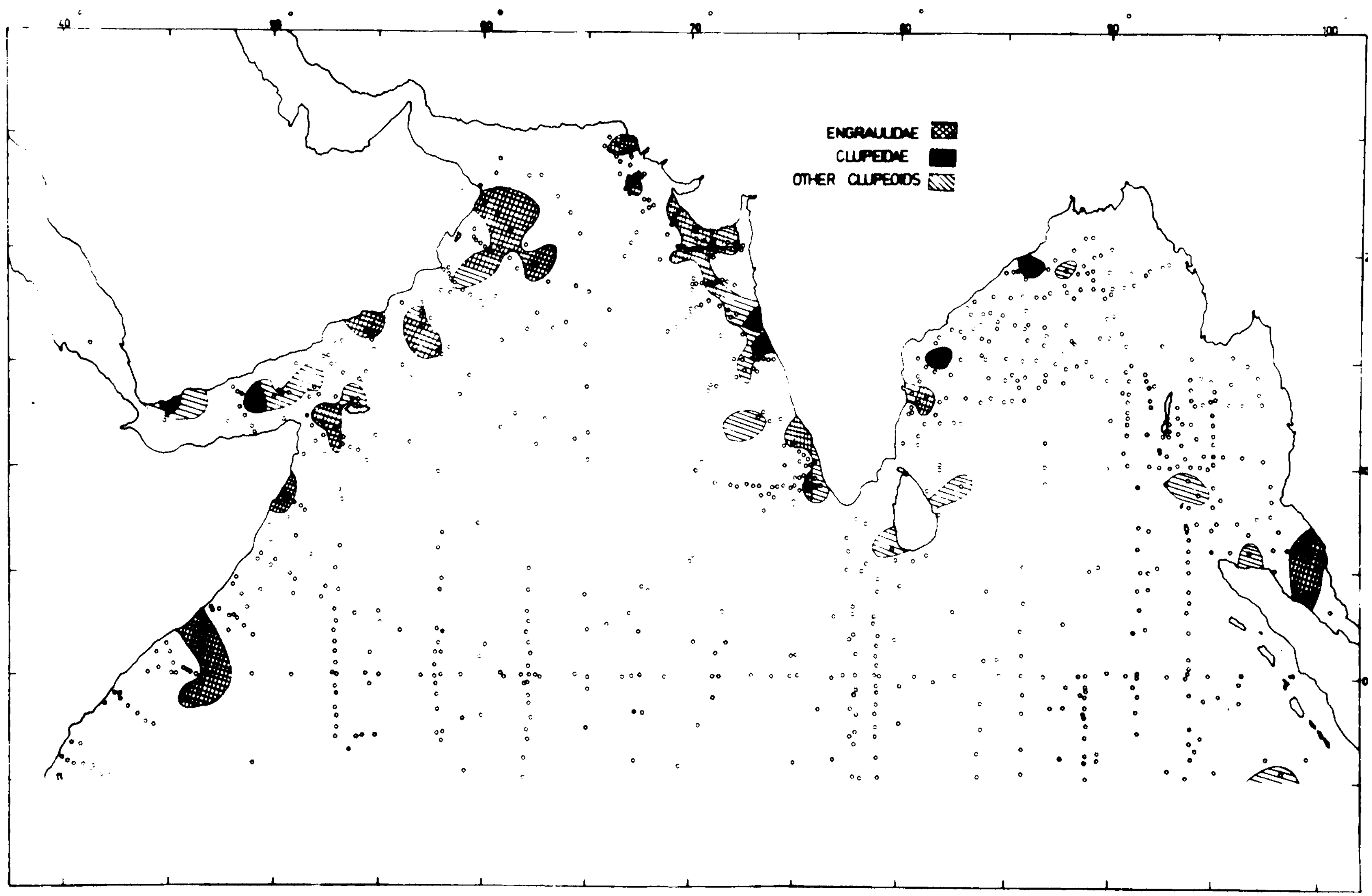


Fig. 1

Arabian Sea the records were from the southern coast of Saudi Arabia. At the eastern side their places of occurrence were at the northern Karnataka waters. In the Arabian Sea they were recorded in the months, February, March and December (Table 7, Fig. 20). The highest number of 4 larvae per haul was collected from 16°45'N - 73°00'E. The surface temperature of the stations from where larvae were collected ranged between 25° and 27°C, and salinity 35 to 36‰ (Table 16).

From the Bay of Bengal a total of 11 larvae were collected from two stations (Tables 5, 6; Fig. 1) 14°16'N - 80°58'E and 18°00'N - 86°00'E. Out of these, 10 were recorded from the station off the coast of Andhra Pradesh and a single one from off Orissa. The larvae were collected during April, June and July (Table 8, Fig. 20). The surface temperature of these two stations varied between 28°C and 29°C and salinity 33‰ and 34‰ (Table 16).

FAMILY ENGRAULIDAE

(Pl. I.11, Fig. 1)

Larvae very closely resemble that of clupeids. Body elongated and rod shaped. Crossed striations of muscle fibre are present as in clupeid larvae. Depth of body is greater than that of clupeids, and less laterally compressed. Preanal part is about 70% of the total length. Mouth is oblique. Pigmentation is present over the head and ventral part of the body. Alimentary canal which is tubular and straight, is attached to the body by connective tissues. Gut length is less than 70% of notochord. Posterior half of alimentary canal is considerably enlarged with ring like thickening or wringles. Swimbladder is clearly visible. Dorsal is single with soft rays only. Dorsal and anal are opposite in position, origin of anal being from the middle of dorsal. The number of myomeres are between 45 and 50.

Fage (1920) made studies on the Engraulidae of the Mediterranean and adjacent seas. Delsman (1929, 1931, 1932) studied the eggs and larvae of whitebaits. John (1951) traced the developmental stages of whitebaits and species of Thrissocles. The larvae of these species were also studied by Nair (1952 a,b) and Bapat (1955). Ahlstrom (1965) contributed to the study of eggs and larvae of Engraulidae from the Californian current region. Whitehead (1967) studied the Indian Ocean anchovies collected by Anton Bruun and Te Vega during 1963-1964. Srikumari (1967) studied the eggs and larvae of white-bait S. zollengeri from the continental shelf of the southwest coast of India.

Engraulids contributed to 5.0% of the total larvae collected from the Arabian Sea whereas in the Bay of Bengal region it was only 0.3% (Tables 4,5,6). The frequency of occurrence also was much higher in the Arabian Sea (8.3%) than in the Bay of Bengal (1.6%). This group was recorded in all months of the year except in September from Arabian Sea, whereas in Bay of Bengal the records were only during the months between March and September (Tables 9, 10; Fig. 1). The highest number of larvae was recorded from Arabian Sea during November and in the Bay of Bengal in the month of August.

In the Arabian Sea engraulid larvae were collected (Table 4; Fig. 1) from the offshore waters of central and northern Somali coast and the Arabian coast along the western side of the Arabian Sea. On the eastern side the areas of occurrence were coastal and offshore waters, of Pakistan, Gujarat coast, off Maharashtra, Karnataka and Kerala. The highest number of 562 larvae per haul was recorded from one station on the northern Arabian coast (22°22'N - 60°05'E). From another station off Karnataka (11°00'N - 75°00'E), 456 larvae per haul were collected. Off the coast of Gujarat the larvae were recorded from several stations in varying numbers. They were collected during almost all months of the year (Table 7; Fig. 20). The surface temperature of these stations ranged from 19°C to 30°C (Table 16). But 95% of these were from waters of surface temperature, 29°C. Salinity varied from 34 to 36‰.

The larvae of engraulids collected from Bay of bengal were from the offshore waters (4 stations, off the coast of Andhra Pradesh and 2 from Straits of Malacca (Table 5, Fig. 1). The highest number of 37 larvae per haul was recorded from one station in the Strait of Malacca (06°05'N - 98°59'E). A total of 65 larvae were collected from six stations during the period from March to September (Table 8, Fig. 20). The surface temperature ranged from 27° to 29°C (Table 16). But 68% of the larvae were from waters of surface temperature, 29°C. The surface salinity at these stations was found to be between 32 and 33‰.

FAMILY BATHYLAGIDAE

(Pl. I.1)

Slender short bodied larvae with short head and small eyes. Some have eyes on short stalks. Snout is beak-like. Preanal part is about 70% of the body.

Depth of body is low. Caudal peduncle is long. Greater development of connective tissue and larval pigmentation are very characteristic of the group. Alimentary canal is straight and enlarged, longer than the body length and attached to body by connective tissue. Dorsal is single with soft rays, situated far back on the body. Adipose fin is present. Dorsal and anal are opposite. Myotomes are about 55 in number.

The available reports on this group are that of Ahlstrom (1965, 1971) who studied the bathylagids of the California current region and eastern tropical Pacific based on the eggs and larvae surveys of that region. Cohen's (1964) work on the argentinoid fishes are confined to western North Atlantic.

In the Arabian Sea this group was represented in 2.61% of the stations and in the Bay of Bengal 2.5% of the stations (Tables 4,5,6). The total contributions were 0.5% and 0.2% respectively of the larvae from the Arabian Sea and Bay of Bengal. June, July and August were found to be the seasons when more numbers of larvae occurred in the collections (Tables 7,8; Fig. 20). The pattern of distribution of larvae showed higher concentration of larvae along the Arabian coast, especially in the oceanic waters towards the northern region, off Tamil Nadu, Andhra Pradesh and central Bay of Bengal. A total of 148 larvae were collected from 15 stations from the Arabian Sea, the highest number of larvae collected per haul being 40 (18°39'N - 58°31'E). From Bay of Bengal a total of 35 larvae were collected from 9 stations, the highest number being 9 from 10°00'N - 82°00'E. The surface temperature of the stations from where larvae were collected showed a wider range (19° - 29°C) in the Arabian Sea than in the Bay of Bengal (29.1° - 29.6°C) (Table 16). The surface salinities were between 35 and 36‰ in the Arabian Sea and 33.1 and 34.9‰ in the Bay of Bengal respectively.

OTHER CLUPEOIDS

(Fig. 1)

From the offshore waters of Arabian Sea and Bay of Bengal clupeoids other than these dealt with above were recorded, which contributed to 0.3% of the larvae collected (Table 6). In the former area they occurred in the Gulf of Aden, Arabian coast, northern Somali coast, coastal and offshore waters of Karnataka, Kerala and southwest of Sri Lanka. The contribution of this mixed group from this region was 0.5% of the larvae collected from the Arabian Sea, with a frequency of occurrence of 2.6% (Tables 4, 6). The highest number of 70 larvae per haul was recorded from a station 13°03'N - 50°00'E during night hours. They occurred during February to November.

In the Bay of Bengal they were collected from east of Sri Lanka, coastal Andhra Pradesh, northern Sumatra coast, in addition to three patches, one off Orissa and the others south of Andaman-Nicobar Islands and southwest of Sumatra. The contribution of these larvae in the Bay of Bengal was only 0.2% of the larvae collected from this region, the frequency of occurrence being 2.5% (Tables 5, 6). The highest number of 8 larvae per haul was recorded from the station 10°00'N - 90°00'E. They were collected in the months of December, January and from March to September.

FAMILY GONOSTOMIDAE

(Pl. I.2,3,4,5; Figs. 2,3)

Elongated slender bodied larvae like that of clupeids. Alimentary canal is tubular and straight. Dorsal and anal are opposite in position. No adipose fin is present. Photophores are usually present. In genus Vinciguerria (Pl.I.2,3) eyes are oval. Origin of anal is at middle of dorsal. Ventral row of photophores are very prominent. In genus Cyclothone (Pl.I. 4,5) eyes are round and small. Dorsal and anal are equal and opposite.

This group is well illustrated by D'Ancona et al. (1931-1956) in the Fauna e Flora et Gulfo di Napoli and in the reports of the Dana Oceanographic Expedition by Jespersen and Taning (1926). Ahlstrom and Counts (1958) studied the development and distribution of Vinciguerria lucetia and related species in the eastern Pacific. Mukhacheva (1964) has given an account of the composition of the species Cyclothone in the Pacific Ocean. Four species of Vinciguerria are recorded from the Indian Ocean. Silas and George (1971) described certain developmental stages of V. nimbaria collected from the waters off the southwest coast of India during the cruises of R.V. Varuna.

Vinciguerria, Cyclothone, Maurolicus and other gonostomatids contributed to 5.9% of the total larvae collected from the Arabian Sea (Tables 4, 6). The species of Vinciguerria was represented in 36.5% of the samples, Cyclothone sp. in 15.5% and other gonostomatids in 1.9%. These larvae were present in all months of the year (Table 7, Fig. 20). The highest number was recorded in the month of August. However, September, November and January registered higher values.

Vinciguerria was distributed in the Arabian Sea mainly in the offshore and oceanic waters as more or less continuous broad patch parallel to the coastline (Fig..2). But there were also small pockets of negative zones. The two stations in the middle of Red Sea recorded larvae of Vinciguerria. But collections from the Gulf of Aden were found to be totally devoid of this larvae. The region between the coasts of central Arabia and the northern Arabia, extending up to Pakistan coast and west coast of India excluding Persian Gulf, certain regions off Kutch, Gujarat, Karnataka, Kerala and Gulf of Mannar had high abundance of larvae. Along the equatorial region also there were positive and negative stations. The central part of Arabian Sea, extending over very large areas (except in the middle(and south of Sri Lanka had several stations devoid of larvae. Of the 573 stations in the Arabian Sea, 215 recorded a total of 1435 larvae (Tables 4, ,6). A maximum number of 340 larvae recorded per haul was the highest number which was from a station off central Somalia coast. The surface temperature of the stations

Fig. 2. Distribution of larvae of Gonostomidae: *Vinciguerria* spp. in the Arabian Sea and Bay of Bengal.

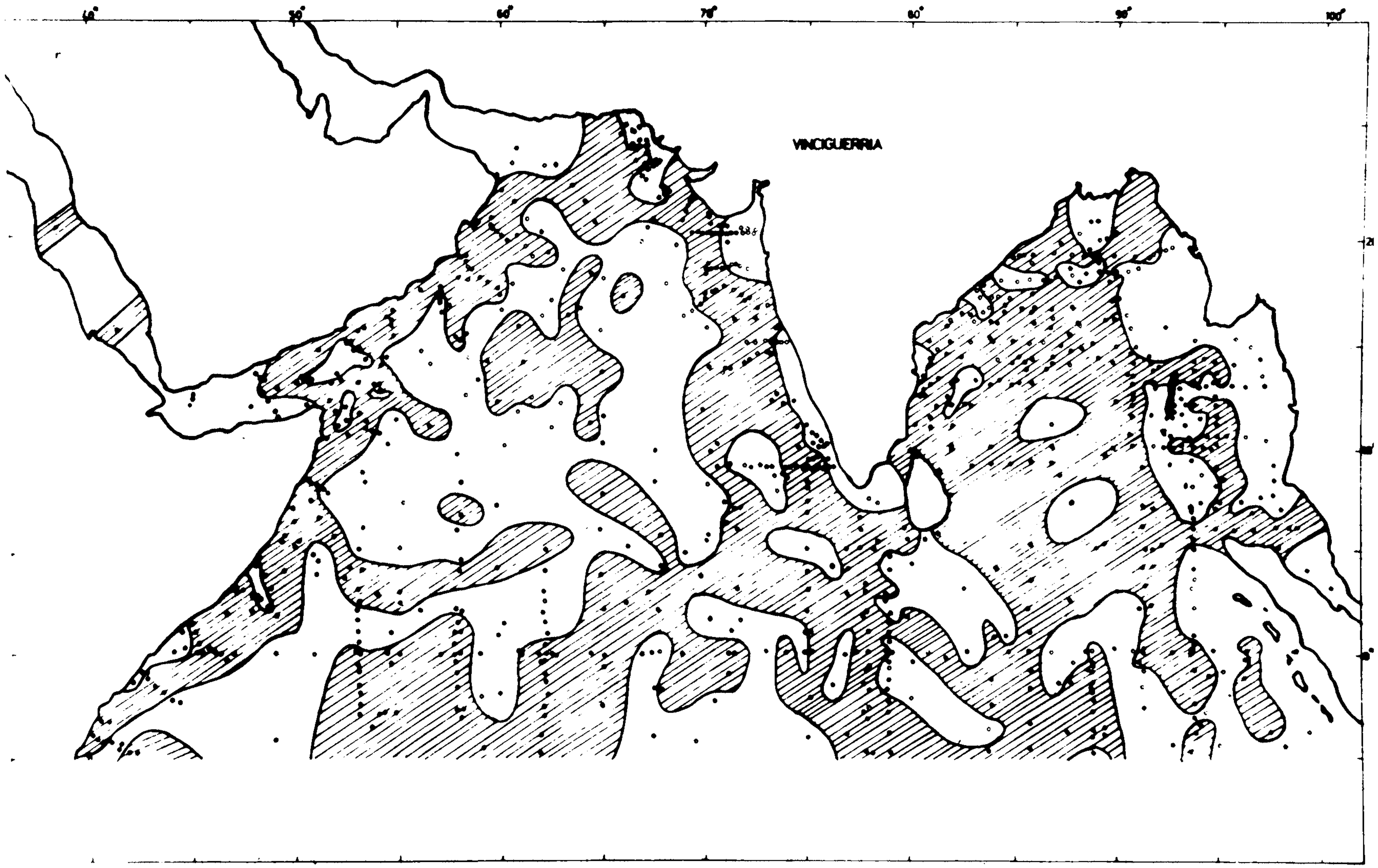


Fig. 2

(Table 16) varied from 18° to 30°C. The highest frequency occurrence of 28% was at 26°C. Though the salinity range was between 33 and 36‰, majority of the larvae (65%) were collected from waters of surface salinity 35‰.

The Bay of Bengal had a much higher numerical abundance as wellas frequency of occurrence covering a major portion of the Bay excluding the eastern part (Tables 5,6). The gonostomatids contributed to 20.5% larvae collected from Bay of Bengal of which 19.6% was *Vinciguerria* species, representing 65.9% of the stations. They occurred in all months of the year recording much higher values than in the Arabian Sea (Table 6 & Fig.20). Thêselarvae exhibited a very wide distribution with several pockets of negative stations in the coastal areas as well as in the offshore and oceanic regions (Fig. 3). Certain areas of the coastal Andhra Pradesh, Orissa, West Bengal, Burma, Malaysia, around Andaman-Nicobar Islands excluding the northern portion, west of Sumatra, central part of Bengal and south of Sri Lanka were some of the places, where the larvae did not occur. A total of 3915 larvae were recorded, whose frequency of occurrence was 239 (Table 6). Off the Orissa coast one station recorded 136 larvae which was the highest record per haul. The surface temperature of the areas of occurrence varied between 20° and 30°C and salinity from 26 to 35‰ (Table 16). 59% of the larvae occurred in waters of surface salinity 33‰.

The contribution of Cyclothone was 1.2% in the Arabian Sea and 0.7% in the Bay of Bengal, their frequencies of occurrence being 15.5% and 9.9% respectively (Tables 4,5,6). In the Arabian Sea they were collected from March to December months (Table 7, Fig.20). Highest number of larvae per haul was recorded during March. The concentration of Cyclothone sp. (Fig. 3) was noticed off Kenya, along the coastal and offshore waters of Somalia, central and northern coasts of Arabia, a few isolated patches in the central part of Arabian Sea, and a wider area south and southwest of Indian peninsula. A total of 392 larvae were collected from the Arabian Sea and their frequency of occurrence was 15.8% (Table 6). The highest number of larvae recorded per haul was 30 and was from the northern coast of Somalia. The surface temperature of the positive stations was between 22° and 30°C (Table 16). The salinity was within the range of 33 to 36‰. But 55 % of the larvae were from waters of surface salinity of 35‰

Fig. 3. Distribution of larvae of Gonostomidae: *Cyclothone* spp. in the Arabian Sea and Bay of Bengal.

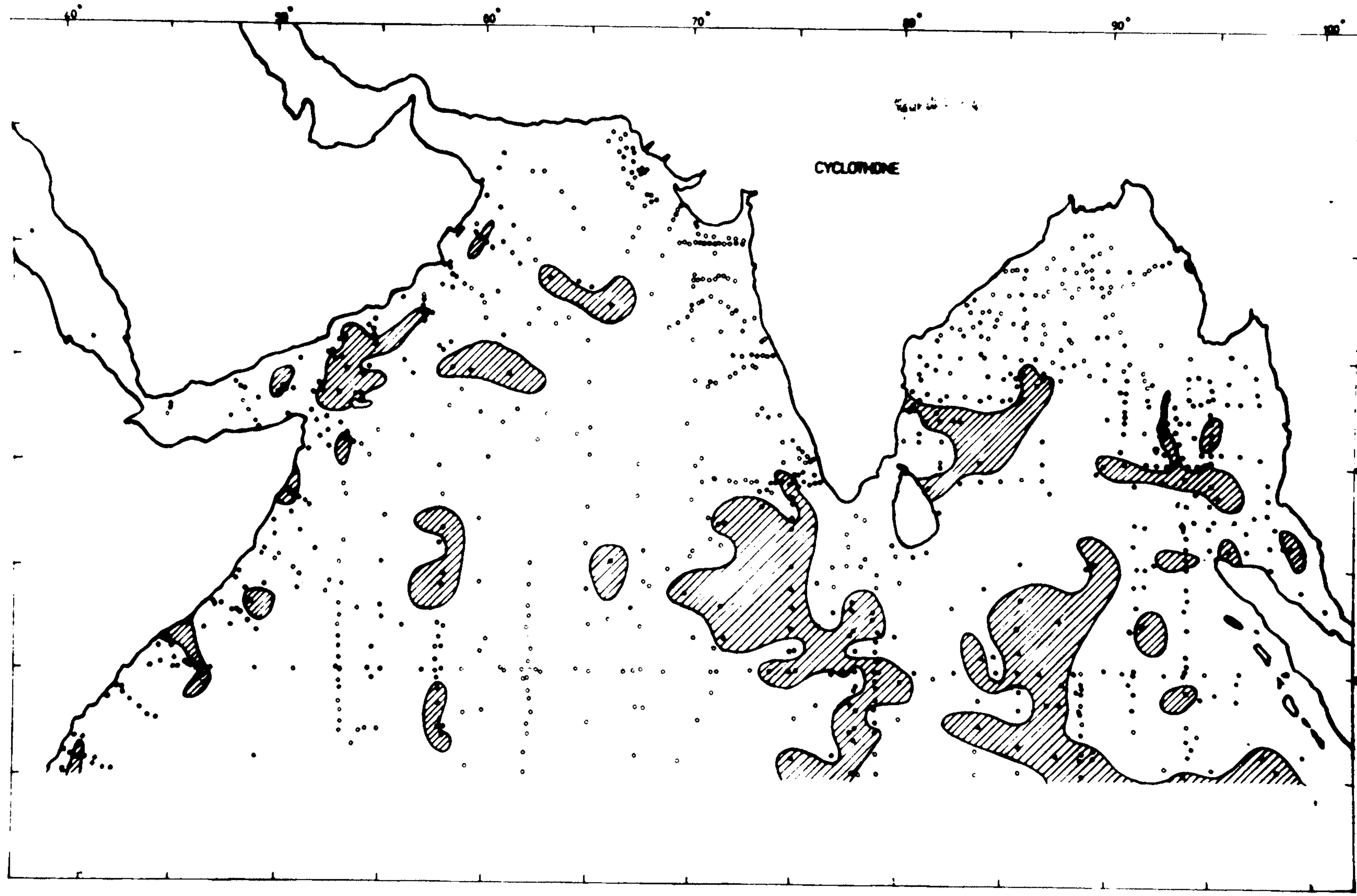


Fig. 3

In the Bay of Bengal they occurred in all months except July (Table 8, Fig. 20). Highest value recorded was during May-June months.

Major concentrations of Cyclothone species were in the oceanic regions (Fig. 3). Southern part of Bay of Bengal and northeast of Sri Lanka had big concentrations. East and south of Andaman-Nicobar Islands, west of Thailand, north and west of Sumatra were the other areas of abundance. Northern and central part of Bay was devoid of larvae of Cyclothone. From 36 stations in the Bay of Bengal, 159 larvae were collected (Tables 5,6). The highest number of larvae per haul (26) was recorded from a station east of Andaman-Nicobar Islands. The range of surface temperature (Table 16) was from 26° to 30°C, and 51% of the stations had temperature of 29°C. The surface salinity recorded was between 32 and 34‰ and 61% of the positive stations had the surface salinity of 34‰.

FAMILY STOMIATIDAE

(Pl. I.8, Fig. 4)

Elongated transparent body with about 60-70 myomeres. Mouth is terminal with lateral cleft. Eyes are very small. The tubular alimentary canal is attached to body by connective tissue and is often longer than the length of the body. Air bladder is clearly visible. The single dorsal with soft rays only. Adipose fin is present. Dorsal and anal are situated at the posterior part of the body. Pectorals are placed below. Pelvics are abdominal.

Ege (1918, 1930) studied the larvae of stomiatidae from the Mediterranean and adjacent seas. Weber (1913) described the larvae of <u>Stomias</u> of the Siboga Expedition. Regan and Trewavas (1930) and Morrow (1964) have also dealt with the stomiatids. Published work for the Indian Ocean is lacking.

The stomiatids in the Arabian Sea contributed to only 0.2% of the total larvae collected from this region, on the other hand in the Bay of Bengal it was 0.4% (Tables 4,5,6). The frequency of occurrence was 7.1% and 5.8% respectively. The frequency of occurrence of larvae was higher in the Arabian Sea, whereas Bay of Bengal recorded a higher percentage of larvae. From the Arabian Sea, 26 larvae per haul was the highest number collected from a station 20°52'N - 59°28'E, during July. This group was recorded in all months except May (Tables 7,8; Fig. 20).

Fig. 4. Distribution of larvae of Stomiatidae in the Arabian Sea and Bay of Bengal.

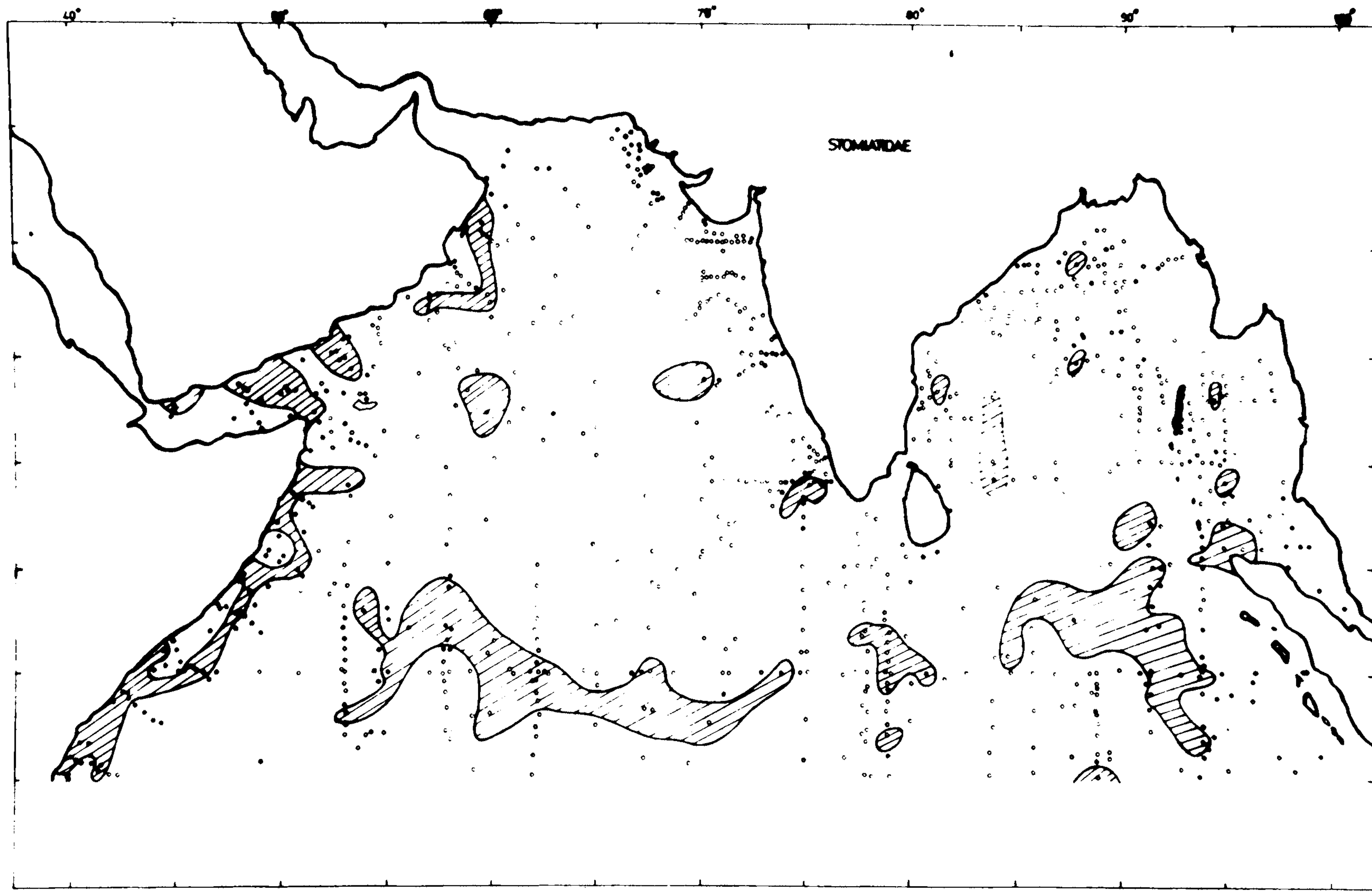


Fig. 4

In the oceanic region along the equatorial zone from 55°E to 75°E there was a big concentration of the larvae (Fig. 4). Another oceanic patch was noticed far off the Arabian coast. Other areas of occurrence were the offshore and coastal waters along Kenya, Somalia and Arabia, as discontinuous patches with pockets of negative stations. Along the Indian side there were two areas of concentration in the osshore waters of Karnataka and Kerala. But for the above 2 patches the entire coasts of India and Pakistan and Persian Gulf were totally devoid of this larva in the collections. There were only 42 positive stations in this region and the number of larvae collected was 97 (Table 6). The highest number of larvae recorded per haul was 26. The surface temperature of the stations varied between 20° and 30°C and salinity 33 and 36‰. (Table 16). 53% of the larvae were collected from waters of surface salinity, 35‰.

In the Bay of Bengal the occurrence was mainly oceanic. The major areas of concentration were north-east of Sri Lanka, off Andhra Pradesh, east of Andamans, north and west of Sumatra, in addition to 2 small patches in the middle of the Bay. At the equatorial region the distribution of stomiatids was very extensive.

89 larvae were collected from 21 stations (Table 6). One station east of Andaman-Nicobar Islands recorded the highest number of 20 larvae per haul. The surface temperature of the positive stations varied between 22° and 29°C (Table 16). 42% of the larvae were from the area with surface temperature 28°C. The salinity had a very wide range at these stations, ranging from 28 to 34‰.

FAMILY IDIACANTHIDAE

(Pl. I.7)

Elongated string like body with slightly flat head. Eyes are situated at the ends of long movable stalks. Snout is spoon shaped. Alimentary canal is tubular and much longer than body, attached by connective tissue often found trailing behind. There is only a single dorsal situated at the middle region of the body. Ventrals are absent.

The idiacanthid larvae collected from the Terra Nova Expedition were previously described as Stylopthalmus by Regan (1924). Yabe (1953) recorded the juveniles of Idiacanthus from the south seas. Gibbs (1964) dealt with the Idiacanthidae of the western North Atlantic.

Balasubrahmanyam (1966) described 2 larval specimens of *I. fasciola* from the Bay of Bengal.

The contribution of idiacanthid larvae numbering 138 (Tables, 4,6) amounted to 0.4% of the total larvae collected from the Arabian Sea and the frequency of occurrence was 5.8%. In the Bay of Bengal (Tables 5,6) only 7 larvae were recorded contributing to 0.03% of the total larvae collected from this region and representing 0.8% of the stations. Majority of the larvae collected were from the oceanic and offshore waters.

FAMILY CHAULIODONTIDAE

(Pl. I.6)

Body is elongated and serpentine with long and tubular alimentary canal in early stages. Eyes are very small. At later stages head becomes enlarged with wide mouth and fang like teeth. Body is pigmented. Photophores are present on the body. Dorsal is small situated before the anterior half of the body, whereas anal is very large extending almost the entire length of the ventral part of the body.

Sanzo (1914) described the larvae *Chauliodus solani*. Regan and Trewavas (1930) made studies on the family Chauliodontidae. The systematics, phylogeny and

PLATE XI

1.	Paralepididae	25.1 mm
2.	" "	10.2 "
3.	Scopelarchidae	19.2 "
4.	Synodontidae	9.3 "
5.	Myctophidae	
6.	" "	4.9 "
7.	" "	6.2 "
8.	" "	5.1 "

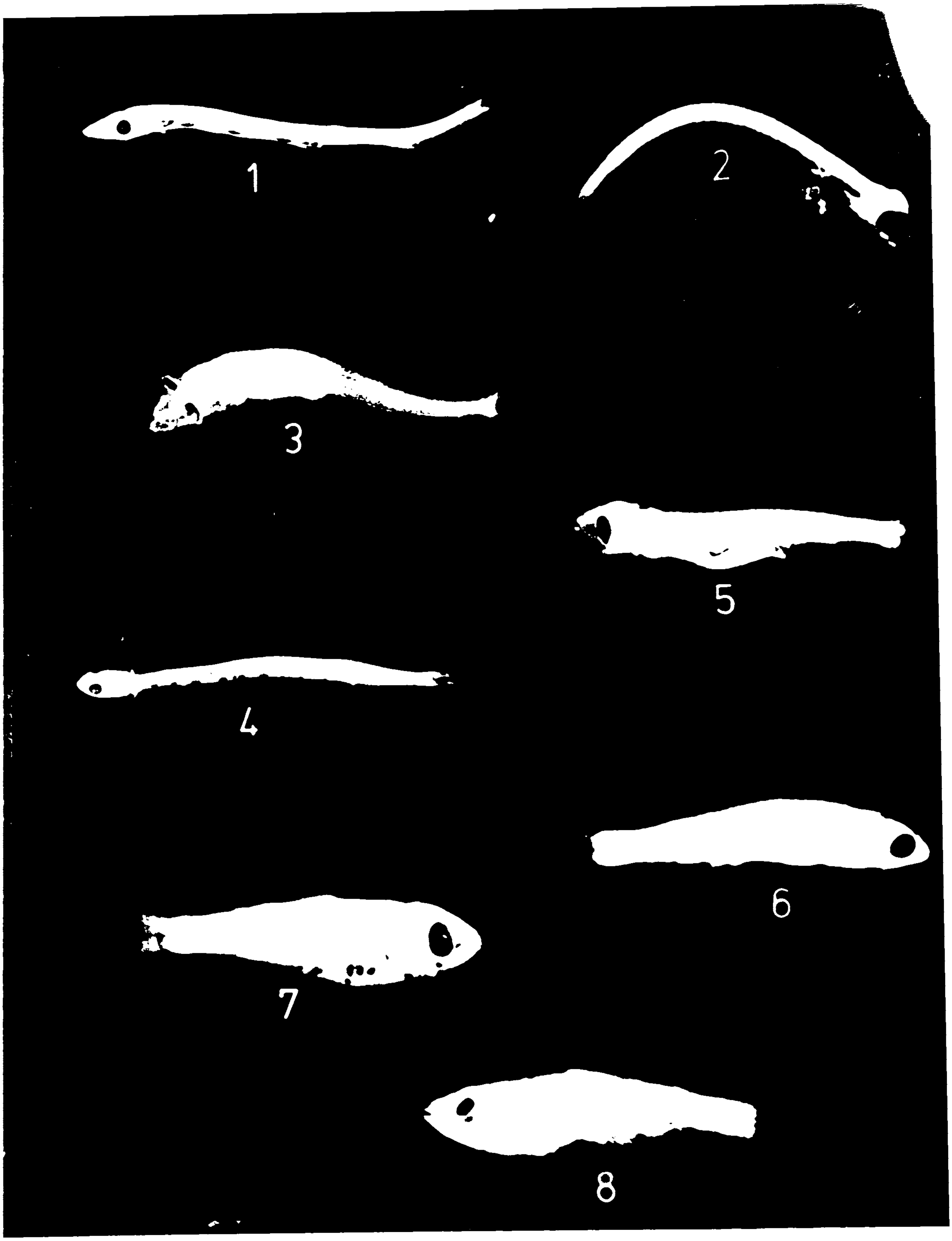


PLATE II

distribution of this bathypelagic group from the Mediterranean waters were studied by Ege (1948). Systematics and zoogeography of Chauliodus pammelas and C. sloani of the Indian Ocean were dealt with by Gibbs and Hurwitz (1967). Description of larvae from Indian Ocean region is not available.

In the Arabian Sea this group contributed to 0.1% of the total larvae and represented in 2.2% of the total stations, whereas in the Bay of Bengal, the corresponding figures were 0.02% and 0.8% respectively (Tables 4,5,6). Majority of the larvae collected were from the offshore and oceanic waters.

FAMILY SYNODONTIDAE

(Pl. II.4, Fig. 5)

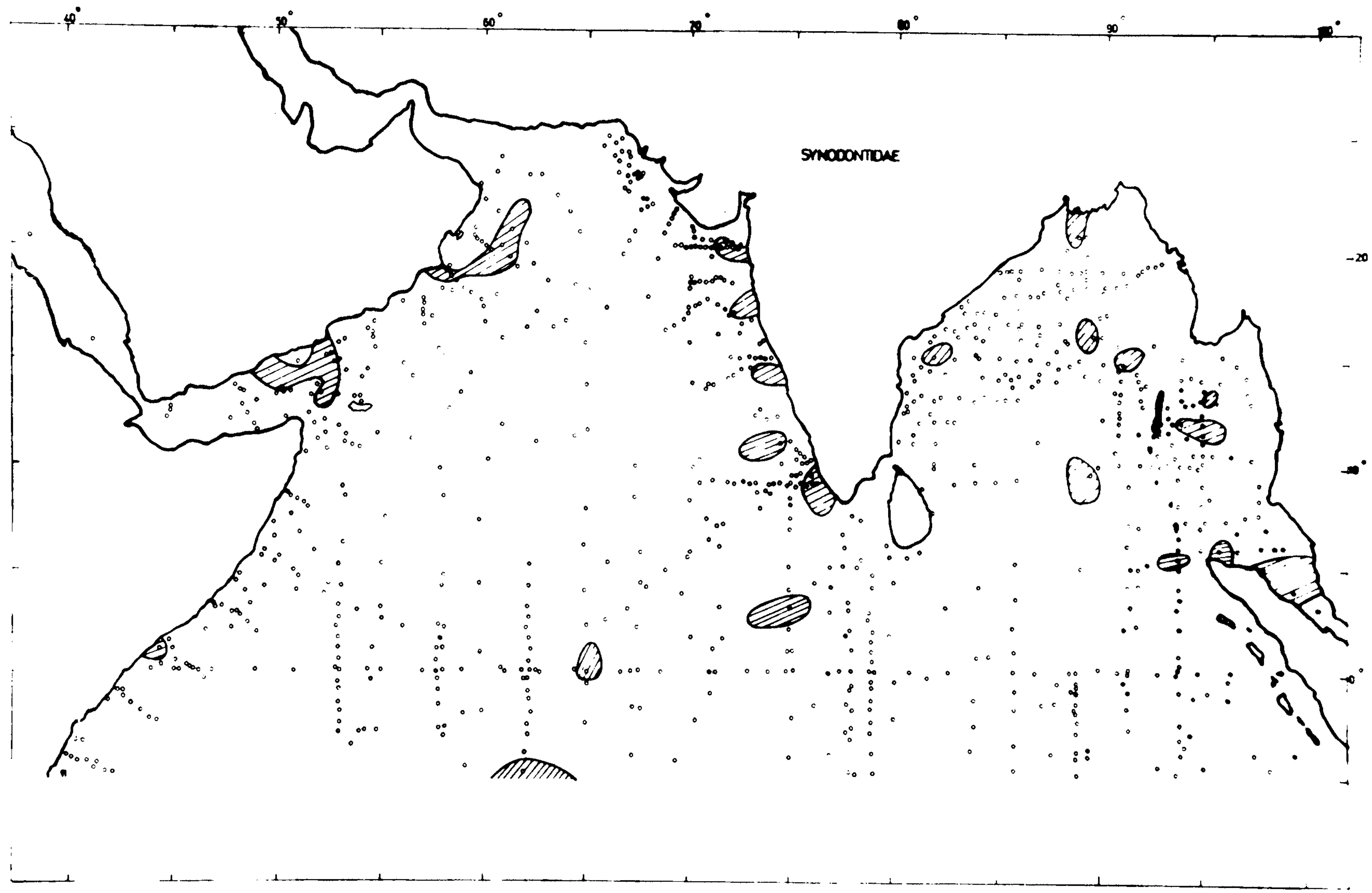
Elongated, some what cylindrical low body with about 50-55 myomeres. Snout is slightly pointed. Pigmentation of the body is in characteristic round blotches on the ventro-lateral sides of the alimentary canal arranged in regular order. Intestine is straight and long. There is only a single dorsal with soft rays. Adipose fin appears only at later stages.

Delsman and Hardenberg (1934) described the larvae of Saurida tumbil from the Java waters. Gopinath (1946) recorded larval and postlarval stages of

Saurus indicus, *S. myops* and *Saurida tumbil* from the coastal waters of Trivandrum. Vijayaraghavan (1957) studied the larvae of *Saurida tumbil* collected from the plankton of Madras coast. Kuthalingam (1958, 1959 b) made studies on the postlarvae of *Saurus* sp. and early larvae of *Saurida tumbil* of the Madras coast. Gibbs (1959) prepared a synopsis of the postlarvae of Western Atlantic lizard fishes. Anderson *et al.* (1960) contributed to the study of the family Synodontidae of the western North Atlantic. Basheeruddin and Nayar (1962) recorded the young fishes of *Saurida tumbil* from the coastal waters of Madras. Zujagina (1965) presented the data on the development of lizard fishes. Dileep (1977) described the life history stages of *Saurus tumbil* from the collections of the southwest coast of India.

The distribution of synodontids in the Arabian Sea was mainly from the coastal and offshore waters (Fig. 5). But for the 3 patches, the entire oceanic area of the Arabian Sea was devoid of these larvae. Along the coast of Somali, 4 larvae were collected from a single station. Two big patches of larvae, one covering the coastal and offshore regions of the mid Arabian coast, and the other, off the northern Arabian region were noticed. Out of the 5 stations in the

Fig. 8. Distribution of larvae of Synodontidae in the Arabian Sea and Bay of Bengal.



-Fig. 5

latter area, one sample recorded 36 larvae. Along the west coast of India, nearshore occurrences were noticed off Gujarat, Maharashtra, Karnataka and Kerala. The oceanic patches noticed were in the offshore waters south of south India, and two patches along the equatorial region. The highest number of larvae recorded was 57 per haul from a station of Kerala (09°00'N - 76°22'E). A total number of 147 larvae were collected from 21 stations, the surface temperature of which ranged from 24° to 29°C (Table 16). About 47% of larvae were collected from waters of surface temperature 28°C. Surface salinity values varied between 33 and 34‰.

In the Bay of Bengal the distribution was in the offshore and oceanic waters (Fig. 5, Tables 5,6). Small concentrations were noticed off Andhra Pradesh, south of West Bengal, central part of Bay of Bengal, east of Andaman-Nicobar Islands, north and northwest of Sumatra and Strait of Malacca. A total of 20 larvae were collected from 11 stations. The highest number of 5 larvae per haul was recorded from the area off West Bengal. The surface temperature of the stations from where these larvae were collected ranged from 26° to 29°C and salinity from 30 to 34‰ (Table 16). 43% of the larvae were from waters of surface salinity 32‰.

FAMILY PARALEPIDIDAE

(Pl. II.1,2; Fig. 6)

Body is very much elongated, low and rather strongly built. Myomeres are around 50. Preanal part is about 30-50% of the body. Snout is pointed. Alimentary canal is long and straight except in early stages. Ventral pigmentation is in the form of big patches which is very characteristic of the group. Dorsal is single with soft rays. Position of adipose fin is far back on the body. Origin of dorsal is posterior to the origin of pelvics. Anal is long extending to the extremity of the body.

D'Ancona et al. (1931-1956) dealt with this group in the Fauna e Flora Gulfo di Napoli. Ege (1930, 1953, 1957, 1958) studied the taxonomy, ontogeny, phylogeny and distribution of Paralepididae (Sudidae), Rofen (1963, 1966 a) contributed to the study of the family Paralepididae of the western North Atlantic. Paralepidids of the Indian Ocean region has not been studied.

In the Arabian Sea this group is represented in 13.6% of the stations though the percentage of larvae collected was only 0.6% of the total. In the Bay of Bengal also more or less similar proportion was

Fig. 6. Distribution of larvae of Paralepididae
in the Arabian Sea and Bay of Bengal.

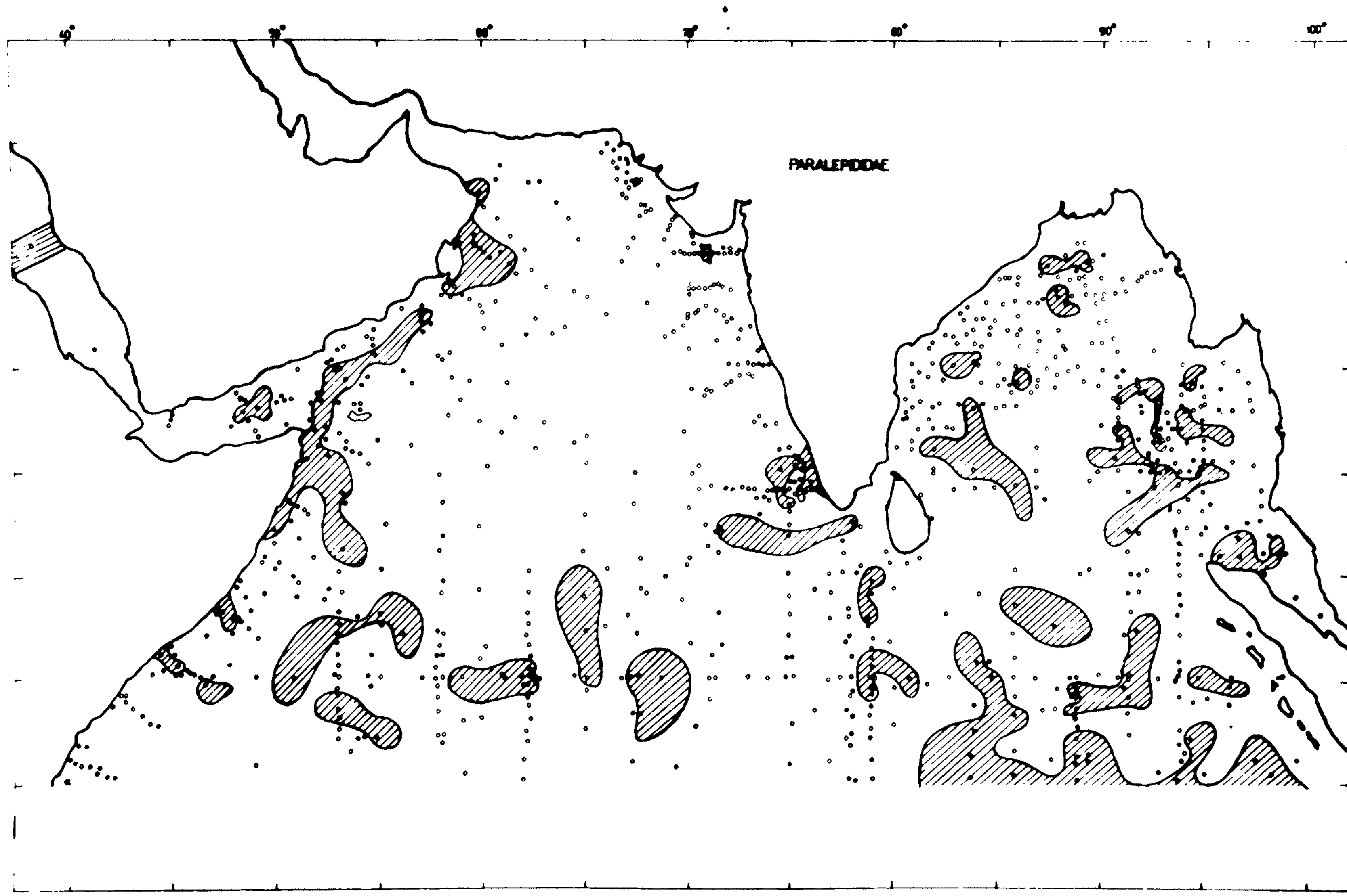


Fig. 6

maintained (15.2% and 0.6%). They occurred in almost all months of the year, (Tables 7, 8; Fig. 20).

The general pattern of distribution (Fig. 6) in the Arabian Sea showed that the main concentration of the larvae was towards its western boarder and along the equatorial zone. In the eastern boundary there was a small patch off Gujarat, and a bigger concentration in the coastal and offshore waters of Kerala and south of Indian peninsula. Along the western boundary, they were recorded from the coastal and offshore waters of Somalia, off Arabian coast and middle of Red Sea. In the equatorial region there were larger areas of abundance, but as discontinuous patches. The central and northeastern parts of Arabian Sea did not record any paralepids. The number of larvae collected from the Arabian Sea (Tables 4, 6) was 196 and that from 8 stations during January to December except September and October (Table, 7; Fig. 20). Twenty larvae per haul was the highest record. The surface temperature of the stations ranged from 17° to 29°C and salinity from 34 to 36‰. (Table 16).

In the Bay of Bengal the distribution pattern of this group was in the form of big patches of varying sizes in the offshore and oceanic waters (Fig. 6). The areas of concentration in the northern half of the Bay were northeast of Sri Lanka, off Andhra and Orissa coasts, around Andaman-Nicobar Islands and north of Sumatra. The southern part especially the equatorial region also had a fairly good representation of paralepids. The areas of distribution in the equatorial zone and south of equator were much wider, but discontinuous. The concentrations at 5°S latitude were continuous and extensive. One hundred and twenty six larvae were collected from 55 stations throughout the year (Table 8, Fig. 20). The highest number of 15 larvae per haul was collected from 2 stations, one from east of Andamans and the other west of Sumatra (Tables 5, 6).

FAMILY SCOPELARCHIDAE

(Pl. II.3, Fig. 7)

Body is of medium height and length. Preanal part is about 50-60% of the body and is slightly broader than the rest. Snout is highly produced and pointed. Cleft of the mouth is wide. A few of the teeth are enlarged and fang like. Eyes are oval. Dorsal is single with soft rays only. Adipose fin is present. Alimentary canal is short with enlarged anterior region. Colouration is appreciably darker.

Rofen (1966 b) dealt with this group while studying the fishes of the western north Atlantic. This oceanic species has not been studied from the Indian Ocean region. They are represented in 7.8% of the samples from Arabian Sea and 4.4% from Bay of Bengal and their total contribution of the larvae were 0.3% and 0.1% respectively (Tables 4,5,6). They occurred in very small numbers (1 to 2) only. In the Arabian Sea they were collected during the period from March to May and from July to September and from Bay of Bengal from March to November (Tables 7, 8; Fig. 20).

In the Arabian Sea the distribution of Scopelarchids (Fig. 7) was found to be restricted to the southern half of the Arabian Sea from 10°N to 5°S leaving the stations of the entire northern part including Red Sea devoid of this group. They were present in the offshore waters of Kenya and southern Somalia. At the northern Somalia coast their occurrence extended to the oceanic regions also. Similar offshore records were noticed in the waters off Kerala coast, south of south India. The equatorial region had a very wide distribution, though

Fig. 7. Distribution of larvae of Scopelarchidae
in the Arabian Sea and Bay of Bengal.

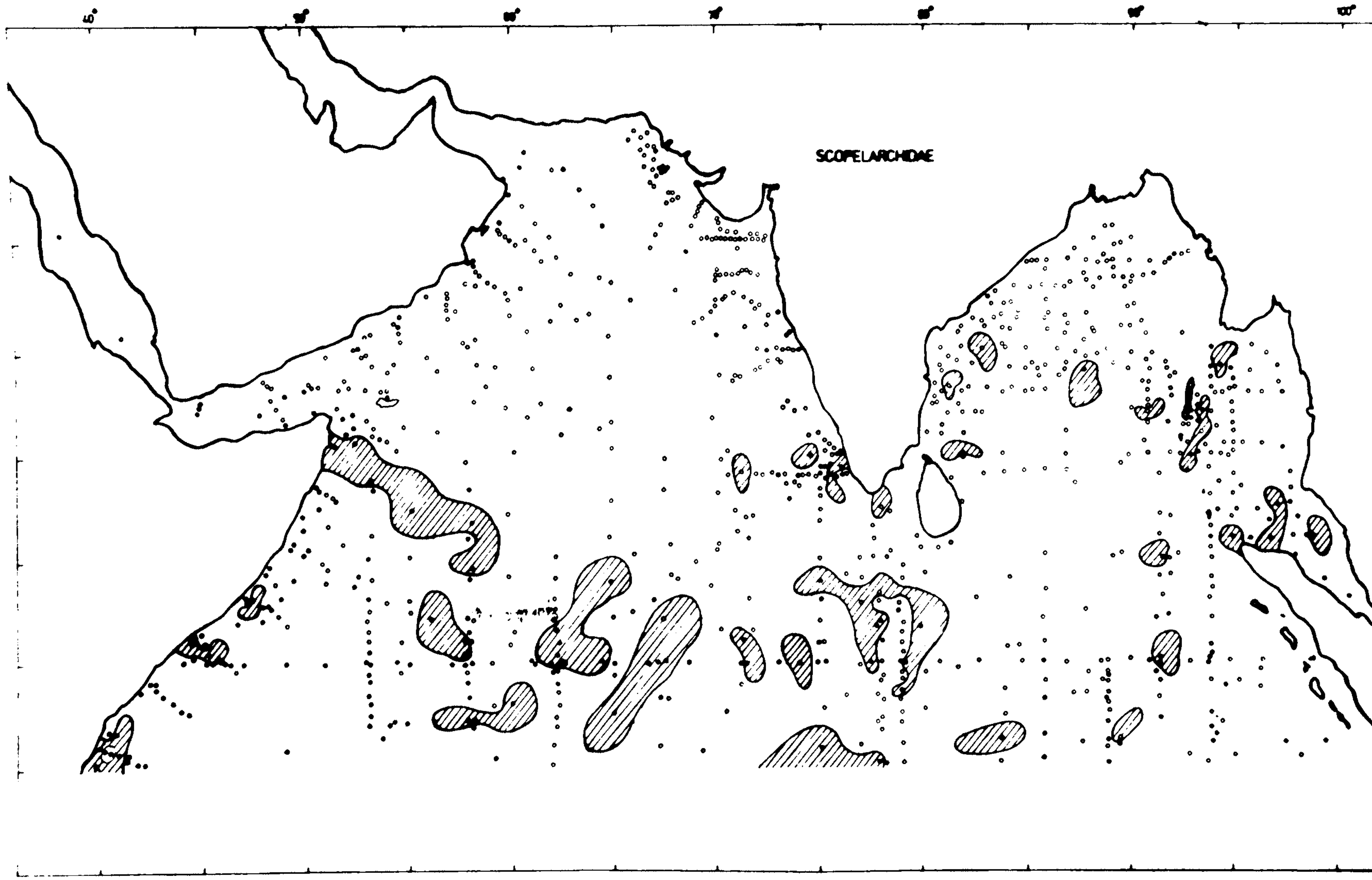


Fig. 7

discontinuous and patchy. A total of 94 larvae were collected and their frequency of occurrence was 8% (Tables 4,6). The surface temperature of the areas of occurrence ranged from 22° to 30°C and salinity from 33 to 35‰ (Table 16).

The distribution of scopelarchids was in the form of 7 patches scattered in the Bay of Bengal between 10°N and 15°N and towards the southeastern region (Fig. 7). The areas of occurrence were the northeastern part of Sri Lanka, off the coasts of Tamil Nadu and Andhra Pradesh, areas around Andaman-Nicobar Islands, northern Sumatra coast and equatorial waters as discontinuous patches. Only 30 larvae were collected from 16 stations in the Bay of Bengal, where surface temperature varied between 27° and 29°C. The salinity ranged from 31 to 34‰ (Table 16).

FAMILY MYCTOPHIDAE

(Pl. II.5-8, Fig. 8)

Early larvae are slender with deep head. Number of myomeres ranges from 21-50. Mouth is wide, either terminal or oblique. Teeth are prominant. Pigmentation is conspicuous mainly on head and alimentary canal. Intestine is short and straight with wringles or glandular cells on the anterior region which is broader. Dorsal is single with soft rays. Adipose fin is present. Photophores appear in the postlarval stages.

Taning (1918) studied the scopelids of the Mediterranean region. Fraser-Brunner (1949) classified the fishes of the family Myctophidae. Bolin (1959) made studies on the Iniomi myctophids from 'Michael Sars' north Atlantic deep sea Expedition. Becker (1964) contributed to the study of Loweina, Tarletonbenia, Gonichthys and Centrobranchus of the Pacific and Indian Ocean. Pertserva-Ostroumova (1964) described the morphological characters of the larvae collected from Pacific and Indian Oceans. Moser and Ahlstrom (1970) contributed to the development of the lantern fishes, Myctophidae in the California current region. Valsa (1977) studied the larval stages of Diogenichthys panurgus collected from the southwest coast of India.

Myctophids contributed to 26.8% of the total larvae collected from the Arabian Sea representing in 68.1% of the stations. Whereas in Bay of Bengal their contribution came to 20.8% representing 72.0% of the stations (Tables 5,6,7). Larvae were recorded during all months of the year in the Arabian Sea and Bay of Bengal, the highest average number (35 & 37) being in July and June and the lowest (8 & 6) in September (Tables 7,8; Fig. 20).

Fig. 8. Distribution of larvae of Myctophidae in the Arabian Sea and Bay of Bengal.

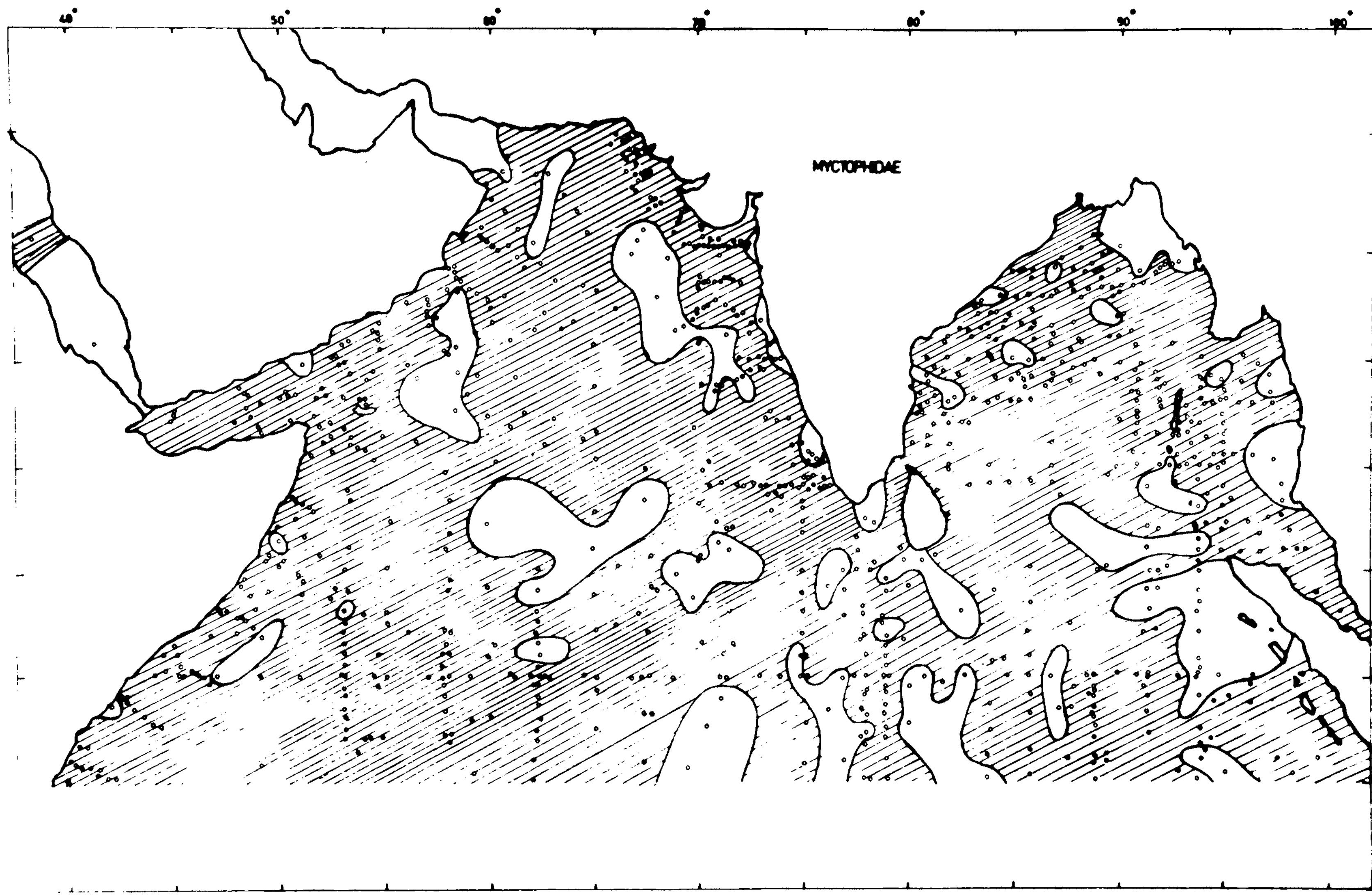


Fig. 8

This group was very widely distributed in the oceanic and offshore regions (Fig. 8). In the areas nearer the coast they were represented in small numbers. However, their absence was noticed in certain pockets in the areas along Somali coast, Red Sea, Arabian coast, Pakistan coast, Maharashtra and Karnataka coasts part of Kerala coast and south of south India and Sri Lanka. Six large isolated areas devoid of larvae were observed in the oceanic region. A total of 8301 myctophid larvae were recorded from 396 stations (Tables 4,6). The highest number of 258 larvae per haul was recorded from a station off northern Arabian coast. This group seems to show a very wide temperature tolerance (varying from 17° to 30°C) (Table 16). Twenty seven percent of the larvae were collected from waters of surface temperature 25°C. The surface salinity range was between 32 and 36‰. 59% of the larvae were from waters of surface salinity 35‰.

In the Bay of Bengal myctophids had a very wide distribution covering major part of the Bay. The regions which did not record these larvae were the head of the Bay towards the northeastern side, west of Thailand, south of Andaman-Nicobar Islands, northwest of Sumatra and several small pockets in the equatorial region as well as in the central and northern parts.

PLATE XII

1.	Anguilliformes	52.6	mm
2.	Syngnathidae	18.5	"
3.	Exocoetidae	5.9	"
4.	" "	3.7	"
5.	Hemirhamphidae	9.6	"
6.	Holocentridae	5.1	"
7.	Mugilidae	6.1	"
8.	" "	5.2	"
9.	Sphyraenidae	17.1	"
10.	" "	10.7	"
11.	Bregmacerotidae	5.2	"
12.	" "	5.9	"
13.	" "	10.1	"

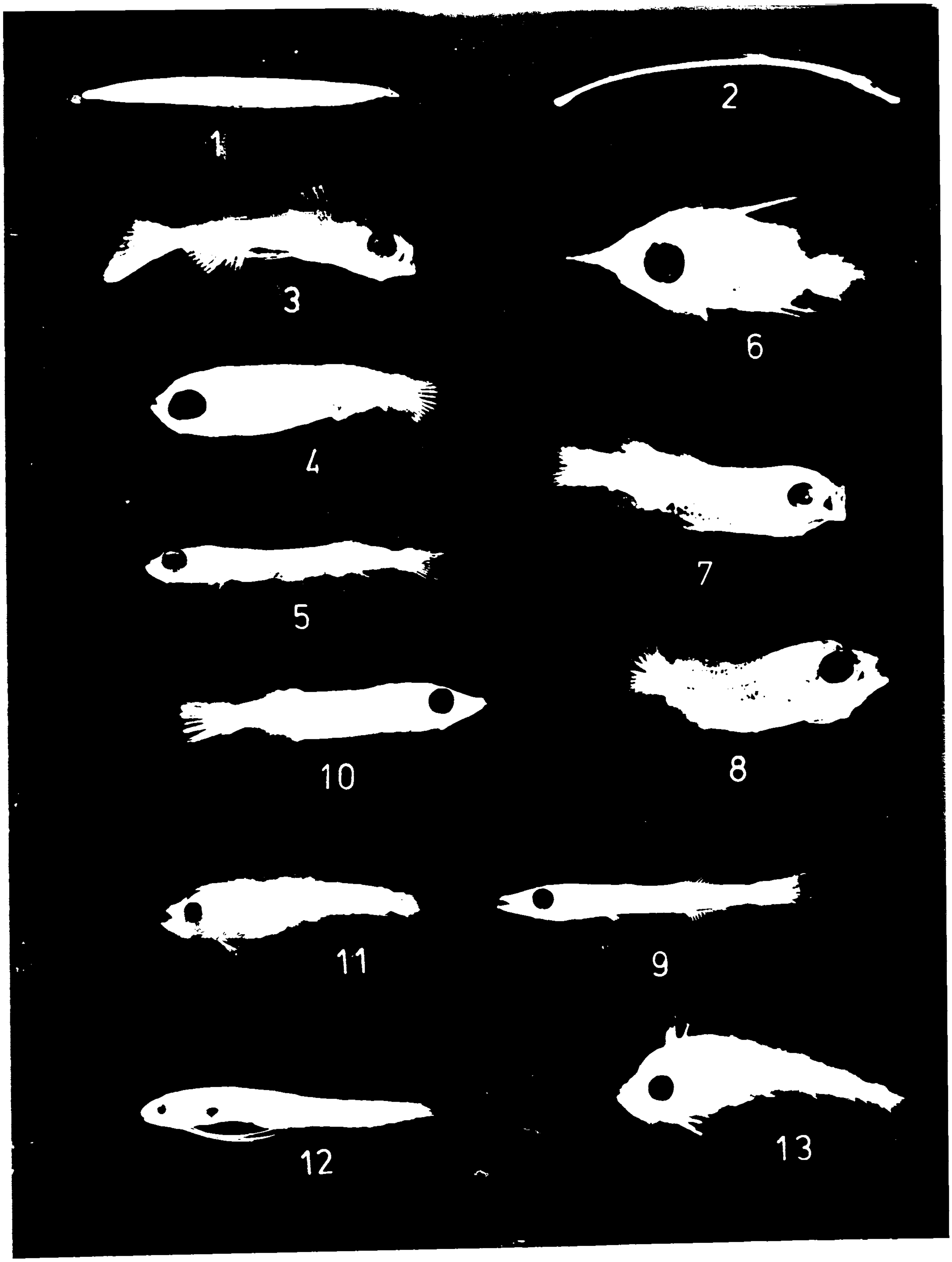


PLATE III

251 stations recorded a total of 4175 larvae (Tables 5,6). The highest number of larvae per haul was 114 which was from a station off West Bengal. The surface temperature of the areas of larval occurrence were between 24° and 30°C (Table 16). 38% of the larvae were from waters of surface temperature 29°C. Salinity ranged between 28 and 35‰.

ORDER ANGUILLIFORMES

(Pl. III.1, Fig. 9)

This order comprising of eels and eel-like fishes is constituted by a large number of families. For the present study, identification of larvae was not done at the family level. All the leptocephali, irrespective of the family were treated as one group.

The leptocephalus has elongated transparent ribbon shaped body with small head. There are about 160 myomeres. Length of the preanal part is more than 70% of the body. Posterior half tapers gradually terminating in small round tail. Mouth is subterminal. larval teeth are very well developed and exposed. Alimentary canal is long and straight. Ventral fins are absent. Only a single dorsal is present. The dorsal and anal are continuous beginning from the nape and ending behind the anus.

Weber (1913) recorded 13 types of leptocephali from the Siboga Expedition. Delsman (1933) recorded early larvae referable to Muraenidae and Ophichthyidae from the Java Sea. In 1944 Aiyar *et al.* studied the eggs of eel and leptocephali belonging to *Muraenesox cinereus* and *Ophichthys boro* of the Madras coast. Nair (1947) described the stages of metamorphosis of the leptocephali of *Muraenesox cinereus* and *M. macrura* from the plankton of Madras coast and (1948) *Congrellus anago*, *Uroconger lepturus* and *M. cinereus* from Gulf of Mannar. He also made some general studies (1961) of the Indian leptocephali. Nair and Dharmamba (1961) described the early developmental stages of an Ophichthyid egg collected from Lawson's Bay. Gopinath (1950) described a few leptocephali of *M. cinereus*, *Congrellus anago* and 4 other unidentified species. Bauchot (1959) contributed to the identification of leptocephali. Nair and Mohamed (1961 a,b,c,d,e) studied the metamorphosing stages of *Muraenesox talbonoides* and *M. talabon* from Bombay waters. Castle (1963, 1965 a, b,c) and Ganapati and Raju (1963) collected five types of ophichthyid and two types of muraenid eel eggs and their larvae.

This group was represented in 0.2% of the stations in the Arabian Sea, whereas in the Bay of Bengal it was 0.5% (Tables 4,5,6). The percentage of occurrence was also higher in the Bay of Bengal (12.7%) compared to the Arabian Sea (4.6%). The highest number of larvae recorded in the Arabian Sea was during the month of January (Table 7; Fig. 20). Majority of the stations had only 1 to 2 larvae. In Bay of Bengal the highest number of larvae collected per haul was 6 in the month of May. Two to four larvae per haul was the common number. In both the regions higher numbers were recorded during night hauls.

Larval distribution in the Arabian Sea (Fig. 9) was widely scattered as small patches. The areas of occurrence along the western half of Arabian Sea were the coastal and offshore waters of Somali coast and Arabian coast. In the eastern side similar areas of occurrence were noticed off Gujarat, Maharashtra and southwest of Karnataka, and southwest of south India. There were also a few patches in the central part of Arabian Sea. Except September, October and November they were present throughout the year (Table 7, Fig.20). Fifty leptocephalus stages of larvae were caught from 27 stations (Tables 4,6) and the highest number of larvae collected per haul was 10 from southern Somalian

Fig. 9. Distribution of larvae of Anguilliformes in the Arabian Sea and Bay of Bengal.

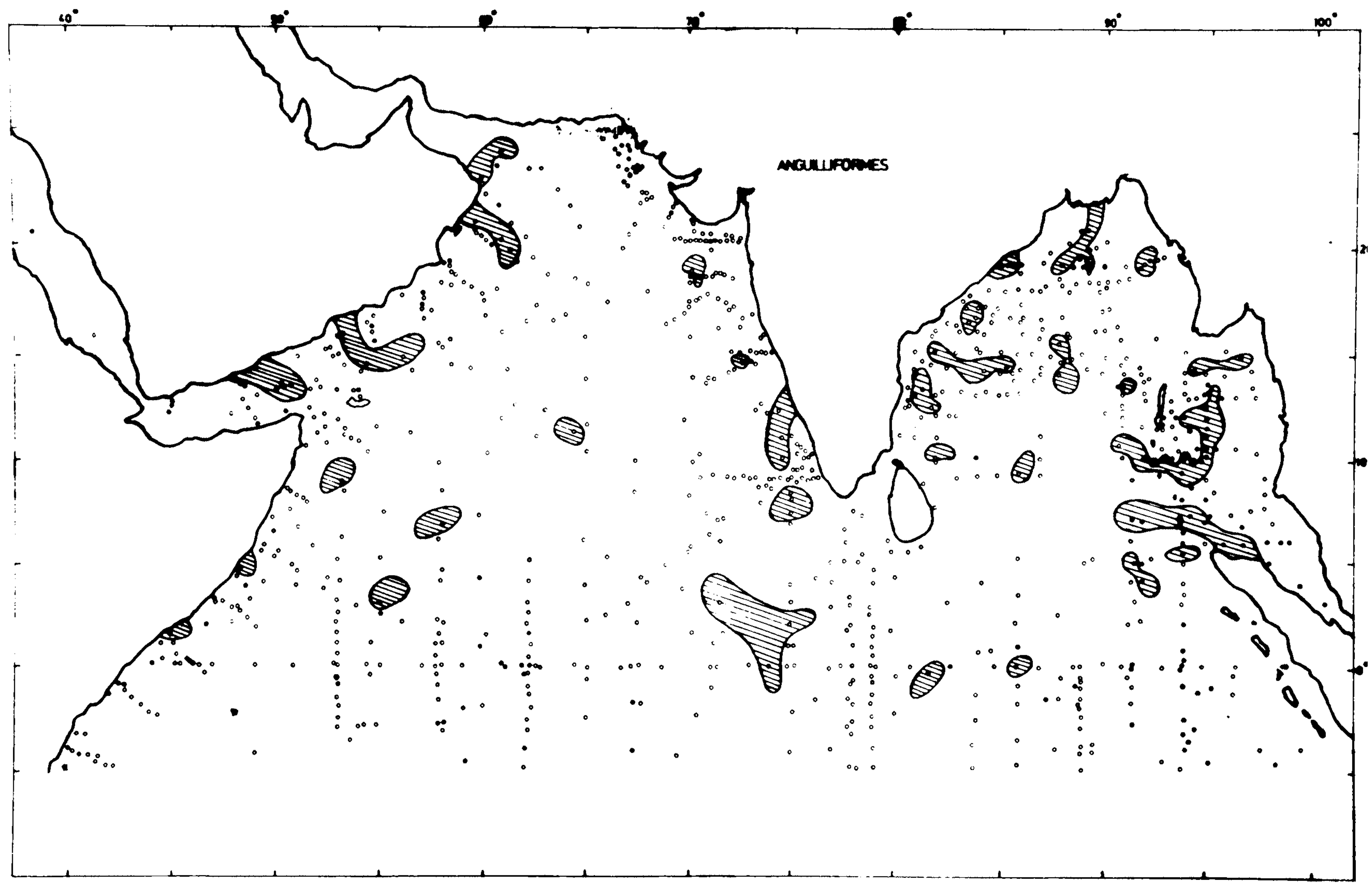


Fig. 9

waters. In the equatorial region they appeared as 4 isolated patches. The surface temperature of the stations ranged between 20° and 30°C and surface salinity 23 to 36‰ (Table 16). But 51% of larvae were recorded from waters of surface salinity of 35‰.

In the Bay of Bengal also the distribution was highly scattered in patches (Fig. 9). The occurrences were mainly in the offshore waters of Andhra Pradesh, Orissa, West Bengal, Burma, south and southwest of Andaman-Nicobar Islands, north and northwest of Sumatra and a few places along the equatorial zone and central parts of the Bay. Larvae were collected during all months of the year except October (Table 8, Fig. 20). 83 leptocephali were collected from 42 stations where surface temperature varied between 25° and 30°C and surface salinity from 30 and 35‰ (Table 16). 41% of the larvae seemed to occur in waters of surface salinity 33‰.

FAMILY EXOCOETIDAE

(Pl. III.3,4)

Larvae are somewhat deep bodied, profusely dotted with dark pigments. Only a single dorsal is present with soft rays. Dorsal and anal are situated far posterior. They are long opposite and equal. Pectorals, anals and in some cases ventrals also are greatly enlarged. Vent is situated far behind the middle of the body.

Hildebrand and Cable (1930) described the developmental stages of Parexocoetus mesogaster and Cypselurus furcatus. Munro (1954) described the eggs and larval stages of certain exocoetids of the Australian waters. Uchida et al. (1958) made studies on eggs and larvae of Oxyporhamphus micropterus micropterus, Parexocoetus mento mento, P. brachypterus and Cypselurus poecilopterus from Japanese waters. Padmanabhan (1963) traced the embryonic and larval stages of Cypselurus cometus from the Trivandrum coast. Gorbunova and Parin (1963) studied the development of flying fishes Cheilopogon unicolor, C. cyanopterus, Cypselurus oligolepis, Hirundichthys speculiger, Euleptorhamph viridis. Kovaleveskaya (1964) and Parin and Gorbunova (1964) described the development of Exocoetus volitans, E. monocirrhus, E. obtusirostris and Oxyporhamphus micropterus collected from the Pacific and Indian Oceans. Balasubrahmanyam et al. (1969) made studies on the larvae and juveniles of Exocoetus volitans and Hirundichtsys coromandelensis from Bay of Bengal. The developmental stages of this species were also studied by Vijayaraghavan (1973).

FAMILY HEMIRHAMPHIDAE

(Pl. III.5)

Body is low, elongated and pigmented in a very characteristic manner with bluish green chromatophores on the head region. Number of myomeres are usually between 55 and 65. Small minute pigment spots are scattered all over the body. Alimentary canal is tubular and long opening far behind the middle of body. Pectorals and ventrals are not enlarged.

Bal and Pradhan (1946, 1947, 1951) recorded larvae and postlarvae of *Hemirhamphus* sp. from Bombay waters. Vijayaraghavan (1957) studied the eggs and larvae of *H. far* from Madras plankton. Jones and Pantulu (1958) recorded larvae and juveniles of *Zenarchopterus buffoni* from the Bay of Bengal and Orissa coast. Balakrishnan (1959) collected larvae of *Hemirhamphus* sp. from Kerala coast. Kuthalingam (1958) studied the postlarvae and feeding habits of *Hemirhamphus* sp. from Madras plankton. Uchida *et al*. (1958) contributed to the study of larvae and juveniles of *Hemirhamphus sojori* and *H. kurumeus* from Japan waters. Parin and Gorbunova (1964) made studies on the reproduction and development of synentognathous fishes of the Pacific and Indian Oceans. Talwar (1967, 1968) innvestigated the biology of *Hemirhamphus marginatus* from Mandapam. Sudarsan (1968 b) studied the eggs and larvae of *Hemirhamphus cuoyi* from Mandapam ärea.

The exocoetids and hemirhamphids (Beloniformes) together contributed to 0.4% of the total fish larvae collected from the Arabian Sea and 0.1% in the Bay of Bengal, their frequency of occurrences being 1.0% and 2.7% respectively (Tables 4,5,6). The highest number of 8 larvae per haul was recorded from two stations in the Arabian Sea - 04°20'S - 40°19'E and 00°05'S - 50°56'E during the month of July. From the Bay of Bengal the highest number recorded was 5 per haul from the station 09°15'N - 83°00'E in the month of June. In both cases 1-2 larvae were found to be the average number in the collections. A total of 67 larvae were collected from 29 stations in the northern Indian Ocean. They occurred in almost all months of the year (Tables 7,8; Fig. 20) and majority of them were during the night hauls.

FAMILY BREGMACEROTIDAE

(Pl. III.11-13, Fig. 10)

Deep headed larvae with tapering body. There are about 50 myomeres. Pigmentation is very dense on the body but not uniform. Two dorsals are present. Second dorsal and anal are opposite and equal with more than 50 rays. First dorsal ray and some of the pectoral rays are elongated. Fins are devoid of spinous rays.

Bal and Pradhan (1945, 1947) and Bapat and Bal (1950) recorded the larval stages of Bregmaceros maclellandi from Bombay waters. Munro (1950) made a revision of the genus Bregmaceros with description of the larval stages. Clancy (1956) contributed to the life history of B. atlanticas from the Florida current. Jones and Pantulu (1958) described the larval fishes of B. maclellandi from the Bengal and Orissa coasts. D'Ancona and Cavinato (1965) contributed to the study of the fishes of the family Bregmacerotidae. Raju and Ganapati (1967) studied the distribution of eggs and larvae of B. artipinnis from the Bay of Bengal area. Balakrishnan (1971) collected the larvae of Bregmaceros sp. from the southwest coast of India.

In the Arabian Sea only 22.9% of the stations were represented by this larvae whereas in the Bay of Bengal it was 31.7% (Tables 4,5,6). The percentage of larvae collected also was higher in the case of Bay of Bengal (5.1%) than in Arabian Sea (2.6%).

Bregmacerotid larvae were recorded in almost all months of the year (Tables 7,8; Fig. 20). The highest number of larvae from Bay of Bengal was collected in the month of August and from Arabian Sea during July.

Bregmacerotids were very widely distributed all over the Arabian Sea excluding the central and southern parts (Fig. 10). At the Kenya and Somali coasts the distribution was mainly in the offshore waters. At the northern region it continued up to Pakistan coast through the coastal and offshore waters of Arabia. In the Red Sea it was recorded only in the middle region. A major portion of the waters off Gujarat, coastal and offshore waters of Maharashtra, Karnataka and Kerala had larger concentrations of bregmacerotids. South and southwest of Indian peninsula had three larger concentrations of the larvae, of which one extending to south of equator. From 135 positive stations in the Arabian Sea 832 larvae were collected (Tables 4,6). From the oceanic waters off northern

Fig. 10. Distribution of larvae of Bregmacerotidae in the Arabian Sea and Bay of Bengal.

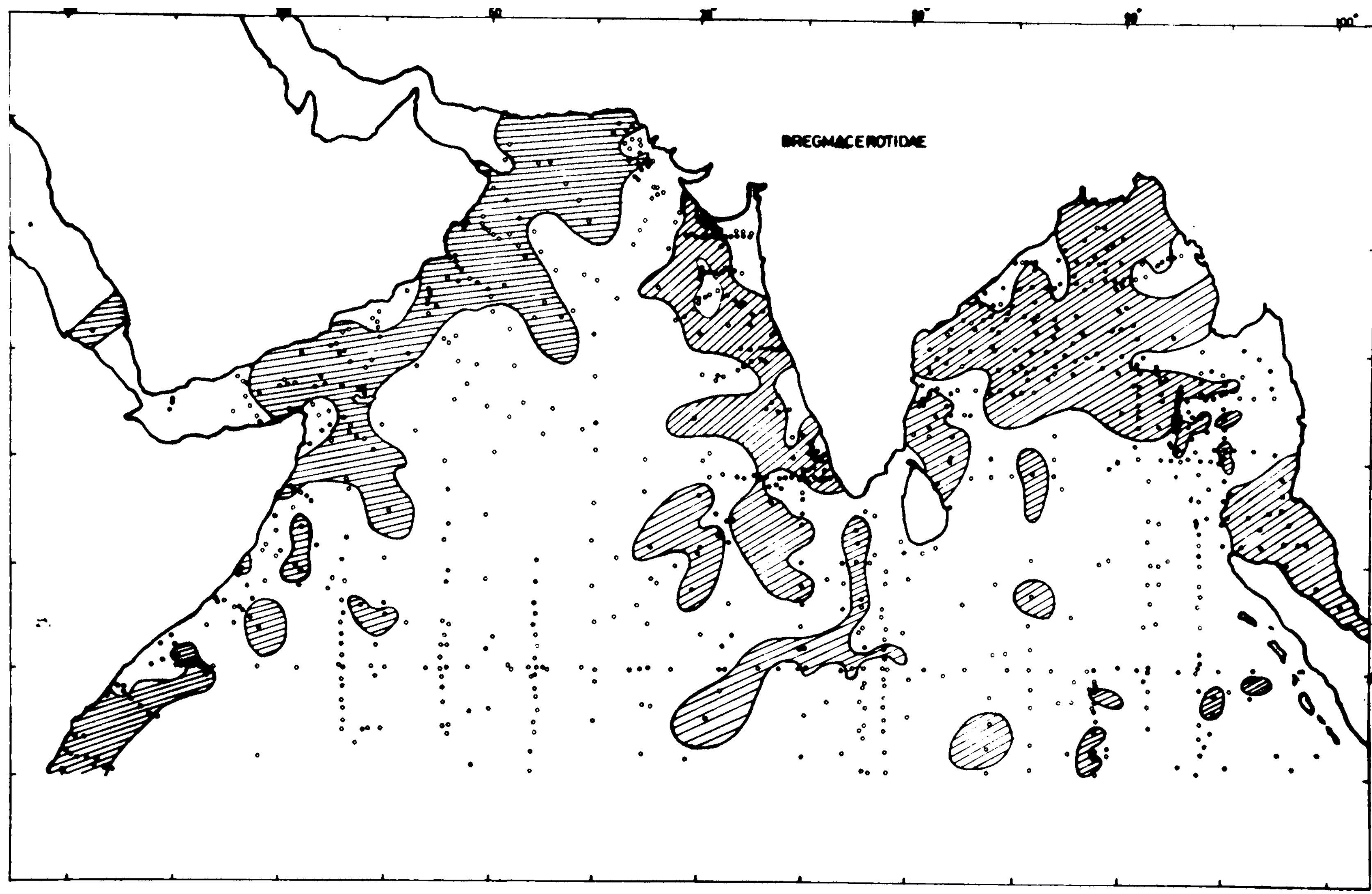


Fig. 10

Somalia and Arabia the highest number of 121 larvae per haul was recorded. These larvae had a wide tolerance of temperature. The surface temperature ranged between 17° and 30°, 33% of the larvae being from waters of surface temperature of 27°C (Table 16). 44% of the larvae were from waters of surface salinity of 35‰, though the range was 33 to 36‰.

The northern part of the Bay of Bengal exhibited wider distribution of the larvae than the southern part (Fig. 10). The coastal and offshore regions east and northeast of Sri Lanka showed an area of abundance extending up to the Tamil Nadu coast. North and northeast of these were much wider areas covering almost the entire northern part of Bay of Bengal, excluding certain areas off the coast of Orissa, Burma and Thailand. In the southern part of the Bay there were several smaller areas of concentration extending up to 5°S latitude. From 122 stations 850 larvae were caught (Tables 5,6). The highest number of larvae recorded per haul was 49, and it was from the waters north of Sumatra. The surface temperature of the positive stations ranged from 20° to 30°C and salinity from 28 to 34‰ (Fig.16). 42% of the larvae showed concentrations in the waters where surface salinity was 33‰.

FAMILY SYNGNATHIDAE

(Pl. III.2)

Postlarvae appear like miniature adults having the characteristic shape of body and fins. The whole bodyincluding fins are pigmented with heavier concentration of spots in the cephalic region. Postlarvae have osseous rings all over the elongated body including tail. Preanal part is about 50-70% of the body. Fins are very short. Ventrals are absent. The single dorsal is situated immediately above the vent. Intestine is long and straight. Osseous rings are found all over the body and tail in the postlarvae.

There is only very little information on the development of Indian pipe fishes. D'Ancona *et al*. (1931-1956) described the larvae in the Fauna e Flora Golfo di Napoli. Jones and Menon (1953) described two embryonic stages and a juvenile of *Ichthyocampus carce* from Mahanadi estuary and Chilka Lake. Balakrishnan (1959) collected larvae of *Syngnathus* sp. from the Kerala coast. Sudarsan (1968a) traced the early development of pipe fish *Syngnathoides biaculatus* collected from the Mandapam area. James (1970) recorded the early developmental stages of *Micrognathus brevirostris* from Gulf of Mannar.

Syngnathid larvae contributed to only less than 0.1% of the total larvae collected both in the Arabian Sea as well as Bay of Bengal and their distribution was coastal (Tables 4,5,6). Larvae were collected during March and September. The surface temperature of the stations ranged between 28.7°C and 29.4°C, whereas the salinity range was between 32.0‰ and 32.6‰.

FAMILY HOLOCENTRIDAE

(Pl. III.6)

Body is highly pigmented. Head is characterised by the presence of three conspicuous spines, one from the tip of snout directed forwards and others from the lateral margins of operculum one on either side directed backwards. Larva has the appearance of a zoea. Eyes are big. Alimentary canal is thick and coiled. Anal fin is with one spine.

McKenny *et al.* (1959) contributed to the life history of squirrel fish, *Holocentrus vexillarius* from Caribbean waters. Jones and Kumaran (1964 a) described the larval stages of 2 species, *Myripristis murdjan* and *Holocentrus* species from west coast of India. Mito (1967) studied the larvae of *Holocentrus* sp.

in the ecological notes on the planktonic fish larvae of Japanese waters. This small group contributed to only 0.1% and 0.07% respectively from the Arabian Sea and Bay of Bengal (Tables 4,5,6), of the total larvae collected.

In the Arabian Sea this group was recorded from the offshore and oceanic waters in small numbers (Tables 4,6). But, from the station 00°58'N - 71°15'E the highest number of 25 larvae per haul was collected. A total of 35 larvae were collected from the Arabian Sea. From 6 offshore and oceanic stations of Bay of Bengal only 15 larvae were collected (Tables 5,6). The highest number of 7 larvae per haul was recorded from the northern part of the Bay, 20°04'N - 88°24'E.

FAMILY MUGILIDAE

(Pl. III.7,8)

Larva is highly pigmented. Depth of body is medium. Mouth is small and oblique in position. Alimentary canal extends to 2/3 of the body length. There are 24 myomeres. Melanophores are scattered on head, sides of body and along the ventral parts. Eyes are large and pigmented. Two dorsals are present, second dorsal is far posterior and opposite to anal in position. Fins are with spinous rays.

Earlier works on larvae of mugilids are of Sanzo (1930) who studied the eggs and larvae of *Mugil cephalus* and *Mugil chelo*. D'Ancona *et al*. (1931-1956) described the eggs and larvae in the Fauna e Flora Golfo di Napoli. Bal and Pradhan (1946, 1947, 1951) collected larvae of *M. dussumieri*, *M. macrolepis*, *M. scheli* and *M. troschelli* from the Bombay waters. Anderson (1957, 1958) contributed to the study of the early development and larval growth of *M. curema* and *M. cephalus* of the south Atlantic coast of United States. Nair (1957 b) studied the eggs, embryonic development and a few of the newly hatched larvae of *Mugil cephalus* from Kayamkulam lake. Kuthalingam (1961) contributed to the study of the life history and feeding habits of *M. cephalus*.

Mugilidae larvae were represented in 0.5% and 0.8% of the stations in the Arabian Sea and Bay of Bengal respectively (Tables 4,5,6). They contributed to only less than 0.01% of the total catch in Arabian Sea and 0.02% in the Bay of Bengal. A total of only 3 larvae were collected from 3 stations from the waters off the coasts of Somalia, central Arabia and Maharashtra. From the Bay of Bengal only 4 larvae were collected from 3 stations from the offshore and oceanic waters west of Sumatra and east of Andamans. The surface temperature ranged between 25.7° and 28.9°C, and salinity between 35 and 35.8‰.

FAMILY SPHYRAENIDAE
(Pl. III.9,10)

Body is elongated, low and pigmented. There are 24 myomeres. Mouth is large with pointed snout. Alimentary canal extends to two thirds of the body length. Two dorsals are present. Second dorsal and anal are long equal and opposite in position. Spines are present on anal.

Bal and Pradhan (1945, 1946, 1947, 1951) recorded the occurrence of larvae of Sphyraena gello from Maharashtra waters. Orton (1955) studied the early developmental stages of California baracuda, S. argentea. Basheeruddin and Nayar (1962) made preliminary studies of the juvenile sphyraenids from the coastal waters of Tamil Nadu. De Sylva (1973) recorded 11 species of sphyraenids in the Indian Ocean.

Only 2 sphyraenidae larvae were collected which were from the northern and southern parts of Laccadive Islands in the Arabian Sea during December (Tables 4,6). The surface temperature of the station was 28.4°C and temperature, 33.8‰. Bay of Bengal collections did not record any larva of Sphyraenidae.

FAMILY SERRANIDAE

(Pl. VI.1, Fig. 11)

Larvae are of medium depth with about 24-25 myomeres. Preanal part is about 40-50% of the body. Snout is slightly produced with large mouth. Head is with spinous structures. Opercular spines are very prominant. Intestine is thick, coiled anteriorly extending up to the middle of body. Dorsal is single and fins are with spinous rays. In certain cases a few dorsal rays are longer with serrations. Anal is with 3 spines.

The earlier work on the developmental stages of Serranidae is by Fage (1918) from the Dana collections. D'Ancona *et al*. (1931-1956) contributed to the study of the serranid larvae in Fauna e Flora Golfo di Napoli. Bal and Pradhan (1945 b, 1946, 1947, 1951) recorded the occurrence of eggs and larvae of *Serranus diacanthus*, *Epinephelus diacanthus* and *E. leopardus* from the Bombay waters. Ukawa *et al*. (1966) studied the spawning habits and early life history of *Epinephelus akaara* of the Japanese waters.

Bay of Bengal recorded higher percentage of larvae (0.7%) and higher frequency of occurrence (9.1%) than in the Arabian Sea (0.2% and 6.4%) (Tables 4,5,6).

A total of 164 larvae were collected from 41 stations. They were present in almost all months of the year (Tables 7,8; Fig. 20).

The distribution was discontinuous and patchy in the coastal and offshore waters of Somalia, Gulf of Oman, southern, northern and central parts of Arabia (Fig. 11). Pakistan coast and northwest coast of India up to 15°N did not record any larvae in the collections. The coastal and offshore waters of Karnataka indicated the presence of serranid larvae. West and southwest of Sri Lanka showed a wider area of distribution. The oceanic distributions noticed were at two places in the equatorial zone. Out of the 37 positive stations only 65 larvae were collected (Tables 4,6). Six larvae per haul was the highest number recorded and it was from the waters off the northern Somali coast. The surface temperature of the stations ranged between 22° and 29°C and salinity 33 and 36‰ (Table 16). 69% of the larvae were collected from stations with surface salinity 35‰.

In the Bay of Bengal the higher abundance of larvae was noticed (Fig. 11) towards the eastern half of the Bay, especially places north and southeast of Andaman-Nicobar Islands, north, northwest and northeast of Sumatra, up to the coast of Thailand and west of

Fig. 11. Distribution of larvae of Serranidae in the Arabian Sea and Bay of Bengal.

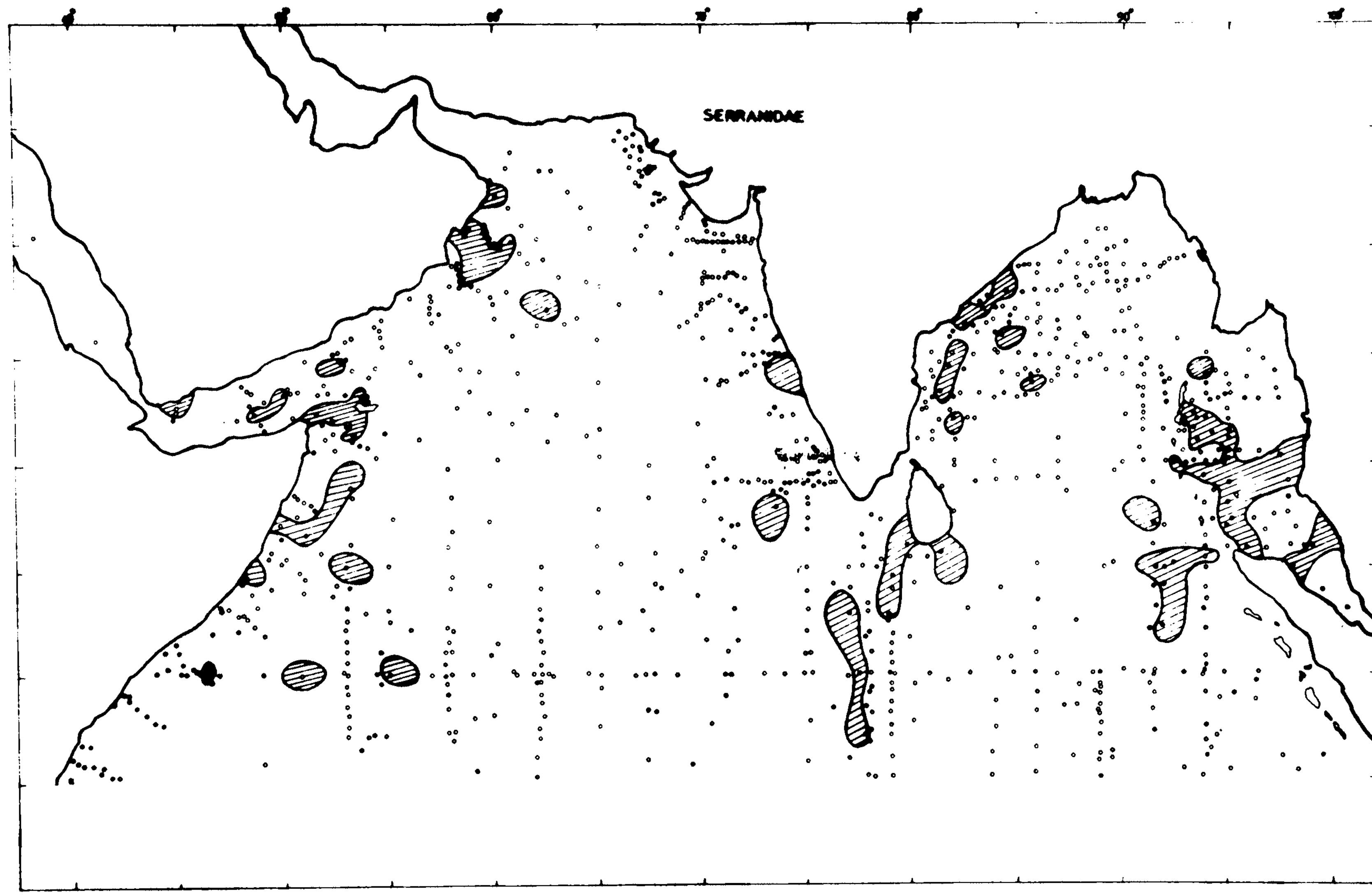


Fig. 11

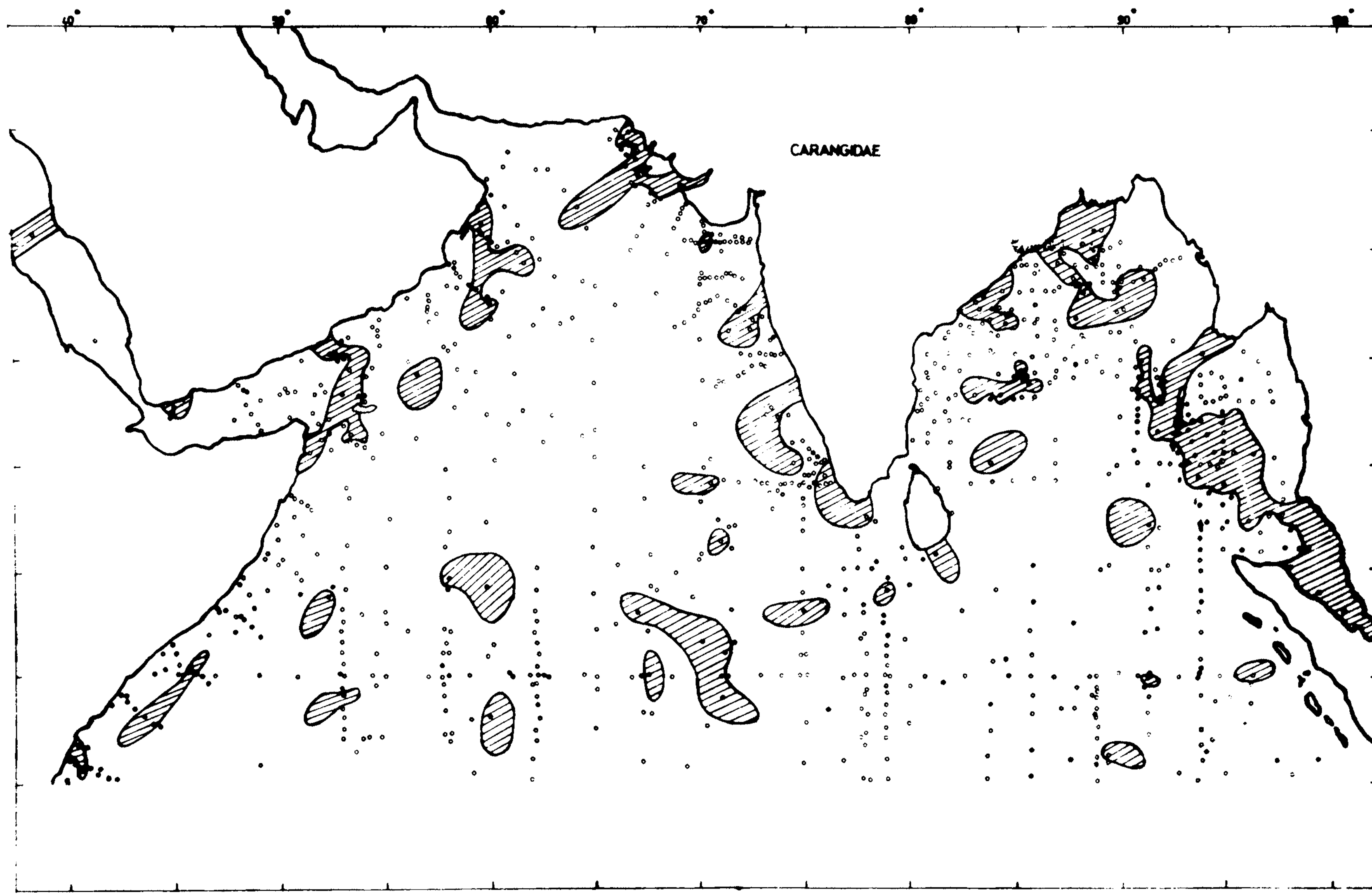


Fig. 12

Malaysia. Along the western half of the Bay, the important zones of occurrence of serranid larvae were south of Sri Lanka, off Tamil Nadu, Andhra Pradesh and Orissa. The central part of Bay of Bengal and major portions of northern and southern regions, the larvae were not recorded in the collections. There were only 33 positive stations from this area with 135 larvae (Tables 5,6). The area south of Andaman-Nicobar Islands recorded the highest number of 41 larvae per haul. The surface temperature of the stations ranged from 22° to 30°C and salinity ranged from 31 to 34‰ (Table 16). 45% of the larvae were from waters of surface temperature 29°C and 48% from salinity of 34‰.

FAMILY APOGONIDAE

Deep bodied larva with about 24 myomeres. Body tapers posteriorly with a conspicuous caudal peduncle. Two dorsals are present. Second dorsal and anal are opposite in position. Alimentary canal is short and coiled.

Fage (1918) dealt with this family while studying the shore fish larvae from "Dana". Bal and Pradhan (1947, 1951) reported the occurrence of Apogon wassinki

PLATE IV

1.	Coryphaenidae	9.1 mm
2.	Carangidae	3.3 "
3.	" "	5.6 "
4.	Sciaenidae	7.1 "
5.	Stromateidae	6.6 "
6.	Labridae	6.2 "

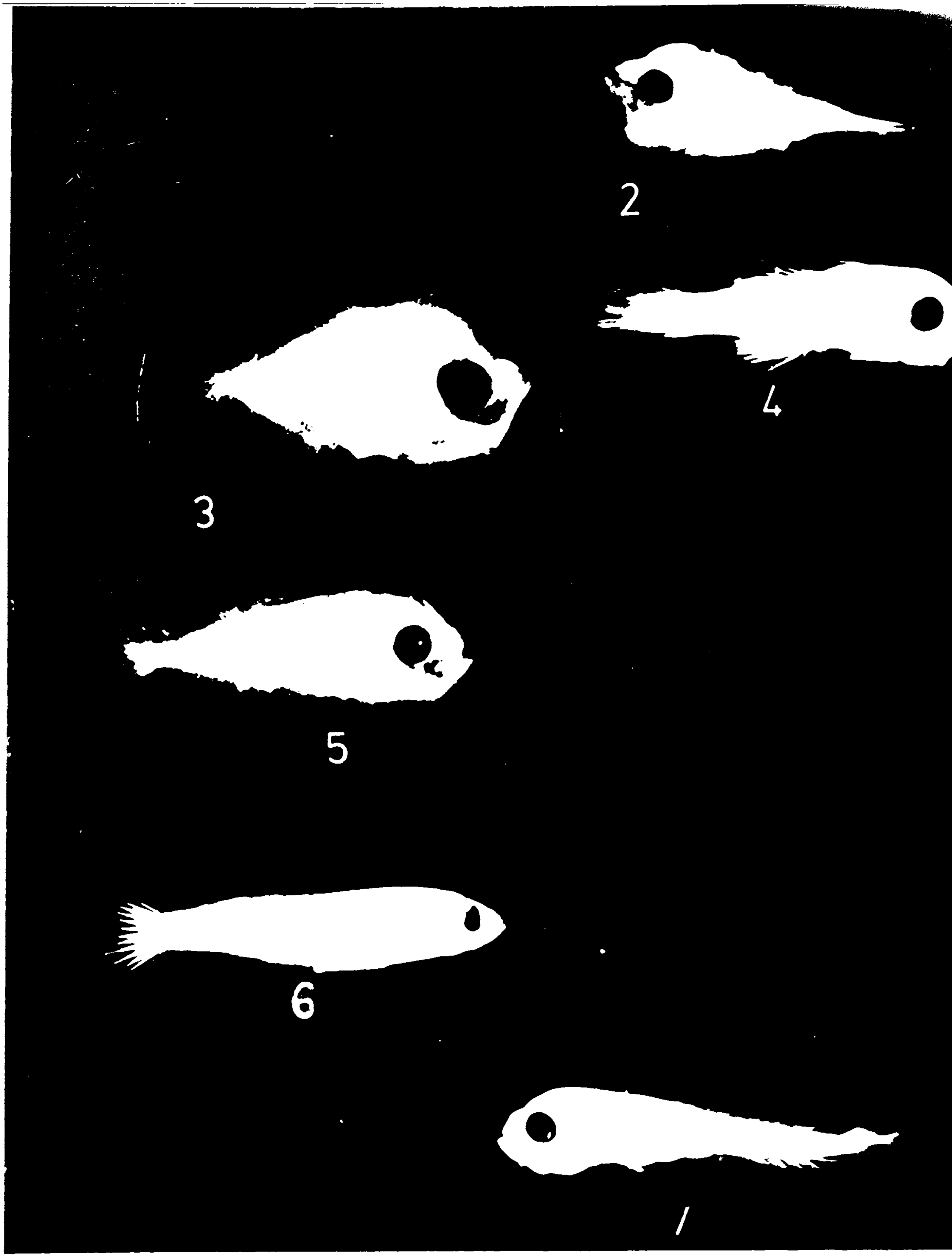


PLATE IV

from Bombay waters. Basheeruddin and Nayar (1962) recorded the larvae of *Apogon lateralis* and *A. frenatus* from the coastal waters of Madras.

The larvae of Apogonidae contributed to 0.02% of the total larvae collected and their frequency of occurrence was 0.5% in the Arabian Sea and 0.8% in the Bay of Bengal (Tables 4,5,6). They were collected in small numbers from the coastal stations of both the Arabian Sea as well as Bay of Bengal. In the Arabian Sea 7 larvae were recorded from 3 stations near the coasts of Arabia and northern Somalia. In the Bay of Bengal area the record was from the coastal waters of West Bengal and east of Andamans.

FAMILY CARANGIDAE

(Pl. IV.2,3; Fig. 12)

Deep bodied stubby larva with 24 vertebrae. Length of preanal part is about 40-60% of the body. Head is large with serrated dorsal ridge at the occiput. Opercular spines are large and strong. Body tapers posteriorly. Mouth is small and oblique. Vent is situated posterior to the middle of body length. Intestine is coiled. Pigmentation is seen on the head and body. Fins are with spinous rays. Two dorsals are present. Anal is with 2 spines.

Delsman (1926) studied the larvae of Caranx kura, C. macrosoma, C. cruminopthalmus, C. gallus and C. ciliares from the Java Sea. Hildebrand and Cable (1930) dealt with the development and life history of Decapterus punctuatus and Seriola dumerili from the vicinity of Beaufort. Gopinath (1946) studied the larval stages of Selar kalla from the plankton of the Trivandrum coast. Bapat and Prasad (1952) described the graded series of developmental stages of Caranx kalla. Ahlstrom and Ball (1954) contributed to the study of eggs and larvae of Trachurus symmetricus and discussed the distribution and abundance in the California waters. Bapat (1955) recorded the eggs and larvae of Caranx leptolepis from Gulf of Mannar. Chacko and Mathew (1955) studied the eggs and larvae of Decapterus russelli, Caranx cruminopthalmus, C. djedba and C. kalla from the southwest coast of India. Vijayaraghavan (1957) described the larvae of Decapterus russelli fom Madras coast. Kuthalingam (1959a) made studies on the life history stages of Megalaspis cordya and Caranx mate from Madras area. Basheeruddin and Nayar (1962) reported the occurrence of Megalaspis cordyla, Decapterus russelli, Selar mate, Ceranx carangua, Carangoides armatus, C. malabaricus, Atropus atropus, Chorinemus tol and Trachinotus blochi. Rao (1963) recorded the eggs and certain early larval stages of Caranx sp. from Porto

Novo coast. Subrahamanyam (1964, 1968) studied the developmental stages of larvae assigned to *Caranx hippos*, *C. carangus* and *Selar kalla*. Premalatha (1977) described the larval stages of *Chorinemus sanctipetri* from the shelf waters of the southwest coast of India.

Carangids were represented in 8.8% of the stations in the Arabian Sea and 13.2% in the Bay of Bengal (Tables 4,5,6). However, their total concentration in these two areas were only about 1.1% each of the total larvae collected. They were present in all months of the year, except February and September in the Arabian Sea and October and November in the Bay of Bengal (Tables 7,8; Fig. 20). Arabian Sea recorded the highest number of larvae of 141 per haul from a station 20°32'N - 59°55'E in the month of July. From the Bay of Bengal the highest number of larvae collected per haul was only 40. This record was from the area 11°49'N - 92°53'E during the month of March.

Carangid larvae were found distributed in the coastal, offshore and oceanic waters (Fi. 12). The stations at the central part of the Arabian Sea did not record any carangid larvae. In general the

Fig. 12. Distribution of larvae of Carangidae
in the Arabian Sea and Bay of Bengal.

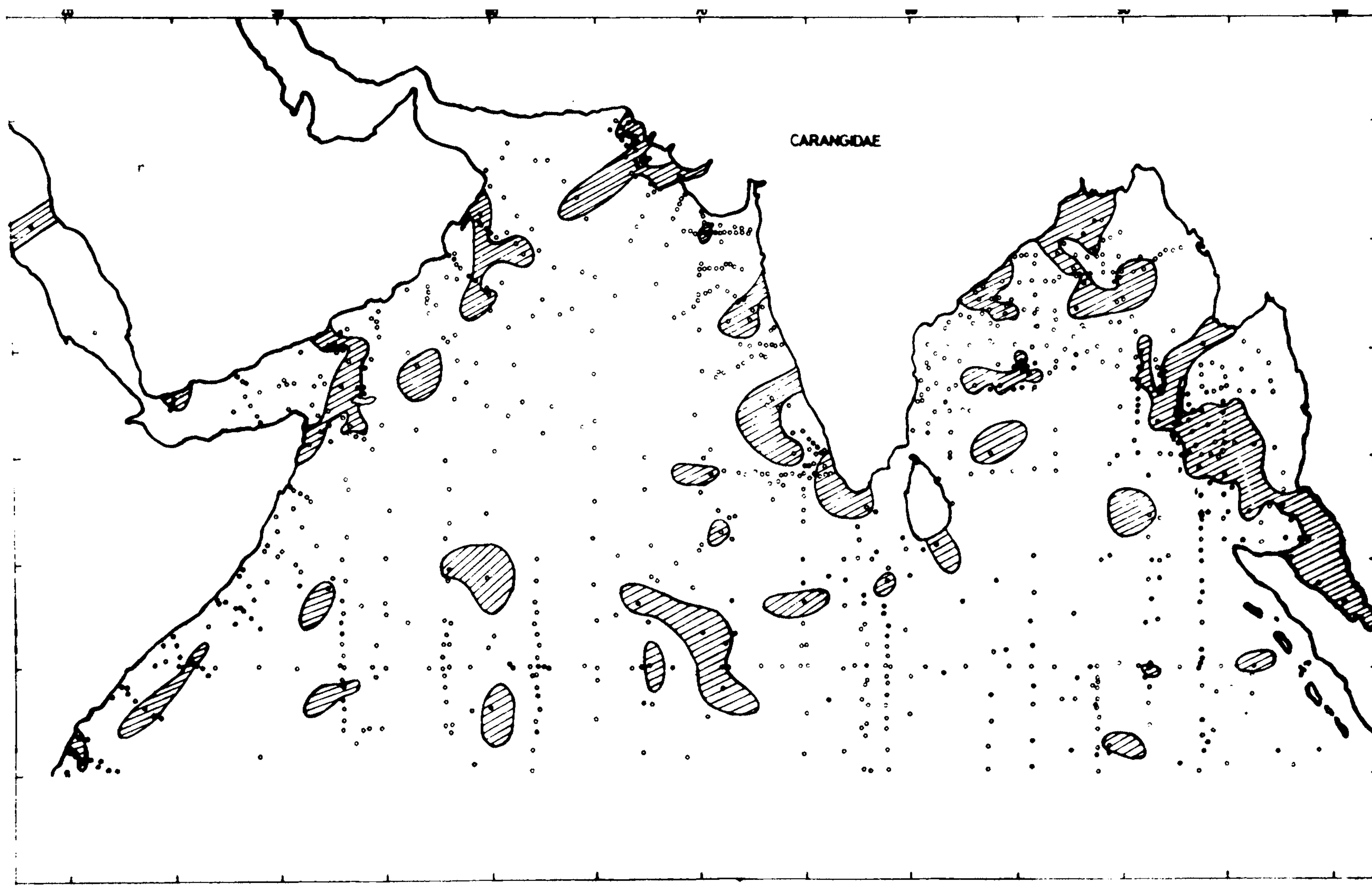


Fig.12

pattern of distribution was discontinuous and patchy. At the coasts of Kenya it was recorded only from a small area. The distribution in the offshore waters of Somalia was discontinuous and away from the coast. At the northern part of Somalia it was coastal as well as offshore. One of the stations in the Red Sea also showed the presence of larvae. The southern, northern and central Arabia had both coastal and offshore areas of abundance. Along the eastern boundary of the Arabian Sea, the waters off Pakistan, Gujarat, Maharashtra, Karnataka, and Kerala recorded the carangid larvae both in the coastal as well as offshore regions. The equatorial region also had a few stations, from where these larvae were recorded. From 53 stations 355 larvae were collected (Tables 4,6). The highest number of larvae (141/haul) recorded was from off the northern tip of Arabian coast. 35% of the larvae were recorded from waters of surface temperature of 23°C although the range was from 16° to 29°C (Table 16). The surface salinity ranged between 34 and 36‰, but 86% of the larvae was collected from waters of surface salinity 35‰.

In the Bay of Bengal also the major part of the concentration was in the offshore and oceanic regions (Fig. 12). At the southern part of Sri Lanka the distribution was coastal. The distribution of larvae at the coasts of Orissa and West Bengal extended to the offshore and oceanic regions also. Off Tamil Nadu and Andhra Pradesh the distribution was oceanic. Another big patch extending from the southwest coasts of Burma covering the northwest and southeast of Andaman-Nicobar Islands to the coasts of Malaysia and Thailand. At the equatorial region also a few stations indicated the presence of carangid larvae. 226 larvae were collected from 48 stations in Bay of Bengal with the highest number of 40 larvae per haul from the waters northeast of Andaman-Nicobar Islands (Tables 5,6). The surface temperature ranged from 22° to 30°C and salinity from 31 to 34‰ (Table 16). 45% of the larvae were collected from waters of surface salinity 32‰.

FAMILY CORYPHAENIDAE

(Pl. IV.1)

Body is elongated, highly pigmented with about 30 myomeres. Preanal part is about 40-50% of the body. Head is somewhat deep with tapering body. Opercular spines are present. Dorsal and anal are without spines. Number of rays are more than 40 in the dorsal and about 30 in the anal.

Gibbs and Collett (1959) made studies on the identification, distribution and biology of *Coryphaena hippurus* and *C. equisetes*. Mito (1960) studied the development of larvae of *C. hippurus*. No work on the larvae of this group is available from the Indian Ocean waters.

The percentage of larvae collected and the frequency of occurrence (0.5 and 3.2) for the Arabian Sea are were much higher than those in the Bay of Bengal (0.07 and 1.4). There were only 74 larvae collected from 17 stations from the former region (Tables 4,6). The highest number of 31 larvae per haul was collected from the offshore waters of northern Arabia (18°55'N - 58°12'E) in the month of July (Table 7). In the Bay of Bengal the record of larvae collected was only 14, the number of positive stations being 7. The highest number of larvae collected per haul was only 5. This was from a station northwest of Sumatra (08°46'N - 94°34'E) during April. They were collected from Arabian Sea in almost all months of the year, whereas in Bay of Bengal they were caught in March, April, June and September (Tables 7,8).

FAMILY SCIAENIDAE

(Pl. IV.4)

Larva is with deep head and tapering body. The number of myomeres are 25 in number. Mouth is oblique. A large space present between the vent and origin of anal with semi-transparent membrane only. This is an important identification character of the group. Two dorsals are present, the second one being longer than the first.

Welsh and Breder (1923) contributed to the life histories of 4 species of sciaenids of the eastern United State coasts. Hildebrand and Cable (1930) described the developmental stages and life history of 11 stages of Leiostomus xanthurus from the Beaufort area. Pearson (1941) studied the larval stages of Cynoscion regalisfrom 1.8 mm stage to 32 mm stage. Bal and Pradhan (1945, 1951) recorded eggs and larvae of Sciaena albida from the Bombay waters. Gopinath (1946) collected larvae and postlarvae of Johnius belengeri from Trivandrum coast. John (1950) reported the occurrence of Pseudosciaena from the Malabar coast while studying the pelagic fish eggs and larvae of that region. Pantulu and Jones (1951) studied the larval development of Gangetic whiting Pama pama. Nair (1952 b) recorded the postlarval stages of Pseudosciaena sp. in the Madras plankton.

The sciaenid larvae contributed to only a very negligible percentage (0.01%) (Tables 4,5,6) in the Arabian Sea as well as in the Bay of Bengal, and their frequency of occurrence also was low (0.5%).

FAMILY LABRIDAE

(Pl. IV.6, Fig. 13)

Laterally compressed deep body with about 30 myomeres. Preanal part is nearly 50-60% of the body. Mouth is terminal. Alimentary canal is more or less a straight tube. Only one dorsal is present. Dorsal and anal are equal and opposite. Fins are devoid of spinous rays.

Page (1918) described the larvae of Labridae collected from the Dana Expedition. Mito (1962) studied the Labrina from the Japanese waters. From the Indian Ocean region the description and distributional accounts of the larvae are not available.

Labridae contributed to 0.4% of the total larvae collected from Arabian Sea and 0.3% of that from the

Bay of Bengal (Tables 4,5,6) and the frequency of occurrence was 9.6% and 7.4% respectively. They occurred during all months of the year except May and November in the Arabian Sea, and February in the Bay of Bengal (Tables 7,8).

The areas of occurrence of these larvae in the Arabian Sea (Fig. 13) were found to be in the offshore waters of Kenya, south Somalia, Red Sea, central and northern Arabia along the western boundary of the Arabian Sea. Similar areas in the eastern side were noticed in the offshore and oceanic regions west of Karnataka and Kerala. There were also a few concentrations of the larvae south of Indian peninsula extending up to 5°S latitude. Along the equatorial zone the distribution pattern was wide and discontinuous. The collections from the central and northeastern part of Arabian Sea were devoid of this larvae. The total number of larvae collected from 56 stations was 132 (Tables 4,6). From 2 stations in the offshore waters of central Arabia (03°00'S - 53°00'E) and southern Somalia (14°15'N - 53°12'E) 13 larvae per haul were recorded. They were recorded in almost all months of the year (Table 7, Fig. 20). The surface temperatures of the stations were between 21° and 30°C, whereas the salinity ranged

Fig. 13. Distribution of larvae of Labridae
in the Arabian Sea and Bay of Bengal.

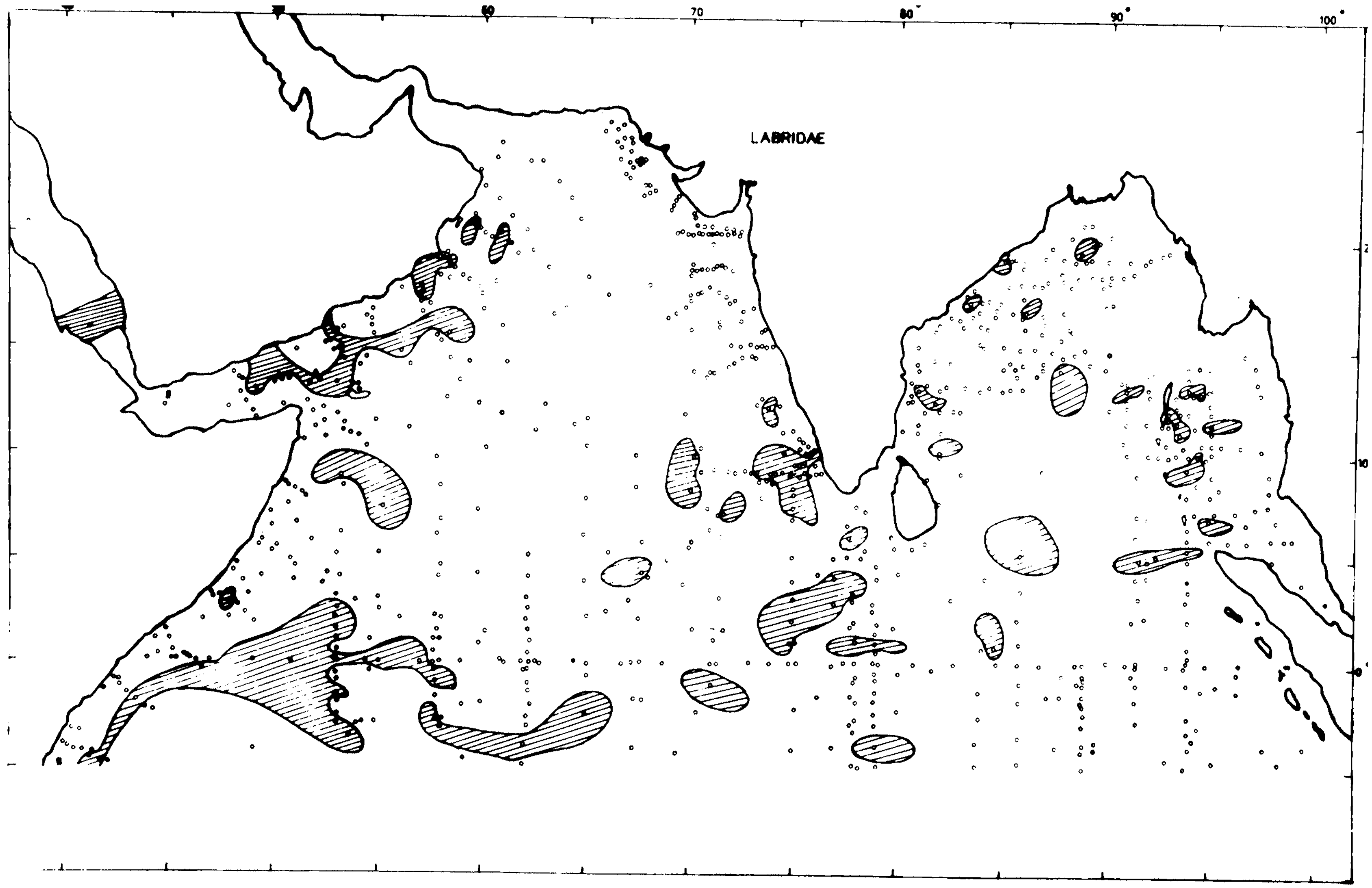


Fig. 13

between 32 and 36‰ (Table 16).

In the Bay of Bengal distribution of labrid larvae was mainly in the oceanic region (Fig. 13). From the offshore region they were recorded off the coasts of Tamil Nadu, Andhra Pradesh, and Orissa. There were several smaller areas of concentration in the central part of the Bay of Bengal from north to south up to equator. Another area of abundance was around Andaman-Nicobar Islands, and north and west of Sumatra. From 27 stations a total of 56 larvae were collected (Tables 5,6). The highest number of 11 larvae recorded per haul was from the waters northwest of Sumatra (09°21'N - 93°56'E). Larvae were collected in almost all months of the year (Table 8, Fig. 20). The surface temperatures of these stations were between 26° and 29°C and salinity between 31 and 35‰ (Table 16).

FAMILY CHAMPSODONTIDAE

(Pl. VI.8)

Larva has deep head and tapering body. Mouth is wide and oblique in position. Minute spines are present on the operculum. Two filamentous structures are developed from the opercular region one on either side.

PLATE V

1.	Trichiuridae	10.7 mm
2.	" "	41.7 "
3.	Gempylidae	7.8 "
4.	Thunnidae	5.4 "
5.	Scombridae	5.3 "
6.	Scomberomoridae	5.6 "
7.	Histiophoridae	12.1 "

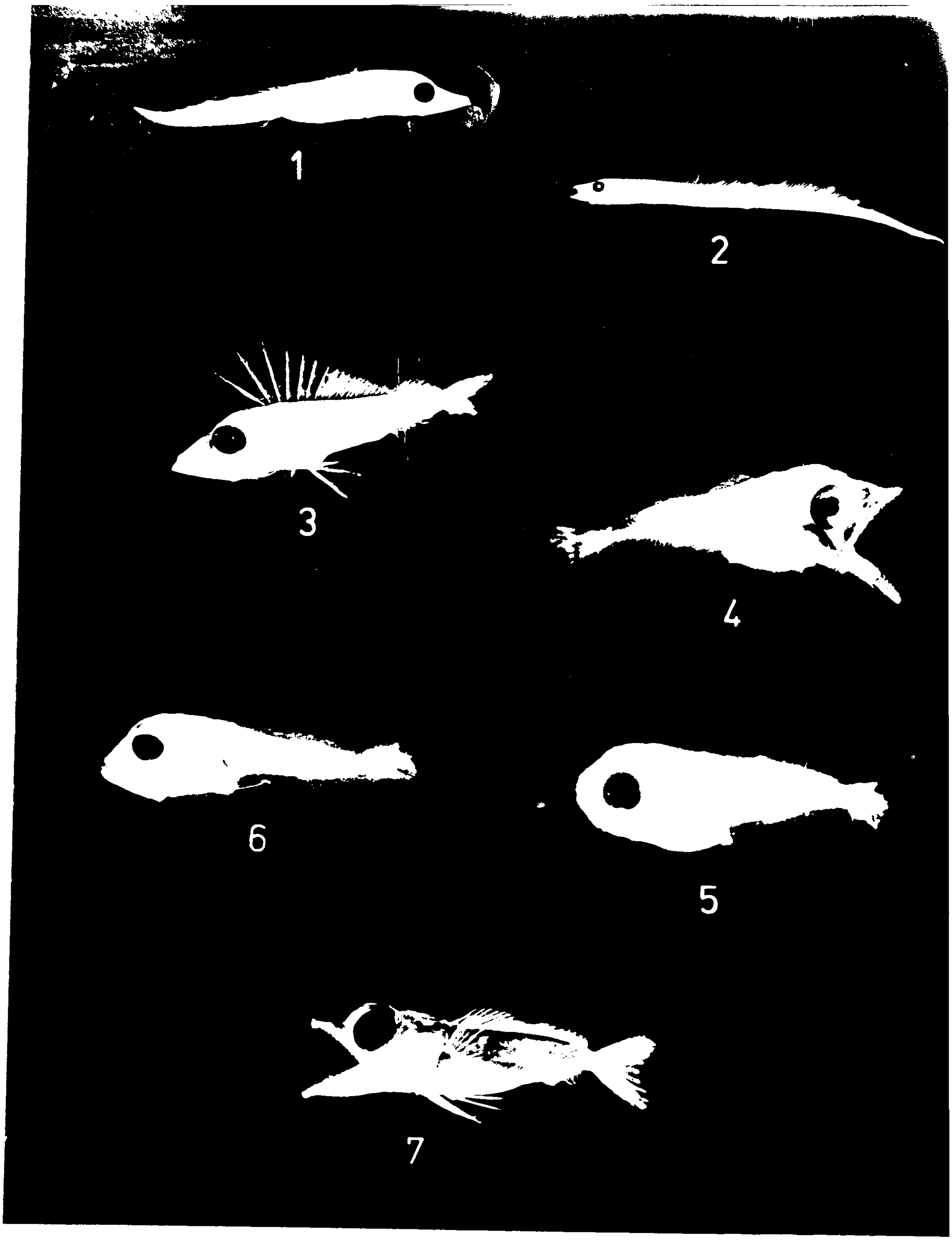


PLATE V

Mito (1962) studied the egg development and early larvae of the trachinoid fish, Champsodon snyderi from the Japanese waters. Nellen (1973 a,b) recorded the larvae of Champsodon sp. from the Gulf of Oman and illustrated its pattern of distribution. The present collection did not include any larvae from the Arabian Sea. From the Bay of Bengal two stations, north of Sumatra, 06°00'N - 98°38'E and 05°57'N - 96°56'E recorded 4 larvae each during August and September months(Tables 5,6). They were collected from night hauls. The surface temperature and salinity of the stations ranged between 28.6° and 29.3°C and 32.7‰ and 32.9‰ respectively.

FAMILY TRICHIURIDAE

(Pl. V. 1,2; Fig. 15)

Highly elongated laterally compressed body which tapers posteriorly to a point. Myomeres are about 150 in number. Preanal part is less than 30% of the body. Tip of head is beak-like. Alimentary canal is straight reaching middle of body. First three dorsal spines bear minute teeth-like process or serrations. Caudal is not forked. Dorsal is very long. Anal is with 2 spines.

Delsman (1926 c) described the early developmental stages of 4 species of Trichiurus from the Java Sea, *T. haumela*, *T. savala*, *T. glossodon* and *T. muticus*. Nair (1946) collected the eggs and larvae of *T. haumela* from the Madras plankton. Bapat and Bal (1950) recorded larvae of *T. savala* from Bombay waters. Chacko (1950) collected eggs and larvae of *T. savala* from Krusadi area. Jones (1967 a,b) dealt with 3 larval stages and juveniles of 3 species of *Trichiurus* from Indian waters.

The contribution of trichiurids in the Arabian Sea and Bay of Bengal were found to be 0.1% and 0.04% respectively of the total larvae collected (Tables 4,5, 6). The percentage of occurrence of larvae were 1.0 and 0.8 in the Arabian Sea and Bay of Bengal respectively. The highest number of larvae recorded was during the month of July. They were collected from May to August and also in November (Tables 7,8; Fig. 20). In the Bay of Bengal they were caught only in June and September.

Area off the south Somali coast, the region between the northern tip of Somalia and Socotra Island and off the central Arabian coast were the places from where the larvae of trichiurids were collected. Along the west coast of India trichiurid larvae were recorded only

Fig. 15. Distribution of larvae of Trichiuridae and Gempylidae in the Arabian Sea and Bay of Bengal.

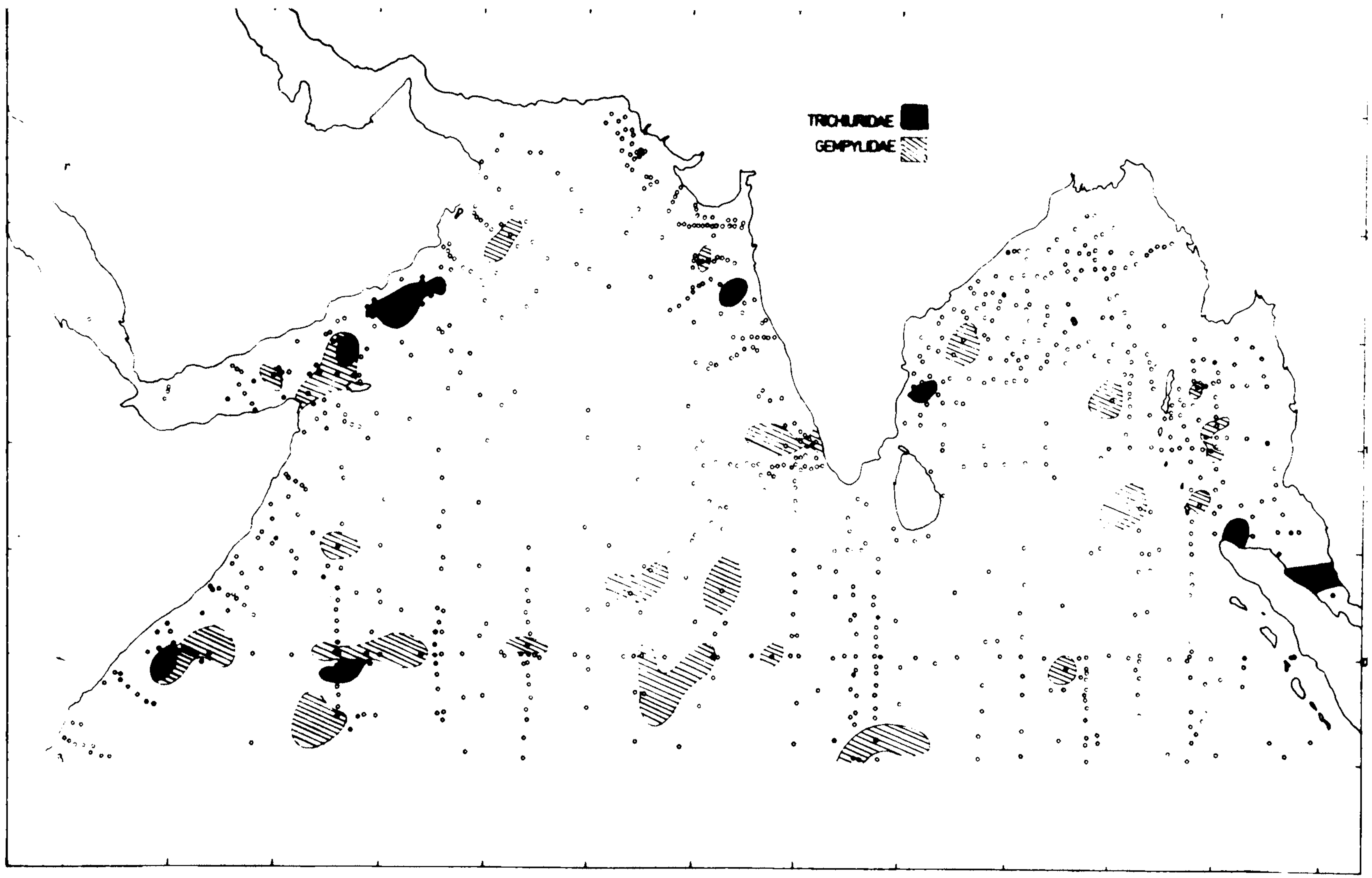


Fig. 15

from off Maharashtra coast. From the equatorial region also these larvae were collected. There were only 18 larvae collected from the Arabian Sea and the highest number of larvae collected (8 larvae per haul) was from off the southern Somalia coast (00°01'N - 45°25'E) (Tables 4,6). They were recorded from May to August and during November months (Table 7, Fig.20). The range of surface temperature was between 23° and 29°C and salinity between 35 and 36‰ (Table 16).

The record of trichiurids in the Bay of Bengal was found to be very scarce. Of the coasts of Andhra Pradesh this was collected from one of the stations. Other areas of occurrence were northern coast of Sumatra and also the strait of Malacca. The northern half of the Bay did not record any trichiurid larvae. Only 9 larvae were recorded from these areas (Tables 5,6). The highest number of 4 larvae per haul were collected from the waters north of Sumatra (06°00'N - 96°00'E). Larvae were collected only during June and September (Table 8, Fig. 20). The surface temperature of these stations was 29°C and salinity between 32 and 33‰ (Table 16).

FAMILY GEMPYLIDAE

(Pl.V.3, Fig. 15)

Larva has deep body with myomeres numbering about 100. Head is with pointed snout and large mouth having prominant teeth. Preanal part is less than 30% of the body. Alimentary canal is thick anteriorly and extending backwards to two-thirds of the body. Body is partially pigmented. Opercular spines are present on the head. Eyes are very big. Fins are with spinous rays.

, Jones (1960 a) described the early larval stages of Gempylus serpens from the Laccadive Sea. Voss (1954) studied the postlarval development of gempylids of the Florida current.

The number of larvae and frequency of occurrence in the Arabian Sea were much higher than those of the Bay of Bengal (Tables 4,5,6). The total percentage of larvae in the Arabian Sea was 0.2 and in Bay of Bengal 0.05. Similarly they were represented in 5.2% of the stations in Arabian Sea and 2.2% of the stations in Bay of Bengal. The highest number of larvae from the Arabian Sea was collected in the month of July. Larvae were recorded in all months of the year except

November (Tables 7,8; Fig. 20). In the Bay of Bengal they were collected from March to September except in July.

Among the areas of occurrence of gempylids (Fig.15) the equatorial region was found to be a dominant one. The pattern of distribution was discontinuous and patchy in the area between 5°S and 5°N latitudes. Off the coasts of Somalia and Saudi Arabia and a few stations in the Gulf of Aden were the places of occurrence along the western boundary of the Arabian Sea. At the eastern side they were noticed off the coasts of Maharashtra, Kerala and south of Indian peninsula at 5° latitude. There were only 31 positive stations and the total number of larvae collected was 48 (Tables 4,6). Five larvae per haul was highest record and it was from the waters off the northern Somalia. Larvae recorded almost throughout the year (Table 7, Fig. 20). The surface temperatures of the stations were between 24° and 26° whereas the salinity was between 34 and 36‰. (Table 16).

The distribution of gempylids in the Bay of Bengal (Fig. 15) was found to be exclusively oceanic. The places of their occurrence were off Andaman-Nicobar

Islands, northwest of Sumatra and a station at the equatorial region. From 13 positive stations only 16 larvae were collected from these areas (Tables 5,6). The highest number of larvae collected per haul was only 3 and it was from a station north of Sumatra (07°08'N - 91°31'E). Larvae were collected during March to September months (Table 8, Fig. 20). The surface temperature of the stations varied from 20° to 29°C, whereas the salinity was between 31 and 34‰ (Table 16).

FAMILY SCOMBRIDAE

(Pl. V.5, Appendix I)

Larva has deep body with 31 myomeres. Preanal part is about 30 to 40% of the body. Head is devoid of opercular spines. Eyes are big. Móuth is wide with ɕoiled intestine. Ventral part of the body is with a row of melanophores.

Earlier works on the larvae of this family in the Indian Ocean has been reviewed by the author (Peter, 1969 b), while describing the 3 very early stages of Rastrelliger larvae recorded from the Arabian Sea and Bay of Bengal (Appendix I). The later records of the larvae of Rastrelliger are of Silas (1974) collected from the southwest coast of India, Girijavallabhan and Gnanamuthu (1974) from the inshore waters of Madras and from the collections of the southwest coast of India, by the FAO/UNDP/Pelagic Fishery Prbject (Anon, 1974).

Only two larvae measuring 2.7 mm and 3.1 mm were recorded from the collections of the Arabian Sea, from stations 22°22'N - 60°05'E and 16°37'N - 41°00'E during November and December months. From Bay of Bengal only one larva was recorded measuring 5.3 mm during the month of August (Tables 4,5,6). All the three larvae were collected from the night hauls. The surface salinity range of the stations in the Arabian Sea was between 36‰ and 37‰ and temperature 28° and 29°C.

FAMILY THUNNIDAE

(Pl.V.4, Fig16, Appendix II)

Deep head with tapering body consisting of about 40 myomeres. Snout is pointed with wide mouth. Preanal part is about 30 to 40% of the body. Intestine is short and triangular in shape. Position of vent is near the middle of body. Eyes are big. Head, pectorals and dorsal are pigmented. Opercular spines are prominent. Two dorsals are present. Fins are with spines. Second dorsal and anal are equal and opposite.

Jones (1960 a,b) collected early larvae of *Katsuwonus pelamis* and *Neothunnus macropterus* from the Laccadive Sea. He also recorded (1961) early larvae and juveniles of *Auxis thazard*, *A. thynnoides*, *Sarda orientalis* and *Euthynnus affinis*. Matsumoto (1962) identified the early larval stages of *Kishinoella tonggol*, *Thunnus alalunga*, *T. orientalis* and *Parathunnus sibi*, from the Indo-Pacific. Gorbunova (1963) made studies on the larvae of scombroid fishes, *Thunnus albacares*, *T. alalunga*, *Parathunnus obesus*, *Katsuwonus pelamis*, *Euthynnus affinis*, *Auxis thazard* and *Gymnosarda unicolar* from the Indian Ocean. Jones and Kumaran (1963) studied the geographical and seasonal distribution of larvae of *Katsuwonus pelamis*, *Neothunnus macropterus*, *Euthynnus affinis* and *Auxis thazard* collected from the Indian Ocean by the Dana Expedition. Silas (1963 a,b) studied the distribution of eggs, larvae and juveniles of *Grammatorcynus bicarinatus* and *Sarda orientalis* in the Indo-Pacific and Indian Ocean regions. Ueyanagi (1969) made observations on the distribution of tuna larvae in the Indo-Pacific waters in relation to the spawning areas of Albacore, *Thunnus alalunga*. Williams (1963) prepared the synopsis of the biological data of *Auxis thazard* from the Indian Ocean. Gorbunova (1967) also contributed to the study of spawning localities and larvae of *Grammatorcynus bicarinatus*, *Thunnus albacares*, *T. obesus*, *Katsuwonus pelamis*, *Euthynnus affinis*, and *Auxis thazard*. Peter (1977) studied the distribution and abundance of tuna larvae in the Arabian Sea.

Thunnidae contributed to only 0.4% of the total larvae collected from the Arabian Sea and represented in 10.2% of the samples, whereas in the Bay of Bengal their contribution was 0.6% and frequency of occurrence 13.8% (Tables 4,5,6). In the Arabian Sea they were collected in all seasons of the year (Table 7, Fig.20). But the higher numbers of larvae were mostly collected in June-July months. February, March and April were the poor months for the larvae. About 28.8% of the stations had only one larva per haul each and 5.9% of the stations 2 larvae each. The highest number in the collections was 10, and it was recorded from central part of the Somali coast (01°28'N - 44°52'E). The next higher numbers (8-9 per haul) were from the northern region of the Arabian coast. Out of 74 stations which recorded tuna larvae 24 were day and 50 night stations. From the Bay of Bengal tuna larvae were collected during all months except November, December and February (Table 8, Fig. 20). 11.8% of the stations had only 1 larva each per haul, 10.9% of the stations had 2 larvae and 1.8% of the stations 3 larvae. Out of the 56 positive stations, 87 larvae occurred in the 43 night collections, and 25 larvae in 13 day collections.

Analysis of the species composition of the larvae revealed the presence of Auxis sp., Euthynnus affinis, Katsuwonus pelamis and Thunnus species like T. alalunga, T. obesus and T. albacares, both in the Arabian Sea and Bay of Bengal.

Arabian Sea showed that tuna larvae had a wide distribution in the coastal, offshore and oceanic waters (Appendix II, Fig. 16). The highest oceanic concentration was noticed in the equatorial region between 5°S and 5°N latitudes. They were in the form of wide patches. At the Kenya coast the distribution was in the offshore waters, whereas in the southern Somalia area they were mainly coastal. At the northern half of Arabian coast the larvae were collected both from coastal as well as offshore waters. They were represented in the collections from Red Sea also. The

Fig. 16. Distribution of larvae of Thunnidae
in the Arabian Sea and Bay of Bengal.

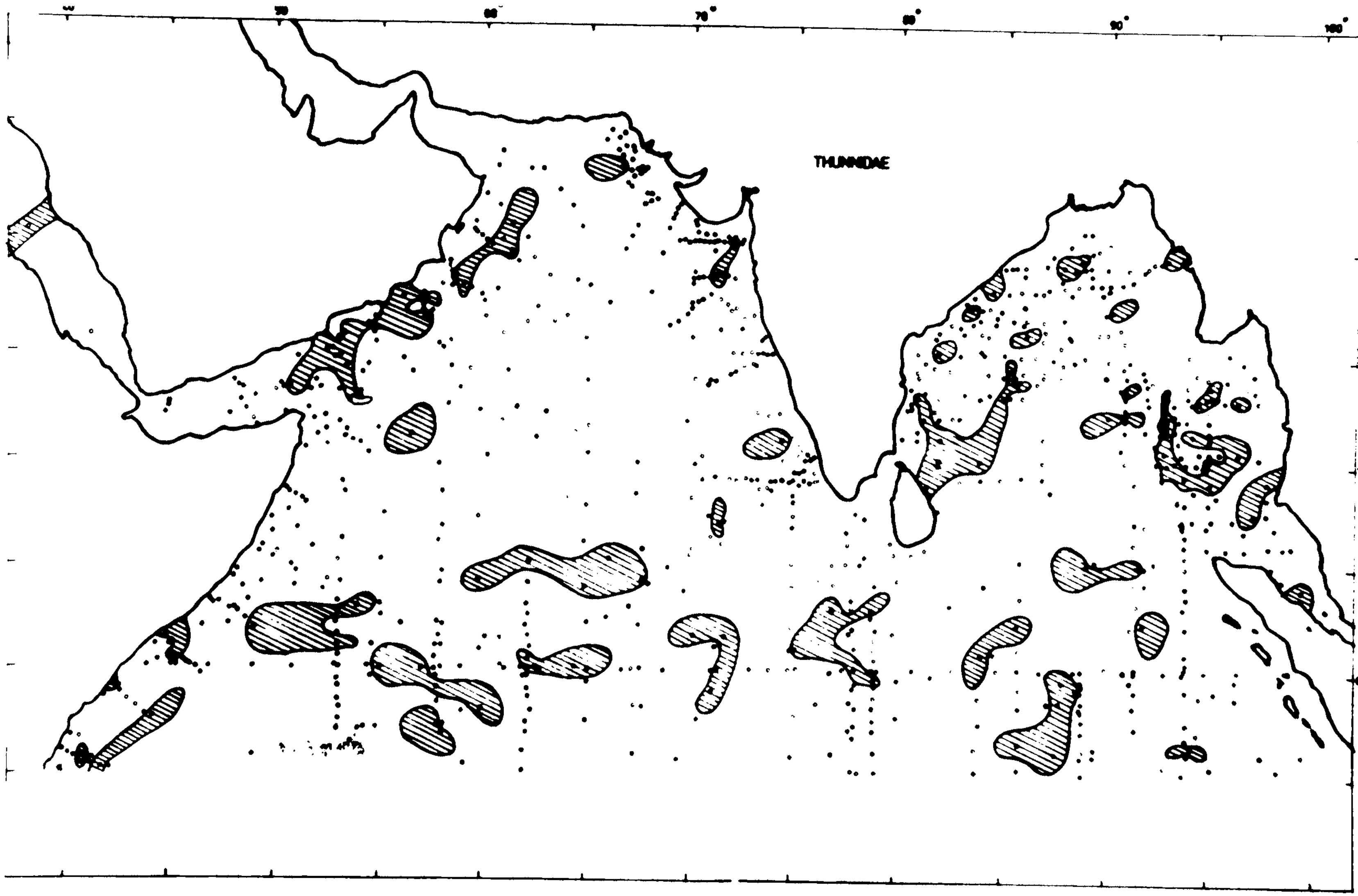


Fig. 16

pattern of distribution was in the form of isolated patches in the offshore waters of Pakistan, Gujarat, Maharashtra and Karnataka. The collections from the central part of Arabian Sea were devoid of tuna larvae. A total of 130 larvae were collected from 60 stations (Tables 4,6). The highest number of larvae per haul recorded was 10, from the coastal waters of southern Somalia (01°28'N - 44°52'E). The surface temperatures of the stations from where larvae were collected were from 23° to 30°C and salinities from 33 to 36‰. 62% of the larvae were from waters of salinity of 35‰ (Table 16).

In the Bay of Bengal the northeastern part of Sri Lanka was one of the larger areas of abundance extending from the coast to the offshore region as well as to the coastal Tamil Nadu and Andhra Pradesh. Several other smaller areas of concentration were also noticed both in the coastal and oceanic regions of the northern Bay of Bengal. There were a few major concentrations of tuna larvae around the Andaman Nicobar Islands too, of which the biggest one was found at the southeastern part. They were also recorded in the collections from the west coast of Thailand and east coast of Sumatra in small numbers. In the equatorial region there were a few places of abundance including the areas within the 5°N and 5°S latitudes. 126 larvae were collected from 50 stations (Tables 5,6). The highest number of 11 larvae per haul were recorded from the waters east of Andamans (10°00'N - 93°30'E). The surface temperatures of the stations ranged from 27° to 30°C, and 60% of the larvae were recorded from waters of temperature of 29°C. The range of salinity was between 30 and 34‰, and 52% of the larvae were found in waters of surface salinity of 33‰ (Table 16).

FAMILY SCOMBEROMORIDAE

(Pl. V.6, Fig. 17)

Larvae with medium depth of body, but tapering posteriorly. Body is with about 50 myomeres. Pre-anal part is approximately 30-40% of the body. Snout is beak like, mouth wide with minute teeth, opercular spines are conspicuous. Pigmentation is prominant on head and ventral part of the body. Eyes are big. Intestine is coiled. Two dorsals are present with spinous rays. Second dorsal and anal are equal and opposite.

Delsman (1931) described the early larvae of *Cybium guttatum* from the Java Sea. Munro (1942) studied the eggs and larvae of *Scomberomorus commersoni* of the Australian waters. Vijayaraghavan (1955) reared the eggs, larvae and juveniles of *Scomberomorus guttatus* in the laboratory which were collected from the plankton of Madras area. Basheeruddin and Nayar (1962) recorded the occurrence of juveniles of *Scomberomorus commerson* and *S. guttatus* from the coastal waters of Madras. Jones (1962) studied the larvae and juveniles of *S. guttatus* and *S. commerson* collected from Indian waters and (1967) reviewed the life histories of 3 species. Jones and Kumaran (1964) studied the eggs and larvae of *Scomberomorus guttatus* and *S. commerson*. Matsumoto (1967) dealt with the morphology and distribution of larval wahoo, *Acanthocybium solandri* in the central Pacific.

Arabian Sea and Bay of Bengal contributed to more or less the same percentage of larvae (0.4 and 0.3) of the total (Tables 4,5,6). But the frequency of occurrence was more in Bay of Bengal (5.5%) than in the Arabian Sea (3.7%). The larvae were collected from the Arabian Sea during the period from May to September. Maximum numbers were in the June-July months and the minimum in December-January(Table 7,Fig.20).

From Bay of Bengal higher number of larvae were caught during May and August and minimum in the October-November months.

The distribution of this group in the Arabian Sea was mainly near the land masses and offshore waters (Fig. 17). Along the western boundary of the Arabian Sea the larvae were recorded from the offshore waters of Kenya, northern and southern Somalia, north of Socotra Island and northern Arabian coast with a few oceanic stations. On the eastern side the larvae recorded were from the offshore stations of Karachi, Maharashtra and southwest of Kerala. The central part of Arabian Sea did not record any scomberomorid larvae. From 22 stations 122 larvae were collected (Tables 4,6). One of the hauls from the offshore waters of northern Arabian (19°34'N - 61°14'E) recorded 40 larvae. The surface temperature of the stations ranged from 22° to 29°C and salinity 34 to 36‰ (Table 16).

In the Bay of Bengal also the distribution was found to be coastal and offshore (Fig. 17). The major areas of concentration were the central part of the Bay towards the north, south, southeast of Andaman-Nicobar Islands. Only 62 larvae were collected from 20 stations (Tables 5,6). The highest number of larvae

Fig. 17. Distribution of larvae of Scomberomoridae in the Arabian Sea and Bay of Bengal.

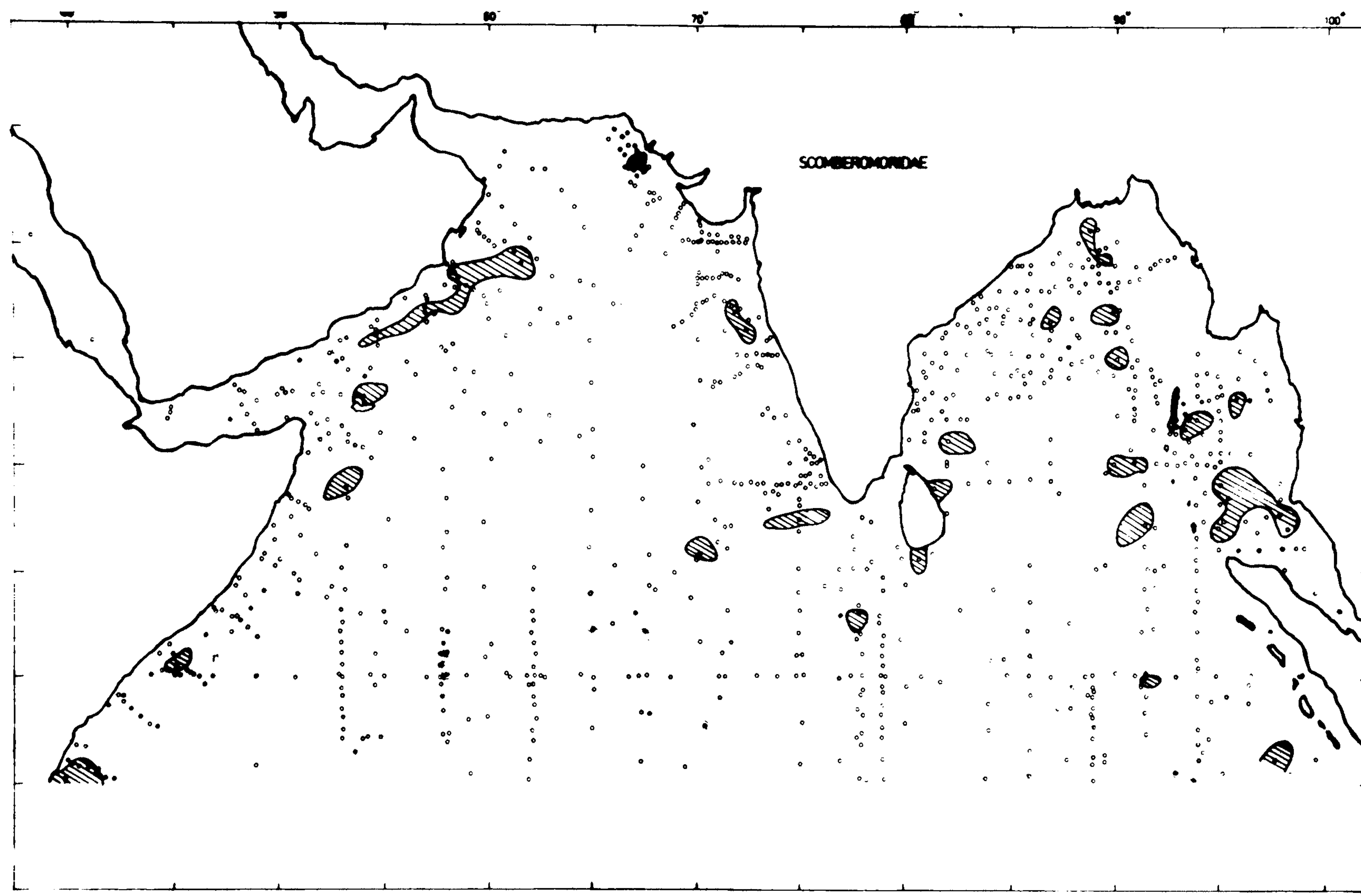


Fig.17

recorded per haul was 10, and it was from the waters south of Sri Lanka (05°42'N - 80°42'E). The range of surface temperature of the stations were between 20° and 30°C, whereas that of salinity 31 and 34‰. (Table 16).

FAMILY HISTIOPHORIDAE

(Pl. V.7)

Short deep bodied zoea type larvae with 24 myomeres. Preanal part is about 50% of the body. Larvae are characterised by their large head, mouth and eyes, long pterotic and preopercular spines with serrated edge. Serrations are also noticed along the edge of the orbital crest and lower jaw. Body is highly pigmented. Jaws are with strong teeth. Intestine is short. Two dorsals are present. Histiophorid larvae particularly those under 10 mm length is very difficult to identify because of their close resemblence in their morphological characteristics. Systematics of this family are still confused largely due to lack of adequate size series of species.

Identification of larvae is facilitated by the data given by Yabe (1953), Gehringer (1956), Jones (1969 a), Jones and Kumaran (1964 b), Tsi-Gen and

Klawe (1960) and Ueyanagi (1964). It appears that the sail fish of the Pacific and Indian Oceans comprise only a single species, _Istiophorus gladius_ (Jones and Silas, 1955). The Dana during her voyage in the Indo-Pacific collected 55 larvae of _I. gladius_ of length 3.82 - 21.75 mm of which all except 3 were from Indian Ocean (Jones and Kumaran, 1964 b). _I. gladius_ is abundant in the tropical seas, but has rather limited distribution range than marlins and sword fishes. Balasubrahmanyam (1973) recorded two larvae of _Istiophorus_ sp. from Bay of Bengal.

In the Arabian Sea histiophorids were represented by only 0.3% of the samples and in Bay of Bengal 0.5% (Tables 4,5,6). They contributed to 0.01% of the total larvae in the Arabian Sea as well as Bay of Bengal.

The larvae were collected from 2 stations, one from the offshore waters of northern Arabia and the other from the northern tip of Somalia. One of the stations (19°55'N - 60°48'E) recorded the highest number of 30 larvae per haul. From Bay of Bengal 3 larvae were collected from 2 stations (oceanic) (12°17'N - 93°21'E) and 18°54'N - 88°37'E). January March and July were the months during which period the larvae were collected (Tables 7,8), thus indicating the possibility of their spawning at that time.

The Dana material included 31 histiophorix larvae from the eastern Indian Ocean during the months of September and October, and 21 specimens from the western Indian Ocean near Madagascar during December-January months. Jones and Kumaran (1964 b) infer that the warmer regions of the eastern and western Indian Ocean are specially favourable for the reproduction of the species.

FAMILY CALLIONYMIDAE

(Pl. VI.6,7; Fig. 14)

Body somewhat cylindrical and sometimes slightly swelled, tapering posteriorly with about 20 myomeres. Preanal part is about 40-50% of the body. Head is with small mouth and large eyes. Two dorsals are present. Second dorsal and anal are long and opposite in positions.

Fage (1918) contributed to the study of the larval stages of Callionymidae. Jones and Menon (1953) studied the breeding habits and development of *Callionymus fluviatilus*. Jones and Pantulu (1958) made studies on the larvae and juveniles of *Callionymus melanopterus* of the waters of Bengal and Orissa coasts.

Fig. 14. Distribution of larvae of Callionymidae in the Arabian Sea and Bay of Bengal.

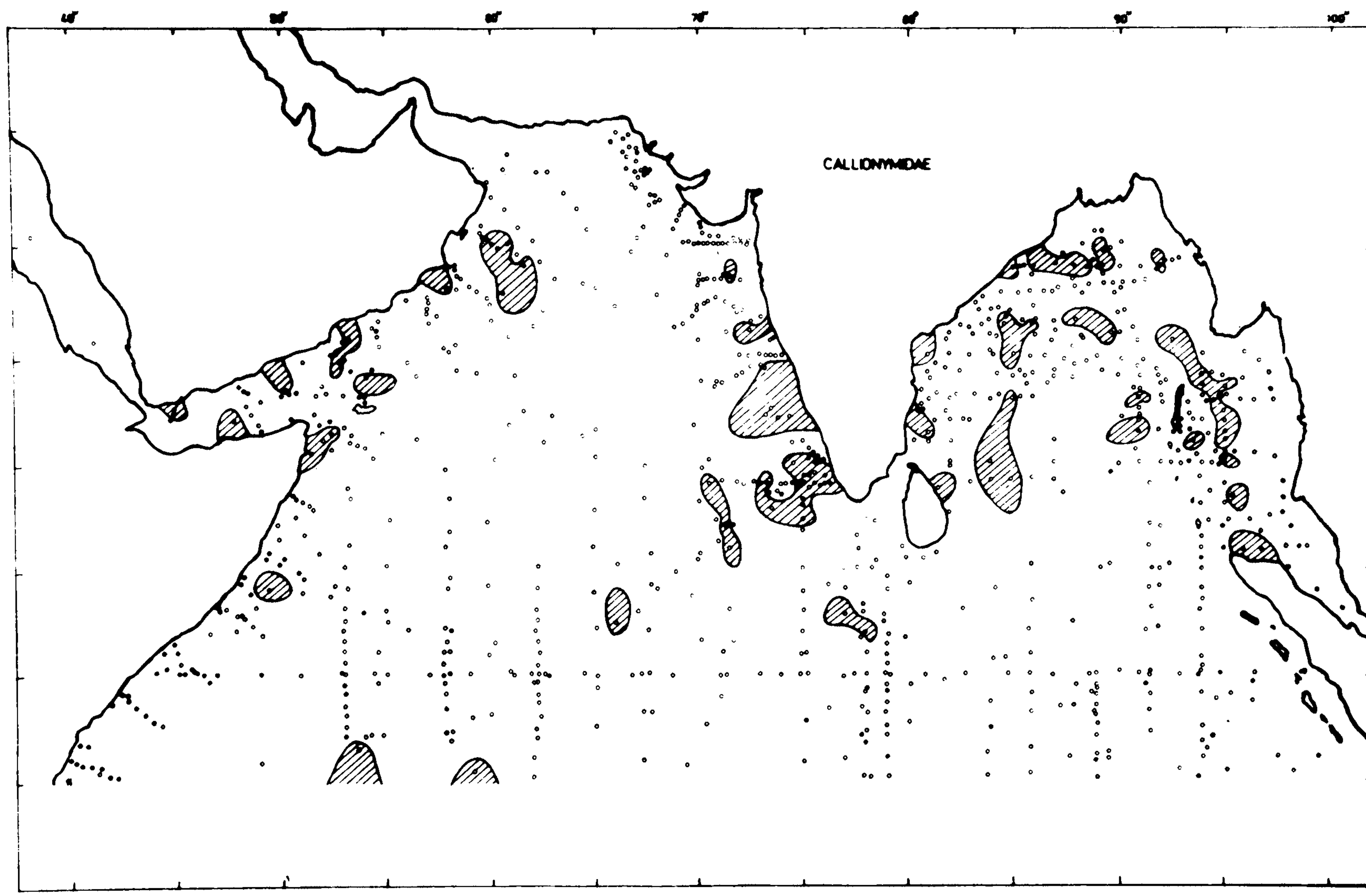


Fig. 14

Bay of Bengal recorded a higher frequency of occurrence of larvae (10.8%) than in the Arabian Sea (8.1%) (Tables 4,5,6). The number of larvae collected also was higher in the Bay of Bengal (0.5%) than in the Arabian Sea (0.3%). They mostly occurred in large numbers.

The concentration of this group (Fig. 14) was in small isolated patches in the coastal and offshore waters of Somalia, Gulf of Aden, Arabian coast, Gujarat, Maharashtra and Karnataka. The larvae were abundant in the coastal, offshore and oceanic regions off Kerala. Other oceanic concentrations of larvae were recorded south and southwest of Indian peninsula, along the equatorial zone, along 5°S between 50° and 60°E. From the Arabian Sea the highest number of 11 larvae per haul was recorded from the offshore waters of the northern Arabia (19°02'N - 61°45'E). A total of 119 larvae of callionymids from 40 stations were collected (Tables 4,6). They were recorded throughout the year (Table 7, Fig. 20). The surface temperature of the stations were found to be between 34° and 36°, whereas the salinity ranged between 17 and 30%. (Table 16).

Callionymidae had a wide oceanic distribution (Fig. 14) in the northern half of Bay of Bengal. Coastal areas northeast of Sri Lanka, off Andhra Pradesh, Orissa

PLATE VI

1.	Serranidae	4.5 mm
2.	Gobiidae	4.3 "
3.	" "	6.6 "
4.	Scorpaenidae	2.9 "
5.	" "	4.7 "
6.	Callionymidae	5.4 "
7.	" "	5.4 "
8.	Champsodontidae	4.5 "
9.	Acanthuridae	3.6 "
10.	Dactylopteridae	
11.	" "	

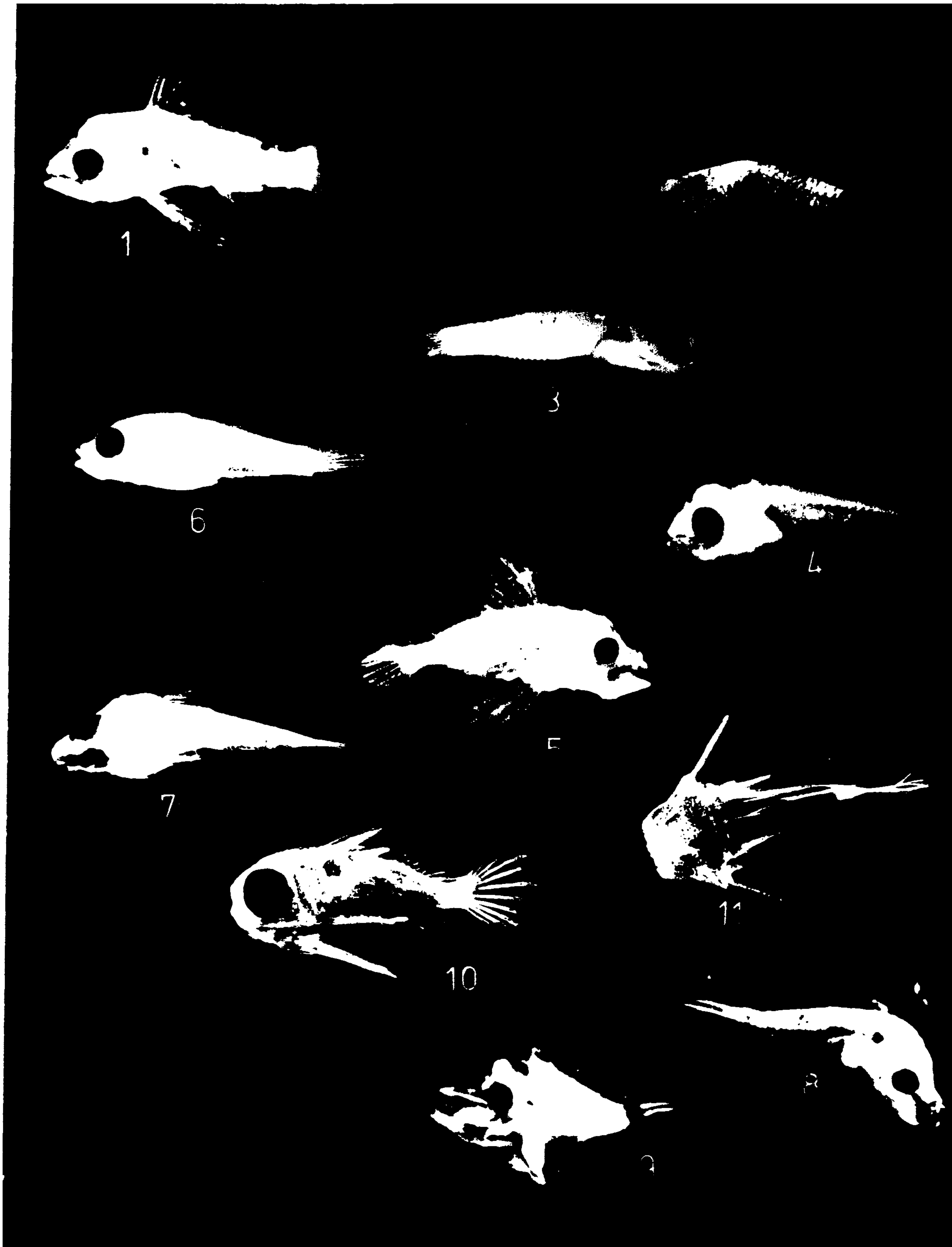


PLATE VI

and northern Sumatra also recorded these larvae. The wider oceanic distributions were noticed off the north-east coast of Sri Lanka, central part of Bay of Bengal and around the Andaman-Nicobar Islands. At the southern half of Bay of Bengal particularly the equatorial region the stations were found to be devoid of these larvae. There were only 38 positive stations from the Bay of Bengal area and the number of larvae collected was 110 (Tables 5,6). The highest number of larvae recorded (33 larvae per haul) was from the northern Bay of Bengal (19°22'N - 89°13'E). They were recorded almost throughout the year (Table 8, Fig. 20). The surface temperature of the stations ranged between 25° and 30° and salinity 28 and 34‰ (Table 16).

FAMILY ACANTHURIDAE

(Pl. VI.9)

Deep transparent body tapering anteriorly and posteriorly, snout is prolonged into a beak like structure. Margin of operculum and lower jaw are serrated. Dorsal and anal are long with almost equal number of rays. First dorsal ray and anal ray are transformed into large spines.

Delsman and Hardenberg (1934) discussed the larval stages of *Acanthurus* sp.in the notes on fish eggs & larvae of Java waters. Basheeruddin and Nayar (1962) recorded the occurrence of postlarvae of *Acanthurus matoides* from coastal waters of Madras. Nellen (1973b) illustrated three types of acanthurid larvae from the Gulf of Aden, Somali coast, off Cochin and off Mangalore. The present collection included only one larva from a station off Cochin (09°84'N - 74°00'E) from a day haul during November. The surface temperature and salinity of the station were 29.4°C and 34.4‰ respectively.

FAMILY STROMATEIDAE

(Pl. IV.5)

Stromatid larvae are deep headed with tapering body. Preanal part is about 50-60% of the body. The larva has 24 myomeres. Mouth is oblique and small.Head and body are pigmented. Opercular spines are feeble or absent. Alimentary canal extends up to the middle of the body. Intestine is coiled. Two dorsals are present. Second dorsal and anal are equal and opposite with more than 40 rays.

Pearson (1941) described the larval stages of stromatoids from Chesapeake Bay. Basheeruddin and Na-

(1962) studied the juvenile stromateids of the Madras coast, Stromateus sinensis, Parastromateus niger. Kuthalingam (1967) made studies on the maturity, spawning and young ones of silver pomfret Pampus argenteus. Mito and Senta (1967) described embryonic development and early larvae of the above species from Japanese waters.

The frequency of occurrence of stromateid larvae was much higher in the Bay of Bengal (11%) than in the Arabian Sea (5.9%) (Tables 4,5,6), although the percentage contribution was almost the same in both the areas. 68 larvae per haul was the highest record from the Arabian Sea (00°01'N - 45°25'E) which was during the month of July (Table 7, Fig. 20). From the Bay of Bengal the highest number of larvae collected per haul was only 26, which was from 12°36'N - 80°40'E during the month of June (Table 8).

FAMILY GOBIIDAE

(Pl. VI.2,3; Fig. 18)

Elongated low bodied larva with 33-34 myomeres. Preanal part is about 40 to 50% of the total length. Snout is tapering and mouth oblique. There is no spinous structures on the head. Alimentary canal is straight and air bladder is conspicuous. First dorsal is short, whereas the second dorsal and anal are equal and opposite.

Delsman (1926) described the postlarvae of *Gobius* sp. from Java Sea. Aiyar (1933 , 1935) studied the breeding and development of *Acentrogobius neilli*. Bal and Pradhan (1946, 1947, 1951) recorded the larvae of *Gobius* species from Bombay waters. From the Trivandrum coast postlarval stages of *Gobius* sp. were studied by Gopinath (1946). Jones and Menon (1953) made studies on the breeding habits and developmental stages of *Paragobiopsis ostreicola*. Dotu (1954, 1955) described the larvae and juveniles of several species of gòbids from the Japanese waters. Nair (1961) studied the development and early embryology of *Stigmatogobius javanicus*.

The contribution of gobiid larvae in the Arabian Sea was 1.2% and in the Bay of Bengal 0.8% of the total larvae collected from the respective areas (Tables 4,5,6). The frequency of occurrence was higher in the Bay of Bengal (14.6%) than in the Arabian Sea (13.2%). The highest record of larvae per haul both in the Arabian Sea and Bay of Bengal were from coastal stations. They were collected in almost all months of the year, the highest abundance being in March (Tables 7,8; Fig. 20).

Along the coastal and offshore waters of Kenya, Somalia, Saudi Arabia and central part of Red Sea, a discontinuous pattern of distribution was noticed (Fig. 18). But the distribution along the Indian side from Kutch to Kerala was a more or less continuous one except for the small gap at the coastal Karnataka region. There were a few more oceanic concentrations west and south of Indian peninsula, and in the equatorial region between 50° and 60°E latitudes. No gobiid larva was collected from the central part of Arabian Sea, from north to south. Altogether there were 78 positive stations which recorded 373 gobiid larvae (Tables 4,6). The highest number of larvae recorded (32 larvae per haul) was from Karnataka coast (10°14'N - 75°43'E). Gobiids tolerated a wide range of temperature (17° to 30°C), 35% of the larvae being from surface temperature of 29°C. The salinity range was from 33 to 36‰.(Table 16).

In the Bay of Bengal the major areas of abundance of gobiids were noticed at the head of the Bay, north-eastern part of Sri Lanka, and area east of Andaman-Nicobar Islands. The other areas of abundance were west of Tamil Nadu, off Andhra coast, strait of Malacca and west of Sumatra. A total of 159 larvae were collected from 53 stations (Tables 5,6). 25 larvae per haul was

Fig. 18. Distribution of larvae of Gobiidae in the Arabian Sea and Bay of Bengal.

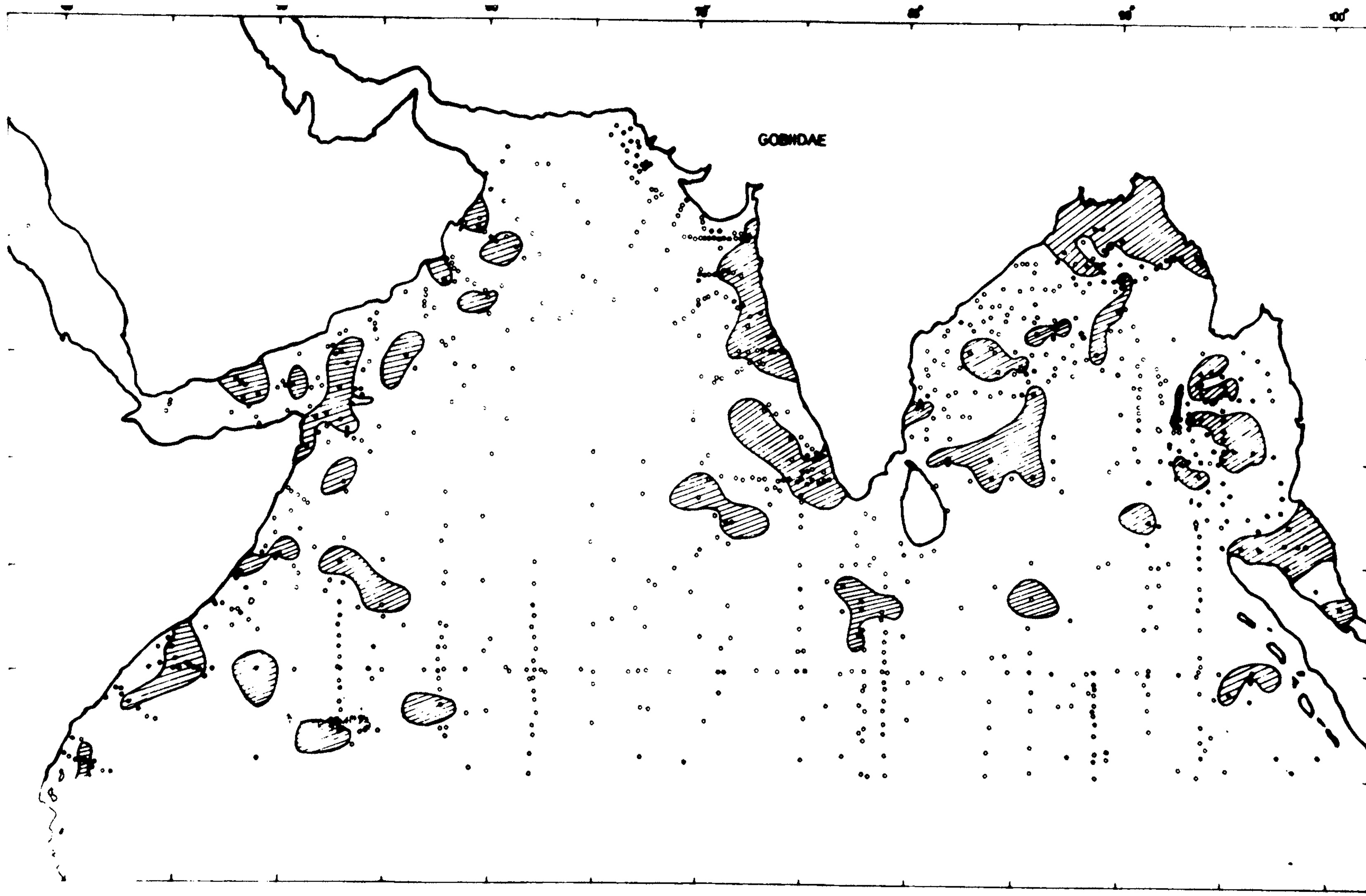


Fig. 18

the highest number recorded, which was from the area west of Thailand (09°54'N - 97°42'E). The range of surface temperature was between 22° and 30°C whereas that of salinity 29 and 34‰ (Table 16).

FAMILY SCORPAENIDAE

(Pl. VI.4,5; Fig. 19)

Deep and stubby bodied larva with about 25 myomeres. Preanal part is about 50-60% of the body. Head and body are pigmented. Head is distinctly armoured with bony structures, characteristically spiny, especially on the occiput and operculum. Intestine is thick anteriorly. Pectorals in some cases are enlarged and fan-like.

The earlier work on the larval stages of Scorpaenidae is of Fage (1918). Fugita (1957) described the larval stages of Sebastes, Pachycephalus nigricans from Japanese waters. Basheeruddin and Nayar (1962) recorded the larvae of Pterois russelli from the coastal waters of Madras. Mito (1963) illustrated the eggs and larvae of Pterois lunulata from Japanese waters.

Scorpaenids collected from Arabian Sea area formed about 1.2% of the larvae collected from that region (Tables 4,6). They were represented in 9.9% of the stations. In the Bay of Bengal they were represented in 11.3% of the stations, contributing to 0.9% of the total number of larvae collected (Tables 5,6). In the Arabian Sea they were recorded during all months of the year and in Bay of Bengal only from March to September (Tables 7,8; Figs. 20).

The larvae of this family were abundant in the Arabian Sea in the coastal, offshore and oceanic waters (Fig. 19). The oceanic distribution was mainly in the equatorial zone. Off Kenya the distribution was in the offshore region. Along the southern and northern Somalia, it was coastal, offshore and oceanic. But in the coastal stations of the middle region there were no larval concentration. The central part of Red Sea recorded the presence of larvae of scorpaenids. At the northern half of Arabian coast the larvae were present in all the three zones, coastal, offshore and oceanic. Off Pakistan coast the distribution was patchy and in smaller areas only. The concentrations along the coasts of Gujarat, Maharashtra, Karnakata and Kerala covered the coastal and offshore waters, and in the latter case it extended

Fig. 19. Distribution of larvae of Scorpaenidae in the Arabian Sea and Bay of Bengal.

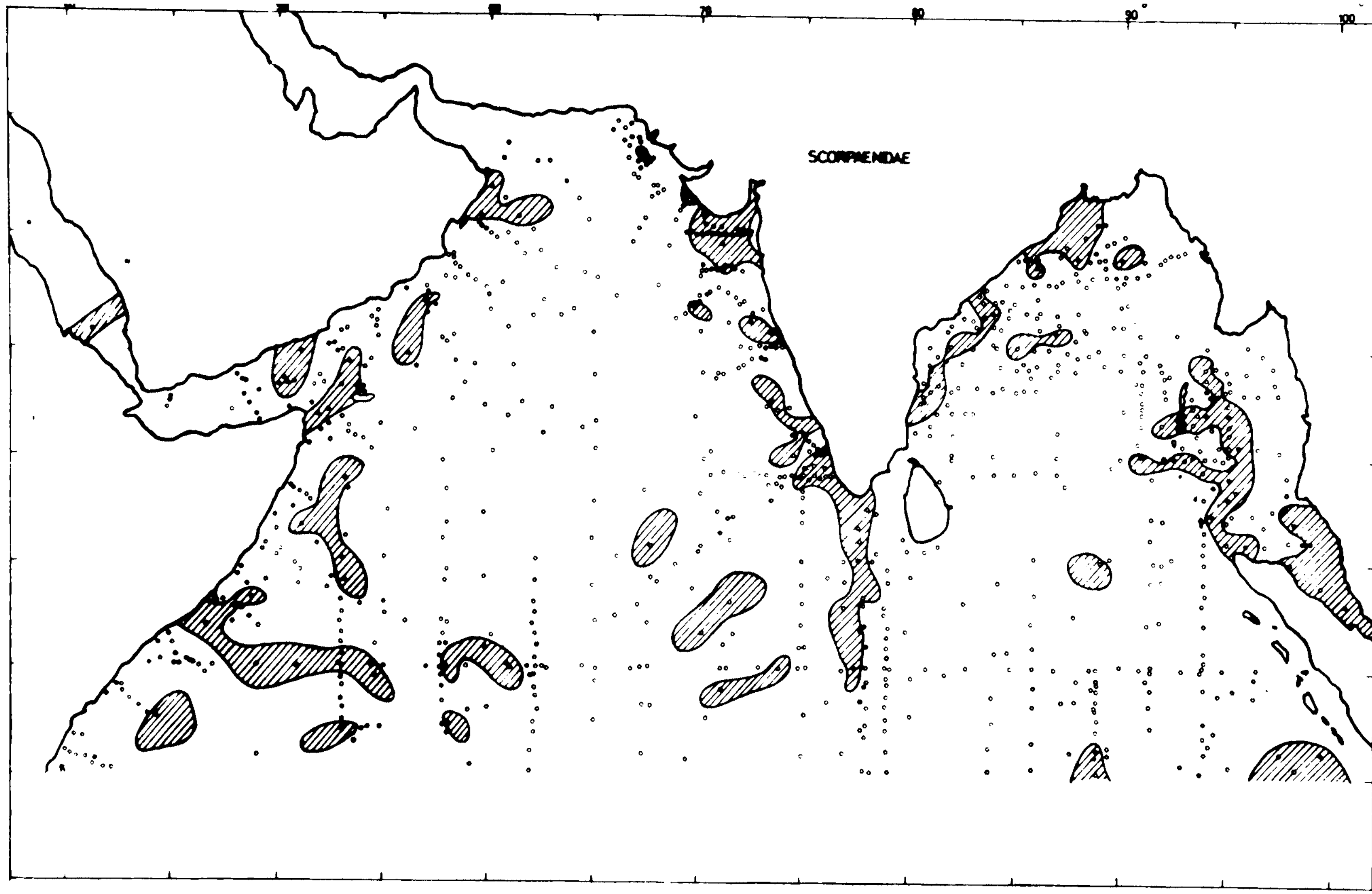


Fig. 19

further south up to the equatorial zone. The equatorial region supported several oceanic concentrations of the larvae, whereas the stations from the central part of Arabian Sea was totally devoid of any larvae. From the 58 positive stations in the Arabian Sea 374 larvae were collected. 126 larvae per haul was the highest record of larvae and it was from the waters of the Kutch region (20°29'N - 70°04'E). The surface temperature of the stations ranged from 20° to 30°C and salinity 23 to 32‰ (Table 16). 53% of the larvae were from waters of surface salinity, 35‰.

In the Bay of Bengal the concentration of larvae along the coasts of Tamil Nadu, Andhra Pradesh and Orissa were coastal, offshore and oceanic in nature (Fig. 19). There was another area of very wider distribution around the Andaman-Nicobar Islands which extended towards the southern region reaching up to the coasts of northern Sumatra and strait of Malacca. At 5°S latitude also there were a few areas with concentration of larvae. The total number of larvae collected from these area were 194 and the frequency of occurrence was 41. The highest number of larvae recorded per haul was 30, from the area west of Malaysia (04°00'N - 99°49'E). The surface temperature of the stations was between 22° and 30°C, whereas the salinity ranged between 29 and 34‰ (Table 16(.

FAMILY DACTYLOPTERIDAE

(Pl. VI.10, 11)

Post larva has the characteristic zoea type body which is completely encased in bony armour with spinous structures. The number of vertebrae are 21. Body quadrangular in cross section. Snout is blunt. Dorsal and ventral margins of operculum are produced into strong spines. Pectorals are enlarged.

Sanzo (1934) described the larvae of Dactyloptena volitans from the Mediterranean waters. Uchida et al. (1958) studied larvae of Dactyloptena from the waters around Japan. Jones (1967) described the species of Dactyloptena, D. orientalis and D. macrocanth. Only two larvae were collected from the Bay of Bengal (Tables 5,6) stations 01°58'S - 88°59'E and 09°20'N - 96°00'E where the surface temperature and salinity were 28.5°C and 34.2‰ respectively. They were recorded during the month of September.

Families Balistidae, Diodontidae, Tetraodontidae, Molidae and Antennariidae were collected from comparatively less number of stations. In no case, early larvae were caught. The juvenile or adult characters were more predominant than the larval characters in all cases. They were like the miniature adults in all respects and were easily identifiable by the adult characteristics.

PLATE VII

1.	Antennariidae	4.1 mm
2.	Diodontidae	4.5 "
3.	Tetraodontidae	3.8 "
4.	Balistidae	12.9 "
5.	Molidae	3.5 "

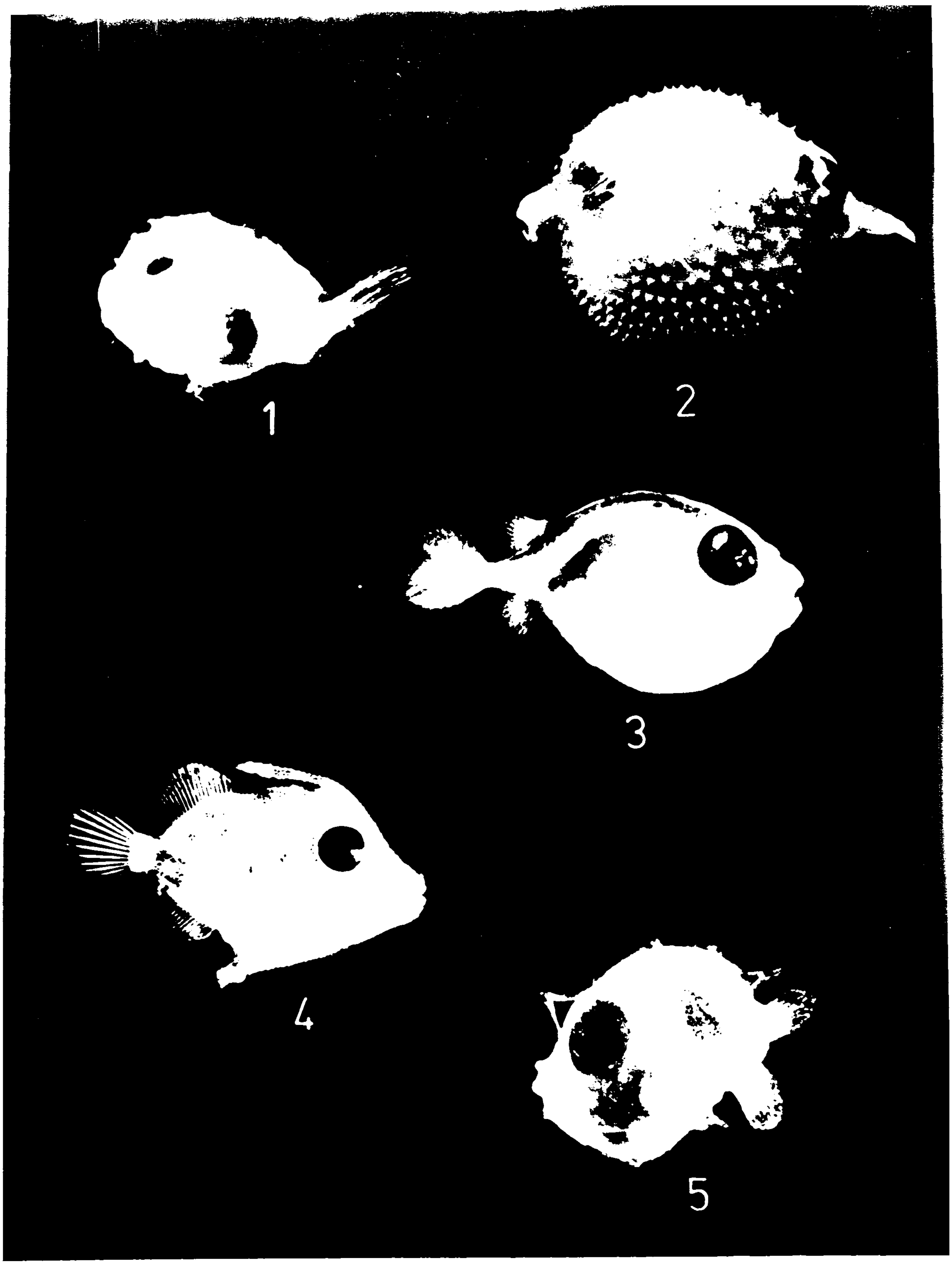


PLATE VII

FAMILY TETRAODONTIDAE

(Pl. VII.3)

Post larva has characteristic oblong body with exoskeleton modified into minute scute-like structures. The number of vertebrae is 20. Teeth are represented by two beaklike structures in each jaw. Fins are devoid of spinous rays.

Bal and Pradhan (1945, 1946, 1947) recorded the eggs and larval stages of *Tetrodon oblongus*, *T. leopardus* and *Tetrodon* sp. from Bombay waters. Fugita and Ueno (1954) described the prelarval stages of *Fugu rubripes* from Japanese waters. Uchida *et al.* (1958) also described the postlarval stages of *Fugu* sp. from the same area. Basheeruddin and Nayar (1962) collected the young ones of *Sphaerodon lunaris* from the coastal waters of Madras.

In the Arabian Sea this group contributed to 0.09% of the total larvae collected from this area with a frequency of occurrence of 2.9% (Tables 4,6). The highest number of 12 larvae per haul was collected from the station 14°25'N - 73°13'E. They occurred in almost all months of the year. The surface temperature of the stations ranged between 24.8° to 29.5°C and surface salinity between 34.3 and 36.6‰. From the Bay of Bengal no larva was collected.

FAMILY DIODONTIDAE

(Pl. VII. 2)

Postlarva has short rounded body with minute scutes. Teeth in each jaw are fused into single beak-like unit. Regan (1916) described the larvae of *Diodon* sp. from the Atlantic waters. There is no published data on the larvae of Diodontidae from the Indian Ocean region.

From the Arabian Sea only 5 larvae were collected from five stations in the months of June, July and November (Tables 4,6). The station positions were 00°00'N - 45°25'E, 15°10'N - 52°32'E, 18°46'N - 28°33'E, 00°96'N - 65°57'E, and 09°94'N - 74°40'E. The four stations which recorded 4 larvae from the Bay of Bengal were 01°30'N - 89°00'E, 04°02'N - 89°00'E, 14°15'N - 81°59'E and 18°00'N - 91°00'E. The Arabian Sea stations recorded the surface temperature between 24.2° and 29.8°C and salinity between 33.7 and 36.1‰. The values for the Bay of Bengal stations were between 27.2° to 29.2°C and 33.6 and 34.5‰.

FAMILY BALISTIDAE

(Pl. VII. 4)

Laterally compressed body tapering anteriorly and posteriorly. Snout is produced into a small mouth. Scales are modified into rough spinous projections. First dorsal is represented by a single isolated large spine. Second dorsal and anal are equal and opposite. Literature on the larvae of this group of the Indian Ocean region is not available. Uchida et al. (1958) described the post larvae of species of Stephanolepis, Rudarius and Navodon from Japanese waters.

Balistidae contributed to only 0.1% of the larvae collected from the Arabian Sea. This family was not recorded from the Bay of Bengal. In the Arabian Sea they were collected during May to September and December months. The surface temperature of the stations ranged between 26.9°C to 29.3°C and salinity, 34.6‰ to 36.0‰.

FAMILY MOLIDAE

(Pl. VII. 5)

Post larva has oblong body covered with somewhat flat spinous structures. Teeth are fused into a single unit. Caudal fin and caudal peduncle are absent.

Sherman (1961) studied the developmental stages of the oblong ocean sun fish Ranzania laevis of the central North Pacific. Published records on the larvae of this fish from the Arabian Sea and Bay of Bengal area are lacking. The present collections included only one postlarva from a station in the Arabian Sea south of equator (05°00'S - 78°10'E) (Tables 4,6). The surface temperature and salinity of the stations were 28°C and 34.8‰ respectively. The larva was collected in the month of January.

FAMILY ANTENNARIIDAE

(Pl. VII.1)

Postlarva has rounded or oblong body. Mouth is oblique in position. Body is pigmented. Gill openings are never before pectorals. Pectorals are very conspicous. First dorsal ray is separated from the rest.

Padmanabhan (1957) studied the embryonic and early larval development of Antennariius marmoratus from the coastal waters of Trivandrum. Bertelsen (1951) dealt with the larvae of ceratoid fishes of the Dana Expedition. From the Arabian Sea only 5 postlarvae were collected in three hauls (Tables 4,6). They were from stations 13°03'N - 50°00'E, 04°51'N - 79°00'E and 10°13'N - 75°39'E. The surface temperature of the stations ranged between 25.2°C and 29.8°C, whereas the

Fig. 20. Seasonal distribution of some of the more common families of fish larvae in the Arabian Sea and Bay of Bengal.

Fig. 20

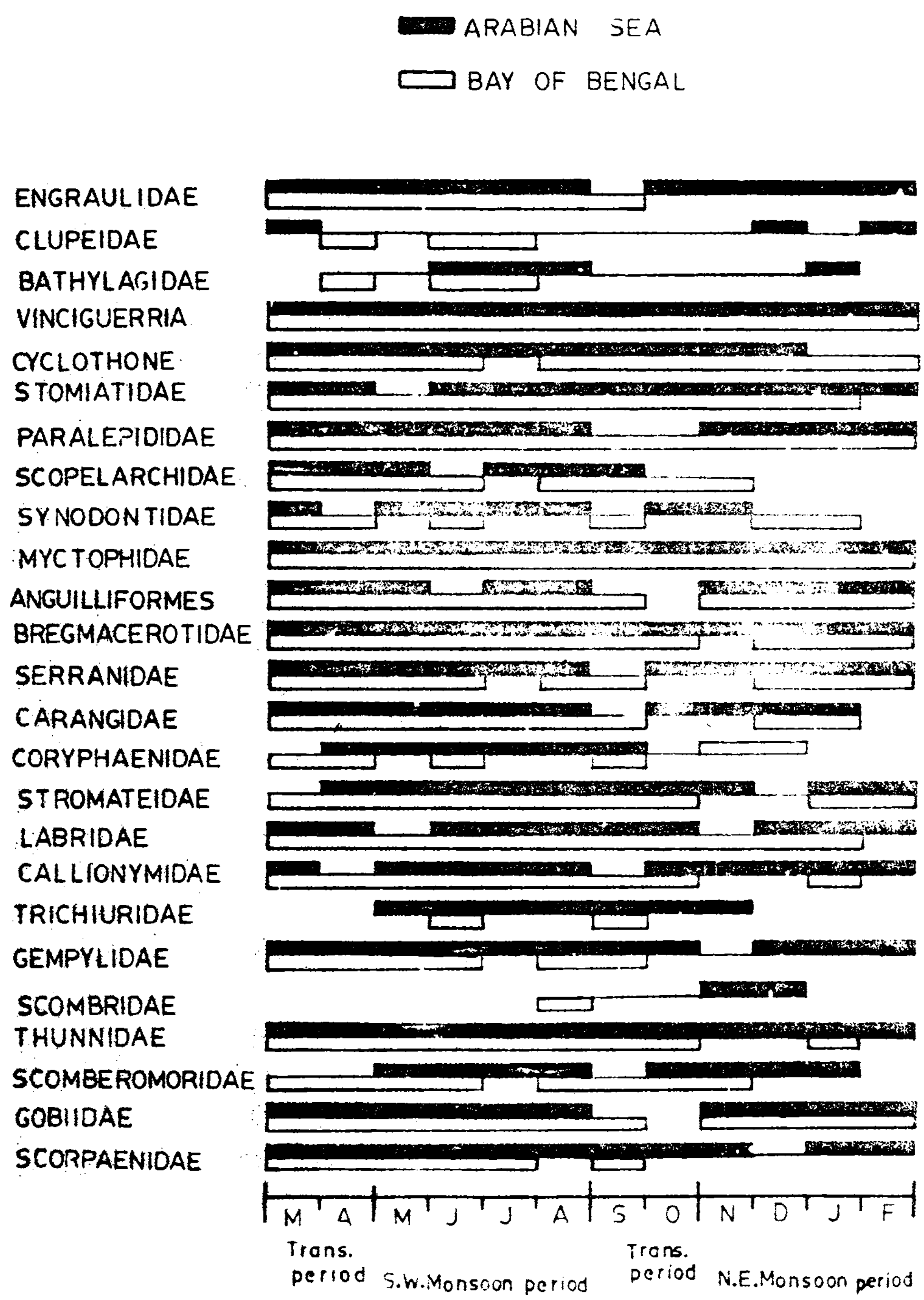

ARABIAN SEA
BAY OF BENGAL
ENGRAULIDAE
CLUPEIDAE
BATHYLAGIDAE
VINCIGUERRIA
CYCLOTHONE
STOMIATIDAE
PARALEPIDIDAE
SCOPELARCHIDAE
SYNODONTIDAE
MYCTOPHIDAE
ANGUILLIFORMES
BREGMACEROTIDAE
SERRANIDAE
CARANGIDAE
CORYPHAENIDAE
STROMATEIDAE
LABRIDAE
CALLIONYMIDAE
TRICHIURIDAE
GEMPYLIDAE
SCOMBRIDAE
THUNNIDAE
SCOMBEROMORIDAE
GOBIIDAE
SCORPAENIDAE
M A M J J A S O N D J F
Trans. period
S.W.Monsoon period
Trans. period
N.E.Monsoon period

Table 4 : Kinds of larvae, total number and frequency of occurrence in each 5° square in the Arabian Sea.

Area Marsden square Nos.		Clupeidae	Engraulidae	Other Clupeoidei	Bathylagidae	Vinciguerria	Cyclothone	Other Gonostomidae
332	(2)	-	-	-	-	-	-	-
331	(1)	-	5/2	2/1	2/1	79/9	24/5	3/1
	(2)	-	-	-	4/1	-	-	-
330	(1)	-	-	-	-	64/3	7/1	-
	(2)	-	-	-	-	32/6	16/3	1/1
329	(1)	-	-	-	-	19/5	18/5	-
	(2)	-	-	-	-	7/3	17/4	-
328	(1)	-	1/1	-	-	10/1	-	-
	(2)	-	-	-	-	60/10	18/9	4/1
032	(1)	-	-	-	-	20/1	39/2	20/2
	(2)	-	2/1	-	-	142/13	31/6	-
	(4)	-	-	-	-	7/3	1/1	-
031	(1)	-	-	-	-	26/5	1/1	-
	(2)	-	-	-	-	39/4	41/5	8/2
	(3)	-	6/1	3/1	-	48/12	20/4	1/1
	(4)	-	-	-	-	-	-	-
030	(1)	-	-	-	-	3/1	8/4	-
	(2)	-	-	-	-	40/7	6/2	-
	(3)	-	-	-	-	3/2	-	-
	(4)	-	-	-	-	1/1	9/2	1/1

Total No. of larvae/frequency of occurrence.

Table 4 (Contd.)

Area Marsden square Nos.		Clupeidae	Engraulidae	Other Clupeoidei	Bathylagidae	Vinciguerria	Cyclothone	Other Gonostomidae
029	(1)	-	-	-	-	14/5	30/5	-
	(2)	-	-	-	-	92/14	9/4	-
	(3)	-	1/1	-	-	114/10	18/6	-
	(4)	-	4/2	41/4	-	57/13	11/5	-
068	(1)	4/2	2/1	-	-	-	-	-
	(2)	1/1	-	-	-	9/3	-	-
	(3)	-	-	-	-	1/2	-	-
067	(1)	-	7/4	91/4	14/3	41/8	39/7	28/1
	(2)	-	-	-	-	5/3	10/2	-
	(3)	-	13/2	-	15/3	18/5	2/2	-
	(4)	-	8/2	7/2	83/6	48/10	2/1	-
066	(1)	-	-	-	-	24/3	7/2	-
	(2)	-	-	-	-	3/2	-	-
	(3)	-	2/1	-	-	42/5	3/2	1/1
	(4)	-	-	-	-	23/3	-	-
065	(1)	-	8/2	21/3	-	177/12	-	-
	(2)	-	458/2	-	-	-	-	-
	(3)	5/2	66/10	-	-	48/8	-	-
105	(2)	-	-	-	-	13/1	-	-
103	(2)	-	-	-	-	17/2	5/1	-
102	(1)	-	591/3	-	30/1	32/6	-	-
	(2)	-	122/8	-	-	39/9	-	-
101	(1)	-	305/6	-	-	18/6	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Stomiatidae	Sternoptychidae	Astronesthidae	Idiacanthidae	Chauliodontidae	Other Stomiatoidei
332	(2)	-	-	-	-	-	-
331	(1)	6/4	3/2	-	1/1	1/1	7/3
	(2)	-	-	-	-	-	-
330	(1)	4/1	-	-	-	-	-
	(2)	-	2/1	1/1	2/1	-	-
329	(1)	2/2	8/2	-	1/1	2/1	7/3
	(2)	1/1	-	-	-	2/1	-
328	(1)	1/1	-	-	22/2	2/1	2/2
	(2)	4/2	1/1	-	1/1	3/1	10/7
032	(1)	2/1	-	-	-	-	-
	(2)	4/3	1/1	-	1/1	-	13/4
	(4)	1/1	-	-	-	-	-
031	(1)	1/1	-	-	-	-	5/5
	(2)	4/3	-	2/1	1/1	-	9/3
	(3)	4/2	-	-	-	2/1	-
	(4)	-	-	-	-	-	-
030	(1)	-	-	-	-	-	1/1
	(2)	2/1	2/1	-	-	-	-
	(3)	-	-	-	-	-	-
	(4)	-	-	-	-	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Stomiatidae	Sternoptychidae	Astronesthidae	Idiacanthidae	Chauliodontidae	Other Stomiatoidea
029	(1)	2/1	-	-	1/1	-	-
	(2)	4/2	2/1	-	2/1	1/1	5/4
	(3)	-	2/2	-	4/2	2/1	4/2
	(4)	2/1	-	-	1/1	1/1	7/4
068	(1)	3/1	-	-	-	-	-
	(2)	5/2	-	2/1	1/1	-	1/1
	(3)	-	-	-	-	-	-
067	(1)	8/4	-	5/2	25/4	-	39/8
	(2)	3/2	-	-	-	-	-
	(3)	1/1	-	-	7/2	-	-
	(4)	9/3	-	2/1	38/5	15/4	43/9
066	(1)	-	-	-	-	-	-
	(2)	-	-	-	-	-	-
	(3)	-	-	-	12/3	-	3/2
	(4)	-	-	-	-	-	-
065	(1)	-	-	-	1/1	-	-
	(2)	-	-	-	-	-	-
	(3)	-	-	4/2	-	-	1/1
105	(2)	-	-	-	-	-	-
103	(2)	24/2	-	-	7/3	-	10/3
102	(1)	-	-	1/1	10/2	-	13/2
	(2)	-	-	-	-	-	6/1
101	(1)	-	-	-	-	-	-

Table 4 (Contd.)

<u>Area</u> Marsden square Nos.		Synodontidae	Paralepididae	Scopelarchidae	Myctophidae	Anguilliformes	Beloniformes
832	(2)	-	-	-	-	-	-
331	(1)	-	-	7/3	485/18	-	-
	(2)	-	3/1	-	53/3	-	-
330	(1)	-	10/4	-	141/12	-	-
	(2)	-	6/1	2/2	191/10	2/1	-
329	(1)	-	10/4	2/2	92/10	-	-
	(2)	2/1	6/2	1/1	60/6	-	-
328	(1)	-	-	-	1/1	-	-
	(2)	-	1/1	7/4	315/13	-	-
032	(1)	4/1	1/1	3/1	158/4	10/1	-
	(2)	-	20/5	13/3	423/19	1/1	-
	(4)	-	1/1	-	38/2	-	-
031	(1)	-	2/2	-	249/11	-	6/1
	(2)	-	8/4	4/3	227/14	1/1	3/2
	(3)	-	7/2	4/2	404/15	-	-
	(4)	-	2/1	3/2	65/5	1/1	-
030	(1)	-	4/4	6/3	18/6	-	-
	(2)	-	9/6	9/4	282/10	-	-
	(3)	-	-	-	29/2	-	-
	(4)	-	-	-	25/3	-	1/1

Table 4 (Contd.)

Area Marsden square Nos.		Synodontidae	Paralepididae	Scopelarchidae	Myctophidae	Anguilliformes	Beloniformes
029	(1)	-	-	6/4	129/8	2/2	-
	(2)	1/1	14/6	11/5	186/16	1/1	1/1
	(3)	-	13/4	4/3	188/15	-	-
	(4)	58/2	9/5	10/2	304/16	7/4	-
068	(1)	-	-	-	80/4	-	-
	(2)	-	5/2	-	157/12	2/1	-
	(3)	-	1/1	-	24/1	-	-
067	(1)	4/3	8/7	2/2	860/31	4/4	1/1
	(2)	-	-	-	199/5	2/1	-
	(3)	8/1	1/1	-	254/9	1/1	-
	(4)	36/1	16/5	-	666/16	-	-
066	(1)	-	-	-	7/5	-	-
	(2)	-	-	-	13/3	-	-
	(3)	4/2	6/1	-	332/11	1/1	-
	(4)	-	-	-	39/4	-	-
065	(1)	5/2	-	-	242/16	6/4	-
	(2)	-	-	-	10/1	-	-
	(3)	2/1	20/1	-	341/22	10/3	-
105	(2)	-	3/1	-	25/1	-	-
103	(2)	-	8/5	-	481/5	-	-
102	(1)	7/3	2/2	-	314/12	-	-
	(2)	-	-	-	315/22	-	-
101	(1)	16/3	-	-	118/2	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Bregmacerotidae	Syngnathidae	Fistularidae	Holocentridae	Sphyraenidae	Mugilidae	Serranidae	Carangidae
332	(2)	-	-	-	-	-	-	-	-
331	(1)	17/8	-	-	-	-	-	1/1	10/3
	(2)	-	-	-	-	-	-	1/1	-
330	(1)	1/1	-	-	-	-	-	-	-
	(2)	2/1	-	-	-	-	-	-	1/1
329	(1)	2/1	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-	-
328	(1)	1/1	-	-	-	-	-	-	1/1
	(2)	-	-	-	-	-	-	3/2	3/1
032	(1)	-	-	-	-	-	-	-	-
	(2)	24/2	-	-	-	-	-	-	1/1
	(4)	-	-	-	-	-	-	1/1	-
031	(1)	3/3	-	-	-	-	-	-	1/1
	(2)	2/1	-	-	-	-	-	1/1	3/3
	(3)	4/2	-	-	-	-	2/2	9/3	-
	(4)	1/1	-	-	-	-	-	-	1/1
030	(1)	-	-	-	-	-	-	-	-
	(2)	2/2	-	-	-	-	-	4/2	1/1
	(3)	-	-	-	-	-	-	6/1	-
	(4)	2/1	-	-	-	-	-	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Bregmacerotidae	Syngnathidae	Fistularidae	Holocentridae	Sphyraenidae	Mugilidae	Serranidae	Carangidae
029	(1)	5/2	-	-	26/4	1/1	-	-	2/2
	(2)	5/3	-	-	4/2	-	-	6/4	3/3
	(3)	29/9	-	-	-	-	-	1/1	5/1
	(4)	51/5	-	1/1	-	-	-	9/4	6/3
068	(1)	-	-	-	-	-	-	3/2	6/3
	(2)	2/1	-	-	-	-	-	1/1	-
	(3)	7/1	-	-	-	-	-	-	-
067	(1)	54/17	-	-	-	-	-	12/6	62/5
	(2)	2/1	-	-	-	-	-	-	1/1
	(3)	7/1	-	-	-	-	-	-	-
	(4)	183/8	-	-	-	-	-	2/2	16/1
066	(1)	7/1	-	-	-	-	-	-	-
	(2)	28/5	-	-	-	-	-	-	-
	(3)	17/5	-	-	-	-	1/1	1/1	1/1
	(4)	-	-	-	-	-	-	-	-
065	(1)	61/9	-	1/1	3/2	1/1	-	-	8/4
	(2)	68/2	1/1	1/1	-	-	-	-	-
	(3)	44/19	-	-	-	-	-	1/1	4/3
105	(2)	-	-	-	2/1	-	-	-	2/1
103	(2)	20/3	-	-	-	-	-	2/2	166/2
102	(1)	148/10	-	-	-	-	-	2/2	1/1
	(2)	28/6	-	-	-	-	-	-	47/8
101	(1)	4/2	-	-	-	-	-	-	-

Table 4 (Contd.

Area / Marsden square Nos.		Apogonidae	Coryphaeni-dae	Sciaenidae	Stromateidae	Labridae	Callionymidae	Trichiuridae
332	(2)	-	-	-	-	-	-	-
331	(1)	-	-	-	-	9/2	2/1	-
	(2)	-	-	-	-	-	3/1	-
330	(1)	-	-	-	-	17/5	-	1/1
	(2)	-	-	-	-	12/4	-	-
329	(1)	-	1/1	-	-	1/1	-	-
	(2)	-	-	-	-	1/1	-	-
328	(1)	-	1/1	-	-	1/1	-	-
	(2)	-	-	-	-	-	-	-
032	(1)	-	-	-	-	-	-	-
	(2)	-	-	2/1	80/7	5/2	1/1	8/1
	(4)	-	-	-	-	-	-	-
031	(1)	-	-	-	-	5/4	-	-
	(2)	-	1/1	-	8/4	4/1	-	-
	(3)	-	-	-	3/2	3/1	-	-
	(4)	-	1/1	-	-	1/1	-	-
030	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	2/2	2/1	2/1	-
	(3)	-	-	-	-	-	-	-
	(4)	-	-	-	-	-	-	-

Table 4 (Cont'd.)

Area Marsden square Nos.		Apogonidae	Coryphaenidae	Sciaenidae	Stromateidae	Labridae	Callionymidae	Trichiuridae
029	(1)	-	-	-	1/1	12/7	-	-
	(2)	-	-	-	9/5	9/6	6/2	-
	(3)	-	-	-	9/6	8/5	4/3	-
	(4)	-	-	-	-	-	22/6	-
068	(1)	-	-	-	-	-	3/2	-
	(2)	-	-	-	-	2/1	-	-
	(3)	-	-	-	-	3/1	-	-
067	(1)	1/1	69/6	1/1	14/3	25/3	18/5	2/1
	(2)	-	-	-	-	3/1	-	-
	(3)	-	3/1	-	-	1/1	1/1	3/1
	(4)	2/1	74/7	-	-	4/4	1/9	4/2
066	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-
	(3)	-	-	-	-	1/1	12/3	-
	(4)	-	-	-	-	-	-	-
065	(1)	-	-	1/1	3/3	1/1	17/8	-
	(2)	-	-	-	-	-	6/2	-
	(3)	-	-	-	-	-	1/1	-
105	(2)	-	-	-	-	-	-	-
103	(2)	4/1	-	-	-	2/2	-	-
102	(1)	-	1/1	-	4/2	-	12/2	-
	(2)	-	-	-	-	-	-	-
101	(1)	-	-	-	-	-	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Gempylidae	Scombridae	Thunnidae	Scomberomoridae	Histiophoridae	Gobiidae	Scorpaenidae
332	(2)	-	-	-	-	-	-	-
331	(1)	1/1	-	7/5	2/2	-	2/2	-
	(2)	1/1	-	5/2	-	-	1/1	-
330	(1)	4/3	-	6/3	-	-	2/1	3/2
	(2)	1/1	-	3/3	1/1	-	1/1	2/1
329	(1)	2/2	-	3/3	1/1	-	-	1/1
	(2)	-	-	1/1	-	-	-	-
328	(1)	2/2	-	2/2	-	-	-	3/1
	(2)	-	-	-	-	-	-	-
032	(1)	-	-	10/2	-	-	-	-
	(2)	1/1	-	2/2	1/1	-	6/5	6/3
	(4)	-	-	-	-	-	-	-
031	(1)	-	-	4/2	-	-	-	-
	(2)	2/1	-	4/2	5/1	-	2/1	2/2
	(3)	15/1	-	-	1/1	1/1	3/1	2/2
	(4)	-	-	-	-	-	1/1	3/2
030	(1)	-	-	1/1	1/1	-	-	2/2
	(2)	2/2	-	4/4	12/3	-	-	1/1
	(3)	-	-	1/1	-	-	-	-
	(4)	-	-	1/1	-	-	-	2/1

Table 4 (Contd.)

Area Marsden square Nos.		Gempylidae	Scombridae	Thunnidae	Scomberomoridae	Histiophoridae	Gobiidae	Scorpaenidae
029	(1)	3/2	-	3/3	-	-	-	3/3
	(2)	2/2	-	8/3	1/1	-	12/5	6/2
	(3)	3/3	-	-	2/1	-	6/4	-
	(4)	1/1	-	-	3/1	-	56/8	9/4
068	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	3/3	-
	(3)	-	1/1	-	-	-	-	-
067	(1)	3/3	-	3/2	8/1	-	17/9	11/4
	(2)	-	-	4/1	-	-	3/1	1/1
	(3)	-	-	9/3	1/1	-	-	-
	(4)	-	-	14/5	37/3	-	1/1	2/1
066	(1)	-	-	-	-	-	1/1	-
	(2)	-	-	-	-	-	3/1	1/1
	(3)	1/1	-	9/2	42/2	30/1	-	-
	(4)	-	-	-	-	-	-	-
065	(1)	1/1	-	-	-	-	33/4	3/3
	(2)	1/1	-	-	-	-	32/1	5/2
	(3)	1/1	-	9/3	-	-	73/13	8/3
105	(2)	-	-	3/1	-	-	6/1	-
103	(2)	-	-	-	-	-	15/2	1/1
102	(1)	1/1	1/1	10/2	-	-	1/1	3/2
	(2)	-	-	4/1	4/1	-	1/1	60/4
101	(1)	-	-	-	-	-	92/9	234/9

Table 4 (Contd.)

Area Marsden square Nos.		Pleuronecti- formes	Champsodonti- dae	Trachypteri- dae	Bramidae	Ophididae
332	(2)	-	-	-	-	-
331	(1)	2/2	-	-	-	-
	(2)	-	-	-	-	-
330	(1)	2/1	-	-	-	-
	(2)	-	-	-	-	-
329	(1)	-	-	-	-	1/1
	(2)	-	-	-	-	-
328	(1)	2/2	-	-	1/1	-
	(2)	-	-	-	-	-
032	(1)	-	-	-	-	-
	(2)	1/1	-	2/1	-	4/1
	(4)	1/1	-	-	-	-
031	(1)	5/1	-	-	-	-
	(2)	1/1	-	-	10/1	-
	(3)	1/1	-	-	1/1	-
	(4)	-	-	-	-	-
030	(1)	-	-	-	-	-
	(2)	-	-	-	-	-
	(3)	-	-	-	-	-
	(4)	-	Rs	-	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Pleuronecti-formes	Champodontidae	Trachypteridae	Bramidae	Ophididae
029	(1)	-	-	-	-	-
	(2)	-	-	-	-	-
	(3)	4/4	-	-	-	-
	(4)	42/8	-	-	-	-
068	(1)	2/1	-	-	-	-
	(2)	2/1	-	-	-	-
	(3)	1/1	-	-	-	-
067	(1)	4/3	-	-	17/6	-
	(2)	-	-	-	-	-
	(3)	2/1	-	-	-	-
	(4)	3/3	-	-	10/1	-
066	(1)	-	-	-	-	-
	(2)	-	-	-	-	-
	(3)	5/1	-	-	-	-
	(4)	-	-	-	-	-
065	(1)	5/2	-	-	-	-
	(2)	-	-	-	-	-
	(3)	5/2	-	-	-	-
105	(2)	-	-	-	-	-
103	(2)	3/2	-	-	-	-
102	(1)	2/1	-	-	-	-
	(2)	4/2	-	-	-	-
101	(1)	-	-	-	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Dactylopteri-dae	Balistidae	Diodontidae	Tetraodonti-dae	Antennari-dae	Ceratoidei	Branchio-stegidae	Molidae
332	(2)	-	-	-	-	-	-	-	-
331	(1)	-	-	1/1	3/1	-	-	-	-
	(2)	-	-	-	-	-	-	-	-
330	(1)	-	-	-	1/1	-	-	-	-
	(2)	-	-	-	-	-	1/1	-	-
329	(1)	-	1/1	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-	1/1
328	(1)	-	1/1	-	-	-	-	-	-
	(2)	-	1/1	-	-	-	-	-	-
032	(1)	-	4/1	-	-	-	-	1/1	-
	(2)	-	-	-	1/1	-	-	-	-
	(4)	-	-	-	-	-	-	-	-
031	(1)	-	-	-	-	-	-	-	-
	(2)	-	4/2	-	-	-	-	-	-
	(3)	-	-	-	1/1	-	-	-	-
	(4)	-	-	-	-	-	-	-	-
030	(1)	-	-	-	1/1	-	-	-	-
	(2)	-	-	-	-	-	-	1/1	-
	(3)	-	-	-	-	-	-	-	-
	(4)	-	-	-	-	-	-	-	-

Table 4 (Contd.)

Area Marsden square Nos.		Dactylopteridae	Balistidae	Diodontidae	Tetraodontidae	Antennariidae	Ceratoidei	Branchiostegidae	Molidae
029	(1)	-	-	-	-	-	-	-	-
	(2)	-	1/1	-	1/1	1/1	-	-	-
	(3)	-	7/3	1/1	3/3	-	-	-	-
	(4)	-	5/2	-	-	-	2/2	-	-
068	(1)	-	8/3	-	1/1	-	-	-	-
	(2)	-	-	-	-	-	-	-	-
	(3)	-	-	-	-	-	-	-	-
067	(1)	-	8/2	-	2/2	-	2/2	-	-
	(2)	-	-	-	-	1/1	-	-	-
	(3)	-	-	1/1	-	-	-	-	-
	(4)	-	1/1	-	-	-	-	-	-
066	(1)	-	-	-	1/1	-	-	-	-
	(2)	-	-	-	-	-	-	-	-
	(3)	-	-	1/1	-	-	1/1	-	-
	(4)	-	1/1	-	12/1	-	-	-	-
065	(1)	-	3/2	-	-	-	-	-	-
	(2)	-	-	-	-	3/3	-	-	-
	(3)	-	1/1	-	1/1	-	-	-	-
105	(2)	-	1/1	-	-	-	-	-	-
103	(2)	-	-	-	1/1	-	-	-	-
102	(1)	-	-	-	1/1	-	1/1	-	-
	(2)	-	-	-	-	-	-	-	-
101	(1)	-	-	-	-	-	-	-	-

Table 5 : Kinds of larvae, total number and frequency of occurrence in each 5° square in the Bay of Bengal.

Area Marsden square Nos.		Clupeidae	Engrauli-dae	Other Clupeoidei	Bathy-lagidae	Vinciguerria	Cyclothone	Other Gonosto-midae
327	(1)	-	-	-	-	70/5	31/2	5/1
	(2)	-	-	7/2	-	77/11	6/3	1/1
326	(1)	-	-	-	-	111/10	2/1	2/1
	(2)	-	-	-	-	80/5	7/2	-
028	(1)	-	-	-	-	12/3	1/1	-
	(2)	-	-	-	-	90/10	46/6	-
	(3)	-	-	-	7/2	54/5	3/1	-
	(4)	-	-	11/2	-	47/7	6/1	-
027	(1)	-	-	-	-	235/9	3/1	-
	(2)	-	3/1	-	-	1/1	-	-
	(3)	-	8/1	7/2	-	70/10	1/1	-
	(4)	-	37/1	1/1	-	120/10	25/5	2/1
026	(1)	-	-	-	-	-	-	-
064	(1)	1/1	15/1	6/1	15/2	690/23	16/4	4/4
	(2)	-	-	-	1/1	229/12	5/2	1/1
	(3)	-	-	-	1/1	464/20	-	-
	(4)	10/1	1/1	5/1	11/3	826/35	-	-
063	(1)	-	-	-	-	447/38	3/2	-
	(2)	-	-	-	-	48/8	3/3	-
	(3)	-	1/1	-	-	229/14	1/1	6/4
	(4)	-	-	-	-	2/1	-	-
100	(2)	-	-	-	-	1/1	-	-
099	(1)	-	-	-	-	12/1	-	-

Total No. of larvae/frequency of occurrence.

Table 5 (Contd.)

Area Marsden square Nos.		Stomiatidae	Sternoptychidae	Astronesthidae	Idiacanthidae	Chauliodontidae	Other Stomiatoidei
327	(1)	2/2	-	-	-	-	7/2
	(2)	-	8/3	-	-	-	5/3
326	(1)	2/2	32/3	-	-	-	16/2
	(2)	-	-	-	-	-	37/4
028	(1)	1/1	-	-	-	-	-
	(2)	1/1	22/2	-	-	1/1	23/5
	(3)	-	-	-	-	-	9/3
	(4)	-	-	-	-	-	6/2
027	(1)	45/5	11/3	-	-	-	13/3
	(2)	-	-	-	-	-	-
	(3)	7/2	-	-	4/1	-	13/4
	(4)	20/4	-	-	-	-	4/3
026	(1)	-	-	-	-	-	-
064	(1)	8/3	-	-	-	-	27/8
	(2)	-	-	-	-	-	4/1
	(3)	-	-	-	1/1	-	3/2
	(4)	3/1	-	1/1	1/1	1/1	16/7
063	(1)	-	6/2	-	1/1	1/1	6/3
	(2)	-	-	-	-	-	-
	(3)	-	-	-	-	-	4/1
	(4)	-	-	-	-	-	-
100	(2)	-	-	-	-	-	1/1
099	(1)	-	-	-	-	-	-

Table 5 (Contd.)

Area Marsden square Nos.		Synodontidae	Paralepididae	Scopelarchidae	Myctophidae	Anguilliformes	Beloniformes
327	(1)	-	9/3	2/1	121/4	1/1	-
	(2)	-	9/6	1/1	160/12	-	-
326	(1)	-	17/2	-	100/5	1/1	2/2
	(2)	-	8/4	-	102/6	-	-
028	(1)	-	15/6	-	47/5	-	-
	(2)	-	4/4	-	206/11	1/1	-
	(3)	-	-	-	199/6	-	1/1
	(4)	-	1/1	-	70/6	1/1	3/2
027	(1)	-	6/4	1/1	82/8	-	-
	(2)	1/1	-	-	14/1	-	-
	(3)	1/1	15/1	1/1	143/19	9/5	4/1
	(4)	3/2	14/5	3/3	388/18	5/4	1/1
026	(1)	-	-	-	2/1	-	-
064	(1)	2/1	3/3	2/2	666/23	14/6	4/1
	(2)	1/1	1/1	1/1	259/16	2/2	-
	(3)	-	4/4	2/1	264/19	6/3	-
	(4)	-	6/3	12/4	553/36	12/4	-
063	(1)	1/1	10/7	8/1	388/36	18/7	1/1
	(2)	6/3	4/1	-	69/13	18/7	2/1
	(3)	-	-	-	166/13	5/3	-
	(4)	-	-	-	60/1	-	-
100	(2)	5/1	-	-	116/2	2/1	-
099(1)		-	-	-	-	-	-

Table 5 (Contd.)

Area Marsden square Nos.		Bregmacerotidae	Syngnathidae	Fistularidae	Holocentridae	Sphyraenidae	Mugilidae	Serranidae	Carangidae
327	(1)	2/2	-	-	-	-	-	-	-
	(2)	2/2	-	-	-	-	-	-	-
326	(1)	170/3	-	-	-	-	1/1	3/1	-
	(2)	2/1	-	-	-	-	-	-	-
028	(1)	-	-	-	-	-	-	-	-
	(2)	3/3	-	-	-	-	-	-	-
	(3)	7/2	-	-	-	-	-	1/1	3/1
	(4)	2/1	1/1	-	-	-	-	-	-
027	(1)	-	-	-	-	-	-	1/1	1/1
	(2)	4/1	-	-	-	-	-	-	16/1
	(3)	-	-	-	-	-	-	45/5	31/2
	(4)	104/16	2/1	-	5/2	-	-	32/7	21/5
026	(1)	7/1	-	-	-	-	-	-	1/1
064	(1)	54/12	1/1	-	-	-	-	19/4	6/3
	(2)	60/5	-	-	-	-	-	2/1	3/2
	(3)	82/15	-	-	-	-	-	4/3	11/5
	(4)	181/27	-	-	-	-	-	-	14/4
063	(1)	53/6	1/1	2/1	1/1	-	2/1	26/8	80/1
	(2)	3/3	1/1	-	1/1	-	1/1	2/2	17/[illegible]
	(3)	96/11	-	-	1/1	-	-	-	10/[illegible]
	(4)	-	-	-	-	-	-	-	-
100	(2)	170/3	-	-	7/1	-	-	-	12/[illegible]
099	(1)	18/1	-	-	-	-	-	-	-

Table 5 (Contd.)

Area Marsden square Nos.		Apogonidae	Coryphaenidae	Sciaenidae	Stromateidae	Labridae	Callionymidae
327	(1)	-	-	-	-	-	-
	(2)	-	-	-	-	-	2/1
326	(1)	-	-	-	-	-	-
	(2)	-	-	1/1	-	-	-
028	(1)	-	-	-	-	-	-
	(2)	-	-	-	4/2	-	-
	(3)	-	6/3	-	4/2	-	7/2
	(4)	-	-	-	1/1	8/3	1/1
027	(1)	-	-	-	-	1/1	-
	(2)	-	-	-	-	1/1	-
	(3)	2/1	5/1	-	11/2	18/3	-
	(4)	2/1	3/1	-	6/5	3/1	9/4
026	(1)	-	-	-	-	-	-
064	(1)	-	-	-	13/6	3/3	6/3
	(2)	-	-	-	3/2	1/1	-
	(3)	-	-	-	7/4	1/1	3/2
	(4)	-	-	-	35/9	4/4	58/11
063	(1)	-	-	-	-	12/7	12/7
	(2)	-	-	-	1/1	3/1	6/4
	(3)	-	-	-	21/5	-	6/3
	(4)	-	-	-	-	-	-
100	(2)	1/1	-	2/1	1/1	1/1	1/1
099	(1)	-	-	-	-	-	-

Table 5 (Contd.)

Area Marsden square Nos.		Trichiuridae	Gempylidae	Scombridae	Thunnidae	Scomberomoridae	Histiophoridae	Gobiidae	Scorpaenidae
327	(1)	-	-	-	-	-	-	1/1	-
	(2)	-	-	-	3/2	-	-	-	-
326	(1)	-	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	1/1	3/2
028	(1)	-	-	-	2/1	-	-	-	-
	(2)	-	1/1	-	2/2	4/1	-	1/1	1/1
	(3)	-	2/1	-	7/2	20/3	-	1/1	-
	(4)	-	-	-	1/1	-	-	-	-
027	(1)	2/1	-	-	4/3	-	-	-	-
	(2)	-	-	-	1/1	-	-	16/1	30/1
	(3)	-	4/2	-	3/2	-	-	5/1	15/2
	(4)	4/1	-	-	7/4	19/4	-	25/7	63/8
026	(1)	-	-	-	-	-	-	1/1	-
064	(1)	3/1	-	-	8/5	2/1	-	15/15	4/3
	(2)	-	-	-	19/3	-	-	7/1	-
	(3)	-	-	1/1	4/2	-	-	2/2	2/2
	(4)	-	1/1	-	22/6	7/3	1/1	26/8	14/3
063	(1)	-	2/2	-	28/10	6/6	2/1	13/5	28/10
	(2)	-	1/1	-	12/4	1/1	-	23/3	9/5
	(3)	-	-	-	3/2	-	-	8/2	17/2
	(4)	-	-	-	-	-	-	-	-
100	(2)	-	-	-	-	3/1	-	8/2	6/2
099	(1)	-	-	-	-	-	-	11/1	-

Table 5 (Contd.)

Area Marsden square Nos.		Pleurone-ctiformes	Chaetodon-tidae	Trachypte-ridae	Bramidae	Ophidae
327	(1)	-	-	-	-	-
	(2)	-	-	-	-	-
326	(1)	-	-	1/1	-	-
	(2)	-	-	-	-	-
028	(1)	-	-	-	-	-
	(2)	1/1	-	-	-	-
	(3)	-	-	1/1	-	-
	(4)	-	-	-	-	-
027	(1)	-	-	-	21/2	-
	(2)	17/1	-	-	-	-
	(3)	1/1	-	-	-	-
	(4)	22/8	8/2	-	-	-
026	(1)	-	-	-	-	-
064	(1)	-	-	-	1/1	-
	(2)	-	-	-	-	-
	(3)	-	-	5/1	1/1	-
	(4)	-	-	1/1	5/1	-
063	(1)	-	-	-	-	-
	(2)	-	-	-	-	-
	(3)	-	-	-	-	-
	(4)	-	-	-	-	-
100	(2)	-	-	-	-	-
099	(1)	-	-	-	-	-

Table 5 (Contd.)

Area Marsden square Nos.		Dactylopteridae	Balistidae	Diodontidae	Tetraodontidae	Antennariidae	Ceratoidei	Branchiostegidae
327	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-
326	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-
028,	(1)	-	-	-	-	-	-	-
	(2)	1/1	-	-	-	-	-	-
	(3)	-	-	-	-	-	-	-
	(4)	-	-	-	-	-	-	-
027	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-
	(3)	-	-	-	-	-	-	14/2
	(4)	1/1	-	-	-	-	-	1/1
026	(1)	-	-	-	-	-	-	-
064	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-
	(3)	-	-	-	-	-	-	-
	(4)	-	-	-	-	-	-	-
063	(1)	-	-	-	-	-	-	-
	(2)	-	-	-	-	-	-	-
	(3)	-	-	-	-	-	-	-
	(4)	-	-	-	-	-	-	-
100	(2)	-	-	-	-	-	-	1/1
099	(1)	-	-	-	-	-	-	-

Table 6 : Percentage of the number and frequency of occurrence of different families of fish larvae in the Arabian Sea, Bay of Bengal and both the areas combined.

Groups	Arabian Sea				Bay of Bengal				Total			
	Larvae Collected		Frequency of occurrence		Larvae collected		Frequency of occurrence		Larvae collected		Frequency of occurrence	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Elopidae	1	0.003	1	0.2								
Clupeidae	10	0.03	5	0.8	11	0.05	2	0.5	21	0.04	7	0.7
Engraulidae	1601	5.00	49	8.3	65	0.3	6	1.6	1666	3.3	55	5.9
Bathylagidae	148	0.5	15	2.6	35	0.2	9	2.5	183	0.4	24	2.6
Other Clupeoids	165	0.5	15	2.8	37	0.2	9	2.5	202	0.4	24	2.6
Gonostomidae												
Vinciguerria	1435	4.5	215	36.5	3915	19.6	239	65.9	1650	3.3	454	48.6
Cyclothone	392	1.2	91	15.5	159	0.7	36	9.9	551	1.1	127	13.6
Other Gonostomids	67	0.2	11	1.9	31	0.1	10	2.7	98	0.2	21	2.2
Stomiatidae	97	0.3	42	7.1	89	0.4	21	5.8	186	0.4	63	6.7
Sternoptychidae	21	0.1	11	1.9	79	0.4	13	3.6	100	0.2	24	2.6
Asteronesthidae	17	0.05	9	1.5	1	0.1	1	0.3	18	0.04	10	1.1
Idiacanthidae	138	0.4	34	5.8	7	0.03	4	1.1	172	0.32	38	4.1

Table 6 (Contd.)

Groups	Arabian Sea				Bay of Bengal				Total			
	Larvae collected		Frequency of occurrence		Larvae collected		Frequency of occurrence		Larvae collected		Frequency of occurrence	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Chauliodontidae	31	0.1	13	2.2	3	0.02	3	0.8	34	0.07	16	1.7
Other Stomiatidae	186	0.6	65	11.0	194	0.9	54	14.9	380	0.8	119	12.7
Synodontidae	147	0.5	21	3.6	20	0.1	11	3.0	167	0.3	32	3.4
Paralepididae	196	0.6	80	13.6	126	0.6	55	15.2	322	0.6	135	14.4
Scopelarchidae	94	0.3	46	7.8	30	0.1	16	4.4	124	0.2	62	6.6
Myctophidae	8590	26.8	401	68.1	4175	20.8	261	72.0	12765	25.3	662	70.8
Anguilliformes	51	0.2	27	4.6	95	0.5	46	12.7	146	0.3	73	7.8
Exocoetidae & Hemirhamphidae	12	0.04	6	1.0	18	0.1	10	2.7	30	0.1	16	1.7
Bregmacerotidae	832	2.6	135	22.9	1020	5.1	115	31.7	1852	3.7	250	26.7
Pleuronectiformes	99	0.3	42	7.1	41	0.2	11	3.0	140	0.3	53	5.7
Sphyraenidae	2	0.01	2	0.3								
Mugilidae	3	0.01	3	0.5	4	0.02	3	0.8	7	0.01	6	0.6

Table 6 (Contd.)

Groups	Arabian Sea				Bay of Bengal				Total			
	Larvae collected		Frequency of occurrence		Larvae collected		Frequency of occurrence		Larvae collected		Frequency of occurrence	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Syngnathidae	1	0.003	1	0.2	6	0.03	5	1.4	7	0.01	6	0.6
Fistulariidae	3	0.01	3	0.5	2	0.01	1	0.3	5	0.01	4	0.4
Sciaenidae	4	0.01	3	0.5	3	0.01	2	0.5	7	0.01	5	0.5
Holocentridae	35	0.1	9	1.5	15	0.7	6	1.7	50	0.1	15	1.6
Serranidae	66	0.2	38	6.4	135	0.7	33	9.1	201	0.4	71	7.6
Carangidae	355	1.1	52	8.8	221	1.1	48	13.2	581	1.2	100	11.0
Apogonidae	7	0.02	3	0.5	5	0.02	3	0.8	12	0.02	6	0.6
Coryphaenidae	151	0.5	19	3.2	14	0.07	5	1.4	165	0.3	24	2.6
Stromateidae	133	0.4	35	5.9	107	0.5	40	11.04	240	0.5	75	8.0
Labridae	132	0.4	57	9.6	56	0.3	27	7.4	188	0.4	84	8.9
Callionymidae	111	0.3	48	8.1	111	0.5	39	10.8	222	0.4	87	9.3
Acanthuridae	1	0.003	1	0.2								
Trichiuridae	22	0.1	6	1.0	9	0.04	3	0.8	31	0.06	9	0.9
Gempylidae	48	0.2	31	5.2	11	0.05	8	2.2	59	0.12	39	4.2
Thunnidae	130	0.4	60	10.2	126	0.6	50	13.8	256	0.5	110	11.8

Table 6 (Contd.)

Group	Arabian Sea				Bay of Bengal				Total			
	Larvae collected		Frequency of occurrence		Larvae collected		Frequency of occurrence		Larvae collected		Frequency of occurrence	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Scombridae	2	0.006	2	0.3	1	0.005	1	0.3	3	0.006	3	0.3
Scomberomoridae	122	0.4	22	3.7	62	0.3	20	5.5	184	0.4	42	4.5
Histiophoridae	31	0.1	2	0.3	3	0.01	2	0.5	34	0.1	4	0.4
Gobiidae	373	1.2	78	13.2	159	0.8	53	14.6	532	1.1	131	14.0
Scorpaenidae	374	1.2	58	9.9	192	0.9	41	11.3	566	1.1	99	10.6
Bramidae	39	0.1	10	1.7	28	0.1	5	1.4	67	0.1	15	1.6
Brancheostegidae	2	0.006	2	0.3	16	0.1	4	1.1	18	0.04	6	0.6
Ophididae	5	0.001	2	0.3								
Champsodontidae					8	0.04	2	0.5				
Trachypteridae	2	0.006	1	0.2	8	0.04	4	1.1	10	0.02	5	0.5
Dactylopteridae					2	0.001	2	0.5				
Balistidae	47	0.1	23	3.9								
Diodontidae	4	0.01	4	0.7								
Tetradontidae	30	0.1	17	2.9								
Antennariidae	5	0.02	5	0.8								
Molidae	1	0.003	1	0.2								

Table 7 : Average number of some of the more common families of fish larvae per haul during different months in the Arabian Sea.

Groups	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
Engraulidae	4	1	4	2	22	7	116	4	-	4	110	1
Clupeidae	-	1	3	-	-	-	-	-	-	-	-	2
Gonostomidae: *Vinciguerria*	11	4	6	6	4	6	7	14	13	6	12	7
Cyclothone	-	-	12	6	4	4	4	5	3	3	3	6
Paralepididae	3	2	2	6	2	2	2	2	-	-	3	1
Stomiatidae	2	2	2	1	-	2	4	3	2	1	1	2
Scopelarchidae	-	-	2	1	1	-	2	2	1	-	-	-
Myctophidae	15	18	17	21	16	21	35	39	8	10	16	21
Synodontidae	-	-	1	-	5	5	8	2	-	1	16	-
Anguilliformes	10	2	1	3	5	2	1	-	-	-	1	1
Bregmacerotidae	3	1	7	3	2	3	2	16	8	22	3	3
Pleuronectiformes	1	1	2	2	2	1	2	2	-	1	6	2

Table 7 (Contd.)

Groups	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
Callionymidae	2	3	3	-	2	4	6	2	-	3	2	1
Carangidae	2	-	2	3	2	13	30	1	-	1	6	3
Serranidae	1	1	3	1	1	1	1	4	-	1	1	2
Trichiuridae	-	-	-	-	1	1	1	1	-	-	1	-
Gempylidae	2	1	1	1	1	1	2	1	1	1	-	2
Thunnidae	2	1	2	3	3	3	3	2	1	3	3	1
Scombridae	-	-	-	-	-	-	-	-	-	-	1	1
Scomberomoridae	1	-	-	-	3	6	9	3	-	4	3	1
Coryphaenidae	-	-	-	1	1	1	10	1	1	-	1	1
Labridae	2	3	3	2	-	8	2	2	1	5	-	3
Gobiidae	1	2	12	3	8	3	3	4	-	-	7	1
Scorpaenidae	1	2	1	1	5	1	1	1	1	3	6	2

Table 8 : Average number of some of the more common families of fish larvae per haul during different months in the Bay of Bengal.

Groups	J	F	M	A	M	J	J	A	S	O	N	D
Engraulidae	-	-	1	20	5	15	1	37	6	-	-	-
Clupeidae	-	-	-	1	-	1	10	-	-	-	-	-
Gonostomidae: Vincigenerria	35	20	10	11	17	21	25	11	11	13	14	12
Cyclothone	6	6	1	3	9	6	-	16	4	11	2	2
Stomistidae	-	4	3	2	1	4	2	2	3	1	1	1
Paralepidae	2	5	1	4	2	3	1	3	2	4	1	1
Scopelarchidae	-	-	1	1	1	1	-	1	1	2	2	-
Myctophidae	18	24	18	31	18	37	19	31	6	14	27	13
Synodontidae	1	-	1	5	-	3	-	-	2	-	-	1
Anguilliformes	3	1	2	2	6	2	2	2	2	-	1	1
Bregmacerotidae	5	14	4	8	2	4	8	8	2	1	-	3
Pleuronectiformes	2	2	2	2	34	1	6	3	3	2	-	-

Table 8 (Contd.)

Groups	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
Callionymidae	2	-	1	1	20	1	3	2	2	1	-	-
Carangidae	1	-	5	4	4	1	2	7	6	-	-	1
Serranidae	1	2	3	8	1	2	-	5	1	-	-	1
Trichiuridae	-	-	-	-	-	3	-	-	3	-	-	-
Gempylidae	-	-	1	1	1	2	-	1	3	-	-	-
Thunnidae	2	-	1	1	20	1	3	2	2	1	-	-
Scombridae	-	-	-	-	-	-	-	1	-	-	-	-
Scomberomoridae	-	-	1	3	4	2	-	6	2	1	1	-
Coryphaenidae	-	-	2	3	-	1	-	-	1	-	-	-
Labridae	1	-	1	3	3	1	1	1	2	1	1	2
Gobiidae	3	1	12	3	6	2	3	3	4	-	1	1
Scorpaenidae	-	-	3	2	1	1	1	-	5	-	-	-

salinity range was 34.6‰ - 35.9‰. The records of larvae were during February, March and August.

4.3. Distribution in general.

Numerical abundance indicating density in a statistical way ranged from 0 to 1600 per haul. The maximum number of larvae collected per haul from the whole of Arabian Sea amounted to 1600 from a station off Kerala coast, 11°00'N - 74°33'E in the month of July. From the Bay of Bengal the highest record was 441 larvae per haul from a station, 13°03'N - 81°08'E, during April. In the Arabian Sea, fish larvae were present in 95.6% of the 573 samples collected accounting for a total number of 31,994 (Table 9). The average number of larvae recorded per haul from this region was 56. The Bay of Bengal represented by 362 stations had 96.7% positive hauls (Table 9). A total of 21,492 larvae were collected and the average number of larvae per haul was 59 indicating a marginal increase in percentage over that of Arabian Sea. The percentage of stations which recorded up to 20 larvae per haul in the Arabian Sea was 26.2 and in Bay of Bengal 19.0. Larvae between 20 and 100 per haul were recorded in 59.5% of the stations in Arabian Sea and 65.5% in Bay of Bengal. Similarly stations with more than 100 larvae per haul in the

Table 9 : Seasons, area, number of samples and fish larvae collected from Arabian Sea and Bay of Bengal.

Seasons	Area	Standard hauls			Fish larvae		
		Total No.	% of samples	% of positive hauls	Total No.	%	Average No. per haul
May-Aug.	Arabian Sea	270	73.8	96.5	17222	32.2	64
	Bay of Bengal	96	26.2	95.8	6306	11.8	66
Sept.-Oct.	Arabian Sea	47	37.6	95.4	1985	3.7	48
	Bay of Bengal	78	62.4	88.4	3928	7.3	50
Nov.-Feb.	Arabian Sea	210	73.2	94.7	10494	19.6	50
	Bay of Bengal	77	26.8	98.7	4104	7.7	53
Mar.-Apr.	Arabian Sea	46	29.3	93.4	2293	4.3	50
	Bay of Bengal	111	70.7	99.0	7154	13.4	64
Total	Arabian Sea	573	61.3	95.6	31994	59.8	56
	Bay of Bengal	362	38.7	96.7	21492	40.2	59
		935			53486		

Fig. 21. Distribution of fish larvae (total) in the Arabian Sea and Bay of Bengal.

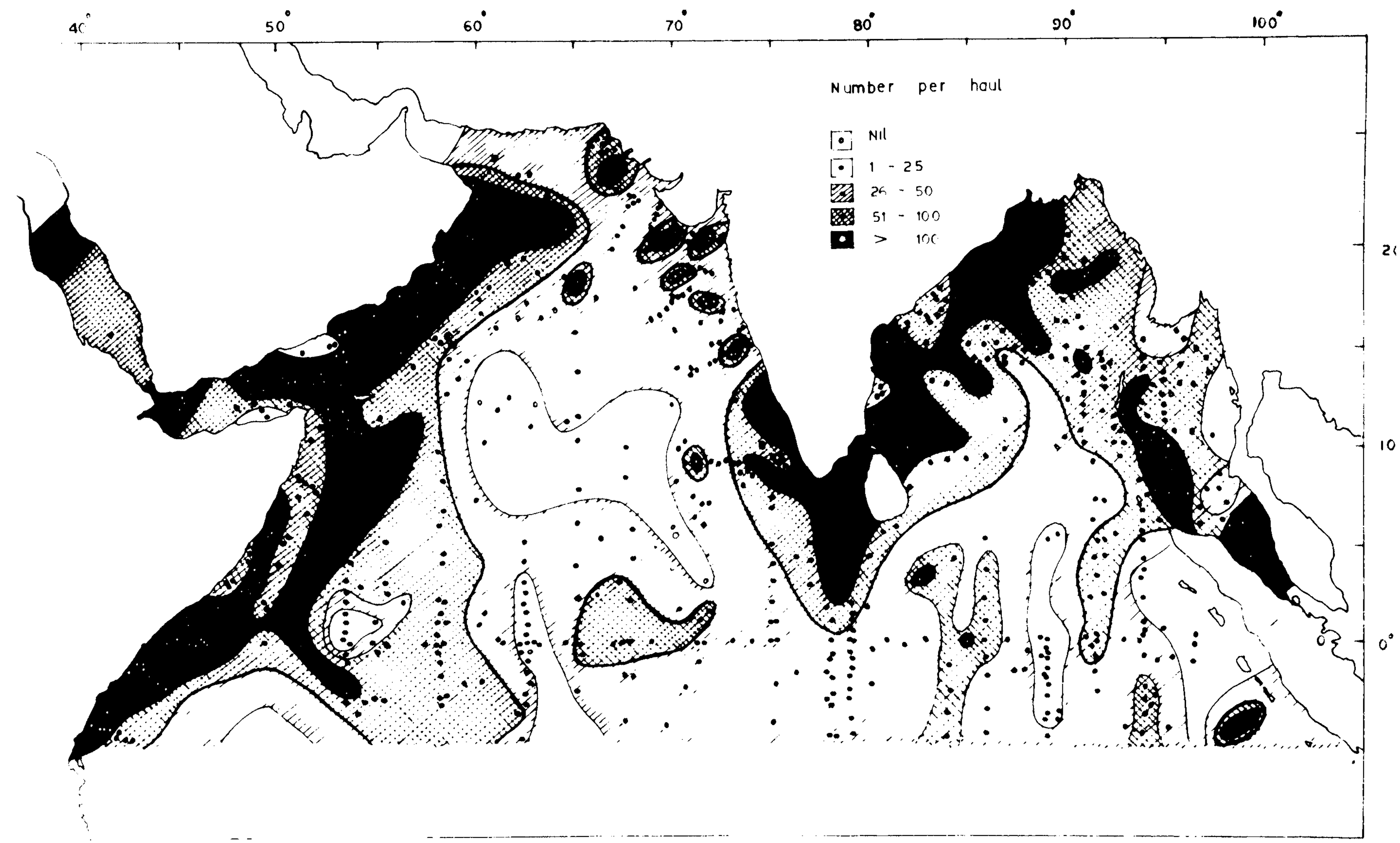


Fig. 21

Arabian Sea came to 14.3%, whereas in Bay of Bengal to 15.5%.

The numerical data obtained were plotted on a map and contoured to give a general picture of the geographical pattern of distribution and abundance. The maps showed several areas of high fish larval population as well as places where they were medium, low or even totally absent (Fig. 21). The highest range of density (above 100 larvae per haul) in the distribution of larvae was located in the central part of Red Sea, Gulf of Aden and along the African coast, north of Kenya extending north along the Arabian coast in the western half of the Arabian Sea. In the eastern half, this grade of density was noticed as dense patches in areas north of Kutch, off Maharashtra coast, Malabar coast, the Wadge Bank, Gulf of Mannar and west of Sri Lanka coast extending up to equator. The density of 51 - 100 also covered a similar area adjacent to high density areas, in addition to three large patches along the equatorial Indian Ocean. The offshore and oceanic areas such as central Arabian Sea and the equatorial regions were represented by the third range of 26 - 50 larvae. Areas of very low densities (1-25 larvae) were noticed in the central part of Arabian Sea as three patches in the equatorial region. In the Bay of Bengal the highest density of above 100 occurred along the western half of the Bay parallel to the coast excluding part of Andhra coast, extending right up to the centre of northern Bay, south-east of Andaman-Nicobar Islands and strait of Malacca. The next range of 50 - 100 was noticed in a very wider area covering the northern part of the Bay adjacent to the highest density areas excluding the central part. The southern part of the Bay of Bengal also represented this grade by two big patches extending up to the equatorial zone. The lowest grade of 1 - 25 was noticed off Burma coast and central part of southern Bay.

The average number of fish larvae when estimated and plotted for each five degree squares, showed a clear picture of their latitudinal and longitudinal pattern of distribution. The longitudinal variation is shown in Fig. 22. In the Arabian Sea along the 35°E to 40°E longitude, the only haul made from a 5° square in the Red Sea area between 20°N - 25°N recorded 121 larvae. The area between 40°E and 45°E longitude represented by four 5° squares, two from Red Sea and one each from southern Somalia and Kenya coasts had 73 larvae on an average. Similar values obtained for areas between 45°E and 50°E, 50°E and 55°E and 55°E and 60°E were 52, 55 and 84 respectively. These high values were obtained due to the occurrence of higher densities of

Fig. 22. Longitudinal distribution of fish larvae in the Arabian Sea and Bay of Bengal.

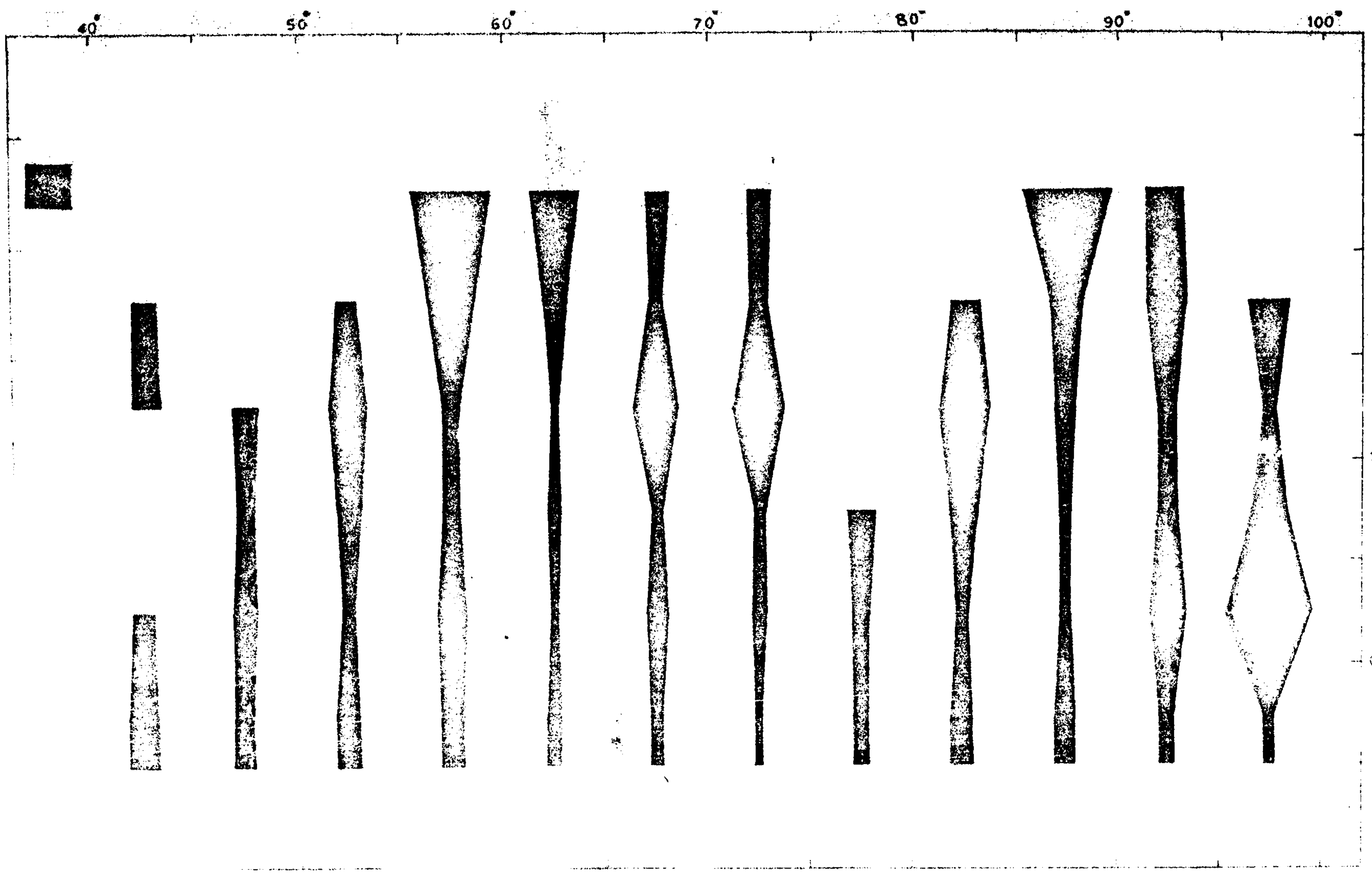


Fig 22

fish larvae in the offshore waters of Arabia and Somalia. Between 60°E and 65°E the average number of larvae obtained was 43 because of the very low larval densities in the central and southern Arabian Sea (12, 15) despite the higher value (112) at the northern region. Between 65°E and 70°E, 70°E and 75°E and 75°E and 80°E the average numbers of larvae obtained were 46, 48 and 47 respectively eventhough two 5° squares along 10°N to 15°N had average values as high as 114 and 116.

In the Bay of Bengal between the 80°E and 85° zone of longitude the values were higher off Tamil Nadu, with 105 larvae per 5° square whereas the average number of larvae for this zone was 66. The zone between 85°E and 90°E had the average number of 74 larvae eventhough the northernmost 5° square south of West Bengal recorded 194 larvae. Between latitudes 90°E and 95°E the average number of larvae recorded was 56, although the 5° square south of West Bengal had 85 larvae, since the central and southern part had lower values. The average number of larvae collected from the zone of 95°E to 100°E longitude was 87 inspite of the 211 larvae recorded from the only haul from a 5° square west of Sumatra.

The latitudinal distribution of fish larvae plotted at intervals of 5° zone in the Arabian Sea (Fig. 23) recorded an average number of 98 larvae between the

Fig. 23. Latitudinal distribution of fish larvae in the Arabian Sea and Bay of Bengal.

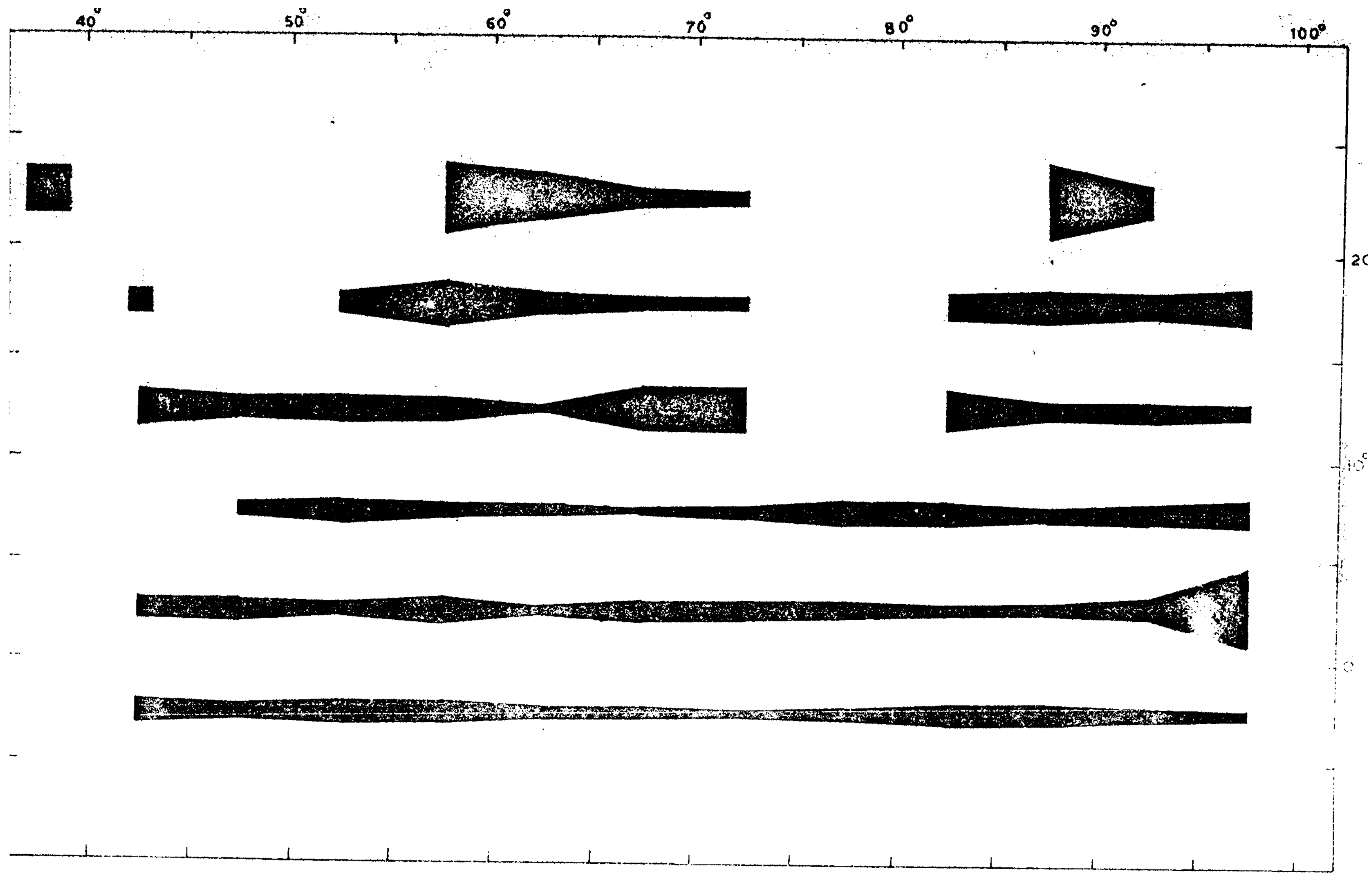


Fig. 23

25°N - 20°N latitude, eventhough 5° squares in the Red Sea and the northern Arabian coast gave average numbers of 121 and 180 respectively. Latitudes between 20°N and 15°N recorded an average number of 57 larvae the maximum number noticed being 113 per 5° square, off the northern Arabian coast, which showed a decreasing trend towards the eastern and western sides. Along 15°N to 10°N latitudes the average number of larvae was 74, whereas the lowest value of 12 larvae per 5° square was recorded in the centre of the Arabian Sea, which increased to 116 towards the eastern side. Between 10°N and 5°N latitudes the average number of larvae per 5° square ranged from 20 to 65 from west to east, with the minimum number in the central Arabian Sea, the average number for the entire zone being 41. Between 5°N and 0° latitudes the average number of larvae per 5° square showed a very wide range from 15 in the south central Arabian Sea to 69 in the adjacent 5° square west of this. This zone recorded an average value of 48. In the region between 0° and 5°S latitudes the average number of larvae recorded was 42. The 5° square values in this zone varied between 71 (Kenya coast) and 13 (between 70°E and 75°E).

In the Bay of Bengal an average number of 140 larvae was recorded within the zone of 25°N to 20°N latitudes (Fig. 23). The 20°N to 15°N latitude zone also had considerably higher number of larvae (58 to 95) with an average of 75. Along the 15°N to 10°N latitudes the highest number of 105 larvae per 5° square occurred east of Tamil Nadu, and the lowest value of 38 larvae per 5° square west of Thailand, the average value in this zone being 61. In the area between 10°N and 5°N, the average number of larvae obtained was 54. From this zone, the lowest value of 36 larvae per 5° square was recorded in the central Bay of Bengal, but the areas east of Sri Lanka and west of Malaysia had values of 64 and 68 respectively. Between 5°N and equator the average number of larvae recorded was 83. But the highest value of 211 larvae recorded from a single haul in the 5° square west of Sumatra, gradually decreased to 31 in the 5° square southwest of Sri Lanka. The area south of equator up to 5°S latitude showed values of 23 and 61 larvae per 5° square varying from east to west, the average value for the entire zone being 44. The stations which recorded more than 200 larvae per haul are listed in Tables 14 and 15. There were only 19 such stations in the Arabian Sea and 15 in the Bay of Bengal. Out of these 13 each were from night hauls.

Based on the seasonal regime of currents, the data in respect of Arabian Sea and Bay of Bengal were split up into 4 periods (Gallagher, 1966) namely Southwest monsoon, Northeast monsoon and two transitional periods of fall and spring. The patterns of monsoonal distribution in terms of areas of abundance were found to be different from that of the general distribution. The Arabian Sea and Bay of Bengal recorded the highest number of larvae during the Southwest monsoon period and the lowest in the transition period that followed.

4.4. Distribution during Southwest monsoon period (May-August).

Of the 366 samples collected during the Southwest monsoon period, 270 (73.8%) were from the Arabian Sea. Larval abundance during this period is shown in Fig. 24, and Table 4. 95.5% of these samples had fish larvae amounting to a total number of 17,222 with an average number of 64 larvae per haul. During this season, the western part of Arabian Sea exhibited very high densities (> 100/haul) of fish larvae. Majority of the records of numerical abundance from the Arabian Sea were also during this season. The high density areas were not continuous as seen in the general distribution. Along

Fig. 24. Distribution of fish larvae (total) in the Arabian Sea and Bay of Bengal during Southwest monsoon period (May–August).

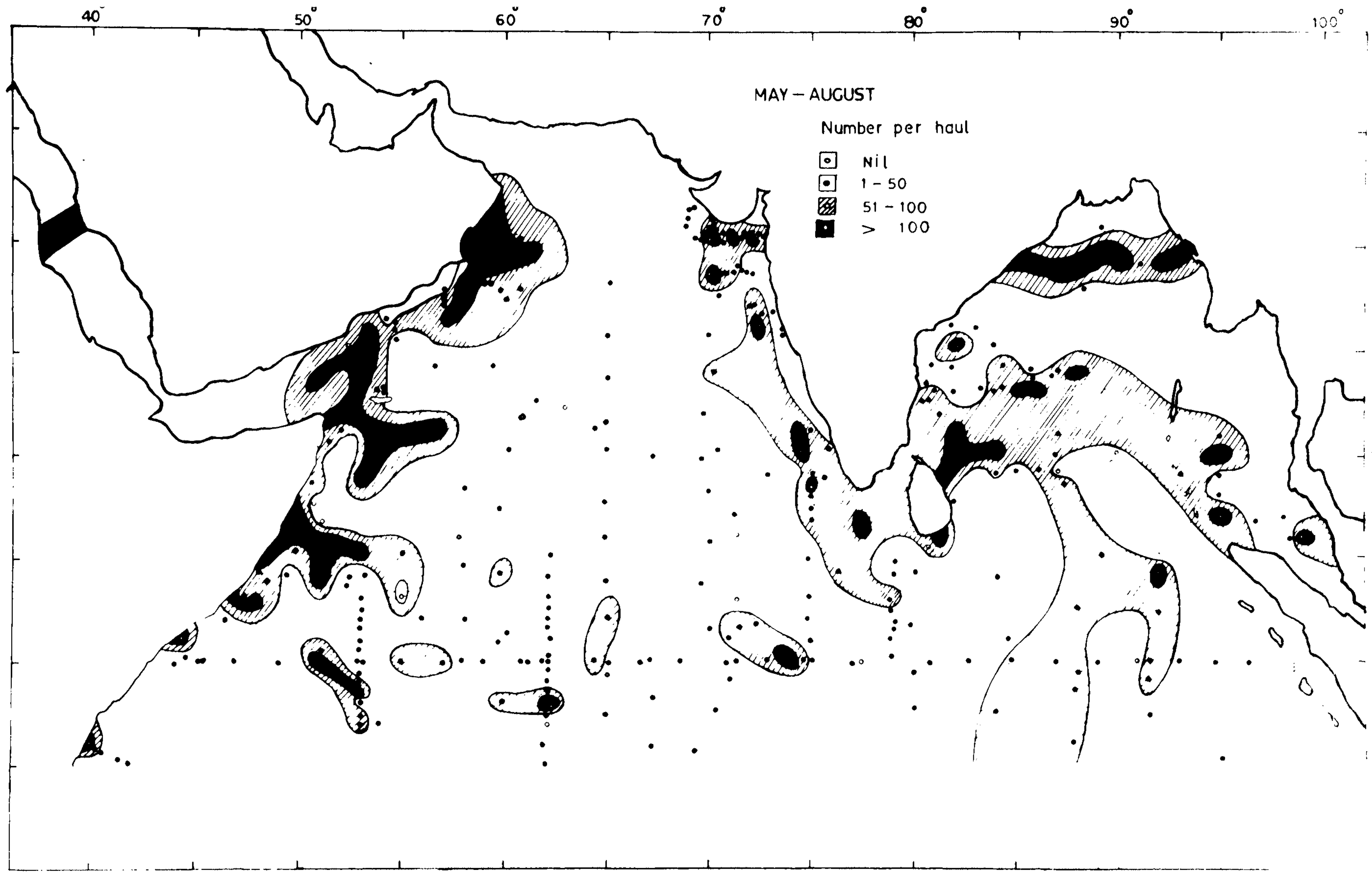

MAY — AUGUST
Number per haul
Nil
1 - 50
51 - 100
> 100
40°
50°
60°
70°
80°
90°
100°
10°

Fig. 24

the western half of the Arabian Sea they were all broken up as large patches confined to coastal and offshore areas as in the middle of Red Sea, northern and central part of Arabian coast and northern and southern Somali coast. Along the eastern half the high density areas were widely scattered in much smaller patterns, off the coasts of Gujarat, Maharashtra, Kerala and south of the southern tip of Indian peninsula. Similar high density patches were also noticed at three places along the equatorial zone. The Red Sea patch recorded 121 larvae per haul. The maximum number of larvae recorded from the northern Arabian coast was 472, while that of central Arabian coast being 192 per haul (Table 15). The northern and southern Somali coast recorded maximum numbers of 291 and 391 larvae per haul respectively. The maximum number of larvae recorded from coasts of Gujarat, Maharashtra, Kerala and south of south India were 149, 194, 1600 and 118 per haul respectively. The three high density equatorial patches recorded 274, 132 and 135 larvae per haul respectively. The next range of density of 51 to 100 larvae per haul was distributed as large patches along the Arabian and Somali coasts and offshore areas of west Indian coast. Areas of density, 1 - 50 larvae per haul were widely distributed occupying the entire oceanic regions. A total absence of larvae was noticed at a few stations in the central part of the Arabian Sea.

During the Southwest monsoon period the 96 samples collected from Bay of Bengal accounted for only 26.2% of the total samples (Table 9). As such the total number of larvae collected from May to August was considerably less (6306). Still the average number of larvae per haul worked out to be 66, a slightly higher value than that of Arabian Sea, however exhibiting a uniform numerical abundance in the Bay of Bengal and Arabian Sea during the Southwest monsoon period. The highest density range of larvae of greater than 100 observed parallel to the coast in the general distribution, disappeared. The higher density of larvae noticed at the head of the Bay was found stretched across between the coasts of Orissa and Burma (Fig. 24). This large band extended along 20°N latitude in the northern basin. Another area of concentration of larvae at the northeast coast of Sri Lanka was retained in this season. This patch had the highest number of 216 larvae per haul. In addition 7 discontinuous patches were noticed in the western and southeastern Bay. The highest records of larvae from the three western offshore patches were 236, 126, and 106 per haul. The 2 patches along the southwestern region of Andaman-Nicobar Islands had 100 and 113 larvae each per haul and the patch along the west coast of Malaysia had 163 per haul and the single patch along the equatorial region had a concentration of 206 larvae per haul. The next lower grade in density of larvae of 51 to 100 was noticed at considerably vast areas close to higher density areas, at the northern, central and southern regions of the Bay. The rest of the areas were represented by lower grade of 1 - 50 larvae per haul. Four oceanic stations in the Bay of Bengal did not have any fish larvae.

4.5. Distribution during transition period (September-October).

Out of the 125 samples collected during this period, 47 were (37.6%) from the Arabian Sea, of which 45 samples (95.4%) had fish larvae (Table 9). During this period the coverage of this area was very inadequate, as there was no collection from a major portion of the eastern Arabian Sea. A total of 1,985 larvae were collected giving an average of 42 per haul. This indicated a considerable decrease in the abundance of larvae towards the close of the Southwest monsoon period. The highest density of larvae (>100/haul) was confined to 3 small patches (Fig. 25), one at the northern tip of Somalia and the others at the coastal and offshore regions of

Fig. 25. Distribution of fish larvae (total) in the Arabian Sea and Bay of Bengal during transition period (September-October).

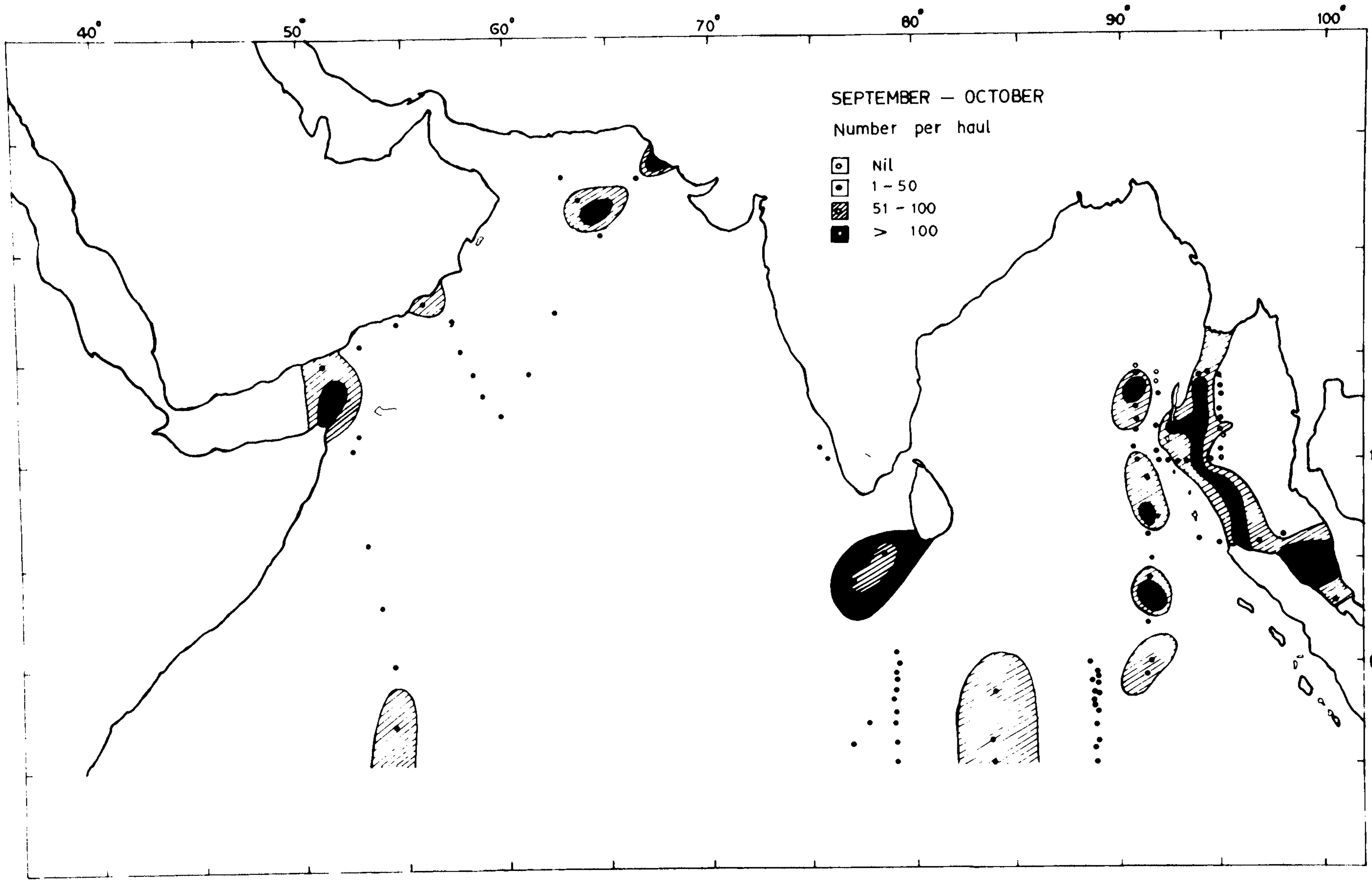

SEPTEMBER — OCTOBER
Number per haul
Nil
1 - 50
51 - 100
> 100
40°
50°
60°
70°
80°
90°
100°
20°
10°
0°

Fig. 25

Pakistan. The highest records of larvae from these areas were 106, 175 and 164 respectively. The area southwest of Sri Lanka recorded the highest value of 164 larvae per haul. The next density range (51 - 100) also had a restricted distribution in the central Arabian coast, southwest of Sri Lanka and at 55°E between equator and 5°S. The low density (1 - 50) areas were noticed at all other stations wherever collections were made. Larvae were found to be totally absent only in two collections.

In the Bay of Bengal during this transition period there were 78 collections representing 62.4% of the samples with an average number of 50 larvae per haul, the total number of larvae collected being 3,928 (Table 9). During this period the sampling was confined mainly to the south-eastern and equatorial region of Bay of Bengal, leaving the rest of the Bay uncovered. The highest density of > 100 larvae per haul was confined to eastern half of the Bay between equator and 15°N lat. as a long band. Three similar high density patches of larvae isolated along the 90°E longitude were also noticed in this region. The highest value of 335 larvae per haul was recorded from the area east of Andaman-Nicobar Islands. The density of larvae between 51 and

100 per haul was noticed at several places close to the above high density regions and along the equatorial zone between 80°E and 95°E. The low density of 1 - 50 larvae per haul were found scattered at several areas. The total absence of larvae was observed in nine samples.

4.6. Distribution during Northeast monsoon period (November-February).

Of the total number of 287 samples collected during this season, 210 (73.2%) were from the Arabian Sea of which 94.7% had fish larvae (Table 9). The number of larvae recorded from these samples amounted to 10,494 giving an average number of 50 larvae per haul. This indicated a fall in the numerical and general abundance in the Arabian Sea, as compared with the Southwest monsoon period. High density of larvae (> 100/hl) were confined to the patches noticed along the coasts of Kenya, southern and northern Somalia, southern, central and northern Arabia, off Pakistan, nearshore and offshore waters of Kerala coast, south of Indian peninsula and in the equatorial zone (Fig. 26). 159 larvae per haul were collected from a station at the northern tip of Somalia. The Arabian coast had a very high numerical abundance of larvae (623 per haul) at the northern end, whereas

Fig. 26. Distribution of fish larvae (total) in the Arabian Sea and Bay of Bengal during Northeast monsoon period (November–February).

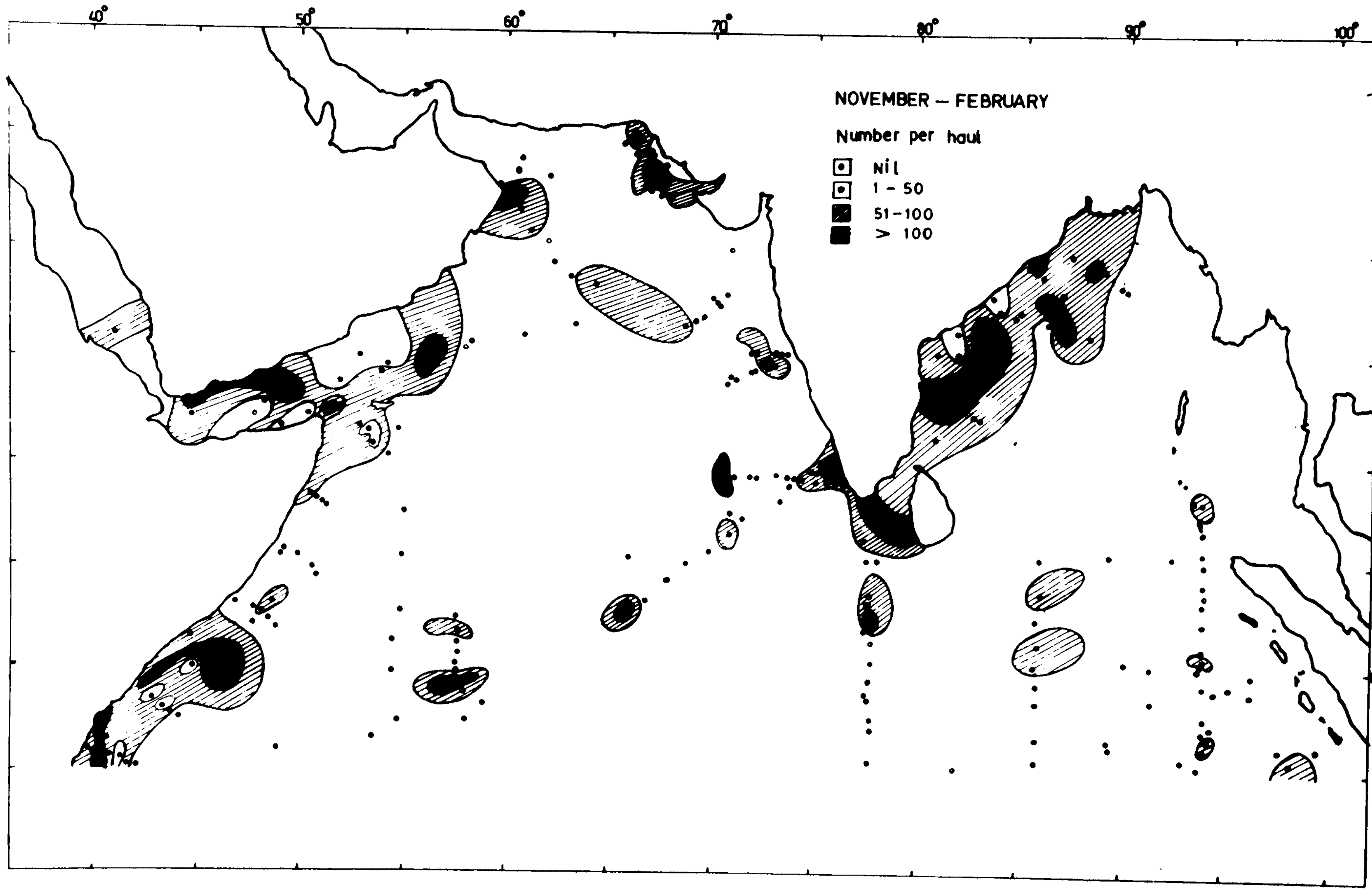

40°
50°
60°
70°
80°
90°
100°
20°
10°
0°
NOVEMBER — FEBRUARY
Number per haul
Nil
1 - 50
51-100
> 100

Fig. 26

the southern region recorded only 355. The offshore waters of Pakistan had 204 larvae per haul. From the Malabar coast the highest record was 117 larvae, and the west coast of Sri Lanka had 144 larvae per haul. The larvae recorded from the three stations along the equatorial zone were 114, 173 and 153 per haul respectively. The next range of 51 - 100 larvae per haul was distributed closer to the same localities, but extending to wider areas. At the northern part of the Arabian Sea a wider patch of this range was located. The low density areas of 1 - 50 larvae per haul were found widely scattered. 11 samples collected from this region did not record any fish larvae.

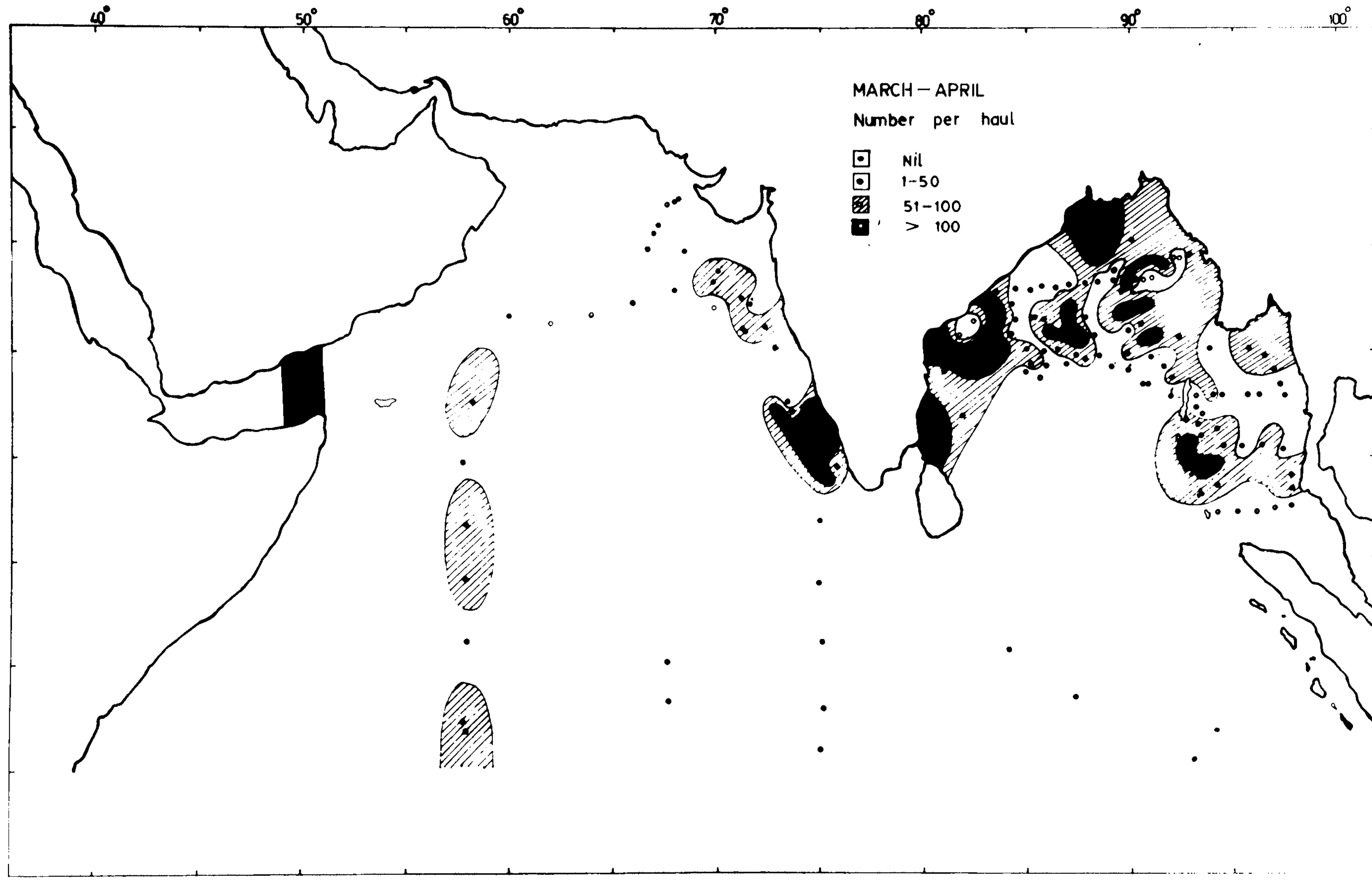
During Northeast monsoon season, 77 samples were collected from the Bay of Bengal representing 26.8% of the total which recorded 4,104 larvae. The average number of larvae collected from this region was 53, which showed a slight increase in the value over that of Arabian Sea. This also indicates a fall in numerical abundance from that of Southwest monsoon period. The higher concentrations of larvae noticed at the southeastern part of the Bay during the transition period were reduced to the next lower grade, shifting the high density patches to the western half of the Bay parallel to the coast.

The central part of the Bay was also found to be inadequately sampled. The higher density of > 100 larvae per haul was mainly observed as patches in the offshore waters of Andhra Pradesh and Orissa. 342 larvae per haul was recorded from a coastal station off Andhra Pradesh. The density range of 51 - 100 larvae per haul was observed intermixed with the highest range on the western side parallel to the coast, and at 2 places along the 85°E and 3 places along 94°E longitudes. The lowest grade of 1 - 50 larvae per haul was recorded at 2 regions along coastal Andhra Pradesh, Orissa and several places at the southern part of the Bay. Only 3 samples collected from this region were devoid of fish larvae.

4.7. Distribution during transition period (March-April).

During the second transition period 157 samples were collected of which 29.3% (46 samples) were from Arabian Sea. Fish larvae were found to be present in 93.4% of the samples amounting to a total number of 2293 larvae, which showed an average of 50 larvae per haul (Table 9). The highest density of larvae (> 100/hl) was noticed at two places in the whole of Arabian Sea, one in between the Arabian coast and northern tip of Somali coast in the Gulf of Aden, and the other in the

Fig. 27. Distribution of fish larvae (total) in the Arabian Sea and Bay of Bengal during transition period (March-April).



40°
50°
60°
70°
80°
90°
100°
20°
10°
0°
MARCH – APRIL
Number per haul
Nil
1-50
51-100
> 100

Fig. 27

coastal and offshore areas of Kerala (Fig. 27). The maximum number of larvae recorded per haul from this patch was 404 whereas the haul from the former patch recorded only 199. The next range of density (51 - 100) also had a restricted distribution in 3 patches along 57°E longitude between 5°S and 15°N, and another one off Goa, in addition to the adjacent areas of the high density region west of Kerala. Here again the distribution study had limitations owing to the lesser number of collections during this period. The low density of 1 - 50 larvae occurred off Gujarat and at a few stations along the 57°E - 67°E and 75°E longitudes. Total absence of larvae was noticed only in three stations between 15°N and 20°N latitudes.

In the Bay of Bengal 111 samples (70.7% of the total) were collected during this period contributed to a total of 7154 larvae (Table 9). Of these 111 samples, 99.0% had fish larvae giving an average of 64 larvae per haul. This indicated a numerical abundance in the Bay of Bengal in contrast to the Arabian Sea. High density of larvae ($>$100 per haul) was confined to coastal, offshore and oceanic patches (Fig. 27). The areas include north of Sri Lanka extending to coastal Tamil Nadu, east of Andhra Pradesh excluding part of the coastal area, south of West Bengal, northwest and south of Andaman-Nicobar Islands. Of all these places the highest record of 441 larvae per haul was from north of Sri Lanka, followed by 345 larvae from south of West Bengal and 270 from off Andhra coast. The next range of the density 51 - 100 extended over vast areas excluding major part of the central and south Bay of Bengal, in addition to two pockets of low density areas along the eastern and western parts. The less number of larvae in the southern Bay may be attributed to the lack of sufficient number of collections in that area. The areas of low density of larvae (1 - 50) were noticed south of equator, and off Orissa, Thailand and central part of northern Bay. The absence of larvae was noticed only in one collection.

4.8. Distribution during different months.

Figure 28 shows the total number of larvae collected during the period 1960-1965, distributed month-wise in the Arabian Sea and Bay of Bengal. The pattern of distribution and abundance of larvae in the Arabian Sea showed great fluctuations during the different months of the year. The average number of larvae per haul during January was 56, which in the month of February became 46. There was a slight increase to 49 and 47 in the number of larvae during March-April months respectively, after which it was reduced to the minimum of 39 in May. The month of June registered a steep rise in the number of larvae (70) reaching the maximum of 114 in July. During August-September, the number suddenly dropped to 56 and 42 respectively. In October more or less the same value (41) persisted which again shot up to 61 in November following a decline to 39 in December. Thus in the Arabian Sea of all the months May and December recorded considerable fall in number of larvae. The periods of high abundance fell within the Southwest monsoon season. The graph (Fig. 28) clearly showed that the peak catch was in July, whereas low values were in the months of May, September, October and December. Cruise-wise analysis of samples indicated that the area sampled determined the degree of abundance rather than month.

The distribution of larvae in Bay of Bengal during different months showed considerable variation in their pattern of abundance (Fig. 28). The average number of larvae per haul during January was 75 which in the next month suddenly increased to 129. In March the value was 44, followed by 75 in April and 65 in May. June

Fig. 28. Monthly variation of fish larvae (total) in the Arabian Sea and Bay of Bengal.

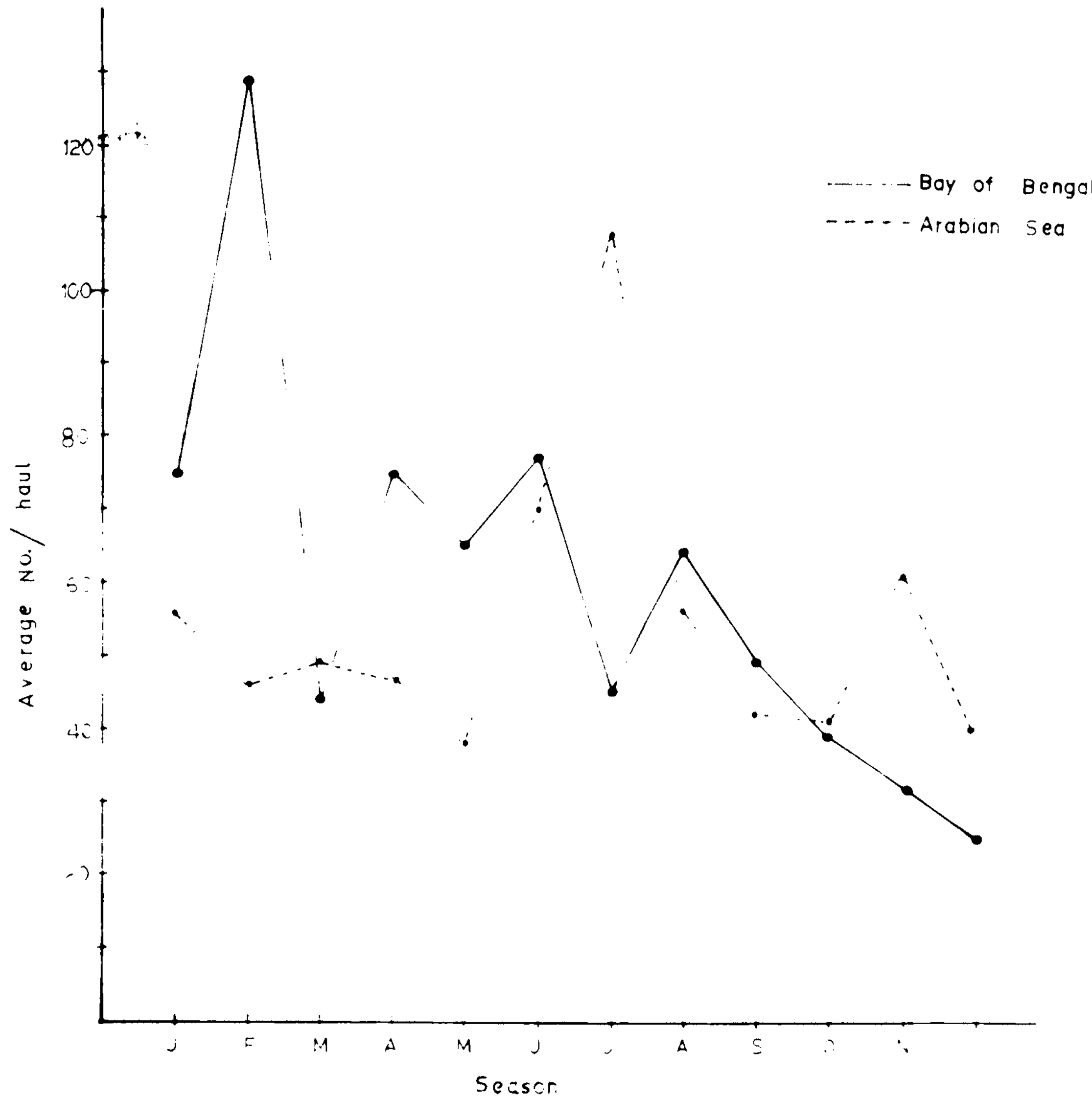

Bay of Bengal
Arabian Sea
Average No./ haul
120
100
40
J
F
M
A
M
J
A
S
Season

Fig. 28

recorded slightly higher value (77), which again reduced to 45 in July. The number then increased to 65 in August, after which it gradually decreased (50, 54 and 32) falling to the minimum of 26 in December. The month of February exhibited the highest peak period of abundance, followed by 3 other peaks in April, June and January. A general decline was noticed from June to December. In general, it may be mentioned that the paucity of the larvae was noticed towards the close of the Southwest monsoon periods following the peak periods of abundance. So the period of abundance of larvae in the Arabian Sea was noticed during Southwest monsoon recording the highest peak in the month of July and minor peaks in Northeast monsoon period. Whereas in the Bay of Bengal the abundance noticed was during Northeast monsoon with the highest peak in February and minor ones in Southwest monsoon season.

4.9. Distribution during day and night.

The distribution pattern of larvae in the Arabian Sea and Bay of Bengal during the night hours was found to be in very close agreement with that of the general distribution pattern in the highest grade of concentration of larvae ($>$ 100 per haul), whereas the next grade of 51 - 100 showed marked difference. Similar difference

Fig. 29. Distribution of fish larvae (total) in the Arabian Sea and Bay of Bengal during day and night.

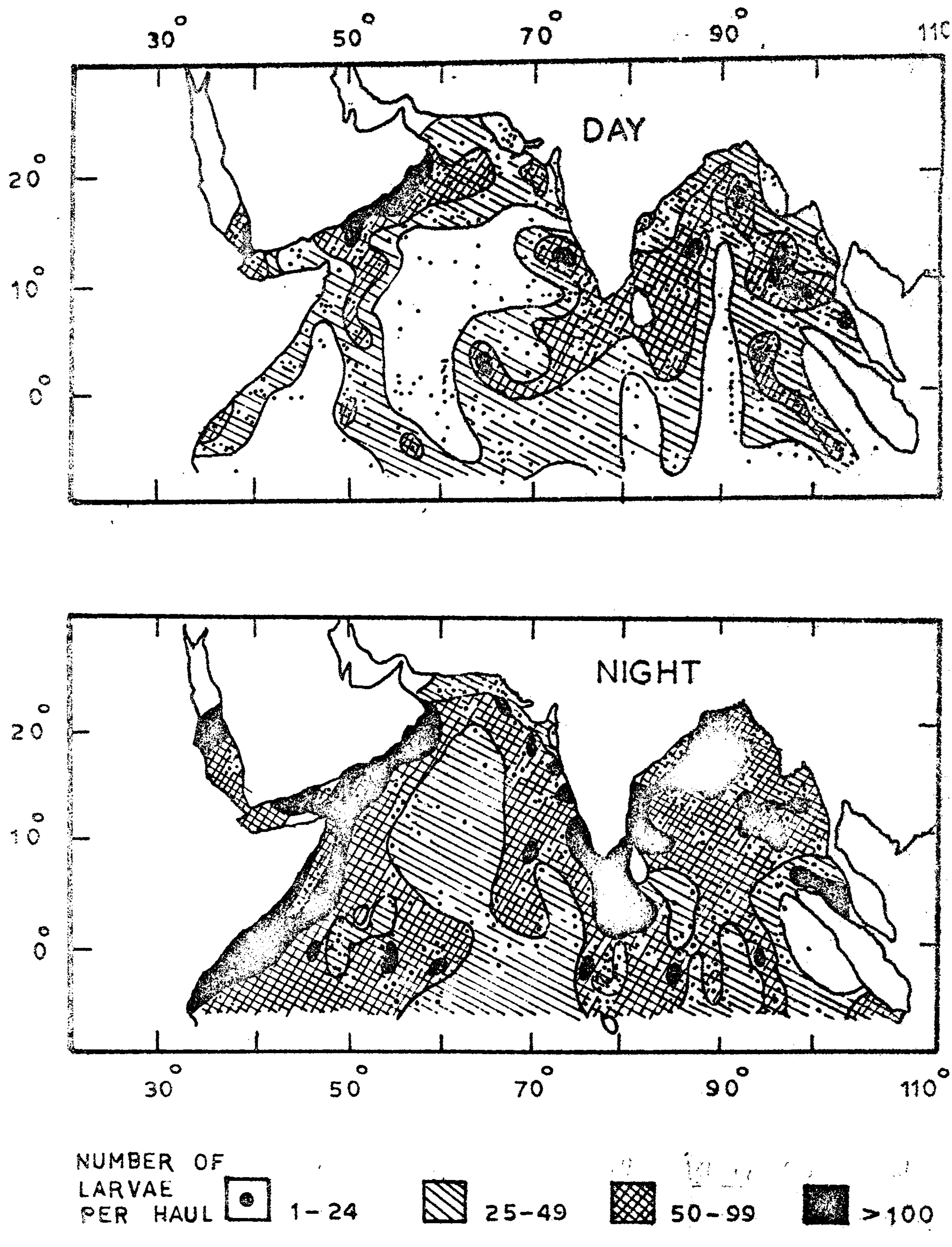

30°
50°
70°
90°
110°
DAY
20°
10°
0°
NIGHT
NUMBER OF LARVAE PER HAUL
1-24
25-49
50-99
>100

Fig. 29

was also noticed in the lowest grade of 1 - 50 larvae.

The map showing the distribution of larvae during the night hours (Fig. 29) showed the presence of high density belts ($>$ 100/haul) starting from Kenya along the African coast excluding nearshore areas of Somalia and extending up to the northern tip of Arabia, in addition to a patch in the middle of Red Sea. Along the west coast of India isolated high density patches were noticed off Kutch, Maharashtra and Karnataka. A continuous coastal belt of this high density grade beginning from 12°N extended up to equator adjoining the west coast of Sri Lanka. This also continued along the east coast of India excluding coastal Andhra Pradesh reaching up to West Bengal. Three patches of this grade were noticed around Andaman-Nicobar Islands, and another bigger area west of Malaysia. Along the equatorial zone 7 high density patches were found. The next grade of density (51 - 100 larvae per haul) was very widely spread excluding the central part of Arabian Sea which was dominated by the lowest grade of 1 - 50 larvae per haul. Approximately 3/4th of the Bay was under the density range of 51 - 100. The lowest range was observed as isolated bands in the southern Bay.

During day hours (Fig. 29) the highest range of larvae (>100) was found only as patches along the coasts of northern Arabia, Aden, Kenya, Goa and Kerala. In addition to these, 2 small patches of this high grade of concentration were present in the equatorial zone of the Arabian Sea. In the Bay of Bengal similar larval concentrations were noticed mainly in the region east and northeast of Andaman-Nicobar Islands and west of Malaysia. The other areas were three small patches in the north, south and central parts of the Bay respectively. The next lower grade of density (51 - 100) also was located adjacent to the high density regions covering much wider areas. The waters of the regions between south of Kutch and off Maharashtra, south, southwest and southeast of Indian peninsula also came under this grade. The area east of 80°E between equator and 15°N which also showed the same density of larvae continued to the northern basin as a narrow band in addition to regions around the Andaman-Nicobar Islands, and at the northern and southern parts of the Bay. The rest of the area was dominated by the lowest grade (1 - 50).

In the Arabian Sea 53.6% of the samples were collected during day hours and 46.4% during night hours (Table 10). It was noticed that the larvae collected during day and

Table 10 : Day and night collections and fish larvae caught from the Arabian Sea and Bay of Bengal.

Samples/larvae	Arabian Sea	Bay of Bengal	Total
No. and % of day collections	307 (53.6)	173 (47.8)	480 (51.3)
No. and % of night collections	266 (46.4)	189 (52.2)	455 (48.7)
No. and % of larvae in day collections	11260 (35.2)	5873 (27.3)	17133 (32.1)
No. and % of larvae in night collections	20734 (64.8)	15619 (72.7)	36353 (67.9)
Average No. of larvae/day haul	37	34	36
Average No. of larvae/night haul	78	83	80

% given in brackets.

night were not proportional to the respective number of samples. The higher number of day hauls contributed to only 35.2% of the total larvae collected, whereas the value for the night hauls came up to 64.8%. The average number of larvae recorded during day and night were 37 and 78 respectively, thus indicating that the night values were more than double that of day.

The average highest number of larvae recorded per 5° square during day (Table 11) was 162 at the northern tip of Arabia. The next lower value of 98 and 81 larvae per 5° square was recorded from Gulf of Aden and northern Arabian coast respectively. 5° squares of the northern and southern parts of Somalia, area between Pakistan and Arabian coasts and central Arabian coast also had average values ranging from 61 to 65. The areas which recorded lower values were Gujarat and Pakistan coast (18), off Maharashtra (17), central Arabian Sea (12), Northern Somali coast (11),Central part of southern Arabian Sea (10) and Karnataka coast with the lowest average value of 2 larvae per 5° square.

During night hours (Table 12) the highest average number of larvae recorded per 5° square was 282 from an area north of Laccadives. The northern Arabian waters which recorded the average number of 81 larvae

Table 11 : Latitudinal variation of the range of average number of larvae per 5° square during day in the Arabian Sea and Bay of Bengal.

	Latitude intervals	Lowest No. of larvae per 5° square.	Areas	Highest No. of larvae per 5° square	Areas
Arabian Sea	25°N–20°N	18	Gujarat & Pakistan coasts	162	North of Arabian coast
	20°N–15°N	17	Off Maharashtra	81	Northern Arabian coast
	15°N–10°N	2	Karnataka coast	98	Gulf of Aden
	10°N– 5°N	11	Northern Somali coast	62	Northern Somali coast
	5°N– 0°	12	Central Arabian Sea	61	Southern Somali coast
	0° – 5°S	10	Central part of southern Arabian Sea	65	Off Somalia
Bay of Bengal	25°N–20°N			119	South of West Bengal
	20°N–15°N	37	Off Orissa	45	Orissa coast
	15°N–10°N	20	Central Bay of Bengal	172	Off Thailand
	10°N– 5°N	38	Southeast of Andaman-Nicobar Islands	83	East of Sri Lanka
	5°N– 0°	9	Equatorial zone (Central Bay)	90	Southern part of Central Bay
	0° – 5°S	7	Central part of Southern Bay	13	Southern part of Central Bay

Table 12 : Latitudinal variation of the range of average number of larvae per 5° square during night in the Arabian Sea & Bay of Bengal.

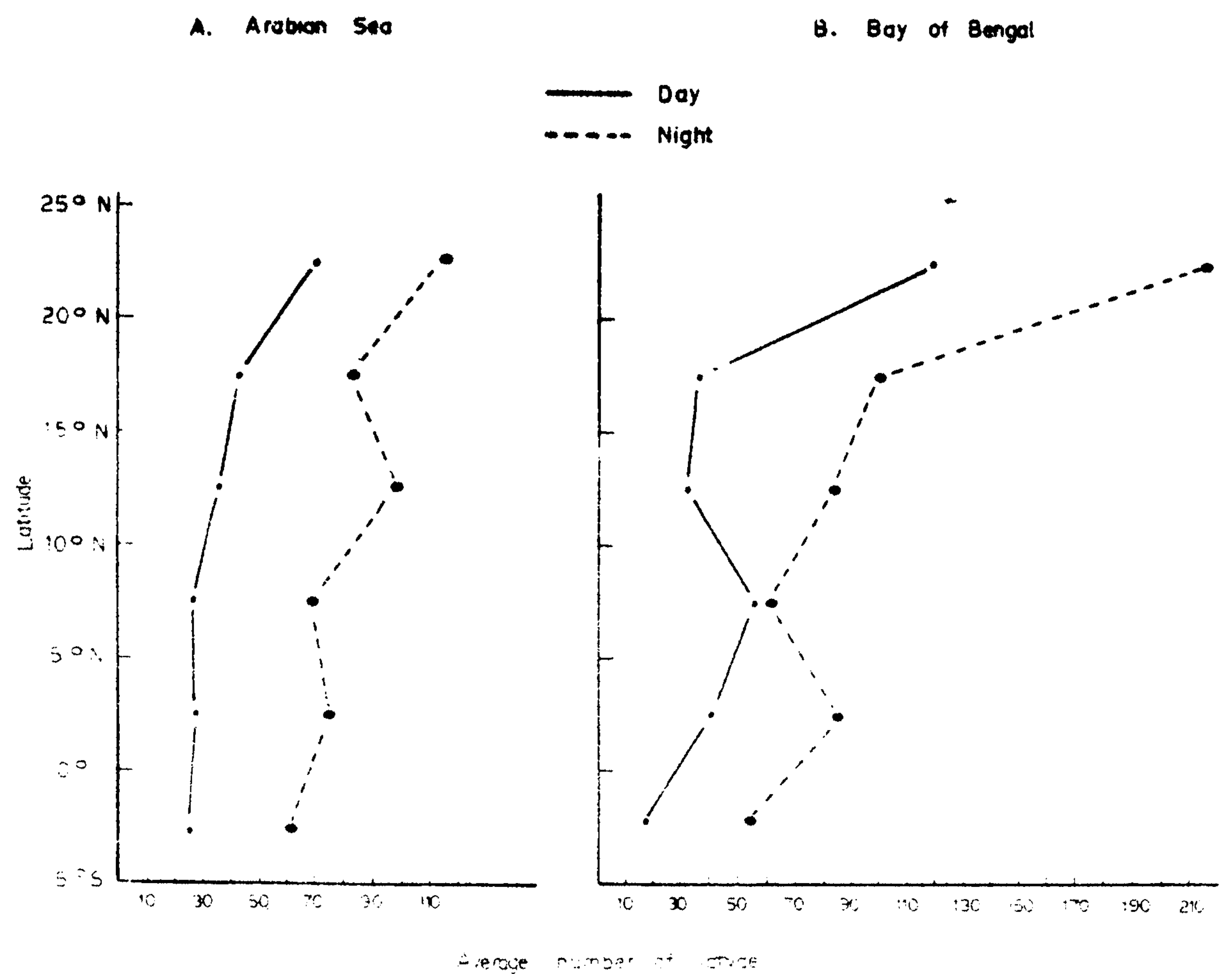
	Latitude intervals	Lowest No. of larvae per 5° square	Areas	Highest No. of larvae per 5° square	Areas
Arabian Sea	25°N-20°N	51	Gujarat coast, Pakistan coast	193	Northern Arabian coast
	20°N-15°N	11	Central Arabian coast	199	Northern Arabian coast
	15°N-10°N	19	Central Arabian Sea	282	North of Laccadives
	10°N- 5°N	29	Central Arabian Sea	113	Somali coast
	5°N- 0°	22	Central Arabian Sea	102	Somali coast
	0° - 5°S	35	Southern Arabian Sea	112	Off Somali coast
Bay of Bengal	25°N-20°N	85	West of Burma coast	345	South of West Bengal
	20°N-15°N	96	West of Burma coast	122	Off Orissa
	15°N-10°N	46	West of Burma coast	129	Off Thailand
	10°N- 5°N	23	West of Thailand	57	West of Sri Lanka
	5°N- 0°	32	Central Bay of Thailand	62	Central Bay of Bengal
	0° - 5°S	49	Southern Bay of Bengal	84	Southern Bay of Bengal

per 5° square during day showed a much higher number of 199 during night. Similarly the northern tip of Arabia and off Somalia which recorded higher values of 193 and 112 respectively at night had only lesser number of larvae during day hours. The lowest value recorded during night was 11 which was from the central Arabian Sea.

In the Bay of Bengal 47.8% of the samples were collected during day and 52.2% in the night (Table 10). The average number of larvae collected during night was 83, which was about 2½ times higher than that of day (34). Thus the pattern of diurnal variation in the Arabian Sea and Bay of Bengal was almost the same. During day time the number varied from 7 to 172 (Table 11). These samples were collected from central part of southern Bay of Bengal and off Thailand respectively. On the other hand catch record during night varied from 23 to 345 in the samples taken from west of Thailand and south of West Bengal respectively. Both Arabian Sea and Bay of Bengal showed their abundance in the night collections (Fig. 30). This proportional increase was maintained in the Arabian Sea and Bay of Bengal in the area between 5°S to 5°N and 15°N to 25°N, except between 5°N and 10°N where a fall in the number of larvae during night was noticed.

Fig. 30. Relationship between the day and night distribution of fish larvae per 5° square in the Arabian Sea and Bay of Bengal.

Fig. 30


A. Arabian Sea
B. Bay of Bengal
Day
Night
25° N
20° N
15° N
10° N
5° N
0°
5° S
Latitude
10
30
50
70
90
110
130
150
170
190
210
Average number of

4.10. Number of larvae and frequency of occurrence.

It was noticed that in majority of the collections from Arabian Sea the frequency of occurrence of fish larvae was more in the lower density range (Fig. 31). For example, the lower density of larvae of 1 - 20 numbers per haul had the highest frequency of occurrence of 206 (Table 13). This was followed by the next density range of larvae 20 - 40 numbers, with 115 occurrences. The higher few densities including the highest, 1581 - 1600 had only one occurrence each. Similarly the type of relationship was also seen between the average number of larvae per haul and frequency of occurrence.

In the Bay of Bengal also the frequency of occurrence of larvae was maximum in the lowest density range (Fig. 32). In the 1 - 20 density range there were 94 occurrences (Table 13). The next higher density range of 20 - 49 had the frequency of occurrence 82. The higher few density ranges including the highest 441 - 460, had only one occurrence each. The same relationship was noticed between the average number of larvae per haul and frequency of occurrence. The effect of currents is one of the important factors that facilitates the distribution of larvae to the neighbouring areas. Further,

Table 13 : Relationship between number of fish larvae per standard haul and frequency of occurrence in the Arabian Sea and Bay of Bengal.

Class interval	Frequency of occurrence	
	Arabian Sea	Bay of Bengal
1 - 20	206	94
21 - 40	115	82
41 - 60	64	41
61 - 80	41	39
81 -100	35	29
101 -120	28	23
121- 140	16	11
141- 160	17	4
161- 180	4	4
181- 200	7	3
201- 220	4	6
221- 240	2	2
241- 260	1	-
261- 280	4	1
281- 300	2	1
301- 320	-	1
321- 340	1	-
341- 360	1	3
361- 380	-	-
381- 400	2	-
401- 420	-	-
421- 440	-	-
441- 460	-	1
461- 480	1	-
481- 500	-	-
501- 520	-	-
620- 640	1	-
1581-1600	1	-

Fig. 31. Relationship between the number of fish larvae and frequency of occurrence in the Arabian Sea.

Fig. 31

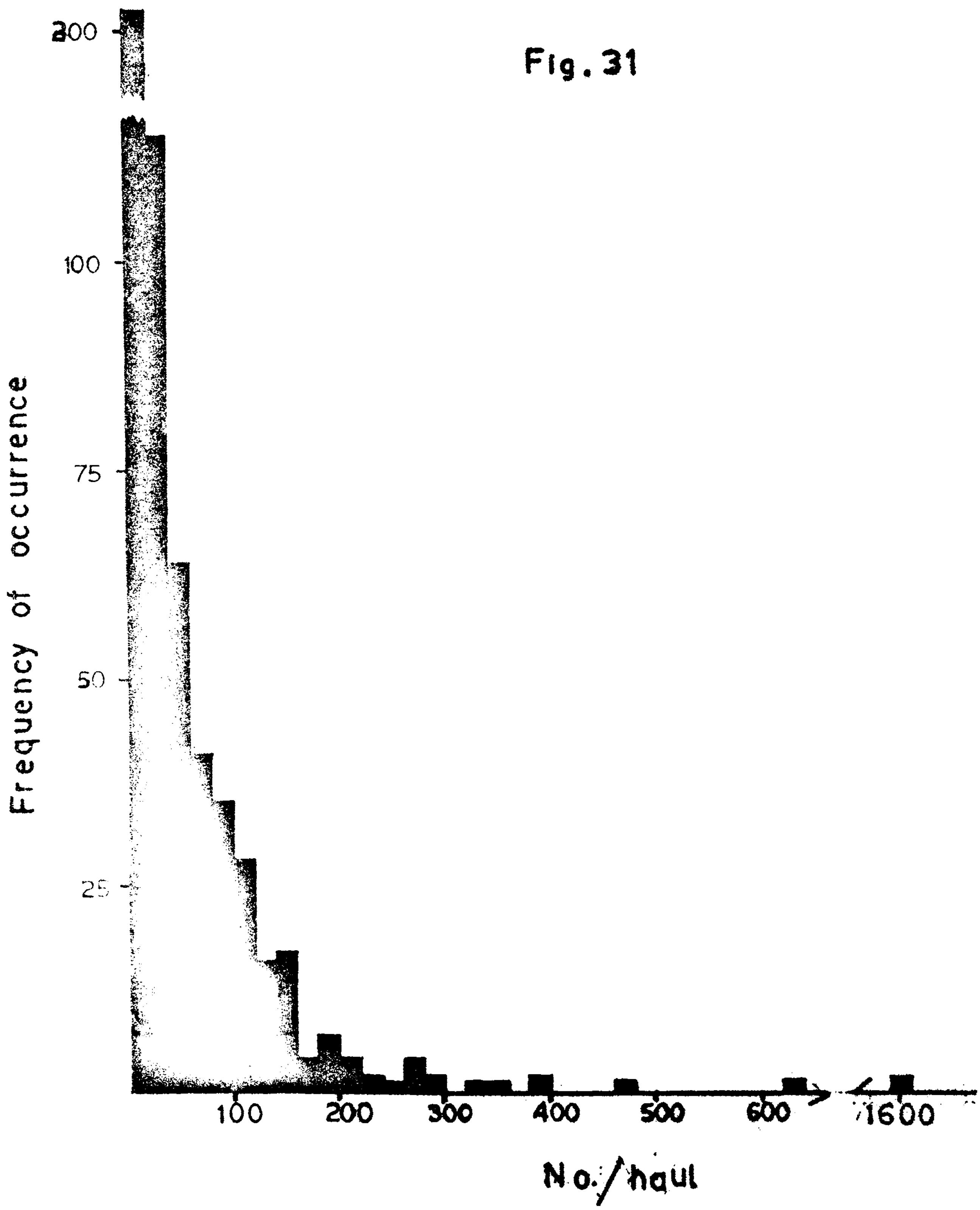
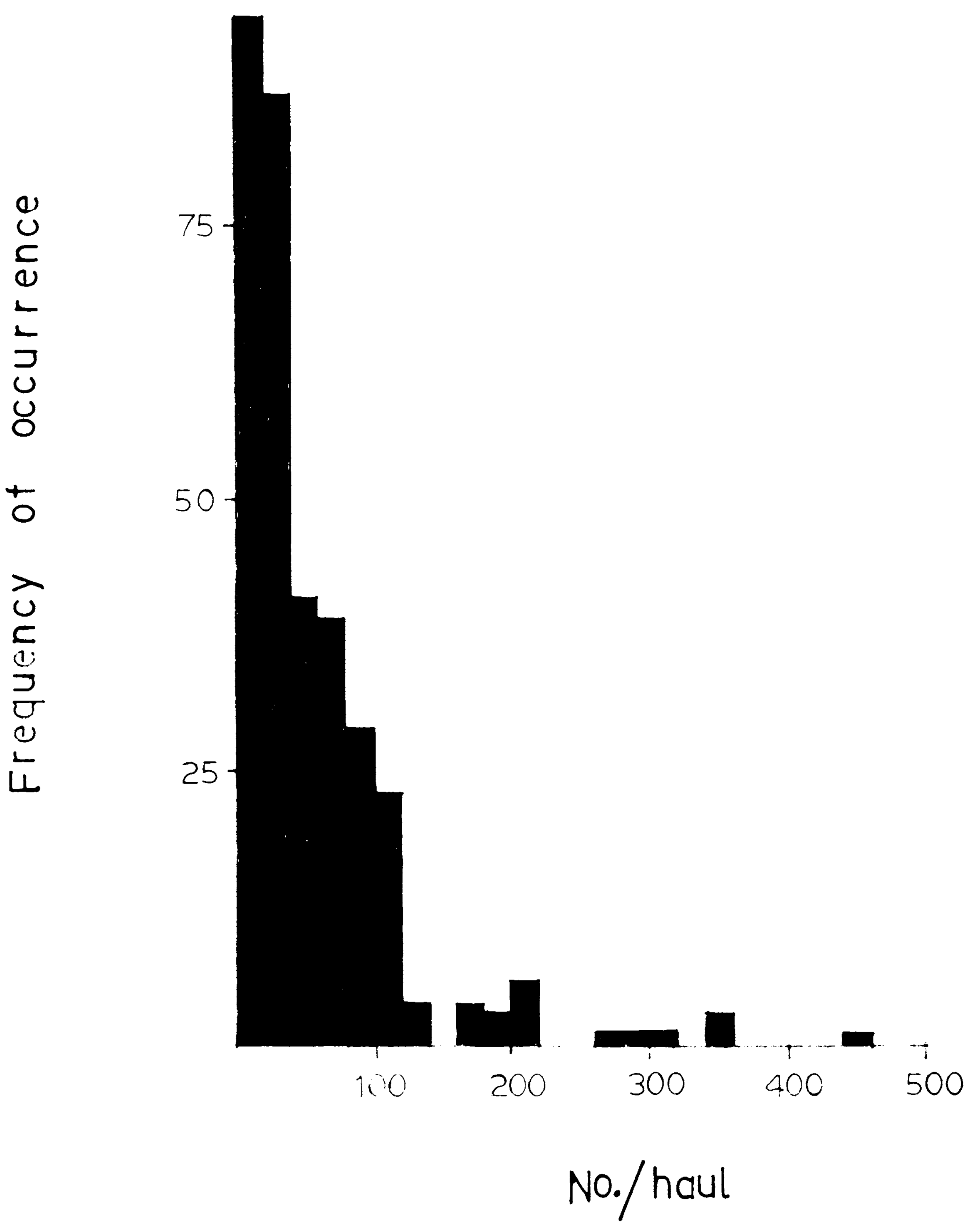

200
100
75
50
25
Frequency of occurrence
100
200
300
400
500
600
1600
No./haul

Fig. 32. Relationship between the number of fish larvae and frequency of occurrence in the Bay of Bengal.

Fig. 32



fish larvae being capable of free swimming, disperse fast to the surrounding environment. Hence they occur in large number of samples collected from wider areas, but in lesser numbers.

4.11. Larval abundance in relation to zooplankton biomass.

When the total counts of fish larvae in each sample of the Arabian Sea were plotted against the corresponding volume of the plankton samples, it was noticed that in several cases, when the plankton volumes were higher, the number of larvae were not proportionally higher in the case of majority of the samples (Fig. 33). The Bay of Bengal also showed the same type of inconsistant relationship (Fig. 34). The highest record of larvae from the Arabian Sea (1600/haul) and from Bay of Bengal (441/haul) were from samples of biomass 51 ml and 55 ml respectively (Tables 14, 15). Similarly the next lower numbers from the Arabian Sea and Bay of Bengal were 623 and 345 from samples of biomass 17 ml and 43 ml respectively. So it was observed that in general the higher numbers of larvae were not collected from samples of larger biomass, but from samples which were neither higher nor lower in biomass.

Fig. 33. Relationship between the number of fish larvae and zooplankton biomass in the Arabian Sea.

Fig. 33

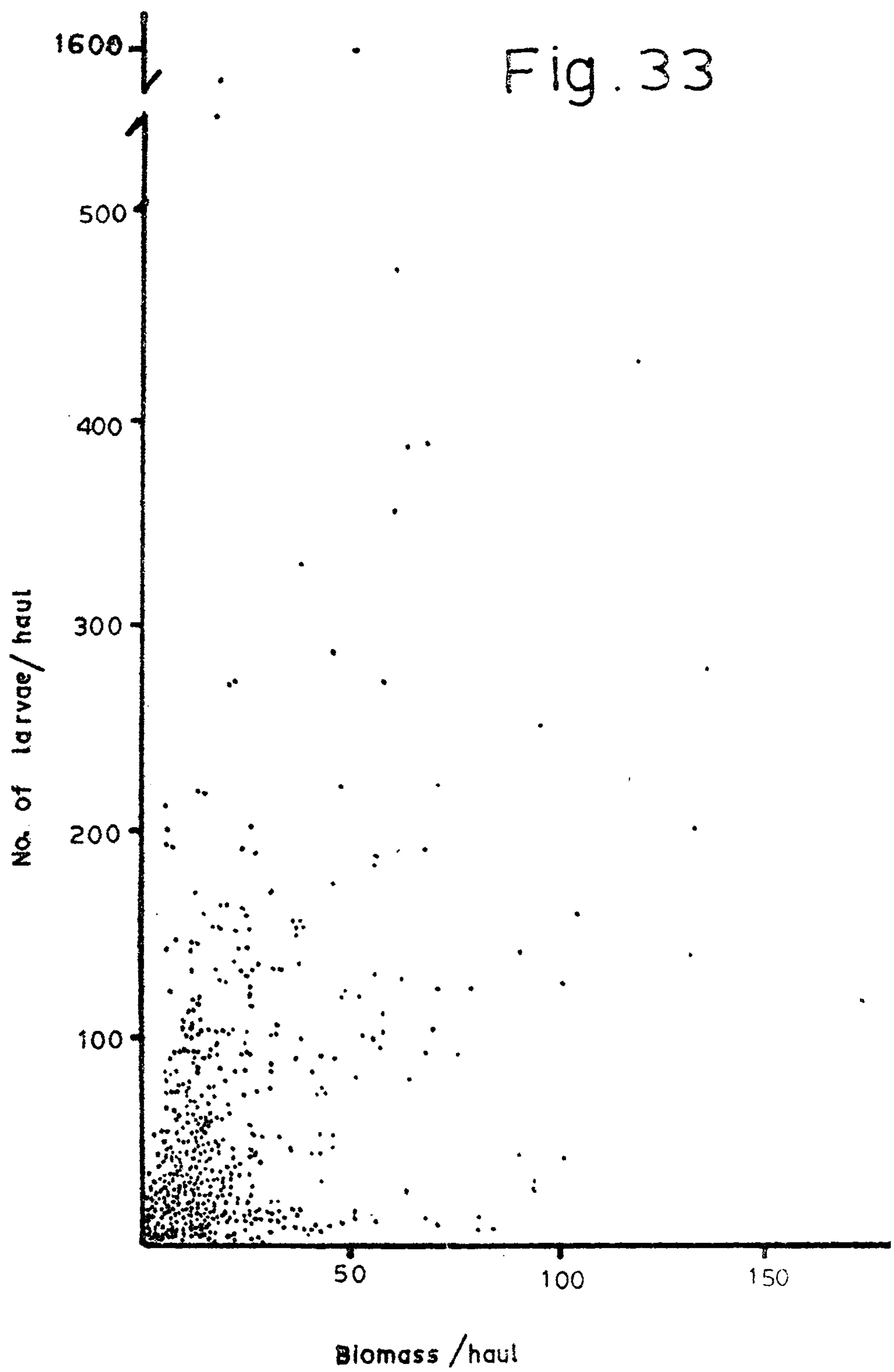

1600
500
400
300
200
100
No. of larvae/haul
50
100
150
Biomass /haul

Fig. 34. Relationship between the number of fish larvae and zooplankton biomass in the Bay of Bengal.

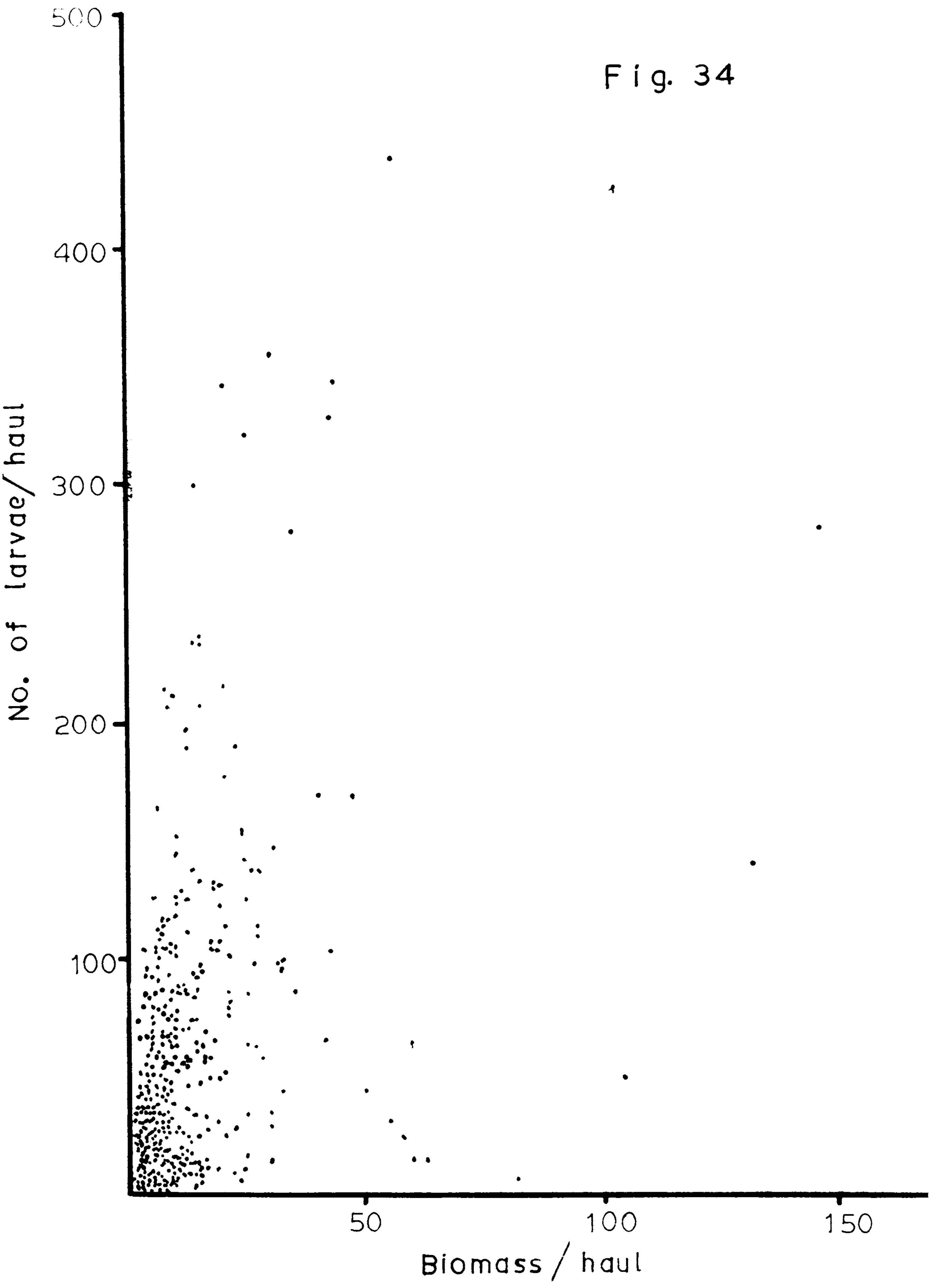


Fig. 34

Table 14 : Zooplankton samples with more than 200 larvae per standard haul in the Arabian Sea.

Identification (Vessel. Cruise. St.No.)	Position Lat.	Position Long.	Season	Time Day/Night	Biomass (ml)	No. of larvae
Ki.11.259	11°00'N	- 74°33'E	Jul.	N	51.0	1600
AB.4A.194	22°22'N	- 60°05'E	Nov.	N	17.0	623
Di.3.5051	18°46'N	- 58°23'E	Jul.	N	60.0	472
Ar.Do.69	03°00'N	- 55°00'E	Aug.	N	68.0	391
Di.3.5062	20°52'N	- 59°25'E	Jul.	N	63.0	389
AB.A.2	12°41'N	- 48°00'E	Feb.	N	60.0	355
Di.3.5069	19°34'N	- 51°14'E	Jul.	N	37.5	328
Ar.Do.47	08°53'N	- 53°09'E	Aug.	D	187.5	291
AB.A.3	13°03'N	- 50°00'E	Feb.	N	45.0	288
Di.3.5037	17°28'N	- 57°03'E	Jul.	D	135.0	280
Ar.Lu.40	01°29'N	- 53°01'E	Aug.	D	21.0	274
Di.3.5052	18°39'N	- 58°31'E	Jul.	N	57.0	274
Va.31.1811	16°49'N	- 72°29'E	May.	N	25.5	212
Di.3.5049	18°55'N	- 58°12'E	Jul.	D	95.0	247
Di.3.5065	20°32'N	- 59°55'E	Jul.	D	70.0	223
Di.3.5539	03°57'N	- 51°03'E	Aug.	N	47.5	221
Zu.Zu.16	23°10'N	- 67°10'E	Nov.	N	13.0	220
Zu.Zu.18	22°53'N	- 66°49'E	Nov.	D	9.0	204
Ki.25.666	10°13'N	- 75°39'E	Mar.	N	25.0	202

Table 15 : Zooplankton samples with more than 200 larvae per standard haul in the Bay of Bengal.

Identification (Vessel. Cruise. St.No.)	Position: Lat.	Position: Long.	Season	Time Day/ Night	Biomass (ml)	No. of larvae
Ki.26.704	13°03'N	81°08'E	Apr.	N	55.0	441
Pi.442.12	20°27'N	88°55'E	Apr.	N	43.0	345
Ki.22.587	12°49'N	80°51'E	Feb.	N	20.0	342
Ki.17.440	18°04'N	88°00'E	Jul.	N	24.5	323
Ki.21.559	18°52'N	85°30'E	Jan.	N	14.0	301
Pi.442.14	19°22'N	89°13'E	May.	N	34.0	283
AB.1.91	17°14'N	83°47'E	Apr.	N	10.5	270
Ki.15.378	12°36'N	80°40'E	Jun.	N	14.0	236
Ki.14.347	13°30'N	91°00'E	Sept.	N	16.0	235
Ki.15.369	11°00'N	82°00'E	Jun.	N	9.0	216
AB.1.86	20°04'N	88°24'E	Apr.	D	20.0	215
Ki.20.527	04°00'N	99°49'E	Sept.	N	6.0	211
Ki.20.531	06°00'N	99°00'E	Sept.	N	15.0	209
Pi.442.38	00°57'N	92°00'E	Jun.	N	8.0	206

4.12. Distribution in relation to surface temperature and salinity.

The variations noticed in the distribution of various groups of fish larvae throughout the year in the Arabian Sea and Bay of Bengal may be explained as partly due to the differences occurring in the temperature and salinity factors (Table 16).

The individual groups selected for this study had a preference for the range of surface temperature between 17° and 30°C in the Arabian Sea. These groups comprised of families such as Paralepididae, Myctophidae, Bregmacerotidae, Carangidae and Gobiidae. Families such as Clupeidae, Synodontidae and Gempylidae however preferred only a shorter range of 25° to 27°C.

In the case of surface salinity, the widest range tolerated by the larvae was between 32 and 36‰, whereas the narrowest range was from 32 - 33‰. Majority of the groups, the Gonostomidae, Stomiatidae, Bregmacerotidae, Pleuronectiformes, Serranidae, Thunnidae, and Gobiidae tolerated the surface salinity from 33 to 36‰, whereas Paralepididae, Callionymidae, Carangidae, Gempylidae and Scomberomoridae were found within the range of 34 to 36‰. Clupeidae had the narrowest range of 32 - 33‰.

Table 16 : Range of temperature-salinity parameters in the distribution of fish larvae in the Arabian Sea and Bay of Bengal.

GROUPS	Arabian Sea		Bay of Bengal	
	Range of surface temp. (°C)	Range of surface Sal. (‰)	Range of surface temp. (°C)	Range of surface Sal. (‰)
Clupeidae	25 - 27	32 - 33	-	-
Engraulidae	19 - 30	-	27 - 29	-
Gonostomidae				
Vinciguerria spp.	18 - 30	33 - 36	20 - 30	26 - 35
Cyclothone spp.	22 - 30	33 - 36	20 - 30	32 - 34
Stomiatidae	20 - 30	33 - 36	22 - 29	28 - 34
Synodontidae	24 - 29	32 - 33	26 - 29	30 - 34
Paralepididae	17 - 29	34 - 36	-	-
Scopelarchidae	27 - 29	33 - 35	27 - 29	31 - 34
Myctophidae	17 - 30	32 - 36	24 - 30	28 - 35
Anguilliformes	20 - 30	33 - 36	25 - 30	30 - 35
Bregmacerotidae	17 - 30	33 - 36	20 - 30	28 - 34

Table 16 (Contd.)

GROUPS	Arabian Sea		Bay of Bengal	
	Range of surface temp. (°C)	Range of surface Sal. (‰)	Range of surface temp. (°C)	Range of surface Sal. (‰)
Pleuronectiformes	20 - 29	33 - 36	22 - 29	28 - 34
Serranidae	22 - 29	33 - 36	22 - 30	32 - 33
Carangidae	17 - 29	34 - 36	22 - 30	31 - 34
Labridae	21 - 30	32 - 36	26 - 29	31 - 35
Callionymidae	17 - 30	34 - 36	25 - 30	28 - 34
Trichiuridae	23 - 29	35 - 36	29 - 30	32 - 33
Gempylidae	24 - 30	34 - 36	27 - 29	31 - 34
Scombridae	28 - 29	36 - 37	29	34.6
Thunnidae	23 - 30	33 - 36	27 - 30	30 - 34
Scomberomoridae	22 - 29	34 - 36	27 - 30	31 - 34
Gobiidae	17 - 30	33 - 36	22 - 30	29 - 34
Scorpaenidae	20 - 30	32 - 36	22 - 30	29 - 34

In the Bay of Bengal the range of surface temperature between 20° and 30°C was tolerated by various groups. The species of Vinciguerria and family Bregmacerotidae occurred in the widest range of surface temperature between 20° and 30°C. Gobiidae and Scorpaenidae had the range between 22° and 30°C, while Stomiatidae preferred surface temperature of 22° - 29°C. A shorter range of 27° to 29°C was tolerated by groups such as Engraulidae, Scopelarchidae, Gempylidae and Thunnidae.

The widest surface salinity range recorded in Bay of Bengal was 26 - 35‰ where the distribution of Vinciguerria sp. was very dominant. In the 28 - 34‰ range, Stomiatidae, Bregmacerotidae and Callionymidae were recorded. Synodontidae, Anguilliformes and Thunnidae tolerated the surface salinity range of 30‰ to 34‰. While the families Scopelarchidae, Carangidae, Gempylidae, Scomberomoridae and Labridae occurred in the waters of surface salinity range of 31‰ to 34‰, the shortest range of 32‰ to 33‰ was dominated by Gempylidae and Thunnidae. Arabian Sea exhibited a higher range of surface temperature (17° to 36°C) compared with that of Bay of Bengal. Similarly the salinity values were also higher in the Arabian Sea (32‰ to 36‰) in contrast to Bay of Bengal

(26‰ to 35‰). Despite these variations most of the groups were present in both Arabian Sea and Bay of Bengal.

4.13. Statistical analysis.

The coexistence of the various groups calculated by means of correlation coefficient matrix of size 27 x 27 showed that about 62.4% correlations were positive in the case of fish larvae collected from Bay of Bengal. Whereas 51.6% of the correlation coefficients were found to be positive in the case of larvae collected from the Arabian Sea. About 20% of the correlations were significant at 1% level ($P < 0.01$) and 4%, only at 5% level ($P < 0.05$ but $P > 0.01$), and *Vinciguerria*, *Cyclothone*, Stomiatidae and Myctophidae were the prominent ones in correlating significantly with the rest (Table 17). In the Arabian Sea about 22% of the correlations were significant at 1% level ($P < 0.01$) and about 5%, significant at 5% level ($P < 0.05$, but $P > 0.01$) and *Cyclothone*, Stomiatidae, Myctophidae, Labridae and Stromateidae were the prominent groups which were significantly correlated with the rest (Table 18).

The correlation coefficient of all the groups with the parameters temperature and salinity were calculated. In the Bay of Bengal, while none of the groups was found to be significantly correlated with salinity, *Vinciguerria*, Myctophidae, and Paralepididae were found to be significantly correlated with the temperature at 1% level ($P < 0.01$). However in the Arabian Sea, *Cyclothone*, Scopelarchidae, Trichiuridae and Gobiidae were found to be significantly correlated with salinity at 1% level ($P < 0.01$) and Paralepididae at 5% level ($P < 0.05$), and Coryphaenidae, Stromateidae, Callionymidae, Trichiuridae and Gempylidae were found to be significantly correlated with temperature at 1% level ($P < 0.01$) and Paralepididae at 5% level ($P < 0.05$) (Table 19).

From the normal equations

$$\Sigma y = n b_0 + b_1 \Sigma x_1 + b_2 \Sigma x_2 \quad \text{— (i)}$$

$$\Sigma x_1 y = b_0 \Sigma x_1 + b_1 \Sigma x_1^2 + b_2 \Sigma x_1 x_2 \quad \text{— (ii)}$$

$$\Sigma x_2 y = b_0 \Sigma x_2 + b_1 \Sigma x_1 x_2 + b_2 \Sigma x_2^2 \quad \text{— (iii)}$$

the regression coefficients b_{01}, b_1, b_2 were calculated. The equation of the fitted regression for the prediction of abundance of fish larvae calculated from Bay of Bengal was

$$y = -14.333747 + 1.493990\, x_1 - 0.020725\, x_2$$

and for the prediction of abundance of fish larvae calculated for the Arabian Sea was

$$y = 24.7494 + 0.260649\, x_1 - 0.07738\, x_2$$

Table 19 : Correlation coefficient of the groups of fish larvae with each of the variables, temperature and salinity in the Bay of Bengal and Arabian Sea.

Groups	Bay of Bengal		Arabian Sea	
	Temperature	Salinity	Temperature	Salinity
Clupeidae	0.063514	0.005056	0.027907	0.015121
Engraulidae	0.018199	0.005903	0.004175	-0.007913
<u>Vinciguerria</u>	0.165723	0.069404	0.017065	0.019364
<u>Cyclothone</u>	0.057856	0.012229	-0.011273	0.111828[b]
Stomiatidae	0.003806	0.013267	0.035520	0.042361
Sternoptychidae	0.001161	0.007278	-0.007934	-0.000125
Astronesthidae	-0.028666	0.006958	0.034538	0.021899
Idiacanthidae	0.031130	0.006958	0.037939	0.036503
Synodontidae	0.007225	0.007278	0.040983	0.023462
Paralepididae	0.200805[b]	0.008535	0.101232[c]	0.090646[c]
Scopelarchidae	-0.016506	0.009332	0.060385	0.165409[b]
Myctophidae	-0.301969[b]	0.012832	0.029657	0.038787
Anguilliformes	-0.000944	0.012080	-0.022156	-0.003620
Bregmacerotidae	-0.105012[c]	0.091623	-0.000222	0.020944
Holocentridae	0.000123	0.000167	0.087755[c]	0.056851
Serranidae	0.009332	0.007712	0.105283[c]	0.018687
Carangidae	0.010169	0.011007	0.071328	0.026850

Table 19 (Contd.)

Groups	Bay of Bengal		Arabian Sea	
	Temperature	Salinity	Temperature	Salinity
Coryphaenidae	0.007132	0.006070	0.188512[b]	0.037141
Stromateidae	0.019609	0.012290	0.151430[b]	0.012800
Labridae	-0.015434	0.009811	-0.058651	0.067512
Callionymidae	0.047214	0.0121175	0.746080[b]	0.007720
Trichiuridae	0.008264	0.004403	0.376553[b]	0.196692[b]
Gempylidae	0.043086	0.006957	0.3066521[b]	0.021953
Thunnidae	0.015802	0.016132	0.067324	0.044799
Scomberomoridae	-0.045098	0.009232	0.038344	0.030908
Gobiidae	0.010669	0.015304	-0.079127	-0.205939
Scorpaenidae	-0.032135	0.002360	-0.056085	-0.066611

b = Significant at 1% level.

c = Significant at 5% level.

Table 20 shows the analysis of variance of the significance of the regression coefficients. From this table it was seen that the regression coefficients were all significant at 1% level ($P < 0.01$) indicating that the fitted regression model was capable of explaining a significant part of the variability in the abundance of fish larvae collected from Bay of Bengal. But it was seen that the regression coefficients were not significant even at 5% level ($P > 0.05$) indicating that the fitted model was not capable of explaining a significant part of the variability in the abundance of fish larvae collected from the Arabian Sea.

From Table 21 it was found that the temperature was the prominant factor controlling the abundance of fish larvae in the Arabian Sea and Bay of Bengal. But salinity had a more important role in the Arabian Sea than in Bay of Bengal.

The values of Fisher's diversity index α given in Table 22 ranged from 3.1054 to 4.0598 which indicated that the type of environment in all areas were more or less of the same kind, but neither too old, nor new, severe nor unpredictable. The variance of α ranged from 0.06143 to 0.2213. The variance of α being small, it follows that α values calculated will remain almost constant for all the areas.

Table 20 : Analysis of variance table for testing the significance of the regression model fitted to predict the abundance of fish larvae.

Area	Source	Sum of squares	Degrees of freedom	Mean sum of squares	F ratio
	Regression	381448.0140	2	190724.007	817.1271*
Bay of Bengal	Deviation	77958.2768	334	233.4080	
	Total	459406.2908	336	1367.2806	
	Regression	937.136	2	468.568	0.17016**
Arabian Sea	Deviation	1583343.159	575	2753.640	
	Total	1754821.678	577	2745.7198	

* ($P < 0.01$). F is significant at 1% level, i.e. Regression fitted is significant at 1% level.
Variability explained by regression is 87%.

** ($P > 0.05$). F is not significant at 5% level, i.e. Regression model fitted is not significant at 5% level.

Table 21 : The relative importance of the parameters used in fitting the model.

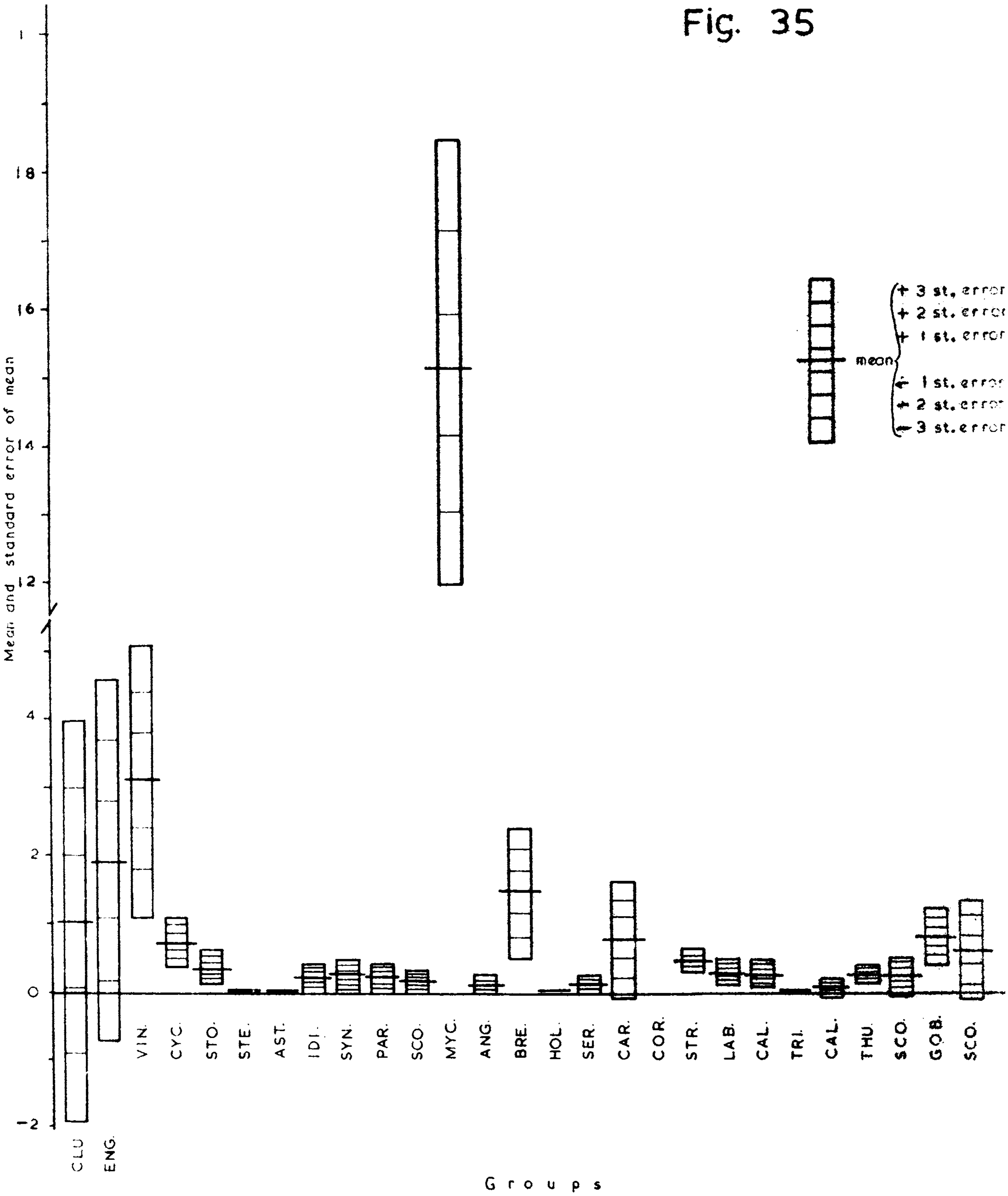
Variables	Relative importance	
	Bay of Bengal	Arabian Sea
Temperature	0.060798	0.055045
Salinity	0.018583	0.38451

Table 22 : Fishers diversity index and variance of the diversity index, α

Area	S	N	α	V ( )
Arabian coast	26	3781	3.760887	0.074328
Red Sea and Persian Gulf	18	353	4.009839	0.2213880
East coast of Africa	25	2848	3.771827	0.082264
Central Arabian Sea	22	913	4.059840	0.142447
West coast of India	24	3538	3.463114	0.068092
East coast of India	23	4045	3.258960	0.061631
West coast of Burma & Thailand	22	1840	3.734336	0.107431
	21	2927	3.105463	0.064639
Central Bay of Bengal Equatorial region	24	2227	3.758132	0.089610

Fig. 35. The mean number of fish larvae and its variance standard error limits for the fish larvae collected from the Arabian Sea.

Fig. 35



Mean and standard error of mean
1
18
16
14
12
4
2
0
-2
+ 3 st. error
+ 2 st. error
+ 1 st. error
mean
- 1 st. error
- 2 st. error
- 3 st. error
CLU
ENG.
VIN.
CYC.
STO.
STE.
AST.
IDI.
SYN.
PAR.
SCO.
MYC.
ANG.
BRE.
HOL.
SER.
CAR.
COR.
STR.
LAB.
CAL.
TRI.
CAL.
THU.
SCO.
GOB.
SCO.
Groups

Fig. 36. The mean number of fish larvae and its variance standard error limits for the fish larvae collected from the Bay of Bengal.

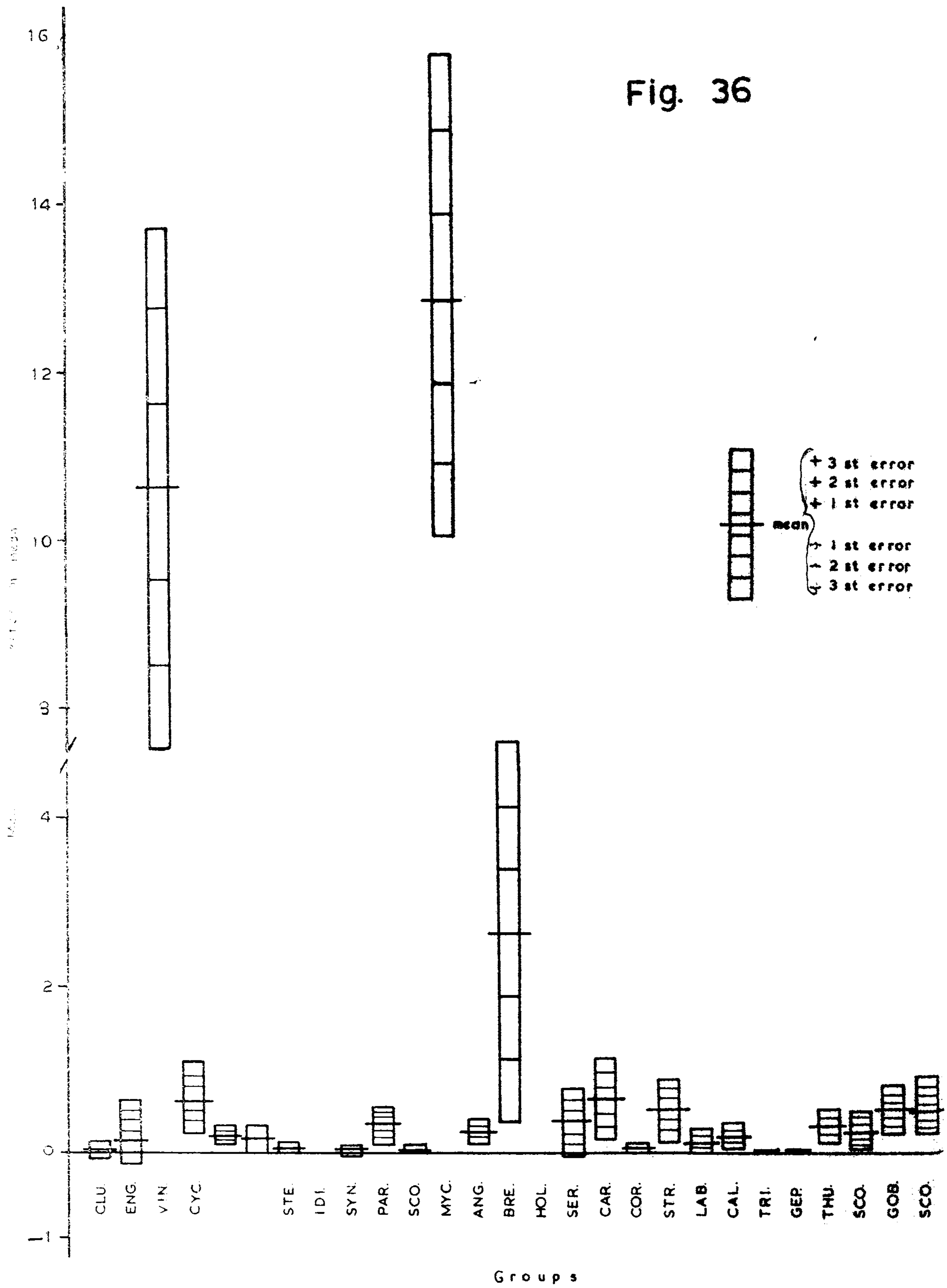

16
14
12
10
8
4
2
0
-1
CLU.
ENG.
VIN.
CYC.
STE.
IDI.
SYN.
PAR.
SCO.
MYC.
ANG.
BRE.
HOL.
SER.
CAR.
COR.
STR.
LAB.
CAL.
TRI.
GEP.
THU.
SCO.
GOB.
SCO.
Groups
+ 3 st error
+ 2 st error
+ 1 st error
mean
- 1 st error
- 2 st error
- 3 st error

Fig. 36

Table 23 shows the mean number of fish larvae and its standard error (S.E.) together with 1 S.E., 2 S.E., and 3 S.E., confidence intervals for each group, represented graphically, for the Arabian Sea as well as Bay of Bengal (Figs. 35, 36). This showed that, while *Vinciguerria*, Bregmacerotidae and Myctophidae were distributed almost similarly in the Bay of Bengal, only Myctophidae was distributed over a very wide range in the Arabian Sea.

5. DISCUSSION . Pages 237 - [illegible]

5. DISCUSSION.

5.1. General distribution of larvae.

Earlier works on the Ichthyoplankton of the Indian Ocean region were highly localised, confining to certain isolated areas particularly of the coastal waters. The Dana Expedition of the Carlsburg Foundation which also surveyed the Indian Ocean did not cover the northern region, except a few stations in the Bay of Bengal. The fish eggs and larvae survey carried out by the FAO/UNDP Pelagic Fishery Project (Marr and Olsen, 1974) covering all seasons during the period from 1971 to 1978 (later than IIOE) was restricted to the continental shelf waters of the southwest and southeast coasts of India. Hence comprehensive informations on the Ichthyoplankton fauna of the offshore and oceanic regions, the areas and seasons of spawning etc. were practically not available except through the International Indian Ocean Expedition (1960-1965) which made valuable contribution to our knowledge on these lines. One of the objectives of this expedition was to determine accurately and precisely, the composition, distribution and abundance of Ichthyoplankton over space and time. But the lack of standardization of gears and techniques used during the expedition created considerable diffiulties in the interpretation of results. However they were made use of in the most effective way to determine (1) the spawning areas and seasons, (2) the migration of adults (3) the relation of oceanographic conditions to the distribution and abundance of larvae and (4) the trophic relations among fish larvae and zooplankton. The present study could project a detailed picture of the distribution and abundance of 55 groups of fish larvae in relation to environmental parameters in the offshore and oceanic waters of the northern Indian Ocean and delineate the spawning grounds and season. This may also provide useful information for the stock assessment and management of fishery resources of the region. The eggs and larvae obtained during plankton collections provide a direct measure of the spawning areas and seasons. In the absence of proper data on adult fishes of the area, the larval collections could probably delineate best the areas and time of spawning. The mortality between the eggs and larval stages is a serious problem in stock assessment. Dementjeva (1965), Gulland (1965) and Shellbourne (1957) have recognized the importance of survival rates during the early life stages of fishes. Under the species interaction during larval stages the competition for food is a major factor affecting survival and subsequent year class strength.

The first publication of the IIOE fish larvae material was on the 3 very early stages of mackerel larvae which were recorded from the Arabian Sea and Bay of Bengal (Peter, 1967). This was the first record and description of such early stages of larvae from the Indian Ocean, although the author had later came across several larvae of mackerel while examining the plankton collections of FAO/UNDP/PFP made from the coastal waters of the southwest coast of India. All the other later records of the larvae (Silas, 1974; Girijavallabhan and Gnanamuthu, 1974) were also from the coastal waters. The paucity of mackerel larvae in the IIOE sample was probably due to the nature of the hauls (vertical hauls: 200 - 0 m) and the least number of coastal collections. Ahlstrom (1968 made an appraisal of the IIOE larval fish collection based on the examination of 50 representative samples and found that the intermediate zone was the richest in fish larvae as compared to the coastal and oceanic zones. The results of the present study also was in agreement with the above observation. Devi (1969) described the larvae of Pseudorhombus elevatus from 2 stations off the south-west coast of India and (1977) the distribution of larvae of flat fishes in the Indian Ocean. She observed that flat fish larvae were represented only in 12.4% of the IIOE samples and they were more abundant in the northern half of Bay of Bengal than anywhere else in the Indian Ocean showing a preference to the neritic waters of lower salinity. Balachandran (1980) indicated that the major factor controlling the vertical migration of fish larvae is light rather than temperature, based on his studies on the day and night distribution of Meroplankton in relation to thermocline in the western Indian Ocean. However the duplicate collections made by R.V. Anton Bruun, F.S. Meteor and R.V. Vitiaz during the IIOE were studied earlier. Larvae of scombroid fishes in the Indian Ocean were studied by Gorbunova (1963, 1965a, 1967) and the development of flying fishes by Kovalevskaya (1964). Della Croce and Castle (1966) recorded 22 speciments of leptocephalus belonging to 5 families from the Mozambique channel. The present collections include 51 larvae from the Arabian Sea and 95 from Bay of Bengal, the identification of which was not done up at the family level. Nellen (1973 a,b) observed the predominance of larvae of myctophids and gonostomids in the oceanic stations while studying the distribution of various groups of fish larvae in the Persian Gulf and Arabian Sea, excluding the waters of the Arabian coast. The results of the present study also corroborated these findings.

The Tables 2 and 3 show that a total of 53486 fish larvae collected from the Arabian Sea and Bay of Bengal were from 14653.5 ml of zooplankton biomass. 70.2% of the total biomass were from Arabian Sea with 59.8% of larval and 29.8% of the biomass from Bay of Bengal with 40.2% of larvae. The average biomass per haul from these regions were 18.4 ml and 12.4 ml with 56 and 59 larvae respectively. These figures indicate that Bay of Bengal has a higher value in the percentage of larvae (40.2% in 29.8% of the biomass) and in the average number of larvae per haul (59) as well as the number of larvae per haul during night (83). A similar situation has also been recorded in the case of fish eggs earlier by the author (Peter, 1970).

Studies made during the IIOE revealed that there are several areas in the Indian Ocean which are exceptionally rich in nutrients, chlorophyll, organic production and zooplankton biomass. Panikkar (1969), Schaefer and Alverson (1968) and Messeck (1969) are of opinion that very high productivity indicates the presence of large potential resources. Schaefer and Alverson (1968) pointed out that this region might support commercial fisheries not dissimilar in magnitude to those off Peru, where the annual fish harvest is about 10 million tonnes. Wooster *et al*. (1967) indicated that the level of productivity recorded from the Somali Arabian region is about 3-4 times more productive than the rest of the Arabian Sea. A comparison with the result of similar studies recorded from Bay of Bengal (Panikkar, 1969) showed that the productivity of the northern part of Arabian Sea to be many times more. The areas of high productivity in terms of fish larval abundance overlapped at several places with regions of zooplankton abundance recorded by Prasad (1968a, b; 1969 and Rao, 1973). Maps showing the general distribution and abundance of fish larvae as a whole demarkated certain areas of high abundance of larvae coinciding with the active spawning areas of fishes in the northern Arabian Sea (Peter, 1969a, 1970). Low concentrations of fish larvae were met with in the central Arabian Sea and Bay of Bengal areas from where the number of eggs collected were in the order of 1-24 eggs per haul and productivity rates were low. Although fish larvae were present in 95.6% and 96.7% of the samples from Arabian Sea and Bay of Bengal respectively, the presence of larvae of fishes of commercial importance was only 11.7% and 6.1%. Out of a total yield of 2.1 million tonnes of fish from Indian Ocean (FAO, 1967), 44.7% were from the Arabian Sea and 33.6% from Bay of Bengal. Sardines and anchovies ranked formost among the pelagic fishes of India, which are known to be fairly exploited. Productivity studies made by Koblentz-Mishke et al. (1970) recorded high primary production generally in the proximity of land masses. Accordingly a primary production of 250 $mgC/m^2/day$ occurred in the Arabian Sea up to 8°N whereas in the Bay of Bengal the productive rate showed a declining trend to 100 $mgC/m^2/day$ in the southern Bay. On the basis of primary productivity made by Prasad et al. (1970) reported the estimated potential yield from the Indian Ocean is about 11 million tonnes. The present study also indicated the presence of large numbers of engraulid larvae in the offshore waters along with tuna and other scombroid larvae, suggesting the possibilities of potentially important fishery resources probably remaining under-exploited by

India at present. The presence of larvae of certain demersal fishes particularly perches in the offshore region also indicates the possibility of their exploitable resources from these areas.

Temporal variations in the occurrence of fish larvae are associated with seasonal cycles in oceanic and neritic environments. According to Sournia (1969) and Blackburn et al. (1970) there is very little evidence for predominant maxima and minima associated with seasonal events in the tropical oceans. However in the northern Indian Ocean the variations are largely determined by the changes in hydrology and biology of the area brought about by local weather conditions and movements of watermasses. In the area like off Somalia, Arabia and the western Indian coasts where intensive upwelling occurs, a relatively high biomass of plankton can be observed followed by abundance of fish larvae. The annual variation in the concentration of larval fish in the surface waters off the west and east coasts of Arabian Sea and Bay of Bengal varied directly with southerly (cyclonic circulation) and northerly (counter cyclonic circulation) transfer of water during the changing monsoons. The distribution of fish larvae in the equatorial area is governed by the eastward drift and the westward flow. The concentration of fish larvae in the oceanic waters is the outcome of the southward surface drifts along the southwest coast during the late premonsoon to early postmonsoon period, the currents causing same kind of translocation of the larvae during the major part of the spawning period. But for the lower salinities occurring off the west coast of India during June to November, the high salinity ($> 35‰$) of Arabian Sea water controls the larval population. Seasonal changes in the neritic larval population of Bay of Bengal is the result of low salinity ($< 33‰$) water of the Bay due to the river outflow from the Indo-Burmese subcontinent.

During the Southwest monsoon period high concentrations of larvae were seen as large patches along the coastal areas. The above distribution extended to offshore areas considerably. The premonsoon (spring transition - March-April) recorded relatively very high concentrations of larvae along the southwest coast of India and in the western and northern Bay of Bengal extending into the oceanic regions. But George (1979) found relatively poor abundance of fish larvae and eggs during January to April than in the monsoon during 1970-1975 along the southwest coast of India. The Northeast monsoon also recorded good catches of larvae especially from the east coast of India. Along south-west Indian coast during the period November-March, onset of northerly current with the postmonsoon conditions prevailing, very high oxygen concentration, plankton bloom following upwelling and the gradual rise in sea temperature resulting from the recession of the upwelling process, provide the fish fauna with favourable environmental conditions. Different years (1960-1965) indicated wide variations in the intensity, duration and onset of upwelling depending upon the prevailing current systems and not the wind. Since upwelling brings about changes in the temperature and dissolved oxygen content values, effect of upwelling on local fishery is considerable.

A general classification of the plankton/fish larvae abundance based on availability of nutrients is used in describing waters as eutrophic, mesotrophic and oligotrophic in decreasing order of plankton abundance (Hutchinson, 1969). The maxima for the plankton biomass always coincided with the peak periods of upwelling followed by larval fish abundance as many of the pelagic fishes are plankton feeders. From the nature and characteristics of the upwelled water, the abundance of fish larvae can be predicted in advance. The absence of proportional increase in biomass in certain areas can be attributed to the rocky bottom of the upwelled areas. Prevailing upwelling brings mesopelagic larvae to the surface.

Biogeographical distribution of plankton-fish larvae have been based on the very early recognition that specific environmental factors such as light, temperature, salinity and nutrient requirements to some extent determined the occurrence and succession of species. While many fish larvae tolerated a wide range of temperature (eurythermal), others tolerated only a narrow range (stenothermal); similarly salinity (euryhaline and stenohaline) and light (euryphotic and stenophotic) tolerances can be noted. Bary (1963) defined such plankton distribution in terms of their temperature and salinity tolerances (called T-S-P diagram). As emphasized by him the importance of such diagrams were in showing distribution of plankton in certain water bodies, rather than the exact geographical location of the samples. Occurrence of a species in another water body might occur from a shift in the direction of a current. Over large areas temperature is important in limiting species distribution, while in subareas, where temperature variation is small, salinity variations restrict distribution.

Environmental data on biotic and abiotic variables such as light, temperature and salinity gradients, winds, currents, plankton productivity and predation revealed larval fish reacting strongly to the above properties and the various boundary conditions. Thus these factors influence the aggregation or dispersion of fish larvae species, which in turn decides the abundance of a species. Some of the casual relationship already established are as follows. Uda (1961) has given the optimum temperature range for 21 different species of fishes. Rae (1957) has shown a correlation between average wind strength and brood strength of haddock. Blackburn (1965, 1969) has brought out a very general relationship between zooplankton abundance and tuna catch, eventhough tuna generally occur in waters warmer than 20°C, where zooplankton abundance is less. When temperature was taken into account it was concluded that the 20° isotherm determined the overall range of the tuna, while zooplankton concentration determined the distribution of tuna within the animal's temperature range. In general, prediction of abundance on single or multiple component correlation have not been successful. Thus Ahlstrom (1961) could not find any relationship between year class strenth of sardines and high plankton productivity. Lillylund (1965) found biotic factors more associated with abundance than abiotic. Steele (1964) concluded that prediction of fishery required more knowledge on food-web structure.

Bapat (1955) noticed that the maximum spawning activity of fishes of the Gulf of Mannar were during low salinity and temperature periods. Matsumoto (1959) reported favourable surface temperature range of 23.5° to 29°C for Auxis and 23.5° to 29°C for Euthynnus sp. of the 'Dana' collections from the Pacific and Atlantic. The maximum number of tuna larvae collected from the Indian Ocean area during 'Dana Expedition' were of the temperature range 26° to 29°C (Jones and Kumaran, 1963). Klawe et al. (1970) recorded an optimum temperature 27°C for Auxis larvae in the Gulf of California. Richard et al. (1971) reported the widest temperature range of 21.6° to 30.5°C for Auxis larvae and a temperature higher than 24°C for the larvae of yellowfin, big eye and skipjack tunas in the Gulf of Guinea and off Sierra Leone. Matsui (1970) found Rastrelliger larvae occurring in the Gulf of Thailand and adjacent waters having a temperature range of 26.2° to 31.7°C and salinity range between 29.43 and 34.5‰. Alikhan (1972) correlating distribution of fish larvae from Gulf of Aden and waters off the coast of Pakistan with surface temperatures ranging from 23.5° to 24.5°C for *Stolephorus commersoni* and 24° to 26°C for *Vinciguerria* sp. A good number of mackerel larvae were collected by Silas (1974) during May 1964 from the southwest coast of India, where the vertical temperature, salinity and dissolved oxygen content of the area ranged between 26.6°C and 29.5°C, 35.13‰ and 35.08‰ and 4.5 ml/l and 5.55 ml/l respectively. Boonprakob and Debtaranon (1974) noted the distribution of *Rastrelliger neglectus* larvae in the Gulf of Thailand at a temperature range of 27° to 29°C and salinity range of 31.75‰ to 32.75‰.

In the distribution studies, the volume of water filtered during the collection of the sample is an important factor that determines the true representation of the species of the region. McGowan (1971) in the experiments conducted while following a current drogue, showed that for fish larvae the amount of water to be filtered in order to include all species was in excess of 10,000 m^3. However, the relationship between the number of species and the volume of water filtered was logarithmic, for example, about 80% of the fish larvae species were found in about 1000 m^3 of water. But in the present collections only 200 m^3 of water was filtered [illegible] ...ily. Hence great caution has to be made in looking for the factors responsible for the abundance of species in a locality.

Very high numerical abundance of fish larvae occurring in certain collections may be the result of patchiness of plantkon distributions, which are caused by the various environmental parameters together with the resultant physiological responses of planktonic organisms. The uneven distribution of fish larvae can also be due to the tendency of adult fishes to release clmps of eggs, and this contagious distribution on eggs might be carried through in the developing stages of eggs. Social behaviour among the nektonic fishes is of greater significanse in causing patchiness. Wiebe (1970) showed that both small scale and large scale patchiness were common in the distribution of species. Cassie (1962) observed that patchiness was greater in calm seas. The frequency distribution of fish larvae of the Arabian Sea and Bay of Bengal is given in Figures (31 & 32) to establish an empirical relationship as done by Barnes (1952).

Coactive factors which determined the composition of species may be more directly caused by predation pattern of the different trophic levels in the plankton community. According to Cushing (1966, 1967) the coincidence of a food supply with larval distribution is important and probably critical for their survival. Lebour (1923) showed that as chaetognaths preyed upon fish larvae, their vertical distribution overlapped that of fish larvae.

The major portion of the fish zones come under the coastal and off coastal areas. The central parts of Arabian Sea and Bay of Bengal particularly towards the south came under the lowest range in density.

A general interpretation for this particular pattern of distribution could be made in the light of the physico-chemical factors prevailing in the ocean. The watermasses of the Arabian Sea and Bay of Bengal are known to be different from each other in their physical and chemical properties. The Arabian Sea surface water has high salinity, high temperature and steep gradient of dissolved oxygen content, falling to very low values at 100-150 m depth. The sub-surface water has an even higher salinity, but low temperature and less dissolved oxygen content. In Bay of Bengal high temperature is associated with low salinity, but low temperature in the sub-surface layer. The temperature decreases from lower to higher latitudes. The geographical differences of environmental conditions in the northern part of the Indian Ocean is further enhanced by seasonal reversal of conditions caused by monsoonal systems. The areas where the density of larvae were found to be greater correspond to more productive areas. These areas of high abundance of larvae coincide with areas of upwelling or places that are under the influence of divergence. Areas such as Somali coast, Arabian coast, west coast of India, west coast of Bay of Bengal, are all noted to be areas of upwelling during some seasons of the year, or having divergence caused by coastal currents. Similarly areas along the equator are under the influence of equatorial current and equatorial counter current systems. On the other hand, areas within the cyclonic gyre, where water is not well mixed with water of the surrounding regions, the density of larvae is low. Examples are the central Arabian Sea and Bay of Bengal.

5.2. Day and night variations.

The diel changes occurring in a planktion community regularly in every 24 hours is equally applicably to fish larvae also. The distribution of fish larvae during the day and night have been discussed by several workers, majority of whom reported the occurrence of higher numbers of larvae in the night collections. A lesser number of larvae of Pacific sardine, *Sardinops caerulea* in the day catches was observed by Silliman (1943) and Ahlstrom (1954). Bridger (1956) reported higher rates of larval catches, as high as seven times and four times in the case of clupeids and pilchards respectively during night than day. Ahlstrom (1959) found no consistant difference in the day and night catches of *Trachurus symmetricus* larvae in the California and Baja California waters. Higher records of larval tunas in the night collections have been made by Wade (1951), Matsumoto (1958), Strassburg (1960), Nakamura and Matsumoto (1966), while lesser catches of *Auxis* were noted by Klawe (1963). But Ueyanagi (1969) did not find any difference between the number of tuna larvae collected during the day and night up to a depth of 30 m. However, studies on the distribution of tuna larvae in the north western Gulf of Guinea and off Sierra Leone (Richards, *et al*., 1971) indicated the more frequent catches of yellowfin and bigeye larvae at the surface during night. But in the case of *Auxis* larvae no marked difference was noticed between day and night collections.

The higher abundance of postlarvae at depths lesser than 25 m during night was noticed in the case of *Scomber japonicus* in the Japanese waters (Watanab, 1970). Schnack and Hempel (1971) noticed that the herring larvae sampling had higher catches of larger larvae in the night, whereas catches of smaller larvae were equal during day and night. Ahlstrom (1971) recorded marked differences in the day and night occurrence of scombroid larvae with higher numbers in the night during the ESTROPAC surveys. He has also observed (1978) gonostomid larvae occurring 2.9 to 4.3 times more at night. Alikhan (1972) observed that the average number of larvae in the 50 m surface in the Gulf of Aden during night was 2-4 times higher as compared to day. Larvae of *Rastrelliger kanagurta* showed nocturnal abundance in the southwest coast of India (Silas, 1974). But Boonprakab and Debtarahon (1974) recorded large numbers of postlarvae of

Rastrelliger neglectus congregating 5-10 m during day and sinking to greater depths from dusk to night exhibiting some kind of positive photo taxis reaction. George (1979) reported that the average catch of fish larvae per night station was 1.4 times higher than that of day catch in the coastal waters of the south-west coast of India. He observed 100% increase of larvae of *Vinciguerria* sp. during night, while 50% increase in the case of *Sardinella* spp. and *Euthynnus affinis* and marginal increase for all other scombroids from the same area.

In the present study, it was observed that Arabian Sea and Bay of Bengal recorded considerably higher numbers of larvae in the night hauls than in the day. Earlier, the author (1970, 1977) has observed the increased catch of fish larvae during night in the Indian Ocean. The relationship between the average number of larvae collected during day and night showed very distinct differences. In the Arabian Sea the larval catch during night was double that of day record, while in the Bay of Bengal it was 2½ times higher than in the day (Fig. 30). More or less same type of relationship was noticed at different latitudes also (Tables - 11 & 12). The avoidance of net by the larvae, the diurnal vertical migration and their photo-taxis reaction exhibited by several groups could be the possible reasons for this high count of larvae in the night hauls. It is reported that (UNESCO, 1975) the towing speed less than 100 cm/sec caused increased avoidance of the sampler by the larvae. Ahlstrom (1959) and Hartman (1970) have ovserved that several kinds of fish larvae perform diurnal vertical migration. In the present collections water columns of 200 - 0 m were sampled which collected the pelagic as well as bathypelagic species during the day hauls. So the effect of vertical migration in these collections is comparatively less because of the sampling depth. However, the possibility of several bathypelagic forms from greater depths coming to the upper layers cannot be ignored. The ratio of the night catches to day, in vertical and horisontal tows confirmed that the night tows could overcome the effect of avoidance by the larvae of most taxa. Hence the importance of night sampling cannot be ignored while conducting Ichthyoplankton surveys.

5.3. Fish larvae and zooplankton biomass.

The relationship between the number of fish larvae and zooplankton biomass has been reported to be directly proportional in several cases, whereas it was iniversaly proportional in others. Nakamura and Matsumoto (1966) found that large catches of fish larvae occurring in low or moderate volume of zooplankton samples. They could not establish a significant correlation between tuna larvae and abundance of plankton in the individual samples. George (1979) reported a positive relationship between the two in the collections from the coastal waters of the south-west coast of India. Strasberg (1960) noticed an inverse relationship in his study on larval skipjack and yellowfin tuna in relation to the volume of plankton. Alikhan (1972) also found the same inverse relationship in the samples taken from Gulf of Aden.

The present study indicated that when the plankton volumes were higher, the number of larvae were not proportionally higher or vica versa as observed by the author earlier (1969a). It was also observed that the higher numbers of larvae were not recorded from samples of large biomass, but from samples which were neither high nor low in biomass. However the general relationship between fish larvae and plankton biomass in individual samples was neither very close nor uniformly proportional. This inconsistent and irregular relationship depended mainly on the gear used, area sampled, time and duration of haul and general composition of zooplankton. In many of the plankton samples quite a number of carnivorous organisms such as ctenophores, ostracods, chaetognaths etc. are present depending on the nature and size of the sample. Fraser (1969) has observed that larval fish are important in the diet of medusae such as Aurelia, Cyanea, etc. Lillelund and Lasker (1971) have reported the heavy predation of copepods on sardine larvae. Chaetognaths and ostracods are found to feed on fish larvae (Nellen, 1973 b). Alikhan (1972) recorded the presence of semidigested larvae from the guts of chaetognaths and ctenophores.

Apart from the number of predators in the sample, the type of gear, time, nature and duration of hauls are also factors that might influence the relationship between fish larvae and zooplankton biomass.

In the sea, food chain can be expressed as a continuous flow of biomass from phytoplankton to fish consisting of approximately 6 trophic levels. Hence depending on the age of the ecosystem from where the plankton sample is collected, the amount of biomass showed reduction in proportion to growth of predatory organisms as fish larvae leading to iniverse relationship. Salmon feeds on euphausids, and adult anchovy feeding directly on phytoplankton is well known. The predominace of planktivorous fish selectively grazing large zooplankton, markedly decrease in the volume of plankton collected. The relationship noted in the present study is the result of tropical plankton communities and food webs characterised by high diversity, low productivity and high stability.

5.4. Composition, frequency of occurrence and pattern of distribution in the northern Indian Ocean.

Analysis of the catch composition of fish larvae in the Arabian Sea and Bay of Bengal revealed that Myctophidae outnumbered all the rest of the groups. This was represented by a large number of genera and species. Among the various genera of myctophids *Diaphus* had the highest abundance followed by

Lampanyctus and Diogenichthys. Symbolophorus, Hygophum, Notolychnus and Myctophum were also very common. Ceratoscopelis and Scopelopsis were rather rare. The larvae of lantern fishes are very peculiar and show great diversity of form. Species of different genera differ from each other in the shape of eye, body, finfold, pectoral fin, pigmentation etc. Valsa (1979) described the larval stages of Diogenichthys panurgus from the shelf waters of the southwest coast of India. Published works on the larvae of Myctophidae of the Arabian Sea and Bay of Bengal are very scanty. In the present collections this family was represented in 70.8% of the stations of the Arabian Sea and Bay of Bengal and contributed to 25.3% of the total larvae. Arabian Sea recorded a higher percentage of larvae (26.8%) than in the Bay of Bengal (20.8%) whereas the frequency of occurrence was vica versa, with 68.1% and 72.0% respectively. Ahlstrom (1968) estimated the percentage of myctophids in 50 IIOE samples of the Indian Ocean to be about 47.6. Moser and Ahlstrom (1970) reported that in California current region Myctophidae contributed to 10 - 15% of the total fish larvae collected. The NORAC and ESTROPAC Expeditions which surveyed two widely different ecological regions emphasised the dominance of this group of fish in most oceanic areas. Nellen (1973 b) traced the distribution of two of the myctophid genera *Lampanyctus* and *Benthosema* and found that the distribution in the Arabian Sea was confined to two separate regions. *Lampanyctus* was concentrated at the Gulf of Oman, Somali coast and the offshore waters of Mombasa and Kerala coasts, whereas *Benthosema* species, in the Gulf of Oman and some stations between Bombay and Karachi. George (1979) recorded small numbers of larvae in the continental shelf waters of the southwest coast of India and major concentrations of $10/m^2$ in the belt of 80 - 40 miles wide from the coast.

Myctophids are perhaps the most widely distributed family of fishes in the world oceans. This economically unimportant group being both abundant and wide spread constitute one of the forage food in the ocean forming a vital link in the food web. The more compactly schooling myctophids *Benthosema panamese* are fed directly by tunas (Alverson, 1963; Watanabe, 1960). Moser and Ahlstrom (1970) reported that myctophids are also a major food of cetaceans at a depth of 200 - 250 m. Legendre (1934) showed that young lantern fishes are an important food of the albacore, *Thunnus alalunga*.

The larvae of myctophids are recorded in all months of the year both in the Arabian Sea and Bay of Bengal showing that the breeding is continuous and prolonged. As indicated by the distribution chart (Fig. 8), they breed over extensive areas, mainly in the oceanic and offshore waters.

The next dominant group of larvae was that of light fishes belonging to the family Gonostomidae. *Vinciguerria* and *Cyclothone* were the most abundant genera in the collections. The genus *Maurolicus* was also represented in the samples in lesser numbers. Gray (1964) recognised 21 genera of gonostomids and approximately 60 species. Seventeen species of *Cyclothone* were taken by *Anton Bruun* (Craddock and Hedroch, 1973). From the Indian Ocean *V. lucetia* and *V. nimbaria* have been recorded by Norman (1939) and Misra (1947). Silas and George (1971) described several stages of *V. nimbaria* collected from the continental shelf waters of the southwest coast of India. Ahlstrom and Counts (1958) have reported that only four species of *Vinciguerria* were recorded,namely *V. nimbaria*, *V. lucetia*, *V. attenuata* and *V. poweria*. The gonostomids contributed to 12.0% of the larvae collected from the Arabian Sea and Bay of Bengal, of which the latter area recorded a higher percentage of larvae (20.5%), more than three times higher than that of Arabian Sea. The frequency of occurrence in the Bay of Bengal was also double that of Arabian Sea. The distribution pattern of Vinciguerria in the Arabian Sea and Persian Gulf described by Nellen (1973 a,b) indicated the oceanic nature of the concentration, and the absence of larvae in the continental shelf area of the south-west coast of India. The present collections which had a wider coverage of the Arabian Sea showed negative records at the major part of the continental shelf region of the west coast of India. From the Bay of Bengal there is no earlier work on the distribution of larvae of Vinciguerria, especially from the oceanic region. The collections from the eastern part of Bay of Bengal recorded no larvae of Vinciguerria. The concentration of larvae distributed in the major part of the Bay was more or less continuous patch except at the eastern side and a few other isolated areas. Vinciguerria are recorded in all months of the year in the Arabian Sea and Bay of Bengal and hence the breeding is continuous and prolonged over extensive areas of the oceanic and offshore water.

Cyclothone spp. contributed to only 1.1% of the total larvae collected from Arabian Sea and Bay of Bengal, with a frequency of occurrence of 13.6%. Out of these, Arabian Sea had a higher percentage in the number of larvae as well as the frequency of occurrence. Ahlstrom (1974) observed that gonostomid *Cyclothone* has been singled out as the most abundant group of fishes in the ocean. But in the Indian Ocean it was only second to gonostomid *Vinciguerria*. Ahlstrom (1959) has also found out that larvae of *Cyclothone* are distributed in the shallow regions and they occur principally in the upper mixed layer and they remain in this depth zone through the prometamorphic stage, afterwards moving to more deeper levels. Later metamorphic stages of *Cyclothone* are never taken in plankton collections made within the upper 200 m. The distribution of *Cyclothone* in the Arabian Sea also agrees well with the pattern described by Nellen (1973 a,b), showing the complete absence of larvae from the west and north western parts of Indian Peninsula. For *Cyclothone* species there is no published record available dealing with the distribution in the Bay of Bengal region. The present study revealed that the collections from the northern half of Bay of Bengal were completely devoid of this larvae. In comparison, Arabian Sea had a higher contribution of *cyclothone*.

The clupeoids comprising of coastal species such as sardines and anchovies, contributed to 3.8% of the total larvae collected from the Arabian Sea and Bay of Bengal. Of these the major contribution was that of Engraulidae, 5.0% in the Arabian Sea and 0.3% in the Bay of Bengal, where frequencies of occurrence were 8.3% and 1.6% respectively. The contribution of clupeoids were only 0.03% and 0.05% respectively from Arabian Sea and Bay of Bengal.

The earlier studies made on the distribution of clupeids are confined to the coastal waters only. The acoustic survey conducted by the Pelagic Fishery Project showed very large quantity of standing stock of about 500,000 tonnes of white baits in the continental shelf water of the southwest and southeast coasts of India (Anon, 1976). *Stolephorus heterolobus*, *S. bengnensis*, *S. zollengeri* and *S. bataviensis* were the main species. The clupeid fraction consisted of sardines, *Sardinella longiceps* which is the most dominant species. Other types of clupeoid larvae met with in lesser numbers were those of white sardine, *Kowala coval*, rainbow sardine *Dussumieria* spp. and anchovy *Thrissa* spp.

Nellen (1973 b) found that the distribution of engraulids and clupeids followed more or less the same pattern in the Arabian Sea and Persian Gulf.

Since the coastal areas are not properly covered during the expedition, the coastal species are not well represented, in the collections. However from the off-shore regions a few clupeids and a good number of engraulids were collected. These are commercially important groups of the coastal waters. The present record of engraulids in the offshore waters indicate that there is an exploitable resource of engraulids in the offshore regions also.

Hornel and Nayudu (1924) observed that spawning took place only once a year from June to August. Results of the survey conducted by the Pelagic Fishery Project (Anon, 1974, 1976; George, 1979) showed that sardine larvae were present in all months in the coastal waters of the southwest coast of India, but dominant occurrence being during March to September, with peak in July. Gopinath (1946) reported the seasonal occurrence of large swarms of postlarvae of Stolephorus commersoni off Trivandrum coast during winter months. Sreekumari (1977) recorded the larvae of Stolephorus zollingeri from the southwest coast of India with the maximum abundance in April-May periods, and a secondary abundance in November/December months. The present collections recorded clupeid larvae during February, March and December in the Arabian Sea and during April, June, July in the Bay of Bengal. Engraulids were recorded in the offshore waters of Arabian Sea in all months except September and in the Bay of Bengal during March to September. During these periods they seem to breed in the offshore waters also.

Bregmacerotidae which is an economically unimportant group contributed to 3.7% of the total larvae collected from Arabian Sea and Bay of Bengal with a frequency of occurrence of 26.7%. The contribution of Bregmacerotidae in the Bay of Bengal was nearly double that of Arabian Sea. The frequency of occurrence also was higher in the Bay of Bengal. *Bregmaceros macleliandi* was the most common species in both the Arabian Sea and Bay of Bengal. Balakrishnan (1971) collected larvae of *Bregmaceros* from the southwest coast of India. Nellen (1973 b) recorded the larvae of *Bregmaceros* spp. at the Gulf of Aden, Somali coast, north and north western coasts of India extending up to the Persian Gulf. George (1979) reported the occurrence of the larvae mostly at the mid-shelf of the southwest coast of India. The present collections showed the total absence of larvae in the middle of Arabian Sea from Pakistan coast to 5°S latitude. The area parallel to the coasts had good concentrations of larvae. In the Bay of Bengal the concentration of larvae was towards the northern half and the area between Malaysia and Sumatra. But the coasts of Thailand and southern parts of the Bay were devoid of the larvae excluding certain isolated patches. Balakrishnan (1971) recorded the larvae from the southwest coast of India during January, March, April, November, whereas Goerge (1979) reported the occurrence of larvae throughout the year, but with more concentration during February to August. The present collections recorded the larvae during all months of the year in the Arabian Sea. In the Bay of Bengal except for the month of November, all months recorded the larvae. The larvae seem to have a prolonged breeding season and an extensive breeding ground.

Carangidae, another significant component of the marine fisheries contributed to only 1.2% of the total larvae collected. The frequency of occurrence of this group was 11.0% of the stations. The major species contributing to the fishery are scad (*Decapterus* spp.) and horse mackerel (*Megalaspis cordyla*). Species of caranx are also caught from shallow regions. The present collections included species of *Decapterus*, *Chorinemus*, *Megalaspis* and *Caranx*. Nellen (1973 b) recorded carangid larvae only in very few numbers from the oceanic regions of the Arabian Sea. In the present collections they were recorded from the coastal, offshore and oceanic waters and the Arabian Sea and Bay of Bengal represented more or less the same percentage of larvae. George (1979) reported the occurrence of larvae almost throughout the year in the continental shelf of the southwest coast of India, with higher abundance during May-June months. In the Arabian Sea it was noticed that the larvae were present throughout the year except in February and September. In the Bay of Bengal they were not collected during the months February, October and November. Carangids also have a prolonged breeding season over extensive areas in the coastal, offshore and oceanic regions in the Arabian Sea and Bay of Bengal.

Scorpaenidae was the next dominant group in the collections and it contributed to 1.1% of the total larvae collected. Scorpaenids were represented in 10.6% of the stations. The number of larvae collected from the Arabian Sea was much higher than that from the Bay of Bengal, but the frequency of occurrence was more in the Bay of Bengal. Nellen (1973 b) recorded larvae of *Pterois* spp., *Kanapus* spp. and *Scorpaena* spp. from the Arabian Sea. In the Arabian Sea they seem to have a prolonged breeding season, as they were collected in all months of the year, except December. In Bay of Bengal they were collected from May to July and in September months.

Family Gobiidae contributed to only 1.1% of the total larvae collected. Arabian Sea though had a higher percentage of larvae than Bay of Bengal, the frequency of occurrence was less. Nellen (1973 b) recorded larvae of gobiids mainly from the coastal and offshore waters. He collected only very few larvae from oceanic waters. The present collections recorded larvae from several oceanic stations both from Arabian Sea as well as from the Bay of Bengal, in addition to the coastal and offshore stations. They were collected in all months of the year except September and October in the Arabian Sea and October in Bay of Bengal. The presence of larvae throughout the year indicates that the breeding is continuous and the pattern of distribution shows that they spawn in the coastal, offshore and oceanic regions.

Paralepididae was represented in 14.4% of the stations, contributing to 0.6% of the total larvae collected. The percentage contribution of larvae in the Arabian Sea as well as Bay of Bengal was more or less the same. Nellen (1973 b) collected Sudidae larvae, *Lestidiops Jayakari*, *Macroparalepis* spp. and *Sudis* spp. from Gulf of Oman, and Somali coast. There is no published report about the distribution of the larvae for the Bay of Bengal region. From the Arabian Sea these were collected from January to December excluding September and October, whereas it was present throughout the year in Bay of Bengal. The presence of larvae throughout the year indicates that paralepids are continuous breeders.

Thunnidae which sustains a major fishery in the Indian Ocean contributed to only 0.9% of the total larvae collected. Bay of Bengal recorded higher percentage of larvae as well as frequency of occurrence than that of Arabian Sea. The tuna fishery is constituted mainly by species of *Auxis*, *Euthynnus affinis*, *Sarda orientalis*, *Thunnus tonggol*, *T. albacares* and *Katsuwonus pelamis* in the Arabian Sea and Bay of Bengal. They occur in the tropical and subtropical waters.

Auxis spp. are reported to be found near the land masses as well as areas far distant from land (Matsumoto, 1959; Yabe and Ueyanagi, 1962; Klawe, 1963). *Euthynnus* larvae usually occur closer to land masses (Matsumoto, 1959). *Katsuwonus pelamis*, *T. albacares* and *T. alalunga* are oceanic species. Gorbunova (1963) reported the absence of tuna larvae in the Arabian Sea, excluding Aden Bay from where large number of larvae were collected, of which *Auxis thazard* and *Euthynnus affinis* were from the coastal region, whereas *Thunnus albacares* and *T. alalunga* were from oceanic waters. Jones and Kumaran (1963) found that *Katsuwonus pelamis* and *Thunnus albacares* of the 'Dana' collection had a wide range of distribution in the Indian Ocean. Ueyanagi (1969) observed that the larvae of *Katsuwonus pelamis* had the widest range in the distribution among tunas. Nellen (1973 a,b) recorded the distribution of *Auxis* spp. in the Arabian Sea, mainly in the Somali and Gulf of Aden regions, whereas the other species of tuna occurring in the offshore and oceanic regions. Peter (1977) (Annexure II) observed that in the Arabian Sea the coastal stations were represented by mainly *Auxis* and *Euthynnus* spp., while *Thunnus albacares*, *T. alalunga* and *Katsuwonus pelamis* were the main species collected from the offshore oceanic regions, their concentrations being in the equatorial zone. George (1979) reported that *Katsuwonus pelamis* had the maximum frequency of occurrence in the continental shelf waters of the south-west coast of India, followed by *Euthynnus affinis* and *Thunnus* spp. The results of the present study showed that larvae of tuna are abundant in both Arabian Sea and Bay of Bengal with higher concentrations along the equatorial zone. At the same time, a wider area in the central part of Arabian Sea showed total absence of larvae in the collections.

Gorbunova (1963) observed that larvae of *T. albacares* were found in the Indian Ocean from January to April and from October to December. In the open sea they were caught from November to March. Larvae of *T. obesus* were in the open parts of the central Indian Ocean in February, March and December. The spawning of *Katsuwonus pelamis* was observed during winter and spring. In the Bay of Bengal and Andaman Sea larvae were collected during winter season. In the central part of the ocean southward from equator, they were caught in comparatively large quantities from December to March. More information is available on the spawning of *Euthynnus affinis* in the Indian Ocean. Off the eastern coast of Africa it spawns in September, October and in March-April. Similar data are available on the spawning periods in the Gulf of Aden and Bay of Bengal. They seem to spawn mainly in coastal waters. George (1979) observed along the southwest coast of India beyond 50 m depth the occurrence of these larvae from March to August months with significant abundance only in May and June. Larvae of Auxis thazard like those of Euthynnus are found in coastal waters. They are reported to occur from October to April. In the present collections tuna larvae were recorded from Bay of Bengal during January and from March to October, whereas they were present throughout the year in the Arabian Sea, thus indicating the prolonged breeding nature of the group. The spawning ground also was found to be very extensive covering the coastal, off-shore and oceanic regions particularly the equatorial region. Auxis larvae, the most abundant of all scombroid larvae occur in thick belts of 50 km along the southwest coast of Kerala with peak abundance in July (George, 1979).

Callionymidae contributed to 0.4% of the total larvae collected. The higher percentage of larvae as well as frequency of occurrence were noticed in the Bay of Bengal. Larvae of Callionymus fluviatilis recorded by Jones and Menon (1953) and C. melanopterus by Jones and Pantulu (1958) are from coastal waters. Records on the oceanic species from the Indian waters are not available. Nellen (1973 b) reported the occurrence of Callionymus spp. from a few stations in the Persian Gulf and Arabian Sea. The present collection recorded scattered distribution of larvae over a very wide area. But major part of the central Arabian Sea and southern region of Bay of Bengal did not record any larva. They seemed to spawn almost all months of the year, except in April and September in the Arabian Sea and February, November and December in Bay of Bengal.

Serranidae is one of the important economically important groups which contributes considerably to the demersal fisheries. This group contributed to 0.4% of the total larvae collected and had a frequency of occurrence of 7.6%. Bay of Bengal represented higher percentage, both in the number of larvae and frequency of occurrence. This family is constituted by large number of genera and species. Serranus and Epinephelus are the common genera recorded. The major parts of the central Arabian Sea and Bay of Bengal did not yield the larvae of this group. Their breeding was found to be extended throughout the year except in September in the Arabian Sea and July, October and November in Bay of Bengal.

Scoberomoridae forms a significant component of the scombroid fishery. The catch contributed to only 0.4% of the total larvae collected. The frequency of occurrence of the larvae was 4.5%. Arabian Sea had a higher percentage in the contribution of larvae, but Bay of Bengal showed a higher frequency of occurrence. Scomberomorous commerson, S. guttatus, S. lineolatus, Acanthocybium solandri are reported to be the common species present in the Arabian Sea and Bay of Bengal. Nellen (1973 b) recorded Scomberomorus spp. and Acanthocybium solandri from Indian coast and Somali coast respectively. George (1979) recorded one postlarva of Scomberomorus commerson (10.7 m t.l.) from a station off Cochin where the salinity, temperature and oxygen values were 34.8‰, 28°C and 4.5 ml/l respectively.

Scomberomoridae seem to spawn in the costal areas. The spawning period (Vijayaraghavan, 1955) is rather long and observed from July to January, and also April to July (Krishnamurthy, 1958). From the Arabian Sea the larvae were collected from May to August and October to January. In Bay of Bengal the occurrence was from March to June and August to November.

Labridae contributed to 0.4% of the total larvae collected and their frequency of occurrence was 8.9%. The percentage of larvae and frequency of occurrence was higher in the Arabian Sea than in Bay of Bengal. Labridae also contributed to the fishery. Nellen (1973b) recorded species of <u>Callyodon</u>, <u>Coris</u> and <u>Stethojulis</u> from the Persian Gulf and other species from the Arabian Sea. Publications on the distribution and life history of this group from the Bay of Bengal region are not available. The present study shows that the distribution is mainly oceanic. The collections from the north eastern and central part of Arabian Sea were found to be devoid of labrid larvae whereas they were highly scattered and patchy in the Bay of Bengal. The larvae were recorded during all the seasons except in May and November in the Arabian Sea and February in Bay of Bengal thus indicating a rather continuous and prolonged spawning.

Bathylagidae was represented by 2.6% of the stations which contributed to 0.4% of the total larvae collected. Out of these only about 1/3 was collected from the Arabian Sea. But more or less the same frequency of occurrence was noticed in both the areas. This is one of the groups that is found commonly in the mesopelagic region. Publications on the distribution and larval history of this fish for the Indian Ocean region are not available. They were collected during January, June, July, August months from Arabian Sea, while April, June and July from Bay of Bengal.

Larvae of lizard fishes contributed to only 0.3% of the total larvae collected. They occurred in 3.4% of the stations. The number of larvae recorded from Bay of Bengal was very negligible, the major share being from the coastal and offshore waters of Arabian Sea. Saurida tumbil, Saurus myops, S. indicus, S. gracilis are the common species recorded from the coastal waters of Arabian Sea (Gopinath, 1946; Vijayaraghavan, 1957; Kuthalingam, 1958, 1959; Basheeruddin & Nayar, 1962; Dileep, 1977; George, 1979). Nellen's record (1973 b) from the Persian Gulf and Arabian Sea was from the coastal and offshore waters. Publications on the distribution of Synodontidae of the Bay of Bengal region are not available. Gopinath (1946) recorded the larvae during January-February period, whereas Dileep (1977) observed during November, December and January to April. George (1979) observed that larvae were abundant during February to March and November months with lesser numbers in July and August. The present collections which covered mainly the offshore and oceanic regions showed that they were present during March, May to August and October to November in the Arabian Sea and January, March, April, June, September and December in Bay of Bengal indicating their prolonged spawning.

Coryphaenidae also contributed to more or less the same percentage (0.3%) as Synodontidae. They were represented in 2.6% of the stations. The major share of the contribution was from the Arabian Sea (0.5%). The frequency of occurrence also was about 4 times higher than that of Bay of Bengal. _Coryphaena hippurus_ is reported to be the common species in the Indian Ocean. From the Persian Gulf and Arabian Sea Nellen (1973 b) reported the larvae of _Coryphaena_ in the coastal and offshore waters.

Coryphaena larvae were collected from Arabian Sea from April to September and November to December, whereas they were caught from Bay of Bengal during the months of March, April, June and September.

The next group in the order of abundance was Anguilliformes. The leptocephali of eels and eel-like fishes contributed to only 0.3% of the total larvae collected. The frequency of occurrence was 7.8%. The percentage of larvae recorded from Bay of Bengal was about 3 times higher than that of Arabian and their occurrence also showed more or less similar proportion. This is a very large group comprising several genera and species. This group was collected during almost all months of the year, except during June, September and October in the Arabian Sea and

October in the Bay of Bengal. The spawning seems to be prolonged and continuous.

5.5. Spawning season and areas.

Knowledge of the eggs, larvae and juveniles of fishes contributing to fisheries is an indispensable factor for understanding the biology of the group. This information on several such groups is known inadequately, particularly for the Indian Ocean region. Of great importance is the knowledge about the duration of ripening of gonads, as well as the time and condition of spawning and the development at the time and condition of spawning and the develop- ment at the early stage of life. The spawning season of fishes vary in different areas in association with their pattern of migration to places where spawning conditions are more or less the same.

Spawning periods of fishes, particularly of coastal species based on the studies of gonads and ova diameter have been determined by several workers (Karandikar and Palekar, 1951; Prabhu, 1956; Dharmamba, 1959; Annigiri, 1963; Antony Raja, 1964; Raju, 1964; Radhakrishnan, 1965; and Kagwade, 1968). Information on the spawning periods of several marine teleosts has been reviewed by Qasim (1973). He observed that fishes along the west coast of India largely spawn during monsoon (June to September), and postmonsoon months (October to January). Gopinath (1942) recorded the concentration of postlarval fishes along the Trivandrum coast during November to March period. From the same area Menon (1945) reported fish eggs and larvae during September to November and May to July. George (1953) found that fish eggs and larvae were scarce during monsoon months off Calicut, but Mukundan (1967) observed them in large numbers during the period from August to December. George (1979) observed that in the southwest coast of India *Sardinella* spp., *Rastrelliger kanagurta*, *Stolephorus* spp. and *Auxis* spp. spawned throughout the year with maximum spawning activity in the monsoon period. Tunas other than *Auxis* spawned only during the period February to August. Though he observed a reduced spawning activity during postmonsoon (September to December) a general increase in the larval abundance of *Bregmaceros* sp., myctophids, gonostomids, *Stolephorous* spp. and *Rastrelliger kanagurta* was observed in November. A survey of the literature on this subject shows that many of the fishes are continuous breeders with prolonged spawning lasting for several months. While the above studies based on the collections of eggs and larvae are mainly from the coastal waters, Gorbunova (1963, 1965) studied the spawning of scombroid fishes in the Indian Ocean covering the coastal and oceanic regions. It was observed that _Thunnus albacares_, _T. obesus_, _T. alalunga_, _Auxis thazard_, _Euthynnus affinis_, _Scomberomorus_ spp. and _Rastrelliger_ spawned in the coastal waters. The author has earlier (Peter, 1973) reported that in the Arabian Sea fish eggs were abundant during June to August, the poor season being December, January and February months whereas in the Bay of Bengal (1979) the abundance was in the months of April, July, September and October, the lean periods being December and February.

Peter (1969, 1970) delineated the active spawning areas in the Indian Ocean based on fish eggs of the IIOE zooplankton samples. He observed higher concentrations of fish eggs $>$400/hl in the Arabian Sea at places like northern half of Arabian coast, northern tip of Somali coast, northern and southern parts of Socotra Island, areas off Kutch and Gujarat, Kerala coast and south of Sri Lanka. Of these places, north of Socotra Island was found to be one of the richest areas in terms of fish eggs recorded from the Indian Ocean. About 2000 eggs per haul were collected from one of the stations in this locality. Places like east of Socotra, off north Somali coast, northern part of Arabian Sea, off Kutch and Gujarat had more than 300 eggs per haul. The lowest range of 1–24 eggs per haul was noticed at the central part of Arabian Sea. In the Bay of Bengal region the highest concentration of fish eggs (>400 per haul) was found at the north western half of the Bay, excluding coastal areas. East and west of Andaman-Nicobar Islands also came under this grade. Of these two places, the former zone had a higher concentration of > 300 eggs per haul. The lowest value of 1–24 eggs per haul was recorded at the central part of Bay of Bengal.

The general pattern of distribution of fish larvae in the present study showed that the areas of abundance of fish larvae overlapped those of fish eggs at several regions. The places such as north-eastern half of Arabian coast, northern tip of Somali coast, Kerala coast, southwest of Sri Lanka, north-eastern half of central Bay of Bengal and a few places along the equator came under such common zones of abundance both for eggs and larvae. If these rich areas of abundance could be considered as spawning areas, it would be interesting to consider the north-western half of Bay of Bengal also as a potential spawning ground, despite the low fish landing records. This is perhaps one of the most interesting observations made in the present study.

5.6. Zoogeography of the northern Indian Ocean and distribution of fish larvae.

The topographical features of Arabian Sea and Bay of Bengal - the land locked northern boundary, various islands, ridges and a wider continental shelf along the eastern sector and a narrower one along the western sector - influenced the composition of the zooplankton samples collected, which were mainly from the offshore and oceanic regions. Extensive continental shelf areas are seen from Ras Fartak to Rasal Hadd in South Arabia, in the gulf between Iran and Arabian peninsula, along the west coast of Indian sub-continent including that of Gulf of Kutch and Gulf of Cambay, Gulf of Mannar and Palk Strait between India and Sri Lanka, Orissa coast, Burmese coast, Strait of

Malacca and west coast of Sumatra. The continental shelf samples recorded the highest abundance of larvae dominated by clupeids, engraulids, synodontids, flat fishes etc. The oceanic region was dominated by the larvae of mesopelagic and bathypelagic fishes such as gonostomids, stomiatids, paralepids, scopelarchids and myctophids. The intermediate zone noted for the number and kinds of larvae represented those of oceanic and coastal fishes including several commercially important groups such as Engraulidae, Synodontidae, Carangidae, Serranidae, Coryphaenidae, Stromateidae, Labridae, Callionymidae, Trichiuridae, Thunnidae and Scomberomoridae. The various zoogeographical regions recognised in the Arabian Sea and Bay of Bengal are the Arabian coast, Red Sea and Gulf of Aden, East African coast, central Arabian Sea, west coast of India, east coast of India, west coast of Burma and Thailand, and central Bay of Bengal. These areas exhibited some kind of variations depending on the topography.

The Arabian coast is reported to be one of the richest areas of the Indian Ocean in terms of primary production and zooplankton biomass. 34.7% of the larvae collected from the Arabian Sea were from the Arabian coast. Major families of fish larvae (in terms of numerical abundance) collected from here included Myctophidae (57.4%), Clupeidae (12.3%), Bregmacerotidae (8.5%), Carangidae (5.1%), Gonostomidae (4.5%), Stromateidae (3.7%), Coryphaenidae (3.1%), Scomberomoridae (0.9%), Callionymidae (0.8%), Thunnidae (0.9%), Labridae (0.7%), and Gobiidae (0.7%). Occurrence of Gonostomidae and Myctophidae amounting to 61.9% of the total larvae indicated the oceanic nature of this area in consequence to a narrow continental shelf.

The Red Sea and Gulf of Aden areas contributed 23.1% of the total larvae collected from the Arabian Sea. The topography of this region clearly indicated that it was an extension of the Arabian Sea. Accordingly Myctophidae, a typically oceanic group contributed to 79.3% of the larvae collected from this region along with other oceanic groups such as Gonostomidae and Stomiatidae which were only about 3%. As such coastal and offshore groups like Clupeidae, Engraulidae, Bregmacerotidae, Carangidae, Callionymidae and Gobiidae were represented in the collections only to the extent of 9%.

The East African coast having a very narrow continental shelf had the 200 m contour line at many places within 4 km from the shore. This oceanographic condition might also account for this comparatively less number of larvae (7.2%) collected from here. However, the most dominant groups were the oceanic families, Myctophidae contributing to 63.2% of the larvae, followed by Gonostomidae (16.2%) and another 3% shared by Stomiatidae, Paralepididae and Scopelarchidae. Oceanic stromateids, labrids and gempylids made up to 3%. The nearshore groups like Engraulidae (0.5%), Synodontidae (0.2%), Bregmacerotidae (5.7%), Carangidae (4.6%), Callionymidae (2.3%), Thunnidae (1.0%), Gobiidae (0.5%), Scorpaenidae (0.3%) etc. showed the highly diverse nature of the fauna in this region.

The central Arabian Sea is a typical oceanic region possessing an identical larval composition as that of East African coast. This region recorded 12.3% of the total larvae collected from the Arabian Sea. About 86% of the larvae collected from this region belonged to the mesopelagic and bathypelagic groups, the Gonostomidae (15.7%) and Myctophidae (66.6%). Other major groups recorded were Bregmacerotidae (3.8%), Serranidae (0.7%), Carangidae (0.4%), Stromateidae (0.6%), Labridae (0.5%), Thunnidae (1.2%) and Gobiidae (0.3%).

The west coast of India is characterised by a very broad and extensive continental shelf which maintained a large assemblage of coastal, offshore and oceanic species. However only 22.7% of the larvae collected from the Arabian Sea was recorded from here. The oceanic groups caught from this region were mainly Gonostomidae (30.3%) and Myctophidae (26.9%). The nearshore groups represented in this area were Gobiidae (7%), Bregmacerotidae (6%), Synodontidae (2"), Callionymidae (1.2%), Anguilliformes (0.6%), Thunnidae (0.2%), Scorpaenidae (0.2%) and Carangidae (0.1%).

Along the east coast of India the continental shelf is narrow except at the northern end and so mainly the oceanic characters prevailed in this area. As such the larvae of bathypelagic and mesopelagic fishes formed 84.7% of the total larvae recorded from the east coast of India. 34% of the larvae collected from the Bay of Bengal were from this region. The numerical abundance of gonostomids and mycyophids were 41.7% and 42.3% respectively. As the number of coastal samples were less, the larvae of Engraulidae and Clupeidae together contributed to about 0.6% only. The density of Bregmacerotidae was 7%. Other groups that occurred in more stations were Serranidae (0.8%), Carangidae (1.1%), Stromateidae (0.8%), Labridae (0.2%), Trichiuridae (0.6%), Thunnidae (0.6%), Gobiidae (0.9%), and Scorpaenidae (0.2%).

The west coast of Burma and Thailand differed from that of the east coast of India by its comparatively wide and prominant continental shelves supporting rich mangrove swamps. From the Bay of Bengal maximum larvae of 45.5% were collected from this region. However the contribution of oceanic groups such as gonostomids and myctophids were 28.7% and 33.9% respectively. Rest of the groups were Bregmacerotidae (12%), Scorpaenidae (4.7%), Gobiidae (3.5%), Carangidae (2.6%), Serranidae (1.8%), Anguilliformes (1.4%), Stromateidae (1.4%), Thunnidae (1.3%), and Callionymidae (1.1%) which included the coastal species of this region.

The central Bay of Bengal, a typically oceanic region recorded 20.3% of the total larvae collected from Bay of Bengal. This region was dominated by larvae of Gonostomidae, Stomiatidae, Paralepididae, Scopelarchidae and Myctophidae which formed 79.4% of the larvae collected from this area. The highest density of larvae was that of Myctophidae (39.1%)

followed by Gonostomidae (34.4%). Bregmacerotidae was another major group of this area with 6.9% of the larvae. Carangidae contributed to 2.9%. All the rest of the groups recorded at the eastern and western parts of the Bay were present here also, but none of the groups contributed to more than 2% of the total larvae collected from this region.

5.7. Statistical inferences.

In the correlation coefficient matrix prepared for the 27 groups positive correlations showed that their environmental requirements in the Bay of Bengal were more or less the same, while more number of groups had different environmental requirements in the Arabian Sea.

In the case of fish larvae collected from the Bay of Bengal, though the fitted regression model was capable of explaining a significant part of the variability (87%), the unexplained variability may be due to other environmental factors such as dissolved oxygen, nitrate-nitrogen, phosphate-phosphorus, current, turbidity, depth stratification, interaction of the above factors, etc. Since only a small part of the variability (13%)

remained unexplained, it emphasises that, not all, but only a few of the factors mentioned above need be taken so that in future investigations, the prediction ability of the model can be further improved. In the Arabian Sea since a major part of the variability remained unexplained, it follows that all the environmental factors, or most of them, along with the interaction of the factors mentioned above in addition to that of temperature and salinity need be taken, so that a considerable improvement could be expected in the future surveys.

Since the regression coefficients were found to be significant in the Bay of Bengal, but not in the Arabian Sea, it could be concluded that other factors that are not taken may have less relative importance in the Bay of Bengal, and more relative importance in the Arabian Sea with respect to temperature and salinity, i.e. a considerably large group of fish larvae will be significantly correlated with those environmental factors in the Arabian Sea than in the Bay of Bengal, when compared to temperature and salinity.

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6. SUMMARY

The major objectives of the present study were to assess the composition, distribution and abundance of fish larvae in the IIOE collections from the Arabian Sea and Bay of Bengal during 1960-'65. The quantitative data obtained have been used to determine the relative abundance and distribution of larvae both in space and time with a view to providing information for the stock assessment and management of fishery resources of the region.

Fish larvae sorted out from 935 standard zooplankton samples with a total volume of 14653.5 ml from the northern Indian Ocean yielded 53486 specimens which were identified into 54 families and 1 order. The standard samples were defined as those sampled in the water column under 1 m^2, the stratum sampled being the upper 200 m in deep water, and the entire water column over the continental shelf, where the sounding was less than 200 m.

The important oceanographic parameters such as topography, current systems, water masses, upwelling, hydrological properties and zooplankton biomass of the area studied, during the expedition were reviewed with a view to find out the possible correlation with the abundance and distribution of fish larvae.

The larval characters, area, period and frequency of occurrence and percentage contribution of fish larvae belonging to 45 groups were dealt with in detail.

Larvae of the scopeliform fishes outnumbered all the rest of the groups in the percentage of abundance contributing to 26.76% of the total larvae collected from the Arabian Sea and Bay of Bengal. Among all the groups of larvae classified at the family level, Myctophidae ranked first (25.3%) with a frequency of occurrence of 70.8%. This group was collected round the year from both the areas. The distribution was very widespread covering majority of the oceanic regions with higher percentage of larvae in the Arabian Sea, though frequency of occurrence was more in the Bay of Bengal. The contribution of Paralepididae was 0.6% of the total, having major concentration in the oceanic regions. They were present uniformly in both the areas in almost all months of the year, except in September and October in the Arabian Sea. Distribution of Scopelarchidae which was confined to March-September periods was mainly oceanic, contributing to 0.2% of the larvae collected. Arabian Sea recorded 3 times more larvae of this group than that from the Bay of Bengal. Synodontidae, mainly distributed in the coastal and offshore waters was represented by 0.3% of the larvae collected, Arabian Sea having about 7 times more number of larvae than in the Bay of Bengal. Larvae occurred from March to November excluding April and September in the Arabian Sea and during January, March, April, June, September and December in Bay of Bengal.

Gonostomidae ranking second in abundance, contributed to 12% of the larvae collected. In spite of their wide distribution, 3/4 of the larvae collected was from the Bay of Bengal. Genus Vinciguerria formed the major component of the family and this occurred throughout the year in both the areas. Genus Cyclothone accounted for 1.1% of the total larvae and was collected throughout the year except during January and February from Arabian Sea and July from the Bay of Bengal. Stomiatids having major concentrations in the offshore and oceanic regions contributed to 1.6% of the total larvae. They were present in both the areas during almost all months of the year.

The clupeoids comprising of coastal species such as sardines and anchovies were recorded in offshore waters, also contributing to 3.8% of larvae collected from the Arabian Sea and Bay of Bengal. Of these, the major share was that of Engraulidae (5.0%) in the Arabian Sea and 0.3% in the Bay of Bengal, as against the contribution of Clupeidae of 0.03% and 0.05% respectively from Arabian Sea and Bay of Bengal. Twenty one larvae of Clupeidae were collected, of which 10 were from the Arabian Sea and 11 from Bay of Bengal. Of the 1,666 engraulids collected, 1,601 were from the Arabian Sea and 65 from Bay of Bengal. They were recorded in almost all months of the year in the former area and from the latter, only from March to September. Bathylagidae amounting to 0.4% of the total larvae were more abundant in the Arabian Sea than in the Bay of Bengal.

Bregmacerotidae, which was third in the order of abundance at the family level, contributed to 3.7% of the total larvae collected with a frequency of occurrence of 26.7%. The Bay of Bengal had nearly double the contribution of larvae than in the Arabian Sea and a higher frequency of occurrence. Coastal, offshore and oceanic distributions of larvae were noticed throughout the year.

Among percoids, Carangidae had the highest contribution of 1.2% of the total larvae collected. Though the percentage contribution was almost the same in both the areas, Bay of Bengal showed a higher percentage of occurrence. Larvae were collected from coastal, offshore and oceanic areas throughout the year. Serranidae which occurred throughout the year, accounted for 0.4% of the total larvae, the higher share being from the Bay of Bengal. But the frequency of occurrence was more or less the same. Only 0.3% of the larvae collected belonged to the family Coryphaenidae. Of these, the major part was from the Arabian Sea. They were present during March to December except in October. Labridae accounted for 0.3% of the total larvae and occurred throughout the year with slightly higher representation in the Arabian Sea than in the Bay of Bengal, in spite of the larval scarcity noticed towards the northern part of the areas.

The scombroids like Thunnidae, Scombridae, Scomberomoridae and Histiophoridae contributed to 0.95% of the total larvae, Thunnidae having a major share of 0.5%, followed by Scomberomoridae. Scombridae was represented by only three larvae, 2 from the Arabian Sea and 1 from the Bay of Bengal (first record from the area studied). While the distribution of Histiophoridae was oceanic, Scombridae and Scomberomoridae were coastal and offshore; it was coastal, offshore and oceanic in the case of Thunnidae. Majority of the scombroids occurred in almost all months of the year.

Among the larvae of other perciform fishes, Gobiidae contributed to 1.1% of the total larvae with a frequency of occurrence of 14%. The percentage of larvae collected was higher from the Arabian Sea than that of Bay of Bengal. Distribution was found to be coastal, offshore and oceanic with occurrence in all seasons. Scorpaenidae contributing to 1.1% of the total showed a higher numerical abundance in the Arabian Sea; larvae were present in the coastal, offshore and oceanic regions. Stromateidae representing 0.4% of the total larvae, had a frequency of occurrence of more than double in the Bay of Bengal as compared with that of the Arabian Sea. Callionymids with the concentration of 0.4% and higher frequency of occurrence in the Arabian Sea than in the Bay of Bengal were collected during April and September in the former area, and February, November and December in the latter. Trichiurids and gempylids together contributed to only 0.1% of the total larvae collected. While Arabian Sea had higher records of Gempylidae, Trichiuridae were more in the Bay of Bengal.

There were quite a number of groups whose percentage contribution and frequency of occurrence were very low as indicated in Table 6. The contribution of Anguilliformes comprising of the various families of the eels and ell-like fishes had a very scattered distribution with less number of larvae amounting to 0.3% of the total. Arabian Sea with higher percentage and higher frequency of occurrence recorded these larvae during November to September period. In Bay of Bengal only October did not record any larvae of this group. Exocoetidae and Hemirhamphidae which occurred throughout the year together contributed to only 0.1% of the total larvae collected, of which Bay of Bengal had the higher numerical abundance and frequency of occurrence.

The families Balistidae, Diodontidae, Tetraodontidae, Antennariidae and Molidae were represented in the present collections only from the Arabian Sea by postlarval stages.

The general distribution of fish larvae from the Arabian Sea and Bay of Bengal showed higher abundance in the coastal and offshore waters. Based on their distribution, 9 different zoogeographical areas reflecting the hydrological regimes in the Arabian Sea and Bay of Bengal were differenciated. The areas of highest abundance of larvae, though overlapped at certain places with areas of zooplankton abundance, did not always coincide with the regions of their highest density.

The numerical abundance of fish larvae ranged from 0 - 1600 per haul (200 m^3) and comparatively high values (neritic abundance) were noticed towards the western Arabian Sea, western Bay of Bengal and along the southwest coast of India; the oceanic regions showing a gradual reduction in number towards the central parts of the Arabian Sea and Bay of Bengal and the equatorial regions. Compared to the Arabian Sea, Bay of Bengal recorded higher numerical abundance of larvae. This may probably be an indication of the presence of hither to unexploited pelagic fishery resources in the Bay of Bengal.

Swarms of fish larvae were observed at restricted areas, which may be as a result of the social behaviour of the pelagic-necktonic fishes leading to contagious distribution of eggs.

Distribution studies of fish larval populations based on four seasons indicated the concentration of larvae as large patches with maximum during May-August period and minimum during September-October period showing the effects of monsoons. During the Southwest monsoon period (May-August) western part of the Arabian Sea exhibited very high densities of fish larvae as large patches along the coastal and offshore areas, whereas the rest of the Arabian Sea and major part of Bay of Bengal had only small patches. Transition period (September-October) indicated a considerable decrease in the abundance of larvae towards the close of the Southwest monsoon period. The Northeast monsoon period (November-February) showed a fall in the fish larval population of Arabian Sea and Bay of Bengal compared to the Southwest monsoon period. The transition period (March-April) recorded more larvae in the Bay of Bengal compared to Arabian Sea.

The month-wise distribution studies in the Arabian Sea revealed great fluctuations in the distribution pattern showing maximum abundance in July and considerable fall in May and December months, whereas in the Bay of Bengal the maximum yield of larvae was in February and minimum in December. In general, the peak months of abundance were during the Southwest monsoon period in the Arabian Sea and Northeast monsoon period in the Bay of Bengal which got reduced to the minimum in the respective transitional periods that followed.

Analysis of the day and night catches of fish larvae indicated nocturnal abundance of more than double of that during day.

Areas of high abundance of larvae and their continuous occurrence over extensive periods observed in several cases could be looked upon as indication of spawning grounds and breeding seasons of several fishes. A good number of the offshore and oceanic fishes are continuous breeders with prolonged spawning season.

The distribution of engraulids indicates the presence of an exploitable resource of that group in the offshore waters. The resources of scombroids, particularly tunas, and certain other perciform fishes also are appreciable in the offshore and oceanic waters.

Frequency distribution of fish larvae revealed lower density of larvae having highest frequency of occurrence both in the Arabian Sea and Bay of Bengal.

The relationship between the number of fish larvae and the volume of the respective plankton sample in the Arabian Sea and Bay of Bengal was found to be very inconsistent. An inverse relationship could be noticed in certain cases.

The distribution and abundance of fish larvae in relation to environmental parameters such as salinity and temperature were analysed. Majority of the families of fish larvae occurred both in the Arabian Sea and Bay of Bengal, irrespective of the differences in the range of temperature and salinity.

The correlation coefficient matrix prepared for the 27 groups showed that their environmental requirements in the Bay of Bengal were more or less the same, while more number of groups in the Arabian Sea had different environmental requirements.

The coefficient of correlation calculated for the various groups from the Bay of Bengal with temperature and salinity showed that none of the groups was significantly correlated with salinity, whereas, *Vinciguerria*, Paralepididae and Myctophidae were significantly correlated with temperature. However, it was found that about 10 groups were significantly correlated either with temperature, salinity, or both in the Arabian Sea.

The regression model developed was found to be significant at 1% level ($P < 0.01$) showing that it was capable of explaining a significant part of the variability in the prediction of abundance of fish larvae for Bay of Bengal, the number being correlated with temperature and salinity. But the regression model developed for the Arabian Sea was found to be not significant even at 5% level ($P > 0.05$), showing that it was not capable of explaining a significant part of the variability in the prediction of abundance of fish larvae.

The variance of the "Fisher's diversity index" calculated for the abundance of fish larvae in 9 areas was found to be small indicating that the type of environment in the above areas were more or less of the same kind, but neither too old, nor new, severe nor unpredictable.

While Vinciguerria, Bregmacerotidae and Myctophidae were widely distributed in the Bay of Bengal, only Myctophidae had wide distribution in the Arabian Sea.

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