DISTRIBUTION OF LARVAL TUNA COLLECTED BY THE CARLSBERG FOUNDATION'S DANA EXPEDITION (1928-30) FROM THE INDIAN OCEAN

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Abstract

The geographical and seasonal distribution of larvae of five species of tuna (*Katsuwonus pelamis*, *Neothunnus macropterus*, *Euthynnus affinis affinis*, *Auxis thynnoides* and *Auxis thazard*) in the Indian Ocean based mainly on the collections made by the 1928-30 *Dana* Oceanographical Expedition are dealt with.

Larvae of skipjack and yellowfin constitute the bulk of the larval tuna catches. Larvae of these two species seem to have a wide range of distribution in the tropical and sub-tropical parts of the Indian Ocean though not with uniform abundance. Most of the larvae were obtained from an area west of 50°E longitude between 0° - 25° S latitude. They were found to be abundant in the surface layers of the sea and the maximum numbers were collected from areas of high temperature ranging from 26°C to 29°C.

REPARTITION DES LARVES DE THONS RECOLTEES DANS L'OCEAN INDIEN PAR L'EXPEDITION OCEANOGRAPHIQUE DU DANA, DE LA FONDATION CARLSBERG (1928-30)

Résumé

Le document traite de la repartition géographique et saisonnière dans l'océan Indien des larves de cinq espèces de thon (*Katsuwonus pelamis*, *Neothunnus macropterus*, *Euthynnus affinis affinis*, *Auxis thynnoides* et *Auxis thazard*) en se fondant principalement sur les resultats de l'Expédition océanographique du *Dana* (1928-1930).

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Le gros des récoltes de larves de thons porte sur les bonites à ventre rayé et les thons à nageoires jaunes. Les larves de ces deux espèces paraissent entre très largement reparties dans les zones tropicale et subtropicale de l'océan Indien, quoique leur abondance ne soit pas uniforme. La plupart des larves ont été prelevées dans une zone s'étendant à l'ouest du 50° de longitude Est, entre l'équateur et le 25e parallèle Sud. Elles se sont revelées entre abondantes dans les couches superficielles de la mer, les quantités maximales étant récoltees dans des zones de haute température (de 26 a 29° C).

DISTRIBUCION DE LAS LARVAS DE ATUN RECOGIDAS POR LA EXPEDICION DEL DANA DE LA CARLSBERG FOUNDATION (1928-30) EN EL OCEANO INDICO

Extracto

Trata de la distribución geografica y estacional de larvas de cinco especies de atunes (Katsuwonus pelamis, Neothunnus macropterus, Euthynnus affinis affinis, Auxis thynnoides y Auxis thazard) en el Océano Indico, a base principalmente de las colecciones obtenidas por la Expedicion Oceanográfica del Dana en 1928-30.

El grueso de las capturas de larvas de atunes lo constituyeron las de barrilete y atún de aleta amarilla. Las larvas de estas dos especies parece que tienen un amplio margen de distribución en los sectores tropicales y subtropicales del Oceano Indico, aunque su abundancia no es uniforme. La mayoria de las larvas se obtuvieron en una zona situada el oeste de los 50° de longitud E, entre los 0° y 25° de latitud. Se observó que abundaban mucho en las capas superficiales del mar y las cantidades máximas se recogieron en zonas de elevada temperatura, que oscilaba entre los 26°C y los 29°C.

1 INTRODUCTION

The Dana Expedition of 1928-30 round the world covered the Indian Ocean from August 1929 to January 1930. Out of the material collected, the larval scombroids from stations 3905 to 3975 were placed at the disposal of the senior author by the Carlsberg Foundation and this is dealt with in a preliminary way in this account, incorporating all existing information available on the subject for this region. Out of a total of 71 stations from longitude 88°05'5E and latitude 4°44'N between Nicobar and Ceylon to longitude 18°37'E and latitude 35°42'S off Cape of Good Hope, 62 stations contained tuna larvae, numbering in all 2183. Part of the Indian Ocean collections made by the Dana Expedition from the eastern sector south of the Sunda Archipelago as far as Cocos Keeling and Christmas Islands, from the Straits of Malacca and Singapore and stations east of longitude 90°E, along with collections from the Pacific and Atlantic Oceans were placed at the disposal of the Pacific Oceanic Fishery Investigations, now Bureau of Commercial Fisheries, Biological Laboratory, Honolulu, Hawaii. The larval *Euthynnus*, *Auxis*, *Parathunnus sibi*, *Thunnus germo*, *T. orientalis* and *Kishinoella tonggol* from the above have already been worked out by Matsumoto (1959 and 1961).

The phenomenal development of the tuna fisheries in the high seas in recent years has brought in its wake several investigational problems aimed at a proper appraisal of this potential resource and the work carried out in the Pacific (Schaefer and Marr 1948, Wade 1950 and 1951, Mead 1951, Matsumoto 1958, 1959 and 1961, Strasburg 1960) within the last 15 years has helped to advance appreciably our knowledge of the distinguishing characters of larval and juvenile stages of this important group of fishes and their pattern of distribution. Being oceanic fishes the tunas have very wide distribution and most of the species occurring in the Indo-Pacific are common to both the oceans. The information we have on the early stages of tunas in the Indian Ocean is limited to the contributions of Jones (1959, 1960a and 1960b), Jones and Kumaran (1962), Yabe and Ueyanagi (1961) and Bogorov and Rass (1961).

Identification of some of the larvae was rendered difficult as the collections examined were made over 30 years ago and as juveniles were scarce. The chromatophores in many had faded considerably and a number of specimens were either damaged or not in a good state of preservation. From the material available the authors have been able to distinguish larvae of five species of tunas - *Katsuwonus pelamis*, *Neothunnus macropterus*, *Euthynnus affinis affinis*, *Auxis thazard* and *Auxis thynnoides*. Since other species of tunas are also known to occur in the Indian Ocean, the possibility of the early larval stages of some others getting mixed up with the above cannot be entirely ruled out in spite of all efforts to avoid such a contingency. The present account deals with the geographical, seasonal and vertical distribution of tuna larvae in the Indian Ocean based on the information available so far.

2 GEOGRAPHICAL AND SEASONAL DISTRIBUTION

2.1 The oceanic skipjack *Katsuwonus pelamis* (Linnaeus)

1083 larval and postlarval stages of the oceanic skipjack *Katsuwonus pelamis* measuring in total length from 3.1 mm to 24.9 mm, forming almost 50 percent of the total tuna larvae were obtained between stations 3905 and 3975 during the cruise of the research ship Dana in the Indian Ocean. In Table 1 the localities of capture, surface temperature, size range of the specimens etc., are given. Areas of capture of larvae inclusive of all other previous records are plotted in Fig. 1. Seasonal occurrence of larvae is given in Table 7. It could be seen that most of the larvae were obtained during the months of December and January from the western Indian Ocean, whereas 40 larvae were obtained during November from the northern Indian Ocean. Considering the capture of larvae per hour of plankton haul, a fairly extensive area along the track of the Dana between the Seychelles and Durban seems to be an important spawning area of this species. The most southern record of occurrence of larvae is at station 3972 (36°09'S, 21°52'E). Even though skipjack larvae were obtained all along the course of the Dana in varying degrees of abundance, it is presumed that spawning of skipjack is intensive in the tropical and sub-tropical parts of the western Indian Ocean between 3°S - 30°S latitude.

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Table I
Details of collection of larvae of Katsuwonus pelamis

Dana stations (1)	Date (2)	Position (3)		Surface temperature (4)	No.of specimens (5)	Size range in mm (6)
3905	19-11-29	4° 44'N	88° 05.5'E	-	2	7.14-12.50
3906	20-11-29	4° 26.5'N	85° 21'E	28.8	9	4.85-7.36
3907	21-11-29	3° 59'N	82° 57'E	-	6	5.13-10.45
3908	22-11-29	4° 28'N	82° 13'E	-	8	4.85-6.74
3910	23-11-29	5° 28'N	80° 00'E	-	15	4.73-9.87
3913	1-12-29	6° 36'N	79° 08'E	-	6	4.79-12.56
3914	2-12-29	4° 52'N	77° 08'E	-	15	5.59-7.99
3915	3-12-29	3° 14'N	75° 21'E	29.3	22	5.08-7.42
3916	4-12-29	1° 45'N	73° 03'E	-	2	7.02-7.36
3917	5-12-29	1° 45'N	71° 05'E	28.8	18	3.99-8.45
3918	7-12-29	0° 35'N	66° 09'E	-	24	4.22-27.57
3919	8-12-29	0° 07'S	63° 56'E	-	10	4.45-12.33
3920	9-12-29	1° 06'S	62° 25'E	30.4	7	5.19-7.25
3921	11-12-29	3° 36'S	58° 19'E	-	35	4.91-9.42
3922	12-12-29	3° 45'S	56° 33'E	28.6	7	5.59-8.50
3925	16-12-29	7° 13'S	52° 22'E	28.2	1	6.68
3926	16-12-29	8° 27'S	50° 54'E	-	17	4.73-7.90
3927	17-12-29	10° 55'S	50° 15'E	-	1	damaged
3928	18-12-29	11° 20'S	50° 10'E	27.3	9	4.08-6.33
3929	18-12-29	12° 11'S	50° 18'E	-	1	6.22
3931	19-12-29	12° 09'S	49° 34'E	-	80	4.68-13.36
3932	20-12-29	11° 35'S	49° 45'E	-	1	6.28
3934	20-12-29	11° 24'S	50° 05'E	-	5	4.11-7.25
3936	22-12-29	10° 28'S	47° 30'E	-	2	damaged
3937	22-12-29	9° 26'S	46° 05'E	-	4	4.96-9.82
3938	23-12-29	9° 10'S	45° 17'E	27.9	5	5.31-5.93
3939	23-12-29	8° 44'S	43° 54'E	-	23	3.93-8.16
3940	24-12-29	8° 24'S	42° 54'E	-	2	5.3-7.76
3941	24-12-29	7° 24'S	41° 51'E	-	106	4.68-9.50

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Table I (contd.)

(1)	(2)	(3)		(4)	(5)	(6)
3942	25-12-29	6°47'S	41°27'E	28.2	7	6.62-10.10
3943	25-12-29	5°30'S	40°40'E	-	33	4.33-12.73
3944	26-12-29	4°45'S	40°10'E	-	9	5.02-7.19
3946	3-1-30	3°26'S	42°58'E	-	31	3.82-9.07
3948	6-1-30	10°45'S	41°57'E	27.5	7	6.62-16.78
3949	6-1-30	11°33'S	41°44'E	-	2	5.99 & 12.45
3950	7-1-30	12°23'S	41°43.5'E	-	10	4.85-8.05
3951	7-1-30	14°16'S	41°48'E	-	7	7.53-10.33
3953	8-1-30	16°12'S	42°04'E	27.9	40	3.71-7.88
3954	9-1-30	16°53'S	42°12'E	-	42	5.13-16.73
3955	9-1-30	18°30'S	42°18'E	-	19	3.14-7.86
3956	10-1-30	21°13'S	42°26'E	27.9	63	4.22-24.93
3957	11-1-30	21°30'S	42°32'E	-	27	4.39-10.62
3958	11-1-30	23°11'S	42°54'E	-	7	4.85-19.27
3959	12-1-30	23°40'S	42°54'E	26.6	116	3.65-15.58
3960	13-1-30	25°23'S	42°52'E	26.0	18	4.16-14.78
3961	14-1-30	24°57'S	40°18'E	-	36	4.73-9.87
3962	14-1-30	24°33'S	38°26'E	26.5	18	5.62-15.36
3963	15-1-30	24°30'S	37°48.5'E	-	1	9.02
3964	15-1-30	25°14'S	36°21'E	28.6	76	4.11-8.45
3965	17-1-30	28°18'S	33°49'E	26.3	12	5.08-6.73
3969	27-1-30	31°33'S	30°07'E	-	38	5.36-9.19
3970	28-1-30	34°07'S	27°38'E	24.0	4	9.02-11.47
3971	29-1-30	35°49'S	23°09'E	24.2	13	5.99-11.19
3972	30-1-30	36°09'S	21°52'E	23.4	2	damaged
3974	31-1-30	35°42'S	19°51'E	20.9	1	damaged
3975	31-1-30	35°42'S	18°37'E	21.0	1	damaged

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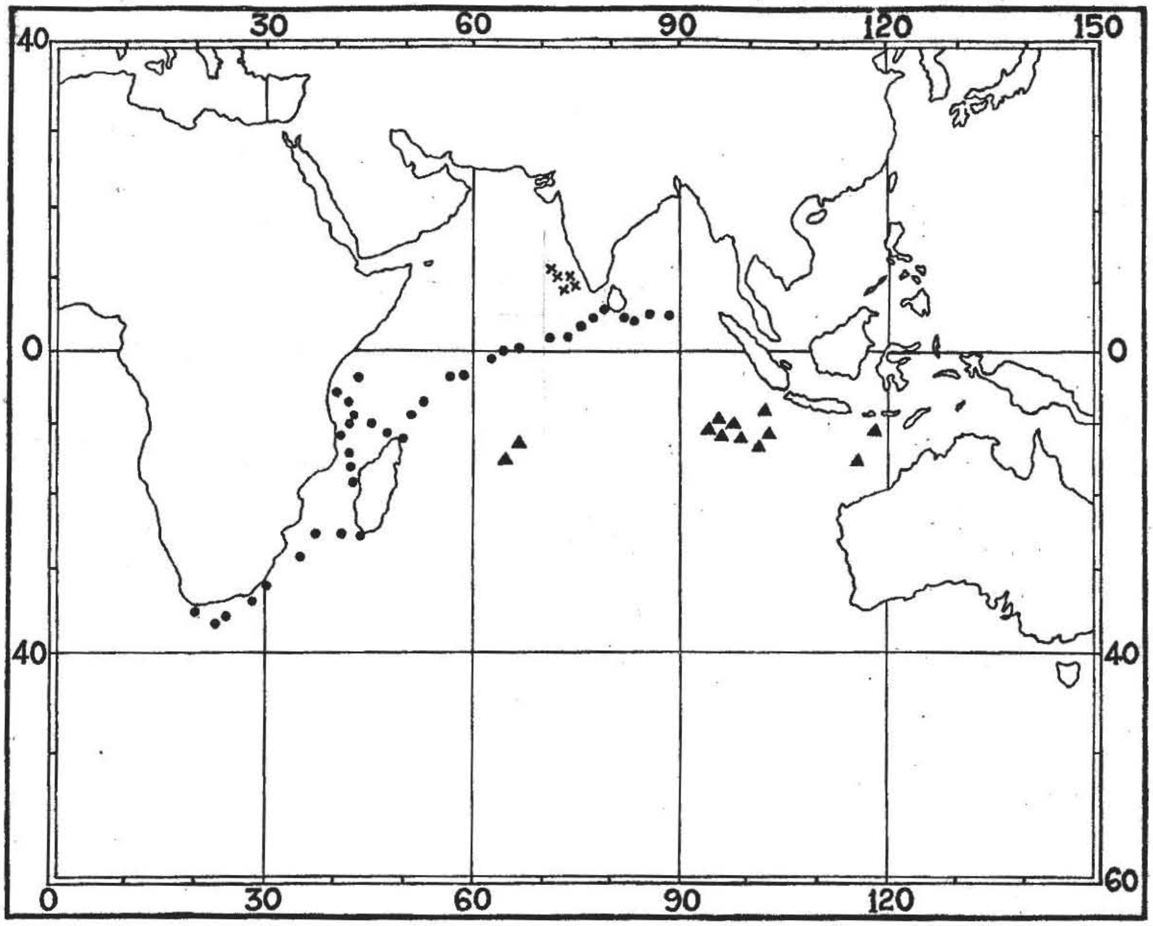

Fig. 1 Localities of capture of larval oceanic skipjack (Katsuwonus pelamis)

● Dana collection; X Indian collection;
▲ Japanese collection.

Larvae were collected from the eastern and central Indian Ocean during January-February and June-July (Yabe and Ueyanagi 1961). Most of these collections were made during February. It has been stated by Bogorov and Rass (1961) that the existence of numerous spawning schools of N. macropterus, K. pelamis and A. thazard is indicated by the presence of larval tunas in some parts of the Indian Ocean. The localities of capture of larval tunas as given by them are shown in Fig. 5. Larvae were collected from an area south of Sumatra and Java during October and from the central part of the Indian Ocean during November and December. Their total absence in the collections of the Vityaz from the western part of the Indian Ocean remains to be explained. During the months of December to April, 30 specimens ranging in length from 2.63 mm to 7.08 mm have been collected from the Laccadive Sea (Jones 1959). The period of occurrence of larvae is observed to correspond with the presence of adult with mature and spent ovaries in the Laccadive Sea. Skipjack landings in Minicoy usually show an increase during January and February. The most northern record of occurrence of skipjack larvae in the Indian Ocean is near Chetlat Island (11°70'N, 72°65'E) in the Laccadives (Jones 1959) during the month of April. It is evident from these observations that larvae are abundant during November to April between 0° - 12°N latitude and during November to February in the western Indian Ocean between 0° - 30° S latitude. The data available so far do not permit the authors to infer whether there is any difference in the spawning seasons between skipjack populations of the different parts of the Indian Ocean. According to Wade (1951) breeding of skipjack occurs throughout the year in Philippine waters, the peak spawning period being October to April. Capture of larvae was found to be high in the tropical and subtropical Pacific (Yabe and Ueyanagi, 1961) and this holds almost true for the condition prevailing in the western Indian Ocean. The possibility of occurrence of spawning in the tropical Indian Ocean throughout the year as in the Pacific cannot be ruled out as intensive collections have not been made from the area so far.

2.2 The yellowfin tuna Neothunnus macropterus (Temminck and Schlegel)

745 yellowfin larvae ranging in size from 3.4 mm to 19 mm were available for study. This comes to about 34 percent of the total catch of tuna larvae. In Table 2 the details of stations where larvae were captured are given. Larvae have been collected from mid-ocean and very near to land. From the northern Indian Ocean, 5 specimens were obtained in November. The maximum recorded (541 larvae) was from the western Indian Ocean west of 50°E, between 0° - 12°S. Of the above, 266 were obtained in a single haul from station No. 3941 (7°24'S, 41°51'E) situated south-east off Mombasa. Number of larvae in the collections gradually declined towards the south. Localities of capture of larvae are indicated in Fig. 2.

Spawning of yellowfin takes place during February to April in the Laccadive Sea as evidenced by the capture of 36 larvae from the area (Jones 1959). Yabe and Ueyanagi (1961) have shown the localities of collection of larvae from the Indian Ocean. It would appear from the above that there is a concentration of larvae in the low latitudinal areas of the eastern Indian Ocean east of 94°E between latitudes 8°S to 15°S but the months of capture of larvae have not been indicated by them.

Larvae were collected by the Vityaz (Bogorov and Rass 1961) from the eastern and northern Indian Ocean during October to January. It is supposed from the available data that spawning occurs in the tropical and subtropical parts of the Indian Ocean during October to April. Spawning of yellowfin was observed to take place throughout the year in the tropical Pacific (Yabe and Ueyanagi 1961). The fishery for Neothunnus macropterus in the northern and western parts of the Indian Ocean is high during the months of January to May. As mature fish are present in the area as evidenced by the length frequency data presented by Japanese workers (Mimura 1958, Tsuruta and Tsunoda 1960) it is presumed that some spawning occurs during the above period.

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Table II
Details of collection of larvae of *Neothunnus macropterus*

Dana stations (1)	Date (2)	Position (3)		Surface temperature (4)	No. of specimens (5)	Size range in mm (6)
3908	22-11-29	4° 28'N	82° 13'E	-	1	9.25
3910	23-11-29	5° 28'N	80° 00'E	-	3	5.53-5.59
3912	24-11-29	6° 52'N	79° 30'E	28.2	1	12.04
3914	2-12-29	4° 52'N	77° 08'E	-	36	5.59-7.42
3915	3-12-29	3° 14'N	75° 21'E	29.3	19	5.25-7.93
3916	4-12-29	1° 45'N	73° 03'E	-	3	5.94-7.93
3917	5-12-29	1° 45'N	71° 05'E	28.8	11	5.02-8.10
3918	7-12-29	0° 35'N	66° 09'E	-	1	5.08
3919	8-12-29	0° 07'S	63° 56'E	-	4	5.93-11.54
3921	11-12-29	3° 36'S	58° 19'E	-	8	4.33-7.93
3927	17-12-29	10° 55'S	50° 15'E	-	30	4.05-9.47
3928	18-12-29	11° 20'S	50° 10'E	27.3	13	4.62-8.05
3929	18-12-29	12° 11'S	50° 18'E	-	2	4.22-6.85
3932	20-12-29	11° 35'S	49° 45'E	-	2	6.45
3934	20-12-29	11° 24'S	50° 05'E	-	5	5.02-7.99
3935	21-12-29	10° 50'S	48° 30'E	-	2	6.91-8.22
3936	22-12-29	10° 28'S	47° 30'E	-	1	4.45
3937	22-12-29	9° 26'S	46° 05'E	-	1	7.48
3938	23-12-29	9° 10'S	45° 17'E	27.9	1	5.77
3939	23-12-29	8° 44'S	43° 54'E	-	29	4.91-8.62
3940	24-12-29	8° 24'S	42° 54'E	-	8	4.79-8.51
3941	24-12-29	7° 24'S	41° 51'E	-	266	3.94-10.50

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Table II (contd.)

(1)	(2)	(3)		(4)	(5)	(6)
3942	25-12-29	6°47'S	41° 27'E	28.2	14	4.45-8.73
3943	25-12-29	5°30'S	40° 40'E	-	47	5.53-9.71
3944	26-12-29	4°45'S	40° 10'E	-	40	5.31-19.01
3946	3-1-30	3°26'S	42° 58'E	26.7	12	5.48-8.96
3948	6-1-30	10°45'S	41° 57'E	27.5	4	4.39-8.10
3949	6-1-30	11° 33'S	41° 44'E	-	2	damaged
3950	7-1-30	12°23'S	41° 43.5'E	-	2	5.88-8.22
3951	7-1-30	14°16'S	41° 48'E	-	18	6.38-9.71
3953	8-1-30	16°12'S	42° 04'E	27.3	16	4.45-6.62
3954	9-1-30	16° 53'S	42° 12'E	-	25	4.11-10.85
3955	9-1-30	18° 30'S	42° 18'E	-	38	3.37-9.47
3956	10-1-30	21° 13'S	42° 26'E	27.9	42	5.12-9.31
3957	11-1-30	21° 30'S	42° 32'E	-	6	4.57-10.11
3959	12-1-30	23° 40'S	42° 54'E	26.6	6	6.16-10.39
3960	13-1-30	25° 23'S	42° 52'E	26.0	15	5.53-10.33
3962	14-1-30	24° 33'S	38° 26'E	26.5	1	6.28
3963	15-1-30	24° 30'S	37° 48.5'E	-	1	7.59
3964	15-1-30	25° 14'S	36° 21'E	28.6	9	5.13-10.89
3969	27-1-30	31° 33'S	30° 07'E	-	2	6.85-7.94

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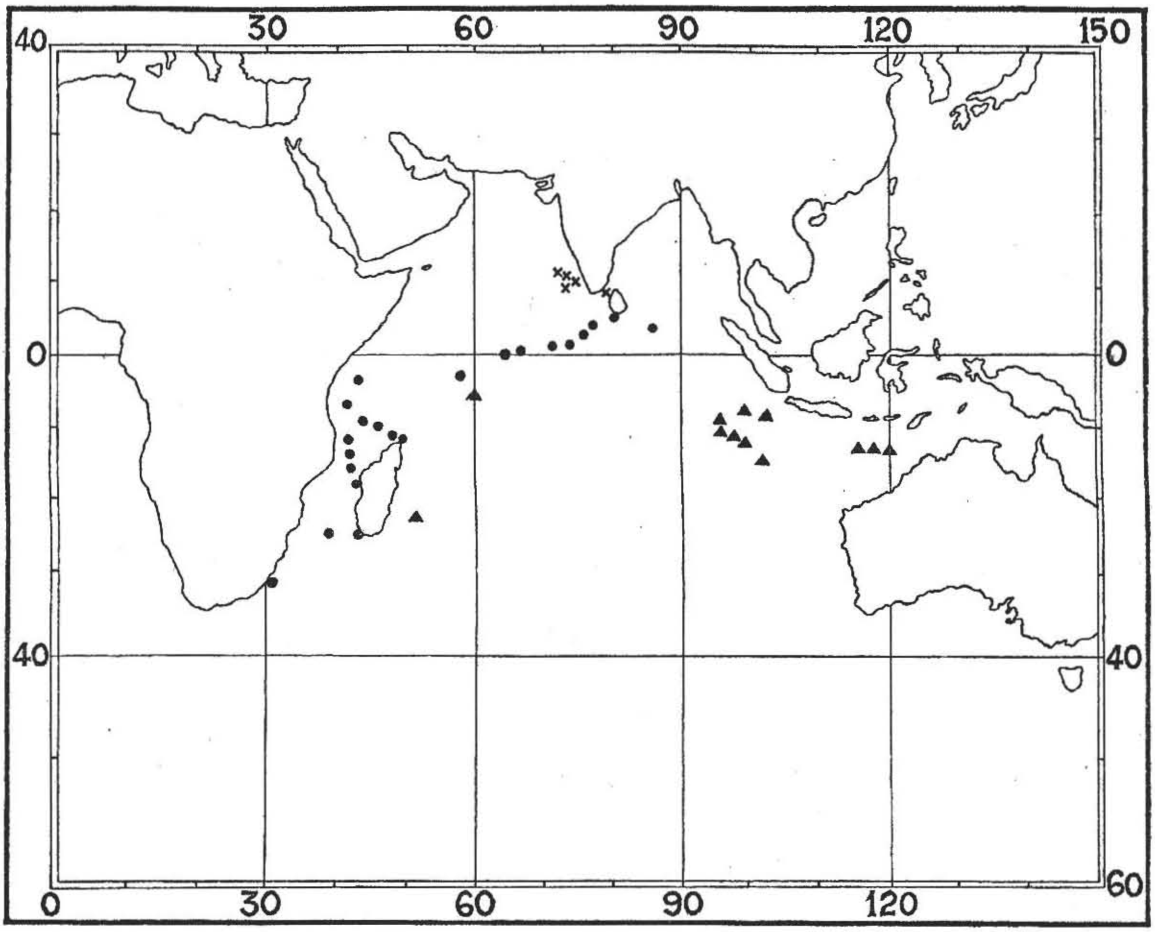

Fig. 2 Localities of capture of larval yellowfin (<u>Neothunnus</u> <u>macropterus</u>)

● Dana collection; X Indian collection;

▲ Japanese collection.

2.3 The little tunny Euthynnus affinis affinis (Cantor)

There are 179 larvae ranging in size from 4.6 mm to 12.7 mm supposed to be of this species in the collection. Details of localities of capture of larvae are given in Table III. In the northern Indian Ocean larvae of this species were rarely obtained during the time of the cruise but they were taken in good numbers in the western Indian Ocean between 3°S to 25°S latitude where some spawning appears to take place during December and January. Most of the specimens were collected in the vicinity of land. Even though the fishery for this species is restricted to coastal areas, a few larval specimens were obtained from offshore areas. Matsumoto (1959) has examined 61 larval specimens collected by the Dana from the eastern part of the Indian Ocean near Sunda Archipelago during August-October which he considers as of Euthynnus yaito. In Fig. 3 the localities of capture of Euthynnus larvae are indicated. In this connection it may be stated that the species of Euthynnus occurring in Indonesian waters is considered to be affinis, the type of which was described from Malaya by Cantor (1850). E. yaito of the Pacific may be a different geographical race of E. affinis and it is possible that the seas between Indonesia and the Philippines may be an area of mixing of the two races.

2.4 The long corseletted frigate mackerel Auxis thynnoides Bleeker

20 larval specimens tentatively identified as A. thynnoides ranging in size from 5 mm to 11.5 mm were obtained during December and January from three stations between the island of Madagascar and the African coast. The details of capture of larvae are given in Table IV and the localities of capture including all former records of Auxis larvae from the Indian Ocean are plotted in Fig. 4. Two types of Auxis larvae have been reported to be present in the collections made by the Dana from the eastern Indian Ocean southwest off Sunda Archipelago during August to November (Matsumoto 1959). According to Yabe and Ueyanagi (1961) spawning occurs during May to July near Japan and during January to February in the Celebes Sea and the south China Sea. Low latitudinal areas of the eastern Indian Ocean southwest off Sunda Archipelago and the western Indian Ocean between Madagascar and the mainland of Africa are assumed to be good spawning areas of A. thynnoides. However, the data presently available are too meagre to draw definite conclusions about the spawning of this species in the Indian Ocean.

2.5 The short corseletted frigate mackerel Auxis thazard (Lacépède)

There are 131 larvae of this species ranging in total length from 4.6 mm to 11.2 mm in the material examined by the authors. Table V gives details of stations where larvae were captured. One larva was obtained in December from the northern Indian Ocean the location being 4°52'N, 77°08'E. Almost all the specimens were obtained from an area west of 50°E between 3°S and 24°S during December and January. It appears that most of the Auxis larvae collected by the Dana from the eastern part of the Indian Ocean (Matsumoto 1959) belong to this species. For reasons given elsewhere (Jones 1962b) the larval Auxis obtained from the Laccadive Sea during January and April (Jones 1960b) belong to A. thazard. Bogorov and Rass (1961) have indicated the presence of spawning schools of A. thazard in the Indian Ocean. It is therefore reasonable to assume that the species has an extended spawning period in the Indian Ocean from August to April, but data are not available for the rest of the year.

It has been observed (Matsumoto 1959) that Auxis is a more "pelagic spawner" than Euthynnus as indicated by the capture of larvae from the central Pacific and Atlantic. This view is corroborated by the capture of larvae of A. thynnoides from the Indian Ocean relatively far from land.

2.6 Thunnus spp.

25 larvae presumably of Parathunnus sibi (P. mebachi), and Kishinoella tonggol were obtained from the western Indian Ocean. Table VI gives the details of collection of these larvae. Good catches of bigeye Parathunnus sibi have been reported from the western Indian Ocean (Nankai

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Table III
Details of collection of larvae of *Euthynnus affinis affinis*

Dana Stations (1)	Date (2)	Position (3)		Surface temperature (4)	No. of specimens (5)	Size range in mm (6)
3917	5-12-29	1°45'N	71°05'E	28.8	1	7.08
3918	7-12-29	0°35'N	66°09'E	-	1	damaged
3922	12-12-29	3°45'S	56°33'E	28.6	2	6.05-7.14
3924	14-12-29	5°01'S	54°46'E	-	1	5.94
3926	16-12-29	8°27'S	50°54'E	-	1	5.59
3930	19-12-29	11°55'S	49°55'E	-	2	4.7 damaged
3931	19-12-29	12°09'S	49°34'E	-	8	6.62-12.72
3938	23-12-29	9°10'S	45°17'E	27.9	1	6.58
3940	24-12-29	8°24'S	42°54'E	-	3	5.14-7.94
3941	24-12-29	7°24'S	41°51'E	-	56	4.68-8.73
3944	26-12-29	4°45'S	40°10'E	-	15	5.42-12.16
3946	3-1-30	3°26'S	42°58'E	26.7	34	4.74-8.69
3947	4-1-30	4°21'S	42°56'E	-	2	6.11 damaged
3951	7-1-30	14°16'S	41°48'E	-	3	6.79 damaged
3953	8-1-30	16°12'S	42°04'E	27.9	14	4.79-9.14
3955	9-1-30	18°30'S	42°18'E	-	1	damaged
3956	10-1-30	21°13'S	42°26'E	27.9	3	5.65-5.88
3958	11-1-30	23°11'S	42°54'E	-	2	7.08-8.39
3964	15-1-30	25°14'S	36°21'E	28.6	29	4.62-7.42

Table IV
Details of collection of larvae of Auxis thynnoides

Dana stations	Date	Position		Surface temperature	No. of speci-	Size range in mm
3940	24-12-29	8°24'S	42°54'E	-	1	damaged
3946	3-1-30	3°26'S	42°58'E	26.7	18	5.02-11.48
3955	9-1-30	18°30'S	42°18'E	-	1	8.28

Table V
Details of collection of larvae of Auxis thazard

Dana stations	Date	Position		Surface temperature	No. of specimens	Size range in mm
3914	2-12-29	4°52'N	77°08'E	-	1	5.65
3925	16-12-29	7°13'S	52°22'E	28.2	1	6.79
3931	19-12-29	12°09'S	49°34'E	-	15	5.42-11.23
3946	3-1-30	3°26'S	42°58'E	26.7	103	4.74-11.13
3947	4-1-30	4°21'S	42°56'E	-	1	7.76
3955	9-1-30	18°30'S	42°18'E	-	4	4.62-7.59
3958	11-1-30	23°11'S	42°54'E	-	2	6.11-8.39
3959	12-1-30	23°40'S	42°54'E	26.6	3	.8.85
3966	18-1-30	29°25'S	32°00'E	23.7	1	9.93

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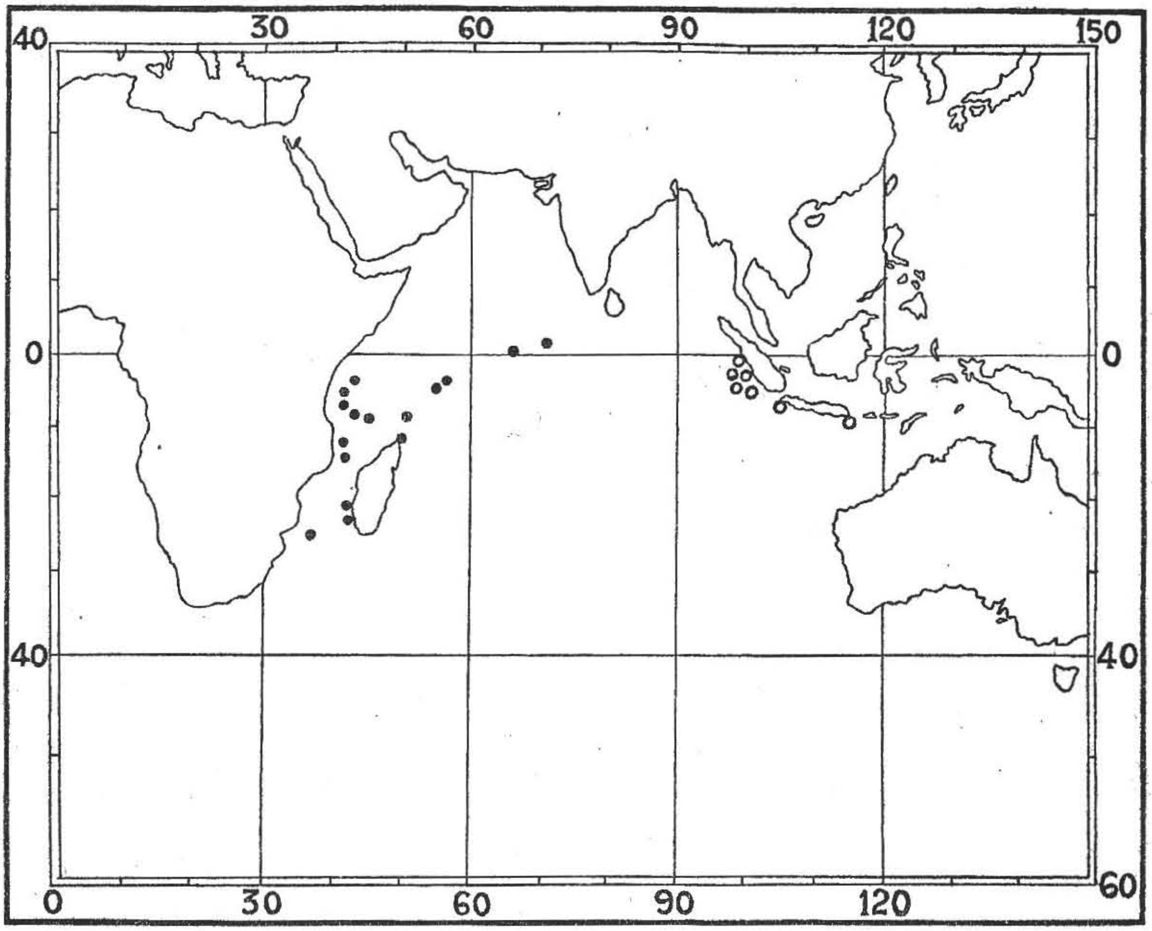

Fig. 3 Localities of capture of Euthynnus larvae by the Dana

● Euthynnus affinis affinis; ○ Euthynnus yaito.

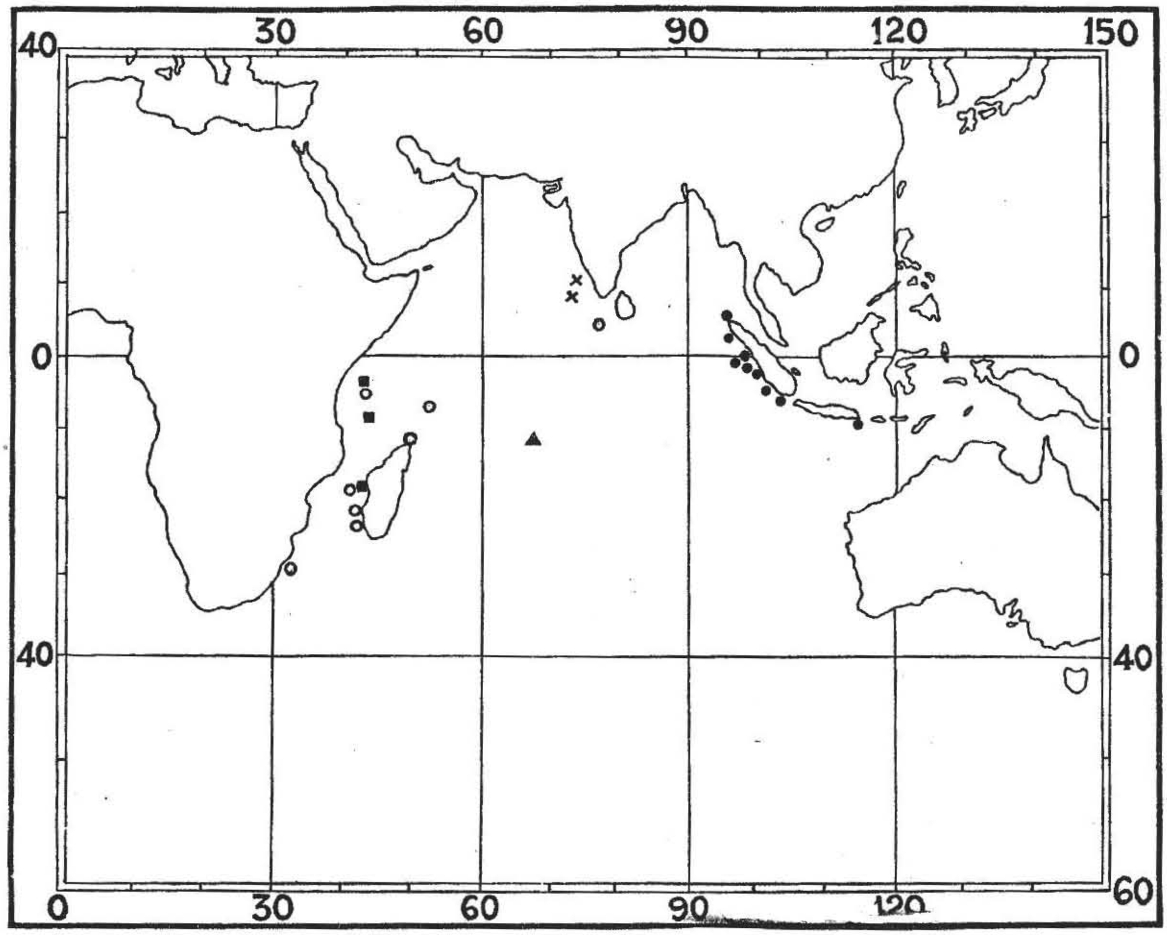

Fig. 4 Localities of capture of Auxis larvae

O Dana collection (A. thazard); X Indian collection (A. thazard); ■ Dana collection (A. thynnoides); ▲ Japanese collection (A. thynnoides); ● Dana collection (Auxis spp., after Matsumoto 1959).

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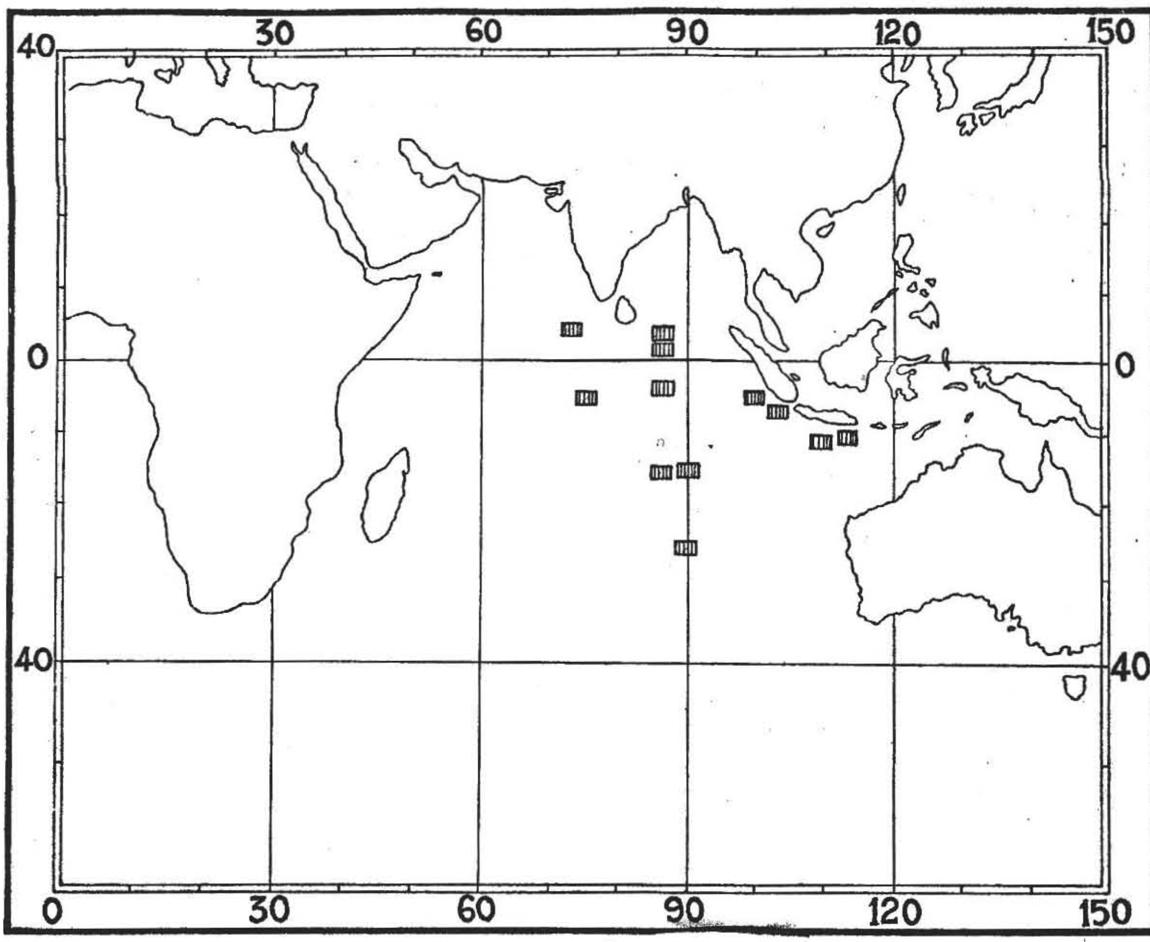

Fig. 5 Localities of capture of tuna larvae by the Vityaz (after Bogorov and Rass 1961)

Regional Fisheries Research Laboratory 1959).

3 VERTICAL DISTRIBUTION

The method adopted by Tåning (1955) has been followed here to find out the number of fishing hours and the depth of plankton tows. Number of fishing hours and the number of specimens obtained per hour of plankton haul at different depths are given in Table VIII 72 percent of the larvae were captured in nets operated in the upper 30 m and it was found that the percentage of capture of larvae decreases with depth. As open type nets were used, the actual percentage of capture of larvae from the surface layers must be higher than 72 percent as it is possible that an appreciable number of larvae found in nets operated in the lower layers were obtained while the nets were being raised. The percentage of capture of larvae per hour of haul from the lowest layer was insignificant. Matsumoto (1959) has shown that tuna larvae make a vertical, diurnal migration through relatively shallow depths and that most of the larvae occur near the surface both during day and night. According to Yabe and Ueyanagi (1961) tuna larvae occur rarely in the surface layer during the day but are distributed abundantly in the midlayer below 20 m and their distribution is more or less uniform in the upper 50 m layer during the night. Increase in larval catches with increase in depth in subsurface waters during the day was suggested to be mainly on account of the downward migration and to a limited extent on reduction in the amount of dodging with decrease in illumination (Strasburg 1960). It could be presumed that a comparatively higher percentage of larvae of Katsuwonus pelamis inhabits the lower layers (vide Table VIII).As almost all the collections were obtained during the night, the data for day and night hauls have not been analysed separately. However, percentage of capture of larvae was found to be less in the collections made in the early morning and just after sunset.

4 DISCUSSION

The information we have at present on the distribution of larval tunas in the Indian Ocean is too incomplete to warrant any conclusions. The specimens obtained by the Dana were only incidental in the course of the general plankton collections made during the expedition and collections by other agencies also do not give adequate coverage to the area in relation to space and time, though those by the Vityaz, the details of which are lacking, appear to be comparatively more intensive. However, certain indications which are evident from the available data are mentioned below.

It is obvious that environmental factors such as temperature, currents, salinity, nearness to land and availability of food may influence the nature of distribution, abundance and survival of larvae to a great extent. Surface water temperatures in areas where larvae were collected ranged from 20.9°C to 30.4°C. Percentage of capture of larvae at stations where temperature ranged from 26°C to 29°C was found to be high and so it is assumed that active spawning occurs in areas of fairly high temperature. These temperature ranges for larval tuna distribution in the Indian Ocean are in general agreement with the range 24.5°C to 29.0°C for the collection of Euthynnus larvae and the range of 22.5°C to 29.0°C for Auxis larvae given by Matsumoto (1959). In this connection the area west of longitude 50°E between 3°S to 20°S latitude deserves special mention. More larvae per haul were obtained from there than

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from anywhere else and a look at the temperature chart (Fig. 7) would show that this region has the highest temperature viz., 29°C to 29.5°C than any other area in the open Indian Ocean. The Mozambique Channel which is influenced considerably by the warm waters of the Agulhas Current flowing towards the south appears to be another area of abundance of tuna larvae. The western Indian Ocean as a whole has been reported to be rich in tuna by the Japanese. However, the absence of any tuna larvae in the *Vityaz* collections (Bogorov and Rass 1961) in this region requires explanation. Since the cruise of the *Vityaz* in that region was during March-April as against December-January by the *Dana* it is presumed that spawning is slack during this period in that area.

Probably the most important factor that influences the temperature and consequently the spawning activity of tuna and distribution of their larvae is the current system. The surface currents of the Indian Ocean (Fig. 6) are subjected to seasonal variations due to different winds. Most of the areas in the western part of the Indian Ocean where larvae were abundant are under the influence of the Equatorial Currents which flow in a westerly direction and bring about upwelling near the East African coast (Sverdrup *et al*, 1942) where primary production also is reported to be high (Kabanova 1961). It would therefore appear that the abundance of larvae west of 50°E longitude during December and January is due to the congregation of spawners in the warm water of this area. Currents should also play an important part in the dispersal of the larvae. According to Matsumoto (1958), spawning of tuna occurs in areas of north and south Equatorial Currents in the Pacific and the displacement of the early larvae caused by the flow of the currents is estimated to be about 2°.

Tunas are known to congregate in areas of high productivity. No detailed information is available at present about the zooplankton distribution in the area during different months of the year and as such no definite conclusions can be drawn with regard to the relation, if any, existing between the zooplankton abundance and occurrence of larvae.

Areas of very low salinity are generally avoided by tunas. Salinity variations in the open ocean are not marked (Fig. 8) and such slight variations do not seem to influence the distribution pattern of either the adults or the larvae.

It is natural to expect a relation between the abundance of larvae and that of the spawners. Larvae have been obtained from most of the areas where good catches of tuna have been reported by the Japanese (Nankai Regional Fisheries Research Laboratory 1959). However, the abundance of larvae in some of the areas where there is no regular fishing for tuna at present indicates that they could form potential tuna fishing grounds.

Table VI
Details of collection of unidentified tuna larvae

Dana station	Date	Position		Surface temperature	No. of speci-mens	Size range in mm
3922	12-12-29	3°45'S	56°33'E	28.6	12	6.28-8.11
3926	16-12-29	8°27'S	50°54'E	-	1	damaged
3928	18-12-29	11°20'S	50°10'E	27.3	1	6.17
3931	19-12-29	12°09'S	49°34'E	-	1	7.48
3937	22-12-29	9°26'S	46°05'E	-	2	4.85-4.91
3969	27-1-30	31°33'S	30°07'E	-	8	5.71-8.27

Table VII
Monthly distribution of tuna larvae (Dana)

	Month			Total
	November	December	January	
Katsuwonus pelamis	40	452	591	1083
Neothunnus macropterus	5	541	199	745
Euthynnus affinis affinis	-	91	88	179
Auxis thynnoides	-	1	19	20
Auxis thazard	-	17	114	131
Unidentified tuna larvae	-	17	8	25

Table VIII
Distribution of larval tunas according to depth of haul (*Dana* collections)

Depth of haul in metres	No. of fish-ing hours	*K. pelamis*		*N. macropterus*		*E. affinis affinis*		*A. thynnoides*	
		No. of speci-mens	No. per one hour of haul	No. of speci-mens	No. per one hour of haul	No. of speci-mens	No. per one hour of haul	No. of speci-mens	No. per one hour of haul
0-Ca. 20	38	323	8.5	219	5.8	41	1.1	5	0.1
Ca. 30	82	350	4.3	387	4.7	111	1.4	106	1.3
Ca. 50-70	62	261	4.2	70	1.1	13	0.2	15	0.2
Ca. 100-200	245	152	0.6	69	0.3	14	0.1	5	0.02

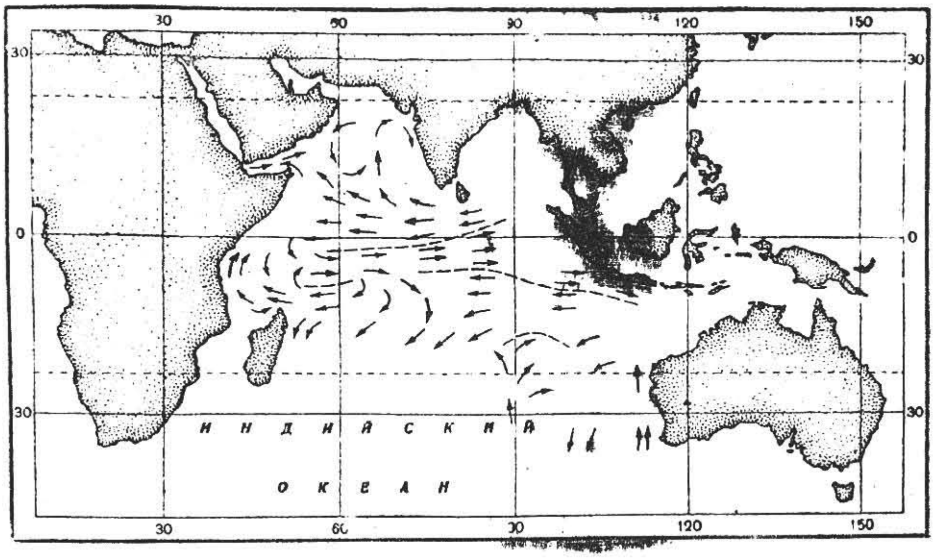

Fig. 6. Currents of the Indian Ocean at a depth of 15 m (reproduced from Ovchinnikov 1961)

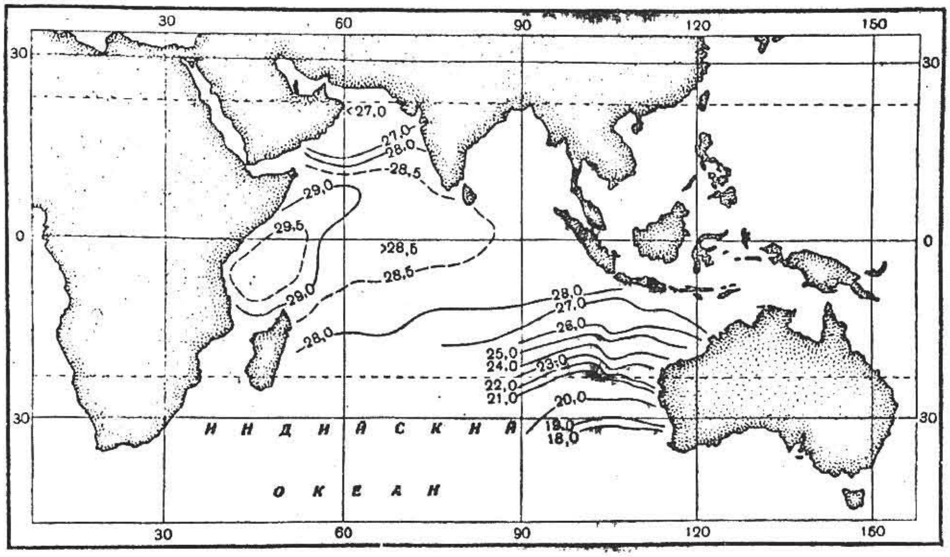

Fig. 7. Temperature distribution of water at the surface (reproduced from Lukyanov and Moiseyev 1961)

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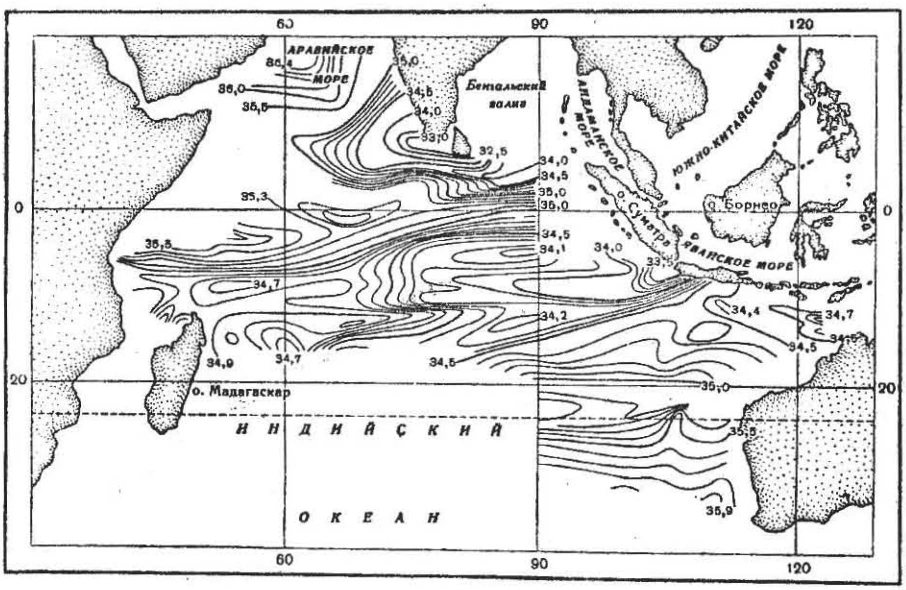

Fig. 8. Surface salinity of the Indian Ocean (reproduced from Ivanov-Frantzkevitch 1961)