IV. BIONOMICS AND LIFE HISTORY

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4. 1 REPRODUCTION

4. 1. 1 Sexuality

Mackerel is heterosexual and two instances of hermaphroditism were recorded one in a specimen caught from Majali, near Karwar (Prabhu & Antony Raja, 1959) and the other in a specimen obtained at Ullal, near Mangalore (Rao, 1962). In the first instance, the left gonad, situated slightly anterior to the right one, showed the characteristics of an ovary and contained yolky eggs ranging in size from 0.15 mm to 0.31mm mixed with a large number of transparent immature eggs. The right gonad had the characters of a normal testis. The genital ducts (oviduct and vas deference) emerging from them appear to open outside through a common aperture. The ovary was in stage III of maturity.

In the ullal specimen the right gonad was an ovo-testis, the testis portion being connected by connective tissue with the ovary portion. The left gonad was a complete ovary. Blood supply to the ovarian and testicular portions of the ovo-testis was common and the ova were in stage III of maturity. As the ovary portion of the ovo-testis was only slightly assymmetrical with the left ovary and as it was directly connected with the oviduct and blood vessels, it is presumed that the testis was an overgrowth on the ovary.

4. 1. 2 Maturity

Size and age at first maturity: Devanesan & John (1940) stated that mackerel attains maturity at about a length of 190 mm and Chidambaram & Venkataraman (1946) placed it at 200 mm. The minimum size at first maturity as determined by Pradhan (1956) is 224 mm. Radhakrishnan (1965) stated that the mackerel mature for the first time when they measure

210-220 mm in total length. Rao *et al.* (1965) have indicated that mackerel below 200 mm are immature. From the above observation it can be inferred that the mackerel spawn after the completion of the second year of their life (Pradhan, 1956 and Sekharan, 1958) or at the end of the first year (George & Banerji, 1968). It is possible to distinguish sex in fish of about 120 mm in length.

4. 1. 3 Spawning

Spawning season: Earlier workers who examined the maturity stages of mackerel from Calicut coast observed that spawning season of mackerel extends from June to September (Devanesan & John 1940 and Devanesan and Chidambaram, 1948). Chidambaram and Venkataraman (1946) advanced the commencement of the spawning season by one month, i.e. from June to May. Chidambaram *et.al.* (1952) noted the ripening of gonads in March-April and May and placed the spawning season from April to September. The observations of Bhimachar & George (1952) agreed with the above finding. Panikkar (1952) stated that the spawning period on the west coast corresponds with south west monsoon. According to Pradhan *(op. cit)* the spawning season of mackerel at Karwar extends from June to September. Subsequently, Radhakrishnan (1956) recorded mature and spent mackerel, also in November at this place. Sekharan *(op. cit)* examining specimens caught off South Kanara coast reported that the spawning starts in April itself, if not in March. Further north at Ratnagiri, there were indications of two spawnings, one in early May and another at the end of September or the beginning of October. The studies carried out at Mangalore showed that spawning takes place from March to October *(*Rao *et al., (op. cit).* The same authors indicated the possibility of mackerels spawning throughout the year with peaks at certain intervals. George, *et. al.* (1959) mentioned the probability of a longer or a subsidiary spawning season along the Mangalore coast. The occurrence of individuals in maturity stages of V and VI b in Cannanore as late as October and of partially spent or fully spent specimens at Calicut in the same month showed that the spawning season extends up to October along the Malabar coast (Quart. Sci. Repts. Of CMFRI for Dec. 1961 and for Dec. 1965). It is interesting to note that in 1966 mackerel in advanced stages of V and VI were noted at Calicut in March itself, ahead of the usual spawning period i.e. April-May (CMFRI Annual Rept., 1966). Rao (1964b), analysing the maturity stages and also distribution of young stages of mackerel as recorded by different workers, felt that on the west coast intensive spawning takes place during July-August followed by a supplementary spawning in November-December. He also observed that intermittent spawning in between the two periods is likely and the spawning may be a prolonged one extending from March to December. At Cochin, spawning seems to be from April to July as evidenced by the occurrence of advanced stages of IV to V (CMFRI Annual Repts., 1961, 1964, 1965).

On the South west coast of India, off Vizhinjam, investigations have led to the inference that mackerel spawn from about October till the end of February (Rao, 1965) and from earlier studies at the same centre it was indicated that the fish spawned during 1955 and 1956 from early March to July, (Balakrishnan, 1957). Bennet (1967), based on the occurrence of juveniles has mentioned the possibility of two main spawning seasons for mackerel at Vizhinjam one from March to May and another from August to September with a subsequent minor spawning season from December to January. He even envisages the possibility of the existence of two spawning stock drawn from west and east coasts of India. Observations made at Mandapam on the south east coast of India also indicated the possibility of two spawning periods, one during October-November and the other major spawning in May-June (CMFRI Annual Rept., 1957). Subsequent studies made at Mandapam showed that the maturation process starts much earlier by about second half of January itself and by March stages III, IV and V predominate. Some ripe specimens (stage VI) have also been recorded during this period. In April to November month in addition to fishes in above stages, spent and spent-recovering specimens have been found in the collections (CMFRI Annual Rept., 1967). At Porto Novo, the gonadial studies showed that the first spawning takes place in April or May (CMFRI Annual Rept., 1959).

In contrast to this, the occurrence of young mackerel off Madras in March-April months of 1953, 1954 and 1955 (Rao and Basheeruddin, 1953 and Basheeruddin and Nayar, 1961) indicated that the fish breed during or after the north east monsoon on the east coast. Investigations made on the maturity condition of mackerel caught in Lawson's Bay, off Waltair, showed that the spawning season commences by about October or November and lasts until April or May coinciding with the north east monsoon (Rao, 1964a). Sastry

(1969) recorded juveniles of Indian mackerel of size range 46 to 168 mm for the first time from Kakinada area on the east coast during March-May period. Rao (1964b)inferred that the intensive spawning period for this species on the east coast is from about October to December, with a second spawning period being likely in about April. In Port Blair (Andamans) the peak spawning season seems to be from November to January (CMFRI Annual Rept., 1964).

It could be seen that both on the west coast and east coast of India the spawning season is a prolonged one, extending from about March to October on the west coast and from about October to April on the east coast, with some variations in some areas. A supplementary spawning in November – December is indicated in some places on the west coast. In both the coasts, the intensive spawning season seems to coincide with the monsoon periods.

Spawning frequency: Pradhan (1956) observed that the Indian mackerel spawns in succession and only a small percentage of ova mature each time. Ova diameter studies carried out at Malpe (Sekharan, 1958) showed two peaks, one for the immature group and another for maturing group. Within the maturing group, eggs, both opaque and those in various stages of transparency were in different modal stages, thereby indicating that the eggs are ripened and released in batches. The author does not rule out the possibility of the other eggs undergoing degenerations, after the first batch is shed.

Subsequent investigations (Radhakrishnan,1965) made at Karwar and Porto Novo (Vijayaraghavan, 1965) confirmed the observations of Sekharan *(op. cit)* though some difference was noted in certain details by the latter author. In Karwar specimens, several minor modes were observed within the mature group of ova (measuring about 0.323 to 0.612mm) and there was also a group of ripe ova (0.629 to 0.749 mm). Since there was a well marked differentiation in the modes of the mature group, it is obvious that the eggs in this group would ripen in batches, as and when ripe ova would be shed. It has also been noted that the duration of sheding of ova extends over a long period (Fig. 3,4, and 5). Vijayaraghavan *(op. cit)* examining the mature group of ova under greater magnification found the existences of a series of distinct modes which made clear that the ripening group of ova would reach the final stages of maturity in well defined batches. He did not agree with the possibility that after the first batch of eggs is shed the others may undergo degeneration (as

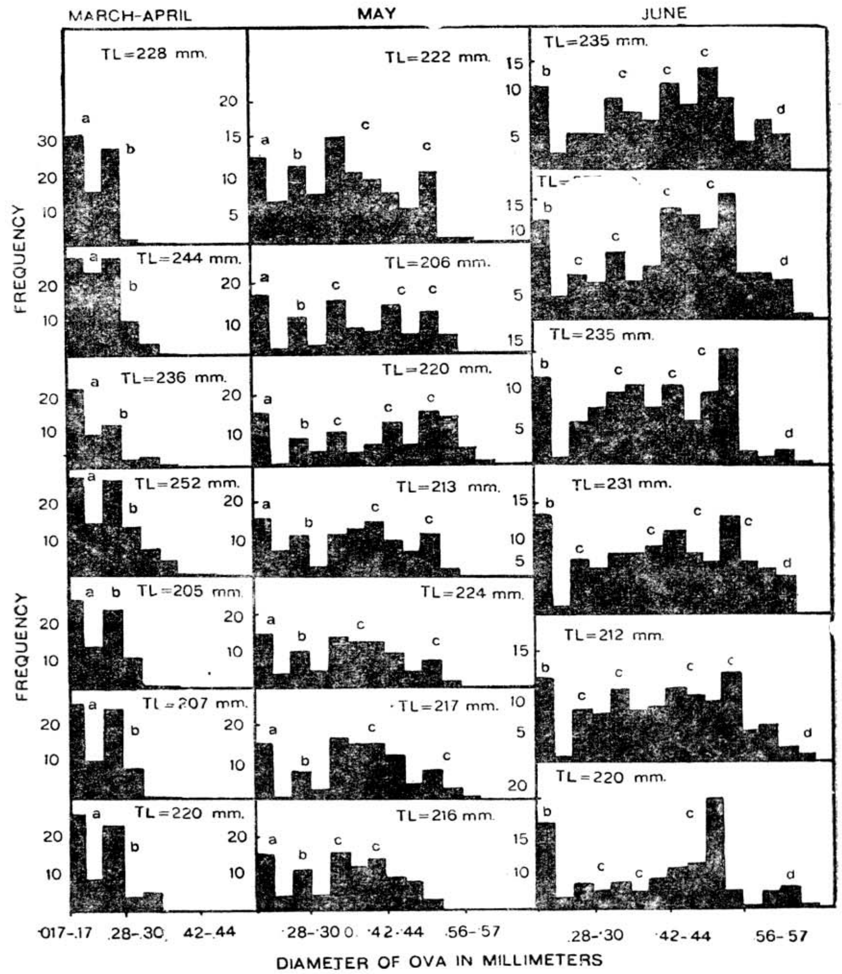

Fig. 3. Ova diameter frequency of ***Rastrelliger kanagurta*** during March-June at Karwar (Reproduced from Radhakrishnan, **1965**).

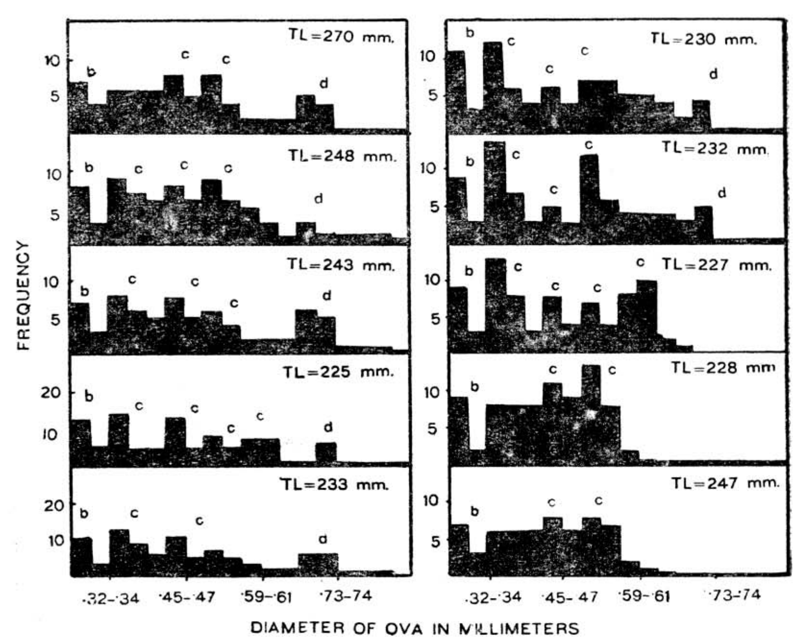

Fig. 4. Ova diameter frequency of ***Rastrelliger kanagurta*** during July at Karwar (Reproduced from Radhakrishnan, **1965**).

expressed by Sekharan, 1958). His conclusions were supported by the samples of fish obtained, representing almost a continuous gradation of ovaries ranging from fully ripe but unspawned to fully spent condition. Rao (1964a) concurred with the view expressed by the previous workers that the mackerel releases eggs in batches since he found that in the final stages of maturity the ova diameter frequency curves exhibit multiple modes. He also noted that mature ova are seggregated in two distinct group in the final stages of maturity thereby suggesting that individual fish may spawn probably twice in the spawning season. He further observed that as the proportion of the remaining mature ova, after the release of the first batch was very high, it was felt very unlikely that all of them would be reabsorbed, although some reabsorption of residual ova was observed.

Spawning time: Devanesan & John (1940) have stated that spawning takes place at nights. Vijayaraghavan (1965) examined over 3000 fish caught at Porto Novo in each season for a period of four years, but did not observe even a single fish with running ovary in the day catches. He got a few specimens with ova oozing out, only from the night catches, indicating the possibility of spawning being confined to night.

Spawning ground: Devanesan & John *(op. cit)* were of the opinion that mackerel recede from coastal waters during the south west monsoon period for the purpose of spawning. From the occasional occurrence of spent ones in the inshore catches they believed that the fish after spawning do not permanently retire to deep sea, but come back to coastal waters and that their spawning grounds are not very far from the coast. They mentioned Chaliyam, a place 5 miles off Calicut as a breeding place for mackerel as they collected what they believed to be mackerel eggs. The region between Vizhinjam and Cape Comorin off the south west coast of India appears to be a spawning ground, as spawners, young mackerel and post-larvae have been obtained in this region. But the spawning seems to take place outside the present fishing limits beyond 3 miles from the shore (Balakrishnan, 1957).

Table I

Key to the stages of sexual maturity of the female Indian mackerel (*Rastrelliger kanagurta*)

Extent of ovary in the body cavity	Range of ova (mm)	State of maturity	Maturity stage
Ovary less than half the length of the body cavity	0.038-0.13 0.14-0.27	Immature	I
Ovary slightly more than half the length of the body cavity	0.28-0.37	Maturing	II
Ovary extending to about 2/3 the length of the body cavity	0.37-0.46	Maturing	III
Ovary extending a little over 2/3 the length of the body cavity	0.46-0.56	Maturing	IV
Ovary extending over the entire length of body cavity	0.57-0.81	Mature	V
Ovary extending over the entire length of body cavity	0.57-0.81 0.57-0.81	Mature Mature	VI (a) VI (b)
Shrunken ovary about ½ the length of abdominal cavity	..	Spent	VII

(After Jones and Rosa, 1965)

Table II

Key to the stages of sexual maturity of the male Indian mackerel (*Rastrelliger kanagurta*)

Extent of testes in the body cavity	State of maturity	Maturity stage
Testes less than half the length of the body cavity	Immature	I
Tests slightly more than half the length of the body cavity	Maturing	II
Testes extending to about 2/3 the Length of the body cavity	Maturing	III
Testes more than 2/3 the length of the body cavity	Maturing	IV
Testes extending over the entire length of the body cavity	Mature	V
Testes extending over the entire length of the body cavity	Mature	VI
Testes comparatively much reduced in size	Spent	VII

(After Jones and Rosa, 1965)

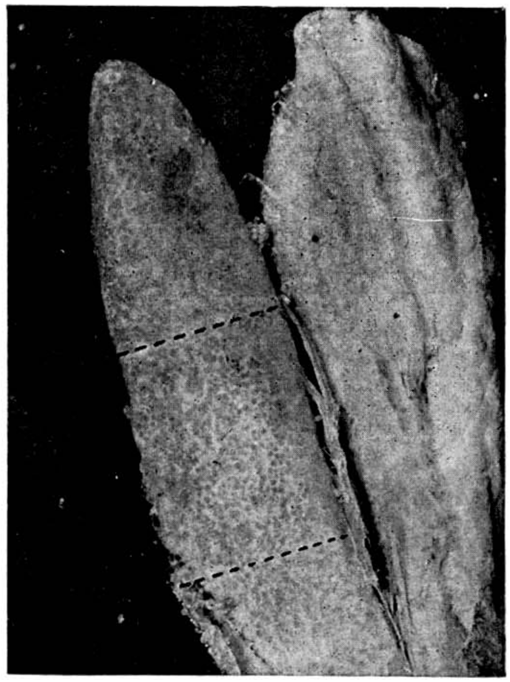

Plate I a. Ovary of mackerel in stages V-VI.

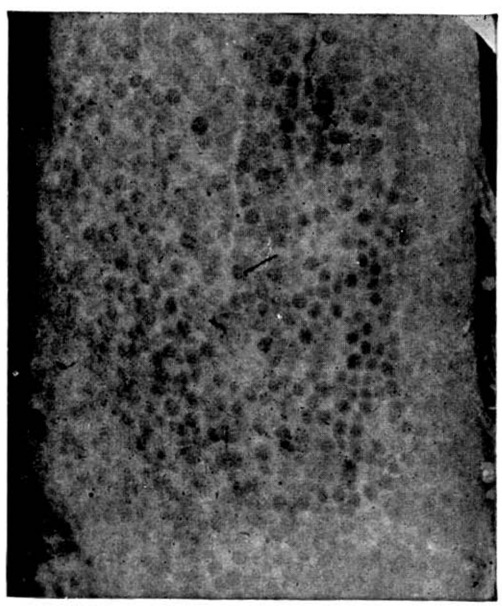

Plate I b. Magnified view of the portion between the dotted lines in Plate I a.

4. 1. 4 Fecundity

The only record of the fecundity estimation in mackerel is by Devanesan & John (1940) who have estimated an average of 94,000 eggs in mackerel.

The maturity key as recommended by the International Council for the Exploration of the Sea in the Herring (Wood, 1930) is followed by the workers of C.M.F.R.I. with modifications as given by Pradhan and Palekar (1956) who subdivided stage VI into stage VI (a) and VI (b)which are described as plum-pudding stage, the ovary having a speckled appearance due to the peculiar mode of the ripening of ova batches (Plate I a & b). The keys prepared by them for male and female mackerel are given in Table I and II respectively.

4. 1. 5 Egg structure

The diameter of the plankton eggs collected by Devanesan and John *(op. cit.)* varied from 0.54 mm to 0.70 mm. They thought these eggs belonged to that of Indian mackerel as they occurred in place where ripe mackerel shoaled and the planktonic egg closely resembled in size and character those obtained from a spawning mackerel. However they agreed that conclusive proof can be had only when spawning fish are obtained and artificial fertilization is carried out.

The range of ova diameters in different stages described by Pradhan and Palekar *(op. cit.)* is as follows; 0.38 to 0.27 immature, 0.28 to 0.56 maturing 0.57 to 0.81 mature. The highly advanced ova are transparent measuring 0.88 to 0.90 mm usually with a large oil globule whose diameter is 0.23 mm. Balakrishnan (1957) found the ova from mature fish measuring 0.6 mm to 0.84 mm and the planktonic eggs, tentatively assigned to mackerel, measuring from 0.84 to 1.009 mm. Vijayaraghavan (1965) studying modal distribution of ova in twenty fishes found them showing three prominent modes "the immature ova measuring less than 0.160 mm, another around 0.288 mm which were maturing and a third around 0.672 mm representing the mature ones…" Radhakrishnan (1965) classified the ova into four categories, immature, maturing, mature and ripe the respective diameter ranges being 0.017 to 0.170 mm, 0.255 to 0.272 mm 0.323 to 0.612 mm and 0.629 to 0.749 mm. The maximum size of the intraovarian egg recorded by him is 0.935 mm: the fully transparent ovum has a single large oil globule measuring 0.20 to 0.25 mm.

4. 2 AGE AND GROWTH

4. 2. 1 Age

Only in the recent past, efforts have been made to determine the age of mackerel based on length frequency analyses (Pradhan, 1956; Sekharan 1958; Balakrishnan, 1962 and George and Banerji, 1968). An attempt has been made to interpret the significance of rings observed in mackerel scales (Seshappa, 1958).

Pradhan (*op.cit.*) after anlysing length frequency data of mackerel from Karwar during the years 1948-49 to 1952-53 came to certain conclusions on the age of mackerel. The pattern of occurrence of different size groups in different months is as follows. In July-September period juveniles of size range 6 to 11 cm are occasionally caught. In the first half of September, a slightly large group of 12 to 16 cm occurs in the fishery. This group is succeded in October by a still larger size group of 18 to 20 cm which usually constitutes the mainstay of commercial fishery. Higher size groups of 21 to 22 cm are met with during February to March. Mackerel in the maximum size range of 22 to 25 cm are caught during the spawning season i.e. from June to September. The cycle is repeated from the commencement of the next mackerel season.

Pradhan (*op. cit.*) believe that the juveniles mackerel of size 6 to 11 cm encountered in July-September period presumably are the off spring of fish which have spawned in the previous fishing season. The average length of this fish which is a year old is about 10 cm. These juveniles do not contribute to the fishery in the succeeding months but leave the inshore waters. This fish grows to about 14 to 16 cm by about April and it enters the fishery in the following season when it reaches a length of 18 cm or more. At the time it enters the fishery it is about two year old. The 12 to 16 cm size group commonly observed in the first half of September is presumably more than one year old and it attains a size of about 22 cm or above in the next spawning season when it matures and spawns. From the above observations, it is deduced that the rate of growth of Indian mackerel is slow and it attains a length of 10 cm in one year and at the time of its entry into the fishery in October it completes its second year, the length being 18 cm or more.

Sekharan (1958) analysed the length data on mackerel collected by him at Malpe for two seasons 1954-55 and 1955-56 and also examined the data on length frequency of mackerel for the period from 1934-35 to 1940-41 from the West Hill area published by the Madras Fisheries Department. The data at Malpe showed that the fishery drew its support mainly from single age group consisting of 180 mm: 190 mm and 210 mm groups. From the analysis of West Hill Data, Sekharan *(op.cit.)* inferred the rate of growth and average size of mackerel at different ages by tracing the progression of monthly modes. The data showed that usually in the month of July juveniles having a modal range of 12 to 14 cm occurred in the fishery. In August-October period they also fluctuated between 16 and 20 cm. In some years, 19 cm groups was seen in the fishery during the same period and in August 1940, there was a modal group at 17 cm. Sekharan *(op. cit.)* considered that all these groups, when they form the mainstay of the catches, belong to roughly the same age class (in the second year of their life). He considers the juveniles of size 12 to 15 cm occurring in July as having completed just one year of their life. He traced these one year old groups through one fishing season till next May-July period by which time they attained a size of 21-23 cm and completed the second year. Thus, according to this author *(op. cit.)* mackerel reaches a size of 12 to 15 cm at the end of the first year of its life and 21 to 23 cm at the end of the second year of its life. He is unable to arrive at the total life span of the fish, as mackerel measuring above 25 cm are scarce in the commercial catches.

Seshappa (1958 and 1970) observed growth rings in the scales of mackerel measuring over 22 cm, and inferred that the rings are likely to be spawning marks. The first ring is found in specimens measuring over 22 cm at which size the first spawning also takes place. In 25-27 cm group, two growth ring are noticed and in still larger specimens indications up to 4 rings are seen. Analysing all the data together, Seshappa *(op. cit.)* considers that the west coast mackerel attains a length of 12 to 16 cm at the end of the first year of its life and 21-24 cm at the end of the second year. The length reached by the end of the third and fourth year of life is about 25-27 cm and 28-29 cm respectively. At the end of five years, it is around 30 cm in length.

Balakrishnan (1962)- as quoted by George and Banerji (1968) based on his studies of mackerel at Vizhinjam during 1955-57, is of the view that the fish measuring 14 cm may be one year old and those in the size groups of 19 to 21 cm may have completed 2 years of life. The specimens (23 cm and above) would have completed 3 years and they may comprise more than one age group.

George and Banerji *(op. cit)* made a study of the length frequency data on mackerel collected at Cochin for 7 seasons from 1957-58 to 1963-64 and also reanalysed the length data published by Pradhan (1956) and Sekharan (1958). They, after finding out the modes in different months for all the seven seasons, calculated the average size of mackerel in successive months from the time of their first appearance in the fishery and traced the same from month to month relating it to its age. Starting from a size of 9.5 cm when it is two months old, the fish grows to a size of 21.6 cm at the end of 12 months. Thereafter the growth slows down considerably. Similar analysis of modes at Karwar and Calicut and the pooled average size data at different ages for all the three places, showed similar growth pattern. A growth estimation made by applying Bertalanffy equation showed satisfactory agreement with observed values. Estimation of age of older fish becomes difficult, due to drastic retardation in growth and consequent overlap of size and age class occurring in them.

The conclusions of George and Banerji *(op. cit)* may be briefly summarised as follows. The Indian mackerel according to them attains a size of about 22 cm at the end of the first year of its life and probably 24 cm at the end of the second year. The commercial fishery mainly comprises of sizes 18 to 22 cm which are in the 0 year or just completing the first year of its life. The success of the fishery depends upon the strength of a single year class i.e. 0 year class which is subject to considerable fluctuations from year to year. The strength of the 0 year class in turn depends upon the survival rate of the young and the environmental factors influencing its immigrations into the fishing zones.

4. 2. 2 Rate of growth

Prdhan (1956) observed a progressive growth in the length of mackerel from the fishing season (October to March) to the spawning season (June to September). The average length during the season fluctuates by 2 or 3 which shows the growth in length during the season. An increase of 1 to 2 cm is noted in the succeeding months of August. Sekharan (1958) also noted well-marked periodicity in the rate of growth of the year classes in the commercial age group. He found that the growth is most rapid during July-September period (3-7 cm) after which it declines in October-December (2-3 cm), the minimum begins in January-June (1 cm). From an analysis of the Length frequency data on mackerel collected from Lawson's Bay, Waltair, Rao (1964a) deduced that the juvenile mackerel grows very rapidly, probably at the rate of 2 to 3 cm per month and the lengths 5-6 cm and 15-16 cm most likely represent about 2 months and 7 to 8 months' growth respectively. Balakrishnan (1962) observed that mackerel grow fast at the rate of more than I cm a month during the first year. Radhakrishnan (1967) estimates that the "monthly growth rate of a brood immediately after it enters the fishery is about 20 mm or more".

4. 2. 3 Age groups and broods

Investigations carried out on the mackerel fishery of the Mandapam area showed (Sekharan, 1965) that the fishery appears to be supported by a single age –group whose modal size varied from 227 to 242 mm during the December-March periods of 1952-56. These modal size are larger than those occurring at Malpe and Karwar during the December-March period. At Mangalore the catches appear to be supported by fish in the second year of their life (Rao *et. al.,* 1965). Radhakrishnan *(op. cit.)* based on the length frequency analysis of mackerel caught off Karwar opines that mackerel of size 115 to 155 mm, enxountered in the fishery, "are obviously the products of the current years spawning' and believes "that the fishery of Indian mackerel is largely dependent on 0 and 1 year class individuals". At Vizhinjam, 0 to 2 year groups occurred in the commercial catches during 1960-63, the minimum and maximum size being 3.5 cm and 28.0 cm. Of these, the 0 year group dominated in the landings (Bennet, 1967).

Length frequency studies carried out at Mangalore (Rao *et. al., op. cit)* suggested the possibility of more than one brood in a year occurring in the fishery, although all broods may not be equally successful or contribute to the catches of a particular area.

Rao (1964b) studies the distribution of the young stages of mackerel and by tracing back the modal values of mackerel population in different months from the very older groups to the younger ones on record, indicated that on the west coast of India two distinct groups of young ones, being the offsprings of spawners that spawned in July-August and November-December respectively, enter the inshore waters in diffeent periods of a year.

It could be soon that there is no agreement among the workers as regards the age of the fish. They have dawn their conclusions based on length frequency analyses. There are missing links in the progression of modes, specially in earlier stages which some workers have tried to fill up on a hypothetical basis based on the rate of growth observed in the previous years for the same periods. The tracing of the progression of modes, from month to month, is rendered difficult especially in earlier stages due to the prolonged spawning season and consequent recruitment of different broods in the fishery. Corroborative evidence in the form of growth checks in otoliths, scales etc. which can be related to age is lacking. The recoveries from the tagging experiments have been very few and do not give any indication of the age and growth of the fish. Direct evidence based on growth checks on scales and in the hard parts, tag recoveries and laboratory experiments on the growth rates of larval, post-larval and juveniles fish is required before a consensus on the age of the fish can be arrived.

4. 2. 4 Longevity

Pradhan (1956) believes that at the time the fish enters the fishery in October (about 18 cm in size), it has completed its second year of life. Sekharan (1958) envisages the possibility of other age groups besides the one and two year olds in the population though he is unable to arrive at the total life-span of the fish. Rao *et al.* (1956) state the effective life-span of mackerel is about 4.91 years. The calculated age lengths at age I, II, III and IV years are 150.7, 225.3, 266.2 and 288.9 mm respectively. George and Banerji (1968) say that this fish attains 216 mm at the end of the first year of its life and 240 mm at the end of second year, beyond which they are not in a position to determine the age of the fish. Seshappa (1970) estimates that the life span of this species may well be over 6 to 7 years.

4. 2. 5 Greatest size

The largest size recorded from Vizhinjam was 320 mm. (Rao, 1965).

4. 3 FEEDING

A number of contributions on the food of mackerel has appeared and it has been possible to get a broad idea of its food and feeding pattern both on the east and west coasts of India. Studies made on the west coast have shown it to be mainly a plankton feeder feeding both on phyto-and zooplanktonic organisms, comprising mainly of diatoms, dinoflagellates, copepods, cladocerans, larval and adult decapods. Some of the other food elements met with in the stomach contents were gastropod and bivalve larvae, polychaete larvae, cirripede nauplii, appendicularians, cypris larvae, mysids and fish eggs and larvae (Bhimachar & George, 1952; Pradhan, 1956; Venkataraman, 1961;Noble, 1965). Observations made on the east coast also showed it to be a plankton feeder, feeding both on phyto-and zooplanktonic elements (Chacko, 1949; Rao, 1964a). The variations in the occurrence of different planktonic elements from season to season, were correspondingly noticed in the stomach contents also. However, there is disagreement among the workers regarding the quantitative occurrence of various planktonic organisnms in the stomach contents. While Bhimachar and George *(op. cit)* noted that the planktonic forms occurred in the stomachs of mackerel of Calicut coast in proportion to their availability in the plankton, it was observed at Karwar "that the order of abundance of various planktonic organisms is not always the same in corresponding analyses" of plankton (Pradhan, *op cit).* But subsequent investigations carried out at the same centre showed that the "quanity and quality of the food of mackerel vary with the variations in planktonic elements in the inshore area" (Noble, *op. cit).*

An examination of the stomachs of mackerel obtained by drift nets in the relatively deeper waters (33-46m) off Vizingam in south Kerala (Rao, 1965) revealed the presence of pelagic tunicates, *Pegea confooderata, Rittteriella amboinensis* and *Thalia democratica* which abound in the open sea from where the fish were caught (Fig. 6). They have rarely been seen as part of the food of mackerel from inshore area and their presence, in the stomachs, show that "the food consumed by the fish living in different waters vary to a certain degree depending upon the exigencies of the environment" as was observed in the European mackerel, *Scomber scombrus* (Allen, 1897; Bullen, 1908 and Steven, 1949).

Although mackerel feeds on a large variety of organisms, a certain amount of selectivity in feeding has been noticed. The dinoflagellate, *Noctiluca* is almost totally avoided by this fish, even though it may be present in the plankton in abundant numbers. Bhimachar and George (1952) differentiated the plankton of the Calicut coast into edible and non edible parts, and the latter part comprising of arrow worm *Sagitta*, salps, medusae, ctenophores, spionid and stomatopod larvae, though common in confirmed by workers in other centres also (Pradhan, 1956; Rao and Rao, 1957 and Noble, 1965).Mackerel is primarilly a filter feeder. However the presence of macro planktonic organisms are taken in by visual selection (Kutty 1965). Such visual feeding has been observed in *Scomber scombrus* also (Bullen, 1912; Steven, 1949).

There is a large measure of agreement among the workers on the food of the adults. But, different views have been expressed on the variations between the food of juveniles and adults. Bhimachar and George (*op. cit)* and Pradhan *(op. cit)* have observed no appreciable difference between the food constituents of the young and the adult. George and Annigeri (1960) after examining a large sample of mackerel below 100 mm from Ratnagiri coast have found that the food of the young mackerel comprised of the same items as seen in adults and believed that the feeding pattern of the young mackerel was not different from that of adults. A reexamination of young mackerel collected from the Madras coast by Rao and Basheeruddin (1953) lead George (1964) to the same conclusion. Sastry (1969) observed the juvenile mackerel at Kakinada to be predominantly a plankton feeder as noticed in the adults.

However, different findings have been recorded by other workers. The food of the juveniles of size 3.2 to 8.9 cm obtained from Waltair on the east coast was found to consist “mostly of fish larvae and *Lucifer* sp. indicating their preference to this diet”. But in contrast, the food of the adults (9 cm and above) comprised of mostly copepods, diatoms, dinophysids and larval decapods and stomatopods, there being no trace of fish in the stomach contents (Rao and Rao, 1957 Rao, 1964a). Chidambaram (1944) and Devanesan and Chidambaram (1948) recorded white baits in the

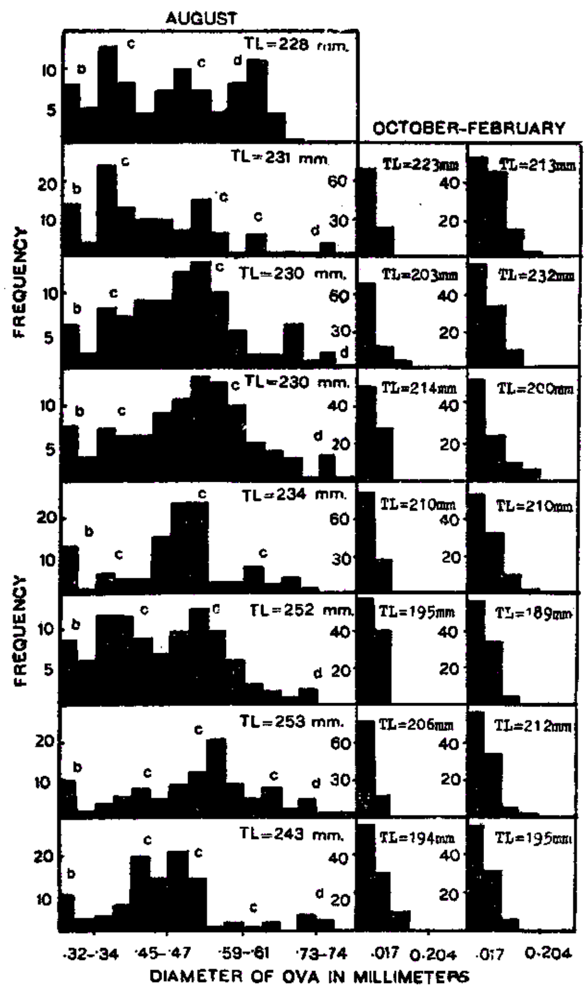

Fig. 5. Ova diameter frequency of ***Rastrelliger kanagurta*** during August and October-February months at Karwar (Reproduced from Radhakrishnan, 1965).

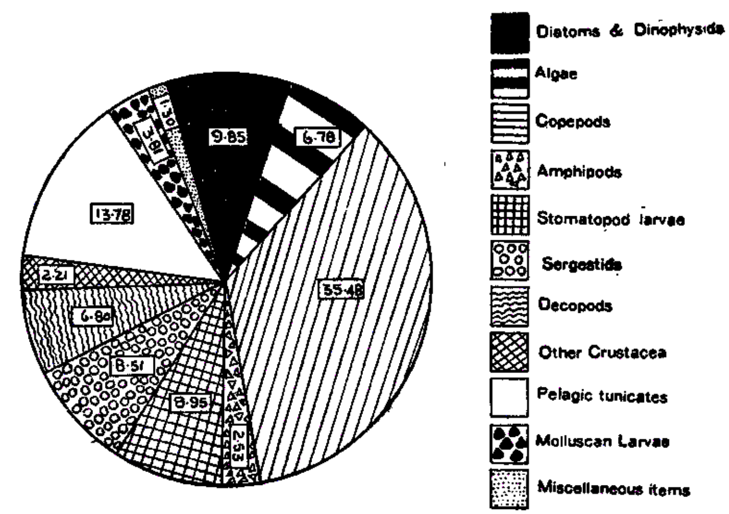

Fig. 6. Food composition of mackerel, ***Rastrelliger kanagurta*** at Vizhingam in volumetric percentage (Reproduced from Rao, 1965).

stomach of young mackerel obtained from Calicut and mention that this indicated a carnivorous habit of young fish. The stomachs of 75 specimens of young mackerel of length 6.4 to 11.3 cm caught off Vellayil, near Calicut in June 1966, were found gorged with parts of fish (clupeids) and fish scales (Venkataraman and Mukundan, 1970).

Kuthalingam (1956) based on his investigations on the food of mackerel from Madras coast categorized the nature of feeding in relation to size of the fish. He found he post-larval forms to be herbivorous feeding on diatoms and other algae and juveniles omnivorous feeding on all surface forms available in the area. According to him, the adults are carnivorous, as post larval and juvenile teleostean fish were found in the stomachs. But the size of the specimens he has included in the adult category starts from as low as 3.5 cm in length. Noble (1965) found the adults at Karwar to be exclusively plankton feeders as “fish larvae and vertebrate materials were totally absent in the guts”. Rao (1965) in his analysis of stomach contents of adults mackerels of size 24 to 32 cm from Vizhinjam area did not come across any fish or parts of fish and doubts the piscivorous habits of the adult fish as mentioned by some workers since “they are likely to have been taken fortuitously; a habit often observed in mackerel when they are enclosed in the boat seines and shore seines”.

In the course of the examination of the food of young mackerel, an interesting feature observed at Waltair is “the higher proportion of phytoplankton in the diet of larger fish than in the younger ones” (Rao and Rao, 1957; Rao, 1964a). Further Rao and Rao (*op. cit)* have found the relative length of the digestive tract to be greater in the adult fish than in the juveniles and this they correlated with the differences in the food habits of the juveniles and adult fish.

The presence of sand grains and fish scales in the stomach contents, recorded by some workers suggests that mackerel, though essentially a plankton feeder, at times resorts to bottom feeding (Chidambaram, 1944; Deveanesan and Chidambaram, 1948; Bhimachar and George, 1952; Pradhan, 1956; Noble, 1965 and Kutty, 1965). Devanesan and Chidambaram *(op. cit)* mention that the mackerel “supplements its diet of planktonic organisms by occasionally feeding at the bottom on dead and decaying fishes, for, in the stomach at times fish scales and sand grains without any traces of fish bones are found". Noble (1965), who agrees with the opinion expressed by Pradhan (1956), states that the inclusion of sand grains in the stomachs might be due to particular mode of fishing and that the scales could have accidentally gone into the stomachs during their brushing up with one another inside the rampan nets. That mackerel, at times, feeds at bottom is proved by the "presence of sand grains, foraminiferans, fish scales and molluscan shell bits" in the stomachs of mackerel obtained in the trawl catches of the Bombay coast (Kutty, 1965). The possibility of subsurface feeding also has been indicated by Bhimachar and George (1952) who have found that when surface plankton is composed of non-edible elements, "the food of the mackerel, as seen from examination of the stomach contents, matched more with the bottom than the surface plankton".

Though the food of mackerel as worked out in different centres of the east and west coasts agree in a broad measure, some local differences in the matter of detail have been noted. Devanesan (1942), Chidambaram (1944) and Devanesan and Chidambaram(1948) found fish eggs as a regular item of food in the stomachs of mackerel from Calicut coast and they have stated that this habit would have an adverse effect on the population of the fishes on whose eggs it feeds. But John and Menon (1942) examining specimens from Trivandrum coast did not find any fish eggs in the gut contents, However, subsequent investigations carried out at Calicut, Karwar and Vizhinjam confirmed the presence of fish eggs in the stomachs, though only occasionally (Bhimachar anf George, *op.cit;* Pradhan, *op. cit.;* Noble, *op. cit.* and Rao, 1965). Another food item on which the findings of the workers differ is the alga, *Trichodesmium.* Whereas John and Menon *(op. cit)* did not find this alga in the food of mackerel and oil sardine of Trivandrum coast, Chidambaram *(op. cit)* observed the same in good quantities in the stomachs of mackerel caught from Calicut area. But this was not noted in the stomach contents of mackerel during later investigations carried out at Calicut and Karwar (Bhimachar and George, *op. cit* and Noble, *op. cit*). Large quantities of brown and red algae have been recoded in the stomachs of mackerel obtained from 18-25 F area off Vizhinjam. However, their occurrence in the stomachs is considered exceptional as mackerel do not normally eat them (Rao, *op. cit).*

It has been found that the feeding intensity in mackerel is low during the prespawning and spawning periods, while in maturing specimens, it is high (Bhimachar and George 1952; Chidambaram *et. al* 1952 and Noble, 1965).. It has also been noted that in spent condition feeding is comparatively more than in mature specimens and in the mackerels of size rage 18.5 to 25.0 cm there was an alternation of high and low feeding intensity in successive size groups except in 24.0 cm size group (Noble *op. cit)*. Chidambaram *et. al. (op. cit)* have observed two periods of intense feeding in mackerel of Calicut coast (noted by Bhimachar and George also), one in October-December and the other in March-April. A corresponding increase in the fat content has also been seen during the respective periods. Similar maxima in the feeding intensity were noticed at Karwar also (Noble, *op.cit.).*

To sum up, it is seen there is agreement among the workers that mackerel is primarily a plankton feeder, feeding both on phyto and zooplanktonic elements. Most of the workers have noticed selectivity in feeding, as evidenced by the avoidance of certain elements in the plankton and by the presence of macroplanktonic organisms in the stomachs contents. The occurrence of sand grains and fish scales in the stomachs have been noticed by a majority of workers, but opinion is divided as to whether they are accidental inclusions in the stomachs or whether mackerel resorts to bottom feeding at times. In this context it is significant to note that sand grains, foraminiferans, molluscan shell etc. were recorded in the stomachs of mackerel caught in the trawl catches of the Bombay coast (Kutty, 1965). The occurrence of fish eggs in the stomachs of mackerel has been observed by most of the workers, but it is doubtful whether this habit would have any adverse effect on the population of the fishes on whose eggs it feeds (a view put forwarded by some workers) as these eggs are taken in stray numbers and that too occasionally. On the question of differences in the food of juveniles and adults, the findings are at variance, but the fact that in many instances fish and parts of it have been noted in the stomachs of juveniles show that they take to fish diet if available in the environment. That to some extent mackerel modifies its diet according to its availability in the environment is seen from the occurrence of pelagic tunicates in the stomach of mackerel caught off Vizhinjam coast (Rao, 1965). Observations made at Calicut and Karwar showed that there is a slackening in feeding during spawning and prespawning periods, the feeding being high in maturing specimens. Two periods of intense feeding have been noticed at both places with a corresponding increase in the fat content.

Fairly detailed knowledge on the food of mackerel from inshore area is now available, but it is restricted to certain centres and related to certain periods of time. Further no quantitative estimation of plankton has been made so as to correlate it with the food of mackerel except at Calicut and Karwar. A simultaneous study on the qualitative and quanititative aspects of the food of mackerel and the plankton available in its environment from all centres of study on the west and east costs have to be made over a period of time which will give an intergrated picture of the food of mackerel and will in all probability throw some light on coastal migrations and fluctuations in the fisheries.

While Bhimachar and George (1952) have stated that the shoreward migration of mackerel shoals during post monsoon season is for purposes of feeding, other workers (Pradhan, 1956 and Sekharan, 1958) do not subscribe to this view. At present we have no idea of the food of mackerel in offshore waters, except for brief observations by Kutty (1965) and Rao (1965) on the food of mackerel from relatively greater depths. It is very essential to make studies on the food of mackerel from offshore areas and on the food in its environment before we can form an opinion on this questions.

In order to facilitate comparison of the results obtained, it is necessary that some methods are followed in the estimations of the food contents and plankton in all the centres of observations. There is considerable confusion in the usage of words 'juvenile' and 'adult'. Whereas in one instance mackerel measuring 9 cm and above has been treated as an adult, in another instance the range in the length of an adult is from 3.5 to 22.5 cm. Terms denoting the food habits have been loosely used, thereby creating considerable difficulties in the understanding of the same. Such confusion can be avoided by standardizing the definitions and by following uniform methods of analysis.

4. 4 BEHAVIOUR

4. 4. 1 Migration

The large scale occurrence of juveniles mackerel in the inshore region during the period immediately following the monsoon is suggestive of migration of this fish from offshore to inshore waters. The inference drawn by Bhimachar and George (1952) that food could from a major factor governing these migrations is contended by Pradhan (1956) and Sekharan (1958). Pradhan (*op. cit*) felt that without studying the plankton available in the offshore waters the shoreward migration should not be linked with the food factor. Sekharan *(op. cit)* observed that "the 0-year-class is practically absent from the landings at a time when plankton of the coastal waters is richest in edible forms" and hence stated the question of food playing a dominant role in offshore to inshore migrations need to be verified. The evidence provided by different workers that the spawning ground may not be far off from the usual fishing belt (30 m depth) indicate that the migration of spawners to coastal waters is probably induced by the special ecological conditions caused by the monsoon.

The fact that the mackerel fishery does not start and close at the same time in different areas of the west coast is indicative of differential pattern of migration into coastal waters. While in Ponnani Mangalore region the fishery starts early (August-September) and lasts longer (terminating in March-April), in Magalore-Ratnagiri region it is of shorter duration commencing later (October-November) and terminating earlier (February-March) (Pradhan and Rao, 1958 Venkataraman , 1967). This indicates that the fishery starts first in the south and then extends north and the disappearance starts from north and then extends to south. Further investigations have to be carried out to find out whether there is latitudinal migration in mackerel or whether these migrations refer to only incursion and excursion from offshore to inshore areas.

Water temperature and salinity seem to play a part in governing the migration of mackerel. Pradhan and Reddy (1964) noted the increase in temperature and salinity affected mackerel catches adversely, whereas their low values exerted less pronounced effect. Further, mackerel was observed to show higher susceptibility towards temperature variations than to salinity. Higher pH may also have an added adverse effect on the fishery. Usually smaller size groups occur in good numbers only at a time (June-September) when the salinity and temperature are low. Bigger size groups show high tolerance towards increase in temperature and salinity as evidenced by the fact that larger ones (18-22 cm) occur in the period immediately following the monsoon followed by still larger specimens in the succeeding months (Pradhan and Reddy, *op. cit*). However it is seen that bigger specimens can also withstand lower salinity and temperature, as evidenced by the occurrence of spawners and spent ones in the fishery during the monsoon months. But observations made in Vizhinjam did not show any direct correlation between the surface or atmospheric temperature and the durations and intensity of the mackerel fishery (Bennet, 1967).

At Karwar it was noticed that when there is wind in north-easterly direction, mackerel shoals enter the inshore waters and when there is strong wind in easterly direction mackerel shoals come close to the shore through deeper layers of waters. The shoals normally move along the current of water at high tide (Pradhan, 1956).

Three instances of mackerel migrating into estuarine waters have been recorded at Karwar, Mangalore and Cochin (Pradhan, *op. cit.;* George *et. al.*, 1959 and George 1966.). Mackerel ascend the estuarine waters of the Kali river at Karwar along the tidal current upto a distances of bout 1½ miles during April and May when the range of salinity of river water is between 29.73 and $34.6^{0}/_{00}$. Further, the same author observes that instances of mackerel occurring in the Kali river in the rainy season when the salinity was as low as $2.04^{0}/_{00}$ have been reported. It was recorded in significant quantities in Netravati estuary, at Mangalore, during January-March, 1958 when the subsurface salinity in the zone of active mackerel fishery ranged from $14.10^{0}/_{00}$ to $23.50^{0}/_{00}$. It is significant that the fishery is supported mainly by a larger size group, compared to that of the catches obtained in the coastal centres. A similar migration was noticed in Cochin backwaters (salinity range 27.90 to $30.13^{0}/_{00}$) also during January-February, 1961 with the difference that samples of mackerel from the sea and the backwater showed similarity in the size pattern. Though no reason has been given for the migration into estuarine waters, the general abundance of pelagic fish populations including mackerel in the coastal waters might be the factor that influenced the entry at Cochin.

Tagging operations on some important pelagic fishes were recently carried out in Indian waters to study their migration and rate of growth (Hamre *et.al.,* 1966; Prabhu and Venkataraman, 1970). Tags used were loop tag, dart tag, semi-internal tag and opercular button tag. 2526 mackerel and 308 lesser sardine *(Sardinells gibbosa*) were successfully tagged and released off Marmgao harbour in December 1966 by the staff and trainees of the Central Institute of Fisheries Educations, Bombay (Hamro *et.al., op. cit.*). Out of 2526 mackerel released, one was caught at Dona Paula about 15 Km north of the place of release 8 days after tagging. The tagged fish moved north and shorewards and mingled with an untagged shoal.

Though a beginning was made at some places in1966-67 season itself, large scale tagging covering several centres on the west coast and east coast was carried out by the staff of the CMFRI in 1967-68 on the Indian mackerel and oil sardine. A total of 290 mackerel was tagged and released in all the centres put together during 1966-67 season, of which only 4 were recovered from Karwar. The recovered specimens were caught near the vicinity of their release. The recovery rate here was comparatively high being 3.57%. 4122 mackerel were tagged and released during 1967-68 season. Of these, 23 were recovered, the overall recovery rate for the season being 0.56%. The centres from where mackerel could be tagged and released were Karwar, Calicut, Cochin, Vizhinjam, Mandapam and Waltair. The recoveries were nil at Karwar, though 3150 specimens were released there. Out of 345 mackerel tagged at Calicut, only one was recovered after two days about 3 km south east of the place from where it was released. The tagging experiments here only showed local movements. At Cochin, 460 mackerel were released after tagging and of this, 10 were recovered at places 16 to 55 km away from the place of release, the maximum time lapse being 50 days. Of the 10 recovered, 5 travelled towards south and 5 towards north. At Vizhinjam, only one mackerel was obtained out of 95 released and this was caught about 32 km north west of Vizhinjam on the day of its release. It showed that the fish travelled 32 km in a matter of few hours. The number released at Mandapam was 42 of which none was recovered. Out of 30 mackerel tagged and released in Lawson's Bay, Waltair,11 were caught on the day of release itself in the same place.

In 1968-69 season, only 187 mackerel could be released after tagging, as the mackerel fishery was poor during the season. At Karwar, Cochin and Vizhinjam, 160, 23 and 4 fish were respectively tagged and released using mostly loop tags. Except for one fish, where recovery was reported from Vizhinjam, there was no other instance of tagged fish being caught in this season. The recovered specimens was obtained at Karunagapally, 19 km north of Vizhinjam, the number of days after liberation being 22.

The overall recovery rate for mackerel and oil sardine all the three seasons together came to 0.61% and 0.28% respectively. The low returns can be attributed to several factors such as initial tagging mortality and non reporting of recovered specimens by fishermen. Based on the number of tags recovered and also judged from the point of causing least injury to the fish, it was seen that loop and opercular tags are comparatively better suited for tagging mackerel and oil sardine. Analysis of colour pattern of tags recovered showed that maximum recoveries were made in respect of red and blue colours.

The results obtained so far from tagging experiments show that the movements of mackerel and oil sardine were of two categories, one local moving near about the vicinity of their release and the other showing migration of a limited extent moving distance north or south of the place of release. It is hoped that with the intensification of tagging programme, further knowledge will be obtained on the pattern of migrations of these commercially important pelagic species.

An interesting aspect of mackerel behaviour has been recorded by Devanesan (1942). He noticed that 10% of plankton obtained from Quilandy, near Calicut, was constituted by ‘mackerel eggs’ the rest being comprised of *Noctiluca*. From this deduced that the mackerel preferred to spawn amidst inedible *Noctiluca* to ensure protection for their eggs from predators and better survival. But Prasad (1954) is doubtful whether mackerel exercises any choice on the selection of the spawning ground. He feels that this “may be an adaptation developed to certain by-products of the growth of *Noctiluca*”.

4. 4. 2 Shoals

The size range of a mackerel shoal is very small and the individuals, as a whole show a remarkable similarity in size (Pradhan, 1956). This indicate that mackerel of different size groups move in separate shoals. They move in semi-circular or arrowhead formations and their speed is about 8 to 10 miles per hour. They scatter when pursued by seer fish. But when the shoals are chased by sharks or porpoises, the mackerel submerge with the head downwards into a compact mass. When the mackerels dive a patch of muddy water is seen at the surface which is due to churning of water by a large mass of fish.

Silas (1967b), while on a cruise on a dark night off Ratnagiri coast, noticed luminous mackerel shoals at about 16 F depth. The luminiscense was caused by mackerel shoals passing through a patch of phosphorescent zooplanktonic organisms which were abundant in the surface. He learnt that this phenomenon which makes the shoals more conspicuous, was not unusual off Ratnagiri coast and suggested investigations on the occurrence of such shoals all along the coast at such depths where purse seining for mackerel can be carried out. Some aspects of mackerel behaviour such as the size of the shoals, direction of movement and swimming speed can be studied by making observations on mackerel shoals at nights aided by bio-luminiscence.

4. 5 PARASITES AND PREDATORS

Numerous free solices of tapeworms or metacestodes were recorded in the pyloric caecae and the gut by Devanesan and John (1940). They further found just a few fully developed milk white tapeworms, some embedded in the peritorial tissue and some loose in the body cavity. The presence of free solices in the mackerel shows that it is the intermediate host of an adult tapeworm or tapeworms, the likelihood of permanent host being among sharks, porpoises etc. which are predators on mackerel. The occurrence of a fully developed tapeworm shows that the solices must have found their way into the body through the food of mackerel (Devenesan and John, *op. cit)*. Trematode, cestode and copepod parasites were recorded from Indian mackerel (Srivastava, 1936a&b; Chauhan, 1945; Pillai, 1962, Rao, 1964a, Unnithan 1964; Tripathi 1957, 1962; Silas, 1967a; Silas and

Ummerkutty, 1967). Females of a new species of copepod parasite, *Bomolochus jonesi* has been described from the eye of the Indian mackerel (Bennet, 1968). Sharks, seer fish, ribbon fish and porpoises are predators on mackerel.

4. 6 ABNORMALITIES

George *et al.* (1959) while examining mackerel specimens obtained from Netravati estuary at Mangalore found that unusually large number of specimens had sub-equal caudal fins, the lower lobe being shorter. They believe that this may be due to multilation at an earlier stage of life or due to some pathological condition or even to some genetic factor. They, however, do not agree with the possibility put forward by the local fisherfolk that the lower caudal fin lobe might have been smoothly rounded off due to constant rubbing with the sandy bottom, for the reason the fin margins were not frayed nor did they show any trace of wear and tear.

Some abnormal specimens of *Rastrellinger kanagurta* from Indian coastal waters have been recorded by Jones and Silas (1964b). Some of them have an appearance similar to *R. brachysoma* and could be mistaken for it. The frequent abnormalities observed are, listed below and these could be made out in the field itself.

"1) Short stumpy forms in which depth of the body is equal or greater than the length of the head.
2) The shortening of the portion of the body behind the second dorsal.
3) "Twisting" or curvature of the vertebral colum in the caudal peduncular region.
4) Loss of one or more dorsal finlets due to injury.
5) Increase in the number of dorsal and anal finlets due to "twisting" of the caudal peduncular region.
6) Increase in number of first dorsal spines.
7) Short first dorsal fin" (Jones and Silas, *op. cit*)

Another instance of occurrence of abnormal specimens of mackerel has been recorded by Bapat and Radhakrishnan (1968). Two abnormal specimens of total length 177 mm and 189 mm were collected from *Rampan* catches at Sashihittal, a fishing village near Kumta on the Canara coast. The body proportions showed appreciable variations, namely, body length/TL, maximum body depth along the pectoral fin/TL maximum body depth along the anal fin/TL.