The Indian Oil Sardine

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THE INDIAN OIL SARDINE

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CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

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THE BULLETIN OF THE CENTRAL MARINE FISHERIES RESEARCH INSTITUTE IS PUBLISHED AT IRREGULAR INTERVALS AS AND WHEN INFORMATION OF A GENERAL NATURE BECOMES AVAILABLE FOR DISSEMINATION.

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FOREWORD

The collection and collation of detailed information on the distribution, abundance, bionomics, life-histories and behaviouristic patterns of fishes (*sensu lato)* of commercial importance with a view to providing the guide lines for the rational exploitation and conservation of the concerned resources have been the objectives of the Central Marine Fisheries Research Institute since its establishment in 1947. Foremost among the members of the neritic-pelagic complex are the oil sardine, *Sardinella longiceps* and the mackerel, *Rastrelliger kanagurta* which at present support fisheries next in importance to those of prawns. The prawns and their fisheries have been dealt with in an earlier Bulletin (No. 14) and the present one deals with the oil sardine.

In spite of its importance as food, oil and fertilizer, investigations of a scientific nature on the oil sardine began only in the early twenties of the present century through pioneering efforts of Hornell. The oil sardine fishery has been estimated to have yielded an average annual catch of only 57, 363 tonnes during the fifties, but its revival has been so remarkable that the returns trebled during the current decade to an annual average of 208,003 tonnes forming about 26% of the total marine fish production in India. The most characteristic feature of the fishery has been its erratic behaviour as a resource, for between a meagre 7412 tonnes catch of 1956 and an all-time record of 3,01,446 tonnes in 1968, it has been fluctuating between 1% and 33% in the all India annual marine fish landings during the two decades. It is only during the last five years that the fishery has been regularly yielding an annual crop of over $2^1/_2$ lakh tones but its continuity in such abundance is clouded in doubt as this report shows for the current season.

For the rational development of an already well-established industry as that of the oil-sardine, the fishery biological programmes should have for their basis a knowledge of the nature and magnitude of the factors responsible for fluctuations to foresee recurrence of such features which determine the extent of the forthcoming fishery yields. The studies in this Institute are geared towards this objective and it has been found that the fluctuations are fishery-independent and are reflective of the oscillations in the rate of yearly recruitment of juvenile broods into the fishery. These variations in turn appear to be related to the vagaries of the environmental conditions when the fish enter their intense spawning phase.

It is considered that a period of two decades is a reasonable time to undertake a review of the work done and the progress achieved in order to chalk out future programme. It is with this intention that the account in this Bulletin is presented covering aspects of fishery biology concerning by far the most important fish species that contributes to the fisheries wealth of this country.

I have immense pleasure to place on record my appreciation and sincere thanks to my colleague Dr. B.T. Antony Raja who had under taken and successfully completed this difficult task of presenting an objective evaluation of the research investigations so far carried out on the subject, which I am confident will be of utmost interest to all fisheries workers in the country. My thanks are also due to all others who helped in various ways in bringing out this publication.

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November, 1969

INTRODUCTION

In the group-wise composition of the world marine fish production, Clupeoids occupy an unassailable position at the top and India is no exception. This group which contributes on an average about 32% to the annual marine fish production is mainly represented by the sardines of which the Indian oil-sardine, *Sardinella longiceps,* subscribes to the best part of it. The importance of this fish in the socio-economic life of the fishing community of the Malabar coast is very aptly expressed as *Kudumbam pularthi* (= provider for the family). The oil-sardine fishery during 1950-1968 period has contributed annually on an average to the extent of 18% to total marine fish landings in India. It is, however, subjected to such wild fluctuations that it has been found to vary between 1% and 33%. It is this undependable and unpredictable nature of the fishery that first drew the concern of Day (1865) and it was left to Hornell (1910b) to emphasise the need for a scientific study which led to the pioneer research report by him and Nayudu (1924). Except for the studies of Devanesan (1943), no important work appeared till almost the beginning of fifties. After the establishment of the Central Marine Fisheries Research Station in 1947, greater attention on various biological aspects was given resulting in the contributions of Nair (1949 *et seq*.), Chidambaram (1950) and Nair & Chidambaram (1951). The synopsis of information on the biology and fishery presented by Nair (1960) to the 'World Scientific Meeting on the Biology of Sardines and Related Species' under the as spices of FAO provided a clear account of the progress made till then. The rapid strides made subsequent to this can be easily evaluated when the history of research contributions of the last 5 decades beginning from the studies of Hornell and Nayudu (*loc. cit.*) relating chiefly and directly on the oil-sardine of Indian waters is looked into, for, as compared to 13 reports released in the previous decades, as many as 56 contributions have been made in the present decade alone of which 40 relate to the biology and fishery and the rest to technological and industrial aspects. It is generally held that scientific knowledge increases more than twice in the span of a decade rendering some of them obsolete with the birth, growth and assemblage of several theories, concepts and techniques. Likewise the quantum of research on the oil-sardine during the current decade has not only enriched our knowledge considerably on the different aspects dealt by the earlier workers-some confirmatory some complementary and some others to a certain extent contradictory but also has indicated the emergence of other vital problems offering an intellectual challenge to accept which, it becomes imperative to take stock of our existing knowledge on the magnitude of the fluctuations, distribution, susceptibility and the behaviour of our resources under the impact of several abiotic and biotic factors, with an appreciation of the past and a realization of the present for a fruitful future.

While Richard Harlan (1825) wrote concisely on the title page of his book "Fauna Americana" 'The manor of living nature is so ample, that all may be allowed to sport on it freely; the most jealous proprietor can not entertain any apprehension that the game will be exhausted, or even perceptibly thinned' there was a growing feeling whether this opinion can be safely applied to the fishery resources, for, over a century ago, with reference to the Indian oil-sardine, Day (1865) expressed in "The Fishes of Malabar" '……… it must be left for future years to demonstrate whether the present increase of fish-oil trade is a healthy or an unhealthy stimulus due to present high prices; for if the latter, the fisheries are being overworked and the future loss will be great'. Although the problem of over fishing is still debated, for, the manner of fishing and the resources on which it is spread differ in different waters, as for the oil-sardine, it is for us to find whether man can indeed over power 'the manner of living nature' or Nature, by bringing in certain unfavourable conditions, acts as a safety valve or whether an unfortunate combination of both can lead to a total decimation of the stock in future, to forestall which, we need a knowledge of not only the maximum sustainable biological yield but of maximum economic yield also. 'Abundant in some years, they occasionally forsake their haunts for several consecutive seasons, returning again in enormous quantities' – so observed Day (1878). But why? Where to? When will they reappear? In what quantity? In short, the questions revolve around the behaviour pattern of the entire resource.

Our oil-sardine resources can be said to be in the midstream, in the sense it is neither at the beginning stages of exploitation nor at the terminal. Hence, perforce, is required a perspicuous understanding of its biology, complex though it may be *vis a vis* ecology leading towards more efficient utilization of this valuable resource. The existing knowledge, no doubt, stem largely from scientific observations on commercial fishing operations which can offer only a limited spectrum for deductions, but nevertheless, should form a basis for productivity research.

The present author has been engaged in the sardine investigations since 1959, during the course of which he had opportunity not only to study the oil-sardine under our conditions but also analyse the forms alleged to belong to the same species in other waters. Incidentally, he could also obtain a knowledge of a few other species of *Sardinella* as well as those of *Sardinops* of Indo-Pacific region and comprehend to a certain extent some of the problems associated with the fluctuations of the Japanese sardine fishery and how the research efforts are directed there towards solving them. With this personal background experience,an attempt is made herein to bring together all the available observations on the oil-sardine not merely in a chronological order which may not be of that much value as compared to a critical evaluation of the accredited research data of past 5 decades. Such a stock-taking need to be, however, considered peremptory but as a basis from which the spheres where research may require acceleration and or change in direction can be spotlighted. Unless otherwise quoted, the entire responsibility of deductions made and suggestions offered for possible course of action solely rests with this author, not as *suggestio curantur* but as a forum for healthy discussions on them in future studies. In this report could only raise the awareness of the magnitude of the problems in perspective, it would have served its purpose.

The format of this monograph largely follows the design set by the Fishery Biology Branch of FAO for reporting synopsis of data on species and stocks. Chapters on technological research and Industry are also included to make it a little more comprehensive. While as much coverage is given for all important published works as possible, among the unpublished observations, some slight overdwelling on the contributions of this author could not be avoided because of direct accessibility to his own data as compared to those that are still in various stages of publication.

The preparation and completion of this account would not have been made possible but for the deep interest, incessant encouragement and constructive guidance offered by his Director, Dr. S. Jones, to whom the author expresses, with great pleasure his profound sense of gratitude and indebtedness. He is specially obliged to Mr. K. Virabhadra Rao, Senior Research Officer, for going through the typescript and for his attentive and critical supervision from that stage till the release of this report. His grateful acknowledgements are extended to Dr. G. Seshappa, Senior Research Officer, for readily making available some reference from his personal library; to Mrs. Kamala Ramachandran, Scientist, publication and Information Directorate, Council of Scientific and Industrial Research, New Delhi, for kindly and expeditiously arranging for translation of certain passages from French; to Mr. K.L.K. Kesavan, Artist, for drawing the figure and Mr. A. Bastian Fernando, Junior Scientific Assistant, for general assistance. The author also acknowledges with thanks all those with whom he had opportunity to discuss certain points and some of whose personal communications are quoted at relevant places.

IDENTITY

1. 1 **Taxonomy**

1. 1. 1 **Definition**

Phylus VERTEBRATA
Subphylum Craniata
Superclass Gnathostomata
Series Pisces
Class Teleostomi
Subclass Actinopterygii
Order Clupeiformes
Suborder Clupeoidei
Family Clupeidae
Genus *Sardinella* Valenciennes 1847
Species *longiceps* Valenciennes

1. 1. 2 **Description**

The original descriptions of Valenciennes (Cuvier and Valenciennes, 1847, *Hist. Nat. Poiss.,* vol. 20) are reproduced below:

Des Sardinelles

"Le genre Sardinelle se compose de poissons, qui ressemblent tellement a la sardine par la forme exterieure, qu'il faut pour l'en distinguer faire attention aux caracteres tires de l'opercule, et plus encore a ceux des dents. En effet, nos sardinelles manquent de ces organs aux machoires et au vomer qui les distingue completement des harongs ou du genre Clupee du genre Harengule. Elles en ont sur les palatines, sur les pterygoidiens et sur la langue, ce qui empeche qu' on puisse les confondre avec les genres don't nous parlerons plustard. Ainsi caracterisees, les especes de ce genre sont faciles a classer" (pg. 262-263).

La SARDINELLE A TELE LONGUE

(Sardinelle longiceps, nob)

"Cette espece

a la tete longue et grosse; le corps etroit et attennue vers la queue; la longueur de la tete fait le tiers de celle du corps, en n'y comprennent pas la caudale, don't les lobes mesurent, a peu de chose pres, le sixieme de la Longueuer totale. Le museau est un peu releve et parait renfle sur les cotes. La careen du ventre est couverte d'ecailles donnant en arriere une pointe tres-petite et aceree qui ne parait pas sortir d'une entaille du bord. La dorsale a ses derniers rayons tres-bas

D.16;A.16.

Nous ne possedons de cette espece que des individus decolores et en mauvais etat; ils sont longs de six pouces. Ils faisaient partie, des collections reunies par M. Bellanger sur la cote de Pondichery". (pg. 272-273).

The above passage can be rendered as follws:

The genus *Sardinella* is comprised of fishes that resemble the Sardine in thier external appearance to such an extent that in order to distinguish it from the latter, one has to carefully observe characters drawn from the operculum, and those of the teeth even more so. In fact, these organs at the jaws and the vomer are wanting in our Sardinella, which completely distinguish them from herrings or the genus Clupea from the genus Harengula, They have them on the palatines, the pterygoids and the tongue, thanks to which one cannot confuse them with the genera we are going to discuss later. Thus characterized, the species of this genus are easy to classify.

THE SARDINELLA WITH LONG HEAD
(*Sardinella longiceps,* nob)

This species has a long and stout head: the body narrow and tapered towards the tail: the length of the head is one-third of that of the body excluding the caudal, the lobes of which measure very nearly a sixth of the total length. The snout is slightly lifted up and looks swollen on the sides. The bottom of the stomach is covered by scales producing a very small and sharp tip in the rear, which does not appear to stem from a notch of the edge. The dorsal has its last rays very low.

D. 16; A. 16

We have but individuals of this species that are discoloured and in bad state; they are six inches long. They were part ofcollections made by Dr. Bellanger on the Pondicherry coast.

The following diagnoses of genus and species are taken from Li (1960);

Genus *Sardinella* Valenciennes 1847

"Body mostly compressed. Snout not prominent. Premaxillaries not protractile. Mouth rather large.Jaws nearly equal. Teeth feeble on palatines and tongue. No distinct median notch in upper jaw. Adipose eyelids broad.Opercle smooth, without radiating striae. Vertical edge of cleithrum covered with dorsal fold furnished with 2 obtuse knobs equidistant and shallow between. Pseudobranchiae present.

Gill 4, slit behind last. Gill membranes separate, free from isthmus. Branchiostegals 6. Belly keeled, with scutes. Scales large, usually firm with interrupted transverse striae. Ventrals opposite dorsal. Anal long, last 2 rays enlarged."

Sardinella longiceps (Valenciennes)

"D. 16-18; A. 14-16; P. 15-16; V. 9; L. I. 46-48; L.tr. 12-13; L.G.R. 200; Postv. Scu. 13-15; Vert. 46-47.

Elongate. Dorsal and ventral profile evenly convex. Height 4 to 4.67; head 2.88 to 3.6. Snout 3.5 to 3.88 in head; eye 5 to 6, sub equal with or slightly greater than interorbital, adipose lid broad.Maxillary reaches 1/3 in eye, length 2.67 to 2.75 in head; upper jaw with slight medien notch. Arborescent striae from preorbital to preopercle above, venules also spreading out horizontally on opercle above and branch extends forward to supraorbital, cluster spreads over cheek, another radiating also at lower angle of preopercle and humeral venules well developed over 3 scales, scales firmly adherent, narrowly imbricated, with 2 to 4 incomplete or more or less broken vertical parallel striae and dozen or more irregular horizontal apical marginal lines. Mostly connected or obsolete; 14 to 16 predorsal medien scales. Dorsal somewhat nearer to caudal than to snout, first branched ray 2.6 to 2.65 in head. Anal low, first branched ray 5.13 to 5.33. Ventrals 3 to 4, its origin behind middle of dorsal. Pectorals 1.6 to 1.67. Caudal well forked, slender lobes pointed. Least depth of caudal peduncle 3.4 to 4.5 in head.

Bluish brown along the back with golden reflections, abdomen silvery shot with purple,Dorsal and caudal greenish brown,other fins pale. A large greenish golden spot on the upper hind margin of opercle. Length 166 mm".

Li (*loc. Cit.*) has not specifically quoted the source of the above description but a perusal of the relevant literature appears to indicate that it is mostly a reproduction from Fowler (1941) except that of coloration which is adopted from Day (1878) and which should refer to a fresh specimen whereas the other descriptions relate to preserved material. While the number of lower gill rakers as 200 and the length of fish as 166 mm indicate that the description pertains to a single specimen, it is seen that the number of lower gill rakers is reproduced from Fowler *(l.c.),* but the source is not traceable for the length of the fish, for Fowler (*l.c.)* has not reported it in his description. However, it is possible that Li (*l.c.)* has inserted the length of the largest fish among the specimens examined by Fowler (*l.c.)* which is found interestingly to be one of the specimens sent byHornell from Calicut. Along with a few observations of Gunther (1868)on *Clupea scombrina* (mistakenly stated as *C. neohowii* by Li (*l.c.)*)

and Day *(l.c.)* on *C. Longiceps*, Li (*l.c.)* has widened the range of measurement ratios and meristic characters from those reported by Fowler (*l.c.)*. A significant feature that appears a little ambiguous is that whereas in the generic character the opercle is reported smooth with no radiating striae, in the specific diagnosis, it is credited with arborescent striae which indeed are present in *Sardinella longiceps.*

While it is intended to make a through study of the taxonomy and identity of the Indian oil-sardine, the description that follows is based on this writer's earlier study on a few morphometric and meristic characters on 200 fish from Calicut (Antony Raja, 1968), an extract of which is available from Antony Raja and Hiyama (1969), as well as based on a few preliminary observations on some other characters not examined earlier. The range of body length of fish thus examined is 82 to162 mm (total length, 104 to 197 mm). For meristic counts the range is given first with the modal number in brackets. For measurable characters, the range of ratios precedes the mean in the parentheses. While parts of head and caudal peduncle depth are expressed in head length, the other ratios are in relevance to body length.For certain characters, due to insufficiency of data on hand, only the ranges are given but not the modal number or the mean ratio.

Meristic counts: Vertebrae 43-48 (47). Dorsal 15-17 (16). Pectoral 15-16. Ventral 9. Anal 13-16 (14). Lateral line scales 45-48: transverse rows 12-14; predorsal 15-18. Ventral scutes 17-20 + 13-16 (14). Lower gill rakers 187-268.

Morphometric characters: Height at dorsal origin 3.57 to 4.57 (4.07). Head 2.76 to 3.08 (2.91). Snout 3.48 to 4.12 (3.81). Eye 4.76 to 5.77 (5.27). Maxillary 2.75 to 3.29 (2.98), reaching the middle of eye or slightly beyond. Minute closely set teeth on medien region of the tongue with black stellar chromotophores densely distributed on either side;teeth are also present on the palatines and pterygoids but none on vomer. Exposed part of interopercle rather triangular with curved angles (mound-shaped). Caudal peduncle depth 4.00 to 5.18 (4.52). Predorsal length 2.1 to 2.2 origin slightly nearer to snout than caudal base. Prepectoral 3.3 to 3.6, origin almost at the lower bend of subopercle, with the shorter few rays covered by a large scale at the base and with the posterior tip of the fin reaching up to origin of dorsal in the smaller fish but very much in advance in larger fish. Preventral 1.69 to 1.85 (1.79), origin distinctly shifted towards caudal base than snout and against middle or at two-third of dorsal fin base. Preanal 1.2 to 1.3. the last two anal rays longer and extensively branched with the tip of the longest ray reaching very near the bend of lower caudal fluke. Caudal, deeply forked, 3.55 to 4.87 (4.31) with two large alar scales between the base of which are two smaller body scales.

Arborescent striae arise behind the orbit at a distance slightly lesser than preorbital length and profusely branched. They run laterally as well as vertically from postorbital through preopercle to opercle and below on the cheek plate. Another such stria arising from the same region run with numerous branching venules up to about half way down the outer border of the gill chamber (scapular region) and spread on the scales of the region. This pattern of venation is so clearly discernible only on the preserved material and when the surface gets dry.

Scales: Cycloid, firm, with the exposed margin crenulated or sometimes rugged. In majority of cases there is a continuous transverse groove, while in some it is discontinuous with mostly two interrupted pairs anterior to it (rarely 3 pairs).

Colour: In fresh condition, the back has an admixture of blue, green and brown. With surface moisture, it appears greenish brown with golden reflections; when dry, bluish. Flanks are silvery, tinged with iridescent pink. Fins mostly pale, caudal fringe a little dusky with the tips of both the lobes and at the fork, blackish. The tips of the first few fin rays of dorsal when set together appear black. At the upper border of the opercle, the gill chambers is partly visible as a dark oval area. The large golden green spot on the upper hind margin of opercle mentioned in some earlier systematic works is not such a striking feature but only represents an inverted triangular region that appears as an iridescent patch of green, blue and yellow. On the upper edge of the preopercular bone 3 small dots/dashes are seen, 2 horizontally and 1 below them which however fade away in preservation. Under long formalin preservation, the back appears brownish and the sides distinctly lighter in shade, but under preservation of shorter duration, the back is slaty with the sides creamy white. (Fig.1).

1. 1. 3 **Nomenclature**

Valid scientific name: *Sardinella longiceps* Valenciennes 1847. The dual authorship of Cuvier and Valenciennes credited to the species in many earlier works is not correct according to the International Code of Zoological nomenclature for Cuvier was no more when the volume containing this species was published (Jones, 1957) and on page precedence the specific name of *longiceps* has come to stay over *neohowii* of Valenciennes (*loc. cit*).

Standard common name: Oil-sardine. The common name Indian oil-sardine is preferred over Malabar oil-sardine of Devanesan (1943).

Vernacular name: In Malayalam it is called *Mathi* or *Nallamathi*, in Kannada *Buthai*, in Telugu *Noona-kavallu* and in Tamil *Nonalai* (Nair, 1960). On Tuticorin coast, it is referred as *Pechalai* in Tamil. Like wise in Ceylon, it is known as *Pesalai* in Tamil and *Pesalaya* in Singhalese (Munro, 1955).

1. 1. 4 **Synonyms**

Sardinella longiceps Valenciennes, 1847 *Hist. Nat. Poiss.* Col. 20, pg.273 (Type locality: Pondicherry): Regan, 1917. *Ann. Mag. Nat. Hist.* ser.8, vol. 19.pg. 379; Hornell & Nayudu, 1924, *Madras Fish. Bull.* vol.17, pg. 152: Fowler, 1924, *Journ. Bombay Nat. Hist. Soc.* vol. 30 pg. 129: *idem*, 1941, *U.S. Nat. Mus.* 100, vol.13, pg. 603 (in part): *idem* 1956, *Fishes of the Red Sea*, vol. 1. pg. 65: Nair, 1953, *Journ. Zool. Soc. India*, vol.5, pg. 119; Misra, 1962, *Rec. Ind.Mus.* vol. 57, pg.115; White head, 1965, Bull. Brit. Mus. Natur. Hist. Zool. Vol.12 (7), pg. 249; Chan, 1965, *Jap. J. Ichthyol.* Vol. 13, pg.3 (in part).

Clupea longiceps Gunther, 1868, *Cat. Fish. Brit. Mus.* vol.7, pg. 428; Day 1878, *Fishes of India* Pt. 4, pg. 637; *idem* 1889, *Fauna of British India, Fishes*, vol.1.pg. 373; Steindachner, 1907, *Denkschr. Akad. Wiss. Wein.* Vol.71, pg. 167: Pillay, 1929, *Journ. Bombay Nat. Hist. Soc.* vol. 33, pg. 355.

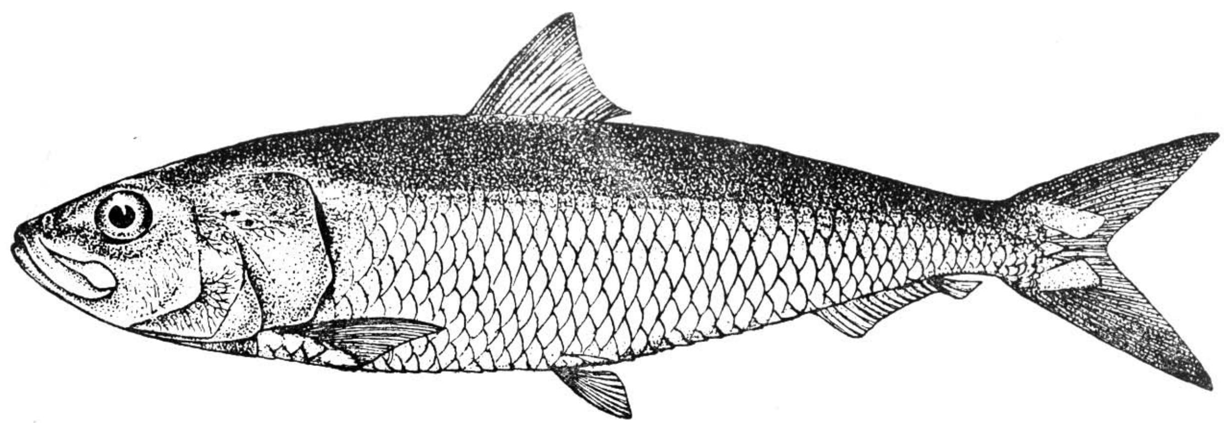

Fig. 1. The Indian Oil-sardine, *Sardinella longiceps* Valenciennes.
(Actual size : 166 mm total length)

Sardinella Neohowii Valenciennes, *l.c.* pg. 274 (Type locality: Cannanore); Day, 1865, *Fishes of Malabar,* pg. 230.

Clupea scombrina Gunther, l.c. pg. Boulenger, 1887. *Proc. Zool. Soc. London,* pg. 666.

After the type description of Valenciennes (*loc.cit.)* on *Sardinella longiceps* from Pondicherry and *'S. Neohowii'* from Cannanore which are considered synonyms, Day's (1865) first report on this fish is as *Sardinella Neohowii'* which Fowler (1941) states as copied but a comparison of original description of Valenciennes *(l.c.)* and the subsequent one of Day (1865) clearly does not indicate so. Further descriptions of Day (1878 & 1889) on *Clupea longiceps* have made some slight improvements over his earlier one and in doing so he seems to have been influenced by Bleeker's materials of *C. lemuru* of Malayan archipelago also. Subsequent to this, Hornell and Nayudu (*op.cit.),* Nair (1953a) and Misra (1962) have given short descriptions of the Indian west coast forms, among whom the latter two authors have only reproduced condensed versions from earlier works. In as much as the species is of prime importance to the west coast neritic pelagic fisheries of India and in view of the fact that the original description of *S. longiceps* refers to specimens from the east coast of India and even that of the west coast from (*'S. Neohowii'*) largely dwells on the colouration and appearance of the fish which no other morphological details, it appears that a more serious attempt to describe the fish is necessary than what has been done in the past. Since the identity is more important before handling other aspects of the biology of a fish, a few interesting comments on the synonymy of *S. longiceps* may not be out of place here.

While presenting '*Sardinella Neohowii´* as a distinct species the description of which immediately follows that of *S. longiceps,* Valenciennes *(l.c.)* mentions that is very close to *S. longiceps* but differs from the latter by virtue of its shorter head, for, it is a fourth of the total length and that this shortness of head gives the species a different look which is easy to discern. However, it should be pointed out here that while he reports the head of *S. longiceps* as one-third of *body length* without caudal, that of *S. Neohowii* is one -fourth of *total length,* which would approximate the same, the small differences, if any being attributable to general variability as well as geographical differences; Moreover in as much as he himself reports that the specimens of *S. longiceps* examined by him were discoloured and in a bad state, it can be easily concluded that both the forms relate to the same species. Since he has also referred to the local name, *Mathi,* for *S. Neohowii*, its availability in huge quantities on the Malabar coast and its use as manure for coconut plantations and rice fields, there appears to be no doubt that the reference is to the oil-sardine. In fact, it is interesting to find the descriptive part for *S. Neohowii* distinctly more assuring than that of *S. longiceps* which is based on badly preserved materials. It is, hence, surprising why Day (1878) while aligning his *S. Neohowii* as a synonym, does not consider that of valenciennes (*l.c.*) as homologous.

Alausa scombrina of Valenciennes (*l.c.* pg. 442)has been regularly considered as a synonym of this species by various authors like Gunther (1868), Day (1878), Regan (1917), Roxas (1934), Fowler (1941), Herre (1953), Nair (1953a) and Li *(op.cit*), while Day (1865 & 1878) considers his *A. scombrina* (Day, 1865) also like wise. In the original description of Valenciennes (*l.c.*) on this specimen obtained from Cannanore, it is seen that whereas the earlier part appears to indicate its similarity to *S. longiceps* including the fin formula, the later part reports the travel notes of Dussumier for this species as “Sardine’ seen abundantly at Mahe (Seychelles)but where its inhabitants call it Mackerel. Valenciennes agrees that the fish has a distant resemblance to Mackerel but because of its body and head having a marked resemblance to *Clupea*, it has perplexed him very much for, he has been inclined to believe it as a species of sardine in spite of its abdomen not being carinate and sharp. However, on further closer examination he records the number of branchiostegals to be at least 17 and feels that the fish may be closely related to *Elops.* Thus it is clear that what he has described under *A. scombrina* may not be a species of *Sardinella* whose branchistegals number only 6 but may refer to another genus. The description of Day (1865) of *A scombrina* appears largely to compare favourably with *S.longiceps*, But the diameter of eye which appears rather very small and the presence of teeth in either jaw and extending along the maxilla but none on the vomer, platine or tongue clearly bring in doubts of its true homology with the oil-saradine. Moreover, the most significant remarks that the species abounds in rivers and even in paddy fields and ditches at certain seasons' with its habitat in 'seas, estuaries and even fresh waters of Malabar and the Seychelles' undoubtedly indicates that it is a different form altogether, for, *S. longiceps* has so far been not reported from fresh water environment. It may be also added here that but for Gunther (*loc.cit)* who has doubtfully included this as a synonym under his *Clupea scombrina*, no other important systematic work has considered this species of Day as homologous with *S. longiceps.* It is also possible that the reports of Valenciennes *(l.c.)* and Day (1865) on *A. scombrina* refer even to two different genera, for, according to the former the number of branchiostegal is 17, whereas the latter records the range as 5 to 8 for his genus *Alausa.* Hence, it is the contention of this writer that the descriptions of both Valenciennes as well as Day on this species cannot be validated with *S. longiceps.*

Gunther's (*op. cit) Clupea scombrina* is generally taken as a synonym of *S. longiceps* but he has reported 'Teeth none on the palate or the tongue' whereas teeth are indeed present on these structures in *S. longiceps*. It is possible, however, that the teeth were lost in the specimen examined by him and according to him, dentition, given importance to by Valenciennes, is an uncertain character in view of the likelihood of loss due to accident or age or to their deciduous nature. The mistake committed, probably by the printers and overlooked by Fowler (1941) in including '*Clupea neohowii* Gunther 1868' instead of *C. scombrina* Gunther,has been unfortunately perpetuated by subsequent systematists like Herre *(op. cit.)*, Li *(op. cit)* and Chan *(op. cit)* who have credited both the names to Gunther, whereas the latter has not described any species as *C. neohowii* but has only listed *S. neohowii* of Valenciennes as well as Day as synonyms under his *C. scombrina.*

While Roxas (*op.cit)* and Nair (1953a) have placed *Clupea(Harengula) longiceps* of Weber and Beaufort (1913) as a synonym of *Sardinella longiceps,* many other workers (Regan, *op. cit.;* Fowler 1941; Herre, *op.cit.;* Chu & Tsai, 1958; Li *op. cit.;* Chan, *op.cit.)* have considered it homologous with *S. aurita.* Examining specimens belonging to both the species, Antony Raja (1968) has reported that the description of Weber and Beaufort *(loc. Cit)* applies largely to the latter and not to *S. longiceps* especially as low a count as 120 lower gill rakers. He has also doubted that the material reported by Chan (*loc. Cit*) *under S. longiceps* might have contained a few specimens of *S. aurita* as well. The descriptions of Roxas *(loc. Cit)* especially those relating to head, snout, eye, maxillary, caudal peduncle depth and number of lower gill rakers answer. *S. longiceps* as having 140 lower gill rakers which shows that it may refer to *S. aurita* Day (1878), it may be pointed out, has remarked that the *lemuru* sent Bleeker from Malay archipelago agreed with *Clupea longiceps* of Malabar. It is, however, known from different reports that the *Lemuru* variously known as *Clupea lemuru* Gunther, *Sardinella lemuru* Bleeker, *Clupea* (*Sardinella*) *lemuru* Bleeker and *Clupea (Harengula*) *lemuru* Bleeker of Malay archipelago and Indonesian waters is synonymous with *Sardinella aurita*. Thus, there appears to be a little confusion in the identity of *S. longiceps* and *S. aurita* as seen from the reports of Day *(l.c.)*, Roxas (*l.c.)* Fowler (*l.c)* Chan *(l.c.)* Ronquillo (1960) and Soerjodinoto (1960). One reason for this confusion appears to have arisen mixing up specimens from India with those of the Philippines and Malay archipelago. Or the species occurring in some parts of South China Sea, java straits and Malay archipelago represents a form intermediate between *S. longiceps* and *S. aurita. Regan (loc. cit)* clearly distinguishes these species on the length of head (longer in *S. longiceps),* number of lower gill rakers (more in *S. longiceps*) and eye diameter (smaller in *S. longiceps).* Chan *(loc. cit)* adds one more character, the exposed part of interopercle (semicircular in *S. longiceps* and crescent shaped in *S. aurita*). However, in the Indian forms the interopercle is rather triangular with curved angles. Antony Raja (l*oc. cit)* and Antony Raja and Hiyama *(op. cit)* have indicated that the maxillary is longer is *S. longiceps* reaching the middle of eye or even slightly beyond and the insertion of ventral is distinctly shifted more towards caudal in *S. longiceps*, whereas it is almost in the middle between caudal base and snout in *S.aurita*.

1. 2 **General variability**

In Table I are presented the nature of general variability of some of the chief morphometric and meristic characters. Only the compilation of Li *(op.cit).* and subsequent comparable works of importance are shown. As stated earlier, the observations of Chan (*op. cit)* might have included a few specimens of *S. aurita* and hence some marked deviations in certain characters like length of head, snout, eye and maxillary. In the range of meristic characters, the noteworthy departure seems only to be in the number of vertebrae, for while Antony Raja& Hiyama *(op. cit)* show the range from 43 to 48, the earlier works have indicated only 46-47.

Hornell and Nayudu *(op. cit)* were the first to be sized of the problem of variablity of characters in the oil-sardine. They examined specimens from Madras on the east coast of India and from several places between Malpe andTanur on the west coast. They felt that the stability in the ratio of head length, height and girth to body length and the number of vertebrae precluded the possibility of local races or even brood differences. Devanesan and Chidambaram (1943) in an abstract, the details of which are not available, on the other hand, showed that between the fish of Aden, Muscat, Bombay-Karachi, Karwar and Malabar, the Karwar forms possessed the largest head and the shortest tail as compared to the other regions which showed varying degrees of decreasing head length and increasing tail. They suggested that the Karwar specimens belonged to a distinct race somewhere between the Malabar and the Bombay-Karachi race, which in turn separated the Muscat race from the Indian west coast forms. The Aden counter parts, they inferred, may be an outlying race by itself. Between Bombay-Karachi and Malabar specimens, Devanesan (1943), based on 18 specimens from the former area, favoured the view that due to differences in the head length, number of pectoral fin rays and stomach contents, the specimens of the former region belonged to a distinct local race. In these investigations, however, either the material examined was too small or the details of statistical analysis, if any were wanting to prove the heterogeneity or otherwise. These studies, nevertheless, indicate that a detailed enquiry is very much in order

TABLE I

Records of general variability in some morphometric and meristic characters in *Sardinella longiceps*

Author	Height		Head		Snout		Eye		Maxillary		Caud. Ped. Depth	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Li, 1960	4.00-4.67		2.88-3.60	-	3.50-3.88	-	5.00-6.00	-	2.67-2.75	-	3.40-4.50	-
Chan, 1965	3.73-4.57	4.15	2.95-3.44	3.20	3.32-3.78	3.55	4.12-5.22	4.75	2.43-2.78	2.59	-	-
Whitehead, 1965	4.05-4.52	-	2.96-3.23	-	3.88-4.00	-	4.44-5.00	-	-	-	-	-
Antony Raja, 1968	3.57-4.57	4.07	2.76-3.08	2.91	3.48-4.12	3.81	4.76-5.77	5.27	2.75-3.29	2.98	4.0-5.18	4.52

Author	Caudal fin		Pre-ventral		V		PVS		DFR		AFR		LGR	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Li, 1960	-	-	-	-	46-47	-	13-15	-	16-18	-	14-16	-	180-250 (Regan, 1917)	200
Cha 1965	-	-	1.71-1.87	1.79	-	-	14-15	15	15-18	16	15-16	15	145-258	210
Whitehead 1965	-	-	1.96-1.84	-	-	-	13-15	-	17-19	-	15-16	-	180-250	-
Antony Raja, 1968	3.55-4.67	4.31	1.69-1.85	1.79	43-48	47	13-16	14	15-17	16	13-16	14	187-268	-

V = Vertebrae; PVS = Post-ventral scutes; DFR = Dorsal fin rays; AFR = Anal fin rays; LGR= Lower gill rakers for, even if it can be shown that there is a likelihood of sub-groups, if not races within the population exploited off the west coast of India, it will have a great bearing on the future investigations on the dynamics of the exploited oil-saradine stocks.

In a preliminary study of some samples of Calicut on three successive year classes, namely , 0, 1,& 2, and subjecting the data to statistical treatment, Antony Raja and Hiyama *(op. cit)* showed that the different year classes appear to exhibit significant differences in the relative growth of head, snout and preventral length and in the mean number of post-ventral scutes, whereas the mean number of vertebrae, dorsal and anal fin rays do not differ significantly. The number of lower gill rakers, ranging between 187 and 268increases rapidly with increase in body length up to 110 mm, after which the rate of increase progressively slows down. Fitting a curvilinear regression for this relationship, Antony Raja (1968) found that $y= -30.42 +3.39X-0.01X^{2,}$ where Y is the number of lower gill rakers and X, the body length in mm. Due to significant differences in height, head and snout between two successive year classes of mature fish and in the mean number of post-ventral scutes between the immature and mature groups, he suggested probable utility of these characters for a study of year class differences. Further detailed studies on biometrics are, however, required before any useful and positive guidelines can be indicated.

II DISTRIBUTION

2.1 **General distribution**

Rosa and Laevastu (1960), in a compilation of distributional records, place *Sardinella longiceps* along the coast of Somalia, Seychelles, Gulf of Aden, Red Sea, Gulf of Oman, Persian Gulf, West Pakistan, Indian peninsula, Ceylon, Malayan Archipelago, around Indonesian and Philippine waters as well as off Vietnam. Of these, Whitehead (1965) reports that there are no reports from either Red Sea or Persian Gulf but confirms the availability in Somaliland, Gulf of Aden and Gulf of Oman. Their presence around Aden, Muscat and Karachi is further supported by the collections examined by Devanesan and Chidambaram *(Op. cit).* From Seychelles, the only record appears to be that of Valenciennes *(op. cit)* on *Alausa scombrina* but which this author, as stated earlier, does not consider as a synonym of *S. longiceps*. The records of Smith and Smith (1963) on “Fishes of Seychelles” also do not included this species and hence the distribution of oil-sardine around Seychelles is doubtful. Around India, although it is recorded from both the coasts, their occurrence on the east coast is reported as sporadic, the specimens being less fatty than the Malabar forms (Day, 1878). While from Ceylon it is recognized by Deraniyagala (1929) and Munro *(op. cit),* the evidences for further continued distribution of *S. longiceps* are rather fragmentary and not very assuring. White head *(loc. cit)* remarks that *S. longiceps* replaces *S.aurita* in the Indian Ocean, but their ranges seem to overlap in Indonesia and the Philippines. However, from the analysis of a sample from Philippines as “*S. longiceps*’ it was found that the species in question is only *S. aurita* and hence it was contended that what Ronquillo *(op.cit)* reports as *“S.longiceps’* forming commercial importance in the Philippines should refer to *S. Aurita* (Antony Raja, 1968). Although there are quite a good number of reference to ‘*S.longiceps’* occurring around the Philippines and even found “entering the river mouths’ (Herre, *op.cit),* any description of the species is totally lacking in many of them. Even where descriptions are available as in Roxas *(op. cit),* it has been shown earlier that they answer mostly *S. aurita.* Likewise, in Indonesian waters the *lemuru, Clupea (Herengula) longiceps* of Soerjodinito *(op.cit)* and *S. allecia* of Unar &Sachlan (1958) refer to *S. aurita*.

As it has been already remarked under the previous chapter, the species of Malacca straits from Bleeker which was considered by Day (1878) as a synonym of *S. longiceps* also relates to *S. aurita*. It is, hence, the opinion of Antony Raja *(loc. cit)* that there appears no overlapping in the ranges of distribution of *S. aurita* and *S. longiceps* in the Indonesian and Philippine waters but the latter appears to enjoy only a restricted distribution from the Arabian coast to the east coast of India around Ceylon but is of great economic importance only along a section of west coast of India. The entire range of reported geographic distribution of *S.longiceps* along with which, the areas of confirmation as well as those that require confirmation for possible occurrence and those that are doubtful are shown in Fig.2.

2. 2 **Differential distribution on the west coast of India**

Except for the report of oil-saradine eggs from Quilandy (Devanesan, 1943) and Calicut (Nair, 1953b) and description of the same as well as the larval and postlarval stages of *'S. longiceps'* (Nair, 1959) the lack of information on the distribution of eggs and larvae is a keenly felt niche in our knowledge.

Regarding the juvenile and adult stages, a fairly wider picture is available, Hornell (1910b) noticed the shoals appearing along the South Kanara Coast earlier than Calicut and Cochin areas in the south. Chidambaram (1950) remarked that whether the oil-sardine striking the coast first in the south move up northwards gradually or whether the fish occurring in the offshore regions strike the coast straight are matters that require further detailed investigations. Between the two he favoured the former. Panikkar (1952)also reported that oil-sardine and mackerel appear earlier in south and move slowly northwards, their disappearance following a reverse pattern. From the reports of Nair (1953b) on the appearance of oil-saradine along the Malabar and South Kanara coasts, it is noticed that whereas in some years the shoals had appeared roughly around the same time at both the extremities, in some other years, Malabar region had witnessed the entry earlier. In all the seasons, however, the shoals had started disappearing from the northern region first followed by those of Malabar area. Thus, these reports show an uniformity in the earlier

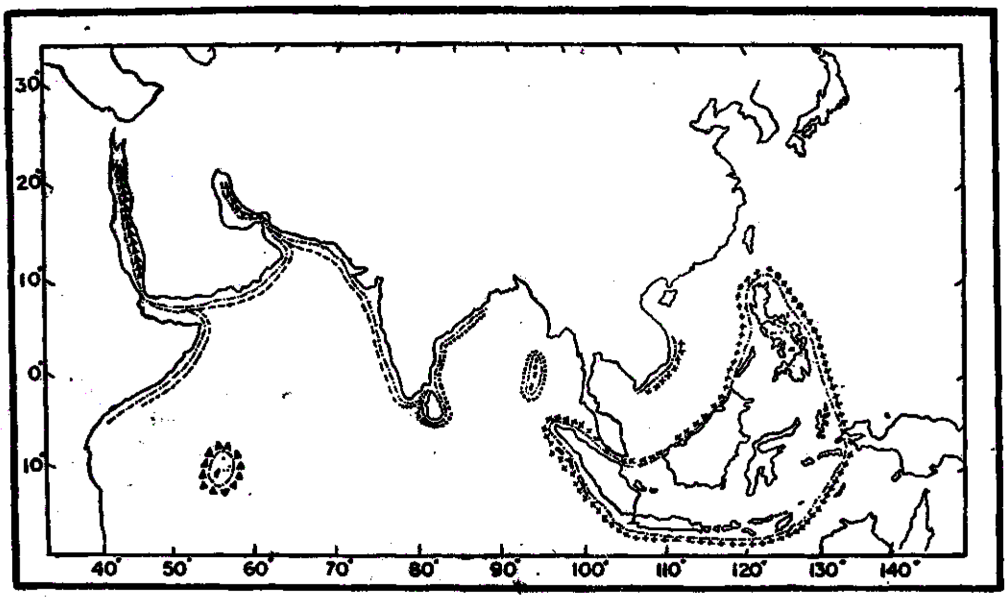

Fig. 2. Distribution of *Sardinella longiceps*.

Dotted dashes represent the extent of reported distribution; *broken line*, occurrence confirmed; *circles*, occurrence under verification; *triangles*, reported occurrence with no records; and *crosses*, occurrence doubtful.

disappearance of oil-sardine shoals in the northern region, but such a feature is not obtained regarding the area of first appearance. Perhaps attempts to draw an overall canvas covering the entire area between Vizhingam and Vengurla for a few years may yield a clearer answer for this.

The fishery, if July-June period is reckoned as the biological year, commences with the entry of spawners following along with which in July-August period are the Juveniles. During September to December, the adults continue to occur in reduced quantity whereas the importance is taken away by the entry of large shoals of juveniles. They, however, get numerically reduced during January-February after which they usually disappear but for sporadic appearance during the next 2-3 months. With the onset of pre-monsoon showers or the regular monsson rains, they enther the inshore waters with the gonads in various stages of ripening from June. The spent-resting adults, on the other hand, appearing occasionally in small quantity along with the juveniles during January-February also disappear during the following months along with them but re-enter for their second spawning together with the virgin spawners.

Various reasons are adduced as causal factors for the above general sequence of events. Hornell (1910b) was of the opinion that this is a normal migration from offshore to coastal waters and *vice versa* coinciding with the prevailing wind conditions. Chidambaram (*op.cit*), observing a gradual increase in temperature from south to north during September to May, accounted it as the probable reason for the gradual succession of appearance of the fish in the like manner and their final disappearance retrogressively from north to south. He pointed out that although the surface water temperature of coastal region is very low in June-July months and hence should attract the fish in greater numbers, the low catch was due to ,the squally and stormy weather which render fishing difficult. Otherwise, it is seen from his records that a temperature of 26^0C to 28^0C is favourable for the inshore migration of the juveniles and with the rise of temperature above 29^0C during March-May period, they disappear to deeper waters. He also related the specific gravity of water, which goes above 1.023 during March-May months, for the disappearance of the shoals, Nair (1959) felt that both the shoreward migration of spawners during the monsoon as well as their outward migration to deeper waters during the post-monsoon months are for spawing purpose. All the workers were unanimous in their expression that the availability of the juveniles in large numbers during post-monsoon months is for feeding on the luxuriant growth of phytoplankton which bloom up during the monsoon and immediately thereafter (Hornell, *loc. cit.*) Hornell & Nayudu, *op.cit.:* Devansean, 1943; Chidambaram, *loc. cit;* Nair, 1953b, to mention a few). Devanesan *(loc. cit.)* discounted the possibility of longitudinal migration either way but preferred to believe it as an excursion from the offshore to inshore grounds and *vice versa* and this, according to him, was due to availability of food items and congenial hydrographical conditions in the inshore waters.

Thus, comparing all the earlier observations together with those recorded in various CMFRI reports for the six-months period, April to September, it appears that evidence are more to presume the shoals of both spawners and juveniles migrating from offshore to inshore are almost simultaneously all along the west coast synchronizing with the period following the outbreak of monsoon. If there is any delay on the onset of southwest monsoon in any area and hence in the reproduction of the resulting congenial conditions, like fall in temperature and phytoplankton production, then there may be a correlated delay in the appearance of fish in that area. In the prevailing rough conditions when fishing activity is slackened, there may be an apparent paucity of oil sardine. But from sardine data available on those days when there was fishing during July-August months, it is possible to believe that the spawners enter the coastal waters most probably due to fall in water temperature and increase in food production, migrating out a little beyond the usual fishing belt (30 m depth) temporarily for spawning but again making a re-entry to complete with the juveniles for feeding. The juveniles enter the coastal waters solely for feeding and due to depleted amount of food items and rise in water temperature during January – March period they gradually mirgrate outside. Probably their disappearance starts first from the northern limits of sardine fishing grounds and ends up in the southern areas later. The chief responsible factors for the offshore-inshore migration, thus, appear to be the strength and duration of southwest monsoon, the changes it brings about in physico-chemical and biological conditions in the coastal waters and probably the location of spawning areas.

It may be worthwhile here to recall the observation of Rosa and Laevastu (*op. cit.)* that *Sardinella longiceps* and *S. aurita* occurring in tropical areas avoid regions were the surface waters are biologically poor and where thermocline is deep. Where there is a seasonal upwelling caused by topography and prevailing direction of current or where the thermocline is close to the surface and where intensive mixing takes place, concentration of these species are found.

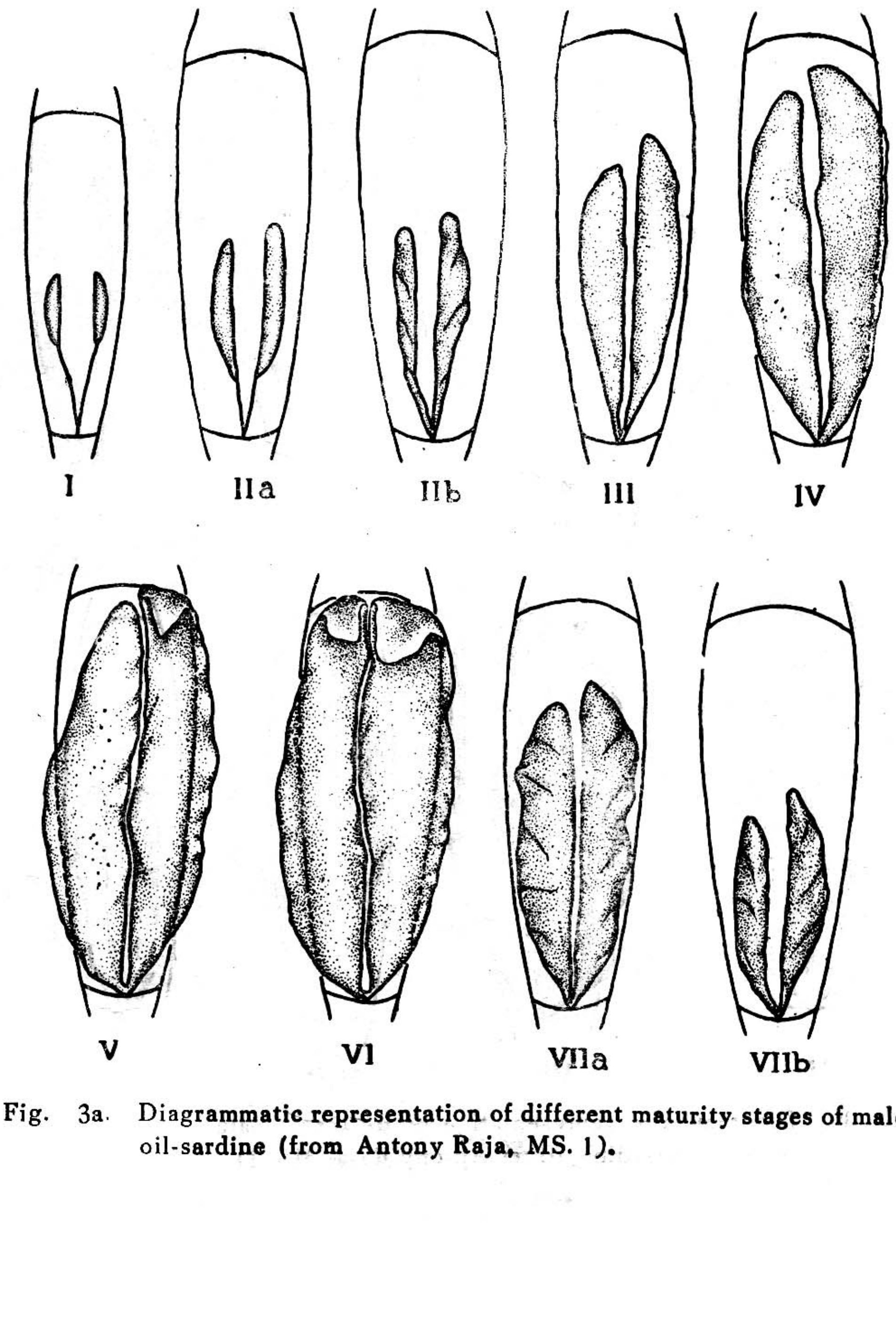

Fig. 3a. Diagrammatic representation of different maturity stages of male oil-sardine (from Antony Raja, MS. 1).

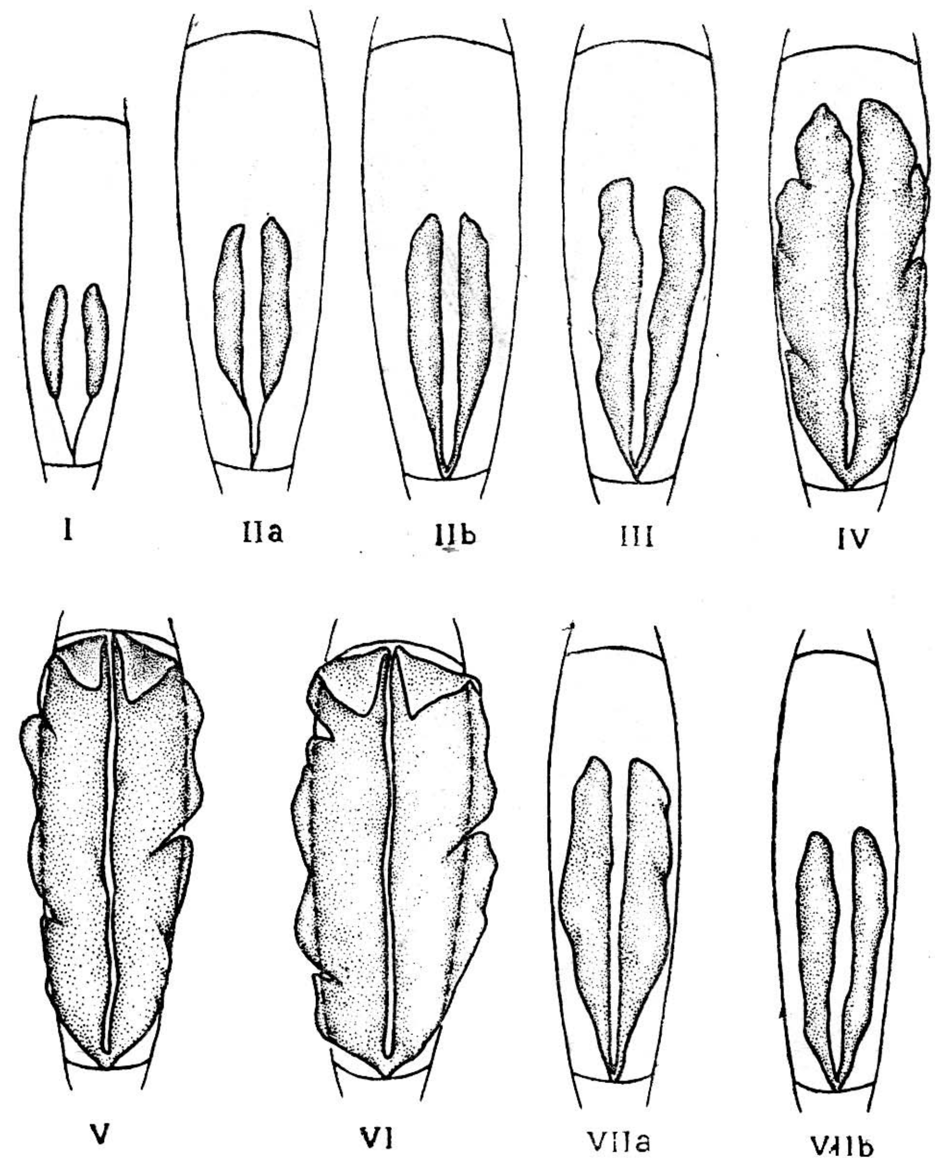

Fig. 3b. Diagrammatic representation of different maturity stages of female oil-sardine (from Antony Raja, MS 1).

III BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3. 1. 1 Sexuality

Oil-sardine is heterosexual. However, an instance of hermaphroditism (Antony Raja, 1963) and various types of testicular and ovarian abnormalities have been recorded (Bensam, 1964 & 1969; Dhulkhed, 1965). George (1959) reported that males can be differentiated externally through a secondary sexual character in the form of a muscular papilla in the cloaca whereas the corresponding structure in the females is membranous and claimed that the method is reliable for sorting out fish above 140 mm length. Sexes can be identified on dissection in fish above 110-120 mm in length.

3. 1. 2 Maturity

3. 1. 2. 1 Stages of maturity

Devanesan (1943) followed Hjort's (1910) maturity key for herring and Nair (1959) adopted the one recommended by the International Council for the Exploration of the Sea (Wood, 1930) for distinguishing the various stages of maturity. Generally the workers in CMFRI are following the ICES scale slightly amended by Blackburn (1941). But Antony Raja (Ms.1), finding the ICES guide as not adequate enough, made and exhaustive study of several factors like general external appearance, extent of gonads in relation to length of body cavity, length and weight of gonads, gonadio-somatic index, maximum and modal size of ova, and their appearance under microscope before finalizing the maturity key. Retaining the same number as in ICES key for reasons of uniformity and clarity of temporal progression, he subdivided stage II into IIa and IIb to differentiate between virgin maturing and spent-resting fish respectively and likewise, stage VII, into VIIa and VIIb to distinguish respectively between partially and completely spent conditions. A diagrammatic representation of the different maturity stages both in male and female is shown in Figs. 3a&b.

TABLE II

Field key of stages of sexual maturity of *Sardinella longiceps*
(From Antony Raja, MS. 1)

Stage	Period of occurrence	External appearance and extent of gonads	
		Male	Female
1	2	3	4
I Immature	Sept. to March-April	Often recognized as a translucent filamentous strand. When easily visible, pinky white in colour, leaf like with long vas deferens. With the duct organs occupy about half the length of body cavity.	Ovaries soft, cylindrical, almost trans-lucent, pink or flesh-coloured. Oviduct fairly long and completely transparent with the result the ovarian bodies appear as detached stubs, short and plump. With the duct, organs extend to about half of body cavity.
IIa Virgin-maturing	April-May	Opaque, pink or white. Vas deferens reduced and thread-like. With the duct, extend to slightly more than half the length of body cavity.	Soft, cylindrical, pink or flesh-coloured. Oviducts thin and thread-like and reduced to not more than 10 mm. With the duct, Occupy slightly more than half of body cavity. Ova not visible to naked eye
IIb Spent-resting	Sept-April	Pink or brownish white, tapering post-eriodly, shrunken and wrinkled. Vas deferens wider than stage IIa. Degree of capacity varies at different regions with semi-opaque patches. Occupy about half or slightly more than half of body cavity length.	Dark red or brownish red or deep flesh-coloured with collapsed and flattened appearance and tapering posteriorly. Surface wrinkled; tunica thicker than stage IIa. Oviducts wider but shorter. Extend to slightly more than half of body cavity length.

1	2	3	4
III Maturing	May-early June	Thickened testes, white. Vas deferens not more than 15 mm. Occupy about three quarters of body cativity.	Turgid, opaque and yellow with granular appearance. Oviducts very much reduced. Extend to more than half the length of body cavity but less than three-quarters. Ova visible to naked eye.
IV Maturing	June to August	Quite massive, creamy white with vas deferens hidden under testes. More than three-quarters of body cavity.	Compact, vascular, bright yellow ovaries. Oviducts not distinct. Occupy more than three-quarters of body cavity.
V Mature	July to Aug-Sept.	Opaque, white, soft and slightly more than the body cavity with their anterior tips folding down. Under some pressure at the posterior end of the testes, spermatic fluid oozes out.	Orange yellow and fully vascular. Tunica being thin, bursts at slight pressure. Slightly more than the length of body cavity with the anterior tips curling down.
VI Ripe	July-August, rarely Sept-Oct.	Very extensive, white in colour and fill the entire space of body cavity displacing the intestines to a fraction of a Space. Both the anterior tips and the Outer edges curve towards interior. Milt extrudes while handling or under slight pressure externally on the flanks of the fish.	Appear as cream coloured cellophane bag filled with boiled sago. At a slight prick gelatinous mass of transparent ova flows out. Ova may be extruded under slight pressure externally or even while handling the fish. More than the length of body cavity and more extensive displacing the intestines to a small space in between the organs.

1	2	3	4
VIIa Partially spent	July to September	Meat-coloured, slightly shrunken with wrinkles on the surface and semi-opaque regions. Leathery in texture. Occupy about three-quarters of body Cavity.	Dark red, either throughout or only at the posterior half. A bit flaccid, shrunken with wrinkles on the tunica. Ovarian lamellae seen as book leaves. Occupy about three-quarters of body cavity.
VIIb Spent	August to October	Deep flesh-coloured, flat, strap-like, shrivelled with translucent patches. Occupy about half the length of body cavity or slightly more.	Elongated, honey-coloured, bloodshot, flabby, limp, flattened and gelatinous with wrinkles on the surface. Tunica leathery. Wide oviduct now discernible. Occupy slightly more than half of body cavity.

An abbreviated field key is given in Table II from which a calendar of maturity stages can be constructed. Stage I is obtained from September to March-April months, IIa in April-May-early June, IV in June-August, and stages V& VI usually in July-August but very rarely in September-October also. The partly spent (VIIa) fish are seen in July-September followed by completely spent condition (VIIb) in August to October which appear as spent-resting state (IIb) in the subsequent months up to next April when re-ripening starts from stage III, thus completing the calendar of maturity stages.

3.1.1.1 **Size and age at first maturity**

Hornell and Nayudu *(op. cit.)* were of the opinion that the oilsardine attain sexual maturity at the age of one year when they measure 150 mm. Subsequently Devanesan (1943) and Chidambaram and Venkataraman (1946) confirmed the finding on size at first maturity but the former, doubting the accuracy of age as determined by Hornell and Nayudu *(loc. cit.)*, was inclined to believe it to be 9 years. Nair (1953b), objecting to the conclusion of the earlier authors, observed that the one year old oil-sardine (100 mm) are indeterminate, two year olds (150 mm) are immature and the three years olds (190 mm) are active spawners. Antony Raja (1967), however, pointed out that Nair's presumption of considerable time-lapse between maturation of gonads to normal size and the actual act of spawning had not been well substantiated and confirmed from his records that the size at first maturity is around 150-160 mm as observed by all the other earlier investigtators. He was also of the view that depending on the growth rate in the previous year of recruitment which might fluctuate according to the prevailing ecological conditions, the size at first maturity also may fluctuate around 150-170mm which he showed later (Antony Raja, MS.4) would be reached at the age of one year. Dhulkhed (1967b) also indicated 160 mm as size at first maturity. Confirmation on the attainment of sexual maturity at the end of one year is forthcoming also from some abstracts available (Bensam, 1968, Radhakrishnan, 1968). Radhakrishna *(loc. cit.)* suggested that the minimum size may be even 120-139 mm. Perhaps this may represent an exceptional case wherein retarded growth has been witnessed. Thus, but for Nair *(loc. cit.)* there is almost an unanimous view that the normal size at first maturity is around 150 mm which is attained in one year.

3.1.3. **Spawning**

3.1.3.1. **Spawning season**

Regarding the spawning season of oil-sardine there seems to be some elasticity in the period as recorded by different workers. Hornell (1910b) tentatively placed the spawning period as extending from June to August which was later corroborated by him and Nayudu *(op. cit.)*. However, the latter hesitated to formulate any explanation for the occurrence of considerable percentage of gonads, half to three- quarters of normal nature size after August. Whether these represented partially spent condition, they were not sure. Devanesan (1943), citing the difficulty of the earlier workers and based on the occurrence of specimens, just spawned as well as in various stages of being spent during September-October period, together with the evidence of planktonic eggs in September, suggested the season to extend from June to October. Nair (1953b) reported eggs as those belonging to oil-sardine in the plankton collections of August and September 1948, November 1949 and August-September 1950. With this record and evidence of spawners being available till the end of November in 1950, he concluded (1959) that the spawning season is a protracted one extending into November with intensity during August and September. As a result of detailed investigation for 5 years, Antony Raja (1967) expressed the view, albeit rarely fishes with gonads had been noticed in October by Devanesan (*loc. Cit.)*, Nair *(loc. cit)* and Antony Raja (1967), they may better be treated as cases of exceptional nature,when, perhaps due to some unfavourable ecological conditions (as was the case in 1959), the delayed spawning season might have extended into October and also indicated that the maximum duration of the spawning season may be taken as from June to October with intense activity during July and August months. With comparable data on other aspects of the biology of the fish, he made a slight modification, expressing that the intense activity may take place during any of the two months within June to August period (Antony Raja, MS 3&4). Moreover, it is seen that the average percentage gonad index rises steeply during June-July, reaches the peak in August only to fall in September as steeply as it has earlier risen up with a further decline during the subsequent months due to resorption of remants of ova from stage VIIa to VIIb (unpublished data). Prabhu and Dhulkhed (1967) believed the spawning to extend even to December which was, however, questioned by Dutt (1968) as unauthenticated. The present author has been engaged in oil-sardine investigations since 1959 and except for October of that year, no instances of even ripening gonads were noticed beyond September. Neither is there any record of small sized juveniles entering the inshore waters after October to suggest spawning as to extend beyond October (Antony Raja, MS.3). Hence, June-October period can be safely assumed as the season of spawning with the month of October as a rare possible extreme-limit and with activity intense during the first 3 months depending on the availability of ideal conditions for the act.

3.1.2.2. **Spawning frequency**

The size distribution of the intraovarian eggs is generally treated as to roughly indicate the frequency of spawning. Examinig material belonging to stages IV to VI, Nair (1959) found an unimodal distribution of maturing stock of ova in stage IV at 0.45-0.47 mm. In stage V, his figure shows a small percentage of transparent ova getting differentiated and forming a modal size at 1.00-1.02 mm whereas the prominent mode stands at 0.49-0.51 mm. In stage VI, there is a distinct biomodal distribution, the more advanced one of transparent ova at 0.96-0.98 mm and the less advanced yolked ova at 0.41-0.43 mm. In spite of this picture, he favoured the view that the eggs of both modal groups are shed in one spawning. However, subsequent detailed studies on intraovarian eggs from stages IIa through IIb (Antony Raja, 1967) showed that even at stage III, the maturing stock of ova shows differentiation into 2 groups which progressively register growth during subsequent stages till stage VI. The rate of progression is comparatively more rapid in the more advanced mode as a result, in stage VI, just before spawning, it stands well differentiated around 0.89 to 0.91 mm, whereas the less advanced mode shows around 0.44-0.46 mm. Since in a partially spent condition (VIIa), the modal size of remanants is at the same level, as the secondary mode in stage VI, namely, 0.44-0.46 mm, he advanced the case of fractional spawning in the oil-sardine. Fig.4 shows the ova diameter frequency in different stages of ripening and resorption of ova. Analysing further indetail all the evidence cited by earlier workers on different fishes to advocate the theory of multiple spawning for an individual fish within the season and from evidences offered by his own data, he concluded that chances are very remote for a secondary spawning but more for the second batch of maturing ova to disintegrate and get resorbed. The observations of Dhulkhed (1967b) lend weight to the above findings in as far as the bimodal distribution of maturing ova from stage IV onwards. But, advancing the methodology of recoding the ova diameter measurements under high-power magnification as of greater utility value, Dhulkhed *(loc. cit)* expressed the view that eggs of the more advanced mode show differential ripening and consequently are released in 3-4 batches during the season. On this opinion, Antony Raja (MS.6) observed that Dhulkhed's own data, at best, may indicate release of eggs in a series of spurts within a spawning act but whether such data offer any evidence for multiple spawning for an individual fish within the same season is highly doubtful.

While according to Nair (1953b) oil-sardine spawn only once in their lifetime, Antony Raja (1967) agreed with the findings of the pioneer workers (Hornell and Nayudu, *op. cit)* that the fish are able to spawn twice in their lifetime. The rarity of spent fish of recovering spawners from September onwards probably indicates that they reach the end of their fishable lifespan after going through two spawning seasons.

3.1.3.1. **Spawning time**

The records of Devanesan (1943) appear to indicate that spawning takes place in the night. His record of planktonic eggs around New Moon day and the observations of Devanesan and Chidambaram (1948) that the fish spawn a few nights before and after New Moon suggest, perhaps, a lunar relationship to spawning. The records of stage V-VI

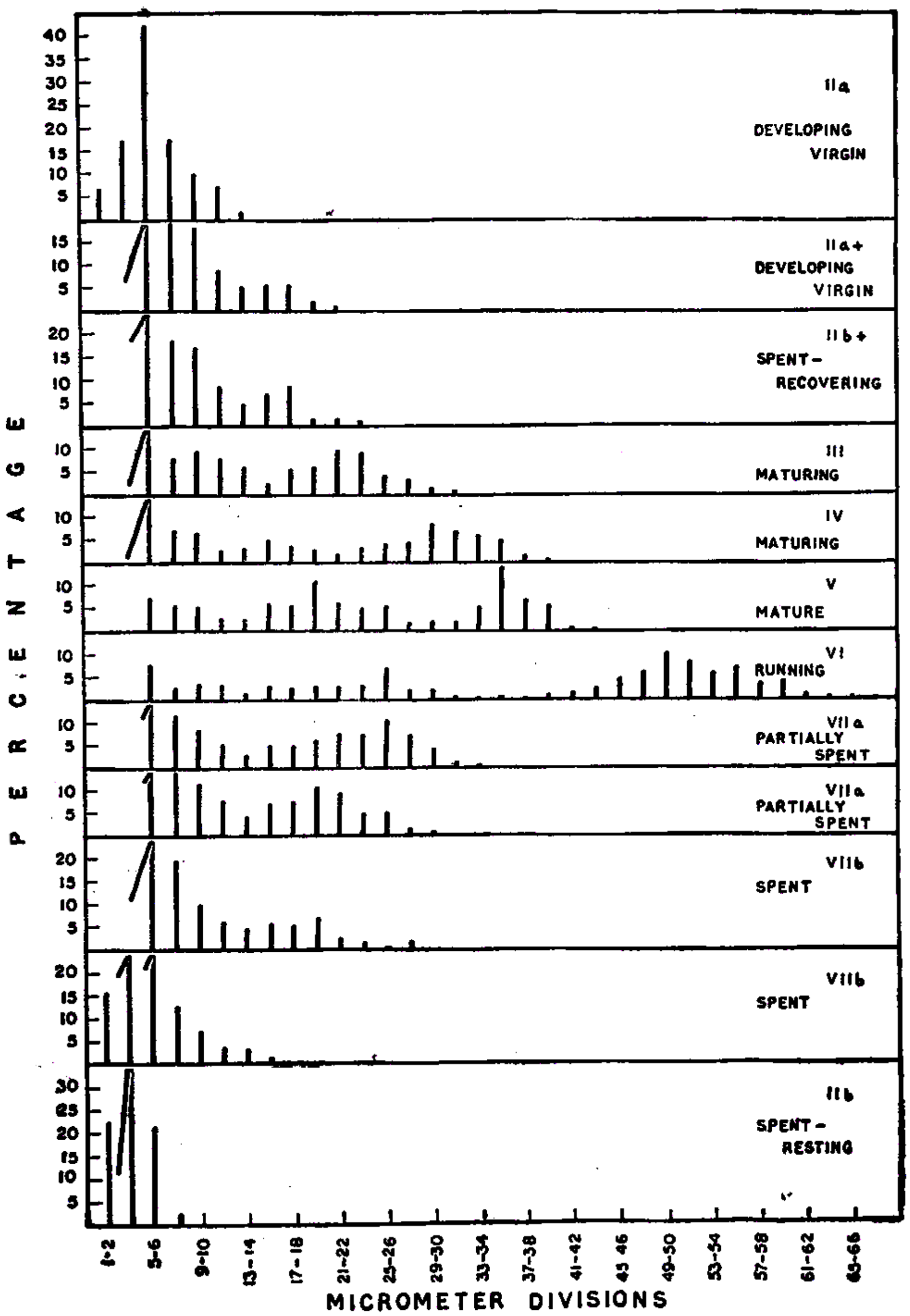

Fig. 4. Ova-diameter frequencies from stage IIa to IIb. (from Antony Raja, 1967)

and recently spawned stage, VIIa, with the present author during the New Moon week and also the records on oil-sardine fry, whose growth could be back-calculated to the same period, appear to support the above view (Antony Raja, 1967 & MS.4).

3.1.3.4 **Spawning ground**

Through collections of oozing specimens and planktonic eggs, Devanesan (1943) indicated the existence of spawning off Quilandy, near Calicut. This is the only direct evidence, along with, perhaps the report of Nair (1953b) on the planktonic eggs believed to belong to oil-sardine. That there is likelihood a spawning ground in Calicut area at about 15 km from the shore is indirectly indicated by the availability of oil-sardine fry in Tanur-Tellicherry belt at various depths ranging up to 30 meters (Horenell, 1910b; Nair, 1953b; Antony Raja, 1967 & MS. 3&4). Such indirect evidence are also available off Mangalore(Prabhu and Dhulkhed, *op. cit.)*. Dutt (1968) appears to have given no importance to any of these reports for he had remarked, “there are no records of planktonic eggs and prolarvae of oil-sardine. In fact, we have little information on spawning seasons and grounds of the important fishes of India.”

3.1.4 **Fecundity**

Devanesan (1943), he and Chidambaram (1948), Nair and Chidambaram (1951) and Nair (1959) gave an estimate of 7000-80000 eggs as the average fecundity of oil-sardine. In view of the tentative nature of this estimate which was based on rather meager data, more detailed and statistically orientated studies were presented by Antony Raja (MS.5). The summary of his finding is the relationships of fecundity with length as well as with weight show significant differences between the years in the adjusted mean fecundity and for a given length or weight, fecundity variations are considerable which are believed to be of biological origin (*vide infra* sec. 3.1.6.). While the heavier of fish of identical length are more fecund, it cannot be said that among fish of identical weight, the shorter have a higher count of ova. Regarding fecundity-age relationship, the older 2-years old fish show higher fecundity values with 45000 ova as compared to the younger 1-year olds with 32000 ova. Among the virgin spawners, which make a major contribution to the spawning stock, there were differences in the fecundity count between the years and among them the fast-grown fish produce more ova than the slow-grown ones. It is estimated that within a range of 27000 to 57000 ova as related to increasing size, an overall average of 37000-38000 ova are produced per individual fish and about 750 million ova per metric ton of adult female biomass *(vide* Table III). Compared to these figures, the reason for a very high estimate of fecundity as obtained by earlier workers is shown to be due to possible inclusion in the count the smaller yolked ova also belonging to the secondary mode but which has been shown to get resorbed after spawning *(vide supra* sec. 3.1.3.2.). It is felt that what ultimately determines the total egg production depends on the strength, size and age composition of the spawning stock and the relationship between fecundity and fish size which is not only conditioned by the somatic state but is also related to other biological idiosyncrasies of a particular generation which may be in turn influenced by environmental changes.

TABLE III

Calculated values of weight in gm and fecundity in
thousand of ova at different lengths in mm.
(From Antony Raja, MS.5)

Length	W	F		No. of ova per gm body weight
		length basis	weight basis	
150	31.3	27.1	28.4	894
160	37.8	31.9	32.4	857
170	45.3	37.1	37.6	830
180	53.6	42.8	43.3	808
190	63.0	49.0	49.7	789
200	73.3	57.0	56.8	775

Recently from an abstract available, it is seen that Balan (1969) has obtained a fecundity count of about 48000 ova. This is an additional evidence to show that the estimation of the earlier investigators was rather on the higher side.

3.1.3. **Egg structure**

Regarding the maximum and modal size of intraovarian eggs just before spawning, there is a very close similarity in the records of Nair (1959) and Antony Raja (1967), for, while from the former's report they are found to be 1.20 and 0.97 mm respectively, from the latter's they are 1.23 and 0.90 mm respectively. The completely transparent and spherical intraovarian egg has a shining yellow oil-globule (0.09-0.13mm) which is occasionally broken up into 2 or 3 droplets (Antony Raja, MS.1). Regarding the planktonic eggs, Devanesan (1943) did not give any measurement for those ova which he tried to fertilise artificially, but instead had given the range from those collected from plankton which was 1.02 to 1.36 mm within which the yolk alone ranged from 0.72 to 0.92 mm and the oilglobule, 0.1 mm. The latter range of yolk diameter shows the eggs to be rather smaller compared with the intraovarian transparent eggs for, after coming in contact with water and after fertilization, the egg is likely to swell up with the formation of a wide perivitelline space. Since the yolk starts getting reduced only after the embryo is formed, the average yolk diameter may be expected to be at least around 0.9 mm. Nair *(loc. cit)* reports an average diameter of 1.4 mm with the yolk itself measuring 0.8 mm and the oil globules 0.1 mm. It would have been much helpful had he indicated the number of ova and the range in size in the collection. While Devanesan (*loc. Cit).* stated there was no difference between the eggs artificially fertilized and those collected from plankton and hence, he presumed them to belong to oil-sardine, Nair *(loc. cit.)* did not show the criterion under which the planktonic eggs were identified with those of oil-sardine. It could have belonged to any species of other sardines, for example, *Sardinella fimbriata* (collection of samples on this species with this author appears to indicate that the spawning season of this species may be coinciding with that of oil-sardine off Calicut).

According to Delsman (1926), the diameter of pelagic egg of *Clupea fimbriata* (= *S. fimbriata*) ranges between 1.4 and 1.5 mm, the yolk itself measuring 0.8 mm and the oilglobule 0.1 mm. Bapat (1955), identifying type H eggs of Mandapam area provisionally as *S. fimbriata*, gave the range as 1.328-1.339 mm with the oilglobule measuring 0.099 mm. Thus, the information contained in these two references on *S. fimbriata* reveals a marked similarity to the eggs reported by Nair *(loc. cit).* So unless the developmental stages are followed to that level when they can be definitely related to the concerned species, the assumption that it belongs to one species and not to the other cannot be sustained. In this connection, it may be significant to point out that Nair *(loc. cit* p. 345) himself observed "….. attempts at artificial fertilization proved successful but the developing eggs could not be reared beyond the cleavage stages since good sea water was not available at that time". Hence, confirmatory evidences appear to be necessary to place the identity of egg beyond doubt.

Kuthalingam (1960) also described the egg (1.7mm) and further developmental stages of a species attributed to oil-sardine. But his account appears to relate to some other species since even the laboratory-reared juvenile from such eggs measuring 28.7 mm does not resemble *S. longiceps* when compared with roughly similar sized individuals collected by this author. Moreover, instead of the characteristic long head of oil-sardine (about 3 in body length), the figure of juvenile given by him shows a much smaller head-nearly 5 times in body length.

3.1.3. **Factors affecting reproduction**

It is well known that the strength of any year class is closely linked up with the success of spawning and survival rate of the spawn that contribute that year class. When there are any factors, physiological or environmental, that are malefic for the normal ripening of sexual products and spawning as well as subsequent larval survival, then, that particular year class will turn out weak and if a commercial fishery depends mainly on this year class, its failure can be easily predicted. Since it has been shown recently by a few workers *(vide infra* sec. 3.2.2.) that the commercial fishery for oil-sardine is chiefly composed of 0-year class, the success or failure of the fishery stands predetermined during the spawning of the same season. Hence *a posteriori*, the causal factor has to be traced to the time and process of reproduction.

Antony Raja (MS.1) reported the incidence of vascular hypertrophy and pre-ovulation follicular breakdown in advanced ovaries, a process which results in the rupture of follicles and disintegration of the already differentiated ova. This he related to atresia reported in many fish ovaries and the eggs involved, *corpora atretica*. While this feature is not rare in oil-sardine ovaries, the percentage of fish experiencing this phenomenon and its extent varies between years. He showed that it was highest in 1963, followed by lesser percentage in 1962 and 1961 and almost negligible in 1960. This feature coupled with the evidence of low production of mature ova in1963 ovaries led him to suspect that 1963 spawning would not have been a successful one which might have, in turn, had baneful effects on the fishery (Antony Raja, 1967). This was subsequently proved to be true by the poor landings in 1963. In 1965 also a similar phenomenon of heavy follicular breakdown was noticed and inspite of rare but frequent availability of small sized juveniles, it was forecast then that the ensuing fishery for the juveniles would not be good (report of CMFRI for quarter ending September. 1965). If on the other hand, 1965-66 season was found to have witnessed a rich fishery, it was not due to the strength of the usual new brood of juveniles of 0-year class but due to older 1-year old adults, a rather unusual feature (Antony Raja, MS.4). Since atresia results in the reduction of the number of ova ready for release, it has a profound influence on the potential egg stock and this was shown through fecundity studies also (Antony Raja, MS.5). It was further observed in the latter investigation that on an average, about 10% of ova are normally lost due to this physiological phenomenon, incidence of which was pronounced in 1963 and 1965 and almost insignificant in 1960 and 1964.

Since it would be environmental factors that may be responsible for this atresia of mature ova, an attempt was made by Antony Raja (MS.4) to study the amount of rainfall during the spawning season for, he observed an erratic monsoon during those years of intense follicular breakdown. It turned out to be a significant feature to find that in the year 1963 and 1965, the total rainfall during June to September at Calicut for the spawning fortnights (a week before and after New Moon Day) and the average daily rainfall for that period were considerably lower than the other years. While in 1961, 1962 and 1964, the average daily rainfall for the period reckoned was about 30 mm, those for 1963 and 1965 were 13 and 19 mm respectively and hence it was provisionally suggested that the erratic, discontinuous and poor monsoon rain may have deterlmental effects on the ova production which was subsequently confirmed through estimations of fecundity (Antony Raja, MS.5).

At the time of writing this report (September, 1969) it is noticed that the said phenomenon is repeating itself this year also. During July-August period, examination of gonads had shown that atresia has been proceeding on a large scale and by late August, gonads have already shrunk to stages VIIa and VIIb, indicating that any major spawning in the ensuring months is very unlikely. The total rainfall at Calicut for the spawning fortnights in June, July and August were 212, 250 and 107 mm respectively, yielding a daily average of 12.6mm only, an amount similar to that noticed in 1963. Hence, the spawning picture for this season is rather alarming and the prospects for the ensuing fishery for juvenile oil-sardine rather bleak. If this forecast proves correct, then, it can be stated without any hesitation that it is the weakness of southwest monsoon that brings in the suspected harmful effects in the spawning potentialities of the oil-sardine.

Another feature that has not been gone into detail, but whose possibility cannot be ruled out is the phenomenon of ‘adolescence’ in the oil-sardine. Although it is unlikely as was felt by Antony Raja (1967) that in tropics the fish reaches maturity but does not spawn for want of ideal conditions and instead resorbs the maturing ova, certain peculiar features presented by the ovaries in 1965 and 1969 appear to indicate that the possibility has to be looked into more carefully.

It would be worthwhile, hence, to combine the meteorological data on rainfall with the oceanographical data for a period extending from 1959 to 1969 and attempt a careful study of the various environmental features resulting from the vagaries of monsoon intensity during June-

August months with special reference to the spawning fortnights so as to identify which of the many abiotic factors would have caused the failure of spawning in 1959, 1963, 1965 and 1969.

3.1. **Growth**

3.2.1 **Larval**

Although descriptions of larval stages of oil-sardine are given by Nair (1959) and Kuthalingam *(op. cit.*), in addition to the reasons stated earlier, since the rearing and identifying methodology has not been indicated by the former, the larval history may have to be considered obscure still.

3.2.2. **Juvenile**

Age and growth studies have been largely based around the length frequency method with a few contributions on the growth rings of scales and otolith. Among those who had employed the first method, Hornell and Nayudu *(op. cit.)* estimated a growth of 125 to 140 mm in 6 months and 155 to 170 mm for one year when the fish attain first maturity (the figures given by the authors in standard length are converted into total length based on the conversion table prepared by this author (ms) to facilitate comparison). Chidambaram *(op. cit.),* on the other hand inferred a growth of 100 mm at the end of first year, 145 mm at the end of second year and 183 mm at the end of third year. Since he referred to even fish around 150 mm as immature, it is presumed that he favoured the completion of juvenile phase during the third year. These observations were supported by Nair (1953b) who estimated 100, 150 and 190 mm for the first three years of life, when he too believed the fish mature for the first time. The contention of these authors that the commercial fishery of juveniles that measure about 100 mm is composed of one-year olds and those between 100-150 mm are in the second year found agreement with the later workers like Sekharan (1965), Prabhu and Dhulkhed (1967), Sekharan and Dhulkhed (1967) and Bennet (1969) who, however, were of the view that juvenile history is completed before the end of second year, thus contradicting the age aspect alone of the earlier investigators, namely, Chidambaram (*loc.cit.)* & Nair *(loc. cit)*. Thus, from the past studies mentioned above, it is clear that there are two distinct views, that of the pioneer workers considering fish of 100-140 mm as 0-year class and that of the later workers feeling it as 1-year old, the dispute being the estimation of growth during the first year of life.

TABLE IV

Mean length in mm at different age in months
(From Antony Raja, MS.4).

Age	Length	Age	Length	Age	Length	Age	Length
1	66.1	6	129.7	15	159.2	24	178.7
2	110.7	9	141.6	18	165.0	27	182.7
3	117.1	12	150.3	21	170.8	30	185.7

Reanalysing some of the published data of the earlier workers, Antony Raja (MS.4) pointed out that their own data can be subjected to an interpretation different from theirs and remarked that none of the later workers had advanced any reason for treating the modal group of 100 mm and more as one-year old, as their estimation was purely based in the group assuming importance in the annual picture which is inevitable, since the fishery for September to December period being the peak, the data collected during these months get their importance projected. The availability of lesser-sized fish discontinuously on a few occasions only during July to October period probably led the previous investigators to presume that they disappear completely only to appear again after a year. Why these smaller fish should disappear when the inshore area during the post-monsoon months offers a congenial environment for and is stormed by the other size groups was, however, not explained away. Antony Raja *(loc. cit.)* further showing that there is such a rapid rate of growth during the first two months that about 70% of growth of the first year is attained by them, estimated from his own data that the fish reach a length of about 60-65 mm in the first month and about 95-110, 110-125, 125-140 and 150-160 mm at the end of 2,3,6 and 12 months respectively, when first maturity is attained. The mean sizes attained during the juvenile phase and thereafter as taken from his data are

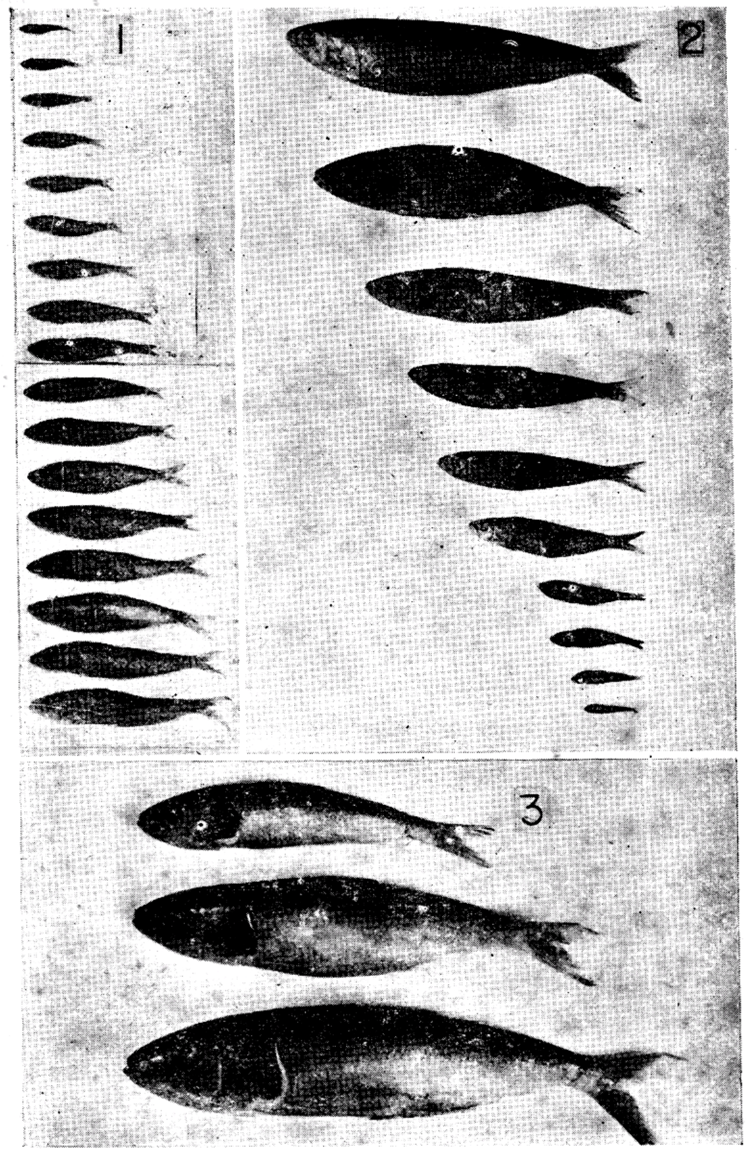

Plate I. Age and growth of oil-sardine.

Photograph 1. Growth during the first three months. (Fish between 30 and 110 mm are arranged at 5 mm intervals.)

Photograph 2. Sizes at 1, 2, 3, 4 weeks, 2, 3, 6 months, 1, 2 and 3 years respectively from bottom to top (30 to 200 mm groups).

Photograph 3. The three successive year classes, namely, 0, 1 & 2, met with in the fishery (120, 150 & 180 mm groups).

(Photographs 1 & 2 from Antony Raja, MS. 4 and Photograph 3 from Antony Raja & Hiyama, 1969)

given in Table IV. He drew attention to the fact that the past workers did not recognise the possibility of this rapid rate of growth during the first two months, obviously for lack of sufficient data on fish less than 100 mm and hence surmised the reason for a sudden change in the picture of dominating modal group to the disappearance of the smaller fish whereas the change in modal size is actually caused by the transformation of the smaller sized group due to high rate of growth. Recently it is known that corroborating evidences are available through the studies of Bensam (1968) and Radhakrishnan (1968) (both abstracts) who have observed that the juvenile phase is completed within the first year when the fish register a very rapid progress of growth. The growth attained during the first three months and for the subsequent period up to 3 years is shown in Plate I (photographs 1 & 2).

Apart from the length frequency studies, other lines of investigations using hard parts for estimating growth were also attempted. Hornell and Nayudu *(op. cit).,* citing evidence from scale readings to corroborate their findings, reported that no ring could be detected in fish less than 140 mm before May after which one ring was clearly discernible. They indicated that there was considerable variation in shape and markings of scales from different parts of the body and noticed a good proportion of scales without any ring formation even in fish believed to have crossed one year. They, however, found the scales from the middle of the body below the dorsal fin gave the best results and believed that due to cessation of growth caused by the paucity of coastal plankton during December-April period, growth checks were formed, which were comparable to ‘winter rings’ of related European fishes. Devanesan (1943), on the other hand observed the first ring in 65 mm long fish and one to six rings in fish of 87 mm. He however relied on the six rings believing that in the other scales the rings were obliterated and felt that the fish would be 6 years old. He inferred 9 rings for a fish of 150 mm implying 9 years at first maturity. But, as he himself admitted that interpretation of so many rings was beset with difficulties and as rightly pointed out by Nair (1949) and Chidambaram *(op. cit.)*, Devanesan was likely to have misinterpreted the false rings resulting from inadequate methods adopted. While Hornell and Nayudu *(loc. cit.)* could not detect any definite lines of growth on the otoliths even when ground to thin flakes, Nair *(loc. cit.)* was able to use them for age determination. Although a maximum of 3 rings was recorded by him, in the majority of cases only two were noticed. He was of the opinion that the growth rings were of annual formation during cessation of growth between December and April as Hornell and Nayudu (*loc. cit.)* contended. Working on scales, Balan (1959) observed that one, two and three rings make their appearance at 90, 120 and 150 mm groups respectively and believed the ring formation taking place during May-July. However, from the details presented by him, it is seen that on an average 150 mm group is characterised by only one ring and 170 mm and above groups by two rings. Making further detailed study, he (1968), however reported that the average length attained at age 1 is 143 mm.

Sekharan (1965) made a significant remark that the length frequency data suggested the possibility of there being two broods in a year. Antony Raja (MS.4) confirming this, indicated that there maybe in some years 3 broods and perhaps, even a still smaller, weaker fourth brood resulting from late spawners, representing the offsprings of 4 spawning months during the season, of which, however, only two manifest themselves strongly in a year in the juvenile fishery which may be from any two spawning months of June to August period. The only difference between Sekharan's suggestion and the findings of Antony Raja is that whereas the former believed the impact of the broods to be felt in the fishery after completion of one year, the latter showed they are recruits from the same year's spawning. The latter also was of the view that the first born have the fastest rate of growth so that what is attained by them during the first 3 months is attainable by the later recruits only in 6 months due perhaps to crowding and competition. Commenting on the bimodal distribution of the incoming broods of juveniles, which most probably influenced some of the earlier workers to consider them as two successive year classes but which, in fact, get merged into an unimodal nature as the fish reach the end of their first year of growth. Antony Raja *(loc. cit.)* observed that this reduction in difference in size between the two groups with passage of time is brought about as a result of growth compensation, a tendency for smaller fish to grow more rapidly than the larger fish of the same age group as the group gets older and hence the initial slower growth of the later recruits is compensated by the time they pass through the spawning season in the subsequent year.

Antony Raja (MS.4) could find as rough alignment of various modal groups recorded all along the west coast with the general pattern of growth seen at Calicut. Broadly speaking, he was of the opinion that the growth increments 1) are at their peak during June to September, 2) slacken during October to December, 3) fall on a plateau during January to March and 4) again develop from April onwards only to get accelerated from June. The probable reasons for these variations may be respectively 1) the physiological tendency of greatest growth rate during early stages of life combined with abundant resources of food supplyto support, 2) natural slackening of growth, crowding and competition for depeleted food crop,3) paucity of favourable food items and 4) reserve resources of muscular fat and possibly more congenial environment away in deeper waters along with some connection between simultaneous gonad and body growth.

That crowding and competition for food supply may account for growth variations can be seen from the records of fastest growth rate among the juveniles in 1963-64 season coinciding with the failure of the fishery and hence thinning of the stock as compared to the slowest growth in the seasons 1961-62 and 1964-65 when the fishery was exceptionally good with thicker concentration of the stock (Antony Raja, MS.4).

3.2.3. **Adult**

Since it has been shown that the juvenile history is completed just before the end of the first year, it would be sufficient to summarise the observations of earlier studies as to the subsequesnt annual growth increments. Hornell and Nayudu *(op. cit)* estimated a growth of 190 mm at the end of second year of life which represents an addition of 20 to35 mm during the year. From the studies of Chidambaram *(op. cit)* and Nair (1953b), it is seen that about 30-40 mm and 20 mm would be added in the subsequent years of growth. It is generally noticed that an additional 20-30 mm is the normal contribution during the second year (Sekharan, 1965; Balan 1968; Antony Raja, MS.4) but even lesser than this is not ruled out in those fish that experience phenomenal growth during the first year when the fishery was poor as in the case of 1963 year class (Antony Raja, *(loc. cit)*.

Attention was drawn earlier that the juveniles have 4 phases of growth variations in the first year of life. This pattern is repeated in the second year also, though the corresponding growth increments are markedly low. Thus, from the recrods of Antony Raja (1967 & MS.4), it may be noticed that the virgin spawners register an acceleration of growth along with ripening and shedding of sexual products during July to September period. From the fact that this growth increment amount to about 10-20 whereas for the remaining 9 month period it is about another 10 mm only, it can be easily concluded that unlike many fishes, the growth of oil-sardine is not impaired by the process of maturation and the act of spawning.

At the completion of second year when they go through their second spawning, the recovering spawners also record some growth increments, but it is still lesser than in the case of virgin spawners. During the second season of spawning the adults appear to add about-5-10mm. After this, the growth during the third year is rather negligible perhaps to an extend of another 5-10 mm. When they fade into insignificance in the post-spawning months, having to compete with both the incoming strong 0-year class as well as the 1-year olds left over after first spawning, they may be around 180 to 195 mm in length, which may represent an increase of about 10-20 mm during the third year depending on how long the group remain distinctly to be identified in the fishery (Antony Raja, MS.4).

3. 1. 3 **Longevity**

Hornell and Nayudu *(op.cit.)*, based on the scarcity of individuals a few months after their second spawning inferred that the normal life span of the oil-sardine is $2^1/_2$ years. The estimation of Devanesan (1943) as 14 years can be discounted for reasons mentioned earlier. The span of life has been indicated to be 4 years by Chidambaram *(op. cit.)* and Nair (1953b). Antony Raja (MS.4) contributes favourably to the view of the pioneer workers that the normal *fishable* lifespan is only about $2^1/_2$ years. If the ring formation in the scales and otoliths is an annual occurrence during December-April period, then the studies of Nair (1949) and Balan (1959) showed that the oil-sardine live between 2 and 3 years normally, a feature which only corroborates the view of Hornell and

Nayudu *(op. cit)*. However, the possibility should not be ruled out that fish may live, though rarely, to complete 3 years and spawn for the third time, but this will have to remain presumptive till clearer evidences are collected.

3. 2. 5. **Greatest size**

TABLE V
Greatest sizes on record

Source	Maximum size (mm) Size group
Hornell & Nayudu, 1924	202
Devanesan, 1943	190-199
Chidambaram, 1950	220-229
Nair, 1953b	210-219
Sekharan, 1965	220-224
Rosa & Laevastu, 1960	220-229
Antony Raja, MS.4	206

The greatest size or groups as taken out from different workers are listed in Table V. It is seen that while the maximum size obtained is found to be generally between 200 and 210 mm, the records of Chidambaram *(op. cit.)* show the 210 mm group (210-219mm) accounting for 44 fish out of 9473 fish (about 0.005%) and one in 2210 mm group. Sekharan's data (1965) for 220-224 mm group relate only to one month in 1956, while otherwise there is not much incidence of fish beyond 210 mm. Employing von Bertalanffy's growth equation and Walford's transformation of growth curve for data on mean size at successive age intervals of 3 months, Antony Raja (MS.4) obtained an asymptotic length of 209.8 mm and observed that instances of fish longer than 210 mm are of very rare occurrence. The greatest size recorded by him is 206 mm which is shown in photograph 2 of Plate I as to represent the 3-year old fish. The annual report of CMFRI for 1967 showed that the asymptotic length from different places along the west coast varied between 168.7 mm and 180.9 mm, the lowest estimate coming from Cannanore data and the highest from Calicut. Since the data analysed for these different places refer to different seasons, variations in growth parameters are involved and hence may not be of comparable nature unless, of course, homogeneity of data is declared. However, a subsequent report of CMFRI for 1968 shows that the asymptotic length for the entire west coast can be taken as 207 mm.

3.3 **Feeding**

Hornell (1910b) surmised a phase of bottom feeding habit for this pelagic fish during October to December months based on the occurrence of flocculent muddy unrecognisable matter in the stomachs. Hornell and Nayudu *(op. cit.)* confirming this, indicated that the flocculent scum consisted of humus embedded in which were diatoms, dinoflagellates, copepods and other minute organisms. The unrecognisable matrix formed a very large percentage during October to December and they were of opinion, comparing their plankton notes, that this mass of debris may be composed largely of infusorians and dinoflagellates plus a varying proportion of the light flocculent vegetable debris brought down by the river floods. They contended that the oil-sardine browse on the settlement of these as semiflocculent mass at the sea bottom. In general, they found three phases of feeding habits, the first from May to August, characterised by diatoms, the second from September to November, dominated by dinoflagellates and the third from December to April which was essentially a miscellaneous one made up of diatoms, influsorians, copepods, larval bivalves and heliozoans. Devanesan (1943) on the other hand, opined that bottom feeding could not be a regular one but may be one of occasional occurrence when foraging conditions on the surface were not favourable for, he recognized that the flocculent scum was nothing but the digested form of diatoms and other planktonic organisms. The absence of sand grains in the stomach contents of the fish of Malabar coast as contrasted to their presence in large quantities in the sample of Bombay coast made him to infer that in the latter region bottom feeding was a possibility but discounted it for the former. He was of the opinion that the oil-sardine is largely a surface feeder on phytoplankton, chiefly the diatoms, *Biddulphia, Fragillaria, Cosinodiscus* and *Thallassiothrix.* While Venkataraman (1961) referred to the presence of sand grains in the stomach contents of oil-sardine as accidental, Bensam (1967b) felt that the inference of Devanesan *(loc. cit.)* on bottom feeding of Bombay specimens was questionable since the gear and mode of capture involved had not been taken cognizance of. However, from observations on shoaling behaviour (Balan, 1962), it is seen that movements near bottom appear to be a common feature during October to January within which period Hornell and Nayudu *(loc. cit.)* had suggested bottom feeding.

There appears a single instance of difference of opinion on the occurrence of fish eggs in the food, for while according to Devanesan (1942) the fish fed regularly on them off Calicut, John and Menon (1942) could not find the same to be the case of Trivandrum coast. They indicated that the fish is essentially a phytoplankton feeder, a view generally held by all the subsequent investigators as well. Thus, Chidambaram *(op. cit)* confirmed that the food of oil-sardine is mostly a diatomaceous one with dinoflagellates and copepods also contributing. Nair (1953b) also said that the chief food of both juveniles and adults is from phytoplankton elements, of which he found *Fragillaria oceanica* as the most important, the fluctuations of whose abundance coincided with the fluctuations of the fishery. Instances of deviations were also not wanting in his observations like the presence of exceptional numbers of cladoceran, *Evadne tergestina* in the stomach of mature fish and the polychaete, *Prionospio pinnata* in the juveniles. While generally he witnessed good feeding activity throughout in all the fish, confirmed later by Dhulkhed (1964) and Kagwade (1967), he found that just at the time of spawning there was cessation as evidenced by empty stomachs in active spawners. While the immature, adults and spawners were found to feed mostly on phytoplankters, there was one significant reference in his observations which showed that the food of very small juveniles of 70 mm modal size consisted mainly of copepods, copepodites and cladocerans suggesting a carcinivorous habit at that phase of life, which was later found to agree with the studies of Bensam (1967b), who observed that while the main food of juveniles in 50-130 mm group came from crustacean contribution, there was tendency in them to feed more and more on the phytoplankton as they grew longer and that the foraging of the adults above 140 mm group was chiefly on phytoplankton. He related this change in the feeding habits to either or both of two cases, namely, 1) that the carcinivorous tendency of the juveniles may be brought about by an indirect selection of larger items by the less efficient sieving mechanism of the gill rakers, while the adults with the mechanism well developed become predominantly phytoplanktonic in habits and 2) that the juveniles are chiefly predators on planktonic crustaceans and the adults on phytoplankton. Dhulkhed *(loc. cit.)* agreed with the earlier workers on the Malabar coast that, off Mangalore also the oil-sardine is chiefly a phytoplankton feeder. From his data, it is seen that among phytoplankters, the importance appeared to be shared equally by *Fragillaria oceanica, Cosinodiscus* spp. and *Pleurosigma* spp., and to a lesser extent by *Biddulphia* spp. The dinoflagellates were more in evidence during October to January months. His observations also showed copepods in larger numbers in younger fish.Kagwade *(loc. cit.)* could not find any periodicity of dominating organisms in the food items but noticed that all the planktonic forms appeared comparatively in greater abundance during May to November. She also did not contribute favourably to the view that *F. oceanica* is the most important of the diatoms consumed, for along with that, she encountered other forms of equal importance like *Pleurosigma* spp. and *Coscinodiscus* spp. Discussing the question of selectivity in feeding, she was of the opinion that there appeared to be a certain amount of selectivity because, out of numerous species of both phyto-and zooplankton, only certain of them were found in the stomachs. She was also of the view that the unrecognizable deterious forming, very often, the bulk of the stomach contents may have some nutritional value and said feeding intensity was not found to differ with any particular item or group of items in different age groups. Noble (1968) in an abstract had reported that both diatoms and copepods were found to be the chief items off Karwar coasts but in total the zooplankters dominated the food.

Collating all these information, it appears that there cannot be any doubt that the oil-sardine is predominatly a surface coloumn feeder, phytoplankton forming the major group, in which a few species of diatoms like *Fragillaria oceanica, Pleurosigma* spp., *Coscinodicus* spp., form important elements. The dinoflagellates and copepods also appear to have a good share in the food chain, the former during October to January period and the latter especially for the juveniles. Bottom feeding also has been found to be resorted to especially during September to November months. The relative abundance of diatoms, flagellates and

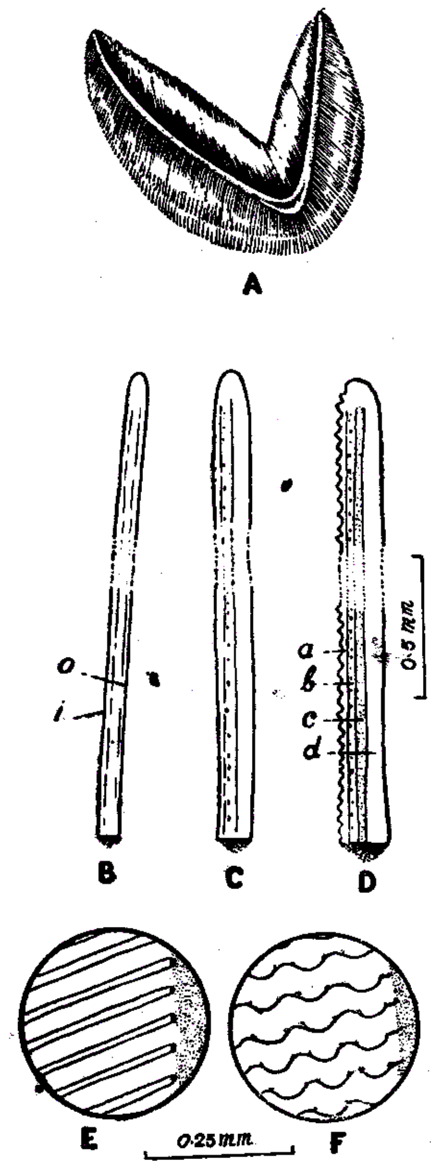

Fig. 5. The gill arch and structural differences of gill rakers between juveniles and adults. A: The first left gill arch showing the closely set gill rakers of an adult fish with the gill filaments arranged in two rows, one of shorter length than the other B, C & D: Gill raker of fish 51, 75 and 179 mm length. E: Magnified sketch of sieving area of a juvenile and F: that of an adult fish. a–zone of papillae; b–zone of pigments; c–zone of cornification; d–zone of clear area; i–inner lateral margin; o–outer lateral margin (B, C, D, E & F copied from Bensam, 1967b).

copepods in the stomach contents directly reflect their respective abundance in the plankton of the area frequented by the shoals. Whenever there should be depletion for their most favourite food, diatom, the fish may not be averse to the dinoflagellate crop. But their distinct ability to avoid areas of *Noctiluca* has also been noticed. It would be interesting if the reports indicating the preference of the juveniles of the smaller size range for the copepods are confirmed with more data, for then, it would account perhaps, for their relative scarcity in the normal fishing belt which is enriched by phytoplankton during the monsoon months and immediately thereafter. Together with an analysis of the nearshore plankton during the days of their appearance, as was the case in 1965, 1966 and 1969, it will establish the depth of correlation, if any, between the two. As for feeding intensity is concerned, there appears to be an year-round activity, which may be intense during June-October, decreasing during November-March but getting accelerated in the following months, except, perhaps for some cessation at the time of spawning.

In Fig. 5 is shown the first gill arch, from the left branchial chamber of an adult fish depicting the closely-set nature of the gill rakers which enable the fish to strain the food most efficiently. Also shown in the same figure are the structural difference of the gill rakers in juvenile and adult indicating the development of the sieving area which influenced Bensan (1967b) to relate it to the changes in feeding habits.

3. 4 **Behaviour**

3. 4. 1 **Migration**

Regarding migration, north-south, offshore-inshore and *vice versa*, the existing views have already been set out in section 2.2. Recently some tagging experiments have been carried out from different centres of observations and it is understood that there are only a very few recoveries which appear to suggest more of local migration only and also emphasise the necessity to improve and intensify the programme. In photographs 4 to 7 of Plate II is shown the tagging operation conducted off Calicut in 1968.

3.4.2. **Shoaling**

Apart from a passing reference by Chacko (1956), the only detailed account of shoaling behaviour of the oil-sardine is by Balan (1962) whose observations are summarized below.

There are different kinds of shoals each having its own characteristic features. Among the surface shoals, flipping, pattering, rippling and leaping types are recognized based on the physical movements of the fish. Through the colour and light effects accompanying the respective shoals, they can be categorised as bluish, pinkish and luminescent shoals. Two types of bottom shoals are encountered, one producing bubbles and the other fish odour. The most common amongst these are the rippling types and the bluish shoals. The next in importance appear to be the bubbling shoals and among the others which are of much lesser frequency may be mentioned, the leaping and luminescent shoals. The rest are almost of rare occurrence. While flipping act is considered to add force or momentum to locomotion in a limited area, the leaping act is an escaping technique and pattering, rippling and emission of fish odour are for attracting more individuals to increase their aggregation. The pinkish and bubbling shoals indicate bottom cruising, this being encountered during October to January period alone. While modest luminescence is considered favourable for fishing, higher intensity is felt not advantageous since it provides increased power of vision for the fish to detect predators and fishing gear. The fish odour may be caused by profuse discharge of mucus. Normally fish belonging to the same size group tend to shoal together assuming a size ranging from 2 sq.m. to 500 sq. m. in surface area. The shape of the shoal is roughly antennuate with the front end pointed and the hind, blunt. The pattering shoals are found to be more or less oblong while the bluish shoals appear rather narrow but long. Certain surface shoals like ripping type cruise at a speed of 5 km per hour. The bluish and pinkish shoals, however, are reported to,have a much slower speed.

Although Balan (*op. cit)* has described so many kinds of shoals, it appear that some of them are not exclusive by themselves. Flipping, pattering and leaping are all behavioural traits in one and the same common rippling shoal, flipping being the splashing noise made by

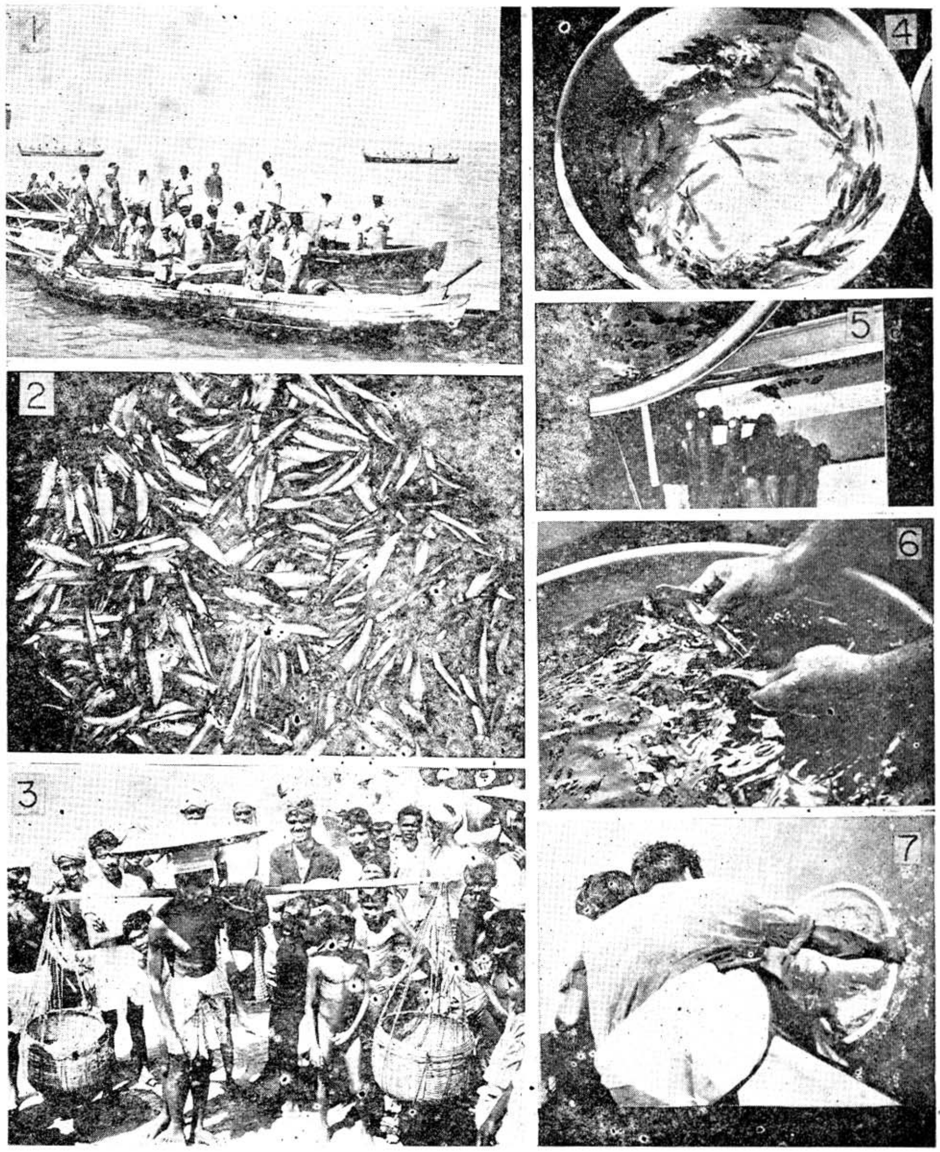

Plate II Photograph 1. Fishing boats
,, 2. Fresh oil-sardine
,, 3. A fish hawker
,, 4 to 7. Tagging operations off Calicut
,, 4—captured fish in the net
,, 5—fish being measured
,, 6—fish being tagged
,, 7—tagged fish being released.

the caudal fin, pattering through the mouth and leaping as a means to gain distance or escape. The luminescent shoals being night shoals cannot be restricted to any particular season of the year. The bubbling shoal is not necessarily a kind of bottom shoals but is also a character seen in any shoal, surface, sub-surface, mid-water or bottom. The *vedinattam* or fish odour is not an exclusive feature of oil-sardine alone, but only an indication of the availability of any fish shoal, mackerel, other sardines, anchovies etc. There appears to be no evidence also to believe that dumping of fish waste drives away the oil-sardine shoals from inshore waters as Balan gathered, for no fish waste is discarded into the sea but into better use as manure. While the cruising speed is believed to be in the range of 3 to 5 km per hour for surface shoals, there is no way of calculating the speed of other shoals. The size of the shoal varies so much that it can range even from 1 sq.m. to 500 sq.m and from 0.5 m deep normally. Sometimes even one square metre shoal will be so densely packed that it can fill in two boats, indicating roughly a depth of even 6-8 m.

From enquiries with the fishermen, it has been reported that high turbidity is associated with availability of large shoals, whereas in clearer waters, they have not been encountered (Balan, *loc. cit.).* The present author, however, learns that both during days of calm sea as well as under rough conditions, the shoals are available but vulenrability for fishing effort is more during the latter condition. With moderate force of north to south wind and discolouration of water due to turbulence, the density of the shoals has been found to get thickened during the fishing season. The eastern dark clouds especially during September-October months also appear to have some atrtraction for the shorewared movement of the shoals.

3. 2 **Parasites and predators**

As Hornell and Nayudu *(op. cit)*. observed, the oil-sardine appears to be a remarkably healthy fish hardly ever showing any pathological lesions or morbidity. The only record of parasites comes from their report, namely the larvae of a teraphyllid cestode, a new genus *et* species, *Platybothrium sardinellae* in the pyloric caeca and an unidentified advanced larval trematode occurring both in the pyloric caeca and in the stomach. While the former was found to be very common, the latter was encountered only during January, March and April.

As for predators, Balan (1962) has recorded two kinds of terns, *Sterna* spp. one of which is known as *mathikakka* in Malayalam, which is predominantly predatory on oil-sardine shoals. The sea gull *(kadalkakka), Larus brunicephalus* is also found commonly preying on this fish. The present author understands that in offshore waters, the hovering of a smaller variety than *mathi kakka*, known as *kozhi kakka* is taken as an indication of the availability of the shoals. It is not known whether one of the terns mentioned by Balan *(loc. cit)* refers to this. The dolphin, *Delphinus delphis* has been recorded by Balan as active chaser after the oil-sardine, disturbing and scattering them. In addition to dolphin, it is understood that the shark is also an active predator.

3. 2 **Other studies**

Bensam (1965) noticed regeneration of caudal fin in the oil-sardine after some injury or truncation, especially involving the lower lobe and recognized five stages in such a process of regeneration. He inferred that in view of its almost exclusive occurrence in the partly and completely spent individuals in September, this may be of some significance to show the behaviour of the fish during spawning. In another article, he (1967a), describing morphology and internal structure of pharyngeal pockets of oil-sardine, expressed that these organs may probably serve to congregate the food organisms filtered by the gill processes and aid in passing them on into the oesophagus. Pillai (1968) has recorded three instances of morphological irregularities, namely, in the curvature of caudal peduncle region and in the absence of anal fin and upper caudal lobe.

IV POPULATION

4.1. Structure

4.1.1. Sex ratio

Hornell and Nayudu *(op. cit)* reported that up to first maturity the females preponderated with the disparity getting reduced to a minimum among the spawners. From the greater incidence of males among the spent survivors, they inferred that there was considerably greater mortality among the females after spawning. Chidambaram *(op. cit)*,however, while describing the 1936-37 season, mentioned that the samples showed equal proportion of sexes for fish up to 200 mm but thereafter the females were found to be more. Nair (1959) was of the same opinion that there was no difference in the proportion of the sexes in the different size categories and based on the rarity of spent and recovering fish in the fishery, he presumed that morality was high among both the sexes after spawning . While these remarks and the observations of the pioneer workers are largely qualitative with no other details to support their respective presumptions, Chidambaram's data *(op. cit)* showing the sex distribution indicate that in some months even in fish less than 200 mm, there appears to be distinct domination of either sex, if Chi-square test is applied. Recently from abstracts available of articles in press, it is seen that off Karwar, males appeared to be relatively more numerous among the immature group but in the spent category, the females outnumbered the males (Radhakrishnan, 1968) and off Cochin coast, a preponderance of females was noticed in all the years which was related to gear selectivity (Balan, 1969). While in the former work no attempt has been made to analyse the sea distribution statistically, the latter is reported to be based on statistically balanced observation (personal communication from the respective authors). Balan (p.c.), clarifying the point on gear selectivity for dominance of females, writes that during fishing operations with *Thangu vala*, a vertical separation of sexes takes place resulting in the higher, passive capture of females. However, it may be stated here that to prove a natural, vertical segregation of sexes, the 'lower' section of the vertical shoals also should be examined to bring out the dominance of males there but which appears to have not been done. The gear, although mentioned by him as surface seine, is actually capable of engulfing the shoal up to at least 20 m depth, for according to Balan himself the maximum breadth of the gear is 30-40m *(vide* sec. 5.1.2). Thus, it appears gear-selectivity cannot be the reason for the dominance of female at Cochin area. In fact, it is common knowledge that unless a gear is selective and there is a sexual dimorphism in relation to size, the gear cannot be expected to cause separation of sexes.

Antony Raja (MS.7) subjecting his data 7 seasons to statistical tests and categorising the fish according to state of maturity, size and months of capture, found that, size-wise, among immature fish, but for 120 mm group in 1964-65 season alone, there were no significant differences in the sex distribution. In the maturing and mature fish, significant differences were noticed in different size groups in different years and the pooled data showed that whereas in the virgin spawners in 140-150 mm group males dominated, among the recovering spawners in 170-190 mm groups, the females outnumbered. In the spent and spent resting class, it is seen that while after first spawning, males continued to be more numerous, it was the other sex during and after second spawning season. When the data were looked from the monthwise distribution, it is seen that in the immature category, except for 2 years when in two different months either sex was found to be dominating there were no marked differences between the sexes. Among the adults also, except in one instance of spent group, the differences were not significant. Concluding, he said that although the individual samples showed dominance of either sex or their equal distribution, there were no seasonal differences in the ratio of males to females, nor dominance of either sex among the juvenile stock. But the females were distinctly more in the overall population of recovering spawners. He was of the opinion that the observed pattern in the sex ratio may be due to diffential mortality or differential growth and recommended that the individual sample size and the pooled data for a group in a season should be large enough to prove the real heterogeneity or otherwise in the population.

4.1.2 **Size and age composition**

TABLE VI

Important modal sizes (mm) encountered at Calicut during different seasons

Season	Modal sizes	Source
1933-34	130	Sundara Raj, 1934 *et seq.*
1934-35	170	
1935-36	160	Green, 1940
1936-37	50, 90, 120 160 200	Chidambaram, 1950
1937-38	90, 130, 140, 170	
1938-39	90, 120 180	
1939-40	70, 90, 120, 140 180, 200	
1940-41	40, 100, 130, 140 180, 190	
1941-42	90, 150, 160 190	
1942-43	130, 140, 170	
1948-49	150 190	
1949-50	100, 130 170	
1950-51	90, 130 190	Nair, 1953b, 1959,
1951-52	120 160 190	1960
1952-53	100, 110 160 180	
1953-54	90 to 110, 150, 160 180, 210	
1954-55	50, 130 to150 170	
1955-56	80, 100, 120 160, 170, 180	
1956-57	100 to 140 160, 170, 190	Sekharan, 1965
1957-58	70 to 140 150-160 190	
1958-59	130 to 150 160, 170, 180	
1961-62	120 160 185	
1962-63	65 to 140 150 170	
1963-64	70 to 135 155 175	Antony Raja, MS. 4
1964-65	80 to 135 150 180	
1965-66	35 to 140 150 185	

In Table VI are given the important modal size groups during the different seasons at Calicut as taken out from various authors for the period, 1933-34 to 1965-66 seasons (except for some interruptions in between). It may be seen that in general, 100-140 mm group has been observed to be a more consistent group as compared to 150-170 and 180-200 mm groups. The availability of different modal sizes within the first mentioned group indicates its prime importance followed by the 150-170 mm group. The 180-200 mm size class, as seen from the percentage distribution recorded by the different workers, is only of minor interest in the fishery. Based on the observations set out earlier on the age question of oil-sardine, these groups respectively fall into 0-year, I year and 2-year categories. Hence, the fishery is mainly dependant on the 0-year class, with the 1-year olds, which enter as virgin spawners when the season begins and are available in the spent resting condition in the post-spawning months, assuming the next importance.

4. 2 **Size and density**

4. 2. 1 **Average size**

Determination of population size of pelagic fishes has always been considered as a difficult task. Usually the estimates are based on catch & tagging data, egg-census and scouting surveys. In India, except the catch data collected at respective centres of biological observations as well as by survey staff which are available as total landings for every quarter, the other methods have not been employed so far (but for some preliminary attempts at tagging). The trends in catch data, centre-wise, region-wise and on all-India basis will be dealt with in the next chapter (sec. 5.4.2).

4. 2. 2 **Changes in density**

Changes in density as shown by the returns for unit effort with particular reference to oil-sardine are not available in published reports.

4. 2 **Natality and recruitment**

The relative strength of the respective year classes has not been assessed in any detail except for stray qualitative references that a particular year class was strong or week, even which, in the light of current opinion on age, have to be reviewed afresh. As fluctuations in the commercial fishery are virtually a reflection of the 0-year class strength, the conditions during the prerecruitment phase largely influence the natality and the recruitment in the exploited phase.

4. 3 **Mortality, morbidity etc.**

Hornell (1910b) described in detail an instance of great mortality among the oil-sardine. In November 1908, he found extensive stretches of oil-sardine, dying, dead or in various stages of decomposition from about 10 km south of Mangalore up to Mulki, about 20 km north and estimated the mortality to have run into hundreds of tons. This was associated with the presence of directly ochreous yellow body of water, dark and thick with suspended matter whose origin he traced to some contaminated foul discharge from the estuaries of the rivers falling into the sea in the area south of Mangalore. He saw the possibility that a body of brackish water of low density laden with a large proportion of very fine and almost slimy organic matter in suspension, possibly accompanied by extractive compounds, as in the case when coconuts were left soaked long in stagnant water, when released into the quiet sea, may remain compact and undissipated for days together although surrounded by water of considerably higher density because of unusual quietude of the sea near the land. This mass of foul water, he thought would have caused the large-scale mortality and as evidences in favour, he mentioned the brackish taste of the ochreous water of low density and a specific gravity of 1.021 and the plankton consisting of obscure, organic and unrecognizable fine debris, revealing an overall appearance of river filth or sewage, Hornell also quoted a somewhat similar strange mortality affecting all fishes in December 1899 as observed by 'Investigator' and recorded by Thurston (1900).

4. 5 **Dynamics of population**

4. 5. 1 **Population parameters**

Studies towards estimation of various parameters involved in the dynamic of exploited oil-sardine stock have been recently initiated. The preliminary studies have shown that the present fishing mortality is only 0.7, whereas yield per recruit attains the maximum when it is double of the present (Annual Report, CMFRI, 1968). Although the maximum biological yield has been provisionally estimated, it is to be seen what part of this would constitute the maximum sustainable economic yield.

TABLE VII

Estimates of growth parameters

(From Annual Report of CMFRI., 1967)

Place	Season	k	L (mm)	t_0 (months)
Cochin	1962-63	0.136	176.79	- 2.292
Calicut	1954-55	0.143	180-85	1.374
Cannanore	1961-62	0.219	168.71	2.335
Mangalore	1958-59	0.209	172.33	2.746
West Coast		0.155	179.49	1.407

Using the mean size at successive month intervals, the estimates of growth parameters in von Bertalanffy's growth equation as observed from the data of different centres are given in Table VII (Annual Report, CMFRI, 1967). The total morality, Z, has been reported to vary between 0.09 and 1.88 in which the component of natural morality has been worked out as 0.26. The Annual Report of CMFRI for 1968 shows that there are no significant differences in the growth parameters between the centres and a single equation can represent the data for the entire west coast, according to which L, is 207 mm, k= 0.53 (on yearly basis) and t= -1.33 years. Employing mean size at 3-month intervals, Antony Raja (MS.4) obtained values of 209.8 mm, 0.05 and 13.42 months for L, k and t respectively for data collected at Calicut from 1961 to 1966.

4.5.2 Length-weight relationship

Based on a year's data, Dhulkhed (1967a) found that although the regression coefficient in the allometric relationship, $W=aL^b$, was highest in the indeterminates followed by females and males, the differences were declared not significant among the groups. Thus, pooling the data he concluded that the samples belonged to a homogeneous population. However, Antony Raja (MS.2) analyzing his data for 5 seasons, found no regular sequence of decreasing values of *b* among the above mentioned 3 groups and drawing attention to the fact that an analysis of covariance on Dhulkhed's own data showed the significant variance-ratio rather nearer 1% level than 5% he contended that pooling the data was not justified and less so Dhulkhed's conclusion that the population is homogeneous. The studies of Antony Raja *(loc. cit)* further revealed that in view of the length-weight relationship differing significantly among fish of different season and maturity groups, different length weight regressions may have to be used to convert the statistics of catch from weight to number of fish. While, generally, the differences between the sexes in the immature and mature categories were not found significant, it was not the case with the fish of spent group. The females were observed to be slightly thinner than the males in the immature state but with the attainment of maturity, they became fatter and slightly more rotund. Between the indeterminate and immature groups of the same season which belong to the same year class, he noticed the slopes of the relationship were comparable but the elevations were significantly different, perhaps caused by the differences in size groups and the related weight. Within the immature group which forms the mainstay of the commercial fishery, he observed that the highest value of regression coefficient was obtained in 1960-61 coinciding with the bumper fishery followed by declining values through the subsequent years up to 1963-64 when the fishery proved a failure. Whether this feature in any way is correlative, he indicated, can be decided only with more such evidences. He also found that one-third of the values of regression coefficients of different groups departed significantly from the isometric growth value of 3 with the majority of the remainder lying between 2.5 and 3.0.

4.5. **Identity of subpopulations**

So far serious studies have not been made to find out whether we are dealing with a homogeneous population or whether there are any regional subgroups. Even those attempts to study geographic variations were of very superficial nature (sec. 1.2.). Antony Raja (MS.4), while analysing the modal groups occurring along the west coast, expressed that there was some difficulty in aligning certain size groups in certain years occurring off Mangalore with the broad pattern of growth obtained at Calicut and other places and suggested that there is justification for initiating studies towards this problem to find out whether the stock exploited off Mangalore and further north differs from that of the southern region.

4.5 **Relation of population to other fisheries, biological productivity etc.**

The structure of neritic pelagic fisheries resources on the west coast, south of Vengurla is built on dual-species fishery, namely, the oil-sardine, *Sardinella longiceps* and the mackerel, *Rastrelliger kanagurta.* Hornell (1910b) drawing attention to the interrelation between these two species, observed that scarcely ever both the fish were abundant in the same year and that there appeared to be an inverse relationship between the respective fisheries, a good year for one coinciding with an unsuccessful fishery for the other. Nair and Chidambaram *(op. cit.)* tabulating the total landings estimated from the fish-curing yard registers of the South Kanara and Malabar districts for 1925-26 to 1948-49 seasons, confirmed the existence of such an inverse relationship.

In Table VIII are shown the details of the estimated landings of both oil-sardine and mackerel for the period from 1925 to 1968. While the data for the seasons from 1925-26 to 1948-49 are taken from Nair and Chidambaram *(op. cit)* but converted from maund to metric tons to facilitate comparison, those relating to the years 1950 to 1968 are taken from CMFRI (1969). The data prior to 1950 relate to South Kanara and Malabar coasts, whereas the catch data from 1950 to 1955 represent all-India figures and those from 1956 to 1968 for Kerala and Mysore coasts For the period 1950 to 1955, while the data on oil-sardine can be taken as to refer mostly the catch from Kerala and Mysore regions, for mackerel also it may be treated roughly the same way, for, it is seen that the west coast (mostly from Kerala and Mysore area) has contributed nearly 98% to the all-India figures during that period (Pradhan and Rao, 1958). In the non-availability of any other published data restricted exactly to the same region, it is considered that within a little error, the figures given in Table VIII are nearly comparable and can be used to study the broad pattern of the problem under review.

TABLE VIII

Comparative landing figures in tones for oil-sardine and mackerel in Kerala-Mysore area

(From Nair & Chidambaram (1951) for the period 1925-26 to 1948-49 and CMFRI (1969) for the period, 1950 to 1968)

Season	Oil-sardine	Mackerel	Season	Oil-sardine		Mackerel		Both Kerala & Mysore	
				Kerala	Mysore	Kerala	Mysore	Oil-sardine	Mackerel
1925-26	43267	99475	1950		Details not available			34420	89163
1926-27	14392	9439	1951		“			17420	104900
1927-28	7003	75221	1952		“			13896	78014
1928-29	1757	35208	1953		“			51831	70748
1929-30	2677	75856	1954		“			33954	28258
1930-31	4204	5439	1955		“			30447	22796
1931-32	2125	305764	1956	5065	1369	8986	3177	6434	12163
1932-33	1093	72919	1957	175851	5779	26187	55754	181630	81941
1933-34	69797	21689	1958	118971	469	55476	65365	119440	120841
1934-35	20254	33058	1959	62036	3321	24689	29332	65357	54021
1935-36	1457	81111	1960	186219	2776	35504	81882	188995	117386
1936-37	26405	36540	1961	166005	1417	20044	7276	167422	27320
1937-38	16547	7644	1962	91203	14100	11938	11446	105303	23384
1938-39	3318	17732	1963	58950	3039	48917	19132	61989	68049
1939-40	6893	42107	1964	190401	83797	9657	7263	274198	16920
1940-41	24565	29896	1965	219170	39035	18048	18125	258205	36173
1941-42	4326	31340	1966	202800	44253	10747	7102	247053	17849
1942-43	894	106915	1967	235410	20481	4500	15050	255891	19550
1943-44	430	79310	1968	247048	53727	3599	5736	300775	9335
1944-45	638	58377							
1945-46	17	119982							
1946-47	9	95415							
1947-48	1158	32090							
1948-49	283	29509							
Average	10563	62584	Average	150702	21043	21407	25126	127078	52569

Let the data prior to 1950 be taken first. A superficial perusal of the data would show that out of 24 seasons, there are 17 instances of inverse relationship in which the mackerel were more in 16 seasons, the oil-sardine stifling out the mackerel only once. Evidences where both fisheries either proved successful or failed or had roughly equal amount of catch come from the rest 7 seasons. But, if the seasons from 1942-43 to 1948-49 when the oil-sardine fishery was actually found to have been disastrous and when a prohibitory legislation was also in force for oil-sardine from 1943 to 1947 are deleted, then the average oil-sardine catch for the earlier period was 14717 tonnes and the corresponding figure for mackerel, 57673 tonnes. The term success or failure is relative, for, the landing figure that looks very high as compared with that of the other species may be, in fact, rather smaller compared to its own normal catch. Hence, if any catch that is less than this respective average is considered as failure, then the picture is slightly different. There is an inverse relationship in 5 seasons in which mackerel fishery was dominant and in another equal number of seasons the oil-sardine fishery was a success. Cases where both fisheries either yielded above or below their respective average account for 7 seasons. Thus, while there are 10 instances to show a negative correlation, there are 7other instances showing the absence of it. Even during the post 1941-42 season, under almost total decimation of oil-sardine population, the strength of exploited mackerel stock is found to be less than their overall average for 3 out of 7 seasons.

Similarly for the period 1950-1968, it is seen that, based on the average landings for 19 years, namely, 127078 tonnes for oil-sardine and 52569 tonnes for mackerel, the inverse relationship is found to be operative for 12 sesons and not so for another 6 seasons, with one year (1958) showing the oil-sardine catch just short of its average but roughly equal to mackerel's with over one lakh tonnes and hence may be treated as to fall under the latter category. In the former case (negative correlation), the mackerel landings showed a success over oil-sardine in 1950 to 1953 (continuation of pre-1950 trend), 1959 and 1963 whereas the reverse was true in 1961 and 1964 to 1968, thus showing equal number of 6 seasons. Among those where both were either success (1957, 1958 and 1960) or failure (1954, 1955, 1956 & 1962) instances are 3 and 4 respectively. The data for so many years, thus, indicate in general that while illustrations are more to show an inverse relationship between the two fisheries, nearly half that number indicates that such a relationship is not strictly operating, perhaps for various other reasons and hence, *ipso facto* the negative correlation need not be a rule. It was only in the recent 5 years from 1964 to 1968 under an overabundant sardine returns of more than 2 lakhs metric tons, that the mackerel has failed to establish itself. Whereas previous to that even when the oil-sardine catch was well over one lakh tonnes as in 1957, 1958 and 1960, mackerel also touched an average one lakh mark for the same years. It is presumed that in future if only there should be some reduction in the oil-sardine catch in a particular season and if the recruitment of mackerel is good in that season, the mackerel may re-establish itself. (The current commercial season's returns from both these fisheries appear to be an indication in favour of this preseumption).

It is well known that in an ecosystem of multiple species fishery, each species has its own set of optimal environmental conditions and seasonality in reproduction, feeding, growth increments etc. In our waters, especially the seasonality of reproduction has been shown to be different for, as compared to oil-sardine, the breeding season of mackerel is reported to be more extended and the habits different. It is possible that each species responds differently than the other to any oscillation in the ecological conditions. A set of those conditions that are favourable for reproduction, larval survival and early growth of one species may not be applicable to one other or the peak seasons when these processes are taking place may not coincide, so much so,the influence of the environmental and biological conditions affecting the strength of a year class recruited may be different for each other. Added to this, inter-specific competion between the two species inhabiting the same area, at times even consisting of different size groups, may result in the success of one over the other on their numerical strength. Herein, the attitude of the fishing community also has to be borne in mind. In so far as capture of these fishes, it may not assume the shape of a big socio-economic problem in as much as both fish are valued by the fishermen but their attitude towards fishing operation is well known. Shoals that are so near the shore are normally sought after by a larger percentage of fishing units than the shoals that are further off. Only when one is not available easily nearby or when the size group of a particular species available nearby cannot provide as good as financial returns as do some larger sized fish-reported in a little far off waters, then, they venture out beyond, even where depending upon the time spent and market conditions, whatever is encountered first on their way, sardine or mackerel, is taken in. Thus, while superficially it might appear that the fishermen have no preference for either, there is a sort of unconscious selectivity, determined by the comparative availability in space and time and size composition of the respective shoals.

It has also been established that our coastal waters get enriched with phytoplankton bloom during the monsoon and post-monsoon months. It has been already shown that this forms the most favourite of oil-sardine food. The season of maximum catch of oil-sardine is seen in October-December months, a period which is also the same for the mackerel, while the latter is also a surface and filter feeder, it is seen from various reports that they feed both on plant and animal components of plankton depending on the fluctuations in the relative abundance in the inshore region from season to season and from place to place. So, if either group of plankton is rich, the mackerel thrive on it, whereas if phytoplankton is poor, oil-sardine would seek different environs for feeding. It can be also expected that when a year class of one species proves rather weak, the bounteous food supply is left uncosumed by the depleted population of that species which will be taken advantage of by the other. The basic biological productivity of the area not only in quantity but also in quality as well, during July-December period may thus have relationships with the strength of stock that come to inhabit a particular area. In this competition for food, that stock which is relatively stronger will go after it displacing the other which may remain back to look for a different area where there is a lesser competition. With the natural tendency for the fishermen to capture the shoals nearer their reach, this may partly account for more catch of one species than the other. This indirectely also shows that shoals which fail to compete and remain off, are likely to be underexploited.

Again the apparent inverse relationship may also be due to recruited year class strength of the respective species which need to be the same but corresponding to which will be decided their availability. If in a particular season the recruitment rate has suffered due to any physiological setback in spawning survival rate in one species whereas it was normal in the other, then this trend will be reflected in the available stock for exploitation. If, on the other hand, in any season it so coincides that the nature of recruitment of both the species is either low or high, then their respective catch also will be low or high in a comparable manner, as seen in the years when the success or failure of both species has been observed to coincide.

Another factor that should be taken cognizance of is within the area of dual-species system, the mackerel show a slightly greater concentration off Mysore coast than Kerala (Rao, 1969). It is also known that on the Mysore coast, the most common gear is the shore-seine,*Rampani*. It is possible that under an overabundant recruitment of oil-sardine, the shoals by their sheer numerical strength may limit the nearshore migration of mackerel in the food competition and hence the *Rampani* catch may be largely composed of oil-sardine only. Perhaps deployment of more effort with boat seine in the area beyond the oil-sardine in those years can bring in an increased catch of mackerel for the Mysore coast.

It is also interesting to note that while in the years prior to 1950, mackerel was generally in ascendency as revealed by their overall average of 62584 tonnes as compared to 10563 tonnes for oil-sardine, in the years that followed especially from 1957, the oil-sardine has leapt to such a prominance as to relegate the mackerel to a minor position in the all-India marine fish production. It is also significant that while the average catch of mackerel has been around 50 to 60 thousand metric tons either for pre-or post-1950 periods, the oil-sardine has almost increased its landings more than tenfold - from an average of about10000 tonnes for pre-1950 years to 127000 tonnes for the subsequent period. Was there any great oscillation in the environment during post-1956 years in favour of oil-sardine? Perhaps future may be in a position to answer this.

It requires, thus, to be seen how the biological productivity has been undergoing variations during the years, especially the ratio between the phyto-and zooplankton elements that are normally consumed by these two fishes, to throw further light on the relationship between their exploited populations. Studies on the differences in the recruitment rate of the respective species, both of whose commercial fisheries are composed of 0-year class, would also contribute towards the solution. It is also to be investigated whether the introduction of nylon nets displacing almost all other types of indigenous gear of cotton fibre on the Kerala coast has contributed to the enormous catch of oil-sardine in the recent years on the Kerala coast and whether under the plenitude of oil-sardine, the conventional fishing method of more reliance on shore seine catch has limited the mackerel returns from the Mysore coast.

It is felt that if a structure of socio-economic-cum-fishing conditions can be created within which the under and unexploited resources in waters beyond the 15 km stretch can be fished in proportion to the ascendancy of the respective species in the ecological system, it may, perhaps, be possible to harvest yields of comparable and sustainable quantity of both the fishes in the same season, provided the strength of the recruited year class of either has not been affected to a disastrous level through conditions, environmental and or physiological.

V EXPLOITATION

5.1. **Fishing equipment**

A short description of the two types of boats in common use along the Malabar and South Kanara coasts is given by Hornell (1910a) who later has drawn a vivid picture of the fishing methods along this coastal stretch (Hornell, 1941). Nair (1953 & 1960) has also given short descriptions of the major fishing craft and gear involved in the oil-sardine fishery based on the above reports. Rao *(op. cit)* has shown *inter alia*, the most common types of the boats and nets used in the oil-sardine fishery in his chart 3.

5.1.1 **Boats**

In Kerala coast, a dug-out canoe called *odam* or *vanchi* of 9 to 12 m length and 3 to 5 ton displacement is usually employed for operating boat seines and a smaller type called *thoni* of about 8 to 9 m length and about 2 ton burden for drift net and gill net fishing. In the northern parts, Kanara and Konkan coasts, along with dug-out canoe, outrigger boats are used for operating *Rampani*. Here the basal part of the hull may consist either of a dug-out region with low vertical sides or of 3 planks rabbeted to the edges of the basal one. The outrigger is formed of 2 bamboo booms and a float. Proximally the booms cross the hull several feet apart and distally they extend outboard 1.5 m and to these distal ends is directly attached a wooden float. (Hornell, 1941). Formerly these were reported to be about 5 to 6 m in length (Hornell, (*loc. cit)* but recently they appear to be much bigger, about 15 m long (Nair, 1960).

5.1.2 **Gear**

Surveying the fishing methods of world sardine fisheries, von Brandt (1960) categorises three main types among the different gears employed, namely, engulfing nets (boat seine), seine nets (Boat seine) and gill nets, according to which are listed some of the important gears operated along the Kerala and Mysore coasts in Table IX. Some of the gears are

Known by the same name in both the coasts with the substitution of vernacular *bale* in Mysore for Kerala coast (=net).

TABLE IX

Important gears operated for oil-sardine fishery on the Kerala and Mysore coasts

I Engulfing net (Boat seine)	II Seine (Beach seine)	III Gill net
Cast net	*Cast net*	*Drift net*
Veechu vala	Veechu vala	Kanda bale
Koori bale		
Boat seine	*Drag net*	*Gill net*
Odam vala	Kara vala	Mathichala vala
Nethal vala	*Shore seine*	Ida bale
Nona vala	Rampani	
Thangu vala	Yendi	
Paithu vala		
Mathikolli vala		
Pattenkolli vala		
Arakolli vala		
Thattum vala		
Arathattum vala		

Although it is seen from Table IX that so many gears have been in operation, the most important are the boat seines, *Kollivala* and *Thangu vala* on the Kerala coast and the shore seine, *Rampani,* on the Mysore region. The gill net, *Mathichala vala* is also occasionally credited with good catch. In fact, *Mathikolli, pattenkolli, Arakolli, Arathattum vala*, *Thattum vala* and *Paithu vala* are all the same type of boat seine, only the size of the net varying. Similarly *odam vala* and *nethal vala* are similar type of bag net, the latter especially operate for small sized juveniles. So is the case with *nona vala* of Cochin area which represents a smaller form of *thangu vala* and similarly employed for capturing small sized juveniles. In the following account, as representatives of these various gears, descriptions are given of *mathikolli vala, Mathichala vala, Thangu vala* and *Rampani* which are based on the reports of Nair (1953b and 1960) who has given a condensed version of the descriptions of Hornell (1941) and that of von Brandt (*loc. cit.)* as well as from personal records and communications. From the original accounts the sizes given below are conversions to metric measurements.

Mathikolli vala: Dimensions-length about 18 m, breadth 5.5 m and mesh size 15 mm. It consists of widemouthed bag, the lower lip of which is continued and raised to form the body *(kolli)* and on the sides as two wings. While the net proper-the bag and the body – is made of cotton, the wings are of coconut fibre. The net is operated from two dug-out canoes with 7 or 8 men in each. The lead line is very short while the float line is set back very far. Each canoe carries half the net and when the shoal is sighted, the net is paid out while the canoes separate. The net and wings are well stretched out by paddling the canoes. The lead line of the net sinks below the level at which the fish are swimming and by adjusting the length of *'kaavi'* snoods, the float line is kept above the level of the shoal. The encircled shoal is driven into the net by the loud noise produced by the auxiliary boats. When the shoal has moved beyond the level of the wings towards the mouth, the two canoes converge and the wings are hauled till the lead line can be lifted above the surface, thus enveloping the fish in the bag. By hauling the float line vertically the catch gets concentrated in the bag.

Of late, the *kollivala* of cotton has yielded to that of nylon twine and in the major portion of Kerala coast, this *silk vala,* as it is called, is operated as *pattenkolli vala.* These nets are larger in size, the length being about 25 to 30 m in which the bag portion occupies half of that. The mesh size (bar length) varies from 5-7 mm in the cod end of the bag portion to about 11 mm on the body. As it can capture any fish shoal,pelagic, midwater, near-bottom, the name *pattenkolli* is retained meaning versatility.

*Thangu vala:*This rectangular piece of cotton net, operated mostly off Cochin from a single boat, is 50 to 60 m in length and 30 to 40 m in width which is narrowed down to 5-6 m at either ends. The mesh size is 20 mm. At the sight of a shoal, one person jumps into water and paying out the net around the shoal, hands over one end of the net to the boat which retains the other end. The net, then, is hauled and lifted up vertically (Balan, p.c.). This net neither has a bunt nor any pursing mechanism and hence, perhaps, cannot be strictly placed under purse seine or lampara type category but probably represents something closer to the French *'bolinche'* in its old form (von Brandt, *op.cit.)*.

Mathichala vala: This is a gill net made of cotton and operated by one or two canoes. The dimensions of each piece of the net are 2.5 to 3.0 m long 4 to 6m broad and with a mesh of 9 to 25 mm. Each canoe or both canoes together carry 7-8 such pieces of net laced together and when the shoal is sighted the net is paid out quickly from the canoe in a semicircular manner across the direction of the movement of the shoal which gets enriched by the net. In their attempts to escape on hearing the terrific noise produced by the fishermen, the fish get firmly gilled. The range of mesh size is so wide to enable necessary combination of different meshed pieces depending upon a rough estimate of the size composition of the shoal, thus, making the gear versatile enough to meet any situation. In some parts of Kerala, the overall size of the net is reported still larger when cooperation of more men is sought at the time of operation.

Rampani This is a large shore-seine made of hemp and consists of nearly 100 pieces linked together. The dimensions of each piece are about 11 m long, breadth varying between 2 and 7 m and with a mesh size varying from 12 to 30 mm. The entire net is narrower at the two extremities with wider mesh, but deeper in the middle with smaller mesh. One end of the net is held by a party of 40 men on the shore and the net is carried on a large boat and is paid out in a semicircular way encircling the shoal. The other end of the net is brought ashore and is handed over to another party. The two ends of the net enclosing the shoal are slowly dragged by the two parties of men.

5.1.2.1. **Efficiency and Selectivity**

Except for some preliminary studies of Joseph and Sebastian (1964) on the effect of differing mesh sizes on the fishing efficiency of gill net in Cochin area and Sekharan (1965) on the catch per unit effort (kg per man-hour) of different gears operated on the Calicut coast, information on this aspect is very meager. Joseph and Sebastian *(loc. cit.)* employing gill nets of type A,B,C and D with respective mesh sizes of 14.0, 16.7, 19.3 and 20.9 mm found that gear B was the most efficient with greater output followed by C, A and D. They also noticed that while the catch of net A had a modal size of 131-140 mm group of oil-sardine and that of B, 161-170 mm, nets C and D captured fish of the same modal size, 181-190 mm. Since they felt that the use of gill nets with mesh size of 14.0 and 20.9 mm was not as economical as those with 16.7 and 19.3 mm mesh, they concluded that the success of fishing with gill net for oil-sardine depends largely on the selection of optimal mesh size for the available stock of fish in the fishery. It may be of interest to point out here, that in fact, fishermen do carry different gill net pieces of varying mesh size and depending on the size composition of the shoal encountered, they operate either those restricted with a mesh size up to 15mm or those in the range above that. While Dutt (1965) is partly right in pointing out that the efficiency as worked out in the above way is strictly not comparable in view of the fact that the selective nature of the mesh comes into operation depending on the relative strength of the size groups in the shoals encountered, his reasoning for the smaller catch of the net D to the lesser number of individuals in 181-190 mm modal group cannot be sustained since net C with a lesser mesh size also had captured fish of the same modal group but in larger numbers. It may be, however, interesting to continue the studies of above nature to find out whether the catch of net D is really poorer than net C and if so whether the reason can be traced to girth size of fish above 170 mm. Similarly, experiments with nets of smaller mesh size than 14.0 mm may show whether incidences of smaller sized fish are not increased and the out put drawing nearer to that of net B. In this way, perhaps we may see three optimal sizes of increasing mesh size for fish of 120-140, 150-170 and 170-190 mm groups, judicious use of which in their respective season of abundance may result in increased catch in the gill net.

TABLE X

Catch per man hour (From Sekharan, 1965) and percentage relative efficiency of different gear at Calicut during 1955-56 to 1958-59

Gear	Catch per man hour (Kg)				Percentage relative efficiency				
	1955-56	1956-57	1957-58	1958-59	1955-56	1956-57	1957-58	1958-59	Average
1. Mathikolli vala	3.60	3.41	10.11	13.17	100	100	100	100	100
2. Pattenkolli vala	-	1.58	4.92	10.47	-	46	49	79	58
3. Arakolli vala	2.26	0.52	-	-	63	15	-	-	39
4. Paithu vala	0.05	0.02	7.11	2.26	1	1	70	10	21
5. Thattum vala	0.65	1.43	7.88	1.35	18	42	78	10	37
6. Arathat-tum vala	1.80	-	-	-	50	-	-	-	50
7. Nethal vala	0.33	-	1.49	-	9	-	15	-	12
8. Odam vala	-	0.52	2.29	-	-	15	23	-	19
9. Veechu vala	3.51	1.93	7.18	-	98	57	71	-	75
10. Mathi-chala vala	0.92	1.00	4.87	3.27	26	29	48	25	30

Sekharan's data (1965) are presented in Table X and the percentage relative efficiency of the gears is worked out. It is seen that the catch per unit effort of different gears varies between the seasons, due perhaps to variations in abundance, for in the seasons of successful fishery – 1957-58 and 1958-59- the CPUE is noticed to be distinctly higher as compared to the two previous lean seasons. It also shows that *Mathikolli vala* is the most efficient and other boat seines of the same type with some variations in size, namely, *pattenkolli, paithu vala* and *thattum vala* have netted slightly lesser returns in 1957-58. The cast net, *veechuvala,* also has fetched good catch in the seasons operated. Using *mathikolli vala's* values as base, the relative percenttage efficiency of the different gears shows that although the inter seasonal variations are rather wise in many of the gears it is generally seen that *veechu vala* and *pattenkolli* are rather consistent with a respective average of about half and three-fourths of *mathikolli's* efficiency.

5. 2 **Fishing areas**

Although the geographic distribution of Indian oil-sardine has been reported to extend from Kathiawar coast to the coromandel and Ganjam coasts as well as off Andamans, the occurrence of oil-sardine on the east coast is sporadic and in negligible amount only and the same applies to Kathiawar coast on the west. The identity of those recoded in Andaman seas- whether *S. longiceps or S.aurita*- has to be established.

On the west coast, it is reported to enjoy distribution of fishery interest from Vengurla in the north to almost the southern tip of Kerala coast (Rao, *op. cit).* This roughly represents an area between about 16^0N to 8^0N latitude respectively. However, large scale shoaling is witnessed in Mysore and Kerala coasts, especially the latter, even within which, the area around 11^0N latitude accounts for the most dense congregation *(vide infra).* The fishing is normally restricted to a coastal belt of about 12 to 15 cm from the shore due mainly to the limitations of craft employed and during times of good harvest, it is even nearer to the shore. The usual depth at which the shoals are captured is up to 15 m.

5. 3 **Fishing season**

With some pre-monsoon showers in late May or early June, some shoals start appearing in the coastal waters but the regular fishery can be said to commence from July along with the outbreak of s.w. monsoon and to terminate by about next March with maximum intensity during October to January. While this is the general pattern, there had been variations in the period of their entry as well as disappearance from the fishery.

5. 4 **Fishing operations and results**

5. 4. 2 **Effort and intensity**

Information is being collected by the survey staff regularly on the effort expended as well as studies are made at selected centres of observations on the trends in catch per unit effort. But so far details are not available as to the extent of variations in the intensity of effort on the stock of oil-sardine and on catch per unit effort. While certain remarks in the reports of CMFRI refer to catch per unit operation of a gear, certain others to CPUE in relation to manhour. If a uniform system could be adopted whereby the comparative efficiency of different gears employed on the coast is studied and expressed in relation to the most common gear, *pattenkolli* and the catch per unit effort weighted in various ways-relating to man-hour, size of the gear and speed of operation and the shoal density in a particular volume of water is calculated, then it would be possible to get an idea into this aspect which will facilitate to gain more information on the stock problem.

5. 4. 2 **Catch**

5. 4. 2. 1 **Annual variations**

A perusal of Tables VIII & XI would show the extent of fluctuations in the oil-sardine fishery from 1925 to 1968 and it has already been remarked how the catch of oil-sardine has increased in recent years to an average of more then two lakh tonnes. The most disastrous season was 1946-47 when only 9 tonnes catch was estimated as the contribution of oil-sardine (due probably in part to a prohibitory legislation in addition to other factors) whereas the most successful fishery was witnessed in 1968 when as much as 301446 tonnes were estimated. If the data from 1950 onwards alone are taken to get an insight into the widely fluctuating nature of the fishery of the recent past (Table XI), it may be seen that there had been three phases, the first between 1950 and 1956, the second between 1957 and 1963 and the third between 1964 and 1968. During the first 7 years the average catch was about 0.37 lakh tones, with a maximum of 0.52 lakh tonne in 1953 and a minimum of 0.07 lakh tonne in 1956. During the next 7 years, the average shot up to nearly 5-fold with a catch of 1.31 lakh tones within which the

TABLE XI

Regional annual landings data of oil-sardine in metric tons for 1950-1968 as compared to all-India total marine fish production. For columns left blank no details are available. The average and percentage are for the period shown. It is presumed that for 1965 to 1967 period, catch data from Goa are included in the figures for the west coast (Source: CMFRI. 1969)

Year	Kerala	Mysore	Maharastra	Gujerat	Madras	Andhra	Total for W. coast	Total for E. coast	Total Catch oil-sardine	All-India total marine fish	percentage oil-sardine
1950	-	-	-	-	-	-	-	-	34420	580022	5.93
1951	-	-	-	-	-	-	-	-	17240	533916	3.23
1952	-	-	-	-	-	-	-	-	13896	528348	2.63
1953	-	-	-	-	-	-	-	-	51831	581463	8.91
1954	-	-	-	-	-	-	-	-	33954	588258	5.77
1955	-	-	-	-	-	-	-	-	30447	595725	5.11
1956	5065	1369	-	-	-	-	-	-	7412	718779	1.03
1957	175851	5779	-	-	-	-	-	-	191469	875516	21.87
1958.	118971	469	-	-	-	-	-	-	123731	755994	16.37
1959	62036	3321	-	-	-	-	-	-	69234	584587	11.84
1960	186219	2776	21	-	-	-	189016	-	189016	879681	21.49
1961	166005	1417	460	-	1	-	167883	1	167884	683569	24.56
1962	91203	14100	4995	2	-	-	110299	-	110299	644244	17.12
1963	58950	3039	1656	1	1	-	63646	1	63647	655484	9.71
1964	190401	83797	-	1	134	-	274199	134	274333	859582	31.91
1965	219170	39035	65	-	32	-	261831	32	261863	832777	31.44
1966	202800	44253	63	-	37	66	247116	98	247214	890311	27.77
1967	235410	20481	353	38	32	-	256292	32	256324	862631	29.71
1968	247048	53727	221	38	412	-	301034	412	301446	902948	33.38
Average	150702	21043	870	9	72	7	207924	79	128719	713360	18.04
Percentage	86.54	12.08	The rest 1.38% is shared by other States				99.91	0.04			

lowest yield came in two years, 1959 and 1963 with about 0.6-0.7lakh tonne and the highest in 1957 and 1960 with about 1.9 lakh tonnes. The post-1963 seasons had yielded such a record average of 2.68 lakh tones, that it not only represents double of the previous 7 years' average but nearly 10 times that of the first phase. This is the first time that the oil-sardine fishery has been giving such a bounteous supply without a break of a failure consecutively for 5 years. From the overall picture of an average of 1.29 lakh tonnes for the 19-year period, it may be seen that slightly over half the number of years had netted below average catch. But if we take the second and third phases stretching for the past 12 years, then it may be noticed that the fishery was a failure only on two occasions.

It can be also perceived from Table XI the amount of contributions of oil-sardine to the annual marine fish production in India. While the fluctuations has been as wide as 1.0% and 33.4% during 1950-1968 period with an overall average of 18% during the first phase mentioned above it has contributed to an average of 4.7% during the second to 17.6% and during the last phase 30.8%. It is also seen that whenever the total marine fish catch had exceeded 8 lakh metric tons, the causal factors was the rich yield from the oil-sardine fishery and that the quantity of the former had been fluctuating between 5 and 9 lakh tonnes reflecting mostly the fluctuations in the availability of the oil-sardine resources. Thus, it clearly stands out that under the present mode of exploitation of marine fishery resources of India, should the oil-sardine fishery prove a failure, as is likely during the current year, it will effect a sizeable reduction in the all-India catch also, athough, the successful yield from any other resources may to a certain extent minimize the fall.

5. 4. 2. 2 **Spatial variations**

The region-wise catch data for the years 1956-1968 as taken out from CMFRI (1969) can be seen from Table XI. How negligible is the catch from the east coast can be easily noticed from its average contribution of only 0.04% which comes almost exclusively from the Madras region. Even on the west coast, the importance is only off Kerala and Mysore states which together subscribe to 98.6% of the west coast catch.

TABLE XII

Seasonal landings in metric tons at selected centres on the west coast for 1960-1966 (From CMFRI reports)
(0= catch less than 1 tonne)

Year and quarters		Karwar	Mangalore (Ullal)	Canna-nore	Calicut (Vellayil)	Cochin (Manassery)	Vizhingam
1960	I	5	0	*	481	*	0
	II	0	0	*	56	*	0
	III	0	10	*	1888	*	3
	IV	95	48	*	3313	*	9
	Total	100	58	*	5738	*	12
1961	I	0	20	*	2421	*	7
	II	0	16	67	147	*	0
	III	0	8	120	2129	*	2
	IV	29	69	845	3473	*	0
	Total	29	113	incomplete	8170	*	9
1962	I	1	352	1744	2240	*	2
	II	0	4	176	173	*	0
	III	1	6	182	900	59	0
	IV	293	35	1039	1181	545	0
	Total	295	397	3141	4494	incomplete	2
1963	I	88	36	397	1111	599	0
	II	0	7	1	60	229	0
	III	1	0	63	2	301	11
	IV	2	7	34	88	233	0
	Total	91	50	497	1261	1362	11
1964	I	25	57	284	73	10	0
	II	0	0	0	24	75	0
	III	0	14	454	901	1248	0
	IV	4	86	1813	4562	2248	0
	Total	29	157	2551	5560	3581	0
1965	I	0	36	1689	2982	845	0
	II	0	36	512	971	331	0
	III	8	34	742	899	597	2
	IV	69	90	1015	2027	825	0
	Total	77	196	3958	6809	2598	2
1966	I	2	158	715	1597	211	0
	II	0	30	66	310	278	0
	III	13	123	*	806	859	15
	IV	0	157	*	1033	941	1
	Total	15	468	incomplete	3746	2289	16
Aver-	I	17	96	1029	1558	416	1
age	II	0	13	172	249	228	0
	III	3	28	360	1065	751	5
	IV	70	70	975	2240	1062	1
	Total	90	207	2536	5112	2457	7

Within these two regions, the landings of oil-sardine on the Kerala coast with an average annual catch of 150702 tonnes forming 86.5% almost eclipse those of Mysore which nets in 21043 tonnes accounting for 12.1%. In order to find out the most productive region within Kerala, the estimated landing figures during 1960-66 of some important centres on the west coast for which comparative data area available are given in Table XII (consolidated from the quarterly and annual reports of CMFRI for the respective years). Based on the highest average annual catch of 5112 tonnes at Calicut, it can be safely stated that the area around Calicut represents the heaviest concentration of oil-sardine. On either side, Cannanore and Cochin roughly record an equal quantity of catch around 2500 tonnes. Further south, off Vizhingam, the fishery loses its importance. Thus, within a range of 16^0N and 8^0N latitude, the area off 11^0N latitude can be said to be the most productive region with the areas around 1^0N on either side of it slightly lesser in importance. Perhaps the region off Quilon (9^0N) may compare favourably with that off Mangalore (13^0N) and further south and north of these respective places the concentration of the fishery dwindles rapidly.

5. 4. 2. 3 **Seasonal variations**

TABLE XIIIa

Oil-sardine catch data in metric tons of Kerala and Mysore coasts for each quarter during the years 1956 to 1968, the regional average and percentage (Source: CMFRI, 1969)

	KERALA					MYSORE				
Year	I	II	III	IV	Annual	I	II	III	IV	Annual
1956	799	-	180	4086	5065	-	-	-	1369	1369
1957	13284	3012	18157	141398	175851	165	241	137	5236	5779
1958	71207	12089	8047	27628	118971	366	9	-	94	469
1959	33615	5657	5233	17531	62036	447	-	-	2874	3321
1960	8068	1528	28802	147821	186219	66	-	516	2164	2776
1961	66009	17968	10496	71532	166005	-	55	190	1172	1417
1962	35070	5583	4858	45692	91203	4580	63	290	9167	14100
1963	26844	6750	3560	21796	58950	633	2	-	2404	3039
1964	20923	1008	33604	134866	190401	6179	-	9	77609	83797
1965	92424	20626	33225	72895	219170	43	81	7	38904	39035
1966	37457	14353	57688	93302	202800	1239	111	2725	40178	44253
1967	70960	11664	27843	124943	235410	10770	168	52	9491	20481
1968	47319	4213	57895	137621	247048	1859	12	100	51756	53727
Average	40306	8035	22276	80085	150702	2029	57	310	18647	21043
percentage	26.8	5.3	14.8	53.1	100.0	9.6	0.3	1.5	88.6	100.0

TABLE XIIIb

Average quarter-wise oil-sardine catch in metric tons for both Kerala and Mysore coasts

	I	II	III	IV	Annual
Average	42335	8092	22586	98732	171745
Percentage	24.6	4.7	13.2	57.5	100.0

A perusal of Table XIIIa wherein quarter-wise and annual landings of each calender year from 1956 to 1968 for the two most important coastal regions, Kerala and Mysore, are given, will show that there is a distinct trend in the temporal variations of oil-sardine catch in the annual picture of the fishery. Off both the coasts of Kerala and Mysore the largest catch comes from the last quarter of the year, when the commercial fishery for the juveniles is at its peak. While this accounts for nearly 88.6% of the average catch of Mysore, leaving the remainder to be shared as 9.6% during January-March, 0.3% during April-June and 1.5% during July-September, the inter quarter disparity is not so marked along the Kerala coast where more gradual decline of landings is noticed. In the latter region, the last quarter nets in a little over half of the annual average catch, the first quarter accounting to a little over one-fourth, the third quarter a little less than one-seventh and the second quarter, about one-twentieth, thus the respective quarters showing roughly about half of the landings of the previous quarter *ad seriatim* which feature is generally indicated when the average pooled catch of both the regions is also looked into (Table XIIIb). It is also seen that in both the regions, the period of low catch is April to June, when the shoals are away from the normal fishing zone. These data further indicate that if the fishery for October-December period is for any reason does not prove successful along the Mysore coast, the whole annual picture for the region will be shattered, whereas off Kerala, due to better showing of the landings during the first and third quarters, it will not present such an adverse feature. An important trend that appears worth mentioning is that perusing Table XII, it is noticed that there is an indication that both off Cannanore and Mangalore centres, the data for the first quarter of the succeeding year show more landings than that for the previous quarter of the preeceeding year, whereas in Calicut and Cochin the reverse is the case. Whether this is an indication of the migratory habits towards north, however, cannot be ascertained with these data alone but can only be underlined for further analysis of more data. Another point of significance is that comparing Cannanore and Cochin, which show almost an equal amount of catch, it is observed that the third quarter's landings of Cochin are almost double of those at Cannanore. This period largely belonging to the fishery for the spawners, it may be of interest to find out whether there is really more concentration of spawners around Calicut and Cochin as compared to northern areas as the figures indicates. Finer analysis of regional data collected by the survey staff may throw some illuminating features of vital importance in the understanding of the temporal and spatial distribution and possible migratory routes of oil-sardine shoals.

5. 4. 3 **Factors affecting fishery**

About a century ago, Day (1865), in his book on 'The Fishes of Malabar' referring to the increased trade of fish-oil, expressed a grave concern that if the later years should prove this trend as an unhealthy stimulus, then the causal factors could be traced to overfishing. Hornell (1910b) stated that periodic combination of certain unfavourable conditions in inshore waters resulting in low production of diatoms would affect the fishery. These adverse conditions, according to him, would be largely influenced by exceptional disturbances of the sea at critical junctures, by longshore current abnormal in power and direction and changes in density of inshore waters either through lack or superabundance of monsoon floods, especially at the end of southwest monsoon. He was strongly inclined towards this last-mentioned factors, at the time of which, the inner coastal zone would not be swept by currents but would settle into a stillness lasting for several months. He also suggested as a working hypothesis, a study of the density of the sea water at different distances and depths together with a comparative study of the local rainfall from mid-August to early October and of the environment biological and physical, that influence the sardine movements. Sundera Raj (1934 & 1937) thought heavy fishing on immature fish would have adverse effect on the fishery of subsequent years. While Devanesean (1943)also suggested over fishing. Devanesan and Chidambaram (1948) were of the opinion that the intrusion of an immature generation in the fishery was a probable cause of the fluctuations. Chidambaram *(op. cit)* expressed the view that the fishery-independent fluctuations in abundance were caused by varying degrees of success of spawning between years and the variability of larval survival. He listed the factors as responsible for this as, the relative number of spawners, hydrological conditions and availability of food for the fry and young fish. Among the hydrological conditions, he felt that an average temperature range of 26.61 to 26.86^{0}C and a specific gravity of 1.0213 to 1.0214 would be ideal for spawning survival. However, it should be mentioned here that these ranges refer to annual average, whereas the spawning season extends only from June to October. Nair and Chidambaram *(op. cit)* attributed the decline in the fishery to fluctuations in abundance, periodical migrations into offshore regions and heavy natural mortality or overfishing etc. Panikkar (1952), Nair (1953b) and Nair & Subrahmanyan (1955) observed that the availability of the diatom, *Fragillaria oceanica* would be one of the major factors governing the fluctuations and Nair (*loc. cit)* also indicated that optimal conditions of temperature (27-28^{0}C) and salinity (34-35%) would influence the appearance of stronger shoals into the fishery. Discussing fish population studies, Banerji (1967) brought out the necessity to search for fishery independent factors to answer the fluctuations in the yearly recruitment. Bennet (1969) was of the view that the over abundant year class exerts a great stress on the fry of one or two successive generations causing reduction in their numbers and hence the fluctuations in the fishery. Antony Raja (MS.4) although concurred with Chidambaram *(loc. cit)* that the strength of the fishery would be influenced by the success or otherwise of spawning and survival rate, was inclined to the view that since the commercial fishery leans more on the 0-year class, the fluctuations in the fishery of a particular season are dependent on the rate of recruitment in the pre-exploited phase of the same season, or in other words, on the strength of the incoming juvenile recruits resulting from the major spawning during June-August months of the same year, thus, indicating that the adverse effect on spawning are reflecting in the same year's fishery for juveniles and not after 2 or 3 years as Chidambaram *(loc cit)* contended. Proceeding further, he showed that greater incidences of *Corpora atretica* and their intensity would cause reduction in the potential egg stock for release which phenomenon he related to the abnormally low average daily rainfall during the spawning fortnights. This was subsequently confirmed by him through fecundity studies as well as (Antony Raja, MS5). His studies (MS.4) further indicated than an average daily rainfall of 30 mm during the spawning fortnight would contribute towards normal maturation and spawning processes and anything less than 20 mm would result in large-scale follicular breakdown and the corresponding decrease in the egg production and larval output. It is, hence, interesting to learn that Murthy and Edelman (MS; Murthy, p.c.), finding a good correlation between the sea-level pressure differences as an expression of monsoon intensity and the oil-sardine fishery, expressed that certain low range of monsoon intensities is unfavourable whereas certain range of higher intensities is favourable. During the former period, the pelagic waters are depleted with dissolved oxygen due to upwelling while at the latter time, wind mixing could compensate for the loss of oxygen. However, it is understood that the monsoon intensity referred to in the above report as difference of pressure need not necessarily be correlative to the amount of rainfall during the spawning fortnights studied by Antony Raja (MS.4). It is also noticed that their observations are based on pre-1957 period and hence, it may be necessary to extend these studies to the subsequent period also which has witnessed the second and third phases of much richer oil-sardine fishery refferred to in earlier pages.

If a patient analysis of these several factors is made, it would become clear that they get reduced down to only one major factor, namely southwest monsoon, if a couple of other possibilities are ruled out. The problem of overfishing suggested by some workers implies that with increasing effort, there would be decreasing catch per effort. But unless it is proved that the present fishing morality is more than that, associated with the maximum catch per recruitment, it cannot be held tenable. Since Banerji *(op. cit)* has noticed no relationship between abundance and fishing effort and in a preliminary study, it is seen that the present level of fishing mortality is only half of that associated with maximum sustainable biological catch (Annual Report, CMFRI, 1968), it may be said that at present the problems of overfishing does not arise. The theory pressure of overabundant year class on the fry of one or two successive generations also appears to be not well-founded, for it is based on the assumption that the fishery is not dependent on the 0-year class but on older groups. Since the commercial fishery of 1964 witnessed such an abundance of oil-sardine as to establish a record in the history of the fishery up to that period and continued to support the fishery in 1965 also as an unusual departure from normal, the rarity of the new incoming juvenile broods in 1965 might have prompted Bennet (1969) to see the determinant in the pressure of overabundant year class on the incoming recruits. But as Antony Raja (MS 4&5) pointed out, the reason for rarity of juveniles in 1965 was not because of pressure of older groups but due to failure of spawning that year and hence its own weaker strength. Moreover, according to the above theory, the overabundant “1963 year class” that contributed to the 1964 fishery, as per that author’s presumption, should have stifled out “1964 & 1965 year classes” and hence, when it fades out in 1966, that year should have had a markedly lean fishery, which, as records show, was not the case, neither the heavy concentrations of fish for five consecutive years from 1964 to 1968 support the theory of “pressure”. Hence, if these two possibilities are discounted, then the other factors suggested responsible for fluctuations are centred around the southwest monsoon and the resulting conditions, both biotic and abiotic.

It, thus, appears that the belief of the fishermen of some connection between rainfall and the fishery as Hornell (1910b) reported is proved to be justified. A chain reaction brought about by the failure of monsoon or even unequal distribution of monsoon conditions during spawning, begins by affecting the spawning habits of the fish and the survival rate due perhaps to the depleted oxygen leading on to the low food production in coastal waters and culminate in the availability of weaker stock for exploitation. If the mackerel stock, recruited earlier than the oil-sardine, proves stronger in the same year, it would smoothen out the oil-sardine in the competition, thus completing the picture of events depicting the oil-sardine fishery as a failure.

5. 4. 4 **Forecast**

Nair and Subrahmanyan *(op. cit),* pointing out the close relationship between the occurrence of the diatom, *Fragillaria oceanica* and the oil-sardine fishery, were the first to venture a forecast on the prospects of successful oil-sardine fishery. They expressed that in the life history of this diatom there is an intense vegetative multiplication immediately after sexual auxospore-formation which results in a *Fragillaria* bloom once in 3-4 years. They reported two such blooms in 1949 and 1953, the earlier of which they argued would have helped the recovery of the oil-sardine fishery, culminating in the good catch of 1953 coinciding with the second bloom. In the light of these evidences, they expected a good fishery during 1956-57 season whereas that season proved a total failure, the worst for the 7-year period beginning 1950. However, Subrahmanyan (1959 & 1960) made a slight modification by relating the observed bloom of 1957 with the bumper oil-sardine landings in 1957-58 season. It may be, however, added here that from the pictorical representation of his data (Subrahmanyan, 1959, p. 173) it is seen that the *Fragillaria* bloom of 1953 is followed by another peak of almost similar magnitude in the very succeeding year, 1954, also but for which no comments were offered. Since the observations of Nair and Subrahmanyam *(loc. cit)* indicated that there is a general reduction in the availability of this diatom within a 4 –year interval, a corresponding influence also is to be expected in the strength of the available fish stock, ending in a condition almost amounting to a lean season once in 4 years, which, however, is also not seen. The continuous crop of rich fishery for the last 5 years also does not appear to support the above view. So while it may be advisable to have more confirmatory data in support of true occurrence of a bloom once in 4 years, it is doubtful whether this diatom alone can occupy such an important link in the fishery chain of oil-sardine, for, it has been shown by different workers that in addition to *F.occeanica,* a few other species of diatoms as well are equally important in the oil-sardine food. It is also significance to recall the remarks of Margalef (1960) who observed that this hypothesis is not in agreement with general experience for, if nutrients were sufficient and *Fragillaria* are not increasing, other diatoms would flourish and the diatom bloom would continue in any way. Hence, it appears that at best, the *Fragillaria* bloom would be an attraction *in loco* with the general luxuriant growth of other phytoplankton organisms under ideal environmental conditions for the migration of oil-sardine shoals to the fishing areas . As Nair and Subrahmanyan *(loc cit)* themselves cautiously qualified their prediction with the availability of favourable hydrological and other conditions, a more reliable indicator for prediction becomes necessary.

Bennet (1968 & 1969) stated that a study of the stronger year class pressure would help to predict the fishery for subsequent one or two years and suggested more intensive fishing of an unusually strong year class to relieve the pressure as a solution for stabilizing the fluctuations. It has been already shown that the above author's assumption and prediction are based on a different interpretation of year classes contributing the fishery and which has been already commented upon. With the regular sequence of new broods of 0-year class forming the mainstay in the fishery every year, the question of long-term prediction of the above mentioned authors just does not arise.

The present author feels that the clue for reliable prediction lies in the features presented by the gonads during the beginning months of the fishery namely, the spawning period of the same season and his forecast for the failure of the juvenile fishery in 1963 and 1965 due to failure of spawning as revealed by heavy atresia which is believed to be caused by erratic monsoon and feeble rainfall during the spawning fortnights has come true (Antony Raja, 1967: CMFRI, Quarterly report for period ending September, 1965). Based on the same criterion, it is also predicted that the current season's fishery (1969) for juveniles will border on failure and if the next important group, spillovers after first spawning, namely, 1-year olds, does not compensate this failure as was the case in1965 , then the chances of as rich a fishery as in the recent 5 years, for 1969-70 season can be ruled out.

The ability to foresee the course of events likely for the ensuing fishery enhances the value of fishery research in the eyes of those involved in the industry, for it will enable them to regulate their activity in the necessary direction and manipulated the fishing effort in such a way as to tap returns from other fish resources, Since in the case of oil-sardine, the commercial fishery is dependent on the juvenile community recruited every year, the responsibility of the fishery researcher is greater, for a reliable forecast for the ensuing fishery from September onwards has to be done very quickly with the data collected during June to August period. Such a prediction will be of short term value for that season alone and will apply only for the incoming juvenile recruitment. Since experience indicates that at the present rate of exploitation, an exceptionally rich year class may be able to contribute such a successful fishery for two consecutive season (as seen for the years 1964 and 1965) as to obliterate the failure of the juvenile brood in the latter of the two years (Antony Raja, MS.5), certain amount of caution may become necessary to make a forecast covering the entire oil-sardine biomass that will be available for exploitation in particular season. A modest beginning has been made to forecast the likelihood of weak broods of juveniles recruits based on the amount of rainfall during the spawning fortnights and the gonadial picture. Since the normal trend is dependence on these juveniles, it may be expected that this method is developed further in correlation with any other abiotic or biotic factors so as to ensure accuracy, though for the present it may remain only qualitative. The fishing industry is not only interested is knowing whether the prospects of oil-sardine fishery are good or bad but expects also from the scientists the likely quantity available as well as the area of availability . For this direct and positive prediction. Spawning and nursery grounds have to be deducted and delimited and a spawning survey and serial scouting undertaken.

5. 3 **Fisheries management and regulation**

The wide seasonal fluctuations of the fishery and its disastrous effects on the industry drew the attention of the then Govt. of Madras who introduced a legislation in 1943 for Malabar and South Kanara districts. The main clauses were the prohibition of 1) the use of *mathikolli vala* during August to April, 2) the use of *mathichala vala* during August to September and 3) the landings of immature sardibe below 150mm exceeding a total weight of 1 maund 36 kg) by any single boat during the fishing season. This legislation was extended for another 2 years from 1945 with a modification to prohibit the use of both these gears throughout the season and landing of immature sardine. It, however, lapsed in 1947 due to practical difficulties in the enforcement of the regulation such as lack of sufficient preventive staff over a long coastline and lack of similar legislation in adjacent states (Nair and Chidambaram, *(op. cit.)*.

The observation of recent years have shown that as long as there is no problem of overfishing, there is no necessity for any restriction for, the unfished stock of spawners can bring in sufficient strength of juvenile recruits for successful fishery provided the conditions in nature are favourable. It is possible that the prohibitory legislation was discontinued not only for reasons mentioned above but also due to total absence of revival of fishery expected under the protection of the laws. With the possibility of very high natural mortality during the early stages of growth, it is felt that the legislation would have in no way helped in the conservation of the stock.

VI TECHNOLOGY

6.1. **Chemical composition**

6.1.1. **Whole fish**

Chari (1948) has reported the following chemical composition for oil-sardine of 180 mm average length.

Edible portion	=	70.00%
Protein	=	19.57%
Water	=	76.49%
Ash	=	1.79%
Phosphorus (P_2O_5)	=	0.79%.
Calcium (CaO)	=	0.47%
Fat	=	2.0
Iron	=	6.09mg/100g

6.1.2 **Sardine oil**

Of the two grades of sardine oil, yellow and brown, the former was found to compare very well with Menhaden or Japanese sardine oil as is reproduced below from Nicholson (1922).

Oil	Specific gravity	Saponification value	Iodine value	Acid value
Menhaden oil	0.931	193	160	7
Japanese sardine oil	0.933	195	181-187	10-34
Oil-sardine oil	0.880	196	156	3-9 12-53

Considerable work has been donne in the recent years by the people in the industry as well as those in Govt. technological research establishments as brought by a recent seminar on "Marine Oils" organised by the Oil Technologists' Association of India in 1968 (Kamasastry, 1961;

TABLE XIV

Properties of sardine oil

Source	Kamasastry, 1961	Kamasastry *et.al.*1964		Sen & Chaluvaiah, 1968	Madhavan & Kaimal, 1968		Kotwal & Pai 1968
Properties	Laboratory Sample	Laboratory sample	Commercial sample	Commercial sample	Commercial sample	Improved sample	Commercial sample
1. Colour	Dark brown black, brown, yellow	Brown, lemon-yellow	Light/dark brown, black yellow	Greenish straw/light/ golden yellow	Deep brown to black	Brown to light yellow	- -
2. Specific gravity	0.918-0.941	0.9253-0.9281	0.9202-0.9264	-	0.9250	0.9219	-
3. Refractive index	1.470-1.476	-	-	1.4734-1.4771	1.4780	1.4755	-
4. Acid value	11.50-99.26	0.56-3.43	6.21-69.00	-	-	-	35.70
5. Iodine value	99.4-161.0	160.6-171.0	152.4-175.8	144.8-176.5	99-161	152-175	145-170
6. Peroxide value	0.0-6.7	1.05-2.14	0.00-9.20	-	0.44-7.20	0.32-2.70	-
7. Free fatty acid (%)	5.79-19.98	-	-	-	5.8-49.6	0.6-3.9	-
8. Saponification value	140.5-213.2	192.3-193.3	192.9-198.0	187.8-202.3	190-198	192-195	195-200
9. Unsaponi-fiable matter (%)	0.58-1.56	1.12-1.20	0.56-1.04	-	0.84-1.55	0.83-1.55	1.0
10. Moisture (%)	0.15-0.92	-	-	-	0.25-0.62	0.20-0.40	-

Kamasastry *et al.*, 1964; Gedam *et al.*, 1967; Ramadas and Aggarwal, 1967; Gedam and Aggarwal 1967; Kaimal and Madhavan, 1967; Kaimal *et al.*, 1968; Sen and Chaluvaiah, 1968; Sen and Revankar, 1968; Madhavan and Kaimal, 1968; Aggarwal 1968; Kotwal and Pai, 1968). While the industrial aspects is dealt with in the next chapter, the chemical composition of the oil as gathered from different workers is consolidated in Table XIV. Kamasastry *(loc. cit)* studied the deterioration in the quality during storage and found that good quality oil can be preserved for one year without marked deterioration. Kamasastry *et al. (loc. cit)*,making further studies, inferred that in the laboratory extracted oil the deterioration was less as compared to the commercial samples. The dark colour of the oil was found associated with the percentages of oxidised acids, nitrogen content and high acid value. Storage of oil in either plain or brown containers appeared to have no effect on the iodine and acid values. Sen and Chaluvaiah (*loc. cit)* observed that the iodine value was found to have seasonal variations, with a peak value in August and significantly low value in March. While from whole fish the colour of the oil was greenish yellow or golden yellow - the greenness due to chlorophyll originating from the gut contents - the oil from the body portion was invariably light yellow. Under aeration, the colour was observed to change rapidly to brown. Freshly extracted oil was almost bland but developed rapidly rancidity and fish odour. Foul and offensive odour associated with indigenously produced sardine oil was found due to the defective procedure of extraction itself.

6.1.3 **Fish manure**

The high nitrogen and phosphate content of fish guano has made it a valuable manure. The difference in the composition between the crude beach-dried and the improved guano is given by Nicholson (1922).

	Beach-dried manure (%)	Improved guano (%)
Water	15.0	9.8
Nitrogen	6.8	8.3
Phosphoric acid	5.3	8.8
Potash	0.7	0.4
Total organic matter	60.0	66.3

6.1.4 Fish meal

Sardine fish meal is obtained by sundrying the press cake after extracting the oil and its composition as given by Chari and Pai (1948) and Kamasastry and Rao (1965) is given below:

Composition	Chari & Pai (%)	Kamasastry & Rao (%)
Moisture	9.7	5.0 - 7.8
Protein	65.3	51.5 - 56.8
Fat	9.5	6.7 - 8.6
Ash	14.8	27.8 - 34.5
P_2O_5	5.8	6.6 – 9.3
CaO	6.0	9.4 – 11.4
NaCl	0.3	-
Insolubles	.	0.7 – 1.7
Non-protein nitrogen	.	1.2 gm%
Total volatile nitrogen		14.7 – 20.5 mg%
a-amino nitrogen	.	138.2 – 169.2 mg%

Kamasastry and Rao *(loc. cit)* working on the composition of different fish manures, found that the protein content of sardine meal is low as compared to Jew fish or mackerel. The high ash content and insolubles in the sardine meal was attributed by them to the large quanity of sand injested with food in the intestinal tract. High value of a-amino nitrogen were recorded for sardine meal. Fish meal samples were found to register a slow increase of moisture during the storage period.

TABLE XV

Fat and moisture contents of (1) head and visceral portions and (2) body portions of oil-sardine (From Sen & Chaluvaiah, 1968).

Month	Moisture (%)		Fat (%)	
	Body	Head and viscera	Body	Viscera
January	64.9	60.3	10.2	15.5
February	69.1	64.7	7.6	10.5
March	68.1	63.9	8.4	11.6
April	69.9	66.9	5.3	10.0
May	71.5	69.2	7.4	7.0
June	72.0	69.9	4.0	6.7
July	72.9	72.7	3.0	4.2
August	68.3	70.1	8.8	8.2
September	63.8	62.7	13.4	13.6
October	65.3	64.8	11.6	12.2
November	64.5	62.6	13.0	13.3
December	64.8	62.1	12.6	14.5

6. 1 **Studies on fat content**

In as much as the disparity in the fatness of the sardine in different months is a matter of great economic industrial importance, attention was focussed on the variations in fat content of oil-sardine since early days. Hornell and Nayudu *(op. cit)* found appreciable quantity of fat in September which suddenly shot up in October and continued to maintain the rise in November also only to decrease as rapidly as it rose up during the subsequent months ending in minimum fat production in June. The maximum fat deposit during October to December was correlated by them to the food intake of the fish, especially the dinoflagellates and infusorians dominant during these months. The contribution from diatoms and copepods was considered by them as lesser importance. The variations of fat content between years were attributed to the variability in the quanity of dinoflagellates and infusorians available and the proportionate intake by the individual fish. Vasavan and Gangadharan (1960) in a small note on the seasonal variations have observed the peak in the same period as mentioned above. Similarly, Sen and Chaluvaiah *(op. cit)* found the maximum fat content (11.0 to 15.7%) during September to December period and minimum (2.7 to 4.4%) during June-July period. The juveniles of about 100 mm were noticed to be comparatively lean with 11.1 to 5.8%. They also observed that the fat and moisture content were interrelated. Table XV shows their data on moisture and fat variations in two main depots from which it is seen that while fat content of both body and viscera were keeping an identical trend of variations, comparatively the visceral fat was more. They concluded that recoverable fat in a year is 9.7% when screw-press is used and 8.5% when basket-press is employed which compared favourably with the estimate of 9% by Hornell and Nayudu *(loc. cit)*, where Madhavan and Kaimal *(op. cit)* observed an average of 12% for the fish. Investigations by the present author on the seasonal variations in muscle and viscera as compared to whole fish (unpublished data) appear to confirm in general the findings of earlier workers, while indicating certain other minor trends in the different categories taken. The fat content was found to be maintained at a higher level by the immature fish for a longer time than the spent ones among

Which those after first spawning had comparatively more percentage of fat. Some quantitative details largely depicting the same picture of variations are available in the Administrative reports of Fisheries Department, Kerala, for the years 1965-66 and 1966-67.

6. 3 **Other technological studies**

Other technological studies relate to behaviour of free amino acids in oil-sardine held in ice storage (Jacob *et. al.,* 1964) and changes associated with lipid breakdown in the oil-sardine under refrigerated temperatures (Nair, 1965).

VII INDUSTRY

7. 1 **Food**

7. 1. 1 **Fresh**

In the former days when storage and transport facilities were not as markedly developed as in recent years, apart from a small quantity consumed fresh and some sent to interior parts packed up with crushed ice, the major portion was salt-cured after supplying to the industry for extraction of oil etc. Taking into account that about 30% of the landings were utilized for curing (Nair & Chidambaram, *op. cit.)* and about 50% towards extraction of oil (Madhavan & Kaimal, *op. cit.)*, only the remainder was available as food in fresh condition. But in recent years, it appears that, in view of the reluctancy on the part of the industry to take to seriously the sardine oil production due to undependable nature of availability and increased coast of production of oil and simultaneous increase in the demand for the fresh fish from interior places which could be met by the increased flow of ice production and organised transport system, consumption in fresh condition has gone up tremendously to at least 60% (Kaimal, *p.c.).* The value of the fish also has been shooting up at such a rapid rate that it has more than doubled in 1966-67 from what it was in 1960-61, as could be seen from the following figures, which are calculated from the data given in the Administrative reports of Fisheries Department, Kerala, for the respective years.

Year	value per m.ton in Rupees
1960-61	73
1961-62	92
1962-63	118
1963-64	203
1964-65	116
1965-66	158
1966-67	184

The price was quoted as about Rs. 250 last season which was a successful one, whereas the high cost in 1963-64 was due to shortage of fish on account of failure.

7. 1. 2 **Canned**

Recently some 4 or 5 companies have started canning in Calicut, Cochin and Alleppey areas, but the quantity diverted to this industry appears to be rather low from which much less is exported. It is said that cost per can is so high that neither in the international market the price is competitive nor in the internal market within the means of those who would like to go for it. This is attributed to high cost of tin in India (Alexander, 1965). If the cost of tin is so prohibitive, a suggestion that can be looked into by the industry is whether it is not possible to export the cooked fish after proper processing and under refrigerated condition to foreign countries where according to taste canning can be done. A procedure for canning of oil-sardine that gives comparatively standard product has been worked out by the Central Institute of Fisheries Technology (*Fish Technology Newsletter,* 5(1), 1964).

7. 1. 3 **Cured**

Formerly, quite a good amount of fish used to be cured and exported to Ceylon. But the trade appears to have considerably gone down now because of local demand in fresh condition. The details of quantity of cured fish in the early years are available in the reports of Nair and Chidambaram *(op. cit)* and Nair (1960).

7. 2 **Sardine oil**

Next to its importance as food, the oil-sardine is sought after for its high oil content. The primitive method of oil extraction in the Last century and the improvement effected by Nicholson in the early part of this century are given in detail by Nair& Chidambaram *(op. cit)*. The present method and the possibility of further improvement to avoid wastage and procure better quality are detailed by Madhavan and Kaimal *(op. cit).* The quantity of oil produced in the

South Kanara and Malabar districts during 1906 to 1949 is tabulated by Nair and Chidambram *(op. cit)* and Nair (1960) from which it is seen that after a record production of slightly over 12500 tonnes of oil in 1922-23, the quantity was reduced to about 2000 to 7000 tonnes during the subsequent 3 seasons but dwindled thereafter fluctuating within about 500 tonnes except for one season (1933-34) when there was a recovery to about 2000 tonnes. Table XVI gives an idea of production of sardine oil and other byproducts in Kerala state during the past 5 seasons.

TABLE XVI

Quantityin tonnes of different by-products produced in

Kerala State (From Kaimal, personal communication).

Season By-product	1964-65	1965-66	1966-67	1967-68	1968-69	Average
Sardine oil	2073.13	1079.88	85.17	5.35	671.26	782.96
Fish guano	7031.35	613.50	85.00	12.00	197.80	1963.66
Fish Manure	5909.18	433.00		3882.48	8808.10	4758.19
Fish meal	-	-	6.08	84.73	22.08	37.63

Sen and Chaluvaiah *(op. cit)* have reported an estimated production of about 3000 tonnes per year on all-India basis, while according to Kotwal and Pai *(op. cit)*, it is in the order of 5000 tonnes. Aggarwal *(op. cit)* has stated that it varies from 3 to 10 thousand tonnes depending upon the catch and demand for the oil. He has also indicated a potentiality of 20000 tonnes. This is perhaps based on an average production of 2 lakh tonnes of fish during the season from which 10% can be extracted as oil. But since large quantity is now required as food, perhaps only about 25% can be rough estimate of feasible diversion from the total landings for the sardine oil industry. Aggarwal *(loc. cit)* is also of the opinion that because the industry is not well organised and crude methods are dopted resulting in high acid value and dark brown colouration in the oil, the production and demand are rather limited. While the price of oil per tonne was about Rs. 900 in 1965-66 (Adm. Report, Fisheries Dept., Kerala, 1965-66), recently it is quoted as to range from Rs. 1250 to 1870 (aggarwal, *loc. cit*) and in the current year it is reported as high as Rs. 2000(Kaimal, *p.c.*), showing thereby how the price has more than doubled within the past 4 years, although the fishery has consistently produced a heavy catch and the price of which has not gone up by that ratio. This is again related to high cost of production which can be, it is understood, minimized under better organization and method of extraction.

Comparatively, however, sardine oil is considered as a cheap fish oil. While the better grade oil is reported to be consumed by fishermen and local people (Aggarwal, *loc. cit)*, the technical grade oil is used for painting bottom of country boats , as a constituent of insecticidal soaps, for batching of jute and dressing leather and for tempering metals (CSIR, *Wealth of India*, Industrial products, Part IV: F-H, pg. 70; Aggarwal, *loc. cit)*. Because of the high unsaturation resulting in the easy susceptibility to oxidation, flavour reversion and the related changes, sardine oil has not so far been utilized for preparation of hydrogenated products, soap manufacture or for domestic consumption Madhavan & Kaimal, *op.cit*). However, it appears that sardine oil can be sulphonated and mixed with fatty oils or mineral oil to obtain a fat liquoring composition in the form of stable emulsion *(Chem. Abst.* 1960 as quoted by Madhavan and Kaimal, *loc. cit).* That by deacidifying the present commercial oil and by splitting it into fatty acids and glycerol, Kotwal and Pai *(op. cit)* have shown that the glycerol thus obtained can be used in soap manufacture also and the left over products for paints and surface coating. Aggarwal *(loc. cit)* has also shown that it can be hydrogenated and quoted its satisfactory use by a soap manufacturing concern. Apart from the above mentioned uses, Madhavan and Kaimal *(loc. cit)* have indicated that the oil can be profitably used to prepare factise for rubber industry,paints, printing ink, and as an additive to lubricating oil. Sen and Revankar *(op. cit)* have found that properly extracted sardine oil is a better medium than ground-nut oil for canning purposes and through hydrogenation the rancidity and high fish odour can be removed. They have also indicated that by controlled interesterification, hydrogenated sardine oil can be given a butter-like consistency also. It is also understood that because of a very high percentage of unsaturated fat, the oil has medicinal value also in treatment for high cholesterol content of blood (Kaimal, *p.c.)*.

Thus, it is seen that the amount of potentials of sardine oil is great if properly extracted and subjected to refined chemical processing and a sound industry can be developed on scientific lines. The major hazard for the industry appears to be the uncertainty, variability and seasonality associated in the abundance of raw materials.

7. 1 **Fertilizer**

Till a few years back whenever there was a glut in the market, even the whole fresh fish were used as manure. But the common forms where the oil-sardine is used to produce fertilizer are guano and fish manure. Guano is the press- cake after oil is extracted from cooked sardine. It has been found to contain 8 to 10% of nitrogen and phosphates and being well cooked it disintegrates and mixes with the soil quickly and is believed to be 15 to 20 times richer than ordinary cattle manure (Mohanty, 1956). Since it is easily utilized by growing plants, it is very much sought after for raising cash crops and in tea, coffee, rubber plantations and exported to Ceylon and Japan (Nair and Chidambaram, *op. cit).* On the other hand, fish manure is made from gills and viscera or sometimes from the whole fish that are spoiled and unfit for human consumption. It is mainly beach-dried and includes, other fishes too. What is available in the market is reported to contain about 5-7% nitrogen and phosphates and when mixed with ash it forms complete manure (Mohanty, *loc. cit).* An idea of the amount of fertilizers produced from 1906 to 1949 can be had from the account of Nair and Chidambaram *(loc. cit).* It is seen that it was fluctuating according to the nature of the fishery ranging from 3 to 35000 tonnes annually. But recently it appears to be around 2000 tonnes of guano and about 5000 tonnes of fish manure on the Kerala coast (Table XVI).

7. 2 **Fish meal**

One of the chief raw materials for preparing fish meal is oil-sardine. It is also made from the press-cake, taking care to prevent admixture with sand. It can be stored in air-tight containers for fairly long periods after proper sterilization. It has proved to be a very valuable protein concentrate and as it has high percentage of calcium phosphate, it is valuable as cattle and poultry feed (Mohanty, *op.cit).* An average of about 37 tonnes has been estimated as annual production in Kerala (Table XVI) and it is learnt that the quantity of fish required to produced one Kg of fish meal is 5 times that amount (Kini, 1956).

VIII FUTURE

When a great deal of published and unpublished data has accumulated it becomes imperative to consider them under one body in order to seek out the nature and relationships of the various problems and to find out how many of them have reached a crystallized form and how many are still elusive. The principles employed in other fishery studies elsewhere, which though need to be necessarily operating under conditions prevailing here, may further serve as useful guidelines in answering a large number of questions. The progress so far registered can then be accelerated with an objective assessment of results, a re-orientation of the lines of investigations and multipronged co-operative attempts to tackle first those problems, immediate and outstanding, so as to increase the chance of solving them within a reasonable period of time.

1. Proceeding *ad seriatim*, although the **IDENTITY** of the oil-sardine on the west coast of India as *Sardinella longiceps* appears undisputed, in view of the absence of any detailed description of the morphological features of the most important commercial fish of India, the intended investigations into it seem to be justified. It is well-known that the taxonomic works are often based but on a few individuals in such a manner as to appear that there are very sharp lines of demarcation in the distinguishing characters, but when a large number of specimens is examined from different localities, the great variability in characters employed for specific distinction comes to light so much so, some of the features which are earlier diagnosed as characteristic, fail to appear so and hence, some workers have recommended proper utilization of regression analysis even for taxonomic studies. The investigation envisaged on the oil-sardine, thus will also offer data for subpopulation studies discussed later in this chapter. The reports of oil-sardine on the east coast as well as Andamans by some workers but with no exclusive taxonomic descriptions introduce a legitimate doubt on its identity as true oil-sardine, especially in view of the fact that what is reported as

S. longiceps in the Philippine waters, Java and Malacca straits is believed to belong to another closely allied species. Hence, in the proposed study will be included also the material from the east coast and Andamans. It is only after the systematic position of these forms is settled, the distributional extent of the Indian oil-sardine can be finalised.

2. On the **DISTRIBUTION** patterns of the juveniles and adults some knowledge is available but it cannot be claimed to be complete. The suggestion that the appearance of the oil-sardine all along the coastal stretch may be simultaneous from the offshore grounds depending on the time of out break and strength of southwest monsoon, the availability of congenial ecological conditions in the inshore belt and the location of spawning areas, and their earlier disappearance at the northern latitudes may have to be appraised by drawing annual space-time canvas for at least a 10-year period from the data collected by the survey staff to cover the entire region from Vizhingam to Vengurla so that admissibility or otherwise of the suggestion can be brought out and an answer provided which till now is rather speculative only. These space-time charts would require details such as the distance from the shore, depth, size composition, time and effort expended, quantity captured etc., for as fine an area as possible within every one degree latitude and perpendicularly for every 5 m depth level. If the information on the environmental features-physical, chemical and biological-relating to this area can be superimposed, the resulting information will be much more valuable since we are more intensely concerned with the patterns of distribution-thus, on behaviour -in relation to the patterns in the environment. Past investigations have given a general picture of regions of availability but the aspect involving their- disappearance has yielded no information to permit even a reasonable speculation of the area of emigration. Perhaps when the preferences of the fish are known in the inshore waters, charting and monitoring of the distributional properties of the area beyond the present fishing belt, would indicate the region that might be sought after by the disappearing shoals. Should there be any changes in the patterns of distribution of the oil-sardine population, the causal factors may be either in the changes in the spawning area and the migratory routes or the rise and fall of the subgroups of population, if any, differing in the distributional areas.

3. Regarding the **BIONOMICS AND LIFE HISTORY** of the fish, the concerted attempts of the past can be said to have yielded some definite and dependable information on important aspects like size at first maturity, spawning season, spawning habits, age & growth. Work on collection of age-size distribution, gonad maturation, maturity indices and fecundity equations should however be continued since it is on the basis of this information, the spawning habits in each season can be understood. Unlike many commercially exploited species that lay more than one batch of eggs, thus, making the quantitative studies of fecundity difficult, in the oil-sardine, an analysis of the more advanced modal group would give a satisfactory estimation of the number of available eggs for release. But an aspect that requires intensive studies is the spatial variability in fecundity, if any. That the geographic differences may be suggestive of genetic difference has been pointed out and should a comparison be attempted for the purpose of stock identification, then, simultaneous collection from different centres and an analysis of the material belonging to identical stages of maturity by the same investigator would respectively eliminate variability due to environmental conditions and estimates with differential bias. This study would be indirectly a contribution towards stock studies also. Another aspects of spawning biology that requires confirmatory evidences is the reported possibility of lunar relationship to spawning and whether, if there is any, it is strictly operative when the normal spawning processes are affected. Herein comes the wide lacuna in our knowledge on the eggs and larvae of the oil – sardine and the area of spawning. The importance of the knowledge of distribution, abundance and biology of the younger stages in the pre recruitment phase towards understanding of many problems in population studies is too well-known to need recapitulation. The early stages of larval history are considered to be the critical stages with respect to morality rate and on which partly depends the success or failure of yearly broods, since survival rate is mediated through environmental changes. Deduction, delimitation and definition of spawning areas can make an important contribution to the solution of the problem of unit stock identification for, genetic differences in subpopulations may be reflected in larval characters such as pigmentation or in the diameter of yolk mass of the fertilised eggs. While records of adults with advanced gonads are available at all the important centres of intensive

observations, it is necessary that we know whether spawning takes place in discrete areas or in indiscrete patches all along the coast. Even off Calicut, the spawning ground appears to be subjected to shifting in relation to distance from the shore. While normally it is believed to be beyond 15 km, there are evidence to presume that at times it might have been rather nearer. All these go to emphasise the urgent necessity of an intensive search to fill up this hiatus in our knowledge. The main handicap towards solving this question has been the lack of ocean-going facilities because, the intensive spawning takes place at the height of monsoon, when the indigenous craft nor small powered boats can venture out to the desired distance. However, with a monsoon-worthy research vessel, a preliminary exploratory attempt solely for this purpose can be made off Calicut, where there are definite indications of existence of a spawning ground (between Quilandy and Parapanangadi) beginning from 50 m depth level and proceeding shorewards especially during the presumed spawning fortnight in each month between June and August. With reasonable chances this author feels that such attempts during one spawning season alone may be met with results paving the way for future elaborate investigations.

With the data for 1963, 1965 and 1969 it is repeatedly seen that uneven distribution of rainfall during an erratic monsoon showing a poorer quantity in the spawning forgnights directly affects the final process of maturation and spawning. It appears that when the mean daily rainfall is below a threshold value, the spawning for that month will be seriously affected, perhaps in the absence of the required stimulus, either delaying it or reducing the number of ova released and if this feature continues in all the months of peak spawning period, the eggs and larvae would be out of phase with the required normal environment and the production of a successful year class becomes unlikely. On the other hand, if the rainfall is adequate, the changes of production of a successful year class are very high but cannot be guaranteed in view of dependence on other factors affecting the survival. It is well-known that poikilothermy limits the activity of the fish to changes in temperature sufficient for the normal rate of metabolic processes. There are reports elsewhere about a critical temperature that stimulates normal reproduction. Although it may be debated whether under tropical condition with limited temperature range, the fish is likely to react adversely to subtle differences in temperature, nonetheless, it would be interesting to find out whether any such critical temperature is involved and affected because of erratic monsoon and the resulting conditions. Thus, it would be an enlightening study if the meteorological data on rainfall and oceanographical data are compared for the period extending from 1959 to 1969 to bring out the various environmental factors resulting from the vagaries of monsoon intensity during June to August months with special reference to the spawning fortnight of each month so as to identifying the specific requirements in the medium that may act as catalyst for spawning and whether these requirements registered any marked changes in 1959, 1963, 1965 and 1969.

That the oil-sardine has a very rapid rate of growth during the early juvenile history can perhaps be regarded as the answer to the controversy that existed earlier. Should there be any doubts, a comparison of length frequency data of different centres can be made after subjecting the modal sizes to judicious interpretation and if there are any marked variations in growth parameters, they can be treated as useful tools in area-stock identity. The question whether there is any possibility of the fish entering their third spawning season can also be looked into during this comparison, if it should indicate that the fishable life-span of the fish extends beyond 3 years in which case also, the isolation of such older groups may help in understanding the population at large.

An important aspect that appears to require further elucidation in the food an feeding habits is on the reported carcinivorous habits of the juveniles below 100 mm length. Since in recent years this group of juveniles has been caught more frequently is the nearshore areas, it may be worthwhile to study the standing crop of plankton at that time to find out the depth of correlation between the two - whether the habit is selective and hence their absence or presence in the nearshore area. Observations elsewhere have reported such fish concentrations spatially and temporarily in areas charactersed by such a biotic feature and hence it would be fruitful that this aspect is also cleared up for a fuller picture on the feeding habits of the fish.

The reason for a striking deficiency in our knowledge on the behaviour of oil-sardine is the lack of facilities for direct observations on it both in nature and in captivity. Although there are some reasonable speculations on the behaviouristic patterns of oil-sardine movements, more specific deductions in relation to feeding, spawning and shoaling are considered necessary. The report of empty stomachs in the active spawners appears to indicate that reproductive drive may supercede the feeding urge, either because feeding drive is partly satiated or the stimulus for spawning is more. Since distribution and density of shoals are also functions of behaviour, considerations of accessibility also forms part of behaviour research. The tagging experiments conducted now may, at best, yield some indications of local migratory movements but not much on growth, in view of the difficulty to capture and tag fish less than 100 mm. Hence, there appears a need to devise suitable tags - probably opercular type which appears least injurious as compared to the dart tag - to ensure that post-tagging mortality is not very high. Since the recovery of tagged fish now amounts to a negligible percentage, further intensification may be more rewarding.

4. With various aspects of fish biology occupying the immediate attention of researchers all these years, as a result of which a fairly composite picture is now available, it appears that in the coming decades, our attention will be concentrated more on the **POPULATION** or stock studies, which hitherto has been in the background, mostly because the vital biological aspects remained to be answered first.

It has been found that although individual samples may show the dominance of either sex or their equal distribution, there may not be any seasonal difference in the ratio during the first year of life. If there should be any in certain years, it may be a reflection of differential growth. But the indication of likely dominance of males during their first spawning but that of females during and after the second spawning offers a sufficient justification for further studies to elucidate the factuality and causation. Sample size also should be increased for reliance on the statistical significances, if any. There may be instances of strong variations between localities in sex ratio. Such differences could be of genetic origin but may be mostly due to differences in accessibility, vulnerability, growth or mortality between the sexes. Since this could have a large bearing on any yield equations prepared, it is essential that studies be carried out with this specific purpose in view.

The size and age composition studies, while being continued, may be required to provide information on natality which is not available now. This means that the studies should be stock orientated. The primary estimates of age composition will be sufficient for correlation analysis of the stock at various stages. There is every possibility to advance the study of population dynamics through more extensive survey of the age composition of the commercial catch. The length composition is quite appropriate for the routine survey of age frequency of the catch except in those rare years when the sizes of two successive year classes may merge due to growth variations in the respective first years. At this time separation would become a real problem when perhaps scale readings may be of help. In population studies it is considered essential to collect information on the relation between 1)egg abundance in any year and the catch from the resultant year class at a later stage, 2) egg abundance and the year classes that contribute it, 3) catch of 0-year class at any given year and the catch from the same year class at a later stage and 4) the catch of virgin spawners and the egg abundance produced by them. No doubt, information on 1, 2 and 4 are associated with an efficient model of spawning survey but in the meantime the relationship mentioned at (3) above can be investigated. To obtain this correlation of relative stock size, it becomes necessary to estimate the efficiency of unit effort which may vary depending upon the size, mechanism of gear and speed of operation and the volume of water in which the available part of the stock is distributed. In fact, catch per unit effort is to be defined and the study intensified. In order to estimate the mortality parameter, the catch may have to be broken up into space time groups and comparison attempted between the exploited population of different areas for the same season.

It is almost an established fact that population identification must be considered because it has been reported that truly homogeneous populations of clupeid fishes rarely exist. Moreover, our oil-sardine resource is neither new or recently subjected to fishing to eliminate the necessity of considering this problems. Three main avenues usually sought to solve this are the biometrical study on the measurable and countable characters, tagging and on blood groups. The tagging experiments are considered as the most efficient tool and more so because they would give additional information on growth, migration and mortality rates which along with information on rate of recruitment could form the basis of a fourth way of approaching this problem. But the prohibitive cost involved in embarking on an ambitious and elaborate tagging programme – for, that is what it requires- has made even those countries than can afford the expenditure, to think seriously about other methods. It is here the studies of blood groups have been resorted to which would give an idea of genetic differences. But herein too conflicting opinions on the interpretation of the data so obtained have come to light recently. The other difficulties in the use of this technique concern the collection and transport of blood samples as well as other difficulties in our existing facilities. The biometric method is usually rejected because it was felt that the studies left much to be desired. The reason advanced is that the characters are susceptible to changes in the environment and hence cannot be relied upon. The classical example cited is the mean number of vertebrae which did not show in some cases the incomplete mixing subsequently revealed by other data. It should be remembered, however, that the fishes studied and the waters involved represent medium of great range of temperature and it is also known in several cases that there is an increase in the number of vertebrae with increase in latitude and hence with decrease in temperature. It is true that the differences between overlapping distributions of meristic characters may not indicate complete independence and the amount of mixing between subpopulations but it does show the possibility of the existence of subgroups. Whether they represents subpopulations of genetic isolation is a subsequent point but not the first question in the population studies. What should be first found is that whether there are characters showing heterogeneity and whether such characters are likely to be affected by the limited range of variations in the environment. It is in the choice of character that shows distinctness lies the merit of methodology which cannot be totally condemned as inadequate. Although it is held that the method may not hold great promise, it has been also cautiously qualified that is should not be discarded as deficient for, in some cases, that may be the only tool available.

The points in favour of initiating biometrical studies on the Indian oil-sardine are 1) the studies on population biology here are in the formative phase, 2) the verdict passed on other fishes inhabiting totally different environs and which are capable of long migrations need not be taken as binding for conditions obtained in our waters where temperature induced differences can be considered negligible, 3) the method has to be given a trial to prove its adequacy or otherwise, 4) a preliminary study of different year classes has shown the possible use of certain characters for this study, 5) it is the most inexpensive and expedient method, and 6) our resources and facilities are not that great and extensive enough to embark on more efficient avenues. Other supporting studies of the differences, if any, obtained from the parameters of the exploited fish populations of different regions, the regional fecundity variations, the size of the yolk mass of fertilized eggs and the pigmentation of the larvae, when spawning survey is undertaken, would all add up as evidences to indicate whether ours is one unit fishery or more.

Since the quantity of catch has more importance than the number from commercial viewpoint, it would be better if more information is gathered on length-weight relationships. Although it has been expressed that different length-weight relationships may have to be employed for conversion, in view of the fact that the majority of the relationships conformed to the cube law and out of those significantly differing only a few did so at 1% level, a suggestion is placed whether for biological reasons, the differences cannot be ignored and a general length-weight formula evolved so that it would be a ready reckoner for conversion.

There is an urgency to correlate the biological changes in the ecosystem to have a clearer understanding of the relationship in the ‘dual-species neritic pelagic fisheries system’ in the area of oil-sardine distribution. The negative relationship between sardine and mackerel seen during certain years is mostly ascribable to the real fluctuations in populations sizes of the oil-sardine for, changes in species preference of the fishermen reported in certain other waters, even if operative at times as exceptional case, may not contribute much towards the observed fluctuations. The density of sardine population appears to be a limiting factor for the inshore movement of mackerel shoals as seen from the data of past years. While the decline in the mackerel catch in certain years may be either due to its own recruitment of a weaker year class and/or due to an overabundance of oil-sardine, the diminution in the sardine catch, on the other hand, can be safely attributed to the earlier cause only. In order to test this hypothesis as conclusive, the best way is a survey of egg and larval abundance of the respective species in a year which would give an unbiased information on their respective population sizes. But in the absence of this immediate verification, studies on the recruitment rate of the respective species as well as studies on the variations of biological productivity of the area, especially the ratio between the crop of phyto-and zooplankton may throw light on the depth of relationship between these two fisheries. If in a particular year the spawning and survival in both the species are found likely to yield a rich fishery and the environmental conditions are also ideal, it is necessary that efforts should be made to tap the source of mackerel stock that is bound to lie beyond the present fishing limit as a result of competition.

5. The bulk of information collected on **EXPLOITATION** can be processed by breaking it down to as fine an interval of space and time as practical so that varied sort of information such as measurements of changes in abundance spatially and temporary and migratory movements can be obtained as well as used for research on population dynamics. Availability of such a report in a compatible form would enable estimation of maximum sustainable biological yield so that an idea of the level of present exploitation can be got, especially during the period 1964-68, when 2.5 to 3.0 lakh metric tons were caught - a magnitude, the like of which is not on record in the history of oil-sardine exploitation. The corollary study would, then indicate how much of the biological yield would get reduced to obtain a maximum economic yield. Deployment of more effort towards unexploited stock lying beyond the present fishing zone may, then, help to increase the total yield without affecting the economic yield in the present area of fishing. In order to know the ideal fish size for maximum sustainable economic yield, comparison of the rate of natural morality between the early 2-3 months and subdequent growth phase within the first year may be helpful, for

if there is not much difference, then for better economic yield, it may become advisable not to exploit much fish below 100 mm. On the other hand, if M should be comparatively and significantly higher for fish below this size, then no purpose would be served by leaving this group unexploited.

Although there is heterogeneity in the nature of gears operated for oil-sardine fishery, *Pattenkolli* may be taken as the standard unit to calculate the ratio of catch to effort as an index of the size of the accessible stock. The catch per unit effort weighted in various ways relating to man-hours, characteristics of different fishing units, speed of operation and to the shoal density in relation to the volume of water may then be used to bring out the necessary information on population dynamics. It is also desirable to cover the night catches also to the extent possible for, there appear to be some indications to show the concentrations of larger sized fish in deeper waters.

The recent conversion of the main fishing gear on the Kerala coast into one on nylon fibre is considered to be partly responsible for the increased catch in view of the merger of gear's colour with the surroundings. In spite of the limitations of the indigenous craft for fishing beyond 15 to 20 km, the fishermen are averse to the operation of mechanised boats for sardine fishery for the fear that the noise of the engine might scare away the shoals. Whether this fear is justifiable may be found out with experimental cum exploratory fishing for sardine mackerel shoals beyond the traditional range of fishing. More studies on the efficiency of the gears and the efficient mesh size for the selective gears also appear to need attention.

Among three major causes for fluctuations in the catch, namely fluctuations in population size, in accessibility and in fishing effort, the fluctuations population size can be more specifically said as fluctuations in the year class recruited every season as far as oil-sardine is concerned. Among the various abiotic and biotic factors reported as limiting the population size, it appears that they can be narrowed down to a meterological feature - air-sea turbulence mixing and the amount of rainfall, which may or may not be inter-related but yet result from the south-west monsoon conditions. The other factors are relative to this and hence of consequential value. It, thus, follows that concentrated studies are to be made on the resulting features of the vagaries in monsoon intensities. Abiotic factors like presence of trace elements, dissolved materials, turbidity, flow of currents and other physical oceanographic features may also have to be considered. Biological factors such as the trigger mechanism for spawning, physiological rhythm of reproduction and region-wise food production as related for feeding habits also require further attention. Thus, although the first warnings for likely reduction in recruitment are seen *ab ovo,* what happens in the medium is also of importance in understanding the processes affecting recruitment.

The problems of fluctuation in accessibility does not appear to arise for, sardines are known to be vulnerable to almost all kinds of fishing methods. Moreover, the question is one of sequential nature to fluctuations in recruited population size as far as oil-sardine is concerned. When the mackerel appear in plenty in the area depleted by oil-sardine, there may be some unconscious fishing preference exercised, but it cannot mean the sardine stock lying elsewhere is not accessible or vulnerable.

Regarding the fishing effect for the fluctuations there are two ways through which the stock may be affected namely, reduction in the stock to such a low level as to reduce the recruitment through reduced reproduction or because of that, the annual net growth increment is reduced and thus the annual sustainable catch is reduced. It has been, however, demonstrated for other clupeids that fishing alone cannot reduce the stock to a level as to affect reproduction. In oil-sardine too it is an record that although the spawning stock of 1964 was rather low, the resultant recruitment was exceptionally rich. Similarly, when the recruitment was affected by monsoon variations, in spite of the spawning stock being higher as in 1959 and 1963, the resultant recruitment failed to enrich the fishery, which feature will repeat this year also. Moreover, since the oil-sardine show rapid early growth and a relatively high natural mortality is suspected, it is unlikely that the present level of fishing can be so intense as to reduce the average annual yield per recruit.

On the other hand, if an attempt can be made to plot the recruited year class strength against measure of rainfall regime of the same year's spawning fortnight and quadrants were formed by lines parallel to the axes, passing through the average year class size and the daily rainfall threshold of 20 mm, a positive correlation may be seen with all successful year classes falling in the upper right quadrant, while unsuccessful ones may find themselves in the lower left quadrant. If there should be any in the lower right quadrant - there may not be with the present data-it may indicate that some other factors have affected the larval survival rate but no year classes will lie on the upper left quadrant. Hence, at present from a practical standpoint, the forecast of the failure of juvenile fishery for oil-sardine can be made empirically based on the rainfall amount during the spawning fortnights but the prediction is only qualitative of gross changes. For prediction of kind, size and time of appearance of fish, comprehensive studies on the oceanic and atmospheric conditions and on the spawning biology of the fish as well as attempts on aerial scouting are required.

Indian oil-sardine fishery resource has many advantages as compared to other world sardine fisheries of commercial value. Ours is rather a purely indigenous one, relatively underexploited with no external competition for the source and which largely leans on 0-year class. With the fishery comprising usually of two successive year classes, the problem of great variations in the yield spread over long periods characteristic of other sardine fisheries with a prolonged life-span does not arise. A reliable forecast that is rendered difficult in other waters because of various factors coming into play, is made rather easier here by, what appears to be at present the chief deciding factor, and the forecast, though has a short-term value, is all that is necessary because of shorter life-span of the fish. The fish show fractional spawning but do not appear to spawn in batches, nor the spawning season in any year prolonged enough to confuse or reduce the accuracy of any estimates based on egg-count, not to cloud the issue of age-size composition with different broods entering the fishery of doubtful origin. With these advantages the pace of research can be accelerated shifting the emphasis to the biology of the fishery now that the biology of the fish is fairly well known.

Thus, the above observations can be considered as three most important subject for future, namely, 1) structure, strength and identity of available stock/stocks with estimations of primary phenomena of population dynamics, 2) spawning survey and 3) environmental studies. In general, the necessity to develop a dynamic concept of the total environment, oceanographical, meteorological and biological and if necessary even all those processes outsides the immediate environment that might affect the oil-sardine's, need not be emphasized. In short, greater coordination of effort and collation of data from different disciplines will contribute to establish more precise theories on the fluctuations in the oil-sardine resources which, in turn, would help to interpret the changes in the mackerel fishery as well. The biological information accruing thus can provide the clues for managing radically these coastal pelagic fisheries that contribute on an average not less than a quarter to the annual marine fish production in India.

SUMMARY

A compilation of our existing knowledge on several aspects of the biology and fishery of the Indian oil-sardine *(Sardinella longiceps*) has become necessary in view of the rapid strides made during the current decade, so that the nature, relationships and extent of the outstanding problems and the spheres where research may require acceleration and/or change in direction can be highlighted. With this view, chapters on identity, distribution, bionomics and life history, population, exploitation, technology and industry are included in this monogrpah with one on the priorities for future research.

1. Although the **identity** of the Indian oil-sardine as *Sardinella longiceps* remains undisputed, the absence of any detailed taxonomic description of the species and records of misidentification of the same in other waters appear to justify a study into it, covering not only the west coast forms but also their counterparts reported from the east coast and Andamans. It is only after establishing the identity of the latter, can the extent of distribution of *S. longiceps* be confirmed.

2. The knowledge on the **distribution** of juveniles and adults on the west coast is one of general nature but on specific issues, incomplete. A suggestion whether there is simultaneous appearance all along the coast from offshore grounds but earlier disappearance at the northern latitudes can be looked into by drawing annual space-time canvas indicating all the details of capture in as fine an area as possible within one degree latitude and for every 5 m depth level perpendicular to it with the environmental features superimposed on the charts. Any marked changes in the pattern of distribution may be indicative of changes in the spawning area and

migratory routes or the rise and fall of subgroups of population, if any.

3. Regarding the **bionomics & life history**, the concerted attempts of the past have yielded some definite information on important aspects like size at first maturity (150-160mm), spawning season (June to October), spawning habits (fractional; once in the season; twice in the lifetime), fecundity (about 38000 per individual and 750 million ova per metric ton of adult female biomass) and age & growth (150-160 mm at the end of first year, 170-180 mm at the end of second year and the rest thereafter). Investigations on spatial variations in fecundity, if any, are desired. The wide lacuna in our knowledge on the abundance, distribution and biology of eggs and larvae is pointed out and an intensive and immediate search is recommended, to begin with from the area off Calicut, in view of its importance in population studies. The failure of spawning in 1963, 1965and 1969 is traced to large scale follicular breakdown in the ovaries, probably caused by poorer daily rainfall in the spawning fortnights that resulted in weaker year classes on which leans the commercial juvenile fishery every season. The initiation of correlative study of the meteorological and oceanographical data for the period 1959-1969 would enable us to identify the specific requirements in the medium which trigger the mechanism of spawning. Should there be any doubts on growth increments, collaborative effort of comparison of length frequency data of different centres can be made after subjecting the modal groups to judicious interpretation and if there are any marked variations in growth parameters, they can be used in area-stock identity. The information on the food and feeding habits of the fish appears quite extensive (chiefly surface/column filter feeder on phytoplankton with the feeding intensity depending on the relative abundance of food) but an aspect that needs confirmatory evidence is the reported carcinivorous habit of the early juveniles so as to infer the causation for their appearance/non availability in the near shore area. More studies on the hehaviour of oil-sardine are emphasised as well as improvements and intensification in tagging experiments.

4. **Population** research will be carrying the emphasis and stress in the next decade since the vital answer on the fish biology appear to have been provided. The reported differences in the sex composition of adults are referred for further study with increased sample sizes so that for any yield equations the spatial difference in accessibility, vulnerability, growth and mortality rates between the sexes can be made use of. Studies towards natality and recruitment are required to attempt correlation-analysis of the stock at various stages. Also included in the programme would be a comparison of the estimate of efficiency on unit effort, with *pattenkolli* as the standard unit, on different space-time groups. Population identification is considered *sine qua non* and in view of difficulties of tackling it through more efficient methods, a beginning is contemplated with biometrical analysis on morphometric and meristic characters which would be later supported by any difference in fecundity estimates, primary phenomena of population dynamics, size of the yolk mass of fertilised eggs and pigmentation of the larvae. The problem of interspecies relationship between the oil-sardine and mackerel is considered and it is felt that while the decline in the mackerel catch may be either due to its own recruitment of a weaker year class and or due to over abundance of oil-sardine, the diminution in the catch of the latter can be safely attributed to the earlier cause only and in such an event, the mackerel is likely to establish itself, provided its own rate of recruitment has not been affected. In order to test this hypothesis, studies on recruitment rate of both the species as well as studies on biological productivity of the area especially the ratio between phyto-and zooplankton may be undertaken to learn the depth of relationship in the 'dual-species metric pelagic fisheries system'.

5. On the aspect of **exploitation**, the abundance of oil-sardine in recent years may be due to successful spawning and survival and conversion of the main gear to one of nylon fibre. However, the prospects for the current year's fishery for juveniles appear rather bleak. The bulk of information collected by survey

staff can be used to obtain information on measurements of changes in abundance spatially and temporally and migratory movements as well as for research on population dynamics. The major causes for fluctuations in the exploited stock are analysed to rule out the possibility of fluctuations in accessibility and fishing effort but trace it to the operation of fluctuations in the year class recruited every season. This is related to the amount of rainfall during the spawning fortnights, the data on which coupled with observations on the gonads enable us to make a reliable forecast on the prospects of juvenile fishery of every commercial season.

6. In view of the several advantages inherent in our oil-sardine fishery resources, the pace of **future** research can be accelerated and directed on three major aspects,namely,1) structure, strength and identity of available stock/ stocks, 2) spawning survey and 3) environmental studies, which would result in a dynamic concept of the total environment and provide clues for radical management of this important costal pelagic fishery.

7. The chemical composition of the different byproducts of oil-sardine, the **technological** studies on them and the **industrial** uses and advances made therein are complied to bring out the amount of potentiality the fish hold for the future but whose development is bracketed with the variability and seasonality in the abundance of the raw material.

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