STUDIES ON THE FISHERY AND BIOLOGY OF THE MALABAR SOLE, *CYNOGLOSSUS SEMIFASCIATUS* DAY

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CONTENTS

I. INTRODUCTION

THE Malabar sole, *Cynoglossus semifasciatus* Day, is a fish of considerable commercial importance along the Malabar Coast. Apart from the fact that it ranks often next only to the sardine and the mackerel in total landings, it is the only fish available on this coast during certain periods of the year. The species was therefore taken up for detailed investigations in the programme of the Central Marine Fisheries Research Sub-Station at Calicut. The work was commenced in April, 1948, and the present paper embodies the results of these investigations up to March, 1952.

Except for a few general points mentioned here and there in the publications of the Madras Fisheries Department (Chidambaram and Venkataraman, 1946; Devanesan and Chidambaram, 1948), there are no previous accounts of the biology of this species. Data relating to the landings of soles along the West Coast (together with those of other fishes) are ollected by the Madras Fisheries Department and these have been published for some of the earlier years.

II. Material and Methods

(a) *Material*

The material for this investigation was mainly derived from weekly or biweekly collections made regularly from the neighbourhood of West Hill from about two to six fathoms in the inshore fishing grounds. Some random samples were also examined from the commercial catches, these being specially useful in the studies on scales.

In addition to the data collected by us during these three years, we have also had at our disposal the figures of landings at different places along the coast* as collected by the Madras Fisheries Department. These figures have been analysed and studied along with the biological data now collected and an interpretation of both taken together is presented with a view to giving as complete a picture as is possible in the present state of our knowledge.

(b) *Methods*

(i) *Measurements.*—Measurements of lengths were all taken correct to the nearest millimeter and usually in the fresh condition. The lengths expressed are the total lengths taken from the tip of the snout to the end of the longest caudal ray. "Standard" or body lengths were taken for a few samples

* List of Stations along West Coast.

1. Kirimanjeswar	19. Bekal	37. Tanur (North)
2. Marvanthe	20. Hosdrug	38. Puthiakadapuram
3. Gangoli	21. Thaikadapuram	39. Paravanna
4. Hurgarkatta	22. Madai	40. Kootayi
5. Malpe	23. Mattool	41. Ponnani
6. Udayavar	24. Cannanore	42. Puduponnani
7. Polippu	25. Edakkad	43. Veliangode
8. Kaup	26. Tellicherry	44. Palapatti
9. Moolky	27. Thalayi	45. Mannalamkunnu
10. Hosabettu	28. Madakkara	46. Puthenkadapuram
11. Baikampadi	29. Madapalli	47. Blangod
12. Thannirbhavi	30. Badagara	48. Kadappuram
13. Bockapatnam	31. Melady	49. Vadanapalli
14. Mangalore	32. Quilandy	50. Nattika
15. Ullal	33. Pudiappa	51. Karimpuram
16. Manjeswar	34. Kozhikode (North)	52. Kodumbi
17. Kumbla	35. Beypore (South)	
18. Adakathabail	36. Parapanangadi	

for comparison with the total length and it was considered sufficient for the purpose of these investigations to take the total length alone. The relationship between the two kinds of length measurements has, however, been determined and presented in a separate section in this paper.

(ii) *Analysis of Food.*—The stomach of *C. semifasciatus* has no clear external demarcation from the succeeding part of the alimentary canal. On this account and on account of the smallness of the gut, as also of the extreme variability in the size and state of digestion of the food organisms, quantitative estimation of the gut contents was not attempted. A qualitative analysis of the gut contents of 313 males, 542 females and 76 indeterminates was made during the period September 1949 to March 1952, each individual being separately examined. This has been found sufficient to give a reliable picture of the seasonal and other features in the food-preferences of this species. It has also been possible to arrive at the importance of the various species of food organisms in the dietary of the fish by a simple reference to the percentage frequency of the food species in the total number of fish examined during a given period and also in the total number of occurrences of all the food organisms during such a period. Hynes (1950) has shown that of the three methods usually employed for the assessment of the importance of the different food organisms in the dietary, namely, the occurrence method, the dominance method and the numerical method, each gives as good a picture as the other and he has further suggested that the occurrence method alone is quite sufficient for many purposes.

(iii) *Age and growth.*—Certain growth rings that have been discovered on the scales of this fish, the length-frequency distribution in random samples taken regularly, and the features of recruitment and spawning have been studied together to advance evidence for the age and rate of growth of the species. Detailed studies have been made on the scale rings to prove their validity in age-determination.

(iv) *Sex and maturity.*—In the large-scale analyses of samples, sex was determined by dissecting the individuals and examining the gonads with the naked eye. The testis is distinct from the ovary in being short, whitish and non-granulated in appearance. During the months, August to November, sex could be easily determined by a mere look at the specimen as the female gonads were highly developed and were easily seen through the skin. Dissection was, however, resorted to wherever doubts arose and also, of course, for determining the maturity stages where necessary.

The different stages of maturity of the female were recognized on the following basis, more or less on the lines of the Hjort scale (Hjort, 1911), but with suitable modifications:—

Stage I. Ovary minute, thread-like and transparent.

" II. Ovary slightly thicker, partly transparent and partly opaque; that is, some ova are transparent and some are opaque, though all are small yet.

Stage III. Ovary completely opaque but not filling the body cavity; ova small and not flowing freely on teasing the ovary as they are still held firmly by interstitial tissue.

„ IV. Ovary large and filling the body cavity; large opaque ova flowing freely on teasing the ovary.

, V. Like stage IV but with some or all of the ova transparent and apparently ripe; ova *not* running out of the genital aperture on the application of gentle pressure on the ovary.

„ VI. External appearance like stage V with transparent ovary; ripe ova running out through the genital aperture on the application of very gentle external pressure on the ovary or even without any such pressure.

„ VII. Spent; Ovarian region usually marked by a groove or depression on the body wall; Ovary bloodshot.

III. A General Description of the Species and its Systematic Position

C. semifasciatus is a fish of small size, growing commonly to about 15 cm. in length, the maximum size so far recorded or noticed during the course of the present work being 17·5 cm. The body is flattened and leaf-like, one side lying on the substratum and being white in colour. Both the eyes are found on the side away from the substratum and this side is pigmented with irregular brown half-bands across the body. The mouth is narrow and unsymmetrical. The dorsal and anal fins are long, extending along the margins of the body. There are two lateral lines on the ocular side and none on the blind side which is the right side of the animal.

C. semifasciatus was described by Day (1889) as follows:—

" D: 98–103 V. 4. A. 75–80. L. 1: 85.

Length of head $4\frac{2}{3}$, height of body $3\frac{2}{3}$ in the total length. Eyes close together, the upper scarcely in advance of the lower, 8 diameters in length of head and $2\frac{1}{2}$ from end of snout. Angle of mouth one diameter behind posterior edge of lower eye and slightly nearer to snout than to gill opening.

Fins—a single ventral attached to the anal.

Scales—ctenoid on both sides. Lateral lines—two on coloured side, separated where furthest apart by 12 or 13 rows of scales; a single lateral line on blind side.

Colour—deep brown, with vertical incomplete or half bands irregularly disposed; they extend on to the dorsal and anal fins.

Habitat—Madras."

A slightly more detailed description and a figure were published by Day in an earlier publication (1878–88). Norman (1928) has given a re-description of the species based on six specimens, all from the east coast of India. This description differs from Day's in two significant points, namely,

(i) that there are 12 to 14 series of scales between the lateral lines on the ocular side; and

(ii) that there is no distinct lateral line on the blind side.

While both these authors and also Alcock and Jenkins (see Norman, 1928) fail to mention the west coast in the habitat of this species, a careful examination of the material dealt with in this paper has convinced us that it belongs to the same species. In the above two points this material is in accord with Norman's description (though specimens with up to 17 series of scales between the lateral lines also do occur). There is definitely no lateral line on the blind side and it seems possible that Day mistook a faint longitudinal depression for a true lateral line. Devanesan and Chidambaram (1948) and Chidambaram and Venkataraman (1946), though identifying the species rightly, also seem to have made a similar mistake. The present authors have examined a large number of specimens in this respect and while a faint longitudinal groove is invariably noticeable in all of them on the blind side, the essential feature of a true lateral line, namely, the lateral line canals on the scales, is found wanting.

Dr. K. S. Misra of the Zoological Survey of India kindly compared some of our specimens with the type specimen of *C. semifasciatus* in the Indian Museum, Calcutta. As a result of this examination, he concludes:—" In the Malabar specimens there are 17 series of scales between the two lateral lines on the ocular side, while in the Day's type specimen of *C. semifasciatus* there are 15–16 scales between the two lateral lines. Norman has put *C. semifasciatus* in the group showing a range of 12–15 scales between the lateral lines. Thus it is clear that a wider range in the number of transverse scales than given by Norman may have to be assumed for the correct identification of *C. semifasciatus*, especially since the Malabar examples agree with the type-specimen in all other relevant characters."

IV. General Features of the Sole Fishery and Its Commercial Importance

The fishery for soles is important only along the Malabar coast, although these fish occur in some quantities along the adjoining coast of South Kanara as well. Many species of soles, including *C. semifasciatus*, are, however, represented on the east coast also. *C. semifasciatus* is the chief among the species that are marketed together under the name of sole (or *Manthal* in Malayalam). While other species of the genus, such as *C. dubius*, *C. puncticeps* and *C. bilineatus*, do occur in the region they are always so few that they are never considered as forming part of the sole fishery. *C. semifasciatus* is the only flat fish that occurs in large shoals. The best season for the fishery is immediately after the south-west monsoon, September being always the month of peak commercial catches. The species has, however, been known to occur in shoals from August of one year to February of the following year.

Figs. 1 to 3 show the results of analysis of the data on the landings of soles at different fish curing yards along the Malabar and South Kanara coasts.

Fig. 1 shows the total annual landings of soles along the Malabar and South Kanara coasts and the total values (in rupees) of these landings during

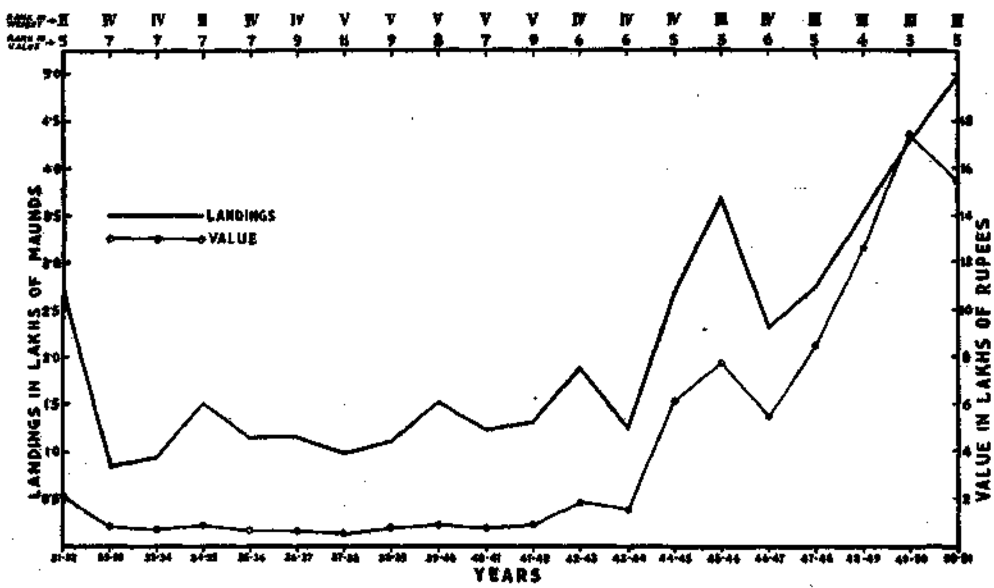


FIG. 1. Total landings of soles and their value along the West Coast of Madras during the years 1931–32 to 1950–51. The rank of soles among the different categories of fishes are shown at the top of the figure.

the twenty years commencing from 1931–32. The landings, which were above two and a half lakhs of maunds in 1931–32, fell to below half this quantity during each of the next two years and though there was some improvement in the subsequent years they did not reach the 1931–32 level till the year 1944–45. There was a further increase in landings in 1945–46, but this was again followed by a drop to slightly below the 1944–45 level. In the subsequent years, however, there has been a steady rise in the catches until in 1950–51 a total of 5,02,759 maunds of soles were landed in the Malabar-South Kanara region. This amounts to nearly double the maximum ever recorded in the pre-war years.

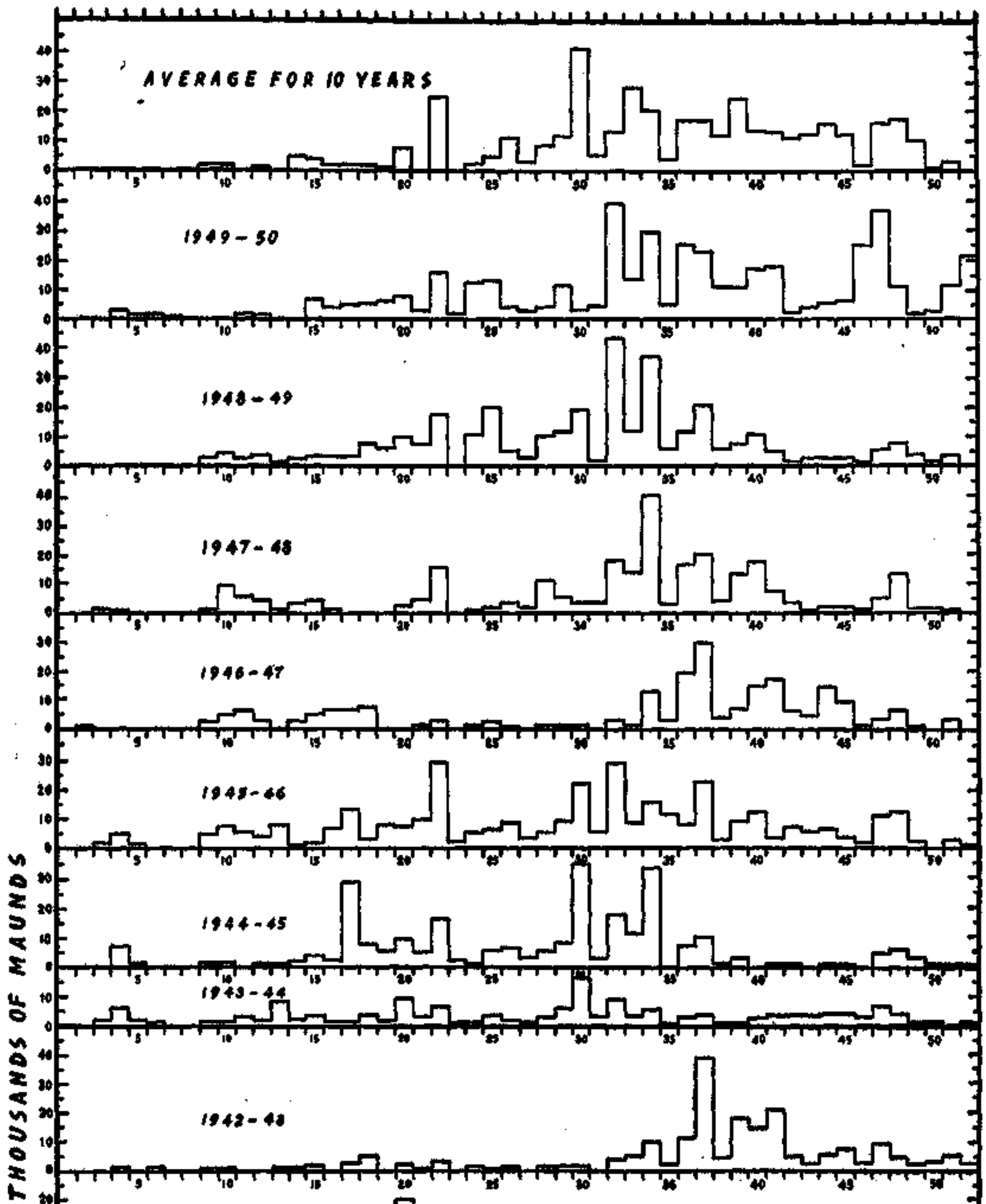


FIG. 2. Annual totals of landings of soles at different stations along the West Coast of Madras for the years 1940–41 to 1949–50 and the average landings for these ten years (Names of stations on page 181).

The soles are inexpensive fish consumed by people of low income. The sardine and mackerel are usually preferred to soles by most people whenever the former are available. Hence the market value of the soles to some extent depends on the availability or otherwise of other fishes, presumably also depending to some extent on the fluctuations in their own landings. The ranks in respect of weight of landings (Fig. 1, Roman numerals) and of values (Fig. 1, Arabic numerals) are not the same in different years. But there is a clear tendency towards a reduction in the gulf between the two ranks during the post-war years. In respect of landings the fishery has never been lower than fifth in the entire period and was second during a few exceptional years; it has continuously held the third rank from the year 1947–48 to the year 1950–51. In respect of money value also the fishery has held the third rank during the years 1945–46 and 1949–50, though lower during other years. In 1950–51, while the catches broke all previous records, the glut actually resulted in low prices; while in quantity the fish ranked third, it was only fifth in value. But even then the estimated value was over fifteen and a half lakhs of rupees, while during the previous year it was just over seventeen and a half lakhs of rupees. The average landings calculated for these twenty years would be 2,10,295 maunds with an average estimated value of Rs. 4,33,048. The importance of the fishery has increased enormously from 1944–45 onwards, the landings and value being both above average during all the subsequent years and much below average during all the previous years, with the sole exception of 1931–32. In that year, the landings were very slightly above the average, but the value in rupees was a little less than half the average. The increase in prices as well as landings from 1944–45 onwards shows clearly that the importance of this fish as an article of food was realised more than ever before during the food crisis which began in the war years and continued long after the war.

The landings of soles in 1951–52, however, showed a considerable decline.

Fig. 2 shows the annual totals of sole landings at 52 fish curing yards (arranged in order from North to South) along the South Kanara and Malabar coasts for the years 1940–41 to 1950–51. It is seen that the fishery was throughout poor along the South Kanara coast, except at the southern end, and that it was best along the coasts of central and southern Malabar. No regular trends in yearly shifts of the fishery were noticeable, either northwards or southwards, along the coast, although the centre of highest landings had not always been the same.

In Fig. 3 are shown the average landings of ten years for each calender month of the year for the 52 stations mentioned above. There was no

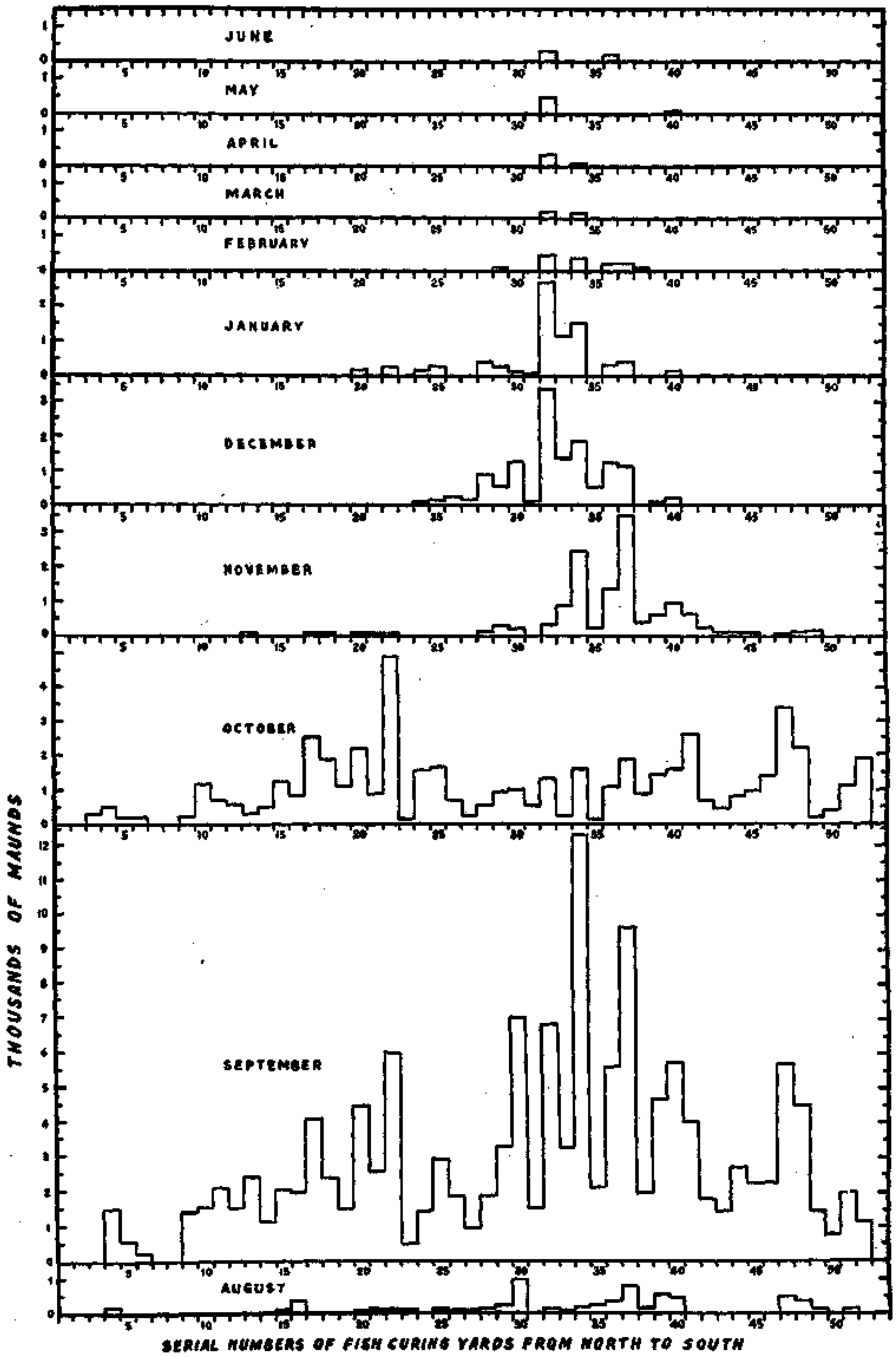


FIG. 3. Average monthly landings of soles at the different fish curing yards along the West Coast of Madras for the period 1940–41 to 1949–50 (Names of fish curing yards on page 181).

fishery in July during any of these years. While August shows some landings, September is the month of peak catches. October shows a considerable fall in landings in most places. During the subsequent months there is not only a gradual reduction in landings but also a gradual restriction of the fishery to the central region, until finally in the pre-monsoon months soles are recorded for very few places other than Quilandy. Soles do occur along the coast during these months, but there is no shoaling and they occur in such small numbers that they do not form a distinct fishery, but are recorded under " miscellaneous " items along with prawns, crabs etc. In Quilandy alone, along the entire coast, does the fishery retain its identity for the best part of the year and is recorded as such. The quantity here also is, however, negligible.

Fig. 4 shows the relative magnitude of the catches during different months of the ten years mentioned above and the seasonal nature of the fishery. The spreading out of the fishing season in some years, particularly from 1947-48 onwards, is noteworthy.

V. Standard Length—Total Length Relationship

In *C. semifasciatus* instances of damaged tails were extremely rare and it was found more convenient to take the total lengths than the body lengths. As a routine, therefore, only the total lengths have been taken throughout this work. In taking the total length, the fish was placed flat on the measuring scale with the blind side lower; it was then straightened so that the mid-point of the snout was in line with the mid-point of the tail; the anterior end was adjusted to zero point and the reading corresponding to the end of the longest caudal ray noted. The standard length, on the other hand, would be the measurement corresponding to the base of the caudal fin when the fish is placed as above on the scale. The base of the caudal fin as taken here is marked by a translucent dotted line.

To determine the exact relationship between the two lengths defined above, they were both taken in a few of the samples and a formula worked out for the conversion of one measurement to the other, if necessary, at any stage of the work. The measurements of a composite sample of 120 individuals are plotted in a scatter diagram in Fig. 5. The total lengths in the sample ranged from 5·7 cm. to 15·7 cm. It is seen that all the points lie about a straight line, the regression line, which has been fitted into the diagram by the method of least squares.

The following relationships are found between the standard length Y and the total length X:—

(i) $Y = 0{\cdot}91\,X - 0{\cdot}09$

(ii) $X = 1{\cdot}09\,Y + 0{\cdot}13$

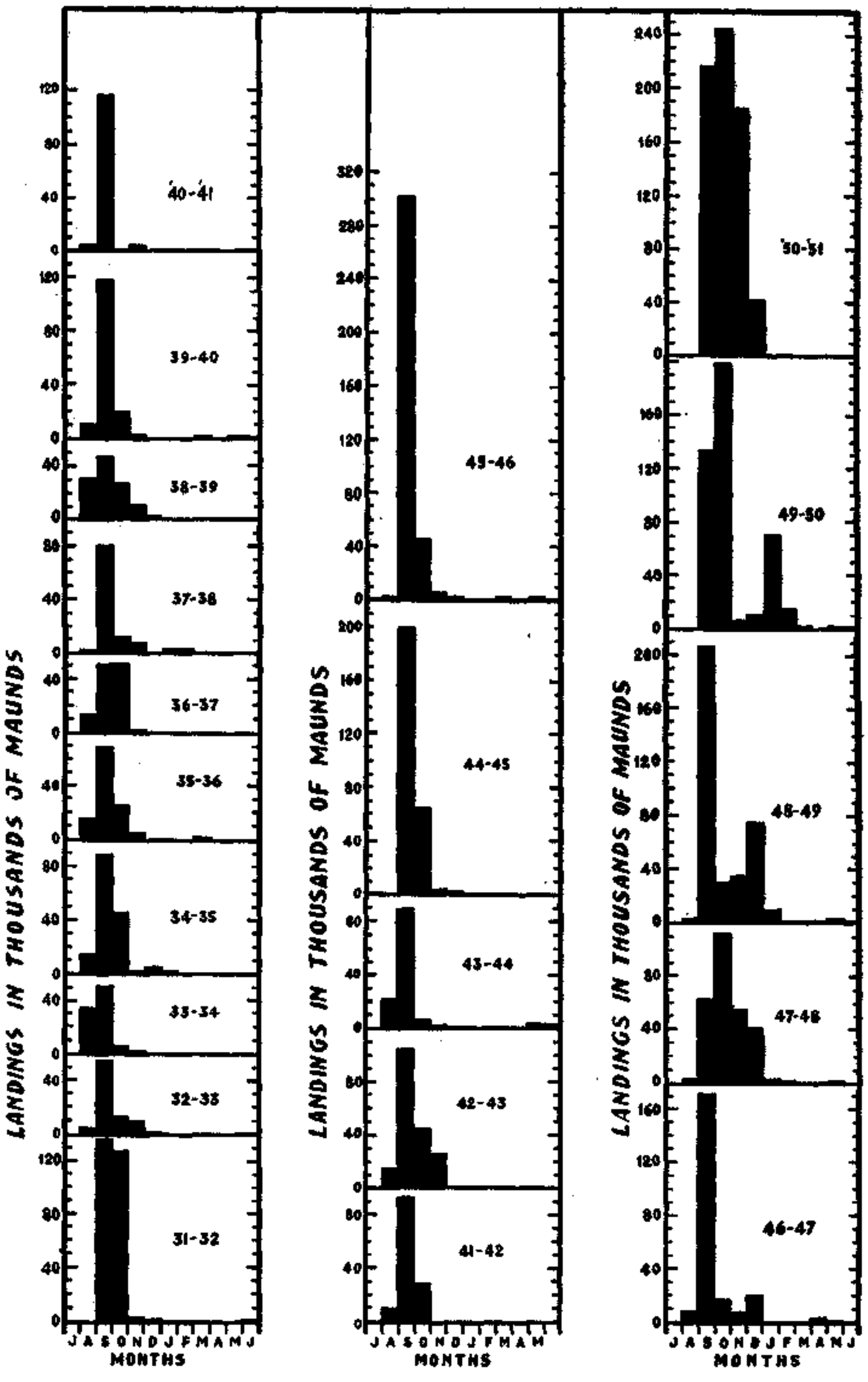


FIG. 4. Histogram showing the monthly distribution of the landings of soles along the Malabar-South Kanara coast during the years 1931–32 to 1950–51.

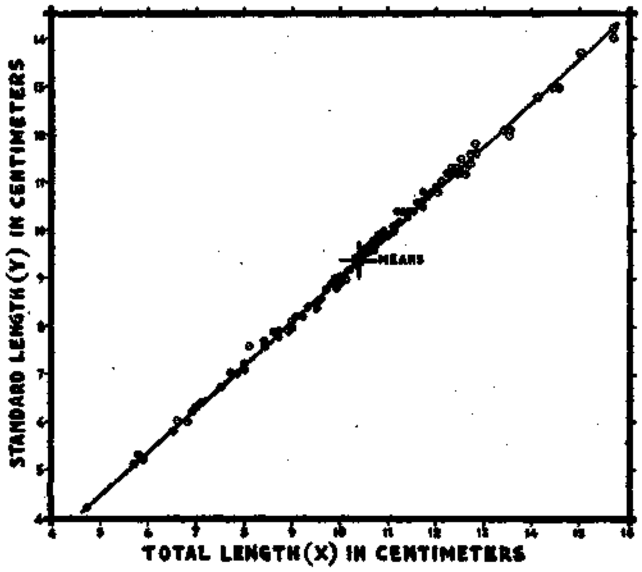


FIG. 5. Relationship between total length and standard length in *C. semifasciatus*.

Roughly speaking, the standard length may be said to be about nine-tenths of the total length.

From the same data, the correlation coefficient '*r*' was also calculated and was found to be + 0·998. This indicates a good correlation between the two lengths and justifies the selection of either of the two for routine recording.

VI. Age and Growth

The age and growth of the Malabar Sole have been studied by two methods, namely,

(i) by analysis of the length frequency distribution in random samples taken during the period, April 1949 to March 1952, and

(ii) by a study of certain rings that occur on the scales of this fish and which have been found to be indicators of age.

This aspect has been dealt with in detail elsewhere (Seshappa and Bhimachar, 1954) but the essential findings are discussed here.

A knowledge of the year-class composition of a fishery during different seasons and years is extremely important for deciding upon a suitable management policy for the fishery. The authors have found definite annual growth rings occurring in the scales of this species (Seshappa and Bhimachar, 1951). The details of the circumstances of the discovery of these rings are given below as they have not been published before.

These rings were first noticed in the latter part of 1949 in the scales of the larger individuals of the fishery. At first it was considered that they may not be true annuli, especially as the otoliths did not reveal the existence of any growth rings though carefully examined. But as the rings occurred repeatedly in all the large specimens examined an attempt was made to compare their structure with that of the annual rings described for other species of flat fishes, and it was found that there was close comparison. In December and January 1950 young individuals of *C. semifasciatus* began occurring in large numbers in the fishery and when these smaller size-groups were examined it was interesting to notice that they had no rings at all on the scales. It was then considered useful to find out reliably the exact frequency of the occurrence of these rings in the different size groups and several random samples were therefore examined in detail. The information obtained from an analysis of large random samples of 195 and 232 individuals on 27-2-1950 and 29-3-1950 respectively are summarised in Table I.

TABLE I

Scale-ring Distribution in Random Samples of C. semifasciatus *taken on* 27-2-1950 *and* 29-3-1950

Date	No. of scale rings	Size groups of fish						Total in all sizes
		Below 12 cm.	12–12·9 cm.	13–13·9 cm.	14–14·9 cm.	15–15·9 cm.	16–16·9 cm.	
27-2-1950 from Quilandy	2	0	0	0	0	3	0	3
	1	0	1	1	3	2	1	8
	0	143	26	12	3	1	0	184
TOTAL ..	..	143	27	13	6	6	1	195
29-3-1950 from Tanur	2	0	0	0	2	1	..	3
	1	0	0	10	8	0	..	18
	0	196	6	4	0	0	..	211
TOTAL ..	..	196	6	14	10	1	..	232

These data showed that the scale rings were absent in the smaller sizes and present only in size groups from 12 cm. onwards, though not in all of them.

The edges of the scales in all cases indicated the " open " stage which meant that growth was proceeding at the time of the collection for examination. The rings were fairly deep in position and this meant that they were formed early during the growth of the individuals. All the smaller sizes being apparently members of the new brood, one is naturally led to the assumption that the rings are formed some time before the commencement of recruitment of the new brood into the fishery, in case the ring formation is the result of any environmental factors.

In April 1950, 247 individuals (ranging from 5 to 15 cm.) on the 4th, 49 (all above 12 cm.) on the 11th, 249 (ranging from 5 to 15 cm.) on the 18th and 286 (all above 13 cm.) on the 25th were examined for scale rings from samples taken near West Hill. From the same region in May, 135 individuals (ranging from 5 to 13·5 cm.) on the 16th, two lots of 259 (5 to 15 cm.) and 25 (all above 12 cm.) individuals on the 23rd and 65 (ranging from 6·5 to 13·5 cm.) on the 30th were examined. All these examinations again showed that the smaller size groups were exempt from the occurrence of the rings and that, with the growth of the individuals of the new brood in the population, there was a tendency for individuals with ringed scales to become fewer in proportion and for some of the larger sizes also to be without rings. The margins of the scale continued ' open ' throughout.

These facts proved that the rings were not erratic structures, but were closely related to the size and age of the fish, and further verification and a test for the time of formation of the rings were possible from a study of the size-frequency analysis in random samples during different months in 1950–51. The results for the period September to December 1950 and the subsequent months showed that

(i) the majority of specimens had developed rings at the margins of their scales by September, the others developing them a little later;

(ii) the rings first appeared at the margins and gradually went deeper in the scales as new growth progressed at the margins; and

(iii) young specimens of the new brood were again without rings.

A further test was also available to check up whether there were still any chances of the rings being erratic in nature and not annuli formed over a definite period of time. A random sample of 240 individuals, consisting of 84 males and 136 females, all of which had formed growth rings on their scales, was used for the test. The fish and the scales were measured in the usual way and the increments in lengths of the fish from the time of ring-formation to the time of capture (December 1950) were calculated from the scale data using Lee's formula (Lee, 1920). The calculated increments were deducted from current lengths of the respective individuals, and the resulting measurements of the entire sample were plotted in a frequency curve for the males and females separately. The result was that the estimated size distribution curves of the sample at the time of ring-formation proved to be closely comparable with the observed distribution curves for December. This result is shown in Table II and depicted in Fig. 6. The curves are more spread

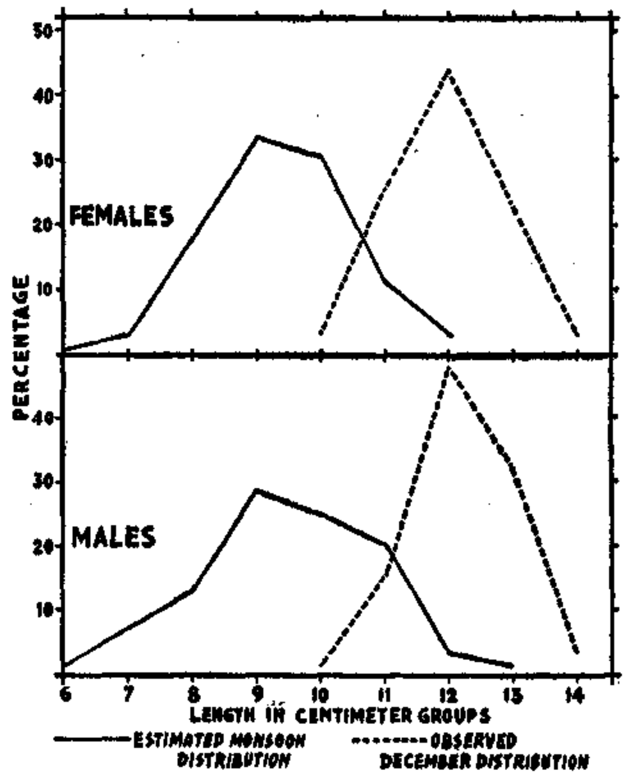


FIG. 6. Curves showing the similarity between the observed December distribution and the estimated monsoon distribution of the sizes in a random sample of *C. semifasciatus.*

out in the case of the estimated distributions. This is as it should be, because with continued growth of individuals, the difference between the largest and smallest individuals of the population will naturally decrease. Thus this test also proved that the scales are all formed over a definite period of time in the population and not erratically.

On the basis of all the findings recorded above the conclusion has been reached that the rings in the scales of the Malabar Sole are regular annuli indicating the age of the fish and that they are formed under the influence of the south-west monsoon. Photographs of scales with 2 rings, 1 ring and no ring have already been published (Seshappa and Bhimachar, 1951).

TABLE II

Observed Size Distribution in December and Estimated Size Distribution at the Time of Growth Ring Formation in a Random Sample of C. semifasciatus

Size groups in cm.	Estimated distribution when ring is formed			Observed distribution in December 1950		
	Males	Females	Both sexes	Males	Females	Both sexes
6– 6·9 ..	1 (01·2%)	1 (00·7%)	2 (00·9%)	..	..	..
7– 7·9 ..	6 (07·1%)	4 (03·0%)	10 (04·5%)	..	..	..
8– 8·9 ..	11 (13·1%)	24 (17·6%)	36 (16·4%)	..	..	..
9– 9·9 ..	24 (28·6%)	46 (33·8)%	70 (31·8%)	..	..	..
10–10·9 ..	21 (25·0%)	42 (30·9%)	63 (28·6%)	1 (01·2%)	5 (03·7%)	6 (02·7%)
11–11·9 ..	17 (20·2%)	15 (11·0%)	32 (14·5%)	13 (15·8%)	35 (25·7%)	48 (21·8%)
12–12·9 ..	3 (03·6%)	4 (03·0%)	7 (03·2%)	40 (47·6%)	60 (44·1%)	100 (45·5%)
13–13·9 ..	1 (01·2%)	..	1 (00·5%)	27 (32·1%)	32 (23·5%)	59 (26·8%)
14–14·9 ..	..	..	..	3 (03·6%)	4 (03·0%)	7 (03·2%)

Figs. 7 to 9 show outline drawings of scales with one and two rings and also an enlarged drawing of a scale with one ring to show the details of the structure observed. Photograph 1 shows an enlargement of a part of a scale with two rings.

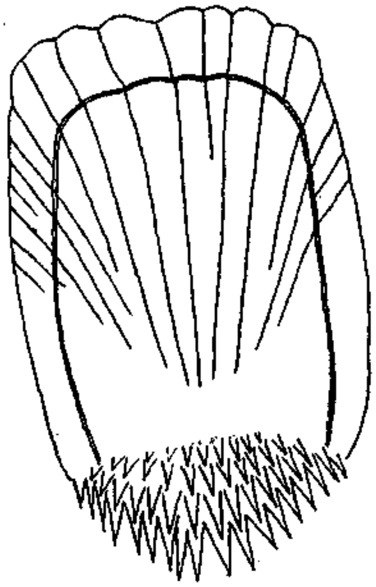
The scale of *C. semifasciatus* is ctenoid and shows variations in form in different regions of the body. For the purpose of age determination the scales used were always from the pectoral region just below the lower lateral line. A juvenile scale shows a centre and a number of circuli. In the fully developed scale the circuli are interrupted by a number of radii. The number of radii gradually increases as the scale increases in size. In a scale with no annuli the structure of the circuli is more or less uniform all over the scale. The annuli, when they occur, can be recognized by the following characters:—

(i) the narrowing of the sclerites and the closing up of the intervals between successive sclerites;

(ii) the sclerites, wavy and broken up elsewhere, becoming continuous and nearly straight from radius to radius;

(iii) an increase in the number of radii outward of the annulus, the new radii commencing just near the annulus; and

(iv) the portions of the radii outward of the annulus being frequently not in a straight line with portions inward of it, but inclined at an angle or even disconnected at the annulus.



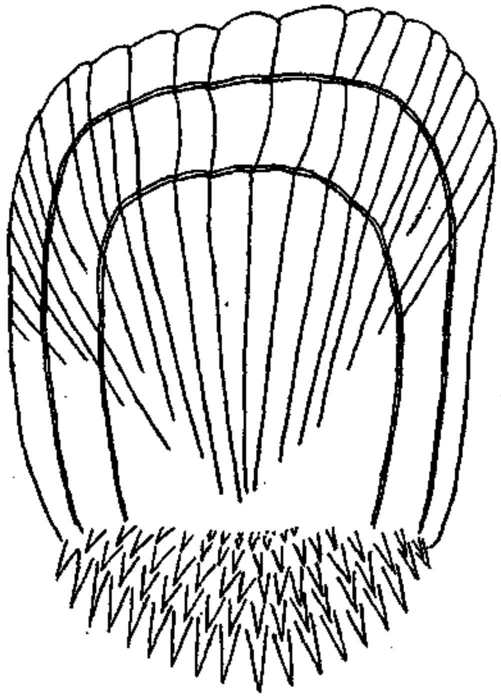


FIG. 7. Camera lucida outline drawing of a scale of *C. semifasciatus* (male 13·5 cm; caught on 21-5-1953) with one monsoon ring, × ca. 35.

FIG. 8. Camera lucida outline drawing of a scale of *C. semifasciatus* (Female, stage V. 15·5 cm.; caught on 17-1-1951) with two monsoon rings, × ca. 35.

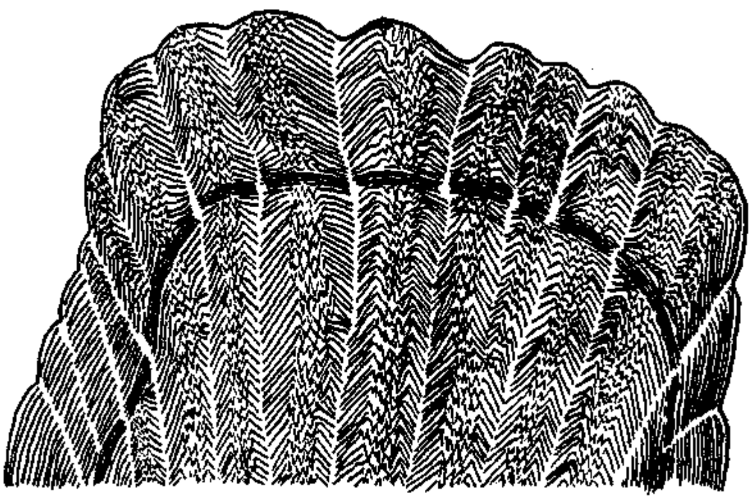


FIG. 9. Camera lucida drawing of a portion of a scale of *C. semifasciatus* (male 13·5 cm.; caught on 21-5-1953) with one monsoon ring, × ca. 70.

We have termed the growth rings in the scales of *C. semifasciatus* the *monsoon rings* and have suggested that they are perhaps formed due to lack of food leading to starvation (1951). The data on size frequency figures have shown (Seshappa and Bhimachar, 1954) that growth is not suspended throughout the monsoon period, because between May and September some growth is usually recorded. If starvation alone is the cause, it must obviously occur during the later part of the monsoon to account for the growth recorded between May and September, and until more is known about the offshore environment of the soles during the monsoon months, nothing can be said with much definiteness on this subject. Rae (1939), working on the Lemon Sole, found little evidence of any influence of physical conditions like temperature, salinity or depth on rate of growth, but suggested that towards the extreme limits of distribution growth may be affected by salinity or depth. He, however, concluded that food available, both regarding quality and quantity, is of the greatest importance in determining the growth rate. The late Professor J. H. Orton mentioned to us in a personal communication in this connection his very interesting work (Orton, 1926) on ' disturbance rings ' in *Cardium* and *Mytilus.* In the case of these bivalves Orton found that rings appeared on the shells consequent on the mere act of taking the shells out of water for a short while for marking purposes. This proves how important the environmental factors can be in inducing such formations. The authors have already pointed out (1951) the environmental factors connected with the occurrence of the south-west monsoon along the Malabar Coast and it cannot altogether be ruled out that factors other than food also play some part in the formation of these rings. Whatever be the cause of variation in rate of growth leading to the ring formation, the fact remains that the ring is annual in nature and can be used in determining the age of the fish.

The studies on age and growth by the use of the scales as well as the size frequency distribution curves have provided the following interesting information regarding the sole fishery during the period of the investigations reported in this paper:

(1) The bulk of the commercial catches of soles during the years 1949–50, 1950–51 and 1951–52 consisted of individuals that had a single monsoon ring, the older individuals being negligible in proportion. The products of spawning of a particular fishery season grow up to the commercial size and directly enter the fishery in the very next fishery season.

(2) During the September-October fishery season in 1949 and 1950, the size group with the highest frequency was 10–10·9 cm., but in the fishery

season of 1951 this was 12–12·9 cm., thus showing a higher growth. This was correlated with a decrease in the total catches of the area.

VII. Food and Feeding Habits

One of us has been separately studying the seasonal and other fluctuations in the composition and abundance of the bottom fauna of the fishing grounds off West Hill (Seshappa, 1953). As the Malabar Sole has been found to be essentially a bottom feeder, the knowledge obtained on the bottom fauna is of considerable use in understanding the food problem of this fish. Productivity assessments of the sole fishery can be based, theoretically speaking, on the productivity assessment of the bottom fauna of the area when the exact relationships existing between the various elements of this fauna and the fish are fully known.

Table III shows the percentage occurrence of the different food items in the total number of fish examined during the period, September 1949 to March 1952. Diatoms and polychæte setæ have been reckoned for this purpose as indicating the occurrence of the respective organisms as food items of the fish only when they were noticed in good numbers. The month to month changes in the extent of occurrence of the different food species in the gut-contents of the sole are shown in this table.

The food organisms can be grouped under four distinct categories, namely, polychætes, amphipods, lamellibranchs and other organisms. Fig. 10 shows the percentage of occurrence of these four groups in the total occurrence of food items during the different months of study. It may be mentioned here that a close qualitative correlation has been found between the composition of the bottom fauna of the inshore fishing grounds and the composition of the gut-contents of the soles caught in the area, the dominant member of the fauna being usually the dominant member in the gut-contents also.

Polychætes were the dominant food animals during the months following the south-west monsoon of 1949 and up to March 1950. *Prionospio pinnata* was the most frequent of these polychætes. During these months it was frequently noticed that the guts examined were gorged with individuals of this species and had on several occasions no other species of food items in them. After March 1950, during the monsoon and pre-monsoon months, the polychætes were rather less important. During the fishery season of 1950 again, *P. pinnata* was the most important polychæte in the food, but the polychætes as a group had become second in importance, the category of other organisms standing first. During the fishery season of 1951, how-

TABLE III

Percentage Occurrence of Different Food Items in the Total Number of Fish Examined During Different Months

	1949				1950					
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Total No. of fish examined	13	12	13	32	33	35	65	30	36	10
Clymene sp.	..	..	..	..	..	..	..	..	..	..
Phyllochætopterus sp.	..	..	..	..	..	..	..	..	..	20·0
Prionospio pinnata	69·2	100	38·4	34·4	36·4	22·9	7·7	3·3	5·6	..
Pectinaria crassa	..	..	..	..	..	..	..	..	8·3	..
Sternaspis scutata	..	..	..	..	..	..	..	..	..	4·0
Diopatra variabilis	..	..	..	..	..	..	..	..	5·6	..
Lumbriconereis latreilli	..	..	..	..	..	..	..	..	..	..
Nereid species	..	..	30·8	..	..	..	..	..	..	..
Total polychætes (including unidentified remains)	69·2	100	69·2	34·4	60·6	68·6	16·9	3·3	27·8	30·0
Amphipods	15·4	..	..	3·1	6·1	2·9	24·6	40·0	..	10·0
Pholas orientalis	..	..	..	..	..	..	26·2	40·0	..	..
Nucula sp.	..	..	..	..	..	..	..	..	..	10·0
Tellina cuneolus	..	..	..	..	..	..	..	..	..	..
Cardium sp.	..	..	..	..	..	..	1·5	..	..	..
Total lamellibranchs (including unidentified remains)	..	..	..	12·5	..	2·9	27·7	40·0	27·8	10·0
Amphiura sp.	..	..	..	..	..	..	..	..	..	..
Gastropod remains	..	..	..	..	..	..	1·5	..	..	..
Acarinid sp.	..	..	..	..	..	..	..	..	..	..
Copepods	..	..	7·7	..	..	..	..	..	..	..
Isopods	..	..	..	..	..	..	..	..	..	10·0
Decapod remains (prawns and crabs)	..	..	..	3·1	3·0	..	4·6	..	11·1	20·0
Fish remains	..	..	..	..	..	..	..	..	..	..
Diatoms	..	..	..	..	3·0	..	..	..	..	..
Total miscellaneous items (including unlisted species)	..	..	7·7	3·1	6·0	..	6·1	..	13·9	50·0

TABLE III—(*Continued*)

	1950						1951			
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Total No. of fish examined	8	14	84	58	41	22	40	51	42	36
Clymene sp.	..	..	..	..	..	..	..	..	..	5·6
Phyllochætopterus sp.	..	..	..	..	..	..	..	..	..	11·1
Prionospio pinnata	..	..	4·8	1·7	7·3	31·8	12·5	15·7	4·8	..
Pectinaria crassa	..	..	..	..	..	..	..	..	..	2·8
Sternaspis scutata	..	..	2·1	..	..	..	..	..	..	..
Diopatra variabilis	..	..	..	..	..	..	..	..	..	..
Lumbriconereis latreilli	..	..	1·2	..	..	4·5	..	..	4·8	..
Nereid species	..	..	..	..	..	..	..	..	..	..
Total polychætes (including unidentified remains)	..	7·1	34·5	25·9	22·0	50·0	52·5	51·0	19·0	19·5
Amphipods	25·0	7·1	..	6·9	22·0	4·5	30·0	39·2	26·2	38·8
Pholas orientalis	..	..	..	1·7	17·1	18·2	30·0	29·4	16·7	19·4
Nucula sp.	12·5	..	13·1	3·4	..	..	2·5	..	..	11·1
Tellina cuneolus	..	..	..	..	..	..	..	..	..	2·8
Cardium sp.	..	..	..	..	..	..	..	..	..	..
Total lamellibranchs (including unidentified remains)	12·5	..	14·3	5·2	24·4	18·2	32·5	29·4	16·7	22·2
Amphiura sp.	..	..	..	..	..	..	..	..	..	..
Gastropod remains	..	..	1·2	..	..	..	..	..	..	..
Acarinid sp.	..	..	6·0	3·4	..	..	..	..	..	..
Copepods	..	..	1·2	25·9	..	..	..	..	..	..
Isopods	..	..	..	..	..	..	..	..	..	..
Decapod remains (prawns and crabs)	..	..	3·6	1·7	..	..	..	..	..	..
Fish remains	..	21·4	4·8	1·7	..	..	..	..	..	..
Diatoms	..	..	22·6	44·8	4·9	..	..	..	..	..
Total miscellaneous items (including unlisted species)	..	21·4	39·4	77·6	4·9	..	..	..	..	..

TABLE III—(*Continued*)

	1951								1952		
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Total No. of fish examined	29	..	..	22	3	10	20	41	60	70	31
Clymene sp.	..	..	..	..	..	20·0	..	..	..	..	..
Phyllochætopterus sp.	34·5	..	..	31·8		..	..	..	..	..	..
Prionospio pinnata	..	..	..	40·9	..	20·0	70·0	14·6	11·7	1·4	3·2
Pectinaria crassa	..	..	..	..	..	..	..	..	..	..	..
Sternaspis scutata	3·5	..	..	..	..	..	..	..	..	..	..
Diopatra variabilis	..	..	..	..	..	..	..	..	..	..	..
Lumbriconereis latreilli	..	..	..	9·1	..	..	..	..	..	..	..
Nereid species	..	..	..	..	..	..	..	..	..	..	..
Total polychætes (including unidentified remains)	58·6	..	..	81·8	..	60·0	75·0	14·6	13·3	4·3	9·7
Amphipods	13·8	..	..	..	..	..	..	..	16·7	75·7	74·2
Pholas orientalis	10·3	..	..	9·1	..	..	15·0	63·4	28·3	1·4	3·2
Nucula sp.	..	..	..	..	..	..	..	..	..	..	..
Tellina cuneolus	..	..	..	..	..	..	..	..	..	..	..
Cardium sp.	..	..	..	..	..	..	..	..	..	..	..
Total lamellibranchs (including unidentified remains)	10·3	..	..	22·7	..	..	15·0	63·4	28·3	4·3	54·8
Amphiura sp.	3·4	..	..	..	..	..	..	..	..	..	..
Gastropod remains	..	..	..	..	..	..	..	..	..	..	..
Acarinid sp.	..	..	..	..	..	..	..	..	..	..	..
Copepods	..	..	..	..	..	..	..	..	..	..	..
Isopods	..	..	..	..	..	..	..	..	..	..	..
Decapod remains (prawns and crabs)	..	..	..	..	..	..	..	..	..	..	..
Fish remains	..	..	..	..	..	..	..	..	..	..	..
Diatoms	..	..	..	..	..	..	..	..	..	..	..
Total miscellaneous items (including unlisted species)	3·4	..	..	..	..	..	..	..	..	..	..

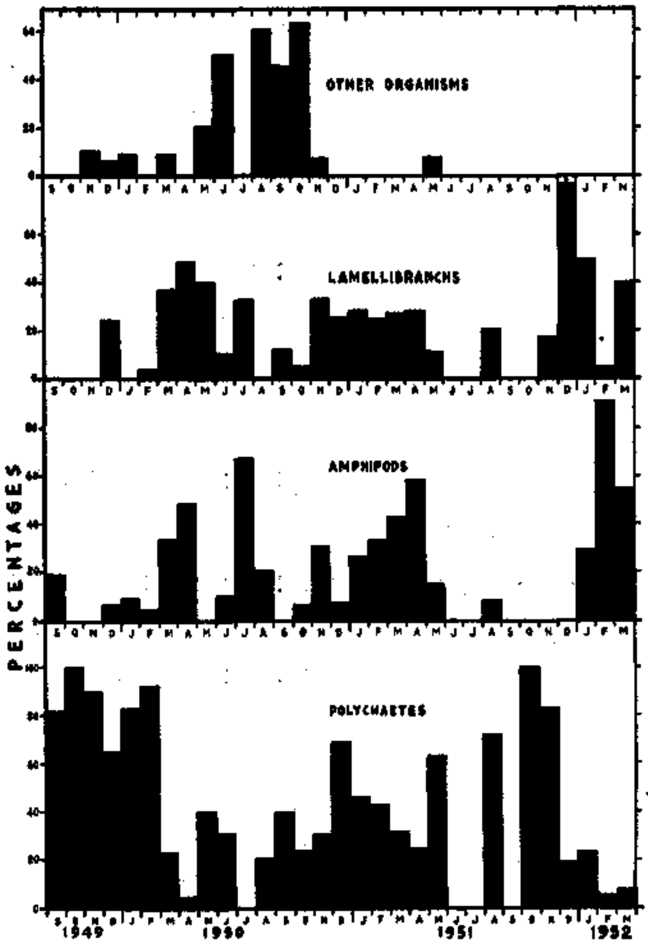


FIG. 10. Histogram showing the relative importance of the main categories of food organisms expressed as percentages of the total number of occurrences of food items during different months of the period September 1949 to March 1952.

ever, the polychætes had regained their place of high importance, with *P. pinnata* as the main species.

Amphipods and lamellibranchs become important in the gut-contents whenever polychætes are poorly represented. The amphipods noticed were *Cheiriphotis megachelis* and an ampeliscid species, the former being more common. Among the lamellibranchs, the species noticed were:

1. *Pholas orientalis*,
2. *Nucula* sp.,
3. *Tellina cuneolus*,
4. *Arca* (*Scapharca*) *gubernaculum*, and
5. *Cardium* sp.

Of these *Pholas orientalis* is the most important and occurs regularly during some of the months as seen in Table III. *Nucula* sp. comes next in importance.

The category of other organisms consisted of heterogeneous elements of occasional occurrence, such as decapod remains (including those of *Neptunus sanguinolentus* and *Metapenæus dobsoni*), gastropod remains (including *Duplicaria* sp.), *Dentalium* sp., *Amphiura*, copepods (including *Pseudodiaptomus* sp.), isopods and an acarinid. Diatoms occurred in considerable numbers on a few occasions (January, and September to November, 1950) and included *Fragilaria oceanica*, *Nitzschia sigma* var. *indica*, *Cyclotella striata*, *Biddulphia heteroceros*, and species of *Coscinodiscus*, *Thalassiothrix* and *Pleurosigma*.* Fish remains were noticed in some guts in the months, August to October 1950, but at no other time during these investigations.

The occurrence of the dominant food species in the gut-contents has been found to be closely correlated with its similar occurrence in the fauna of the area. During the seasons of commercial sole fishery (the months immediately following the south-west monsoon), except during the season of 1950, the food consisted mainly of polychætes, dominated by *P. pinnata*. The bottom fauna studies have shown (Seshappa, 1953) that during the monsoon months, June to August, the inshore sea bottom is very poor in animals, there being practically no species useful as food for the sole in the shallow waters. Immediately after the cessation of the monsoon, polychæte larvæ appear in large numbers in the inshore plankton and start settling on the sea bottom which they recolonize. During the monsoon months *C. semifasciatus* migrates to deeper waters and its return to the inshore grounds has been found to coincide with the commencement of the settlement of bottom animals—particularly of polychætes in the area. Large shoals of soles appear during September-October (September has always been the month of highest commercial landings along the entire coast) and they are found to feed largely on polychætes, particularly *P. pinnata* including its advanced planktonic stages. During the period September 1949 to March 1950 the bottom fauna was very rich in the area and was dominated by *Prionospio*. This was closely reflected in the gut-contents of the soles also. Thereafter the polychætes dwindled in number on the sea bottom and became also less frequent in the gut-contents. During September-October 1950, while a settlement of polychætes was noticed, the development of a fauna did not succeed in the area due to movements of mud banks (Seshappa, 1953). Hence the recession of the polychætes from the first place in the gut-contents during that season. Consequent on the scarcity of polychætes, the miscellaneous items occurred more frequently in the gut-

* We are indebted to Dr. R. Subrahmanyan for help in the identification of these diatoms.

contents during that season. Similarly amphipods and lamellibranchs assumed importance as food when they were adequately represented in the fauna of the area and polychætes were poor.

A glance at Table III reveals that the range of variation in the species-composition of the food is very limited. There are a few items which occur in the gut-contents for a longer duration than the others. *P. pinnata* and *Pholas orientalis* are the two species which stand out in this respect. These and the amphipods may be considered the primary food organisms of the sole when they occur in the fishing grounds. Several of the items have been recorded only on single occasions, as, for example, *Diopatra variabilis*, *Tellina cuneolus*, *Cardium* sp. and *Amphiura* sp. *Pectinaria crassa*, *Clymene* and an acarinid species have occurred during two of the several months of these investigations. These and the others such as diatoms, copepods, prawns and crabs, *Nucula*, *Lumbriconereis letreilli*, *Sternaspis scutata* and *Phyllochætopterus* sp., may be considered as occasional and additional food. *Nucula* occurs more frequently in fish collected from deeper waters than in material from the shallow region up to 6 fathoms. But in months when the shallow region is very poor in its population of animals that are useful as sole food, *Nucula* occasionally occurs in the specimens caught in the shallow waters also. *Nucula* does not occur in the shallow sea bottom and when it does occur in the gut-contents of soles caught in the region inward of the 6 fathom line, it is an indication of the fish having moved shoreward after feeding in the deeper zone.

The relative importance of the four different categories of food organisms for the Malabar Sole during different seasons is brought out in Fig. 10. It is seen that there are considerable variations from period to period in the relative importance of the different groups, depending upon faunal changes. On the basis of the percentages in the totals of occurrences during the entire period, the polychætes, amphipods and lamellibranchs occupy the first, second and third orders of preference respectively in the dietary of the fish. It should be mentioned regarding the lamellibranchs that their usefulness as sole food is limited by the factor of their size, their value becoming nothing when they reach a size that cannot be tackled by the fish. From this consideration also the polychætes and amphipods must decidedly be classed as more important.

Organisms other than those belonging to the above three categories accounted for 44·6 for 67·2 per cent. of the occurrences during the period August to October, 1950 and to 20 per cent. and 50 per cent. of the occurrences in May and June respectively of that year. This was the only period during the entire investigation when this group was of some importance. This was correlated with the fact that the colonization of the sea-bottom by the polychætes was somewhat delayed during that year. Normally, polychæte larvæ start settling on the bottom mud soon after the cessation of the monsoon conditions, and it is seen from the data (Fig. 10) that polychætes account for 81·8 to 100 per cent. of the occurrences during September and October of 1949 and 1951. But while the group had a high frequency for several months after October 1949, it had a very low frequency of 5·1 to 22·9 per cent. from November 1951 to March 1952. The reason for this is that during the post-monsoon period of 1951, while polychætes initiated the colonization of the inshore sea bottom, they were soon succeeded by a population of *Pholas orientalis* which dominated the bottom fauna during the succeeding months. As the polychætes were rather low in number and the newly settled young individuals of *Pholas* could easily be eaten by the fish, this latter species became the chief food item.

Table IV shows the percentages of empty guts (including those classified as 'almost empty' owing to small quantity of gut-content) and of guts whose contents were highly dominated by mud, in the total numbers of guts of *C. semifasciatus* examined during the different months. As the fish browses on the sea bottom, a certain amount of mud is frequent in its gut. The table reveals that a variable percentage of guts was dominated by mud during all the months. Empty guts were also frequent but no relationship has been noticed between the absence or decrease of feeding and spawning activity. Gonadic condition was

TABLE IV

Percentage of Empty Guts and of Guts whose Contents were Highly Dominated by Mud, in the Total Numbers of Guts of* C. semifasciatus *Examined During the Different Months of the Period September* 1949 *to March* 1952

Months	Years							
	1949		1950		1951		1952	
	Empty	Dominated by mud	Empty	Dominated by mud	Empty	Dominated by mud	Empty	Dominated by mud
January ..	..	..	9·1	24·2	0	37·5	11·7	38·3
February ..	..	..	0	33·3	9·8	17·6	8·3	21·6
March ..	..	..	10·8	24·6	2·4	40·5	0	12·9
April ..	..	..	10·0	16·7	16·7	28·0	..	..
May ..	..	..	16·7	22·2	6·8	48·3	..	..
June ..	..	..	0	30·0	..	..	..	..
July ..	..	..	12·5	62·5	..	..	..	..
August ..	..	..	7·1	57·1	0	40·9	..	..
September ..	0	46·2	42·9	17·9	100·0	0	..	..
October ..	0	100·0	1·7	36·6	30·0	30·0	..	..
November ..	15·4	23·1	40·4	22·0	0	20·0	..	..
December ..	31·2	37·5	9·1	36·4	9·8	24·4	..	..

* (Including almost empty guts also)

examined in all the females examined for gut-contents, all the stages of maturity up to stage V and also recovering spents being represented in varying proportions. There was nothing in these data to indicate that there was a suspension or decrease of feeding activity during the spawning season, as has been found in several species of fishes (see Bhimachar and George, 1952). Individuals in stage VI were, however, not available for examination except very occasionally, and as spawning appears to take place mainly in the deeper waters, it is not possible to say definitely whether feeding is not affected even for a very short period in connection with the actual spawning activity.

No differences could be noticed in the food preferences between males and females or between the younger and older size groups (above 5 cm.) except that the smaller specimens prey upon the smaller individuals of the food species. Post-larvæ that were reared in the laboratory were found to feed on copepods and diatoms, being thus plankton feeders. Individuals about 23 mm. in length were, however, able to eat polychætes when supplied in a finely divided condition.

As a result of these studies on the food of *C. semifasciatus*, some light is thrown on the possible causes controlling the movements of this fish into and out of the inshore fishing grounds. As a bottom feeder it seems particularly to favour polychætes, usually dominated along this coast by *P. pinnata* during the post-monsoon months. During the south-west monsoon season every year, the inshore sea bottom is highly agitated and most of the bottom fauna dispersed. During this period the soles move into deeper waters. In August or September, as soon as the monsoon conditions cease, the soles return to the inshore fishing grounds and form shoals. This is the main fishery season along the entire coast for this fish. A coincidence has been noticed between the sole fishery and the commencement of polychæte settlement in the area. It is likely that the food factor plays an important role in the large-scale appearance of the fish in the inshore waters in this period in view of the fact that there seem to be very few organisms of value as sole food available on the sea bottom in the deeper regions at this period. Seshappa (1953) has shown that the bottom fauna of the 8 and 10 fathom regions off West Hill, while not showing a decline at the commencement of the monsoon, does show a decline in later months. This means starvation to the soles, an indication of which is perhaps seen on the scales also in the form of the growth rings or monsoon rings. Another valuable pointer to the conclusion that the food factor may be important is that advanced stages of *Prionospio* larvæ frequently occur in large numbers in the inshore sea at all levels during this period; this also happens to be the period when the fish moves about at all levels in shoals and reveals planktonic stages of *Prionospio* in its gut-contents. If the fish have been in a condition of starvation or semi-starvation in the deeper waters into which they were forced to migrate, it is conceivable that they rush back to the inshore grounds owing to the availability of the polychætes and encouraged by the disappearance of the monsoon conditions of unfavourable salinity and temperature. *Prionospio* larvæ have been found to show two kinds of responses when placed in a finger bowl in the laboratory with one side of the bowl towards light. The larvæ move quickly towards the light and if they are advanced stages, they keep themselves to the bottom of the vessel, this being natural for a form which has to live as a member of the bottom fauna when adult. On account of this, advanced *Prionospio* larvæ must be more numerous in the inshore waters than offshore. In the bottom fauna *Prionospio*, when occurring in high densities, does so only in the shallow region inward of the four fathom line (Seshappa, 1953).

Parasites of the alimentary canal.—An unidentified cestode was frequently found in the alimentary canal of *C. semifasciatus* during all seasons of the year. Its occurrence was in no case associated with any visible abnormalities in the different organs of the alimentary system. The parasite occurred in both the sexes and in all the size groups examined.

VIII. Sex-Ratio, Maturity and Spawning

Sex-ratio

The sexes are recognizable in the Malabar Sole of 6 to 7 cm. total length on examination of the specimens after dissection. There are no external marks to distinguish between the two sexes, but in the case of females with gonads in advanced stages of maturity, the ovaries can be easily seen through the body wall when the fish is held against light. In specimens below about 7 cm. total length it frequently becomes necessary to examine the gonad under a microscope for determining the sex. In practice, therefore, the smaller specimens were examined in detail while the larger specimens were disposed off by dissection and naked eye examination alone. When there were difficulties in ascertaining the state of maturity of the gonad, further examination under a binocular microscope was made.

The sex distribution observed in the monthly totals of samples of *C. semifasciatus* examined during different months upto December 1951 is given in Table V. As it was not possible to examine all the smaller sizes in detail during the subsequent period, the data for the months of January to March 1952 have been omitted in this table.

The sex distribution figures reveal a very interesting feature, namely, that the two sexes were not occurring in about the same proportions during the entire period, but showed considerable fluctuations. During the months, September to December 1949, there were more males than females in the

TABLE V

Sex Distribution in the Monthly Totals of Samples of C. semifasciatus *Examined for Sex During the Period September* 1949 *to December* 1951

Months	Years											
	1949				1950				1951			
	Boat seine collections		Other collections		Boat seine collections		Other collections		Boat seine collections		Other collections	
	M	F	M	F	M	F	M	F	M	F	M	F
January	..	..	..	..	94	124	33	56	266	319	6	11
February	..	..	..	..	49	47	188	244	323	314	7	10
March	..	..	..	..	229	320	32	63	228	249	16	24
April	..	..	..	..	468	544	6	9	179	225	..	..
May	..	..	..	..	472	508	7	14	107	166	..	..
June	..	..	..	..	1	2	8	6	..	..	..	..
July	..	..	..	..	16	18	..	..	..	..	..	..
August	..	..	..	..	6	5	4	2	155	138	53	48
September	2	4	15	8	909	1,001	205	242	9	15	69	72
October	394	371	..	..	427	536	32	59	105	25	12	1
November	..	..	15	6	190	557	27	117	1	2	1	1
December	1	1	104	35	93	149	63	3	15	22	4	5
Total	397	376	134	49	2,954	3,811	548	815	1,388	1,475	168	172

population. But in the subsequent period, except during a few months, the females were more than the males. If we take the totals for the different years, still the males are found to be more numerous during 1949 (four months), but the females are more numerous during 1950, while in 1951 the two sexes are about equally represented. If the grand total for the entire period of investigation is considered as giving a more correct picture of the distribution, then there would be 5,589 males to 7,769 females, giving a ratio of 100 males to about 139 females.

The fluctuation in sex-proportions is even more marked in the weekly data than in the monthly totals presented here for the sake of brevity. As examples of the extreme disproportion noticed in individual samples between the two sexes, the following samples may be cited.

Both in the weekly samples that were actually examined and in their monthly totals the differences in numbers between the two sexes appear to be more marked during the months, October to December, than during

TABLE VI

Sex-Distribution in Certain Samples of C. semifasciatus *to Show the Occurrence of High Disproportion*

Date	Gear used	Total in catch	No. of males	No. of females
15-12-1949	.. Gill net	52	50	2
17-10-1950	.. Boat seine	102	22	79
3-11-1950	.. Boat seine (Market catch)	104	6	98
7-11-1950	.. Boat seine	109	34	75
11-10-1951	.. Boat seine	104	84	20

other periods. In view of the fact that these months form the main part of the spawning period for the species, as will be shown later in this paper, these differences in the numbers of the two sexes are most probably caused by the differential behaviour of the two sexes in their spawning migrations and local wanderings on returning to the inshore fishing grounds. That a certain amount of segregation exists between the two sexes is obvious from Table VI. But, as there are other periods when the numerical difference is not so marked, some seasonal factor must be responsible for this marked difference. It seems to be usual in several species of fishes for the male to ripen earlier and reach the spawning grounds before the female (Kyle, 1926). The main spawning grounds for the Malabar Sole lie somewhere in deeper waters (comparable perhaps with the offshore spawning grounds in the case of plaice) and the migration out of and into the inshore grounds may be taking place in batches. It is to be noted that in September which is the month of peak catches every year, the disparity between the two sexes is not high. Spawning migration seems to commence sometime in October with the weakening of the commercial fishery.

Maturity

A total of 5,076 females of the Malabar Sole was examined for their gonadic condition during the period September 1949 to January 1952. Males were not studied for maturity. The scale used for indicating the state of maturity has already been described. The percentage distribution of the different stages of maturity in the random samples of the different months is given in Fig. 11. Months in which the samples were very small have been omitted in the figure.

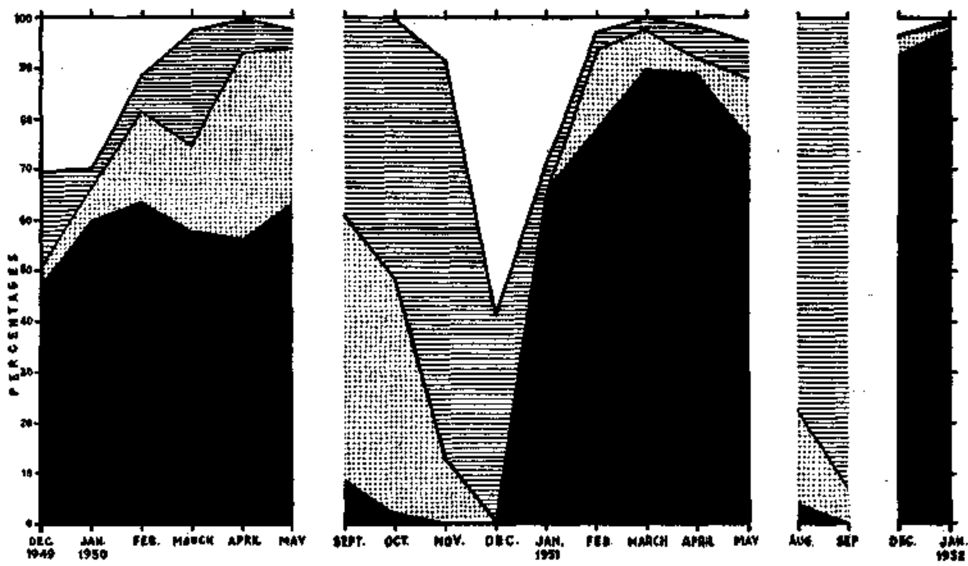


FIG. 11. Histogram showing the percentage distribution of the different stages of maturity during different months of the period, December 1949 to January 1952, among the females of *C. semifasciatus*. Explanation of shading—Black: Stages I and II; stippling: Stage III; line-shading: Stage IV; blank: Stage V and above.

In September 1949, 91·7 per cent. of the females examined had their ovaries in stage IV, only 8·3 per cent. being in stage III and none in the other stages. The number available for examination during that month was only 12. No females were examined in October. In November only six specimens were available, but five of them (83·3 per cent.) were already in stage V and the remaining were in stage IV. 36 Specimens were examined in December and 47·2 per cent. of these were new recruits of the year with ovaries in stages I and II. 2·8 per cent. had reached stage III. 30·6 per cent. of the specimens were in stage V of maturity. This stage, which indicates the approach of spawning, gradually decreased in percentage during the succeeding months, reaching 0·4 per cent. in April 1950 and showing a slight rise to 1·9 per cent. in May 1950. As the recruitment to the lower size groups continued during these months, the percentages of females in the lower stages of maturity remained high, those in stage III rising from 5·5 per cent. in January to 36·7 per cent. in April. This figure fell to 30·0 in May but from June onwards stages IV and V went unrepresented and stages III and below III were all that were seen in the samples. June to August are the monsoon months when the species migrates to deeper waters and hence the samples available for examination are very small.

When the fishery commenced in September 1950 on the cessation of the south-west monsoon, stages III and IV were the dominant ones. Lower stages are also still represented, but a small percentage of the females (0·4 per cent.) is in stage V also. From September to November there is a gradual increase in the percentage of the females in stage IV from 38·0 to 79·1. This falls to 39·6 in the next month, consequent on the increase of the individuals in stage V to 59·7 per cent. The lowest group is unrepresented in both November and December. In January, however, new recruits join the fishery, and 65·2 per cent. of the females are seen to be in the first group; 29·5 per cent. in stage V and above (including a few recovering spents), 5·2 per cent. in stage IV and none in stage III. The next two months mark a gradual increase in the lowest group and a decrease in the highest group, stage V becoming unrepresented in March. Small percentages of this stage again appear, however, during April to June. As stage III increases from 3·1 per cent. in April to 53·2 per cent. in June, the first group decreases from 89·4 per cent. to 39·1 per cent.

During the months following the monsoon of 1951, stage V was not seen at all till November and even then there was only one specimen in this stage, out of the 31 females examined. The first group of maturity stages was unrepresented from September to November and stage III was absent in October and November. Stage IV was represented by 77·4 per cent. of the females in August and 93·6 per cent. of the females in September. This number fell to nil in December. The October and November samples were very small and all the specimens of these two months were in stage IV.

In January 1952 again, stages III and below were predominant, there being only 1·3 per cent. of the specimens examined in stage IV and 0·7 per cent. in stage V and above.

The general pattern of the seasonal features in the gonadic conditions, that can be made out from the above description is that, when the commercial fishery starts immediately after the south-west monsoon, the predominant maturity class is stage IV; the lowest group is either absent or very small in number and stage V may be already represented in a few individuals. During the succeeding months until December, the smaller individuals become increasingly scarce in the samples, and an increasingly larger percentage of females move on to stage V of maturity. From December onwards new young recruits join the fishery, the immatures thus become predominant, the percentages of the higher stages of maturity being reduced. By about the beginning of monsoon the maturity stages V and above cease to appear in the samples. Variations in this general pattern appear to be related to

(i) delay in the ripening of the eggs;

(ii) delayed or early commencement of recruitment of the new brood to the fishery; and

(iii) slight variations in the population characters introduced by the wanderings of the species in and out of the fishing grounds.

The smallest specimen in stage V that was recorded during these investigations measured 10·0 cm. in total length. Normally the ovary is not ripe (stage V) below a size of about 12·0 cm. total length.

Spawning

The ripe ovarian egg is spherical. Several oil globules are present in each egg. The ripe ovary is filled with transparent eggs which are all shed in one or more instalments in the same season. There are no different batches of eggs maturing at different periods in the same spawning season. But different individuals may mature at different times and thus prolong the breeding season. Ripe and full ovaries of specimens measuring 15·6 and 15·9 cm. were found to have 42,200 and 65,900 ripe and ripening ova by estimation.

The appearance of stage V of maturity in the ovary is always an indication of the approach of the spawning season, although the exact time interval required for stage V to reach the spawning stage VI may not always be the same. From Fig. 11 it will be seen that stages V and above occurred in the samples from November 1949 to May 1950, September 1950 to June 1951 (with a break in March) and again in December 1951 and January 1952. The variations in the sizes of the samples available for examination and the peculiarities of the wanderings of the species in the fishing grounds require that the different figures obtained in such estimations should not be considered as very accurate quantitatively, but, subject to this condition, the data do provide a reliable picture of the trend of events in the species in the area under investigation.

The occurrence of spent individuals and recovering spents is also an indication of the spawning season. In the case of the Malabar Sole spawning takes place in deeper waters and spents are rather rare in the inshore area. No spents were found at all here in the 1951 fishery season. During the previous two fishery years, the few that occurred did so between December and June. Stage V did not occur beyond May in any of the years.

The data on the analysis of maturity stages show then that the spawning season commences some time after September and ceases from June onwards. The periods in which stage V was well represented in the samples, roughly from November to January, may be considered to be close to the peak period in the spawning season.

A further evidence for the assessment of the spawning season is the period of recruitment of new young individuals into the fishery. The period of first appearance of these young individuals and the sizes which they have reached while thus appearing, will help to fix the period of spawning fairly accurately, when considered along with the data on gonadic conditions. Young individuals first appeared in the catches in December 1949 and 1950 and in November 1951. The largest of these young ones was already above 5·0 cm. in length. Table VII shows the percentages of juvenile *C. semifasciatus* (5·0 cm. and below) in random samples during different months and gives a rough idea of the intensity of spawning during the different parts of the long drawn out spawning seasons.

TABLE VII

Occurrence of Juveniles below 5·0 cm. in Total Length in Monthly Totals of Boat Seine Samples of C. semifasciatus *During the Period, September* 1949 *to March* 1952

Months	Years								
	1949–50			1950–51			1951–52		
	Total catch	No. of juveniles	Percentage	Total catch	No. of juveniles	Percentage	Total catch	No. of juveniles	Percentage
July ..	..	..	..	34	0	0	..	..	..
August ..	..	..	..	11	0	0	200	0	0
September ..	..	..	..	1,899	0	0	153	0	0
October ..	1,063	0	0	964	0	0	134	0	0
November ..	..	..	..	747	0	0	36	7	19·4
December ..	6	2	33·3	322	37	11·5	75	5	6·7
January ..	1,348	0	0	1,475	184	12·5	1,259	46	3·7
February ..	1,083	29	2·7	1,353	175	12·9	547	11	2·0
March ..	1,088	187	17·2	4,160	638	15·3	814	11	1·3
April ..	1,120	34	3·0	1,438	169	11·8	..	..	..
May ..	1,415	53	3·7	836	53	6·3	..	..	..
June ..	11	2	18·2	35	1	2·9	..	..	..

It seems reasonable to conclude from the data presented here that generally speaking spawning commences in the species in October and continues up to May with varying intensities in between. Eggs and larvæ have also been found in the plankton during some of these months, but a systematic study of the plankton for these stages has not been made throughout the period. Eggs were, however, seen in offshore plankton samples in November 1950 (Fig. 11 *a*); and post-larvæ were collected in April 1952. The actual spawning intensity can be reliably estimated only when systematic

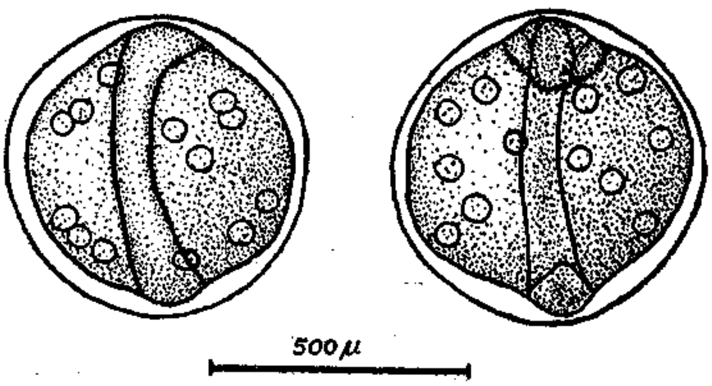


FIG. 11 (*a*). Eggs of *C. semifasciatus* (?) from bottom plankton off West Hill (13 fms. depth; November, 1950).

counts of eggs and larvæ are made in periodic plankton samples in view of the fact that the numbers of young individuals added to the inshore population do not give any idea of the mortality and survival rates in the eggs, larvæ and the smallest juveniles.

The strength of the juvenile populations given in Table VII gives an indication of the future fishery also. It has been shown (Seshappa and Bhimachar, 1951) that the young ones in any one spawning season (say, in December 1951) grow to the adult size and directly enter the fishery in the very next season (September). The number of the juveniles in any one season, therefore, determines, to a large extent, the number of adult fish available for capture during the next fishery season.

IX. Larval Stages, Metamorphosis and Early Growth

Only a few accounts of the eggs and larvæ of Indian flat fishes have been published. John (1951) has described the eggs and larvæ of some species from the Madras coast and Nair (1952 *a* and *b*) has described the eggs and larvæ of *Cynoglossus* spp. from the same locality. Jones and Menon (1951) have described the larvæ and some stages in the metamorphosis of *Brachirus pan* and given notes on certain larval stages of *Cynoglossus* spp. In the present work on *C. semifasciatus* the authors were able to collect large numbers of post-larvæ from plankton samples off West Hill during April 1952. Batches of larvæ were kept alive in the laboratory and it was possible to study from these the various phases of metamorphosis by uninterrupted observation. The young asymmetrical individuals that were metamorphosed were reared in the laboratory up to a size when most of the adult characters were manifest and thus their identity was verified. An account of this work is given below.

An interesting occurrence that was noticed in this work was that the shifting of the eye invariably took place during the night, a good number of symmetrical post-larvæ collected on any day and left alive overnight being found metamorphosed next morning. On two occasions, therefore, freshly collected live larvæ were kept in a finger bowl and observed continuously under a binocular microscope, through a considerable part of the night, for the structural and other changes connected with the metamorphosis. The main phases in the metamorphosis were therefore actually observed and not just inferred. Selected stages were preserved in formalin during the observations and examined in greater detail later on. The measurements given in the following description are based on specimens preserved in 5% formalin.

The larvæ collected from the plankton measured from 2·8 to 4·9 mm.

The 2·8 *mm. stage* has the following structure (Fig. 12): The body is symmetrical and laterally compressed. There is a very prominent bulge on the ventral side containing the intestinal coil. On a prominent protuberance on the postero-dextral aspect of the abdominal bulge is the anus. The head is large and there is a clear operculum. The mouth is anterior and slit-like. The eyes are large and prominent. There is a small slit-like nasal depression in front of each eye. The anterior margin of the head is straight and slopes upwards and backwards without any sinuosities. There is a continuous median finfold extending from the anterodorsal summit of the head to the posterior margin of the bulging belly. Except in the anterior-most region of the dorsal fin no clear fin rays are yet visible in this finfold. The first two rays are very long and form a characteristic tentacular structure above the head. These rays are free along their distal portions. Behind these two rays the dorsal fin is narrow, but it widens out over the rest of its length. The anal fin is similar in structure to the dorsal fin, but has no clear fin rays in any region. Pelvic fins appear to be represented in the preserved specimen by two very small processes in front of the belly ventrally. A pair of large pectoral fins are present; each of these is a pedunculated fan-like structure, the peduncular portion being narrow and the rest of the fin widened out fanwise distally; the distal part of the fin is thin and marked out abruptly from the thick proximal portion.

There are groups of dark pigment spots characteristically distributed over the body

(i) on the surface of the abdominal bulge, particularly on its ventral surface and;

(ii) below the base of the dorsal fin, running in a row longitudinally;

(iii) above the fleshy base of the anal fin, running longitudinally;

(iv) between the fleshy and membranous portions of the anal fin, again running longitudinally;

(v) along the edge of the anal fin, also running longitudinally;

(vi) below the base of the dorsal tentacular process arranged in a group; and

(vii) at about a quarter of the length of the animal from the posterior end, forming a transverse band across the side of the body.

The pigment spots of the belly are particularly dense on the ventral surface. They do not extend on to the anal protuberance. The row below the fleshy base of the dorsal fin is interrupted here and there to form six linear groups of different lengths. The corresponding row below the fleshy base of the anal fin is continuous and uninterrupted, though the spots tend to be more dense in some places than in others. The row between the fleshy base and the membranous portion of the anal fin is also continuous, but is thinner and uniform due to the spots being more sparsely distributed. The row along the edge of the anal fin consists of much fewer tiny round spots arranged in a single file and wider apart than in the previous row.

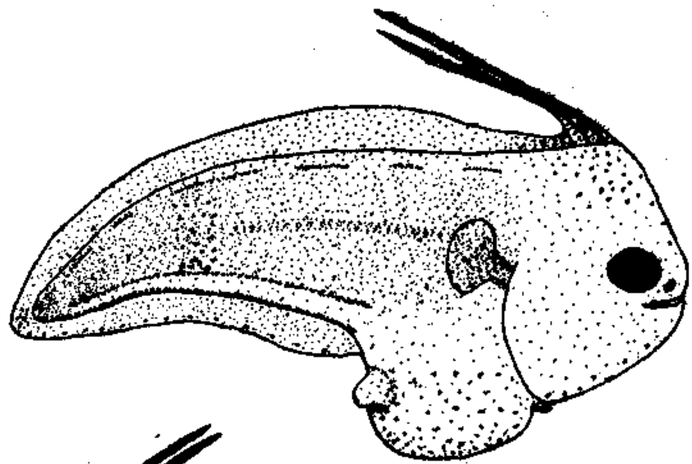
In addition to the above, there are pigment spots distributed in other regions also. A few spots are seen in the region of the air bladder, though the air bladder itself is not visible through the skin in this stage. There are a few spots here and there on the dorsal fin, the long tentacular fin rays and the caudal finfold. A row of sparsely arranged round spots are also seen on the antero-ventral and antero-dorsal margins of the head and on the operculum.

The positions of the brain, auditory vesicle, nerve cord and vertebral column can be easily seen in transmitted light in the preserved specimen. The vertebræ and myotomes are also somewhat distinct, but could not all be counted easily. The caudal end of the vertebral column shows an upward kink.

The pigmentation described above has been noticed in all planktonic stages of the post-larvæ examined.

The larvæ are transparent when alive and are seen to swim about actively at all levels when left in a trough of sea-water.

An older planktonic stage of the post-larvæ is represented in Fig. 13 drawn from a preserved specimen measuring 4·5 mm. in total length. In this stage, it is seen that the body has become more elongated and lanceolate. The bulge of the intestinal mass on the ventral side is less pronounced than in the previous stage. The anal protuberance is more median in position. The anterior end of the fleshy base of the dorsal fin has grown forward from below the tentacular process to form a rostral projection or protuberance which is laterally compressed and slopes downwards and backwards so as to make an obtuse angle with the rest of the front of the head. The gill rakers are visible. The mouth is prominent and anterior, with very minute teeth on the jaws. The nareal depression is more prominent



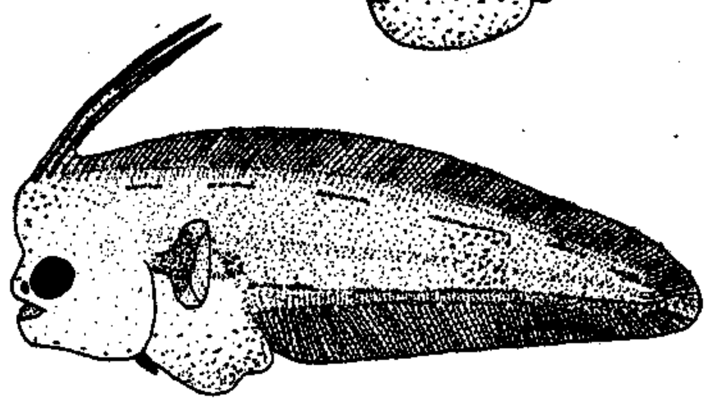


FIG. 12. Symmetrical post-larva of *C. semifasciatus*, 2·8 mm. stage (22-4-1952), × ca. 35.

FIG. 13. Symmetrical post-larva of *C. semifasciatus* (22-4-1952). 4·5 mm. stage, × ca. 20.

than in the previous stage. There are distinct fin rays in the dorsal and anal fins, but all the rays are not yet distinctly formed in the caudal fin. There are about 98 rays in the dorsal fin excluding the first two long rays and about 78 rays in the anal fin. The pelvic fins are clearly seen, but their fin rays are faint. The pectoral fin continues to be without any fin rays. An air bladder is now distinctly visible through the skin and there is a dense group of pigment spots in the region of the air bladder. Groups of pigment spots are also distributed over other regions of the body exactly as in the previous stage.

Post-larvæ slightly longer than the above stage also showed a similar structure except that the rostral projection had grown further and produced downwards into a beak-like process.

Metamorphosis and Early Growth

The first sign of approaching metamorphosis is the further development of the rostral projection into a prominent parrot-beak-like structure which may be called the *rostral beak*. In the most advanced symmetrical stage this is projecting downwards and inwards, enclosing a small space between itself and the interorbital region of the head where a slight depression is developoed. The distal end of the beak may be touching the head. A specimen which had only a slight rostral projection at about 6 P.M. on 14-4-1952 was seen to have developed into this stage by 8 P.M. It was then found to be on the bottom of the vessel, still in the vertical position with the head touching the substratum and the rest of the body disposed at an angle to the substratum. It looked as if the larva was rubbing its head on the bottom of the vessel and jerking the tentacle sometimes. Occasionally it was lying on its right side. In about ten minutes it settled down on the right side and was showing occasional jerky movements. It did not assume the vertical position again after this. The lower jaw was moving constantly and rhythmically and the tentacle was lashing slightly now and then. The larva showed occasional movements of the entire body also, but slowly and still lying on the right side only. The first signs of asymmetry were noticed by about 8-50 P.M., when the right eye had slightly shifted its position. The subsequent stages in the shifting of the eye were reached rapidly, and in about two hours time the eye was completely on the left side. The various stages of this transformation are shown in Figs. 14 to 18. The right eye gradually moves towards the dorsal edge

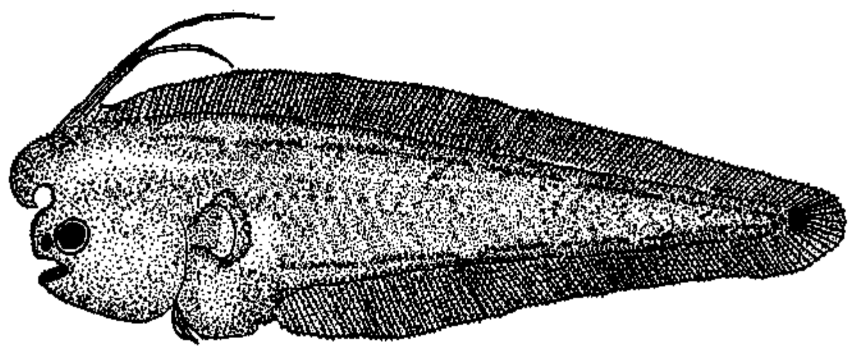
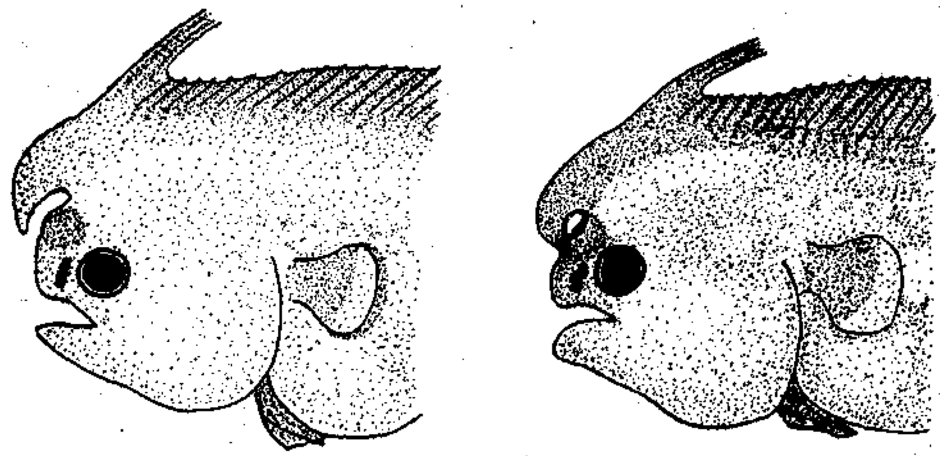
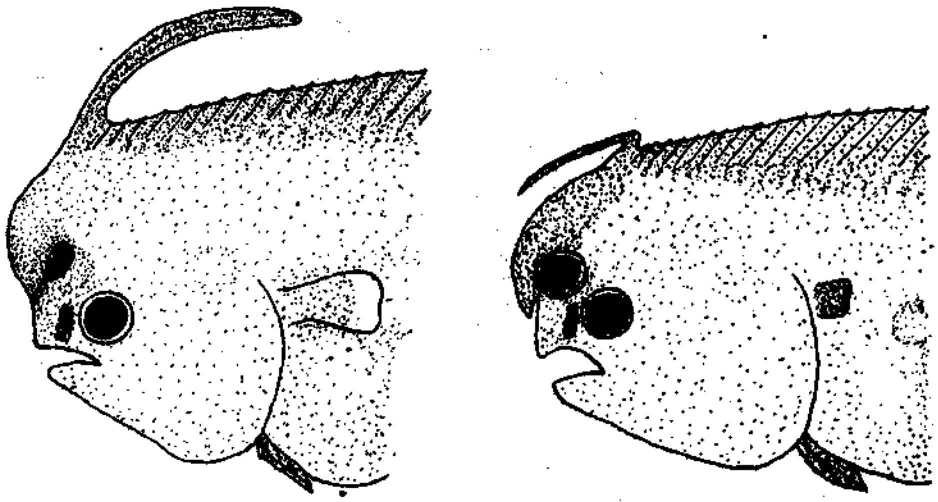


FIG. 14. Advanced symmetrical post-larva of *C. semifasciatus* with prominent rostral beak, × ca. 20.

of the head where the rostral beak enclosed a space between itself and the interorbital depression of the head. As this happens the distal portion of the rostral beak comes more and more in apposition with the front of the head and finally, when the eye has reached the left side, the entire beak presses against the head and finally fuses with it just leaving the eye clear on the left side. By next morning this fusion of the beak is complete and the appearance of the head is very much as in an adult. The eye does not



Figs. 15 and 16. Stages in the shifting of the eye in the metamorphosis of *C. semifasciatus* × ca. 35.



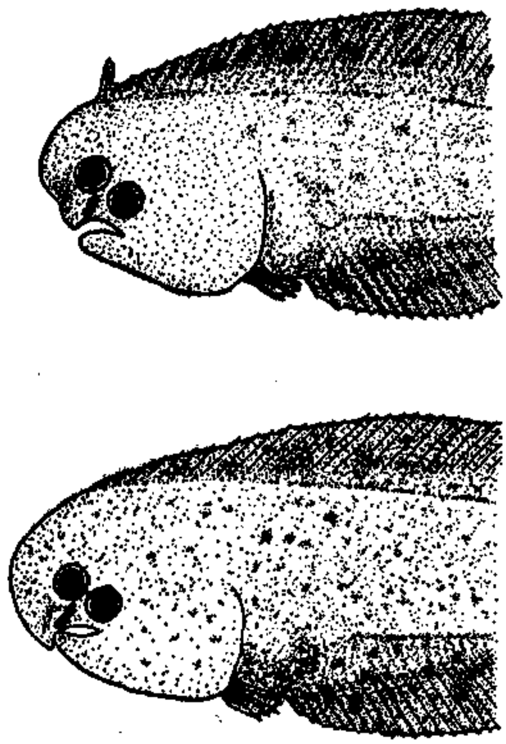
Figs. 17 and 18. Further stages in the shifting of the eye (and the atrophy of the pectoral fin) in the metamorphosis of *C. semifasciatus,* × ca. 35.

seem to shift further towards the original left eye, once it has completely shifted on to the left side of the body.

The changes in the stages shown in Figs. 14 to 15 and in Figs. 16 to 18 were observed separately on two different days, namely, on 14-4-1952 and 22-4-1952 respectively. In the batch observed on 14-4-1952, the frontal protuberance had not yet developed into a beak at 6 P.M., but at 8 P.M. the beak was well formed, as seen in Fig. 14. At 9-30 P.M. metamorphosis had already progressed a good deal and the specimens were in the stage shown in Fig. 16. By 11 P.M. the stage shown in Fig. 18

had been reached. While all the individuals in the batch did not show all the changes strictly simultaneously, it may be said that they kept themselves close to one another in respect of time in the various changes undergone. By next morning it was found that the head had reached an appearance much as in the adult (Fig. 19) except for a stump of the tentacle (and a stump of the pectoral fin in one exceptional specimen).

After the commencement of metamorphosis, the dorsal tentacle ceases to be functional and appears, in the process of metamorphosis, to be partly absorbed into the rostral beak and partly to decay and drop off. The pectoral fin is retained on both sides till a late stage in metamorphosis, even after the larva has settled down on the right side. It was clearly seen on both sides in the stages shown in Figs. 14, 15, 16 and 17. But in the stage figured in Fig. 18 both the pectoral fins had dropped off. The stump of the pectoral fin was an exceptional occurrence in the specimen figured, the same



FIGS. 19 and 20. Further stages in the metamorphosis of *C. semifasciatus*, × ca. 20.

being not seen in specimens similarly metamorphosed during the night and examined next morning.

The main phase of metamorphosis may be said to be over with the shifting of the eye and the correlated adjustments in the structure of the skull. But there are still some minor changes to be undergone before the final adult condition is established. While the abdominal bulge has disappeared on the morning following metamorphosis, it is seen that the ventral and anal fins are still far apart, the air bladder is still prominently visible through the skin, and the scales and pigmentation of the adult have not developed. The larval pigmentation is, however, already marked by the appearance of a number of pale brown pigment spots all over the body, especially on the fins, trunk, operculum and the snout. By next day these spots increased in number and close examination revealed that most of them had a dark centre and a pale periphery. Some of them had a star-shaped appearance while others were irregular and both were arranged in ill-defined rows and groups. At this stage, the ventral and anal fins are also confluent. This is the stage shown in Fig. 20.

Examination of later stages seems to suggest that the star-shaped pigment spots with dark centres are perhaps related to future scale centres. Clear scale centres were noticeable in the skin by about the ninth day of metamorphosis. The light brown pigment spots of the body which had increased in number had by now arranged themselves into irregular transverse bands across the body. The scales examined on the 15th day of metamorphosis had already assumed an oval shape with a wavy anterior margin and had four rows of circuli with no radii, and with a prominent spine projecting from behind. Other spines were still in formation. The length of the scale at this stage when the animal had a total length of 9·1 mm. was about 90 microns excluding the spine.

The growth rates of the different individuals were not the same in the laboratory conditions which were extremely variable and uncontrolled. In all, the growth was very slow (with a maximum of only about 18 mm. during the first 40 days) compared to the rate of growth in the sea. The slow rate was presumably because it was not possible to provide them with suitable food organisms at regular intervals.

No lateral lines were yet visible in a specimen measuring 12·5 mm. in total length. Only one lateral line, the lower one, was visible at a total length of 15 and 19 mm. But both the lateral lines were well formed in a specimen of 23 mm. total length, which was the maximum size reached during the present rearing experiments.

A very interesting occurrence, noticed during these studies, must be mentioned here. As the shifting of the eye was invariably taking place during nights some experiments were tried to see whether metamorphosis could be induced during daytime by keeping nine larvæ in a glass trough covered by dark cloth so as to cut out the light. No changes were noticeable by the evening (after several hours in the darkened trough) and the larvæ appeared quite normal in all respects. Next morning it was found that six of the larvæ had metamorphosed, but of these three had not shifted their eyes to the left side at all. The right eye had slightly moved away from its position, but was imbedded in the tissue of the head. It appeared as though the rostral beak fused with the head too early for the eye to reach the left side. One of these one-eyed specimens is shown in Fig. 21. Others were reared further and the largest specimen that was available during these experiments

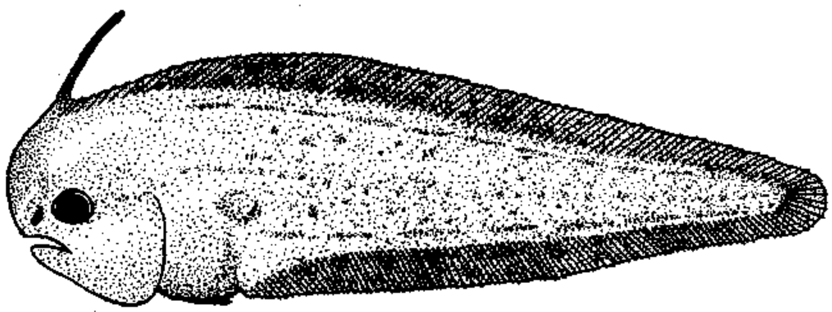


FIG. 21. A one-eyed specimen of *C. semifasciatus* resulting from abnormal metamorphosis, ×20.

was a one-eyed specimen and measured 23 mm. When the larvæ were kept in the darkened trough, there were also some kept exposed to day light as a control experiment. The metamorphosis in the case of these larvæ was found to be normal. When as many as three specimens changed similarly in the darkened trough, it is difficult to pass them off as mere freaks not having anything to do with the conditions provided for them. We were unfortunately unable to try further experiments during the period, but it is proposed to take up further studies on this aspect at a future date.

Norman (1934) cites Holts' description of an adult sole (the European form) in which the eye of the blind side had remained on that side of the head nearly opposite to that of the ocular side, but which was to a large extent embedded in the skin. A few other references to records of arrested rotation of the eyes in the metamorphosis of flat fishes are given by Dean (1923).

Another case of abnormality may also be mentioned here. This is a single case of reversal of the ocular side that was noticed in an adult specimen obtained in the laboratory catches. Such cases are more common in some of the European flat fishes and Norman (*loc. cit.*) cites Cunningham as describing a very interesting case of a turbot where albinism, ambicoloration and reversal were combined in the same individual. It is known that the air bladder and the position of the intestinal coil have an important role in determining the side on which different flat fishes come to rest on the substratum on metamorphosis (Kyle, 1926).

X. Commercial Fishery Trends

In Fig. 1 are shown the annual landings of soles along the Malabar and South Kanara coasts for a period of twenty-two years. An examination of this table shows that there has been a steady increase in the landings of soles from 1946–47 onwards until in 1950–51, the highest catches on record were landed, namely 5,02,759 maunds (a quantity nearly double the maximum ever recorded in pre-war years). Thus there was a steady and progressive development of the fishery in the sense that increased exploitation was possible. The figures for the year 1951–52 show that there is a sudden fall in landings to about the average level noticed before 1946–47. The data for the year 1952–53 have not been examined in detail yet, but the general impression has been one of insufficient improvement in the fishery during the year. In the West Hill Sea, the region of the present sampling investigations, the trends of commercial landings are particularly interesting and are shown in the following Table VIII. The figures are the totals of landings recorded in the Calicut and Pudiappa fish curing yards.

The extreme poverty of landings during the year 1951–52 is at once obvious from a glance at the table, there being a fall to about 5 per cent. of the previous year. The year of peak catches for this area happened to be 1947–48, the next three years also being very good years with average annual landings of 46,069 maunds of soles. Here again 1952–53 data have not been looked into in detail yet, but market conditions were closely watched and it was noticed that the fishery was not good during that year also. The natural questions that will occur are:—Why did this decline occur and what are the remedies to avoid such declines in future ?

We may very briefly re-capitulate here the facts that have come to light regarding the biology of this fish. The species is a bottom feeder and a carnivore; it favours a diet of polychætes, amphipods and small lamellibranchs. *P. pinnata*, a polychæte, is its chief food. The fish does not usually occur in aggregations in the inshore fishing grounds after October, but large shoals occur at all depths in the inshore waters during September and October, which form the chief commercial fishery season for this fish. During the monsoon months of June to August the soles migrate to deeper waters and return to inshore immediately after the disappearance of monsoon conditions, coincident with rising salinity and the commencement of bottom animal settlement. In October they begin to migrate to deeper regions again and this is a breeding migration because the gonads are in an advanced stage of maturity in September and October and juvenile soles are recruited to the inshore fish stocks from December onwards. Spawning starts in October and continues till about the commencement of the south-west

TABLE VIII

Landings of Soles in Maunds in the West Hill Sea during the Years 1940–41 *to* 1951–52

Months	Years											
	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	1949-50	1950-51	1951-52
July ..	0	0	0	0	0	0	0	0	0	0	0	0
August ..	657	0	100	1,290	0	0	0	0	0	0	0	0
September ..	16,901	12,780	11,259	5,734	39,310	19,430	12,392	1,102	30,245	7,030	42,410	2,380
October ..	0	0	1,320	0	3,035	1,700	0	11,225	40	940	4,000	100
November ..	0	0	1,000	0	50	1,740	800	30,000	0	0	1,800	0
December ..	0	0	0	0	410	704	50	11,095	17,505	2,040	0	0
January ..	0	0	0	0	0	0	0	0	720	25,420	0	0
February ..	0	0	0	0	0	0	0	0	0	3,925	0	0
March ..	0	0	0	0	0	5	0	0	0	1,730	0	0
April ..	0	0	0	0	0	0	0	0	0	315	0	0
May ..	0	0	0	80	0	20	0	0	5	80	0	0
June ..	0	0	0	83	0	0	0	0	0	0	0	0
TOTAL ..	17,558	12,780	13,679	7,187	42,805	23,599	13,242	53,422	48,515	41,480	48,210	2,480

monsoon though with variable intensity at different periods of the long-drawn out-spawning season.

The scales have age-rings on them and these and other studies show that the large majority of individuals that contribute to the September-October fishery are only " one year " old, being the products of the previous October-May spawning. Individuals with two monsoon rings on scales, that is, older individuals, are very rare in the fishery, which is thus of an *annual nature*, there being no complications introduced by any mixing up of a number of broods and year-classes. Spawning takes place in deeper waters and the post-larvæ and young move inshore to shallow waters, resembling the plaice to some extent in this respect (Heincke, 1905; Bowman, 1921; Kyle, 1926). From January onwards in any year the juveniles of the same season predominate the stocks.

Table VIII shows that in the West Hill Sea as along the rest of the Malabar coast the peak catches of soles are in September. From 1947–48 onwards, however, a tendency is seen for high catches to occur in later months. In the year 1947–48 the maximum landings were in November and as much as 11,095 maunds were landed in December also. In 1948–49 the peak catches were in September, but as much as 17,505 maunds were landed in December and some quantity landed in January also. In 1949–50 the peak catches were seen in January and some landings were recorded even up to May. In 1950–51, however, the normal September peak was seen and there were no catches after November, but the September catches were the highest for all the period. A consideration of the biological facts mentioned above with these figures of landings indicates that most probably the poverty of the fishery, that is, the phenomenal reduction in landings noticed in 1951–52, was an effect of indiscriminate fishing. There was no apparent reduction in available fishing effort, and there were complaints of unemployment and famine conditions among the fishermen caused by the failure of the fishery. The high growth rate noticed in the species in 1951–52 was apparently the result of the population strength having greatly fallen down (C. G. J. Petersen, 1920). The low numbers of juveniles noticed in samples is a further evidence of a fall in population strength. There are two points of particular importance pointing towards unrestricted fishing as the most probable reason for the decline in the fishery in the present instance. Firstly, in September and October the fish stocks consist of individuals approaching the spawning stage and any abnormally high mortality of individuals in these months means a high removal of potential spawners and consequent reduction in the numbers of eggs and larvæ and hence of the new recruits in the next relevant season. Secondly, a high mortality during the months January to May means a high mortality of juvenile individuals which should normally form the material for the next September-October fishery. As seen in the above table in 1949–50 the peak catches were in January, this obviously resulting in a high fishing mortality in the juvenile stocks. That these stocks were dominated by juveniles is fully proved by the age determination and length frequency studies on the samples of the period in question. This occurrence was followed by a very high fishing mortality in the stocks of potential spawners during September 1950. If we consider the West Hill Sea as a unit, then, it seems highly probable that the exploitation of the fishery went beyond the optimum limits from 1946–47 onwards, in any case during 1948–49 and 1949–50. For the entire coast also, the tendency for a spreading out of the fishery season to later months (leading to considerable juvenile mortality) is seen for recent years from Fig. 4. It seems possible that this spreading and the record landings of 1950–51 for the entire coast have led to the sudden decline in the fishery subsequently. But the problem is by no means as simple as stated here, nor is it possible from the present state of our knowledge to suggest any remedial measures for permanent adoption. In the first place we know nothing about the behaviour of the fish stocks in the deeper waters. While there is nothing to show the occurrence of north-to-south or south-to-north migrations along the coast, the point has yet to be made certain. During 1950–51, the year of general decline in catches along the coast, some places did show increased catches. It is not unlikely that the nature of the bottom fauna affects the occurrence of the soles in the inshore waters in different regions along the coast. In the West Hill Sea the year 1949–50 showed the existence of a very rich bottom fauna, predominated by *P. pinnata* (Seshappa, 1953) which was the most favoured article in the diet of *C. semifasciatus*. Subsequently the bottom fauna has been extremely poor in this area (Seshappa, unpublished work). There is thus an urgent need to study the sole in relation to its environment in several other regions along the coast and also in the deeper waters before any definite conclusions can be drawn.

The question of limiting or in any other way rationalizing the catches during the normal commercial fishery season is difficult in the case of the soles because, firstly it is not possible to prevent the capture of would-be spawners in September-October, these being usually the only months when the fish occur in shoals and can at all be exploited on a commercial scale, and secondly it is impossible to think of any quantitative restrictions yet because no assessment can yet be made of either the stocks available along the coast during different years or of the intensity of spawning and survival strength of the new broods in different years. It may, however, be stated that the information so far collected does give certain useful indications as to how the recovery of the fishery from the recent decline may be expedited. One of the reasons pointed out for this decline was the exploitation of juveniles which, if left uncaptured, would join the commercial fishery of the following September-October season; this large-scale exploitation occurs during the later months of the year, from December-January onwards. If this is effectively stopped for some years, there is no doubt that it will help considerably in the recovery of the fishery. Unless other difficulties come in the way, the restriction may be usefully continued even after a full recovery, as it will help in keeping the yield of the commercial fishery season at a high level. Future work should enable us to base the exploitation of this fishery on rational and scientific principles. In view of the coincidence that has been noticed between the commencement of the settlement of bottom organisms in the inshore area, particularly of polychætes dominated by *P. pinnata*, and the commencement of the post-monsoon sole fishery, further work on this aspect at different regions along the coast may even enable us to forecast the fishery to a certain extent.

XI. Summary

1. This paper comprises the studies made on various aspects of the biology of *C. semifasciatus* at West Hill, Calicut, during the period April 1949 to March 1952. Along with the biological data are also included some data on the landings of soles along the West Coast of Madras and an attempt has been made to interpret the recent trends in these landings in the light of the biological findings.

2. The commercial importance of the species is discussed and it is pointed out that there has been a remarkable increase in the catches during the post-war years followed by a decline in 1951–52.

3. The food of *C. semifasciatus* consists of bottom organisms, except during the period immediately following the cessation of the south-west monsoon when the species occurs at all levels in shoals and feeds also on planktonic stages of polychætes dominated by *P. pinnata*. This is the most favoured single species in the diet of the Malabar sole. The polychætes, as a group, rank first among food items, the amphipods and lamellibranchs coming second and third in order. No starvation is indicated in the spawning season. The food factor appears to be important in determining the inshore migration of the fish immediately following the cessation of the monsoon.

4. Age and growth studies have been made by the analysis of length frequencies and the study of *monsoon rings* on scales. The validity of these rings as indicators of age is discussed.

5. The analyses of the states of maturity of ovaries in random samples studied during the period have shown that the majority of females are in an advanced stage of maturity (stage IV or V) during the usual commercial fishery months (September and October). The post monsoon inshore shoaling of the species is soon followed by a spawning migration to deeper waters. Spawning commences in October and continues till May. Juvenile individuals start appearing in the inshore collections from December onwards, but sometimes from November.

6. The off-springs from October-May spawning grow up to commercial size and form the bulk of the commercial fishery during the September-October season immediately following. The older individuals are very few in these months, thus showing that the fishery is essentially of an "annual" nature.

7. Symmetrical post-larvæ were collected in April, 1952 and metamorphosis was observed. The various stages of metamorphosis are described and figured.

8. The indications are that the decline in the sole fishery noticed during 1951–52 and 1952–53 along the coast in general and in the West Hill Sea in particular, is due to unrestricted fishing as evidenced by the magnitude of catches breaking all previous records. For the West Hill Sea the evidence is marked that there has been too high a capture of would-be spawners and juveniles during the years immediately preceding the present decline.

9. It is also suggested that the juvenile stocks be protected against exploitation, to quicken the pace of recovery of the fishery.

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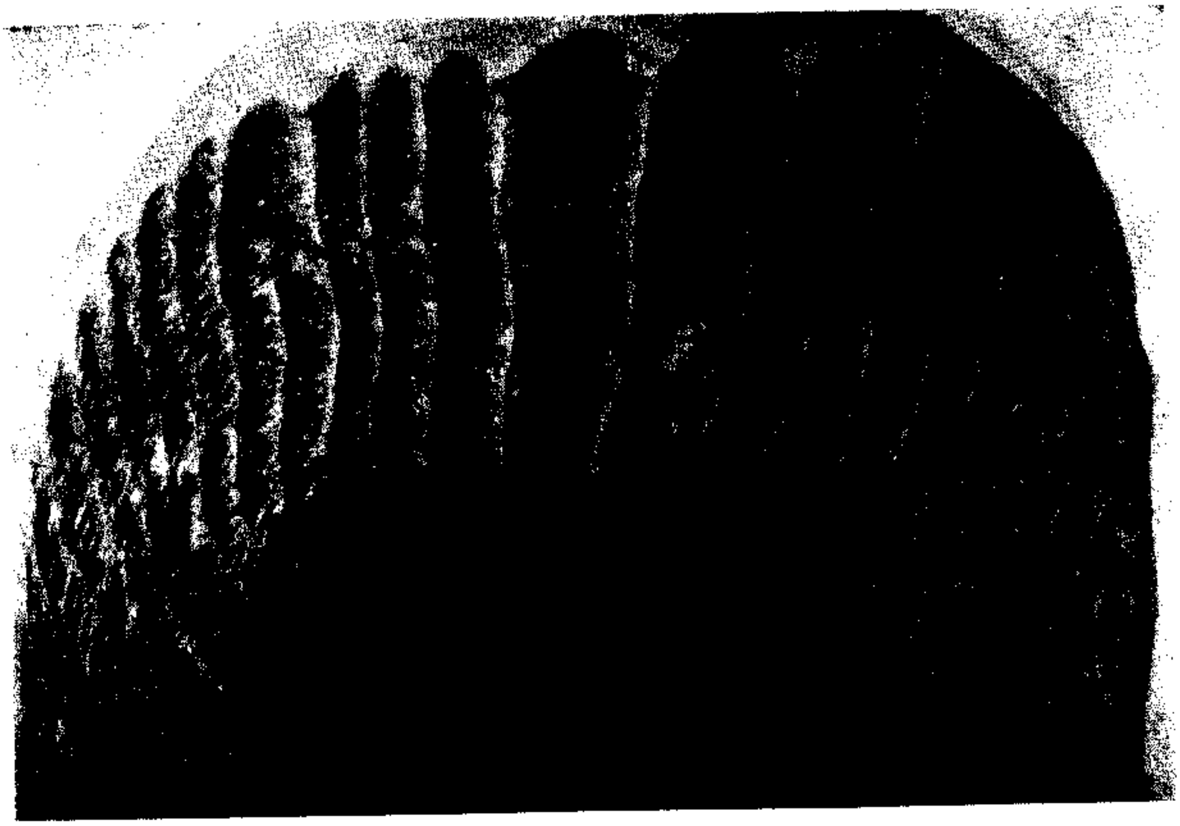

Photo 1

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