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A SYSTEMATIC ACCOUNT OF THE CHAETOGNATHA OF THE INDIAN COASTAL WATERS, WITH OBSERVATIONS ON THEIR SEASONAL FLUCTUATIONS ALONG THE MALABAR COAST.*

(With 14 Tables and 13 Text-figures.)

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(Communicated by Dr. H. S. Rao, F.N.I.)

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CONTENTS.

INTRODUCTION.

Our knowledge of the systematics and distribution of the Chaetognatha (Arrow-worms) of the Indian Coastal Waters, particularly of the west coast of India, is very meagre. The Chaetognaths have assumed considerable importance in recent years, as they have been regarded as useful indicators of movements of oceanic waters (vide Russell, 1937; Kemp, 1938), which have a bearing on fishery problems. The present paper is an attempt to describe in detail the systematics of the Indian genera and species and the seasonal variations in the occurrence of the Chaetognatha along the Malabar Coast with reference to the changes in the hydrographical factors.

The Indo-pacific region is rich in Chaetognatha as is evident from the results of the *Siboga*, *Albatross* and *Sea-lark* expeditions. Aida (1897) and Tokioka (1938 to 1942) have drawn attention to the richness of the group in Japanese waters. Doncaster (1903) described a number of new species from the seas around Maldive and Laccadive islands, many of which were, however, shown by later workers to be synonyms of already described forms.

The only detailed description of Indian coastal species is that by John (1933 and 1937) based on collections made at Madras. Subramaniam (1940) recorded *S. bedoti* Beraneck from the same collection disputing John's conclusions in regard

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to the systematic position of certain species. Varadarajan and Chacko (1942) recorded in the Krusadai area the forms already described by John in addition to *Spadella cephaloptera* and *Krohnia pacifica*. Menon (1945) and Pillai (1945, abstract only) have studied the *Sagitta* of the Trivandrum coast of which two (*S. enflata* and *S. bedoti*) are fairly common and the remaining three are somewhat rare and only occasionally found in the plankton. Two of the three species of *Sagitta* of the Bombay Harbour considered distinct by Lele and Gae (1936) have been referred by George (1949) to *S. enflata* and *S. robusta*.

Material and Methods.

Material for this investigation was collected mainly from the triweekly plankton hauls from the foreshore and offshore waters, off West Hill, three miles north of Calicut in the Malabar District along the West Coast of India (75° 46′ E. and 11° 17′ N.). Plankton was always collected from a point two miles away from the coast (station A) for a period of half an hour between 5 a.m. and 6 a.m. on alternate days so as to maintain uniformity of samples. The studies on the seasonal variations in the distribution of chaetognaths were made from horizontal hauls obtained during a period of twelve months. The specimens found in the other hauls in this area, and those obtained from the offshore area (station B) were made use of in the preparation of the key of diagnostic characters. Samples of chaetognaths obtained from plankton in Madras, Gulf of Manaar, Karwar and Bombay coasts provided material for the additions to descriptions of species. The material collected was preserved in 5% formalin and fractionated by means of Lea-Gibbons Sub-Sampler, and the number of specimens and species, and the morphological peculiarities noted. As far as possible fresh material was used in drawing up a table of diagnostic features, as the preserved material showed a certain amount of shrinkage, especially in the region of the fins and tactile bodies. For the accurate recording of the body proportions and fins, transparent stained specimens were more useful. A 3 to 5 minute immersion in 10% alcoholic solution of Cotton-blue gave good results for staining the fins and body. For studying the nature and pattern of the corona ciliata, specimens previously treated with Cotton-blue were allowed to remain for five minutes in a 1% aqueous solution of methylene blue. This method gave excellent results for delineating the important morphological details. The sketches were made with a camera lucida. All measurements were taken with the help of a counting slide with one mm. squares.

The hydrographical data correlated with the catches are Salinity, Rain-fall and Temperature. Salinity was determined by the Oxner and Knudsen method as described by Harvey. The standard silver nitrate solution was checked by standard sea water supplied by Laboratoire Hydrographique, Copenhagen, and corrected with the help of Harvey's salinity correction table.

The classification adopted in this account is mainly that of Michael (1919) based on Ritter Zahony's works (1911). Burfield and Harvey's (1926) account of the *Sea-lark* chaetognatha was useful as it included a large number of forms from the Indian Ocean and redescriptions of many of Doncaster's species. In drawing up a detailed account of the Indian genera and species, the taxonomic features of the specimens already recorded from Indian, Australian and Japanese waters were found useful (vide Fowler, 1906; Doncaster, 1903; Thomson, 1947; Aida, 1897 and Tokioka, 1938 to 1942). The most serious difficulty in the identification of chaetognatha is the close similarity of several species of *Sagitta*. Hence a key to genera and species of Indian forms is provided, based on such characters that are found not to vary with growth or maturity and that could be made out without much difficulty. A table of diagnostic features is appended at the end of the chapter on systematics, and tables of percentage measurements showing the possible variations within the species are given at the end of the description of each species,

hoping that these would prove more useful than a lengthy discussion of the comparison of specific characters.

ACKNOWLEDGEMENTS.

I am indebted to Dr. H. Srinivasa Rao and to Dr. B. S. Bhimachar for valuable suggestions and encouragement. I am grateful to Dr. N. K. Panikkar for drawing my attention to some aspects of the studies on the systematics and for the kind loan of literature. My thanks are also due to my colleague Mr. K. H. Mohamed for help in the preparation of the illustrations.

KEY TO GENERA OF INDIAN *CHAETOGNATHA* AND KEY TO INDIAN SPECIES OF *SAGITTA*.

Key to genera.

Collarette present, uniformly massive spreading over the single pair of lateral fins	*Pterosagitta*	
Collarette absent or not at all massive		1
1. Posterior pair of lateral fins confined entirely to tail segment	*Spadella* *	
Posterior pair of lateral fins extending over trunk and tail segments		2
2. Single pair of lateral fins	*Krohnitta*	
Two pairs of lateral fins	*Sagitta*	

Key to species of Indian Sagitta.

Collarette present		1
Collarette absent	*S. enflata*	
1. Corona ciliata elongate or looplike arising between or behind eyes		2
2. Tail-septum without any constriction		3
Tail-septum with a pronounced constriction	*S. tenuis*	
3. Collarette extends up to the anterior pair of fins		4
Collarette does not extend up to the anterior pair of fins		6
4. More than 70% of the posterior pair of fins situated on the trunk	*S. planktonis*	
Less than 70% of the posterior pair of fins situated on the trunk		5
5. Corona ciliata elongate arising in between eyes with the lateral fins of equal length or one slightly longer than the other	*S. robusta*	
Corona ciliata hour-glass shaped arising far behind the eyes with posterior pair of lateral fin nearly one and a half times as long as the anterior pair	*S. regularis*	
6. Paired fins rayless anteriorly		8
Paired fins fully rayed		7
7. Body hispid throughout and corona ciliata arising in between eyes with tactile bodies on the fins	*S. hispida*	
Body not hispid and corona ciliata arising behind the eyes with less than 50% of the fin lying in front of tail septum; tactile prominences absent	*S. neglecta*	
8. Anterior pair of fins very long, always more than 30% of the body length	*S. pulchra*	
Anterior pair of fins not very long, always less than 30% of the body length	*S. bedoti*	

DESCRIPTIVE ACCOUNTS OF SPECIES.

Genus *SAGITTA*, Quoy and Gaimard, 1827.

1. *SAGITTA PULCHRA*, DONCASTER, 1903.

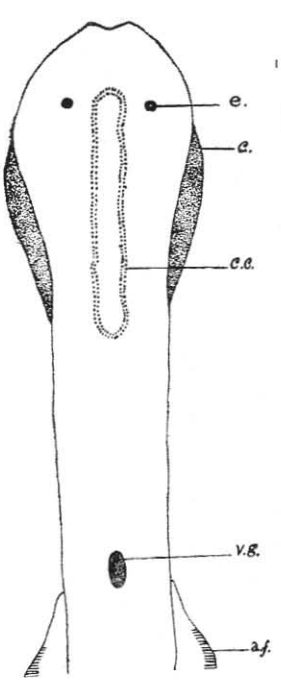
Sagitta pulchra, Doncaster, 1903; Fowler, 1906; Michael, 1919.

This species is not common along the east and west coasts of India. It is intermediate between the 'enflata type' with very thin transparent body and the

* This genus was unrepresented in the present collections, but *Spadella cephaloptera* was previously recorded from Krusadai (Varadarajan and Chacko, 1942) and Trivandrum (Menon, 1945) coasts.

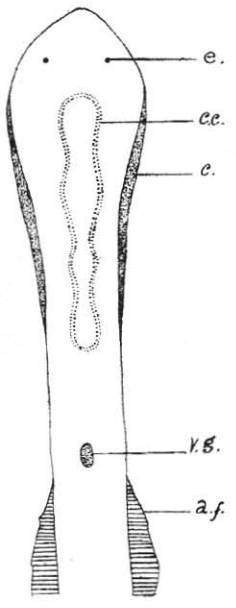
'robusta type' with opaque body and strong musculature. The body is translucent with strong body wall and does not shrink on preservation.

The head is amall and narrow. The collarette is short, never extends up to the ventral ganglion, and stops less than half the distance from neck to the ganglion (Text-fig. 1). The anterior fin is very long, and always more than 30% of the

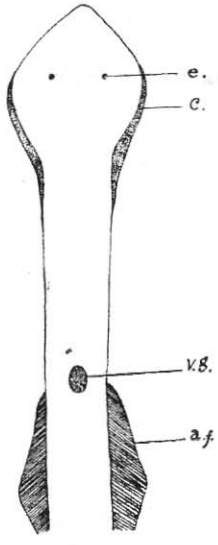


TEXT-FIG. 1.
S. pulchra

TEXT-FIG. 2.
S. planktonis



TEXT-FIG. 3.
S. neglecta



TEXT-FIG. 4.
S. tenuis

total length of the animal, and begins at the base of, or up to, the anterior end of the ventral ganglion but with no connection between it and the collarette. The narrow rayless anterior part of the fin is without extensions into the base of the fin. The shorter posterior fin, which arises close to or immediately behind the anterior is very similar, with more than 50% of its length in the trunk region and extending posteriorly up to the seminal vesicle. The tail region is pointed with the tail fin triangular and fully rayed. The slight constriction at the tail region is visible through the moderately opaque body. The narrowly oblong, relatively short, corona ciliata originates between the eyes, and extends up to the hind end of the collarette. Two-thirds of its length is situated on the trunk region. There are 5 to 8 extremely slender and very much curved prehensile jaws. The anterior and posterior teeth vary in number from 6 to 8 and 8 to 14 respectively.

The species occurs along with *Sagitta enflata* and *Sagitta bedoti*, and can be easily distinguished from the former by the absence of rays in the anterior region and from the latter by the extremely long anterior fin and the inappreciable distance between the fins.

Distribution.—This rare form was recorded for the first time in Indian coastal waters by George (1949) from a collection made in the Bombay Harbour. It is also found in very small numbers in the plankton samples of Bombay, Calicut, Madras and Mandapam. Tokioka (1939) records it from Japanese waters as a rare one.

SAGITTA PULCHRA.

**Table of percentage measurements.*

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum †.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	14·0	6·0	24·0	70·0	5·2	27·0	5·2	1·0	2·5	56·2	32·0	3·4	+1·0	6·0	11·0	7–6	12–11	6–6
II	10·0	5·6	24·5	69·0	5·6	26·8	5·0	0·0	3·0	52·0	31·7	3·0	+0·5	6·0	12·0	6–7	12–11	6–5
III	12·5	5·6	25·0	70·0	5·2	25·5	4·8	0·0	2·0	55·0	32·8	2·8	+0·8	5·5	11·5	5–6	12–11	5–6
IV	9·8	5·0	25·0	70·0	5·8	27·0	4·2	0·0	2·0	51·0	32·0	2·8	+0·5	6·0	12·8	6–7	12–12	6–6
V	12·2	5·3	26·0	69·5	5·6	25·2	5·5	1·0	3·0	57·0	32·5	2·9	+0·5	5·0	11·1	7–7	12–10	6–6
VI	10·6	5·8	25·0	70·0	5·5	26·0	4·6	1·0	2·8	54·0	31·9	2·8	+0·7	5·0	11·0	8–8	12–14	5–6

* In this and in the subsequent tables of measurements, the armature counts in the last three columns are given in absolute numbers; in other columns the size of the part in question is expressed as a percentage of the total length of the animal.

† Denotes percentage of fin lying in front of the tail-septum.

2. *SAGITTA PLANKTONIS*, STEINHAUS, 1896.

Sagitta planktonis, Steinhaus, 1896; Michael, 1919; Burfield and Harvey, 1926
Sagitta planktonis+*Sagitta zetesios*, Fowler, 1906.

Sagitta planktonis occurs along with *S. robusta*. John (1937) considers it to be a rare form on the Madras coast.

The body is opaque and the head is moderately large in size. The uniformly narrow and very long collarette extends up to the ventral ganglion, sometimes up to the anterior fin. (Fig. 2). The ventral ganglion occupies a unique position in that it is reached both by the collarette and the anterior fin on either side. The anterior fin is narrow and slightly longer than the posterior fin. Usually, the fins are very close together but in some cases they are confluent. The posterior fin is broader than the anterior with the rays of the paired fins not reaching the base. The seminal vesicle is situated just at the base of the posterior fin and far above the tail fin, as observed by Tokioka (1940) in those collected from the Japanese waters.

Distribution.—*S. planktonis* is scarce in all the collections. Plankton from Madras and Malabar showed a few ill-preserved ones.

3. *SAGITTA NEGLECTA*, AIDA, 1897.

Sagitta neglecta, Aida, 1897; Fowler, 1906; Michael, 1911; John, 1933; Tokioka, 1939.

Sagitta neglecta occurs on the east and west coasts of India along with *S. bedoti* and *S. enflata*. It has been recorded previously from the Madras coast by John (1933) and from the Gulf of Manaar by Varadarajan and Chacko (1942).

S. neglecta is medium-sized, generally opaque, with a slender body and prominent head. The species could also be easily distinguished by the less opaque tail. There is no pronounced constriction between the body and the tail which is continued uninterrupted from the trunk. Head is conspicuous and the neck is masked by a prominent collarette and thick epidermis. The collarette is narrow and extends to nearly half the distance from the neck to the ventral ganglion (Fig. 3). The long, and broadly sinuous corona ciliata is situated mostly on the trunk, the anterior part beginning from the neck. It extends downwards towards the ventral ganglion. The small and narrow anterior fin begins from the level of the ganglion. The posterior fin is broader and longer but usually never extends to the seminal vesicle. Both the fins are fully rayed. The triangular tail fin is situated below the seminal vesicle which is prominently oval in shape.

Distribution.—*S. neglecta* was obtained in the plankton throughout the year but in larger numbers soon after the South-West Monsoon.

4. *SAGITTA TENUIS*, CONANT, 1896.

Sagitta tenuis, Conant, 1896; Michael, 1919; John, 1933.

This is one of the smallest species of *Sagitta* of these coasts, 5 to 6 mm. long. It was taken in large numbers from July to September on the Trivandrum coast (Menon, 1945). John (1933) and Varadarajan and Chacko (1942) recorded it from the east coast.

The body is slender and opaque and is often found broken up into bits in preserved collections. Head is small and the neck is prominent although a short collarette is present. The collarette is very narrow and inconspicuous and does not extend to more than one-fourth the distance to the ganglion (Fig. 4). The body is also narrow with a slight bulge in the middle region. The tail region is very

SAGITTA PLANKTONIS.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	13·0	8·0	25·0	68·0	3·8	21·0	4·5	0·0	2·0	75·5	23·5	2·8	0·0	24·0	0·0	7–8	16–17	8–9
II	12·5	7·0	24·6	69·0	4·0	20·0	4·0	0·0	1·0	72·0	23·0	3·0	0·0	23·0	0·0	7–8	16–18	8–8
III	11·8	5·0	24·5	68·0	4·2	20·5	4·0	0·0	1·5	75·0	23·1	3·0	0·0	23·5	0·0	7–7	16–16	8–8
IV	13·0	5·8	25·1	68·5	4·0	20·8	3·8	0·0	0·0	74·0	23·7	3·1	0·0	24·0	0·0	8–8	16–?	8–9
V	12·6	6·0	25·0	69·0	3·5	21·0	4·2	0·0	1·0	74·0	23·0	2·9	0·0	24·1	0·0	8–7	16–15	8–9
VI	12·0	6·1	25·2	69·1	3·8	21·3	4·5	0·0	1·2	73·8	23·0	3·0	0·0	24·0	0·0	8–8	17–18	8–8

SAGITTA NEGLECTA.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	7·1	5·0	32·0	68·6	6·5	24·5	4·5	1·8	6·8	40·2	20·3	3·0	0·0	13·0	5·5	5–6	14–17	6–7
II	7·15	4·8	31·9	69·0	6·8	25·0	4·2	1·9	6·5	41·0	21·1	3·0	0·0	12·5	5·6	5–7	14–18	6–8
III	7·0	5·0	31·8	68·5	6·4	25·1	4·6	2·0	6·7	40·0	21·0	3·1	−1·0	13·2	5·4	5–7	14–18	6–7
IV	7·2	5·1	31·9	65·5	6·8	26·0	4·0	2·0	7·0	42·0	21·5	3·0	0·0	13·1	5·8	5–6	15–18	7–7
V	7·4	5·3	32·8	69·0	6·1	26·2	3·8	1·9	6·9	41·0	22·0	2·9	0·0	12·8	5·7	6–7	14–17	6–7
VI	7·5	5·0	33·0	70·0	5·9	24·5	3·5	1·8	7·2	39·0	20·2	2·2	0·0	12·8	5·5	5–7	14–16	7–8
VII	6·9	4·9	31·9	68·0	6·3	22 5	3·4	2·1	8·1	42·0	19·0	2·9	−1·2	12·5	5·8	5–7	15–16	6–6
VIII	7·6	5·2	33·0	71·0	6·0	23·8	5·5	1·6	7·6	38·5	19·0	4·0	0·0	12·5	6·0	5–7	14–16	6–7
IX	7·5	5·3	32·8	70·0	6·0	26·2	5·4	1·7	8·2	39·0	22·1	3·8	0·0	12·6	6·2	5–7	15–15	6–7
X	7·5	5·3	33·0	69·0	6·1	26·0	5·3	1·6	8·1	39·5	21·8	3·5	0·0	12·6	6·0	5–8	14–17	6–7

SAGITTA TENUIS.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	5·5	4·1	26·0	68·0	5·6	24·5	4·2	4·0	4·1	43·0	14·0	2·5	0·0	2·2	13·5	7–7	7–8	8–8
II	5·1	4·0	25·1	65·0	5·5	25·0	4·2	3·2	4·0	41·0	14·1	2·2	−1·0	2·0	14·0	6–7	7–7	8–8
III	5·0	4·5	27·0	65·0	5·8	24·8	4·3	3·2	4·2	42·0	13·8	2·5	−1·5	2·1	14·2	6–7	7–8	8–7
IV	5·3	4·0	26·5	67·0	5·7	24·5	4·2	3·5	3·8	42·5	14·0	2·5	0·0	2·3	14·0	5–6	8–8	8–7
V	5·0	5·0	25·0	64·0	5·5	23·9	4·0	3·2	4·1	41·0	14·1	2·3	0·0	2·2	14·2	5–7	8–7	8–8
VI	5·4	4·8	28·0	65·5	5·6	24·5	4·2	3·3	3·5	41·5	13·8	2·6	0·0	2·4	13·8	7–7	7–8	8–7
VII	5·3	4·5	26·5	65·0	5·5	24·1	4·3	3·1	3·5	42·0	13·6	2·5	−1·8	2·1	14·3	5–7	7–7	7–7
VIII	4·9	4·6	27·1	65·0	5·2	25·0	4·0	3·8	4·2	41·8	13·9	2·5	−2·0	2·3	14·1	7–8	6–7	8–8
IX	5·6	4·9	26·0	67·0	5·6	24·5	4·5	3·0	3·8	42·5	14·1	2·4	0·0	2·2	13·8	5–6	6–7	8–7
X	5·7	5·0	26·2	67·5	5·5	24·6	4·6	3·1	3·6	42·0	14·0	2·5	0·0	2·1	14·0	7–7	6–7	8–7

prominent due to the presence of a thick constriction at the tail septum. The wart-like prominences seen in front of the septum on either side are the openings of the oviducts.

The short and narrow anterior fin arises from the level of the ventral ganglion or even slightly below, but never above it. The posterior fin is half elliptical, longer and broader than the anterior fin. Both the fins are completely rayed. The small seminal vesicle is situated between the posterior and tail fins. The triangular tail region is as opaque as the trunk region.

Distribution.—On the Madras coast *S. tenuis* was uniformly present but on the Malabar coast it was scarce except during the monsoon.

5. *SAGITTA BEDOTI*, BERANECK, 1895.

Sagitta bedoti, Beraneck, 1895; Michael, 1919; Lele and Gae, 1936; Subramaniam, 1940.

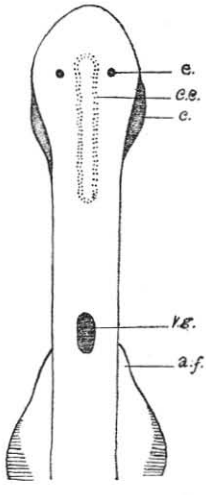
Sagitta bipunctata, Aida, 1897.

Sagitta polyodon, Doncaster, 1903.

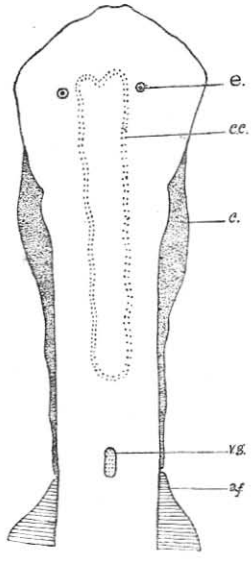
Sagitta bedoti, forma *typica*, Tokioka, 1942.

S. bedoti is one of the commonest species of *Sagitta* of the Malabar coast. It was previously recorded from the Bombay (Lele and Gae, 1936; George, 1949) and Madras coasts (Subramaniam, 1940).

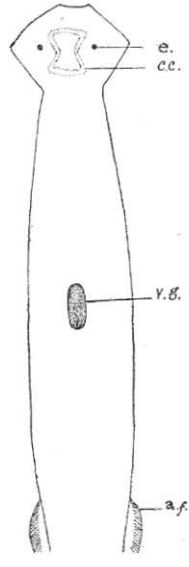
The small head is followed by the semitransparent and needle-shaped body. Fowler (1906) found a slight thickening of the epidermis of the neck instead of a real collarette in the *Siboga* specimens of *S. bedoti*. But Ritter Zahony (1911), Michael (1919) and Burfield and Harvey (1926) observed short but conspicuous collarettes. Lele and Gae (1936) thought that the short slightly thickened epidermis represented the collarette. As in the Japanese specimens (Tokioka, 1940) a distinct collarette is present in my specimens (Fig. 5). It is short, extending to less than



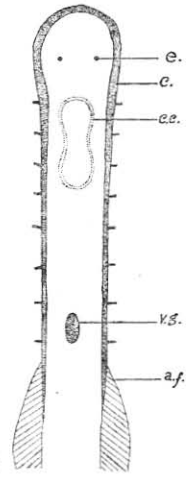
TEXT-FIG. 5.
S. bedoti.



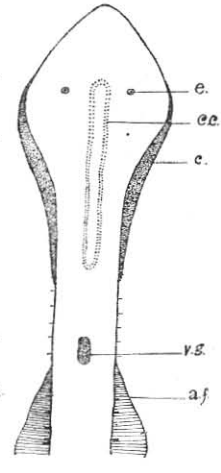
TEXT-FIG. 6.
S. robusta.



TEXT-FIG. 7.
S. enflata.



TEXT-FIG. 8.
S. regularis.



TEXT-FIG. 9.
S. hispida.

SAGITTA BEDOTI.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	9·5	5·6	28·5	72·6	5·5	24·4	4·1	0·0	3·5	48·0	27·4	2·5	0·0	3·1	14·2	10–11	21–23	7–7
II	9·8	5·5	28·0	72·1	5·9	24·6	4·2	0·0	3·2	48·5	27·5	2·5	0·0	3·1	14·5	10–11	21–23	7–8
III	10·0	5·9	28·1	72·8	5·6	25·0	4·0	0·0	3·2	48·0	27·9	2·4	0·0	3·1	14·9	11–11	20–21	8–8
IV	10·5	5·8	27·5	71·8	5·5	27·0	4·5	0·0	3·3	49·2	28·5	2·7	0·0	3·2	14·3	10–12	20–21	8–8
V	12·0	6·0	27·2	69·0	5·5	26·8	4·2	0·0	3·1	49·0	29·1	2·5	0·0	3·2	14·0	12–13	21–23	8–8
VI	13·1	6·2	27·2	69·1	5·4	26·0	4·0	0·0	3·2	49·1	28·0	2·2	0·0	3·8	14·3	12–11	21–23	8–8
VII	13·5	6·3	27·1	69·5	5·6	26·5	4·1	0·0	3·2	48·2	28·0	2·5	0·0	4·1	14·5	12–13	21–23	8–7
VIII	13·7	6·3	25·9	70·0	5·0	26·1	4·6	0·0	3·3	48·2	28·2	2·9	0·0	4·0	14·2	12–13	20–22	8–8
IX	13·8	6·2	25·6	70·0	5·5	26·5	4·5	0·0	3·4	46·5	28·6	2·8	0·0	4·0	14·5	11–12	22–22	8–8
X	14·5	6·5	24·8	69·5	5·4	26·5	4·4	0·0	3·4	46·1	29·0	2·8	+0·5	4·1	14·9	11–13	24–22	8–8

half the distance to the ventral ganglion. The long and narrow corona ciliata arises slightly in front of the eyes and extends to two-thirds the distance towards the ventral ganglion.

The anterior fin extends up to the level of the ventral ganglion, and in large specimens even slightly beyond. The anterior half of both the fins is rayless. The anterior fin is less than a third as long as the animal, which is in contrast to the condition found in *S. pulchra*. The posterior fin is never longer than the anterior fin and more of it lies behind the tail septum. The elongated seminal vesicle is in close contact with the posterior fin and caudal fins. The vesicle is less prominent at the anterior end than in that of *S. robusta*. The tail is continuous with the trunk and without any constriction. The trunk is more or less of uniform width except in the region of the anterior fin where it is slightly wider.

Both rows of teeth show uneven tips. The closely arranged posterior teeth which are as many as 29, give them an appearance of being set in two rows one above the other.

Distribution.—*S. bedoti* occurs in large numbers along both the coasts of India. They form a great part of the collections made in Madras, Mandapam, Calicut and Bombay.

6. *SAGITTA ROBUSTA*, DONCASTER, 1903.

Sagitta robusta, Doncaster, 1903; Burfield and Harvey, 1926; George, 1949.
Sagitta hispida, Aida, 1897.
Sagitta ferox, Doncaster, 1903; Michael, 1919.
Sagitta bombayensis, Lele and Gae, 1936.

This is the most 'robust' chaetognath in the collections from our coasts which shows great variations in the nature of the collarette and the fin length (vide Burfield and Harvey, 1926). George (1949) has shown that *S. bombayensis* Lele and Gae (1936) is a synonym of *S. robusta* Doncaster.

The maximum length attained by *S. robusta* in my collections is 17 mm. Body is opaque and the head is relatively large and broad. Tail is about $\frac{1}{4}$ the total length of the animal. Epidermis is thick all over the body length and particularly so behind the head. The head is broader than the trunk and the neck is almost masked by the well-developed collarette which may extend up to the ventral ganglion reaching even the anterior pair of fins. The collarette is more than a fourth as broad as the body is wide (Fig. 6). The ventral ganglion is generally slightly in front of the anterior fin and covered over by the collarette. As the table of measurements shows these characters are highly variable. The elongate corona ciliata arises between or slightly in front of the eyes extending backwards into the trunk.

The narrower anterior fin may be shorter than, as long as, or longer than, the posterior. In most of the East Coast specimens the anterior fin is slightly longer than the posterior, which in John's (1933) opinion characterises the Philippine forms. The posterior fins are generally as long as the anterior fin but may be longer or shorter than the latter. The broader posterior fin which extends up to the seminal vesicle has more than 50% of its length in the tail segment, and is broadest behind the tail septum.

Distribution.—*S. robusta* is a typical warm-water species found in the collections from Bombay, Karwar, Calicut and Madras. Specimens from inshore collections show a range in length from 7 to 13 mm., while those obtained offshore were much larger.

SAGITTA ROBUSTA.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	10·0	6·6	25·5	68·0	3·5	28·5	5·0	0·0	3·8	48·0	29·0	3·8	0·0	10·0	−5·0	8–9	10–12	8–8
II	10·5	6·0	26·5	69·0	3·1	30·0	4·5	0·0	3·1	48·5	30·0	3·9	+1·5	12·0	0·0	8–8	11–15	8–8
III	10·9	5·9	25·5	68·0	3·5	30·0	5·6	0·0	2·5	43·3	29·6	3·7	+2·0	22·0	+2·0	8–9	16–17	6–7
IV	11·5	6·5	30·5	69·6	4·2	29·0	5·5	0·0	3·0	44·5	29·0	4·9	+1·5	18·3	+2·1	8–8	15–17	6–8
V	12·0	6·0	26·5	70·0	4·0	28·5	4·8	0·0	3·3	46·5	29·0	3·8	+0·5	19·0	+1·0	8–7	12–14	8–8
VI	13·5	6·5	25·8	68·5	3·8	28·9	4·5	0·0	3·5	48·0	29·2	3·9	+1·2	18·9	+1·5	8–8	15–16	8–9
VII	13·6	6·1	26·2	69·0	3·9	28·0	4·2	0·0	3·5	46·9	28·0	3·5	+1·5	11·6	+2·0	8–9	15–15	6–8
VIII	15·8	6·2	26·0	70·0	3·6	27·8	4·6	0·0	3·1	48·5	28·2	3·5	+2·1	11·5	+2·0	8–9	15–15	8–8
IX	16·0	6·4	25·0	68·9	4·0	27·6	4·8	0·0	3·6	46·5	28·9	3·3	+2·0	12·0	0·0	9–9	15–16	8–9
X	16·2	6·5	25·1	68·8	4·0	29·0	4·5	0·0	3·5	47·0	29·5	3·8	+2·2	9·5	−3·5	8–9	15–17	8–7

7. *SAGITTA ENFLATA*, GRASSI, 1881.

Sagitta enflata, Grassi, 1883; Aida, 1897; Doncaster, 1903; Fowler, 1906; Michael, 1919.
Sagitta gardineri, Doncaster, 1903.
Sagitta flaccida, Doncaster, 1903.
Sagitta enflata+*Sagitta gardineri*, John, 1933.
Sagitta gardineri, Lele and Gae, 1936.

This is the most common species of *Sagitta* of both the coasts of India.

The tumid, transparent body with its thin wall presents an 'inflated' appearance. The broad and opaque head is separated from the trunk by a distinct neck (Fig. 7), which is without a collarette. The corona ciliata is limited entirely to the head region. The trunk is widest in the middle. The tail region is extremely narrow and is marked from the rest of the body by a moderately pronounced constriction.

Fins are very transparent, delicate and completely rayed, and except in the tail fin the rays do not reach up to the base. The anterior fin is generally slightly shorter than the posterior fin, but may be as long, and is semi-elliptical in shape. It is situated far down below the ventral ganglion, the distance between the two varying from 12 to 21 per cent of the total length of the body. In preserved specimens this distance varies, with the anterior fin often much less conspicuous than it is in fresh ones due probably to great shrinkage in this region.

The posterior fin is always much broader and longer than the anterior fin. Distance between the paired fins is always more than 8% of the total length of the animal, with the result that they are never confluent. More than 60% of the posterior fin lies on the trunk. The small, spherical seminal vesicle is situated far below the posterior fin almost touching the base of the tail fin, and its glandular and non-glandular areas cannot be differentiated. Tokioka (1939) considers this type of seminal vesicle as the most primitive type as it lacks differentiation into 'head' and 'trunk' regions.

The short tail is always less than $\frac{1}{4}$ its total length and when compared to the inflated trunk the tail is inconspicuous. The body is so transparent that the tail septum is easily seen through. The triangular tail fin is fully rayed.

Distribution.—*S. enflata* is the commonest chaetognath in all my collections, especially in the December to May period. It is rare in the collections of the monsoon season. John (1933) and Michael (1911) have apparently seen small-sized specimens of 12–13 and 15–21 mm. length in the Madras and San Diego collections. Specimens in my collection are as long as 24 mm., especially those obtained from Gulf of Manaar and from the offshore station at Calicut. The specimens obtained from the inshore waters were, however, relatively small as in the length ranges recorded by John.

8. *SAGITTA REGULARIS*, AIDA, 1897.

Sagitta regularis, Aida, 1897; Doncaster, 1903; Fowler, 1906; Burfield and Harvey, 1926.

S. regularis is another small chaetognath which never seems to attain a length of more than 7 mm. This species does not occur in such large numbers as *S. enflata* or *S. bedoti*, but is fairly common during the hot months.

The head is small and inconspicuous. Eyes are large and prominent. The body is small and narrow. The tactile hairs are regularly arranged on either side of the trunk, more so in the anterior region. The well-defined collarette extends to the ventral ganglion and sometimes to the anterior fin. The collarette is of

SAGITTA ENFLATA.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	11·4	12·0	19·0	69·0	4·1	16·0	4·0	5·0	8·8	69·0	13·0	2·2	17·5	..	..	7–8	12–14	8–8
II	13·6	10·6	20·0	70·0	4·0	17·5	4·5	4·8	8·3	70·0	12·4	2·5	17·0	..	..	7–7	12–13	7–8
III	14·0	10·5	18·5	68·0	3·9	17·0	4·0	5·0	8·5	66·7	14·0	2·3	17·0	..	..	7–7	12–13	7–8
IV	15·0	10·0	18·9	71·5	4·0	16·0	4·0	4·8	10·0	66·0	13·0	2·3	19·0	..	..	7–8	12–14	8–8
V	16·5	10·7	18·1	72·0	4·2	19·3	4·1	5·1	8·3	63·9	15·5	2·2	17·8	..	..	7–8	12–13	8–8
VI	18·0	10·0	18·5	71·0	4·0	18·0	4·5	5·0	8·4	66·0	15·9	2·2	17·2	..	..	7–7	12–13	8–6
V II	19·50	9·8	19·0	71·5	4·1	16·0	4·3	4·5	9·0	69·0	13·0	2·5	16·9	..	..	7–8	12–14	8–7
VIII	20·0	10·1	18·8	69·0	4·1	17·0	4·0	4·8	9·0	65·3	13·7	2·1	16·8	..	..	7–7	13–14	8–8
IX	21·5	10·2	19·0	72·0	4·1	17·4	4·2	4·6	8·8	66·0	16·0	2·2	17·0	..	..	7–8	12–13	7–8
X	24·0	10·7	18·2	73·5	4·0	17·5	4·2	4·5	8·9	64·0	12·3	2·1	16·5	..	..	7–8	12–14	8–8

SAGITTA REGULARIS.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	5·9	6·5	33·5	70·0	4·0	29·0	12·0	0·0	7·0	35·0	21·0	7·5	3·3	33·0	+ 4·5	3–3	6–6	6–8
II	6·0	6·2	33·0	69·0	4·2	29·5	11·5	0·0	7·2	35·5	21·2	6·8	3·0	32·0	+ 5·0	3–4	6–6	6–8
III	5·8	6·4	34·0	70·2	4·1	28·2	11·8	0·0	7·0	35·6	20·8	7·0	3·1	31·5	+ 4·5	3–4	6–5	6–8
IV	5·7	6·3	34·1	69·0	4·2	28·5	11·5	0·0	7·2	34·8	20·9	6·8	3·1	31·0	+ 4·2	4–4	6–4	6–8
V	5·9	6·0	34·0	67·0	4·0	29·0	12·0	0·0	7·1	35·5	21·1	7·2	3·0	32·0	+ 4·1	4–4	6–6	6–8
VI	5·4	6·0	35·0	68·0	4·0	29·8	10·8	−1·0	6·8	34·5	22·0	7·1	3·0	32·0	+ 4·0	3–4	5–5	8–8
VII	5·7	6·2	34·1	65·0	4·2	30·0	11·0	0·0	7·15	34·7	22·0	6·8	3·2	32·5	+ 4·5	2–4	6–6	6–8
VIII	5·8	6·35	34·2	67·0	4·3	29·1	11·2	0·0	7·20	35·5	21·0	6·7	3·2	33·0	+ 4·4	2–4	6–5	8–?
IX	5·8	6·30	34·0	68·2	4·3	28·9	11·3	0·0	7·25	35·4	21·0	7·0	3·2	33·0	+ 4·4	3–4	6–6	6–8
X	6·1	6·3	33·5	69·0	4·20	29·55	11·5	0·0	7·20	35·60	21·2	7·2	3·1	31·0	+ 4·5	2–3	6–6	6–7

more or less uniform width between the head and the ganglion. A thick epidermis extends along its length showing a slightly larger thickening behind the head. The corona ciliata is limited to the anterior region of the trunk (Fig. VIII), and is hour-glass shaped.

The semi-elliptical and completely rayed anterior fin arises below the ventral ganglion, and is shorter than the posterior, which is broader and nearly one and a half times longer than the anterior fin. The distance between the two pairs of fins is appreciable. The seminal vesicle is like that of *S. bedoti* except that it does not reach the tail fin, and has the glandular and non-glandular areas not so well differentiated as in *S. robusta*. The triangular tail fin is fully rayed.

Distribution.—*S. regularis* was found in appreciable numbers in Calicut especially during the summer and early monsoon months, but was rare in the collections of the east coast.

9. *SAGITTA HISPIDA*, CONANT, 1895.

Sagitta hispida, Burfield and Harvey, 1926.

S. hispida is very rare in the Malabar plankton. The systematic position of this species was very much in doubt owing to the incompleteness and contradictory nature of the original descriptions and sketches. Burfield and Harvey (1926) redescribed it giving all the well-marked diagnostic characters of the species.

The head is cylindrical and is slightly broader than the trunk. The neck is inconspicuous. Body is translucent, narrow and greatly 'hispid' due to the presence of large number of tactile hairs which extend all over the body. The collarette extends half way to the ventral ganglion. The muscles are strong and do not shrink on preservation although the sensory hairs generally fall off. The ventral ganglion is very nearly reached by the anterior fin, but not by the collarette (Fig. 9). The elongated sinuous corona ciliata starts in front of the eyes and extends half way up to the relatively large and swollen ventral ganglion. The fully rayed anterior fin is narrow and short. The posterior fin is longer and broader than the anterior fin, and has more of its length lying on the trunk and never reaches the seminal vesicle as in *S. robusta*. The tail is roughly a fourth to a third of the total length of the animal. Tactile bodies are very distinct on the tail fin. The prominent seminal vesicle reaches the caudal fin.

Distribution.—*S. hispida* was obtained in small numbers from the Calicut coast in April and May. Two specimens were found along with *S. robusta* in the collections from the Gulf of Manaar.

Genus *PTEROSAGITTA*, Costa, 1869.

Syn. *Spadella*, Langerhans, 1880.
Pterosagitta, Michael, 1919.

1. *PTEROSAGITTA DRACO*, (KROHN, 1853).

Spadella draco, Aida, 1897; Fowler, 1906; Michael, 1911.

Pterosagitta draco, Ritter Zahony, 1911; Michael, 1919; Burfield and Harvey, 1926; Tokioka, 1939.

This species is described as an inhabitant of warm oceanic waters. Only 5 specimens* are present in my collections, of which one is from the Gulf of Manaar.

* One of these collected from Calicut was lent to me for examination by Mr. R. V. Nair to whom my thanks are due.

SAGITTA HISPIDA.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Posterior fin.					Anterior fin.			Collarette.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	To anterior fin.	Tail-septum.	Length.	Width.	To ventral ganglion.	Length.	To ventral ganglion.			
I	8·0	5·9	23·9	70·3	6·6	25·9	5·5	3·0	8·0	59·5	19·2	2·5	3·5	18·5	6·5	5–6	10–11	7–8
II	8·5	5·5	24·0	71·0	6·5	26·0	5·2	2·8	7·5	59·1	19·8	2·6	3·0	17·5	5·9	5–6	11–11	7–8
III	8·9	5·2	25·0	72·0	7·0	25·0	5·2	3·0	7·8	60·1	18·5	2·7	2·0	17·0	6·8	5–6	10–11	7–7
IV	9·0	5·0	24·8	70·0	7·2	24·5	5·0	2·8	7·2	58·9	18·5	2·5	2·0	18·2	6·0	5–5	10–11	7–8
V	9·2	4·8	24·9	71·0	7·0	25·1	5·2	2·7	7·5	59·5	18·9	2·7	2·3	18·5	6·0	5–6	11–10	8–8

PTEROSAGITTA DRACO.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width with collarette.	Width without collarette.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Length of collarette.	Lateral fin.			Ovary.		Number of anterior teeth.	Number of posterior teeth.	Number of prehensile jaws.
								Length.	Width.	To seminal vesicle.	Length.	Width.			
I	4·6	16·1	7·5	43·0	65·2	8·5	75·0	22·5	7·2	0·0	..	..	8–9	15–16	8–8
II	4·8	16·6	8·1	41·6	63·0	8·0	75·2	23·0	7·5	0·0	..	..	8–7	15–17	8–7
III	5·0	16·0	7·5	40·0	70·0	8·0	76·0	21·0	7·0	0·0	9·0	1·2	8–8	15–15	8–8
IV	6·0	13·2	6·5	43·5	71·6	8·7	74·8	21·6	6·5	0·0	..	..	8–7	15–17	7–8
V	6·5	15·0	8·0	43·0	65·0	7·0	75·0	20·0	7·3	0·0	18·5	1·7	8–7	15–17	8–8

The body appears to be very broad due to the long and massive collarette which extends to the fin. Head is large and oval and the neck inconspicuous. The single pair of lateral fins is situated entirely on the tail segment. It is semi-elliptical, small and fully rayed. The collarette with its cellular structure spreads over the fin extending almost up to its posterior end. The triangular caudal fin is fully rayed. The seminal vesicle resembles that of *S. robusta* in being in contact with the fins. In mature specimens the ovary extends far up on the trunk rendering the region opaque.

The tail region is much longer than in any species of *Sagitta* being nearly half the total length of the animal (41·6 to 43·5%), but there seems to be considerable variations in the tail-body proportions (from 39·5 to 57%), judging from the records of Michael (1919), Fowler (1906), and Burfield (1926). The slightly curved prehensile jaws are faintly serrated on their inner edge. Except for two or three of the anterior-most teeth which are long and broader, the rest are all small. The posterior row has generally double the number of teeth than the anterior. A pair of bundles of large tactile hairs were seen on either side of the trunk at the level of the ventral ganglion in the specimen lent to me by Mr. Nair. Except for this peculiarity and except for its being small and immature it is like any other specimen of *Pterosagitta draco*.

Genus *KROHNITTA*, Ritter Zahony, 1911.

Syn. *Krohnia*, Langerhans, 1880 (part); Strodtmann, 1892 (part).
Spadella, Grassi, 1883 (part).
Krohnitta, Michael, 1919.

The genus is represented by two forms which are not very different from one another. Ritter Zahony (1911) and Michael (1919) consider that the difference between them is inadequate to justify their rank as independent species while Tokioka (1939) and Thomson (1947) prefer retention of both the species. Burfield and Harvey (1926) have recognised only one species, but with two forms, *K. subtilis* forma *typica* and *K. subtilis* forma *pacifica*, as the differences noticed are considered to be minor. Although the differences between the two are not very striking, some of the characters appear to be constant and independent for each species and since no intermediate stage has so far been obtained, the two forms are described here as two separate species.

1. *KROHNITTA PACIFICA* (AIDA) 1897.

Krohnia pacifica, Aida, 1897; Doncaster, 1903; Fowler, 1906; Varadarajan and Chacko, 1942; Pillai, 1945.
Krohnitta pacifica, Tokioka, 1939; Thomson, 1947.

This is the common species of *Krohnitta* of Indian coastal waters. The body is short and broad and the neck is very prominent. The head is slightly broader than the trunk. The collarette is absent. The top-shaped corona ciliata extends slightly downwards in the region of the neck. The prominent ventral ganglion lies halfway between the neck and the lateral fin. The fin rays generally do not reach the base. The fins on fixation have been observed in many cases to shrink considerably masking the original pattern. More of the fin is situated on the tail. The seminal vesicle is large, oval shaped and overlapped by the lateral fin. The ovary in mature specimens is long extending beyond the anterior end of the lateral fin. The tail fin is spatula-shaped and fully rayed. The prehensile jaws are curved at the middle and sharply pointed. The degree of curvature of the spines

KROHNITTA PACIFICA.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Lateral fin.				Ovary.		Number of teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	Tail septum.	Length.	Width.		
I	5·0	6·5	31·0	64·9	6·8	34·3	6·5	0·0	37·5	14·6	2·6	11–13	8–8
II	5·2	6·2	30·8	64·1	7·0	34·5	6·7	0·0	37·5	15·5	2·5	10–13	8–10
III	5·25	6·0	31·1	64·2	7·0	34·6	6·9	0·0	37·2	12·8	2·6	11–12	9–10
IV	5·60	6·6	31·0	63·9	6·8	34·6	6·7	0·0	37·0	15·0	2·4	11–12	10–10
V	5·80	6·5	31·8	63·8	7·2	34·5	6·7	0·0	36·8	15·0	2·3	11–11	8–8

vary not only in different individuals but also in the individual jaws of the same specimen. Teeth are broad based and conically arranged.

Distribution.—Varadarajan and Chacko (1942) and Pillai (1945, abstract) have recorded this species from the east and west coasts respectively as *Krohnia pacifica*. This species is represented in most inshore collections on both the coasts of India, although it is more common in the offshore hauls, especially during March and April. Compared to the forms recorded from the Philippines and Japanese waters, the local forms are much smaller in size.

2. *KROHNITTA SUBTILIS* (GRASSI, 1883).

Krohnia subtilis, Strodtmann, 1892; Fowler, 1905 and 1906.

Krohnitta subtilis, Ritter Zahony, 1911; Michael 1919; Burfield and Harvey, 1926 (part); Tokioka, 1939; Thomson, 1947.

This species is very rare in the present collections. The body is longer and more slender than that of *K. pacifica*. The tail septum is very prominent. The paired fin is more round than oval in shape. The ovary is short and stumpy in all the specimens examined. The seminal vesicle is less pronounced.

The confusion that prevailed up to the first quarter of the present century in the systematic position of many of the earlier incompletely described species, due mainly to the lack of full realisation of the wide range of variations in the morphological features chosen as diagnostic characters, was gradually cleared through the efforts of Michael (1919) and Burfield and Harvey (1926). In assigning Doncaster's (1903) numerous species to their correct systematic positions, the latter have shown the importance of percentage measurements, and of the indication of the limits of variation of the length of collarette, of the size, structure and position of the anterior and posterior fins, and of the relative positions of the anterior and posterior fins to the ventral ganglion and to the seminal vesicles respectively.

The variations in the structure and length of the anterior and posterior pairs of fins have been made use of as one of the diagnostic features of *Sagitta*. For instance, the very long anterior fin in *pulchra* occupies more than thirty per cent of the total length of the animal, while, in *bedoti* and *planktonis* the anterior fins are longer than the posterior. In *enflata*, *regularis*, *neglecta* and *tenuis* the anterior fins are shorter than the posterior to a variable degree. In *robusta* the fin length is variable. According to Burfield and Harvey (1926) the relative lengths of the anterior and posterior fins in *robusta* are variable with equality between the two or slight inequality. The numerous combinations of fin length in *robusta* have been suitably illustrated by them with sketches and tables. If relative length of the fins alone is a distinguishing character many difficulties arise as for instance in the correct differentiation of *bedoti* from *robusta* which necessitates the use of other characters in the fins. The structure of the collarette and its relative position to the ventral ganglion and the anterior fin, the shape of the corona ciliata and its position in relation to the eye spots, the structure of the seminal vesicle and its relation to the posterior and caudal fins have been used in the classification of chaetognaths. The variation in the number of jaws and teeth on which Doncaster (1903) based his species have been proved to be unreliable by later workers as this character appears to be correlated with temperatures of warm and temperate waters (vide Michael, 1919). Thomson (1947) has shown that the relative length of the ovary in mature specimens can be used with advantage in the determination of species of *Krohnitta*, although this method has been found to be less suitable with preserved material due to opacity. Characters such as the percentage distance between the genital openings, the presence of thick epidermis, the presence or absence of sensory tufts of hairs, etc., have also been found to be unreliable.

KROHNITTA SUBTILIS.

Table of percentage measurements.

Specimen Number.	Length in mm.	Width.	Length of tail.	Tail to ventral ganglion.	Length of ventral ganglion.	Lateral fin.				Ovary.		Number of teeth.	Number of prehensile jaws.
						Length.	Width.	To seminal vesicle.	Tail septum.	Length.	Width.		
I	6·72	4·5	32·1	63·50	7·30	34·0	7·5	0·0	33·8	8·2	2·1	11–12	8–8
II	6·70	4·8	31·0	63·50	7·30	34·1	7·4	0·0	34·0	8·0	2·2	11–13	8–9
III	6·50	4·5	31·3	63·70	7·32	33·9	7·3	0·0	33·8	8·5	2·1	11–10	8–8

Seasonal occurrence of Chaetognatha in the Malabar Plankton

In the plankton off West Hill, Calicut, Chaetognatha, especially *Sagitta*, never failed to occur in the weekly collections, although there were marked variations in the relative abundance of the different species or in the presence or absence of any particular species in the different parts of the year. Figure 10 (Graph I) illustrates the fluctuations in the occurrence of Chaetognatha along the Malabar Coast and their correlation with salinity and rain-fall from May, 1948 to May, 1949. It shows two peaks of abundance, a major one—the *S. enflata* and *S. neglecta* peak in the October-December period, and a minor one—the *S. bedoti* and *S. robusta* peak from late May to early July. The former is probably due to the return of normal conditions in the sea during the post-South-West Monsoon period. There are two periods of scarcity of chaetognaths, that is, a pronounced one from end of July to the end of September, and a lesser one from January to March. The scarcity in the former is due to the sharp fall in the number of *S. enflata*, the commonest form of the coast, at this time of the year, and in the latter to the general reduction of population of arrow-worms on this coast.

The attached table of monthly percentage distribution of chaetognaths gives an idea of the conditions prevailing in the various seasons. With the break of the monsoon during the latter half of May there was a decline in *Sagitta enflata* which fell rapidly in numbers during June and July becoming very rare in the plankton during August. *Enflata* was replaced in May and June by *bedoti* and *robusta* which reached their peaks of abundance in June and declined steadily thereafter. *Tenuis* appeared in June and July. *Neglecta* and *regularis* were more or less uniformly distributed during the rainy season. *Pterosagitta draco* and *Krohnitta subtilis*, which were recorded in small numbers in May, disappeared during the rest of the period of the South-West Monsoon. While *neglecta* and *enflata* registered a gradual rise during September, *tenuis* and *bedoti* declined, the remaining species being unrepresented.

Chaetognaths reappeared in large numbers during October and almost all the species recorded during the year were represented maintaining the highest total for the month. *Enflata* collected in October was mostly immature and small and occurred in large numbers. It increased in numbers in November reaching its peak in December, and during these months it had attained a length of 24 mm. The *neglecta* peak in October was followed by a steep decline in November and a rise again in December. *Bedoti* and *robusta* also registered a marked rise from October to December. *K. subtilis* was common during October and fully ripe with the ovaries reaching the level of the ventral ganglion. Other species were rare during the cold months. During January, *regularis* attained a peak and was uniformly distributed in the succeeding hot months. Although the *enflata* peak was not attained till December, the species was well represented throughout the hot season. *Bedoti* and *robusta* were also abundant from January to April, the latter showing a minor peak in April. *Neglecta* and *tenuis* were few and the other species rare, during these months. (Text-fig. 11, Graph 11).

Hydrographical Factors.

An attempt has been made to correlate the seasonal fluctuations in the *Sagitta* population in the West Hill Sea with the salinity and temperature of surface waters and the rain-fall. The range of salinity was 36·64% in May to 28·88% in July. The salinity values fell rapidly with the onset of the monsoon and remained very low during June and July after which a slow but steady rise was noticed. They remained more or less steady during the occasional October-November rains. The variations in salinity in the coastal waters of Malabar are not unlike those observed in Bombay Harbour (Bal *et al.*, 1946). The poor North-East Monsoon was

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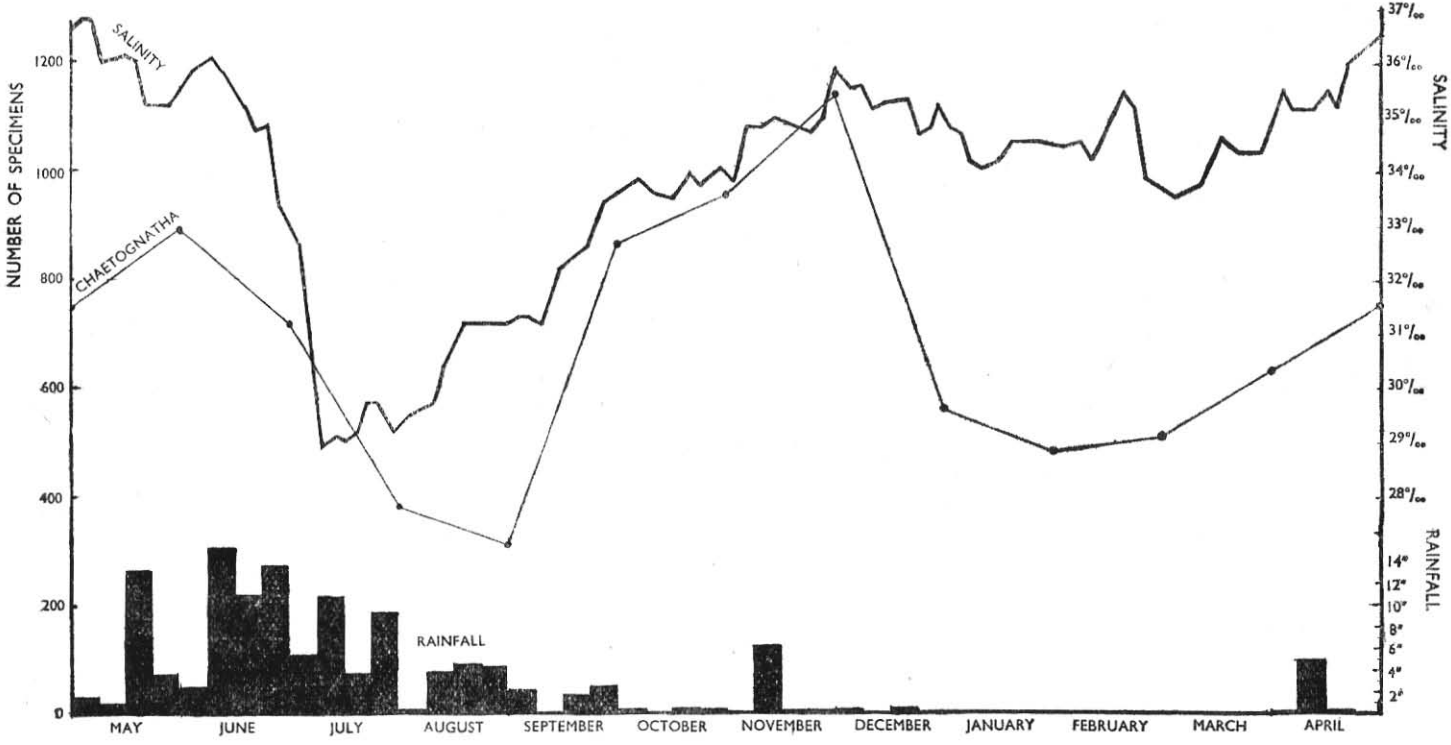


TEXT-FIG. 10.

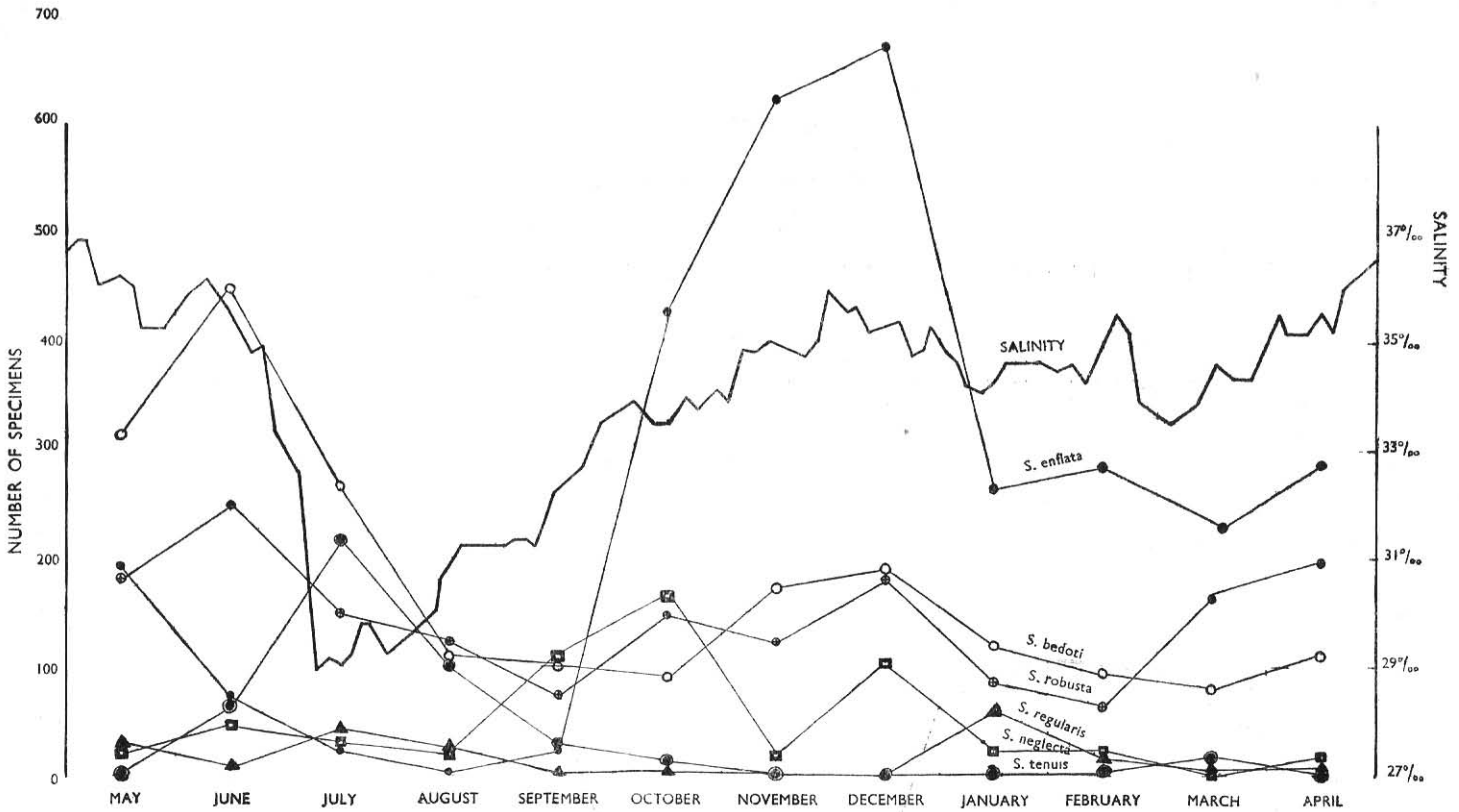
Graph I.

Seasonal Distribution of Chaetognatha with Reference to Variations in Salinity and Rain-fall.

Salinity

Chaetognatha

Rain-fall.



TEXT-FIG. 11.

Graph II.

Correlation Graph showing the Fluctuations of the species of *Sagitta* with Variations in Salinity.

Salinity

S. bedoti.

S. robusta.

S. enflata.

S. neglecta.

S. regularis.

S. tenuis.

MONTHLY PERCENTAGE DISTRIBUTION OF CHAETOGNATHA, MALABAR COAST, 1948–49.

Species.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
S. enflata	25·90	8·50	3·40	0·71	5·10	50·80	65·10	54·00	47·60	51·00	46·70	47·00
S. bedoti	42·10	50·10	37·00	30·50	31·00	10·50	16·60	16·12	20·00	18·80	17·80	16·20
S. robusta	24·00	28·00	18·10	30·29	24·40	16·00	15·38	15·80	16·40	17·50	29·70	30·50
S. neglecta	3·20	5·20	3·60	3·80	34·20	18·50	2·90	13·90	3·50	7·02	..	2·60
S. tenuis	..	7·40	31·80	28·70	5·30	0·80	..	..	..	0·22	3·80	..
S. pulchra	..	..	..	..	..	0·35	..	..	0·30	..	0·02	0·30
S. planktonis	..	..	..	..	..	0·38	..	..	..	0·44	0·02	1·50
S. hispida	0·92	..	..	..	..	..	..	..	..	..	..	0·80
S. regularis	3·34	0·80	6·10	6·00	..	0·35	..	..	12·20	5·02	1·90	0·80
P. draco	0·01	..	..	..	..	0·12	0·02	..	..	..	0·02	..
K. subtilis	0·53	..	..	..	..	2·20	..	0·18	..	..	0·04	0·30

apparently responsible for the small change in the salinity of the inshore waters during the October-November period. The salinities were fairly stationary up to March when they began to rise to the maximum in the first week of May. Early and heavy pre-monsoon rains in the latter half of May maintained salinities and temperatures of the inshore waters at low levels for a period. A decline in the zoo-plankton elements and a gradual rise in the phytoplankton elements towards a peak were also characteristic features of this period. The sudden lowering of salinity and surface temperature results in curious changes in the composition of populations of Arrow-worms as for instance the complete disappearance of ***enflata*** and the attainment of a peak of occurrence in *tenuis*. As the graphs show, the salinity changes do not seem to affect the other species of *Sagitta* to the same extent.

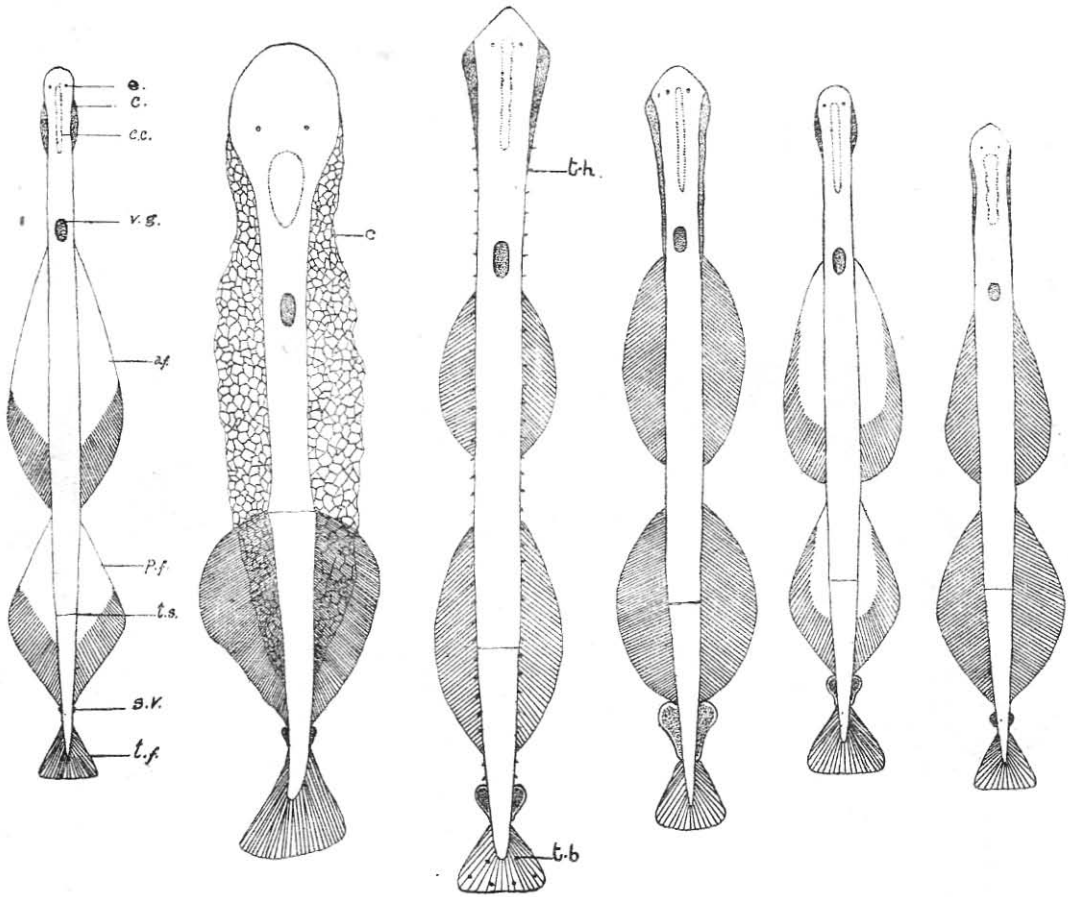
Discussion.

It may be seen from the foregoing account that arrow worms occur in the coastal waters of the West Coast throughout the year with a few periodical inter- and intra-specific fluctuations as shown in the tables and graphs, and the present contribution fully corroborates what has been observed already on the Madras Coast by Menon (1931) and Aiyar, Menon and Menon (1936). The present investigation based on triweekly collections over a whole year shows that although chaetognaths are represented in the plankton all the year round, there are periods of occurrence of maxima and minima as seen in the accompanying graphs. Whether these periods of abundance and scarcity have anything to do with the increase or lowering of salinities have not been elucidated beyond controversy (vide John and Subramaniam, 1937). The plankton of the Malabar coast during the October-December and May-June periods contains abundant chaetognaths with a major peak period for species of *Sagitta* in the former. In the peak that occurs after the South-West Monsoon the larger species, *enflata*, dominates, while in the minor peak during May-June the smaller species *bedoti* and *tenuis* dominate. *S. robusta* seems, however, more or less uniformly distributed in both the periods of maxima.

It is well known that the fluctuations in salinity and temperature are generally of the same pattern in all coastal waters (Sverdrup, 1942). According to Chidambaram and Devidoss Menon (1945) the surface temperature of the inshore waters of the West Hill coast reaches its maximum in March-April and its minimum in June-August. A similar maximum is reached in October. This is in a line with salinity readings recorded by the present author for the same region showing that the fluctuations in temperature and salinity are more or less similar. The histograms illustrating rain-fall on the West Coast in a whole year show that low salinities and temperatures prevail during the season of maximum rain-fall. The present investigation reveals that the chaetognath population in the coastal waters react in different degrees to these fluctuations. The distribution of *enflata* seems to follow closely the rise and fall of salinity. It becomes progressively scarce from May to early August, but in October it tends to rise again reaching a peak in December. This is in accord with the observations of Tokioka (1940) on *enflata* in the regions where the warm oceanic and cold or brackish waters mingle. Clarke *et al.* (1943) have observed on George's Bank that *enflata* occurred entirely outside the margin of the mixed area and that the species could not tolerate lower temperatures and salinities.

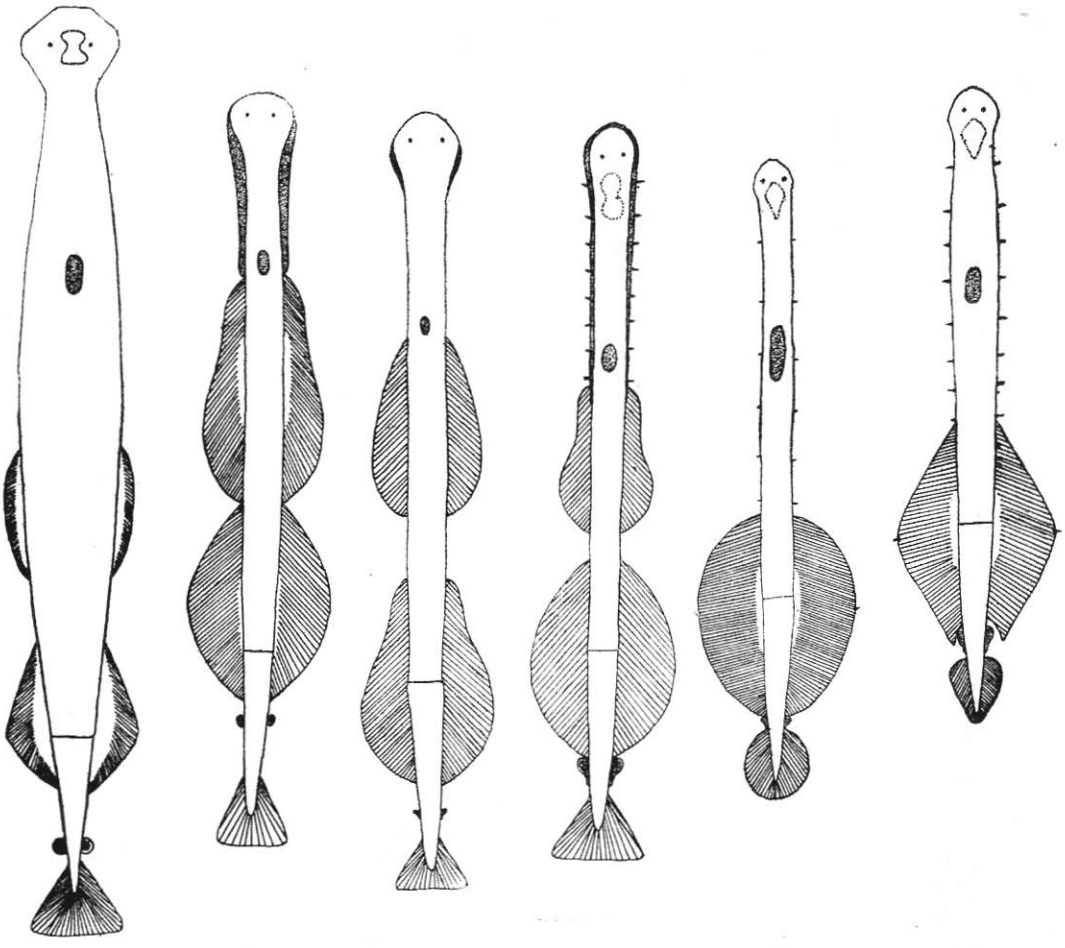
While *enflata* disappears almost completely from the surface plankton during the periods of low salinity and temperature, *tenuis* seems to take its place in coastal waters. *S. tenuis*, the smallest recorded species on the Malabar coast, is almost wholly limited in occurrence to the monsoon period. This is in agreement with the observations of Menon (1945) on the Trivandrum coast. *S. robusta* and *bedoti* have a more or less uniform distribution throughout the year. These and *regularis*

TEXT-FIG. 12.



A *S. pulchra.* B *P. draco.* C *S. hispida.* D *S. robusta.* E *S. bedoti.* F *S. neglecta.*

TEXT-FIG. 13.



G *S. enflata.* H *S. planktonis.* I *S. tenuis.* J *S. regularis.* K *K. subtilis.* L *K. pacifica.*

appear to be less affected than others by sudden changes in salinity and temperature. The interesting suggestion, that the thick epidermis characteristic of these species may be one of the factors which make them less sensitive to the sharp fluctuations in salinity, temperature, and rain-fall, appears plausible (vide John, 1937).

The part played by the *Sagitta* of this coast as indicators of oceanic currents will apparently remain obscure until more information on the Indian Ocean currents affecting coastal waters is forthcoming. The sporadic occurrence during the monsoon season of large numbers of *enflata* in the 15 meter horizontal hauls of plankton seems to be correlated with the abnormal salinity, *p*H, phosphate, and silicate values recorded during the period, indicating the possibility of a sudden influx of oceanic water affecting inshore areas.

According to Hardy (1924) and Lebour (1921) *Sagitta* form a good proportion of the stomach contents of the European Herring, *Clupea harangus*. Varadarajan and Chacko (1942) and Chacko (1950) found arrow-worms in the stomachs of several clupeid fishes and mackerel. The investigations carried out at this research station on the food of mackerel for over a year indicate that arrow-worms constitute a rare inclusion among stomach contents even during periods of abundance of *Sagitta* in the plankton.

It is felt that with a more detailed knowledge of the ocean currents and the biology of arrow-worms of our seas than has been presented in this paper, it will be possible to interpret the significance of their distribution both in relation to their predators and the hydrographical conditions.

Summary.

The systematics of the common Chaetognatha of the Indian coastal waters is briefly discussed. Nine species of *Sagitta*, e.g. *enflata*, *bedoti*, *robusta*, *neglecta*, *tenuis*, *regularis*, *hispida*, *planktonis* and *pulchra*, two of *Krohnitta*, e.g. *pacifica* and *subtilis* and *Pterosagitta draco* are described with special reference to the body proportions which indicate the limits of variations. Keys to the genera and species of Indian Chaetognatha and a table of diagnostic features of Indian *Sagitta* are included. The seasonal variations in the distribution of the Chaetognatha of the Malabar Coast are discussed with reference to temperature, salinity and rain-fall. It is shown clearly that although Chaetognatha as a group occurs in our seas throughout the year the individual species have their own seasons of abundance and scarcity. The most noteworthy feature of the present study is that *S. enflata* cannot tolerate the lowered salinities of sea-water during the monsoon period. The need for further study of the habits of arrow-worms is stressed in view of their importance as indicators of offshore or oceanic water movements.

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KEY TO LETTERING.

a.f. .. anterior fin,
c. .. collarette,
c.c. .. corona ciliata,
e. .. eye,
p.f. .. posterior fin,
s.v. .. seminal vesicle,
t.b. .. tactile body,
t.f. .. tail fin,
t.h. .. tactile hair,
t.s. .. tail septum,
v.g. .. ventral ganglion.