SEX DIFFERENCES IN THE CHALIMUS AND ADULT FORMS OF *CALIGUS POLYCANTHI*, SP. NOV (CRUSTACEA : COPEPODA) PARASITIC ON *BALISTES MACULATUS* FROM MADRAS.

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INTRODUCTION.

Over a dozen specimens of a caligid Copepod were found on the skin of *Balistes maculatus* caught on the Madras shore during February 1947. As these appear to be different from *Caligus balistae* (Steenstrup & Lutken) and distinct from other species of *Caligus*, recorded or described by Bassett-Smith, Scott, Leigh-Sharpe, Wilson and others, they are described as belonging to a new species, *Caligus polycanthi*. Since our knowledge of Copepods parasitic on Indian fishes is scanty, a detailed description of the adult female, and notes on the differences shown by the adult male (*allotype*) are given in the first section of this paper.

The *type-specimens* will be deposited in the collection of the Zoological Survey of India.

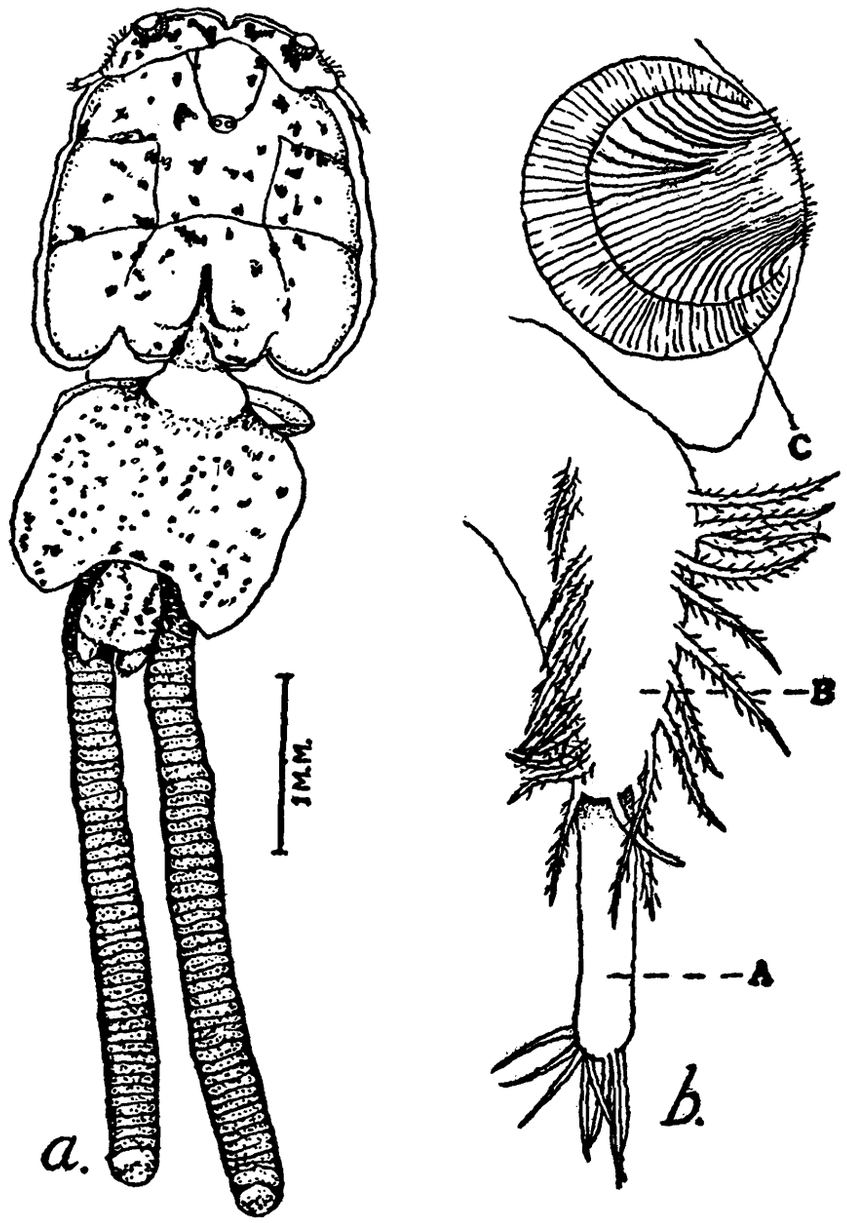
A careful study of the specimens showed that four were egg-bearing females, two were adult females, and one was an adult male and the remaining six belonged to late Chalimus stages of development. Of the six immature forms, two were distinctly female and the others male. As in this species the adult male differs markedly from the female and as these differences could be made out even in the Chalimus stages of the two sexes, a detailed account of the sex dimorphism is given in the second section of this paper.

Caligus polycanthi, sp. nov.

Size : Adult Female.—The entire body is 4 mm. long (excluding the anal setae and the egg strings) of which the carapace forms one half, being 2 mm. long. The carapace is nearly as broad as long but owing to the lateral edges being curved ventralwards it is somewhat elliptical in outline ; dorsally it measures 1·5 mm. at the anterior quarter and 1·8 mm. at the posterior quarter of its length.

Cephalothorax.—The dorsal surface of the cephalothorax is of a dirty yellow colour speckled with reddish dots. The double median eye and the longitudinal and transverse grooves or fissures of the carapace can be seen. The frontal margin is formed by the anterior edges of the first antennae and the frontal plate. Medially there is a notch in the frontal plate, and is occupied by the frontal stalk in the Chalimus stage. The under surface of the dorsally convex carapace, is concave and this concavity facilitates a cupping adhesion to the host's skin. This is further aided by the edges of the carapace being extended into a

wide thin transparent membranous fringe. The posterior border of the carapace extends over the first two segments of the thorax and, being concave behind, exposes the third segment. The free or fourth segment forms a " waist ", being constricted to a width of 0·18 mm. in front and twice as much behind. The genital segment (V and VI segments fused) is very prominent, being 1 mm. long medially and about 1·6 mm. broad. It has a quadrangular form but has its lateral edges convex, posterior margin concave and the hind corners extended behind as obtuse lobes. The posterior corner lobes bear the vestiges of the fifth legs, visible dorsally.

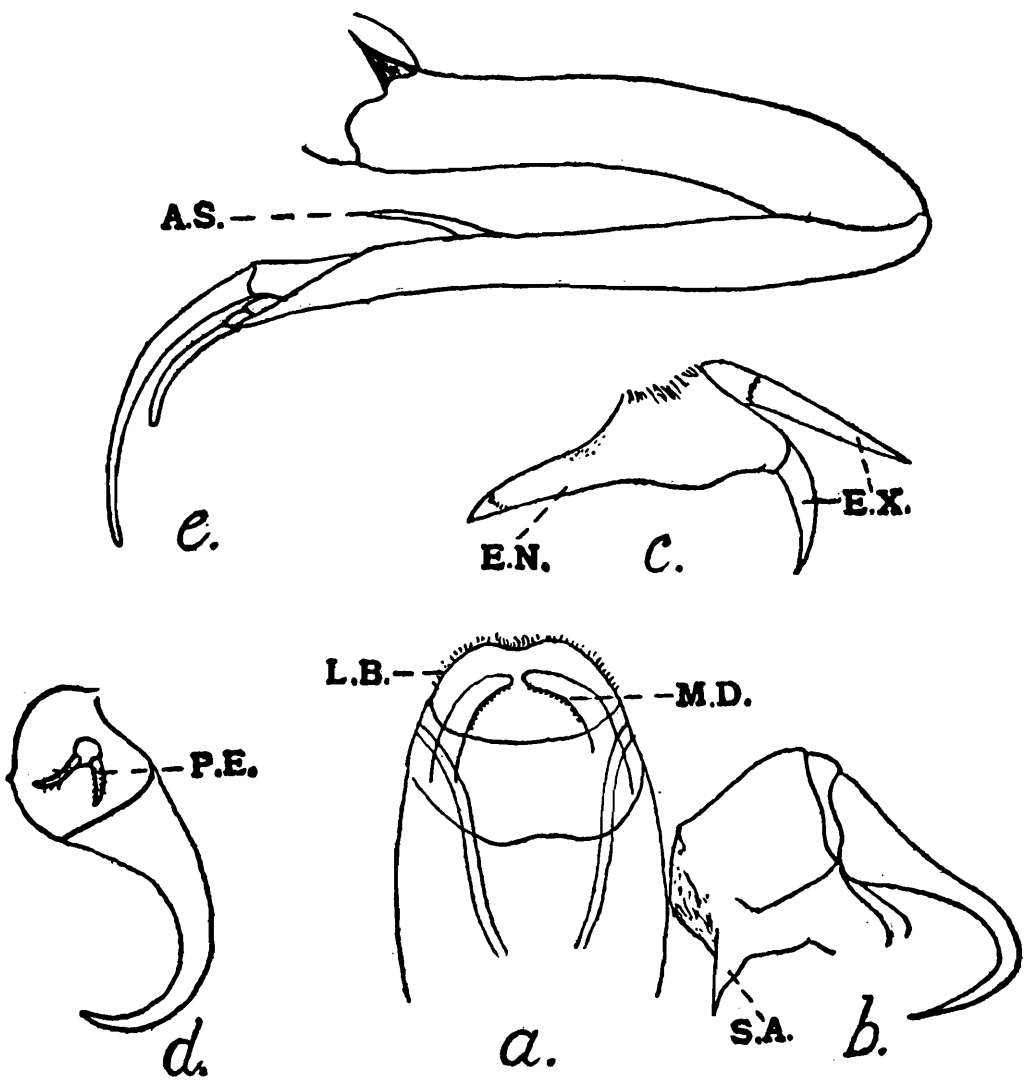


TEXT-FIG. 1.—*Caligus polycanthi*, sp. nov

a. Egg-bearing adult female; *b*. First antenna. A, distal segment bearing nine pines; B, middle segment bearing two rows of setae; C, basal segment bearing lunule.

Appendages of head and thorax.—The first antenna is very large, three-jointed and uniramous. The basal joint, which is continuous with the frontal plate, bears the large circular lunule. This sucking disc occupies nearly the whole width of the segment, the remaining portion of the segment is fringed with fine hairs. The second joint is as stout

as the first but tapers slightly at its distal end. This joint is furnished with two rows of forwardly directed setae, which though plumose, assist in adhesion to the host on account of their pointed and forward ends being buried in the skin of the host. Of the two rows, the more anterior has ten, and the other twelve setae, the more distal setae of each set being shorter and thinner than the rest. The third joint is short, slender and cylindrical and is articulated to the second joint a little before the distal tip. The round outer end of this joint bears nine spines of varying length and thickness. The second antenna is two-jointed. The basal joint is large and stout. It bears a thick, sharp-pointed spur directed obliquely backwards. The second joint is formed by a stout, recurved, sharp-pointed claw prehensile in character. The mandible is a scythe-shaped, curved blade whose cutting edge is finely serrated. The two mandibles curve towards each other at their inner tips and are held



TEXT-FIG. 2.— Cephalothoracic appendages of *Caligus polycanthi*, sp. nov.

a. Mouth tube ; *b*. Second antenna ; *c*. Second maxilla ; *d*. First maxilla ; *e*. First maxillipede.

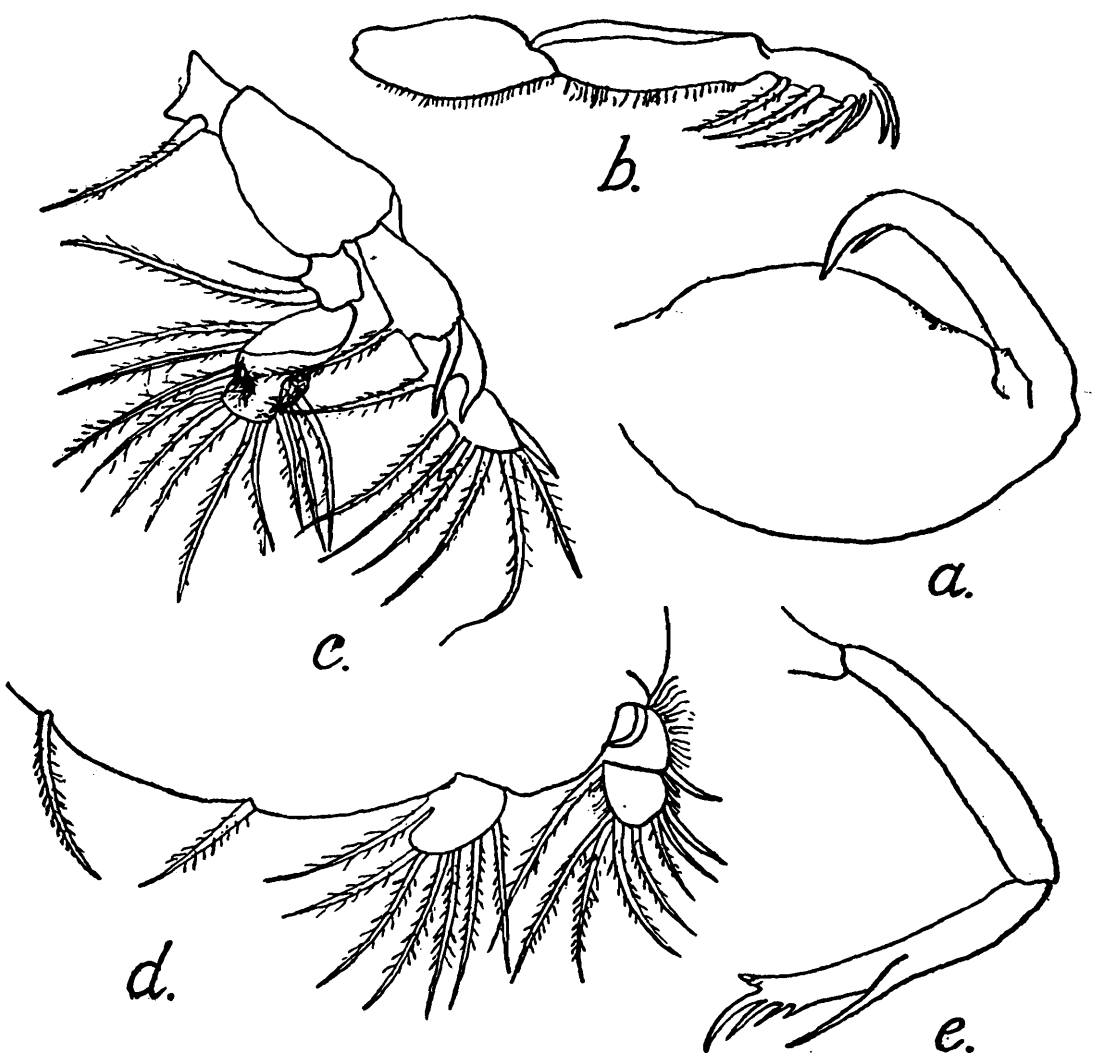
A.S., accessory spine of first maxillipede ;

E.N., endopod of second maxillae ;

A.S., accessory spine of first maxillipede ; E.N., endopod of second maxillae ; E.X., exopod of second maxilla ; L.B., labium of mouth tube ; M.D. mandible ; P.E., palp or exopod of first maxilla ; S.A., spur of second antenna.

within a short conical mouth tube stiffened by several chitinous rods. The lower edge of the tube can be distinguished as the labium. The first maxilla consists of a single joint and is attached more laterally than the other mouth parts. It is a long, sharp-pointed, recurved claw, smaller than the second antenna. On the inner aspect of its base is seen a pair of spines representing the exopod or palp of the appendage. The second maxilla is biramous and is attached close to the median line, though on the same level as the first maxilla. The endopod is long, stout and cylindrical and ends in a point. It is directed medialwards obliquely. The exopod consists of two long spine-like structures. These spines may be turned ventrally or outward. It is probable that the second maxilla with its sharp processes may serve to irritate the host-skin and cause bleeding.

The first maxillipede is attached further behind but more outwards. It is three-jointed. The basal joint, which is stout and short, confers great mobility on this appendage. The second and third joints are extremely long and setose. The last joint ends in two curved, finger-like processes, and bears a small accessory spine a little behind the tip. Of the two terminal processes, one is twice as long as the other. It is possible that, besides being flung out to hold on to the skin of the host



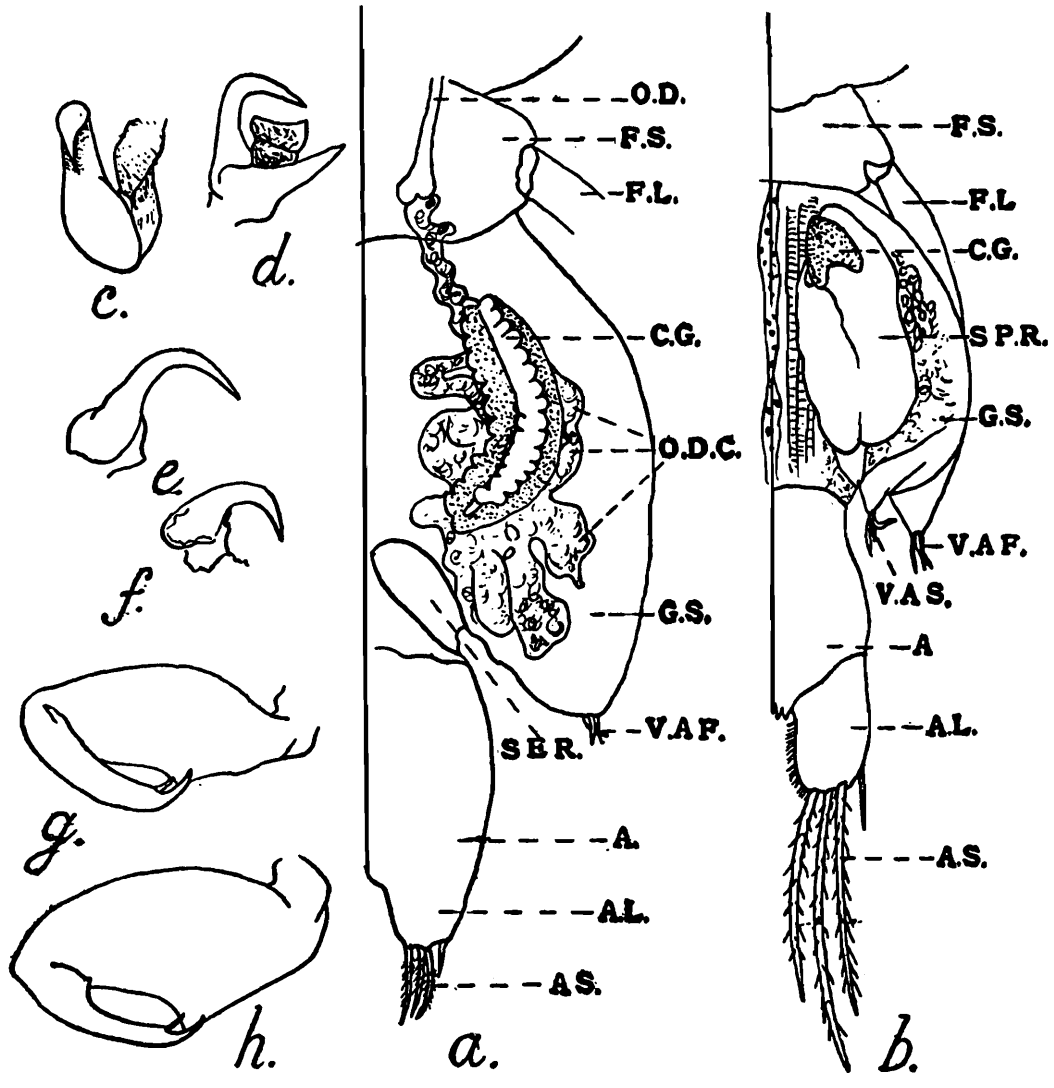
TEXT-FIG. 3.—*Caligus polycanthi*, sp. nov.

a. Second maxillipede ; *b*. First swimming leg ; *c*. Second swimming leg ; *d*. Third swimming leg ; *e*. Fourth leg.

when necessary, the first maxillipede may serve to comb the tip of the mouth tube clean. The second maxillipede is attached close to the middle line and consists of two joints. The first joint is large, stout and muscular, while the second is more slender, sharp-pointed, moving like the blade of a pocket-knife on the first joint. Close behind the sharp tip of the second joint can be seen a small accessory spine.

Swimming appendages.—The first leg, like the fourth, is uniramous. The basal joint, which is stout and large, carries the two-jointed exopod ; the first joint of the exopod is twice as long as the basal joint of the leg but is more slender, while the second or distal joint is as long as the basal joint, but cylindrical and club-shaped. The distal joint bears four long spines at the tip and three longer and stouter plumose setae on its hinder edge, directed back at an angle of 45° The second leg is biramous and typical. The protopodite is two-jointed, the first joint being small and the second much larger and stouter. A plumose seta directed backwards and medialwards, is borne on the first joint. The exopod is three-jointed and is attached in a direct line with the protopodite. The first of the three joints of the exopod is long, cylindrical and bears a slender plumose seta directed obliquely backwards, the second bears a plumose seta and two backwardly curved spines and the flattened terminal joint ends in a straight distal spine and bears six long plumose setae round its tip and hinder margin. The endopod also is triarticulate and is directed almost perpendicular to the protopodite and the exopod. The first joint bears a long, plumose seta, the second bears two, while the third, which is broad and elliptical, bears nine setae round its distal edge. The third leg is definitely foliaceous and unites with its fellow across the middle line. It extends far behind the third segment and even covers a part of the fourth segment. The two rami of this appendage are proportionately far smaller than the laminate protopodite. The plumose setae of the protopodite extend behind from the posterior edge of the lamina, close to the middle line. The exopod and the endopod are inserted into notches on the outer part of the hind margin of the lamina. In the exopod, the three divisions can be made out, the first joint is distinguished by a single stout claw, the second by a straight spine and the third by two spines and six plumose setae. The first joint is narrow while the second and the third are broad and flat. The endopod also is flat but smaller. It appears to be of two joints, the first being indicated by one long, plumose setae on the inner edge and the second being marked by a fringe of six plumose setae. Both the exopod and the endopod are tomentose. *The fourth leg* is uniramous. The exopod, which is two-jointed, is borne by a long basal joint. Of the two joints of the exopod, the first is long and has its distal edge prolonged into a long spine ; the second bears three long plumose setae at its tip which is also marked by two lateral tooth-like spiny projections. *The fifth leg* is represented by three short spines at the posterior tips of the lateral lobes of the genital segment. Two of these are attached close together, while the third is more removed. Each spine appears to have a thick, cylindrical cushion-like base bearing a slender spine once and half as long as the base. The tip of the spine is sharp and curved. No trace of the sixth appendage, which is present

in the male, is seen in the female. In adults without egg sacs, clusters of two or three spermatophores can be seen close to the external opening of the genital ducts. Each spermatophore is long, slender and tapering at both ends. In the egg-bearing forms, the egg sacs vary in length. In the type, on which this description is based, the sacs are slender, cylindrical and as long as the body. Each sac contains a single row of 50 eggs packed one behind the other. The egg strings are narrower than the abdomen.



TEXT-FIG. 4.—*Caligus polycanthi*, sp. nov.

Camera lucida drawings of fourth segment, genital segment and abdomen, as well as of second antennae. first maxillae and second maxillipede of a male and female of same age.

a. Right half of the body of a female ; *b*. Right half of the body of a male ; *c*. Second antenna of male ; *d*. Second antenna of female ; *e*. First maxilla of male ; *f*. First maxilla of female ; *g*. Second maxillipede of female ; *h*. Second maxillipede of male.

A, abdomen ; A.L., anal laminae ; A.S., anal setae ; C.G., cement gland ; F.L., fourth leg ; F.S., free segment ; G.S., genital segment ; O.D., oviduct ; O.D.C., oviducal cells ; S.E.R., semen receptacle of female, S.P.R., spermatophore receptacle of male ; V.A.F., vestigial appendage of fifth segment ; V.A.S., vestigial appendage of sixth segment.

The abdomen.—Proportionate to the rest of the body, the abdomen is small, being only 0·62 mm. long (the anal setae being excluded from all measurements of length) and about 0·43 mm. broad just in front of the laminae where it is broadest. The anal laminae are short and bear four short setae. In several egg-bearing females the setae appeared broken off and even when present are short, slender and weak as compared with those of the male.

The male.—As in all Copepoda, the male is slightly smaller in size than the female. It is only 3·72 mm. long and the genital segment is smaller than in the female. The greater length of the anal laminae and anal setae, however, give the male a more slender appearance. The cephalothorax is marked by a greater length (2·19 mm. as against 2 mm. in the female) and greater breadth (2·19 mm. as against 1·47 mm. in the female). Hence, the outline of the carapace is different from that of the female. The hind margin of the carapace being wider, the third segment is more conspicuous and exposed than in the female. The free fourth segment being of the same width in front and behind, makes the "waist" appear longer in the male. The genital segment is obviously different in outline and smaller in size. It measures 0·44 mm. in length medially and 0·71 mm. in width at its broadest point. The two lateral sides being convex and the anterior side narrower than the posterior concave side, the contour of the genital segment is strikingly different from that of the quadrangular form obtained in the female. Further, the two posterior lateral lobes are far shorter, smaller and more acute. Each lateral lobe bears two tufts of setae. A groove running forward between the two tufts divides the lobe lengthwise. The two tufts probably represent the vestiges of two appendages indicating the two units of which the genital segment is formed, the more medial tufts of three setae being probably the vestiges of the sixth appendage and the outer tuft of three setae those of the fifth appendage.

The other appendages are all similar to those of the female in structure, though proportionately larger (*vide infra*). The abdomen is longer, being 0·7 mm. in length, and narrower. The anal laminae are more marked as also the anal setae, which are as long as the abdomen itself. The length and plumose character of the three anal setae are probably correlated with the greater motility of the male.

Taxonomy.—Though the presence of lunules in the present form may point to eight genera of the sub-family Caliginae, the size of the carapace, the structure of the fourth leg and the first maxillae, and the form of the furca indicate that it belongs to the genus *Caligus*. From Wilson's (1906, pp. 555-561) very useful key (which is rightly based on the relative lengths of the different body regions) it is seen that the present species, which has a carapace just half as long as the body does not belong to *Caligus balistae*, which also, like the present form is a parasite of *Balistes maculatus*. As is already well known, different species of *Caligus* may parasitise the same species of fish and a particular species of the parasite may not be confined to one host-species and as judging from Wilson's description of *Caligus balistae*, there are several features of resemblance

between this species and the present form, a detailed comparison of the two species is given below :

C. balistae Steenstrup & Lutken.	*C. polycanthi*, sp. nov.
1. Carapace (2·6 mm.) more than half the entire length (4·5 mm.) in female and nearly twice the length of the rest of the body in male.	Carapace just half the total length in the females; difference in male within 8 per cent. as allowed by Wilson.
2. Genital segment of female obovate with short acute lobes.	Genital segment quadrangular with an emarginate hind border and rounded lateral lobes.
3. Abdomen same length as genital segment in male and half the length in female.	Abdomen longer than genital segment in male and more than half the length of genital segment in female.
4. Fourth legs with four spines.	Fourth legs with three plumose setae and two short spines.
5. Vestiges of fifth legs not visible dorsally in female.	Vestiges of fifth legs visible dor.. in female.

Species mentioned in Wilson's key, in which the carapace is about half the total length, are found to differ from the present form in the size and proportions of the abdomen and the genital segment or in the size of fourth leg. In view of these differences, the present form is considered a new species and owing to the bunch of nine spines on the distal tip of the first antennae is named *Caligus polycanthi* sp. nov. Based on the foregoing description of the female (*holotype*) and the features of the male (*allotype*) this new species may be defined as follows :

Description of the species.—The carapace is about half the total length of the body, excluding the anal setae. The frontal plate and the lunules are conspicuous. The mandible is curved and serrated at the anterior end. The first maxilla bears a pointed, backwardly directed endopod and a pair of short spines representing the exopod. The first leg is well developed uniramous and bears on its terminal segment three plumose setae and four distal spines. The fourth leg is also well-developed and uniramous, bearing three plumose setae and two short spines terminally on the exopod. The vestiges of the fifth appendage can be seen in a dorsal view of the female while in the male the remnants of the sixth appendage also persist. The sexes differ in the length of the abdomen, anal laminae and anal setae as well as in the size and shape of the genital segment. The abdomen and anal laminae, taken together are longer than the genital segment in the male and more than half the length of the genital segment in the female. The anal setae are nearly as long as the abdomen itself in the male while far shorter in the female.

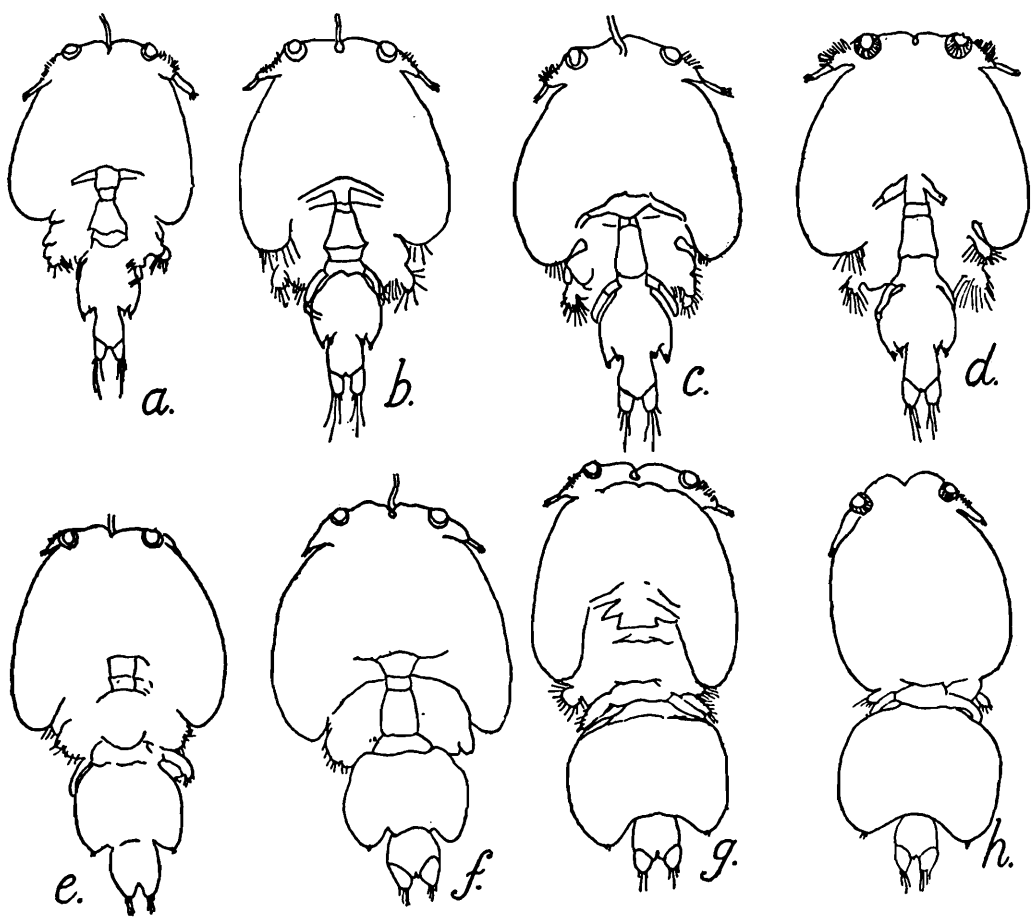
LATE CHALIMUS STAGES AND THE INCIDENCE OF SEX DIFFERENCES.

Chalimus forms of male and female.—Seven specimens of this immature stage of the parasite were found on the skin of the fish host, along with the adults. All these were attached only by the frontal stalks and were capable of movement round this point of attachment. The organs

of prehension in the adult were not in use. The lunules especially were not applied to the skin, their mouths being covered by membrane, and the entire frontal plate lacked the prominence and forward displacement which would enable the lunules of the adult to reach the host's skin. The attachment by frontal filament was so firm, that the young parasites had to be forcibly removed from the skin of the host.

Male Chalimus.—Though they varied in size, the four specimens taken and studied showed a remarkable uniformity in the structure of their appendages and in their general body outline. The steady increase in size denotes uniform growth of the body and genital segment to adult form—in fact the adult does not differ except for a slight increase in length and breadth. This was specially so as regards the form of the genital segment and the disposition of the genital organs visible through the transparent chitin.

Female Chalimus.—The three specimens of the stalked Chalimus stage, when compared with the adult which has not yet formed the egg-sacs, show gradual modification of body contours starting from a stage not very different from that of the male Chalimus. There is a slight decrease in width of the cephalothorax (so that the outline becomes more elliptical), while the genital segment increases rapidly in length and breadth and becomes quadrangular. A comparison of the appendages of the male and female Chalimus forms of the same total.



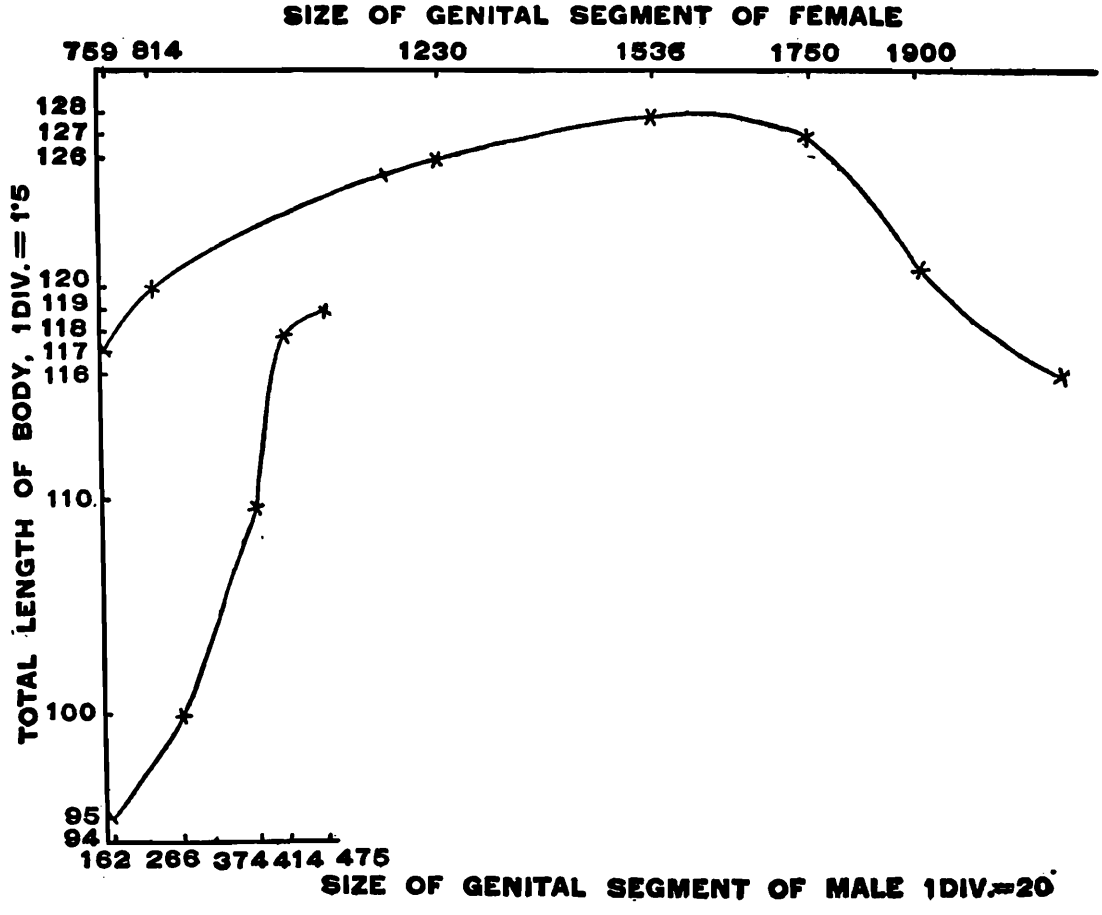
TEXT-FIG. 5.—*Caligus polycanthi*, sp. nov.

Change of form of male and female Chalimi developing into adults.

a., *b.*, *c.* three stages of Chalimi of male; *d.* Adult male; *e.*, *f.* Chalimus stages of female; *g.* young adult; *h.* mature adult.

length sketched with the help of a camera lucida, shows that the second antennae the first maxillae and the second maxillipedes are definitely larger and better adapted for perhension in the male. The same, however, cannot be said about the first maxillipedes and the fourth legs since they appear very nearly the same in size and form in both sexes. The vestiges of the sixth legs appear to have been lost in the female Chalimus as in the adult; on the other hand, the vestiges of the fifth legs appear more conspicuous and well formed in the Chalimus than in the adult female, in which owing to the swelling of the genital segment including the posterior lobes, the full length of the setose vestiges becomes somewhat hidden. The form of the abdomen, the anal laminae and setae marks the two sexes as distinctly as the form of the genital segment. In the male, the abdomen is slightly longer and more slender and the anal laminae more conspicous than in the female. The long plumose anal setae of the male distinguish it from the female beyond any mistake. The free segment of the thorax also is markedly broader and longer in the female the "waist" of the male appearing far more slim. A study of these late Chalimus forms of the females makes it clear that the final female form of the body is in the process of being settled during this period, whereas the external form of the male appears established much earlier. It is probable that this is due to the maturing of the reproductive organs earlier in the male than in the female.

The measurements of the thirteen Chalimus and adult forms of the parasite, especially of the total length of the body and the size of the genital segment (length multiplied by breadth), when tabulated (Tables



TEXT-FIG. 6.—Graph showing the increase of size of genital segment in relation to age or length of body of female and male, Chalimus and adult form.

I and II) and plotted on graph support the above conclusions. In the males the length, the breadth and therefore, the size of the whole body increase with the size of the genital segment, or the development of the sexual organs, steadily from the smallest of the Chalimus forms to the mature adult. In the females on the other hand, the size of the genital segment increases to a marked extent when the Chalimus becomes sexually mature and continues to incresae in size during the adult period, as can be seen from the table ; whereas the sizes of the body increases from the Chalimus, till sexual maturity is reached but thereafter during the adult period gradually decreases, till it becomes smaller than that of the Chalimus. Though the fact of the older adult being smaller than Chalimus and young adult has been recorded for other copepod parasites, the exact measurements are given here for the first time. This difference between the sexes in the change of size of the genital segment as well as the rest of the body during the Chalimus and adult stages, cannot be compared with the difference between "high" and "low" forms Sewell (1912, pp. 317-330) found among certain genera of free living copepods. The data collected and presented in this paper are too scanty for any application of Brooke's law of growth, Fowler (1909) used for explaining changes in size of Ostracoda.

TABLE I.—*Female. Readings ; 32=1 mm.*

No.	Total length of body.	Maximum breadth, *i.e.*, carapace breadth.	Product indicating size of body.	Length of genital segment.	Breadth of genital segment.	Product indicating the size of genital segment.	Remarks.
1	117	65	7605	23	33	759	Chalimus.
2	120	68	8160	22	37	814	Chalimus.
3	126	70	8820	30	41	1230	Adult with egg sacs.
4	128	64	8192	32	48	1536	Adult with egg sacs.
5	127	62	7874	35	50	1750	Adult with egg sacs.
6	121	60	7260	38	50	1900	Adult.
7	116	50	5800	46	46	2116	Adult.

TABLE II.—*Male.*

No.	Total length of body.	Maximum breadth, *i.e.*, carapace breadth.	Product indicating size of body.	Length of genital segment.	Breadth of genital segment.	Product indicating the size of genital segment.	Remarks.
1	95	55	5225	9	18	162	Chalimus.
2	100	56	5600	14	19	266	Chalimus.
3	110	66	7260	17	22	374	Chalimus.
4	118	68	8024	18	23	414	Chalimus.
5	119	69	8142	19	25	475	Adult.

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