

AN ABSTRACT OF THE THESIS OF

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MONSTROSA BERGH (COPEPODA)

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The morphology of a rather rare parasitic copepod was studied. Ismaila monstrosa Bergh, an endoparasitic copepod was found in the nudibranch, Antiopella fusca, at Coos Bay, Oregon. Many anatomical features were found, which were different from previous descriptions. Males were described for the first time. Young males lacked the gonadal lobes found on the dorsal sides of adult males. Both sexes had similar mouthparts, differing only in size. These mouthparts consisted, like those of Splanchnotrophus, of a bifid labrum, a pair of simple mandibles, a pair of maxillae and a triangular labium with side processes. There was only a single pair of maxillae and they are unusual in that they were found to be setigerous and two-jointed. The distal portion of this characteristic maxilla was biramous, the smaller member often obscure. Because of this and other anatomical factors, I proposed

a new variety Ismaila monstrosa var. pacifica and a new subfamily, the Ismailinae.

Although the female possessed three pairs of lateral appendages, the male lacked these, having only the two pairs of ventral appendages. In the female specimens there were two pairs of ventral appendages or "stomach-arms". The first pair was bifurcate, the second pair trifurcate. In the male specimens the first pair was uniramous and the second pair unequally biramous.

The digestive system was found to be incomplete in both sexes. There were no extensions into the "stomach-arms". No portions of either nervous or circulatory systems were found in the sections.

The reproductive system was found to be the major one in the body of the parasite. In the adults of both sexes the gonads were in the dorsal and anterior gonadal lobes. The ovaries connected to an extensively ramified oviduct. The lower part of the oviduct connected to the anterior end of the cement glands. A seminal receptacle was found in the female. In the male two testes were seen in the dorsal gonadal lobes. The vas deferens ran into the lower abdomen where spermatophores could be seen.

THE MORPHOLOGY OF
ISMAILA MONSTROSA BERGH (COPEPODA)

by

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TABLE OF CONTENTS

INTRODUCTION.	1
MATERIALS AND METHODS	4
ECOLOGY AND NATURAL HISTORY	6
MORPHOLOGY.	8
Redescription of the Genus <u>Ismaila</u>	8
External Morphology of the Female	9
External Morphology of the Male.	11
Mouthparts of the Female and the Male	12
Internal Anatomy of the Female	14
Internal Anatomy of the Male	16
SUMMARY AND DISCUSSION	18
BIBLIOGRAPHY.	25
APPENDIX	27

LIST OF FIGURES

Figure

1	Side view of <u>Antiopella fusca</u> with copepods	27
2	Developing nauplius in egg case	28
3	Female of <u>Ismaila monstrosa</u> var. <u>pacifica</u> , ventral view	29
4	Lower abdomen of female showing cement glands	29
5	Nauplii, diagrammatic	29
6	Female of <u>Ismaila monstrosa</u> var. <u>pacifica</u> , dorsal view	29
7	Young male of <u>Ismaila monstrosa</u> var. <u>pacifica</u> , lateral view	30
8	Adult male, lateral view	30
9	Adult male, ventral view	30
10	Adult male, dorsal view	30
11	Appendages and mouthparts	31
12	Female mouthparts	31
13	Composite drawing of male	31
14	Cross sections of the male	31
15	Cross sections of the female	31
16	Male mouthparts	31
17	Composite drawing of female	31

THE MORPHOLOGY OF
ISMAILA MONSTROSA BERGH (COPEPODA)

INTRODUCTION

Ismaila monstrosa, a rare parasitic copepod, is usually assigned to the Family Splanchnotrophidae because of its resemblance to the type genus of this family, Splanchnotrophus described by Hancock and Norman in 1863.

Bergh, in 1866 (2, p. 120), a specialist on nudibranchs, described the copepod, Ismaila monstrosa from the nudibranch, Phidiana lynceus collected at St. Thomas, Antilles, near Puerto Rico. His species description was based on a single female specimen. Later in 1868, an abstract of this work appeared in English in the *Annals Mag. Nat. Hist.* (3, p. 136-137). Thirty-two years after the original description, Bergh (4, p. 506-507; 544) reported other female specimens which were obtained from the nudibranchs, Archidoris incerata and Aeolidia serotina from either Punta de los Lobos or Quiriquina, Tumbes, Chili. His reference here to the original description of Ismaila from Phidiana inca was apparently in error, as the species is Phidiana lynceus.

These two papers have been much cited in subsequent papers on the Splanchnotrophidae, although few if any contributions to the morphology were made. Monod and Dollfus, in their supplement

(13, p. 166) for 1932, record these two occurrences in a survey of copepods parasitic on or in molluscs. Also in this survey Ismailia (sic) sp. of Bergh, 1879 and the Ismaila sp. of Vayssiere, 1901 were made synonyms of Splanchnotrophus (Lomanotricula) insolens Scott 1895. The genus, Ismaila remains monospecific.

Pruvot-Fol in 1934, according to the second supplement of Monod and Dollfus (14, p. 317), described a few appendages and possibly the abdomen of what is believed to be Ismaila sp. from debris in a jar containing Archidoris from the coast of California.

Illg, (in litt., 1964), wrote that he had collected a number of splanchnotrophid copepods mainly from the cephalaspidean, Aglaja diomedea and also from the nudibranchs, Dirona and Triopha. He wrote that he had material of possibly the same species from the nudibranchs, Dendronotus and possibly Eubranthus, collected in California. He thought that Aglaja was the normal host for this copepod in the Friday Harbor, Washington, area.

Some work on the nauplii has been done by Dudley. She wrote, (in litt., 1965), "The first nauplii are definitely planktonic and appear to have a patent gut -- and I obtained a molt to second nauplius in culture in only a very few cases."

Only Bergh has described the morphology and mouthparts and not very adequately. The males were totally unknown. The questionable systematic position due to this lack of adequate study

was again mentioned by Lucien Laubier (11, p. 172).

Hence, a study of the entire morphology of both male and female specimens, but especially of the mouthparts, should be of particular value for the classification. No attempt was made to provide cytological or histological descriptions of the various systems. The purpose of this study was to make a better description of the species and to add information regarding other aspects of these parasites of nudibranchs.

MATERIALS AND METHODS

From June 1963 to January 1965, several thousand opisthobranch molluscs were collected and examined for copepod parasites. The collection was mainly from near Coos Bay, Oregon; especially from Cape Arago, the Charleston Small Boat Basin and from the vicinity of Empire. Some collecting was done at Neptune State Park, Boiler Bay and Newport as well as from Agate Beach. The several tectibranchs collected did not have any copepod parasites. Of the 26 species of nudibranchs examined only one yielded parasites. During the summer of 1963, an unusual copepod parasite was located in the aeolid nudibranch, Antiopella fusca (O'Donoghue, 1924), also known as Janolus fuscus. The copepod, a splanchnotrophid, was identified as Ismaila monstrosa. Although 62 percent of this rather uncommon nudibranch harbored the parasite, only 97 specimens of the copepod were seen and 83 actually collected. A list of opisthobranchs examined is included in the Appendix.

The nudibranchs were collected and brought into the laboratory at the Oregon Institute of Marine Biology, Charleston, Oregon, and maintained in aquaria with running sea water (approximately 15-16 degrees Centigrade).

The nudibranchs were examined under a binocular microscope for any ectoparasites. The egg cases of an endoparasite

could also be seen if present. Whether egg cases were located or not, a large number of nudibranchs were carefully dissected and the internal cavities examined. All copepods discovered were removed, cleaned and then preserved in either Lavdowsky's Solution (AFA) or 70 percent ethyl alcohol for further study.

After hardening in fixing solution, some of the copepods were dissected for anatomy and mouthparts. Some were removed and embedded in paraffin and sectioned at either eight or ten microns. The serial sections were stained in Delafield's hematoxylin and eosin, cleared in xylol and mounted in balsam on slides. A few whole specimens were stained in a 0.5 percent solution of Fast Green before being cleared and mounted. A small group of specimens were treated with a weak solution of sodium hypochlorite to remove cellular contents which obscured the mouthparts in the cephalothorax. These were also stained in Fast Green, cleared and mounted.

Drawings were made with the aid of projection and the camera lucida. A few photographs were also taken.

ECOLOGY AND NATURAL HISTORY

While at the Oregon Institute of Marine Biology, some of the egg sacs of Ismaila were removed and placed in plastic dishes and floated on the surface of the water of the aquaria. In some cases the egg sacs were slit to let the eggs become free in the sea water. The eggs measured 0.053 mm. in diameter. The sea water in the plastic dishes was changed every day until hatching occurred. After two weeks at 15-16 degrees Centigrade, the eggs hatched into nauplii (Figures 2 and 5). As the eggs developed, they became lighter in color. They changed from dark charcoal to light gray. Before hatching the appendages and eyespot could be seen within the egg case. This along with Dudley's work is all that is known of the life stages. The stage at which penetration of the host occurs and how or whether ecdysis takes place in the body of the host, could not be determined.

In the host, the adult parasites can be found in the general body cavity. Although variations exist, two sites are favored by the female copepods. An anterior one, behind the ganglia and near the digestive gland; the other farther back usually behind the digestive gland, sometimes even further caudally. In one nudibranch a female copepod was observed in one of the cerata about midbody. Usually a number of copepods of various stages could be found in

an infected host (Figures 3, 7 and 9). It was not unusual to remove as many as five females and four males from a single host. The males were usually found near the female or between her appendages, near the end of the abdomen.

From three collection sites in the Coos Bay area, the infection was highest at the Small Boat Basin, the second at Fossil Point, near Empire, Oregon, and only one infected nudibranch was taken from Cape Arago.

I have collected also a lichmolgid copepod from one of the cerata of a dredged nudibranch, Tritonia sp. (9 Aug. 1961, Lat. $44^{\circ}23.4'N$, Long. $125^{\circ}04.8'W$, Depth 861 meters, OT-21-37). This is an ectoparasite. Although hundreds of the nudibranch, Hermisenda crassicornis were examined, they failed to yield any of the ectoparasite, Hemicyclops thysanotus Wilson 1935. This copepod, H. thysanotus was described by Wilson (17, p. 783-785) from Elkhorn Slough, Monterey Bay, California. Light and Hartman (12, p. 179-180) reported it on the same host from Corona de Mar, California. Gooding (9, p. 175-176) noted a change in host preference north of California. The hosts were several different species of thalassinids.

MORPHOLOGY

Redescription of the Genus IsmailaFigures 3 and 9

Internal parasite of the coelom or body cavity of opisthobranch molluscs. Chondracanthid, but specifically splanchnotrophid in form. White, colorless, ivory to pale yellow in color. Cuticle thin and membranous. Sexually dimorphic. Female up to 5.5 mm. in length; male to about 1.9 mm. Body easily divisible into three regions; head, upper abdomen and lower abdomen. Head or cephalothorax and upper abdomen not segmented. The upper part of the abdomen with two anterior gonadal lobes on the dorsal side. Lower abdomen of both sexes tapering and it alone segmented; the very end of this region bearing setigerous caudal projections. Both sexes with long abdominal, cylindrical and tapering appendages, but without any thoracic feet. These appendages without setae and proximal side branches (second members) or bulbs. These not jointed nor segmented. Three pairs of lateral appendages in the female. Two pairs of abdominal appendages (ventral "stomach-arms") in the male; the lower pair branched or biramous. The female has in addition to the laterals two pairs of ventral appendages ("stomach-arms"), the upper pair with equal rami; the lower pair both trifurcate, occasionally biramous, and the branches unequal. Head of both sexes bearing similar mouthparts

and appendages.

External Morphology of the Female
Ismaila monstrosa var. pacifica n. var.

Figures 3 and 6

Adult specimens up to 5.5 mm. in length. Shape basically splanchnotropid, somewhat short and stout. Having several appendages along the sides and also ventrally. Body divided into three parts; head or cephalothorax, upper abdomen and lower abdomen. The head small, bearing two pairs of antennae and also mouthparts. The mouth or oral opening surrounded by two ventral, cephalic lobes and situated between the lobes and below the second antennae. Head without any segments, and not articulated. The first antennae quite small and two-jointed; the apical or end joint with approximately six to eight long setae; the lower or basal joint with three large setae at its distal end (Figure 11). The second antennae larger than the first and prehensile, composed of three joints, possessing two spines, distal and proximal. Mouth covered by a labrum, bordered by mouthparts and appendages. Neck separating cephalothorax from upper abdomen. Upper abdomen with two, medio-lateral lobes on the dorsal side near the first pair of lateral appendages. Near the second lateral pair of appendages, also on the dorsal side, a second pair of medio-lateral lobes externally

similar to the first pair. In addition, three cylindrical, tapering, abdominal appendages along the sides. The first pair and the third pair long, the second pair usually long but sometimes short. Ventrally the upper abdomen with two pairs of appendages or "stomach-arms". The first pair biramous and arising from the upper abdomen on a plane equal or level to the first lateral appendages but ventral in orientation. The second pair of ventral "stomach-arms" trifurcate and arising on the same plane as the second laterals. No third ventral abdominal appendages. The third lateral pair of appendages without lobes on the dorsal side. A uniramous and medial appendage, usually curled, and pointing anteriorly. All the appendages; the three lateral pairs, the two pairs of ventrals and the single medial dorsal process, without articulations or setae. All without side-branches, secondary members or bulbs. A slight constriction between upper and lower abdomen. The lower abdomen with an elliptical swelling anteriorly. The portion below this, tapered and apparently possessing three articulations or segments. The first suture rim-like and distinct. Between and below this rim, and the following genital segment a small pair of short, lateral setigerous projections (Figure 4). The first and second sutures divide the ovigerous lobes by their chitinous rings. The white, ovigerous lobes sausage-shaped and containing the gray-white eggs (Figure 1). The third suture, like the second,

less distinct than the first but bearing caudal projections at the very end. Two or three setae on the pointed apex of each caudal projection. No vulva nor anal opening observed.

External Morphology of the Male
Ismaila monstrosa var. pacifica n. var.

Figures 8, 9 and 10

Adult forms measuring up to 1.9 mm. in length, usually smaller than adult females, and similar in shape to a male Splanchnotrophus, although the appendages markedly different. The male differing from the female in possessing only two pairs of ventral appendages. No lateral abdominal appendages. Body divisible into three parts; head or cephalothorax, upper abdomen and lower abdomen. Circular, doughnut-shaped head, large with respect to body as compared to female, with two pairs of antennae and the mouthparts (Figure 16). The mouth, covered by a labrum, below the second pair of antennae and median. Unlike the female, the male without a distinct neck, but with a slight groove above the gonadal lobes. The two pairs of antennae remarkably similar to those in the female (Figures 11, 12 and 16). The anterior portion of the upper abdomen with two gonadal lobes in the adult males, but not in younger stages (Figure 7). Ventrally the anterior portion of the upper abdomen possessing one pair of uniramous

"stomach-arms", which are not segmented or jointed. A slight indentation and an abrupt tapering between the first pair of ventral abdominal appendages and the second. The second pair of "stomach-arms" or ventral abdominal appendages biramous and branching unequally. Dorsally two lateral ridges below the gonadal lobes on a transverse plane at the same level with the second pair of ventral appendages. Three indistinct sutures on lower abdomen. Above the first definite suture a small pair of setigerous projections on the sides of the body. The genital segment between the first and third sutures. The genital pores or orifices at the lower sides of the caudal end of this segment. The last segment marked by indistinct, incomplete striations or partial sutures. At the caudal end of the lower abdomen projections bearing two or three setae on each projection. The anal opening is absent.

Mouthparts of the Female and the Male

Figures 11, 12 and 16

The mouthparts of male and female Ismaila very much alike. The mouthparts quite small in comparison to the body size and consisting of a triangular labrum, a pair of mandibles, a pair of maxillae and a labium with side processes. A small cuticular decoration below the labium and to either side; possibly the vestigial

remnant of a pair of maxillipeds.

The labrum triangular and bounded by the second pair of antennae, with the apex of the lip pointing towards the anterior end of the head. The sides of this lip reaching to about the enlarged portion of the mandibles, the base, which may be ridged or bifid, running across a plane level to the area above the mandibles.

The mandibles transverse in alignment and possessing a styliform, simple curved blade. The lower portion of mandible enlarged and articulated to the body by the attaching muscles. Mandibles simple and without processes.

The single, double-jointed and setigerous pair of maxillae unique and characteristic of the genus. The distal end of the first joint biramous, the smaller ramus spinous and obscure at times. The larger member with ten to thirteen long setae. The smaller ramus with setae also, but these short, fine and numerous, approximately 17 in number. The first joint indented between the distal bifid portion and the wide proximal part. The proximal end of the first part broad and almost square. The second part which articulates with the rest of the body small, about half the size of the proximal end of the first part. Roughly triangular to kidney-shaped.

The small quadrangular to triangular processes of the labium between the mandibles and maxillae on each side. The major part of the labium median and triangular; however, the

greatly rounded or curved apex in this instance inverted and posterior in position.

Internal Anatomy of the Female

Figures 15 and 17

Body Wall: The body wall of the female copepod composed of an outer thin cuticle. Below this is a pavement-type of epithelium, or hypodermis, one cell-layer thick. Underneath and scattered through the general body cavity an inner layer, the subcutaneous mesoderm. The ovoid or spheroid cells similar to or approaching mesenchymal tissue. In the head region, especially in the cephalic lobes on either side of the oral opening concentrated hypodermal glands, and possibly fused frontal and maxillipedal glands.

Musculature: Musculature very simple in this group of animals, and represented mainly by two ventral longitudinal bands and two dorsal longitudinal bands. In the head region, the dorsal portion branching and supplying the two pairs of antennae and the mouthparts. Small transverse bands sometimes occurring in the middle portion of the upper abdomen. The cephalic lobes and the segmented portion of the lower abdomen also with small muscles.

Digestive system: The digestive system lined by a rather thin cuticle. Below this a thinner epithelium. The digestive

system consisting of a short esophagus, leading away from the ventral, sub-terminal mouth, into a slightly dilated, blind stomach, hence, digestive system incomplete, without intestine or anus.

Nervous system: The nervous system not observed in the serial or longitudinal sections.

Circulatory system: No distinct circulatory system in this group. In the serial sections no dorsal or ventral lacunae seen.

Reproductive system: The reproductive system is the major internal system in the body of the female. Two elliptical ovaries within the first pair of gonadal lobes on the dorsal side. Oogenesis observed in some specimens in the anterior portions of the ovaries. The eggs without filament cells. The oviduct joining onto the ovaries and then expanding and branching to fill the ventral and lateral abdominal appendages (Figures 15 and 17). The oviducts fused and surrounding the digestive system. Fused both in the dorsal-anterior position as well as in the ventral-posterior portion. The oviducts joining with the two thick-walled cement glands in the anterior regions. The long cement glands running to the genital segment and ending at the ringed openings of the genital ducts. The seminal receptacle or spermatheca on the dorsal side of the lower abdomen, with a duct leading posteriorly from it to the lower segments. No vulva in any of the sections.

Internal Anatomy of the Male

Figures 13 and 14

Body Wall: A three layered body wall. The outer-most layer a thin cuticle. Middle layer or hypodermis of squamous epithelium. The inner third layer of mesodermal tissue, mesenchymal in the posterior region of the body. Many glands in the head region, in the hypodermis layer.

Musculature: From the dorsal portion of the head, several muscles radiating to the mouthparts and also to the two pairs of antennae. Two dorsal bands spreading longitudinally to the posterior end. The ventral bands coursing longitudinally from around the mouth to the lower abdomen and a transverse band occurring in the mid-body region between the two pairs of ventral appendages.

Digestive system: In the serial sections the digestive system incomplete. The oral opening or mouth leading into a short esophagus lined by a thin cuticle with the epithelium underneath. A dilated stomach, completing the digestive tract, also lined by cuticle. No intestine, rectum, nor anal opening.

Nervous system: In the material studied, no nervous system observed.

Circulatory system: No vessels, sinuses nor lacunae seen in the sections.

Reproductive system: As in the female, the reproductive system was the major system represented in the body of the male. Spermatogenesis within the testes in the pair of gonadal lobes on the dorsal side. Leading from the testes, the vas deferens coursing along the lateral edges of the body cavity in an uneven or convoluted manner. A portion of the vas deferens thickened, and similar to the cement glands of the female reproductive tract. This area lined by cuboidal epithelium and in this region the mature sperm encapsuled into the slightly spindle shaped spermatophores. The spermatophores dense and opaque and seen through the body wall. The lower portion of vasa deferentia opening on the ventral side. The two genital openings on the tips of bluntly pointed projections on the second segment of the lower abdomen or tail.

SUMMARY AND DISCUSSION

Although Hancock and Norman described the genus Splanchnotrophus in 1863, it was placed by them in the family Chondracanthidae where it remained until 1906. They described two pairs of antennae, a labrum, one pair of mandibles, one pair of maxillae and erroneously, two pairs of maxillipeds or foot-jaws. In addition, there were two pairs of thoracic feet. Chondracanthus, on the other hand, has two antennae, a pair of mandibles, a pair of second maxillae, labrum, two pairs of maxillipeds and two pairs of thoracic legs. In 1906 Norman and Scott (15, p. 217) proposed a separate family, the Splanchnotrophidae for these copepods. Later, Oakley in 1930, (16, p. 185) placed them with the Chondracanthidae, but proposed a separate subfamily, the Splanchnotrophinae to include the genus Splanchnotrophus. He stated that more evidence was necessary before the creation of a new family. Probably he was unaware of Norman and Scott's paper. At least seven species of Splanchnotrophus are known, divided into two subgenera; Splanchnotrophus and Lomanoticola. Lucien Laubier (11, p. 168) in a careful study showed that the mouthparts of Splanchnotrophus were simple and reduced, consisting of a pair of mandibles and a pair of maxillae. The mandibles were without a process and contained three teeth at the distal end. The maxillae were nonsetigerous,

but possessed an accessory spine. There were two lips present.

In 1866, Bergh described Ismaila which was followed by a description of the genus Briarella in 1876. Chondrocarpus resembling Briarella was described later in 1903 by Bassett-Smith (1, p. 104) who wrote that they possessed an upper lip, one pair of minute maxillae, mandibles or second maxillipeds. They were without antennae and thoracic legs. The original description of Ismaila was based upon one specimen, a female. The mouthparts were figured by Bergh as consisting of a labrum, a pair of mandibles and a pair of maxillipeds as well as two pairs of antennae. His later description added nothing new to the information concerning mouthparts. Pruvot-Fol's drawings (14, p. 318) showed the abdomen, the second antenna, and appendages labeled appendices cephalique (antennules?) which were possibly the maxillae minus the smaller ramus. Below the lower ridge (labium) in this drawing were possibly the remnants of the maxillipeds on either side. In my study, I found that the mouthparts of both sexes of Ismaila were similar to Splanchnotrophus I have interpreted them here as mandibles and maxillae instead of maxillae and maxillipeds. Even though the maxillae were of different types, more stress was given to their position in regard to the processes of the labium. These processes were located between the two sets of mouthparts. Because of this, I have called them mandible and maxilla instead of maxilla and

maxilliped, even though the maxilla was unusual in being biramose and setigerous. I regard these maxillae as characteristic of the genus along with the absence of thoracic feet which may be found in other genera. Briarella with two pairs of antennae, labrum, pair of mandibles, two pairs of maxillae, one pair of maxillipeds plus two pairs of biramous thoracic legs differs from Ismaila, Splanchnotrophus and Chondracanthus. Until further examination of additional material this genus must remain in seda incerta along with Chondrocarpus.

The application of the collected anatomical facts to the classification of the parasitic copepod, Ismaila monstrosa was attempted herein. Since this form is poorly known, it seems best, at present, to group all known specimens into one cosmopolitan species. However, with more study and collections, several species may actually be found to exist. I propose herein to establish the following as varieties or subspecies of Ismaila.

Ismaila monstrosa var. antillarum n. var.

Dorsal median process forked or bifid. Cephalothorax protruding below the mouth. Cephalic lobes and second pair of dorsal lobes indistinct. Caribbean Sea, Saint Thomas Island, near Puerto Rico. In Phidiana lynceus.

Ismaila monstrosa var. chiliensis n. var.

Cephalic lobes distinct. Side or lateral thoracic appendages

blunt or not pointed. Both pair of "stomach-arms" or ventral appendages biramous, one member blunt and the other pointed. Tumbes, Chili. In Archidoris incerata and Aeolidia serotina.

Ismaila monstrosa var. pacifica n. var.

Dorsal median process uniramous. Cephalic lobes and second pair of the dorsal lobes distinct. All lateral and ventral appendages pointed. California, Oregon and Washington Coasts. In Archidoris sp., Aglaja diomedea, Dirona sp., Triopha sp., Dendronotus sp., possibly Eubranchus sp., and Antiopella fusca.

With future research, these three varieties may be shown to be three separate species.

Although I collected many more specimens than had ever been collected before, they were preserved in AFA or alcohol. They should have been fixed in Bouin's Fluid. It is possibly because of this fixation that several aspects of the morphology are not clear. Also, it is from this material that I have formulated the conclusions herein.

The body wall was similar in construction to that of the genus Chondracanthus with its thin cuticle and epithelium. However, the third layer or subcutaneous mesenchyma was extensive between the parts of the body. It differed also in the presence of hypodermal glands especially in the cephalic region. No massive frontal or maxillipedial glands were located.

Possibly due to the methods of fixation the nervous system was not located in any of the sections. It was probably present and may resemble that of other parasitic copepods. In these other copepods the larger subesophageal ganglion may be seen to fuse into the ventral floor of the esophagus and it is difficult to see.

Likewise, no circulatory system or its parts were observed.

Additional information was found by the study of the digestive and the reproductive systems. From the serial sections, I have concluded that the digestive system was incomplete. I have found no anal opening on the outside. The cuticular lining of the esophagus and stomach was recorded for the first time. Small food particles could be seen in the lumen. Unlike those figured for Briarella, the ventral appendages or "stomach-arms" of Ismaila do not contain extensions of the digestive system (Figures 14 and 15). With the exception of the lower ducts of the seminal receptacle and the oviduct, all parts of the reproductive system in both sexes could be easily observed. The seminal receptacle was located within the lower abdomen of the female as in several other parasitic copepods (Figure 4). El Saby (8, p. 877) indicated a seminal receptacle as a small sac opening separately at the caudal end. Ismaila, however, lacked a conspicuous external opening into the seminal receptacle. I postulated that the lower duct from the spermatheca or seminal receptacle branches

dichotomously and opens by way of these branches or vaginae into the cement glands. In certain copepods the oviducts, cement glands and vaginae all share the two genital openings, one oviduct, vagina and cement gland per side continuing into the ovigerous sac. Copulation probably takes place when the females are immature or when there are no egg sacs present. The spindle shaped spermatophores then could have been inserted into the common duct or junction of the cement gland and the vagina. The sperm may travel up the vagina into the duct and into the seminal receptacle. As the eggs mature, the sperm can travel down the spermathecal duct and through the vagina into the junction of the oviduct or cement gland.

When compared to the ectoparasitic form Chondracanthus, Ismaila seems to have reduced the mouthparts and lost the thoracic feet. The extensions of the upper abdomen, however, have become quite long, and may be useful in respiration as well as housing parts of the reproductive system. This study indicates that Splanchnotrophus and Ismaila are more closely related than is Briarella to either. However, Briarella represents possibly a link between these two genera above, both of which are endoparasites and Chondracanthus, an ectoparasite of fish. Delamare Deboutteville and Nunes-Ruivo (7, p. 111) indicate also the relationship of the Splanchnotrophidae with the Staurosomidae and the

Echiuroidae. Both of these latter families contain copepods with lateral body extensions. These two families were not found on or in either fish or molluscs, but in other types of invertebrates. The phylogenetic problems may be greatly confused if these represent physiological and hence, parallel evolutions.

Because of the type of mouthparts the Chondracanthidae as well as the Splanchnotrophidae should be removed from the Lernaepodoida and placed in the Cyclopoida as Oakley has suggested. The classification is as follows: Arthropoda, Mandibulata, Branchiata, Crustacea, Copepoda, Eucopoda, Cyclopoida and the families Chondracanthidae and Splanchnotrophidae. Because of the absence of the thoracic feet, an unusual setigerous maxilla and other differences, I propose a new subfamily for Ismaila, the Ismailinae, in order to separate it from the genus Splanchnotrophus.

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APPENDIX

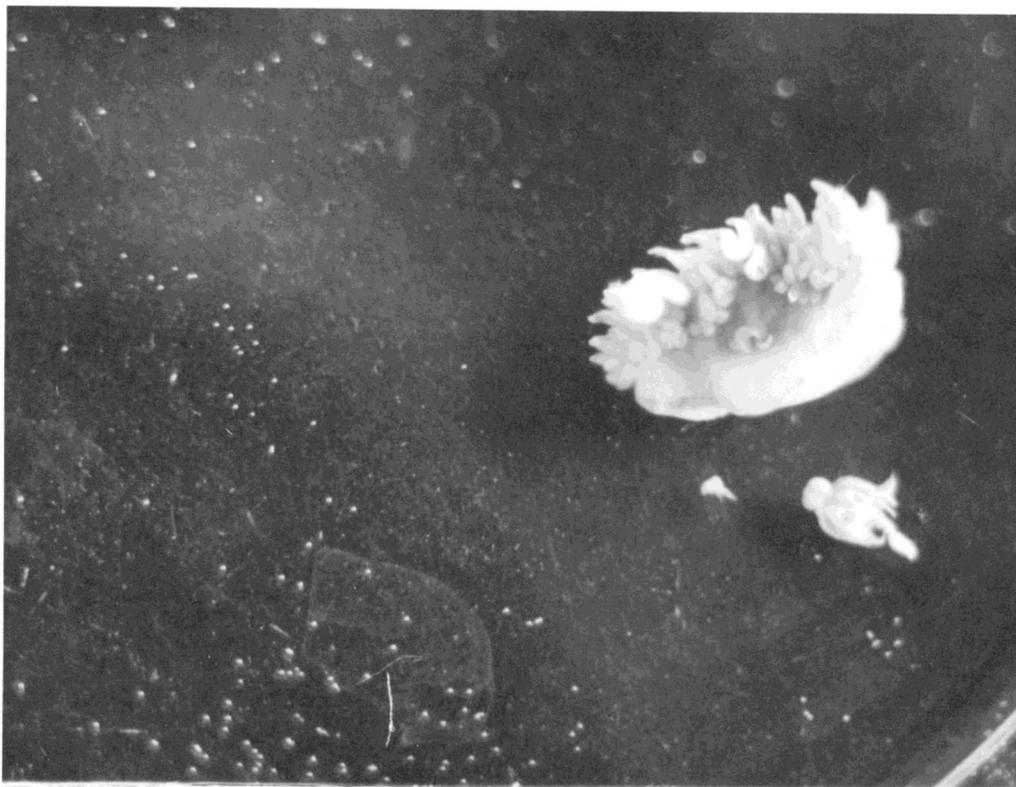


Figure 1: Side view of Antiopella fusca (O'Donoghue 1924) showing two pair of copepod egg cases among the cerata. The small male and larger female of Ismaila monstrosa var. pacifica n. var. can be seen below the host. Length of nudibranch 13 mm.

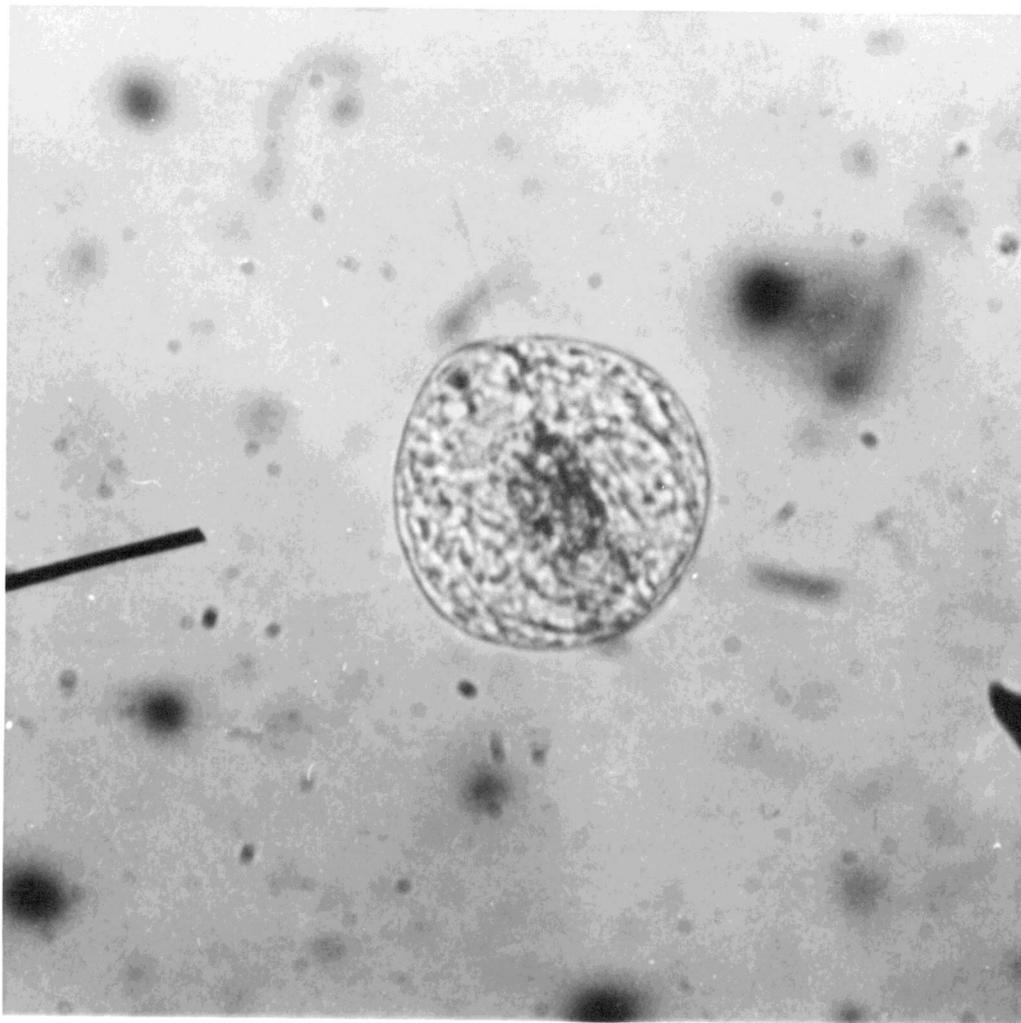


Figure 2: Developing nauplius in egg case. Diameter of egg 0.05 mm.

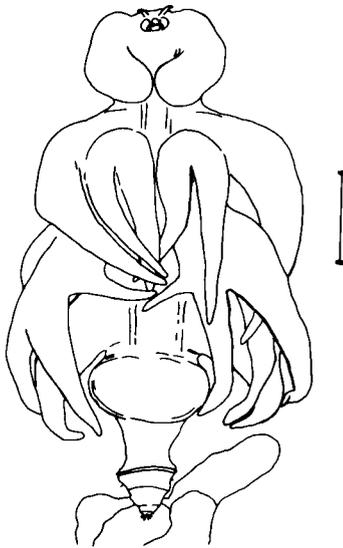


Figure 3: Female of Ismaila monstrosa var. pacifica ventral view, scale 1 mm.

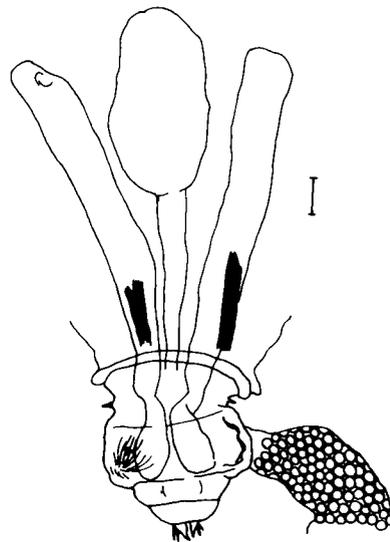


Figure 4: Lower abdomen of female showing cement glands to either side of the seminal receptacle, scale 0.1 mm.

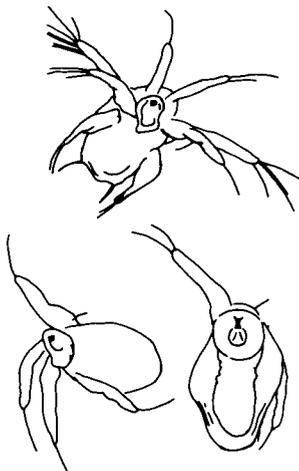


Figure 5: Nauplii, diagrammatic.

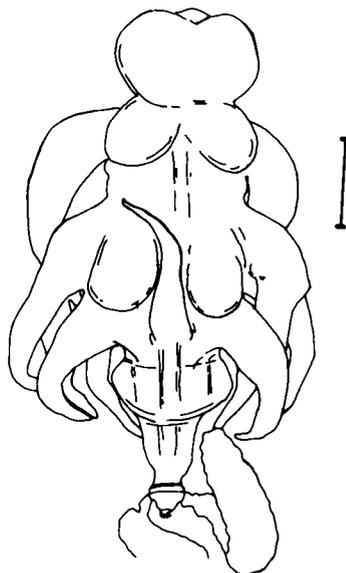


Figure 6: Female of Ismaila monstrosa var. pacifica, dorsal view scale 1 mm.

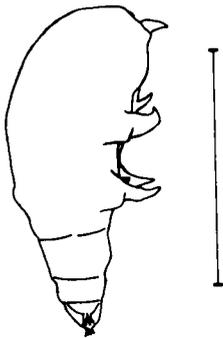


Figure 7: Young male of *Ismaila monstrosa* var. *pacifica*, lateral view, scale 1 mm.

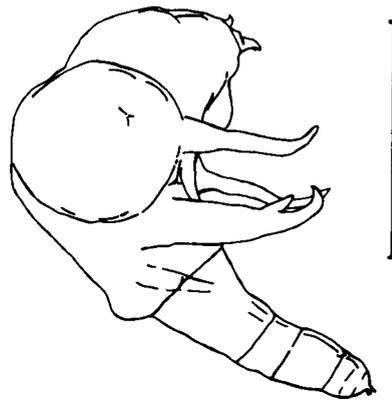


Figure 8: Adult male, lateral view, scale 1 mm.

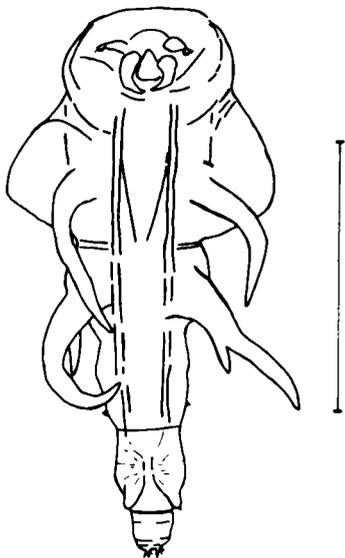


Figure 9: Adult male, ventral view, scale 1 mm.

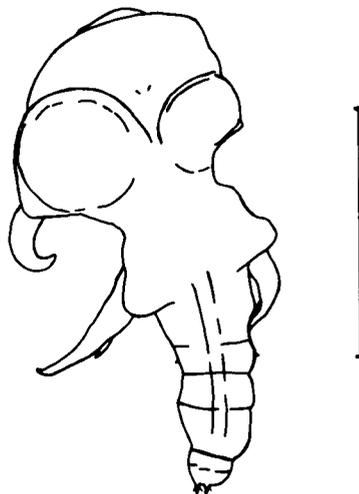


Figure 10: Adult male, dorsal view, scale 1 mm.

KEY TO THE FIGURES

- Figure 11: Appendages and mouthparts: A. First antenna; B. Second antenna; C. Mandible; D. Maxilla; Scale, 0.1 mm.
- Figure 12: Female mouthparts, scale, 0.1 mm.
- Figure 13: Composite drawing of male, muscle tracts in solid black; with incomplete digestive system and reproductive system.
- Figure 14: Cross sections of the male: A. Section through the head and second antennae; B. Section through the gonadal lobes; C. Section through lower abdomen and spermatophore; Scale, 0.1 mm.
- Figure 15: Cross sections of the female: A. Section through ovary; B. Section through upper abdomen; C. Section through lower abdomen and seminal receptacle; Scale, 0.1 mm.
- Figure 16: Male mouthparts, scale, 0.1 mm.
- Figure 17: Composite drawing of female, major muscle tracts in solid black; with incomplete digestive system and extensively branched reproductive system.

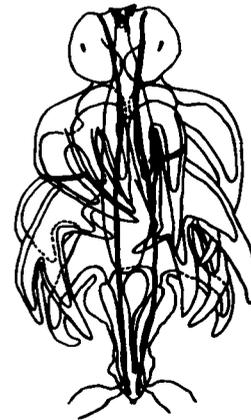
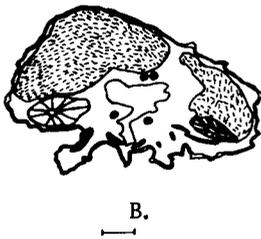
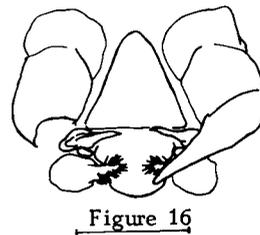
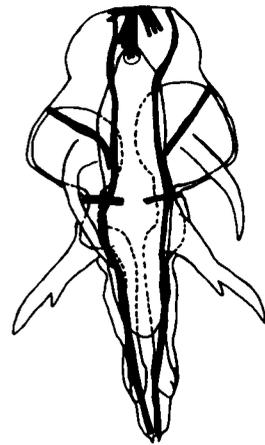
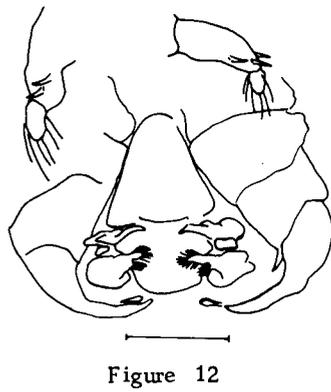
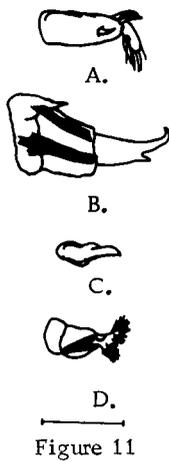


Figure 14

Figure 15

Figure 17

DATA

- 20 June 1963, Fossil Point near Empire, Oregon.
Three female Ismaila copepods (not in collection)
Ten female specimens.
- 23 June 1963, Fossil Point near Empire, Oregon.
One male Ismaila
One female Ismaila
- 4 July 1963, Small Boat Basin, Charleston, Oregon.
One female Ismaila
- 8 July 1963, Small Boat Basin, Charleston, Oregon.
Eleven males of Ismaila
Ten females of Ismaila
- 8 July 1963, Shell Island, North Cove, Cape Arago, Oregon.
One female specimen of Ismaila (not in collection)
- 24 July 1963, Small Boat Basin, Charleston, Oregon.
Two males of Ismaila
Six females of Ismaila
- 28 July 1963, Small Boat Basin, Charleston, Oregon.
Two females of Ismaila
One male Ismaila
- 30 July 1963, Small Boat Basin, Charleston, Oregon.
Thirty females of Ismaila
Eighteen males of Ismaila

Total:

Ninety-seven specimens of Ismaila observed
Eighty-three specimens in collection.

Number of females:

Sixty-four specimens

Number of males:

Thirty-two adult specimens plus one immature specimen

LIST OF OPISTHOBRANCHIA EXAMINED

Onchidiacea

Onchidellidae

Onchidella borealis Dall 1871

Cephalaspidea

Philinacea

Aglajidae

Aglaja diomedea (Bergh) 1893

Anaspidea

Aplysiidae

Dolabrifernae

Phyllaplysia zostericola McCauley 1960

Gymnosomata

Clionidae

Clione sp.

Sacoglossa

Elysiacea

Hermaeidae (Stiligeridae)

Hermaeina smithi Marcus 1961Alderia modesta (Loven) 1844

Notaspidea

Pleurobranchacea

Pleurobranchidae

Pleurobranchus sp.

Nudibranchia

Doridacea

Bathydorididae

Bathydoris sp.

Dorididae

Glossodoridinae

Cadlina marginata MacFarland 1905

Thorunninae

Rostanga pulchra MacFarland 1905

Archidoridinae

Archidoris montereyensis (Cooper) 1862

Discodoridinae

Anisodoris nobilis (MacFarland) 1905

Diaulula sandiegensis (Cooper) 1862
Discodoris heathi MacFarland 1905

Phanerobranchia

Nonsuctoria

Polyceridae

Laila cockerelli MacFarland 1905

Triophidae

Triopha carpenteri (Stearns) 1873

Suctoria

Onchidorididae

Acanthodoris nanaimoensis O'Donoghue 1921

Onchidoris bilamellata (Linnaeus) 1767

Porostomata

Dendronotacea

Tritoniidae

Tritonia festiva (Stearns) 1873

Tritonia exsulans Bergh 1894

Tritonia sp.

Tritoniopsis tetraquetra (Pallas) 1788

Dendronotidae

Dendronotus frondosus (Ascanius) 1774

Dotonidae

Doto columbiana O'Donoghue 1921

Arminacea

Euarminacea

Arminidae

Armina californica (Cooper) 1862

Pachygnatha

Dironidae

Dirona picta Cockerell & Eliot 1905

Dirona albolineata Cockerell & Eliot 1905

Antiopella fusca (O'Donoghue) 1924

Eolidacea

Pleuroprocta

Coryphellidae

Coryphella trilineata O'Donoghue 1921

Eolis sp.

Acleioprocta

Fionidae

Fiona pinnata Eschscholtz 1831

Cleiprocta

Facelinidae

Hermisenda crassicornis (Eschscholtz) 1831

Aeolidiidae

Aeolidia papillosa (Linnaeus) 1761