OBSERVATIONS ON THE DEVELOPMENT AND THE BIOLOGY OF THE MIRACIDAE DANA (COPEPODA: CRUSTACEA)[1]

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ABSTRACT

The stages of development obtained by rearing three species of Miracidae are described. An account of their movements and their reactions to light and to planktonts is also presented.

INTRODUCTION

Macrosetella gracilis (Dana), *Oculosetella gracilis* (Dana) and *Miracia efferata* Dana, pelagic marine harpacticoid copepods, occur in the tropical and subtropical regions of the oceans (Lang 1948 p. 772). *M. gracilis* was abundant in plankton samples taken from the pier of Piscadera Bay (Curaçao) in the Caribbean. It also occurs frequently in surface and in shallow waters off Brazil (Björnberg 1963) and in deep waters of the Atlantic (Moore & O'Berry 1957, Grice 1963). *O. gracilis* and *M. efferata* were found rarely, in small numbers, off Curaçao and in the South West Atlantic. Rearing experiments were tried with the three species at the Caribbean Marine Biological Institute. The results obtained and some observations on the reactions of the young and adult stages are here reported.

METHODS

Females of the three species were separated from freshly caught plankton samples. They have a brilliant blue coloration in waters of high salinity (36‰ or more) but can be easily distinguished from one another, when alive, by the following characteristics: *M. gracilis* and *O. gracilis* have pointed anterior regions when viewed dorsally and a bright orange coloured digestive tract; *M. efferata* has a square anterior region and no visible bright orange digestive tract: *O. gracilis* has eye lenses which are absent in *M. gracilis*. The females bearing egg-sacs were placed in covered glass vials of 30 ml capacity containing sea water. This was changed every six hours and at the same time the females were examined. Wet cloths wrapped around the glass vials kept the temperature of the water constantly below the ambient. The salinity of the water was ca. 36‰ and the temperature between 26° and 27°C. After hatching, the nauplii were kept in the same vials and the same routine was observed. The rearing of healthy larvae was greatly improved by the addition of small tufts of the blue-green filamentous alga

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Trichodesmium thiebauti (Gomont). The larvae that remained attached to the filaments developed well, but any that fell to the bottom of the vials died unless given the opportunity to reattach themselves by clutching at the tufts of algae placed nearby (Fig. 1).

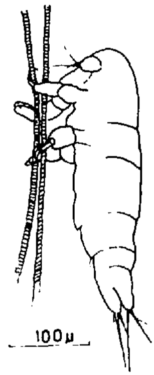

FIGURE 1. Nauplius of *Macrosetella gracilis* clasping filaments of *Trichodesmium thiebauti.*

THE STAGES OF DEVELOPMENT

The mating of *M. gracilis, O. gracilis* and *M. efferata* was not observed. The eggs are of a dark blue colour when just fertilized. As they ripen their colour changes to rose, or orange, and black in transmitted light.

Isolated females were very active for several days prior to hatching of the nauplii, after which they often died. Newly hatched nauplii remained on the egg sacs and their activity was easily observed. The nauplii took about 5 to 7 days to hatch. In *M. gracilis* they remained attached to the parent copepod for some time before fastening themselves to an algal filament by means of the hooks of their second and third appendages. The nauplii did not all hatch at the same time. Those at the distal end of the egg sac hatched first, and those at the proximal end hatched last of all. The same was observed for the other two species.

The first nauplius of *M. gracilis* is triangular in shape and has three pairs of appendages. The first pair has two segments with three long setae at the end of the distal segment and a smaller spine on the ventral medial aspect of the same segment. The second pair of appendages has three segments. The first bears a strong spine-like process, the second two spine-like processes and a seta, and the third has a terminal hook and seta. The third pair of appendages has three hook-like spines of which the most lateral ends as a long filament. Tre labrum has no special features. Ventrally the body of the larva has a row of microsetae and posteriorly two short spines. It is 0.12 to 0.15 mm long. The first nauplius of *M. efferata* (Fig. 3a) is usually bulkier than the corresponding stage of *M. gracilis*. It is 0.15 to 0.19

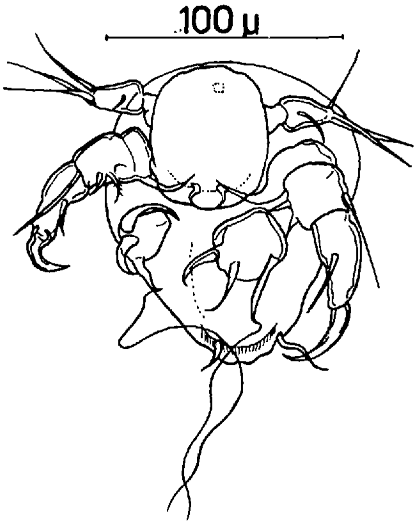

FIGURE 2. *Macrosetella gracilis*, ventral view of first nauplius.

mm long and, when alive, much darker than the nauplii of *M. gracilis* and *O. gracilis*. It has a large medium dark blue belt and below it a smaller orange coloured spot which is the stomach of the larva. Anteriorly there is a square black or dark red spot. Two round structures (the future eye-lenses) are observable just in front of it. The first appendages and the third are similar to those of *M. gracilis* in all the nauplius stages. The second

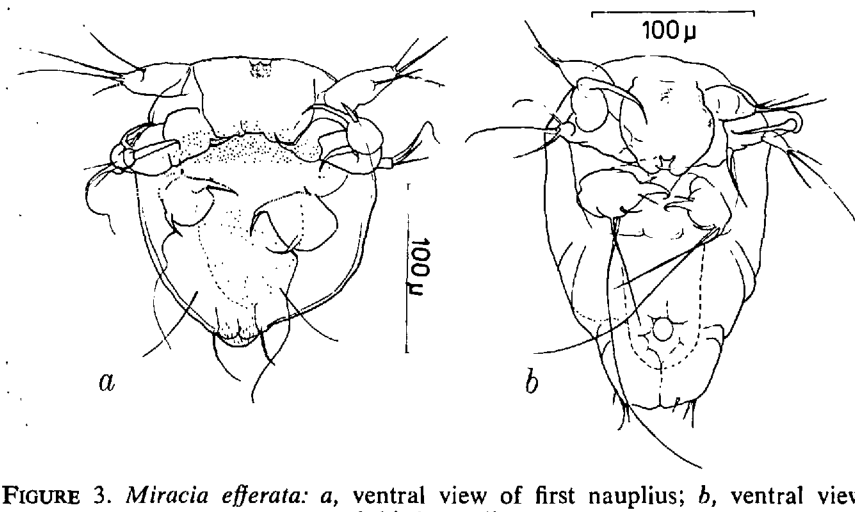

FIGURE 3. *Miracia efferata: a*, ventral view of first nauplius; *b*, ventral view of third nauplius.

appendages are different because they have a rudimentary exopod, composed of a segment and three terminal spines, which are missing in *M. gracilis* (compare Figs 3a and b with Figs. 4a and b). The nauplii of *M. gracilis* and *O. gracilis* also differ from the *Miracia* nauplii, because they are transparent except for the digestive tube which is of a bright orange colour, the black or dark red eye-spot and the dark spot in the middle of the body. In preserved material all these colours disappear. Then the nauplius of *M. efferata* can be identified by its more rounded shape, its bulk and the exopod of the antenna.

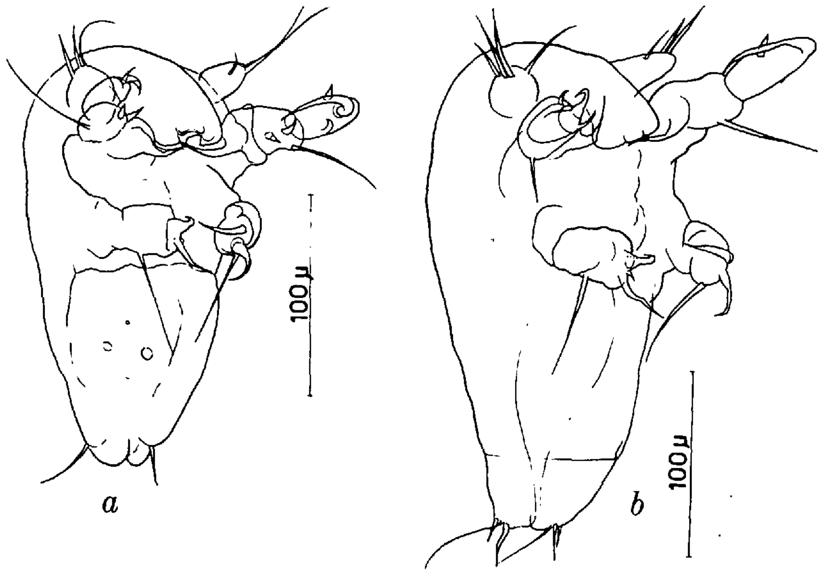

FIGURE. 4. *Macrosetella gracilis: a,* latero-ventral view of second nauplius; *b,* latero-ventral view of third nauplius.

The only change observable in the nauplii in subsequent stages is an increase in length of the caudal region (Figs. 4a and b) and in the segmentation of the body. The last naupliar stages of *M. gracilis* (0.35 mm long) and of *M. efferata* (0.38 mm long) have four body segments (Figs. 5a and b). The nauplius of *M. efferata* has two eye-lenses anteriorly, surrounded by dark pigment. The third naupliar stage (Figs. 3b and 4b) in both species has three pairs of spines on the terminal posterior region of the body. The last nauplius has four pairs of spines (Figs. 5a and b).

The nauplii of *M. gracilis* made slight waddling movements along the *Trichodesmium* filament to which they were attached. The nauplius of *M. efferata* also lived clasped onto clusters of debris in the plankton, but the substratum preferences of the nauplii of this species were not deter-

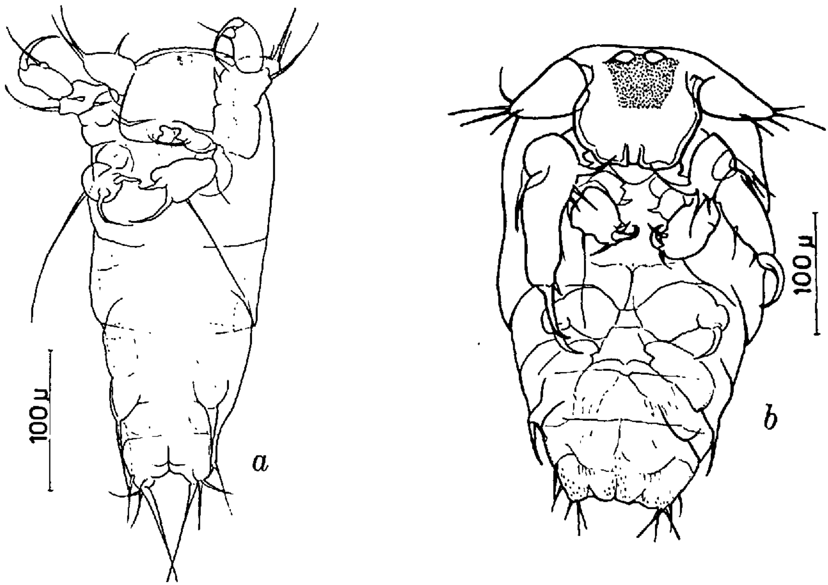

FIGURE 5. *a, Macrosetella gracilis,* last nauplius, ventral view; *b, Miracia efferata,* last nauplius, ventral view.

mined. Only one hatched nauplius of *O. gracilis* was obtained. It died and was lost during fixation.

The metamorphosis of *M. gracilis* was observed several times. The copepodid wriggled out of the nauplius shell which remained attached to the *Trichodesmium* filament.

The first copepodid of *M. gracilis* (Fig. 6), 0.48 mm long, has two pairs of swimming feet and a third rudimentary pair. It has five visible body segments and short bristles on the furcal rami. The second copepodid (0.575 mm long) has seven visible body segments (Fig. 7), three pairs of swimming feet and a fourth rudimentary pair. The two bristles on the furcal rami are as long as the body. The antennule has seven segments. The third copepodid is 0.775 mm long, with seven body segments, four pairs of swimming feet and a rudimentary fifth pair. One pair of bristles on the furcal rami are as long or longer than the body. The fourth copepodid (0.91 mm long) has nine body segments. The number of swimming feet is unaltered but the fifth pair of feet is more developed. The fifth copepodid stage is about 1.32 mm long and the fureal bristles are longer than the body. The next stage of development is the adult form. The fourth and fifth copepodid and the adult stages are blue coloured when alive and reared in high salinity water (36‰ or more). In coastal waters with low salinity (ca. 34‰) off Brazil the colour of the copepodids is a pale orange throughout.

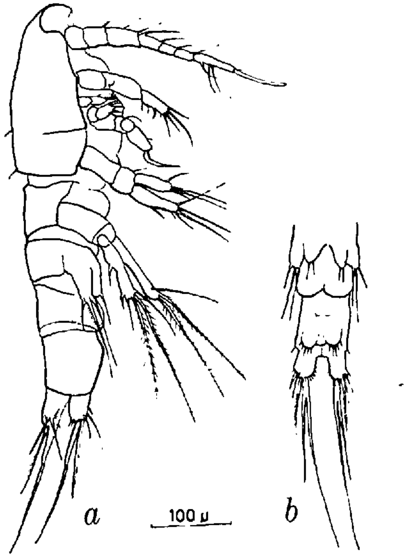

FIGURE 6. *Macrosetella gracilis: a,* lateral view, left appendages omitted; *b,* ventral view of furcal rami and third pair of feet.

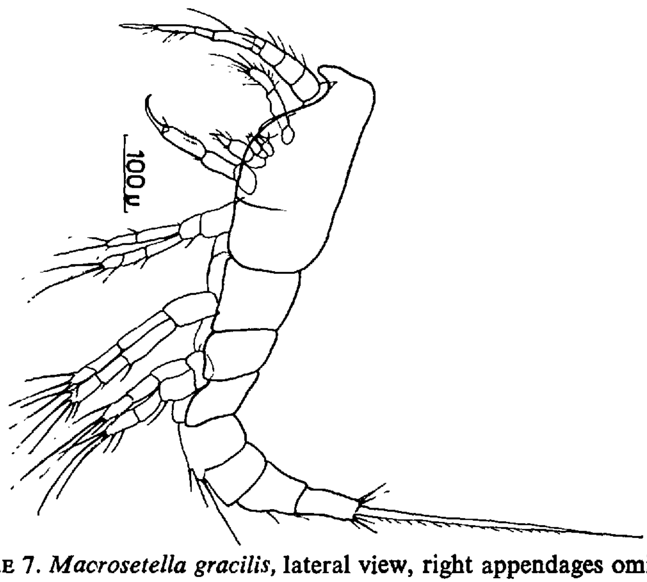

FIGURE 7. *Macrosetella gracilis,* lateral view, right appendages omitted.

M. efferata has a similar development. Only two of its copepodid stages were obtained. Rearing experiments usually failed. The copepodids of this species are immediately recognized in the plankton because of their strong colouring (blue-black) and their large frontal eye-lenses (Fig. 8a). They are easily distinguished from *Macrosetella* and *Oculosetella* copepodids because of their widened head region (thinner in the other two species), their

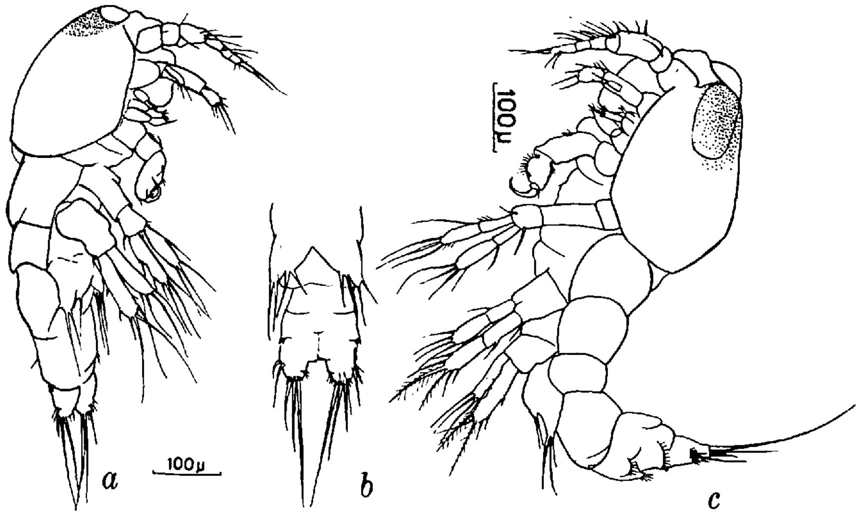

FIGURE 8. *Miracia efferata: a,* lateral view of first copepodid, some appendages omitted; *b,* ventral view of furcal rami and third pair of feet of first copepodid; *c,* lateral view of second copepodid, right appendages omitted.

strong bulky body and the antenna provided with endopod and exopod. The first copepodid of *M. efferata* is 0.6 mm long (Fig. 8a) and the second copepodid (Fig. 8c) is 0.65 mm long. Thus, the growth in length from the first to the second copepodid in this species is less (0.05 mm) relative to the growth of *M. gracilis,* which is of 0.075 mm from the first to the second copepodid.

BEHAVIOUR

M. gracilis from Caribbean waters showed several characteristic reactions while under laboratory observation: (1) the nauplii, copepodids and adult try to clasp any thin filament in the water with the hooks of the antennules and mandibles (in the nauplii) or hooks of the maxillae and maxillipeds (in the copepodids and adults); (2) the copepodids and adults swim slowly with ungraceful paddling movements of the podia when not attached to a filament; (3) when attached to a filament (usually the alga *Trichodesmium*), with strong paddle-like movements of each successive pair of swimming appendages, they glide forwards using the filament as a kind of sledge, while clasping it with the anterior hooks; (4) they usually move towards the lighted side of the aquarium; (5) they show a change of colour from light to deep blue and from pale to bright orange when kept in the dark (in shallow waters they are pale coloured and dark when taken from deep waters); (6) copepodids and adults bend over themselves and clean the maxillae and mandibles with brushing movements of the swimming feet; (7) they eat a filament of *Trichodesmium* slowly (as if sucking it in) whilst clasping other filaments alongside of the one being eaten.

The "filament clasping" reaction provides the animal with a mechanical support, with food, and also facilitates the encounter of males and females. Thus, a male was observed hooked onto the furcal setae of a female. Copepodids were also seen hooked onto each other or onto adults.

The cleaning movements of *M. gracilis* help it to avoid the accumulation of epibionts on its surface. Female *M. gracilis* carrying eggs were frequently found covered with epibionts of the *Zoothamnion type*. This probably occurred because they refrained from cleaning themselves when carrying eggs, probably to avoid detaching them.

Discussion

Reactions to light, eating, and changing of colour were also observed in many Calanoida and in Cyclopoida present in the plankton brought into the laboratory. The other reactions mentioned above were only observed in *Macrosetella* in the plankton samples examined. Calanoida are usually planktonic and have planktonic larvae. Cyclopoida, although not always planktonic when adult, also usually have planktonic or swimming nauplii, but the Harpacticoida are usually benthonic and have creeping larvae. The number of reactions which *M. gracilis* shows, can be interpreted as adaptive specializations enabling this harpacticoid to live, reproduce and develop in the plankton. Morphologically equipped to live in the benthos, *Macrosetella* has a creeping larva as the other harpacticoids and thus depends on the existence of a substratum where this larva can develop. In the Caribbean waters and off Brazil, one of the substrata observed is the planktonic blue-green alga *Trichodesmium,* usually present in most tropical and subtropical waters where *Macrosetella* also occurs. Off the south of Brazil, in coastal and in shelf waters, when tufts of *Trichodesmium* were found in the plankton, nauplii of *Macrosetella* were often found hooked onto them. Off Brazil and off Curaçao the nauplii were found only on this alga. Adult and copepodid stages of *Macrosetella* also occur in the plankton where no *Trichodesmium* is found. It is therefore possible that *Macrosetella* may use other substrata as well. Apparently it is specifically attracted to *Trichodesmium* during its naupliar stages.

There is strong evidence that *Trichodesmium* is capable of nitrogen fixation in impoverished waters and it is abundant when other phytoplanktons are at their seasonal minima (Dugdale *et al,* 1961). If *Macrosetella* not only eats, but also digests and absorbs *Trichodesmium,* it is an important second link in the food chain of impoverished tropical waters.

SUMARIO

OBSERVACIONES DEL DESARROLLO Y LA BIOLOGÍA DE LOS MIRACIDAE DANA (Copepoda: Crustacea)

Se presenta un estudio comparativo del desarrollo de tres copépodos harpacticoideos *Macrosetella gracilis, Oculosetella gracilis* y *Miracia efferata* obtenidos en el laboratorio a partir de hembras ovadas. Las tres especies ocurren en aguas tropicales y subtropicales del Atlántico y del Caribe. La especie más numerosa y frecuente es *M. gracilis.* Las reacciones de *M. gracilis* en cautiverio fueron observadas y discutidas. En especial se notó el uso que hace su nauplio del filamento de una alga *Trichodesmium* como substrato donde realiza su desarrollo.

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REFERENCES

BJÖRNBERG, T. K. S.
1963. On the marine free-living copepods off Brazil. Bolm. Inst. Oceanogr. São Paulo, *12* (1): 3-142.

GRICE, G. D.
1963. Deep water copepods from the Western North Atlantic with notes on five species. Bull. mar. Sci. Gulf & Carib., *13* (4): 493-501.

DUGDALE, R. C., D. W. MENZEL, AND J. H. RYTHER
1961. Nitrogen fixation in the Sargasso Sea. (In Letters to the Editors.) Deep-Sea Res., *7* (4): 297-299.

LANG, K.
1948. Monographie der Harpacticiden. I. Stockholm. A. B. Nordiska Bokhandeln, 896 pp.

MOORE, H. B. AND D. L. O'BERRY
1957. Plankton of the Florida Current. IV. Factors influencing the vertical distribution of some common copepods. Bull. mar. Sci. Gulf & Carib., *7* (4): 297-315.