The Biology of a Harpacticoid Copepod, *Harpacticus uniremis* Kröyer[1)2)]

By

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(*With 14 Text-figures and 1 Plate*)

The taxonomic status within the genus *Harpacticus* Milne-Edwards as well as *Zaus* Goodsir, both belonging to the family Harpacticidae, Harpacticoida, seems to be rather complex. The particular confusion within the former genus was already discussed by Lang (1965), especially on *H. septentrionalis*, *H. uniremis* and *H. chelifer* var. *arcticus* reported by several authors. Such troublesome species have been distinguished by rather minor characteristics from each other, and it makes the interspecific treatment difficult. Apparently the confusion, at least in some of these species, is due to the poor descriptions and further to the marked individual variation which is frequently present within a species. For giving a solution for the confused taxonomy of the genus, minute biological study as well as careful redescription of incompletely described species is now necessary.

Up to the present, *Harpacticus uniremis* Kröyer has been successively reported from various marine littorals (see Lang, 1948, 1965). Although the species is widely distributed in the north Pacific, the biological aspects still remain almost ignored. We have only a brief report of Brian (1919) on the nauplius and copepodid stages.

The present paper deals with the biology of *Harpacticus uniremis* from Hokkaido, and especially the morphology of all successive copepodid stages is fully described and illustrated in detail. And those will be compared with the biology of *Tigriopus japonicus* Mori in the same Harpacticidae, which was studied by the author on the material from the same locality as the present species.

All the material was collected by net sweeping, algal rinsing or plankton sampling from Oshoro Bay near Otaru, on the Japan Sea coast of Hokkaido. Some of them were reared in small glass vessels under a constant lower temperature (about 5°C) without aeration. A little amount of yeast was weekly given to them as nutrition. Another material was preserved in 70 per cent. alcohol. For making total slide preparations, material was treated and dissected in glycerin-alcohol solution, and mounted with Neo-Shigaral medium.

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1) Contribution No. 913 from the Zoological Institute, Faculty of Science, Hokkaido University, Sapporo, Japan.

2) Studies on marine harpacticoid copepods from Hokkaido, IV.

Unless otherwise noticed the body length was measured from anterior edge of cephalothoracic segment, rostrum excluded, to the posterior end of furcal ramus. Details are referred to the previous paper (Itô, 1970).

Before going further the author wishes to express his sincere gratitude to Prof. Mayumi Yamada of Hokkaido University, for his kind guidance and critical reading of the manuscript.

1. Ecology

The author had sampled the littoral harpacticoid copepods in several occasions in Oshoro for about four years, not periodically. In the course of studying the samples, it was noticed that the specimens of *Harpacticus uniremis* were found in certain samples which were collected in winter or early spring; for example, in 1969, 9th, March (+++), 14th, June (—) and 18th, December (+); in 1970, 4th, September (—) and 4th, November (—), all examined from the sample by algal rinsings. Then, the author attempted to study the fluctuation of the population with exact period of the appearance of the species.

Subquantitative samples studied were monthly obtained by net sweepings. The plankton net used is 30 cm. in mouth diameter and 70 cm. in overall length. The mesh is in conformity with the Japanese standard No. XX13. The net with a rope of 5 m. in length was thrown from near shore about 1 m. in depth, and gently towed to hand. Such net sweepings were repeated five times in each occasion. For determining the environmental condition, water temperature was recorded. All samplings were carried out at mid day.

1.1. *Result of the subquantitative study and the related observations.*

The results obtained from December 1970 to April 1971 are shown in Fig. 1. The lowest temperature was recorded in February (3.7°C). The population increased *gradually* according as the temperature decreased, and *acutely* according as increasing at early spring. The maximum population was recorded in March and towards the subsequent month the population became acutely decreased. Adult females were remarkably abundant within the population, more than four times as much as males. It is supposed that the active reproductive period in Oshoro lasts about four months from mid winter to early spring. The ovigerous females were relatively abundant in March. An egg sac contained 229 eggs in mean, 35.4 in standard deviation, in 10 egg sacs examined.

Many individuals of the species were also found near the shore among algae, mostly *Sargassum* sp. and *Nemacystus decipines* Kuckuck, etc. Particularly *Sargassum* sp. harbours not only many individuals of the present species but also those of other various harpacticoids.

1.2. *Remarks.*

Although a number of records of the species have been so far reported from different districts (see Lang, 1948), none of them is concerned in the species which

appears restricted within a certain season. It is quite unknown in what condition the species of Oshoro passes the another seasons, summer and autumn. As the author has studied only near shore and near surface, a thorough study spread to wider range will be necessary.

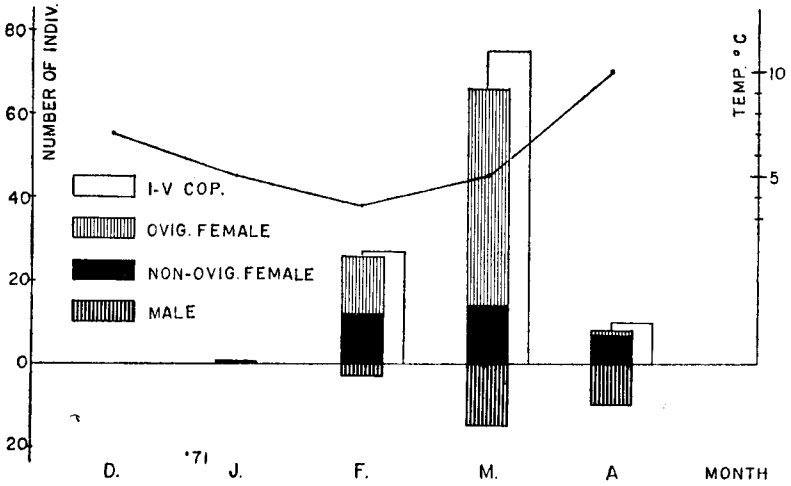

Fig. 1. The occurrence of *Harpacticus uniremis* in Oshoro from December 1969 to April 1970.

2. Ethology

The mating behaviour seems to be almost identical with that in *Tigriopus japonicus* reported by Itô (1970). The anterior partners in pairing were mainly the fifth copepodids with the distinct structure as female. The result from 20 pairs examined is as follows; 15 fifth and four fourth copepodid females, and one third copepodid of sex unknown. The feeding behaviour handling both antennae is alike to that of *Tigriopus japonicus*.

They were occasionally fed a small amount of yeast and reared for more than two months in a small vessel. They apparently took the yeast given. It is evident that they get various different kinds of food source other than yeast, not only of vegetable but also of animal, because some pieces of broken diatoms (Pl. XI, Fig. 2) and, moreover, antennal gnathobase and mandible of nauplii were found in the faeces (Pl. XI, Fig. 1).

3. Morphology of successive copepodid stages

The present species has exactly six successive copepodid stages, and the oral appendages seem to be completed already in the first stage as in the other harpacticoids.

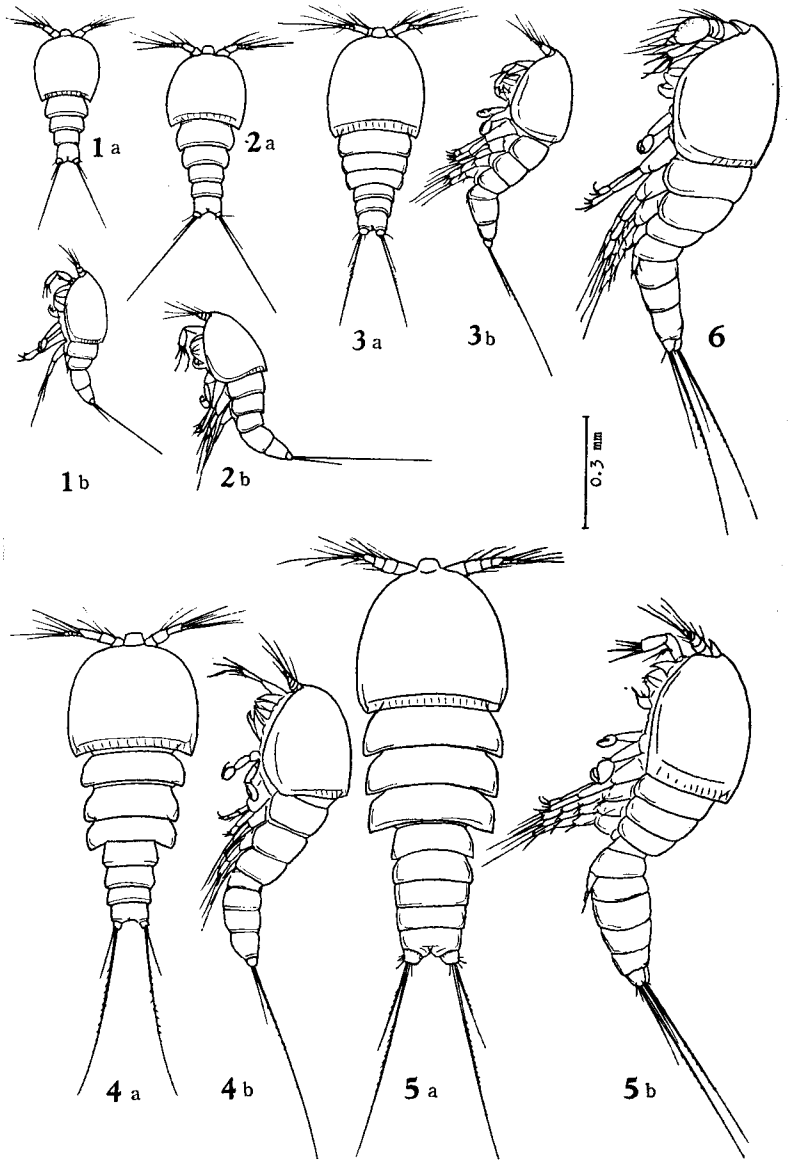

Fig. 2. 1. The first copepodid; 2. The second copepodid; 3. The third copepodid; 4. The fourth copepodid female; 5. The fifth copepodid female; 6. The fifth copepodid male.

The periodical succession through all stages is not described in the present paper. It will be reported and discussed in a further paper.

In the following description, the author admits that some minor structures, rostral hair and spinular arrangement of maxillipede, may have been left undetected in spite of his careful observation.

3.1. *The first copepodid stage*

Body (Fig. 2–1) 0.35 mm. in length, five-segmented. Cephalothoracic segment a little longer than three succeeding segments combined; fourth one bare; fifth (anal) one (Fig. 3–6) furnished with some spinules transversely near posterior end of ventral surface. Furcal ramus a little shorter than greatest width; outer posterior end slightly projected; outer edge with three delicate setae and several spinules; distal end with two long setae fused basally, accompanied with several spinules and one delicate seta; one delicate seta on middle inner edge. Rostrum (Fig. 3–1) square in shape with two pairs of hairs. *Antennule* (Fig. 3–1) six-segmented, remarkably tapering distally; apical two segments thicker than others, and with a couple of one spinulose and one bare setae on anterior edge; second one furnished with one aesthetasc-like seta accompanied with a bare seta; fourth one shortest, with only one short seta on posterior edge; sixth one a little longer than fifth. *Antenna* (Fig. 3–2). Allobasis, about two times as long as coxa, with one short hairy seta on middle anterior edge. Exopodite two-segmented; first segment with two setae, proximal one very small; second one slightly tapering apically, with two marginal hairy setae, and two bare setae and a spinule on distal end. Endopodite with a spinule and two spines along anterior edge; one spine, three geniculate spines, a bare slender seta and some spinules on distal end. *Maxillipede* (Fig. 3–3). Coxa about as long as width. Basis about two times as long as coxa, with two groups of spinules on inner edge. First endopodite-segment about as long as basis with an oblique spinular row on inner middle edge.

Leg 1 (Fig. 3–4). Suture between coxa and basis indistinct. Outer subdistal edge of coxa apparently rounded, and with several well-developed spinules. Basis much shorter than coxa, furnished with one thick spinulose outer seta accompanied with very minute spinules along base; inner half of distal edge spinulose. Exopodite one-segmented, oval in shape, with two groups of spinules on subproximal outer edge, two setulae along outer edge, and four claws, longest one geniculate, on distal end; inner margin smooth. Endopodite one-segmented, about as long as exopodite, but remarkably slender in appearance, with four groups of spinules along outer edge, two thick short setae and one hairy seta on distal end, and two hairy setae on subdistal and middle inner edges. *Leg 2* (Fig. 3–5). Segmentation as in leg 1. Coxa with a transverse spinular row on subproximal outer edge. Outer seta of basis short and bare, accompanied with several minute spinules basally. Exopodite about as long as basal two segments combined, with three outer spines, two well-developed terminal setae, outer one of which spiniform, and one hairy inner seta on subdistal edge. Endopodite a little shorter than

exopodite, geniculate at middle outer edge, with several spinules along outer margin, one short outer spine on subdistal corner, two hairy terminal setae, and one hairy inner seta on subdistal edge. *Leg 3* (Fig. 3–6) represented by a slightly produced plate, of which inner distal corner minutely pointed out, with two spines and one bare seta.

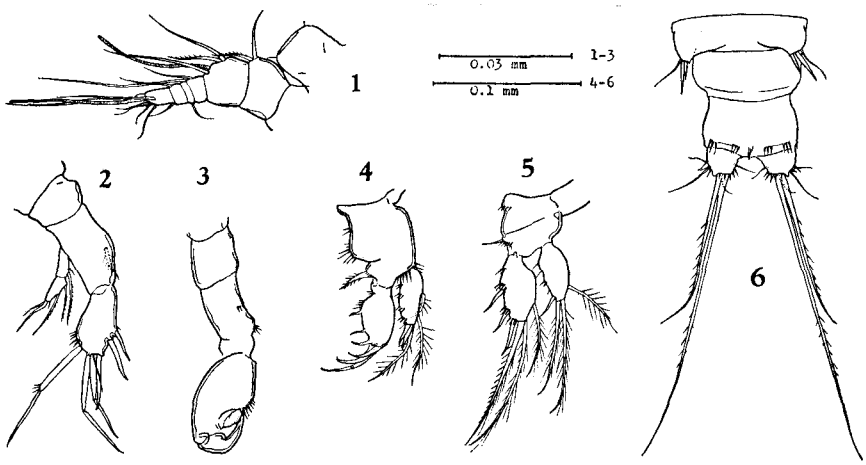

Fig. 3. The first copepodid. 1. Rostrum and antennule; 2. Antenna; 3. Maxillipede; 4. Leg 1; 5. Leg 2; 6. Leg 3 and abdomen.

3.2. *The second copepodid stage.*

Body (Fig. 2–2) 0.45 mm. in length, six-segmented. Fifth segment bare; last one with some spinules along ventral and lateral edges of posterior end. Rostrum (Fig. 4–1) more rounded apically. Terminal setae of furcal ramus distinctly separated from each other. *Antennule* (Fig. 4–1) seven-segmented, with no spinulose seta; first segment with only one bare seta on anterior edge and several spinules; second one a little longer than first, with a distinct aesthetasc. Allobasis of *antenna* (Fig. 4–2) more than three times as long as coxa, with one hairy seta on about two-thirds of anterior edge. Terminal thicker seta of second exopodite-segment with a distinct long hair on middle edge. *Maxillipede* (Fig. 4–3). First endopodite-segment with more a transverse spinular row on subproximal outer edge.

Leg 1 (Fig. 4–4). Basis furnished with one short spinulose inner seta on distal corner as in adult, and with some spinules along inner margin. Both rami two-segmented. Exopodite a little longer than coxa and basis combined; first segment with one short hairy outer seta subdistally; second one much shorter than first, tapering apically, with two outer spines and three terminal claws. Endopodite

a little shorter and slenderer than exopodite; first segment with one long plumose inner seta on subdistal edge, some spinules along both margins and near outer distal edge; second one small, with two terminal claws accompanied with one bare delicate seta, and a longitudinal spinular row near outer margin. *Leg 2* (Fig. 4–5). Coxa and basis almost same as in preceding stage. Both rami two-segmented. Exopodite much longer than coxa and basis combined; first segment widened distally, with one outer spine; second one a little longer than first, with two outer spines, two terminal setae and one inner seta on subdistal edge. Endopodite a little shorter and slenderer than exopodite; first segment forming a small spinous projection at outer distal corner, with one inner seta; second one with one outer spine on subdistal corner, two terminal setae and two inner setae. *Leg 3* (Fig. 4–6) almost as in leg 2 of preceding stage, but basis with one slender outer seta, and both rami rather slenderer in appearance. *Leg 4* (Fig. 4–7) as in leg 3 of preceding stage, but both legs apparently confluent basally.

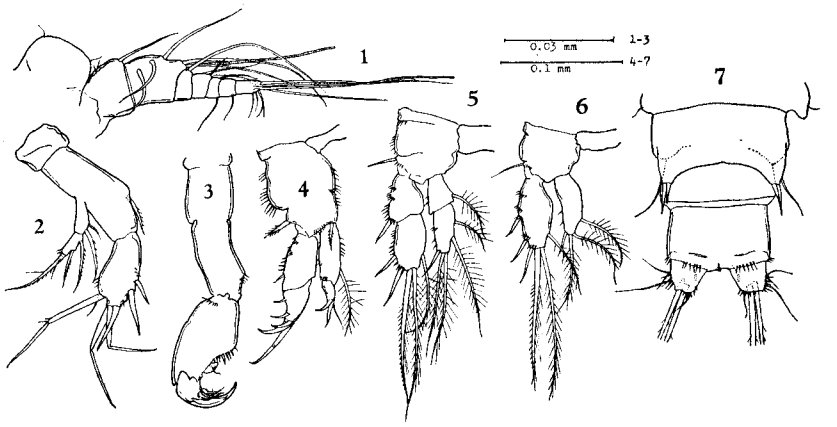

Fig. 4. The second copepodid. 1. Rostrum and antennule; 2. Antenna; 3. Maxillipede; 4. Leg 1; 5. Leg 2; 6. Leg 3; 7. Leg 4 and abdomen.

3.3. *The third copepodid stage.*

Body (Fig. 2–3) 0.55 mm. in length, seven-segmented; sixth segment bare. A pair of hairs on surface of rostrum (Fig. 5–1) was not detected. Anal segment with a pair of hairs on dorsal surface near operculum. *Antennule* (Fig. 5–1) seven-segmented; second segment about 1.5 times as long as first. *Antenna* (Fig. 5–2) as shown in the figure. Basis of *maxillipede* (Fig. 5–3) with one short bare seta on subdistal edge.

Leg 1 (Fig. 5–4). Coxa and basis distinctly separated by a suture from each other. Both rami almost same as in preceding stage. *Leg 2* (Fig. 5–5). Outer seta of basis distinctly spinulose. Exopodite; first segment with one short hairy

inner seta; one outer spine and one inner seta added on second one. Endopodite almost same as in preceding stage. *Leg 3* (Fig. 5–6). Both rami two-segmented. Exopodite; first segment with one outer spine; second one with two outer spines, two terminal setae, and two inner setae; both segments with many spinules along outer margin. Endopodite a little smaller than exopodite; first segment with one inner seta; second one with one outer spine on subdistal corner, two terminal setae and two inner marginal setae; both segments with several spinules sparsely along outer margin. *Leg 4* (Fig. 5–7) almost same as in leg 3 of preceding stage. *Leg 5* (Fig. 5–8) represented by a protuberance with only one bare slender seta on outer distal corner.

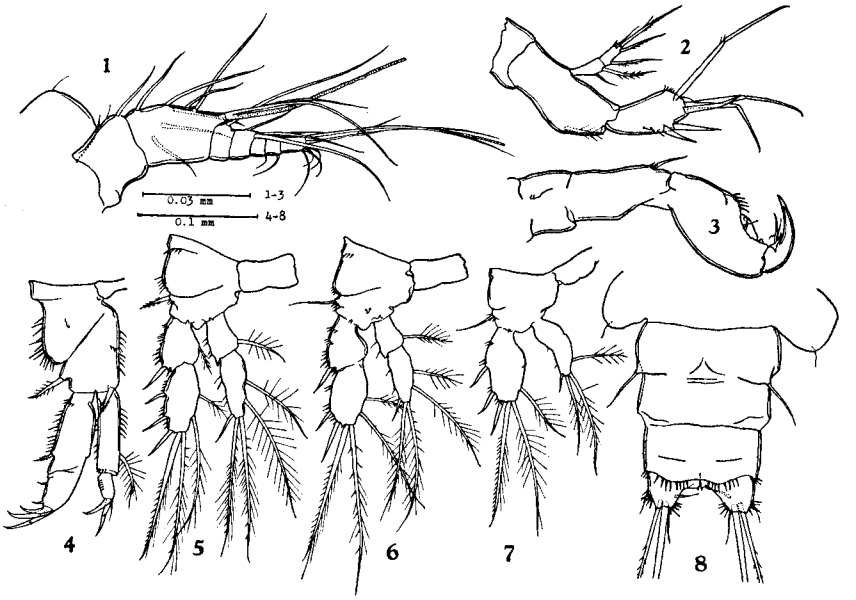

Fig. 5. The third copepodid. 1. Rostrum and antennule; 2. Antenna; 3. Maxillipede; 4. Leg 1; 5. Leg 2; 6. Leg 3; 7. Leg 4; 8. Leg 5 and abdomen.

3.4. *The fourth copepodid stage.*

Female. Body (Fig. 2–4) eight-segmented; sixth segment with a delicate hair on lateral hind edge; seventh one without spinules or hairs. *Antennule* (Fig. 6–1) eight-segmented; second segment a little shorter than first; third one about 1.5 times as long as second, with many setae along anterior edge, aesthetasc about two times as long as apical five segments combined. *Antenna* (Fig. 6–2). More one long geniculate spine added on distal end of endopodite. *Maxillipede* (Fig. 6–3). Basis with a transverse spinular row near inner seta.

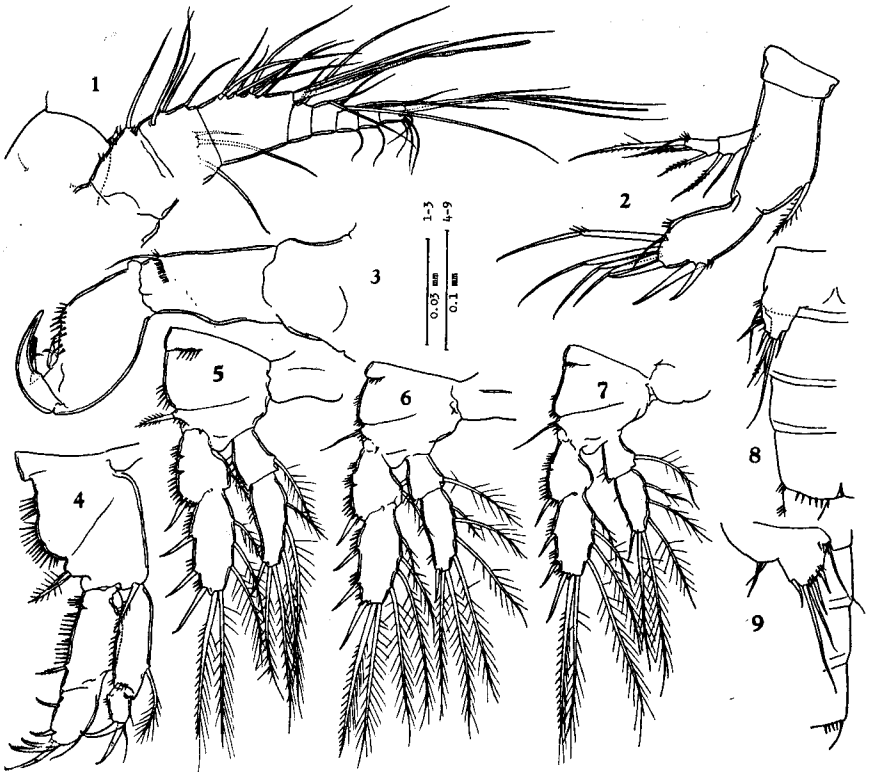

Fig. 6. The fourth copepodid. (♀) 1. Rostrum and antennule; 2. Antenna; 3. Maxillipede; 4. Leg 1; 5. Leg 2; 6. Leg 3; 7. Leg 4; (♂) 8. Leg 5 and abdomen. (♀) 9. Leg 5 and abdomen.

Leg 1 (Fig. 6–4). One short bare seta added on each inner edge of second segment of both rami. Outer margin of second endopodite-segment with two groups of spinules. *Leg 2* (Fig. 6–5). One relatively short seta added on each inner edge of second segment of both rami. *Leg 3* (Fig. 6–6). Exopodite; one inner seta added on first segment; one outer spine and two inner setae, proximal one short, on second segment. Two inner setae added on second endopodite-segment. All setae hairy. *Leg 4* (Fig. 6–7). Both rami two-segmented. Exopodite; first segment with one outer spine; second one a little longer than first with three outer spines, two terminal setae and four inner seta. Endopodite shorter than exopodite; first segment with one inner seta; second one with one outer spine on subdistal corner, two terminal setae and three inner setae. *Leg 5* (Fig. 6–9) represented by a broad bilobate plate; inner lobe (inner expansion of basoendopodite) with two bare setae and small spiniform protuberance; outer lobe

(exopodite) with one spiniform seta on inner subdistal corner, two long setae on distal end, and two short setae accompanied with several spinules along outer edge; one bare slender outer seta (outer seta of basoendopodite).

Male. *Leg 5* (Fig. 6–8) represented by a plate with one short bare inner seta, two terminal setae, of which inner one long, attaining to posterior end of seventh body segment and outer one relatively short and hairy, two short bare outer setae along edge, and one slender outer seta near base.

3.5. *The fifth copepodid stage.*

Female. Body (Fig. 2–5) nine-segmented, 0.9 mm. in length. Sixth and seventh segments with some spinules on each lateral hind surface; eighth segment bare. The pair of hairs on the surface of rostrum (Fig. 7–1) was not detected. *Antennule* (Fig. 6–1 and 2) nine-segmented; fourth segment with one aesthetasc. One delicate seta added on distal end of endopodite of *antenna* (Fig. 7–2). *Maxillipede* (Fig. 7–3) as in the adult except for several spinular rows on basis.

Leg 1 (Fig. 7–5). Coxa and basis almost same as in preceding stage. Both rami three-segmented, but juncture between apical two segments indistinct. All setal and spinal arrangements as in adult. *Leg 2* (Fig. 7–6), *leg 3* (Fig. 7–7) and *leg 4* (Fig. 7–8) almost same as in adult in segmentation and setal and spinal arrangement. But the appearance is rather stumpy than in the adult. *Leg 5* (Fig. 7–9). Juncture between exopodite and basoendopodite rather indistinct. Basoendopodite with four bare short setae on inner expansion.

Male. Body (Fig. 2–6) as long as in female; sixth and eighth segments ornamented as in female, but seventh one with a transverse spinular row on ventral surface near posterior end. Rostrum (Fig. 8–1) as in adult. *Antennule* (Fig. 8–1) eight-segmented, very stumpy in appearance. Distal three segments remarkably small. Third segment furnished with many setae and one strong aesthetasc; posterior distal end of fifth one with two spinous formations.

Leg 2 (Fig. 8–2). Exopodite as in female. Endopodite; outer distal part of second segment modified into a strong mucroniform process, one hairy seta on inner distal edge; third segment about as in female. *Leg 3* (Fig. 8–3) with broad exopodite as in adult male. Distal edge of intercoxal plate in *leg 4* (Fig. 8–4) scarecely concaved. *Leg 5* (Fig. 8–5). Basoendopodite and exopodite clearly distinguished from each other.

3.6. *The sixth copepodid* (*The adult*).

a. *Additional redescription.*

Cephalothorax in male a little flatter than in female as shown in the figures (Figs. 13–7 and 8). Cephalothoracic and thoracic carapaces furnished with several hairs arising from small pit (Pl. XI, Fig. 3). Rostrum in both sexes without a pair of sensory setae as hitherto recognized, but with three pairs of setae or hairs; a pair of long delicate hairs between usually recognized setae on anterior edge and moreover a pair of short setae, each rising from a small superficial

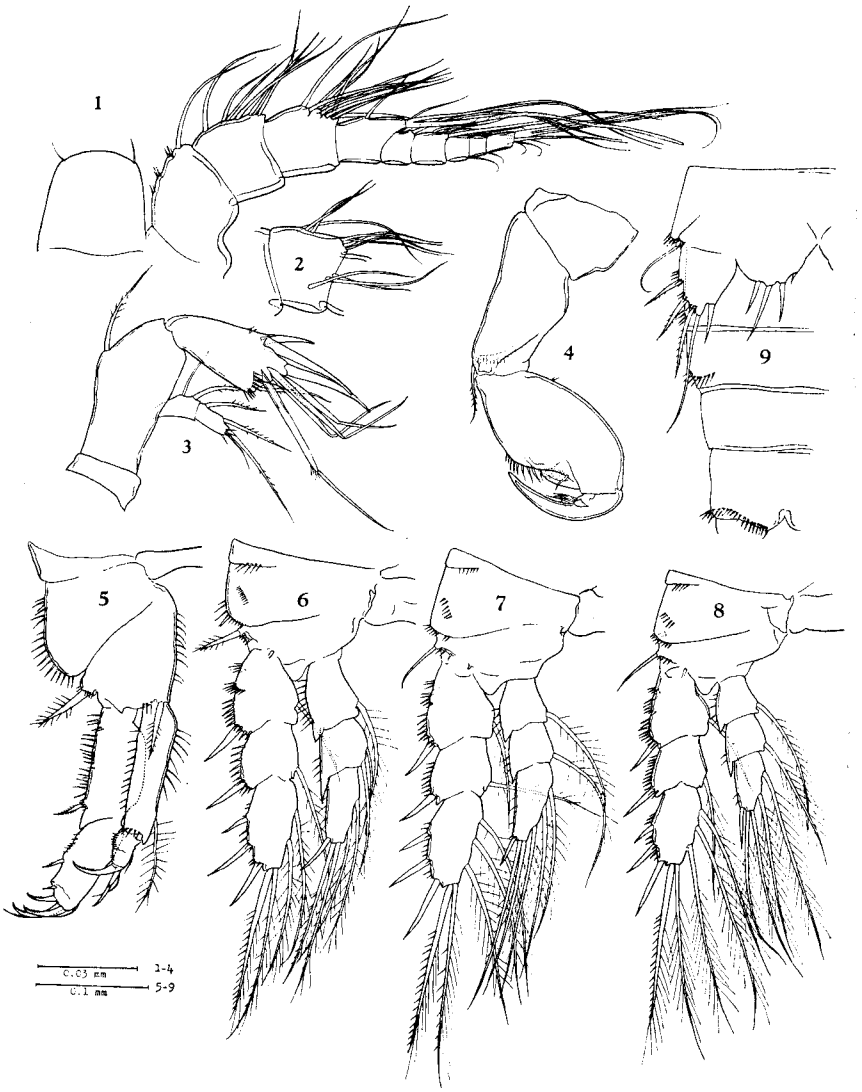

Fig. 7. The sixth copepodid. (♀) 1. Rostrum and antennule; 2. The second segment of antennule; 3. Antenna; 4. Maxillipede; 5. Leg 1; 6. Leg 2; 7. Leg 3; 7. Leg 4; 9. Leg 5 and abdomen.

concavity of middle surface, present. The delicate hairs are very difficult to detect even in careful observation at high magnification of microscope. The abdominal structure in the female entirely coincides with the descripition and

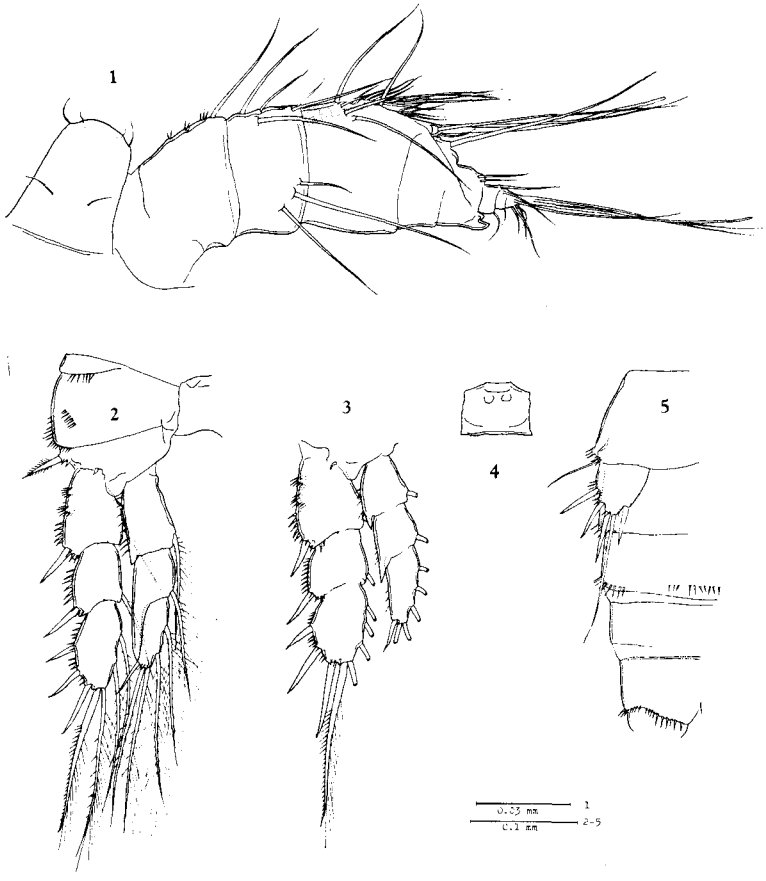

Fig. 8. The sixth copepodid. (♂) 1. Rostrum and antennule; 2. Leg 2; 3. Leg 3; 4. Intercoxal plate of leg 4; 5. Leg 5 and abdomen.

figures of Lang (1965). The abdomen in the male is as shown in the figure (Fig. 13–6), anterior two segments with a transverse row of spinules along each ventral edge. The fourth free thoracic segment with the leg 5 in both sexes bears an oblique spinular row on each ventro-lateral surface. A unique hanger-shape structure (Fig. 9–2), which was usually accompanied with the intercoxal plate, was observed in the preparation of isolated legs. This hanger-shape structure is not so-called intercoxal plate, but chitinous ventro-posterior ridge of certain body segments. In the present material, such structure was found only on the cephalothorax and three succeeding free thoracic segments. The situation of the structure in the two proximal body segments is shown in ventral view schematically (Fig. 9–1, indicated by arrows). Several authors have apparently confounded

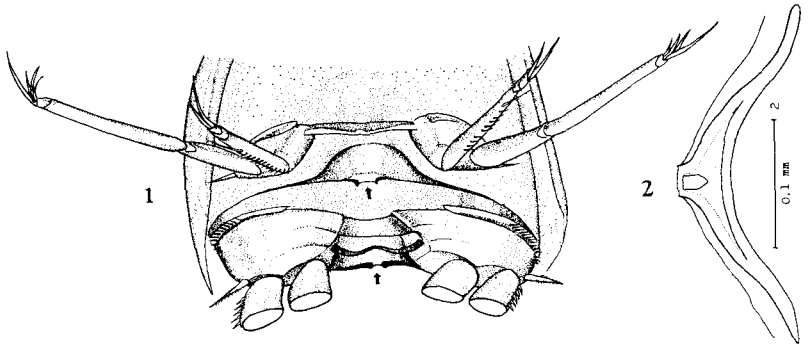

Fig. 9. The adult. 1. Ventral view of two apical body segments (♂). The hanger-shape structure indicated by arrows. 2. The hanger-shape structure of the second free thoracic segment.

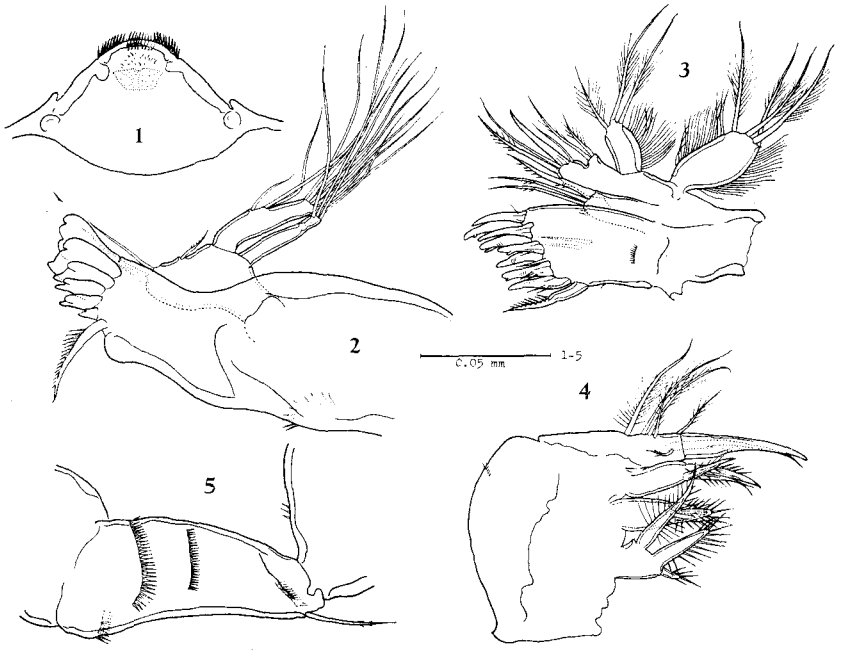

Fig. 10. The adult. 1. ♀, Labrum; 2. ♀, Mandible; 3. ♀, Maxillula; 4. ♀, Maxilla; 5. ♀, Basis of maxillipede.

such structure with so-called intercoxal plate. The structure described has been also reported as the intercoxal plate in *Acrenhidrosoma karlingi* by Lang (1965). *Labrum* (Fig. 10–1) with considerably chitinous ridge; apical margin and subapical posterior surface spinulose. *Mandible* (Fig. 10–2). Praecoxa with an arched row of slender spinules on middle dorsal edge obliquely; cutting edge furnished with strong tridentate pars incisiva, broad lacinia mobilis, four modified spines and one spinulose thick seta. Coxa-basis with three bare setae on distal end and one hairy short seta directed ventrally on subdistal edge. Endopodite one-segmented, about four times as long as greatest width, with one short and two long juxtaposed seta on middle inner margin, and seven long setae on distal end. Exopodite indistinctly two-segmented, a little longer than endopodite-segment; first segment about three times as long as second, and with one distal seta; second one with one subdistal inner and two terminal setae. All setae on both rami bare and slender. *Maxillula* (Fig. 10–3). Arthrite of praecoxa well-developed, with one arched row of delicate spinules on subproximal surface, two parallel setae directed inwards on middle surface; eight modified spines, one bare short seta and one spinulose thick seta along inner subdistal dorsal edges; a spinule on middle dorsal edge. Coxa confluent with basis basally, with one thick spinulose and two geniculate slender spines on inner end; some spinules on inner dorsal edge. Basis bilobated inwards; dorsal lobe with one long spine accompanied with two bare setae dorsally and ventrally, and one spinulose seta; ventral lobe smaller than dorsal one, with two hairy setae. Exopodite slightly swollen outwards, about two times as long as greatest width, furnished with long hairs densely along both margins, one and three setae on inner subdistal and distal edges, respectively. Endopodite smaller than exopodite, two times as long as greatest width, furnished with many long hairs along outer margin three setae distally and subdistally. *Maxilla* (Fig. 10–4). Syncoxa with three endites, proximal one shortest; each endite furnished with three spinulose or hairy thick setae of different lengths; a spinular row on subdistal outer edge obliquely. Basis furnished with a strong comb-like claw accompanied with three setae ventrally and laterally, lateral one of which strong and spinulose; four hairy setae, one of which widely separated from others, on ventral margin (reduced endopodite ?). *Maxillipede* (Fig. 10–5) almost as in the figure by Sars (1914). The basis illustrated by him is furnished with two spinular rows, but in the present material the segment apparently bears more two rows, obliquely near base of subdistal seta and transversely on inner subproximal edge. The former spinular row is probably identical with that illustrated by Poppe (1884) in *Harpacticus cherifer* var. *arcticus*.

The third endopodite-segment of the leg 2 in the male is provided with one outer spine on subdistal corner (Fig. 13–7). The spine is extremely difficult to detect, because several spinules around the spine or the mucroniform process of the middle segment are usually obstructive to found it.

A small elliptical patch (Figs. 12–4, 5 and 6) is observed in middle part of basoendopodite of leg 5 in the female. This seems to be the point of muscular

attachment which binds a retractor muscle of exopodite. Such formation was already illustrated by Tschislenko (1967) in *Harpacticus uniremis*. The spinules fringing along inner margin of basoendopodite are divided into three groups in all specimens examined, and such nature is found in the figure presented by Poppe (1884).

b. *Variation and abnormality.*

Total appearances of both sexes have been already well-illustrated by Sars (1904). He reported on the colour, "gray, with a slight yellowish green tinge." And in his paper, no figures nor description concerning the presence of coloured patterns or colour variation are found. In the present material examined the body varied in colour, yellowish green, light brown and dark blue with several intermediate degrees. The yellowish green colour is found in adult females, and is apparently due to the presence of developed eggs in the oviducts. Further, several patterns modified in various ways were observed on the surfaces of cephalothoracic and thoracic segments. The patterns on the cephalothorax examined in five females are shown rather schematically (Fig. 11). The patterns are light brown or dark blue in colour, and are identical with the "transverse bands" reported by Wilson (1932).

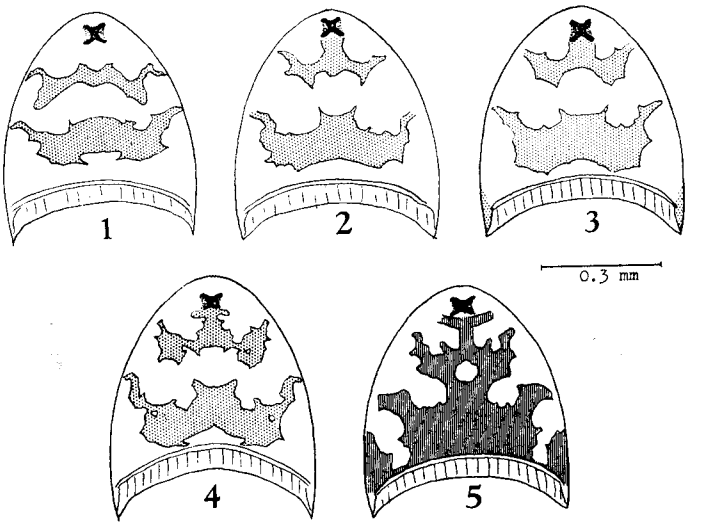

Fig. 11. The coloured patterns of the cephalothorax (♀). 1 to 4 light brown, and 5 dark blue in colour.

The leg 5 in the male (Fig. 13–5) indicates no variable structure, but in the female distinct variations are occasionally recognized. Usual shape coinsides with those reported by Sars (1904) and Lang (1965). Some structures, however, have been overlooked, especially in the spinular arrangement. One spinular row has been

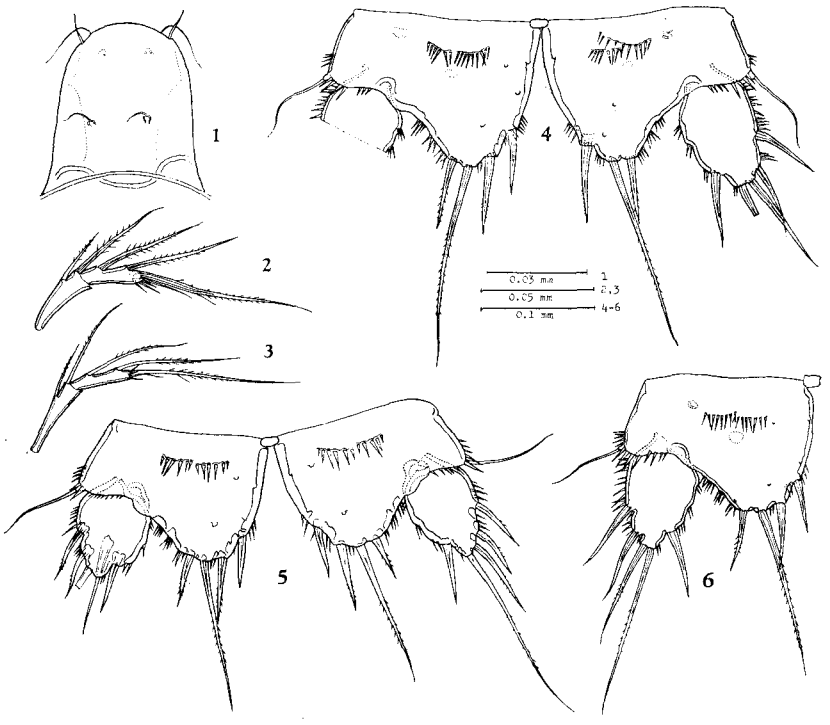

Fig. 12. The adult 1. ♂, Rostrum; 2. ♀, exopodite of antenna; 3. ♂, Exopodite of antenna; 4, 5 and 6. ♀, Leg 5.

so far recognized on the surface of basoendopodite, but in the present material the spinular row is distinctly divisible into two groups (inner and outer rows). Both rows usually consist of six spinules, but the numbers are well variable. Occasionally the outer row remarkably extends inward to just above inner row (Fig. 12–4). In one specimen the inner expansion of basoendopodite is furnished with three setae instead of four (Fig. 12–4). In another specimen all setae on the exopodite are abnormal (Fig. 12–5), probably malformation owing to unsuccessful molting. On the other hand, variable or abnormal nature in the male appears frequently in the leg 2 and the leg 3. In one specimen dissected, the apical segment in one of a pair of endopodite in the leg 2 a little shorter than usual, and without spinules around proximal inner seta (Fig. 13–1a); further, inner apical seta not reduced and the outer spine much reduced into a dwarfed spiniform seta. Another specimen has unique shape of both endopodites of the leg 2 (Fig. 13–2), much elongated spiniform process of middle segment; one stout outer spine on the subdistal corner of the apical segment as in the fourth copepodid stage. In the same specimen one

of a pair of exopodites in the leg 3 has abnormal structure (Fig. 13–4a); middle segment with one retracted outer spine, apical segment furnished with one longer outer spine instead of two.

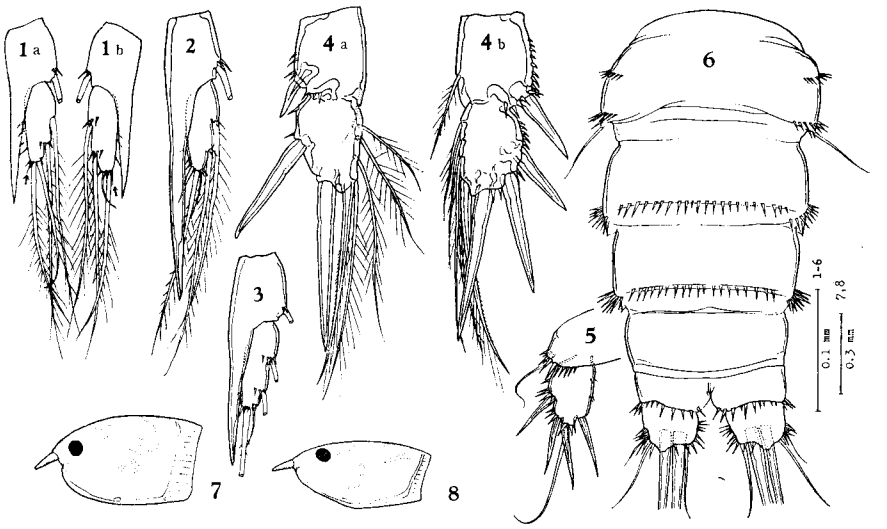

Fig. 13. The adult. 1, 2 and 3. ♂, Apical two endopodite-segments of leg 2. 4. ♂, Apical two exopodite-segments of leg 3. 5. ♂, Leg 5; 6. ♂, leg 6 and abdomen, ventral. 7. ♀, Lateral view of cephalothorax; 8. ♂, Ditto.

3.7. *Molting, formation of new and renewed structures.*

Some specimens which were supposed to be immediately before the casting of the old exoskeleton were found and examined. As the result the manner of appearance of newly formed or renewed structures associated with the molting was recognized morphologically. So-called spines or setae and spinules or hairs fringing around margins of legs are clearly distinghished from each other in their manner of renewing. Spines including claws and setae are formed in old ones at least partly in the case of renewing. The basal parts of renewed ones are retracted as shown in the figure (Fig. 14–1), and immediately after casting they will be rapidly protruded and turned inside out (Fig. 14–2). On the other hand, the spinules or hairs fringing along margins of legs are formed without such retraction and not inserted in old ones without exception. The renewed ones usually fall sideways, and after casting they are settled in a certain angle. The renewing manner of marginal spinules on the coxa of leg 1 is strikingly unique. The spinules lay down inwards on the surface of the segment as shown in the figure (Fig. 14–1). In the fourth copepodid male immediately before casting, the renewed last segment

of endopodite in the leg 2 (Pl. XI, Fig. 5) has an interesting feature; a considerably dwarfed seta is formed in each the old inner terminal seta and the old outer spine. The quite newly formed spines or setae are entirely retracted in the segment (Fig. 14–2, indicated by arrows).

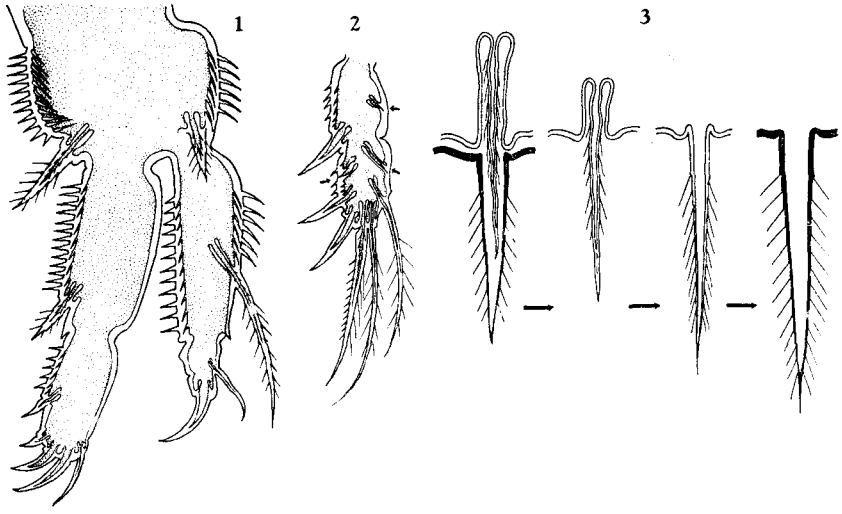

Fig. 14. The formation of new or renewed structures in schema. 1. Leg 1 in the fourth copepodid. 2. Exopodite of leg 2 in the second copepodid. 3. The formation of a renewed seta.

4. Discussion

The segmenting manner of the appendage through all successive copepodid stages is entirely in accord with those of *Tigriopus japonicus* Mori reported by Itô (1970) and also of *T. fulvus* (Fischer) by Fraser (1936). The manner that both rami in the leg 1 to the leg 4 are one-segmented in the start, and subdivided into two segments in the subsequent stage and three-segmented in the prefinal stage, is also recognized in another harpacticoid genus, *Sacodiscus* and moreover in *Eucyclops serrulatus* (Fischer), Cyclopoida, reported by Auvray & Dussart (1966). But in this respect, *Euterpina acutifrons* (Dana), Tachidiidae, is quite different from them, the species has already two-segmented rami in the leg 1 and leg 2 even in the first copepodid stage (Tesch, 1915). On the other hand, *Diarthrodes cystoecus*, Thalestridae, has already three-segmented rami in the fourth copepodid stage; endopodite of leg 2, both rami of leg 3 and leg 4 (Fahrenbach, 1962). The significance of such difference of the segmenting manner within the order Harpacticoida is rather ignored at present, and it is necessary to be clarified in phylogenic point of view.

The principle, that the terminal seta of furcal ramus in the first copepodid stage is bifurcate, and in the subsequent stage the bifurcate seta is divided into two juxtaposed setae, seems to be common nature among several harpacticoid species belonging to the different families. For example following species have been certified: Harpacticidae, *Tigriopus japonicus* Mori (Itô, op. cit.) and *T. fulvus* (Fischer) (Fraser, op. cit.); Macrosetellidae, *Macrosetella gracilis* (Dana) (Tokioka and Bieri, 1966); Tisbidae, *Sacodiscus ovalis* (C.B. Wilson) (Humes, 1960). On the contrary to these, such seta may be left just as the primary shape through all successive moltings in certain species with bifurcate furcal seta even in the adult, for example, *Pholetiscus rectiseta* Humes (Humes, 1956), Canthocamptidae.

In the adult the secondary sexual character of the present species is different from that of *Tigriopus japonicus* (see Itô, 1969 and 1970); namely, rostrum, principal terminal seta of furcal ramus, outer seta of antennal allobasis, and exopodite of leg 3. But the former species entirely accords with the latter in the stage appearing sexual difference in the structure. As another case, the secondary sexual dimorphism of *Diarthrodes cystoecus* (Fahrenbach, op. cit.) is firstly recognized in the third copepodid stage.

The mucroniform process of the second endopodite-segment in the male is homologous to the small protuberance at outer distal corner in the corresponding segment in the female. Such small protuberance is present also in the leg 3 and the leg 4 except for the apical segment. In *Tigriopus japonicus*, on the other hand, the protuberance is very indistinct, and moreover the mucroniform process particulary in the fifth copepodid stage is rather moderate.

The degenerative nature of the third endopodite-segment and its accessory in the male is apparently common to both the species described. A noteworthy fact is the degenerative tendancy of the outer spine on this segment. Nearly all so far known *Harpacticus*-species, except for *H. obscurus* T. Scott and *H. pluvinatus* Brady reported by Candeias (1959) and Lang (1934) respectively, have not been recognized on the presence of such outer spine or even corresponding structure. The outer spine is usually much reduced at least in the present material, but is certainly present, and the distinct spine as in the female is found as unusual or rather aberrant ones, while it is in question whether those of *H. obscurus* and *H. pulvinatus* are usual stuructures or not. If the species are furnished with such distinct outer spine as a decided specific character, those are seemingly interesting material in view of the phylogenic relationship between the other *Harpacticus*-species without the spine and the *Tigriopus*-species which have the spine without exception. Conserning the presence of the outer spine as in the female and undwarfed inner terminal seta, even as aberrant, on the segment, the degenerative nature of the spine as well as the inner teminal seta may not be completely confirmed as a specific importance.

The retracted feature appeared in some setae or spines (Figs. 11-5, 12-4) is regarded as a result of unsuccessful molting followed by immediate expansion. Such feature has been recognized also in another copepods, *Tisbe celata* Humes,

Tisbidae, and *Eucyclops serrulatus* (Fischer), Cyclopidae, Cyclopoida, reported by Humes (1954) and Auvray & Dussart (1966) respectively. The time of casting with certain periods before and after it seems to be the most "critical" time in the whole life history in copepods as well as in other crustaceans (see Lockwood, 1968, p. 64–75). The majority of the abnormal structure may be related more or less to the circumstances during the time.

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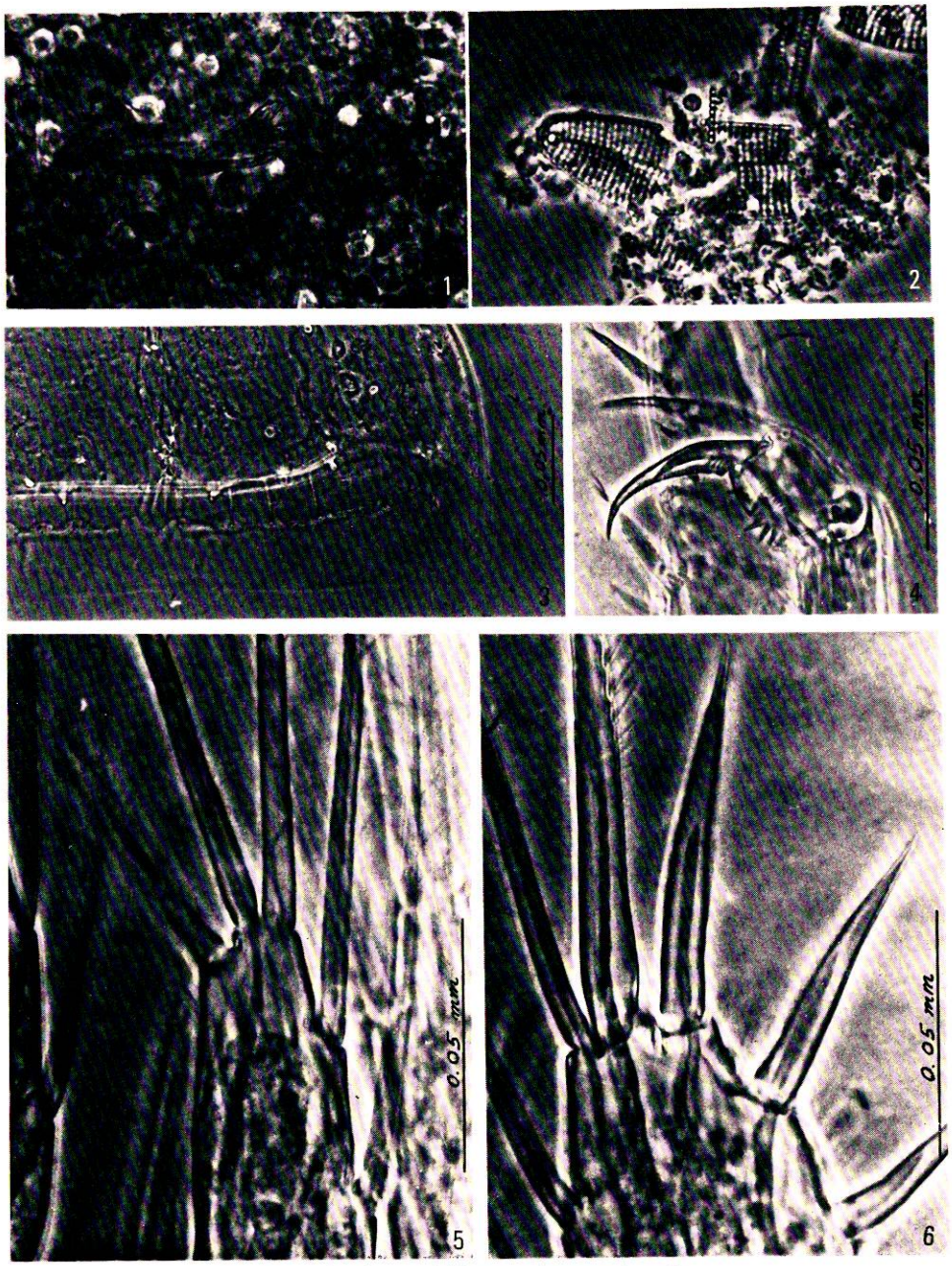

T. Itô: Biology of Harpacticus uniremis

Anhang: Die Nauplien und Copepoditen von *Euterpina acutifrons* (Dana). Rapp. en Verh. Rijksinst. Visscherijonderz **1**: 269–309, pl. 7–9.

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Explanation of Plate XI

Fig. 1. The antennal gnathobasis of nauplius found in a faecal pellet.
Fig. 2. The broken diatoms found in a faecal pellet.
Fig. 3. Some hairs on the carapace of the first free thoracic segment.
Fig. 4. The renewed structures found in the old exoskeleton of the fifth copepodid male immediately before molting. The second endopodite-segment of leg 1.
Fig. 5. Ditto. The second endopodite-segment of leg 2.
Fig. 6. Ditto. The second exopodite-segment of leg 3.