Zoological Studies **41**(2): 194-207 (2002)

Zoological Studies

Postembryonic Development of *Neutrodiaptomus tumidus* Kiefer, 1937 (Crustacea: Copepoda) from Taiwan

Shuh-Sen Young

Department of Science Education, National Hsinchu Teachers College, Hsinchu, Taiwan 300, R.O.C.

(Accepted February 6, 2002)

Shuh-Sen Young (2002) Postembryonic development of *Neutrodiaptomus tumidus* Kiefer 1937 (Crustacea: Copepoda) from Taiwan. *Zoological Studies* **41**(2)**:**194-207. *Neutrodiaptomus tumidus* Kiefer 1937 lives in highland pools and lakes of the central mountain area of Taiwan. In these waters, no other species of calanoid is present. The postembryonic development instars, collected from the field, are described and illustrated in this study. This is the 1st description of the developmental stages of *Neutrodiaptomus tumidus.* http://www.sinica.edu.tw/zool/zoolstud/41.2/194.pdf

Key words: *Neutrodiaptomus tumidus,* Nauplius, Copepodid, Calanoida, Postembryonic development.

Most species of *Neutrodiaptomus* are endemic to East Asia (Banarescŭ 1990). However, only limited information about developmental stages of *Neutrodiaptomus* has been reported. *Neutrodiaptomus tumidus* from Taiwan was described by Kiefer in 1937. Collection localities were lakes and ponds in the mountains of southern Taiwan near Pingtung and Kuangshung at elevations ranging from 2000 to 2300 m. In April 1997, we took zooplankton samples from small pools distributed in the central mountain area of Taiwan, from 2700 to 3000 m. Many red-colored *N. tumidus* individuals were found in these small pools, but no other calanoid was seen. From different samples, we were able to find 6 naupliar and 6 copepodid stages of *N. tumidus*. The present study is the 1st description of the developmental stages of *Neutro-diaptomus tumidus* collected from the field.

MATERIALS AND METHODS

The collections were made from highland pools of the central mountain area of Taiwan on 1-4 April 1997. The collection localities are: Nanko Pool, a small pool located near Nanko Mountain, elevation 2800 m, 0.1 ha surface area, 0.5 m in depth; Whitestone Pool (23°55'40"N, 121°16'00"E) 2770 m, 0.6 ha, 6 m deep; Deer Pond (23°53'30"N, 121°15'10"E) 2850 m, 1 ha, 2 m deep; and Sevencolor Lake (23°45'00"N, 121°13'40"E) 2900 m, 2.2 ha, 7 m deep. Specimens were collected with a plankton net 30 cm in length and 15 cm in diame-ter at the opening, which was equipped with a small collecting bucket at the end with a mesh size of 55 μm. All samples were fixed with 5% formalin in the field, and sorted and identified under a stereomicroscope in the laboratory. Identified specimens were then transferred to 70% ethanol. Appendages were dissected and mounted on microscope slides with polyvinyl lactophenol tinted with lignin pink. Images were made with a camera lucida. Measurements and observations were aided with an image analysis system. Descriptions of morphology and abbreviations follow Shih and Maclellan (1977) and Reddy and Devi (1990). The average and standard deviation of body length and length ratios are based on measurement of 10 specimens.

Postembryonic development of *Neutrodiaptomus tumidus* Kiefer 1937

Nauplius I (Fig. 1)

Total length 0.18 ± 0.01 mm, body oblong, with 2 posterior caudal setae, body unsegmented without oral aperture; antennule: 3 segmented, with 1, 2, and 3 setae; antenna: coxa with 1 seta, basis with 1 seta, exopod 4 segmented with 2, 1, 1, and 2

setae, endopod 1 segmented with 1 medial and 2 distal setae; mandible: coxa with 1 seta inner distal, exopod 3 segmented with 1, 1, and 2 setae, endopod with 2 medial and 2 distal setae.

Nauplius II (Fig. 2)

Total length 0.22 ± 0.05 mm, body oblong, posterior end bilobed, each lobe with 1 seta, body unsegmented with oral aperture; antennule: 3 segmented, with 1, 2, and 3 setae, 3rd segment with hairy lateral and medial margins; antenna: coxa with 1 seta, basis with 3 setae, exopod 5 segmented with 1, 1, 1, 1, and 3 setae, endopod 1 segmented with 1 medial and 3 distal setae; mandible: coxa with 1 inner seta distally, basis with 2 setae, exopod 4 segmented with 1, 1, 1, and 3 setae, endopod with 2 lateral and 4 distal setae.

Nauplius III (Fig. 3)

Total length 0.25 ± 0.06 mm, body oblong, bilobed posteriorly, each lobe with 2 setae, body unsegmented with oral aperture; antennule: 3 segmented, with 1, 2 and 6 setae, 3rd segment with hairy medial lateral margins; antenna: coxa with 1 seta, basis with 6 setae, exopod 6 segmented with 0, 1, 1, 1, 1, and 3 setae, endopod 1 segmented with 2 medial and 3 distal setae; mandible: coxa with 1 inner seta distally, basis with 3 setae, exopod 4 segmented with 1, 1, 1, and 3 setae, endopod fanlike with 7 setae; maxillule bud with 1 seta.

Nauplius IV (Fig. 4)

Total length 0.30 ± 0.14 mm, body oblong, bilobed posteriorly, each lobe with 2 setae ; antennule: 3 segmented, with 1, 2, and 10 setae; antenna: coxa with 2 strong setae, basis with 6 setae, exopod 6 segmented with 0, 3, 1, 1, 1, and 3 setae, endopod 1 segmented with 3 medial and 3 distal

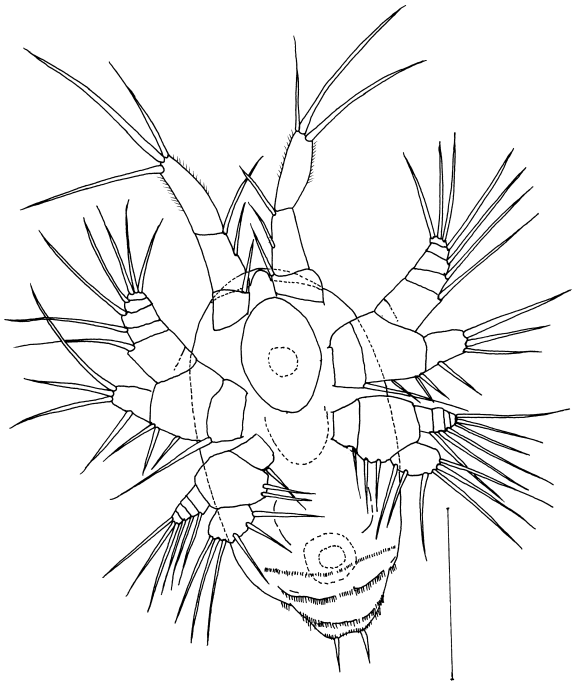

Fig. 2. *Neutrodiaptomus tumidus* Kiefer nauplius II. Scale for specimen represents 0.1 mm.

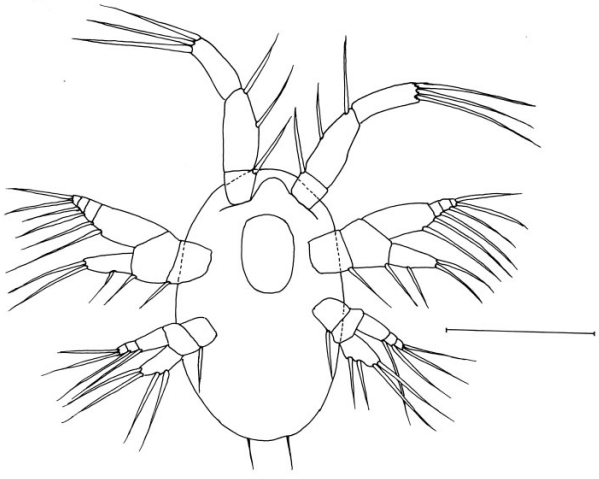

Fig. 1. *Neutrodiaptomus tumidus* Kiefer nauplius I. Scale for specimen represents 0.1 mm.

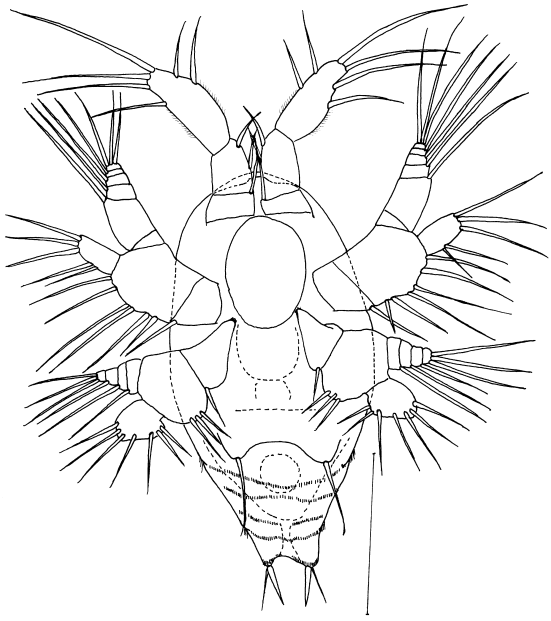

Fig. 3. *Neutrodiaptomus tumidus* Kiefer nauplius III. Scale for specimen represents 0.1 mm.

setae; mandible: coxa with a gnathobase without seta, basis with 3 setae, exopod 4 segmented with 1, 1, 1, and 3 setae, endopod fanlike with 8 setae; maxillule: bilobed, exopod with 3 setae, endopod with 3 setae, protopod with 1 medial seta.

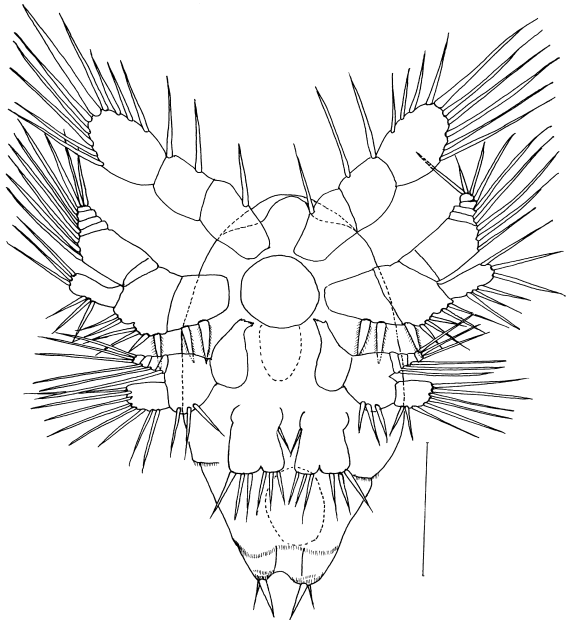

Fig. 4. *Neutrodiaptomus tumidus* Kiefer nauplius IV. Scale for specimen represents 0.1 mm.

Nauplius V (Fig. 5)

Total length 0.34 ± 0.21 mm, body oblong, caudal end bilobed, each lobe with 2 setae; antennule: 3 segmented, with 1, 2, and 12 setae; antenna: coxa with 2 strong setae, basis with 6 setae, exopod 6 segmented with 0, 3, 1, 1, 1, and 3 setae, endopod 1 segmented with 4 medial and 5 distal setae; mandible: coxa with a gnathobase; basis with 3 setae, exopod 4 segmented with 1, 1, 1, and 3 setae, endopod fanlike with 9 setae; maxillule: exopod with 2 lateral and 3 terminal setae, endopod with 1 lateral seta, 2 terminal setae, 1 medial seta, protopod with 2 setae; maxilla: simple triangular lobe with 2 strong setae.

Nauplius VI (Fig. 6)

Total length 0.38 ± 0.12 mm, body oblong, caudal end bilobed, each lobe with 2 strong spines; antennule: 3 segmented, with 1, 2, and 14 setae; antenna: coxa with 3 strong setae, basis with 6 setae, exopod 6 segmented with 0, 4, 1, 1, 1, and 3 setae, endopod 1 segmented with 4 medial and 5 distal setae; mandible: basis with 4 setae, exopod 4 segmented with 1, 1, 1, and 3 setae, endopod fanlike with 10 setae; maxillule: exopod with 6 setae, endopod with 7 setae; protopod with 3 medal setae and 1 lateral seta; maxilla: 6 lobed with 1, 1, 1, 2, 2, and 5 setae; maxilliped: simple lobed with 2 small setae; 1st swimming legs: exopod little broader than

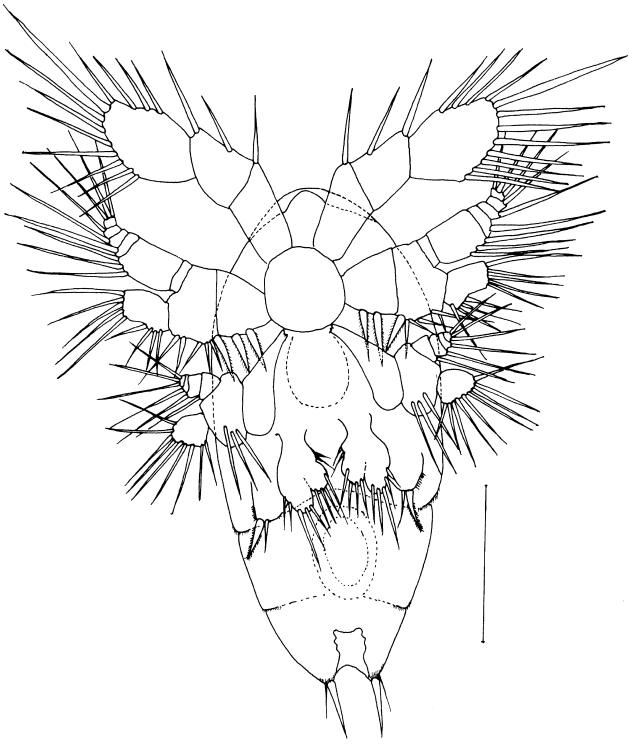

Fig. 5. *Neutrodiaptomus tumidus* Kiefer nauplius V. Scale for specimen represents 0.1 mm.

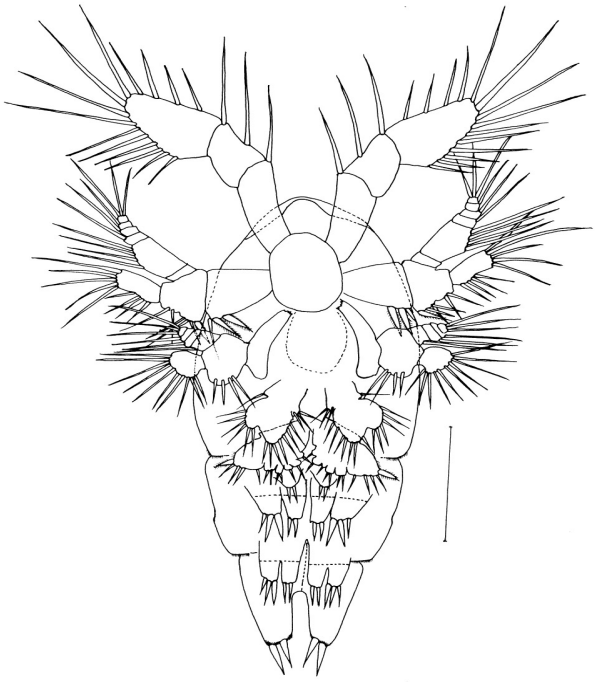

Fig. 6. *Neutrodiaptomus tumidus* Kiefer nauplius VI. Scale for specimen represents 0.1 mm.

endopod, exopod with 3 unequal spines, endopod with 2 spines; 2nd swimming legs: exopod with 3 unequal spines, endopod with 2 spines.

Copepodid I (Fig. 7)

Total length 0.48 ± 0.01 mm (excluding caudal setae); prosome 0.38 ± 0.01 mm. Prosome 5 segmented. Urosome 1 segmented. Ratio of prosome to urosome 3.74 ± 0.32.

Antennule 11 segmented, extending to the last urosomal segment. Antenna: endopod 2 segmented, 1st segment with 2 setae, 2nd segment with 5 medial and 3 terminal setae; exopod 7 segmented with 1, 1, 2, 1, 1, 1, and 4 setae. Mandible: endopod 2 segmented with 3 and 4 setae; exopod 4 segmented with 1, 1, 1, and 3 setae; masticatory process with 6 teeth. Maxilliped with precoxa and coxa fused comprising a well-developed syncoxa with 1, 2, and 2 setae, basispod with 2 setae; endopod 2 segmented, proximal segment with 1 seta and dis-

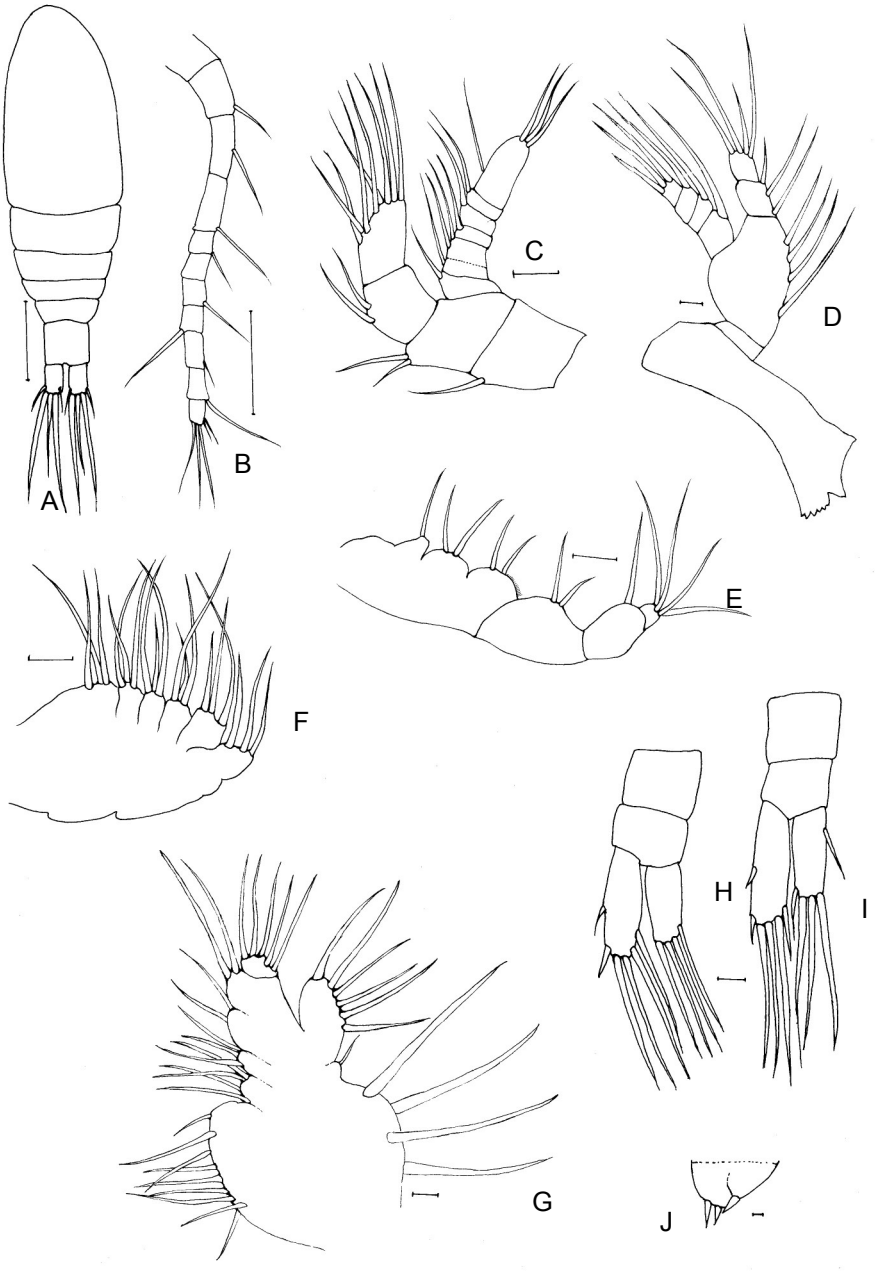

Fig. 7. *Neutrodiaptomus tumidus* Kiefer copepodid I. A. Dorsal view; B. Antennule; C. Antenna; D. Mandible; E. Maxilliped; F. Maxilla; G. Maxillule; H. First swimming leg; I. Second swimming leg; J. Third swimming leg. Scales for specimens and antennule represent 0.1 mm; scales for appendages represent 0.01 mm.

tal segment with 4 setae. Maxilla with 5 endites, with 3, 3, 3, 3, and 3 setae plus a ramus with 3 setae. Maxillule: precoxal endite with 9 setae; exite of coxa with 4 setae; endite of coxa with 4 setae; exite of basis with 1 seta and endite 1 of basis with 3 setae; endite 2 of basis with 2 setae; exopod 1 segmented, shorter in length than endopod, with 6 setae along lateral margin; endopod 2 segmented with 2 and 5 setae.

First swimming leg: exopod 1 segmented, with 1 lateral spine, 1 distal spine, and 4 setae; endopod 1 segmented with 4 setae. Second swimming leg: exopod 1 segmented with 1 lateral spine, 1 distal spine, and 4 setae; endopod 1 segmented with 5 setae. Third swimming leg: rudimentary and bilobed, outer lobe bearing 2 terminal setae, inner lobe with 1 terminal seta. Caudal ramus about 1/2 as long as 1st urosomal somite, each with 5 setae.

Copepodid II (Fig. 8)

Total length 0.6 ± 0.01 mm (excluding caudal setae); prosome 0.48 ± 0.01 mm. Prosome 6 segmented and urosome 1 segmented. Ratio of prosome to urosome 4.17 ± 0.34.

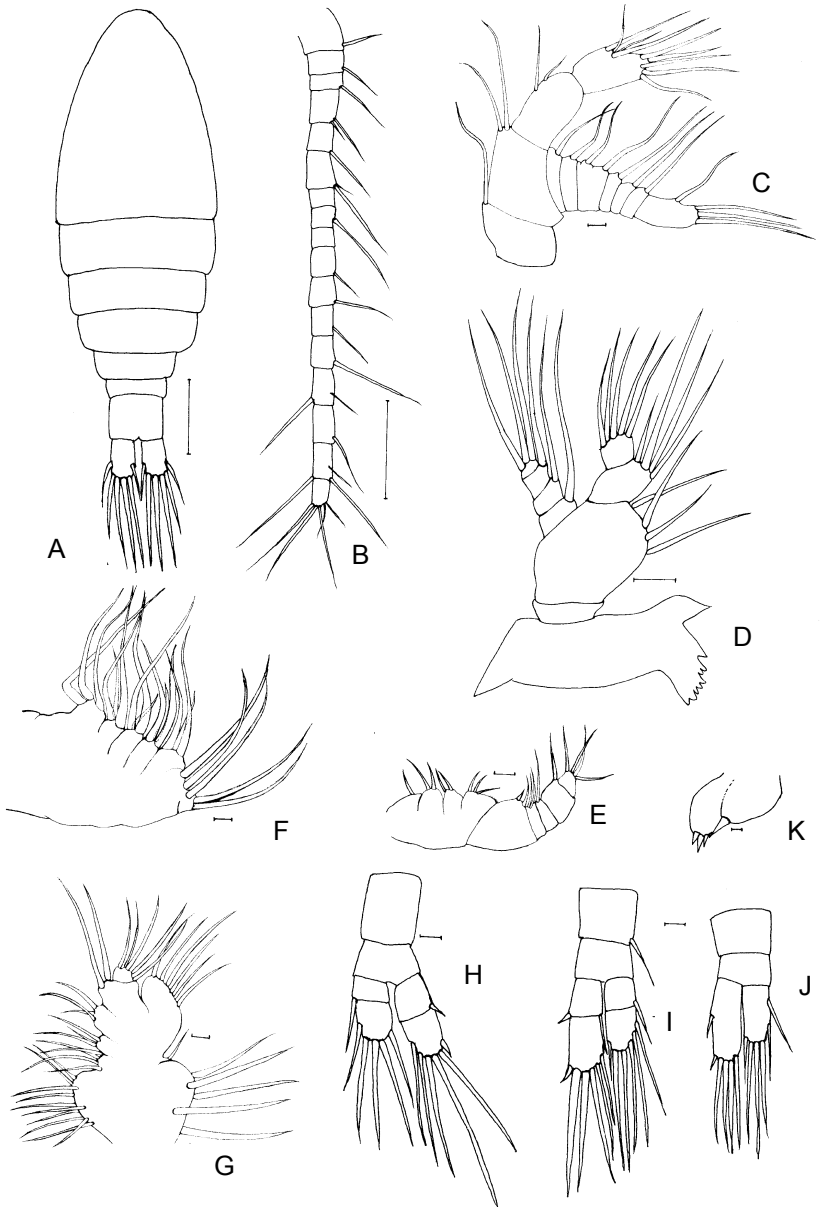

Fig. 8. *Neutrodiaptomus tumidus* Kiefer copepodid II. A. Dorsal view; B. Antennule; C. Antenna; D. Mandible; E. Maxilliped; F. Maxilla; G. Maxillule; H. First swimming leg; I. Second swimming leg; J. Third swimming leg; K. Fourth swimming leg. Scales for specimens and antennule represent 0.1 mm; scales for appendages represent 0.01 mm.

Antennule 17 segmented, extending to last urosomal segment. Antenna: endopod 2 segmented, 1st segment with 2 setae and 2nd segment with 4 medial and 5 terminal setae; exopod 7 segmented with 1, 1, 2, 1, 1, 1, and 4 setae. Mandible: endopod 2 segmented with 4 and 5 setae, and exopod 4 segmented with 1, 1, 1, and 3 setae. Maxilliped syncoxa with 1, 2, 2, and 3 setae, basispod with 2 setae, endopod 4 segmented, with 2, 1, 1, and 4 setae. Maxilla with 5 endites, with 3, 3, 3, 3, and 3 setae plus a ramus with 5 setae. Maxillule: precoxa endite with 10 setae; exite of coxa with 5 setae, endite of coxa with 4 setae; exite of basis with 1 seta and endite 1 of basis with 3 setae; endite 2 of basis with 3 setae; exopod 1 segmented, shorter in length than endopod, with 6 setae along later margin; endopod 2 segmented with 2 and 5 setae.

First swimming leg: exopod 2 segmented, 1st segment with 1 lateral spine, 2nd segment with 1 spine and 5 setae; endopod 2 segmented, 1st segment with 1 inner seta, 2nd with 5 setae. Second

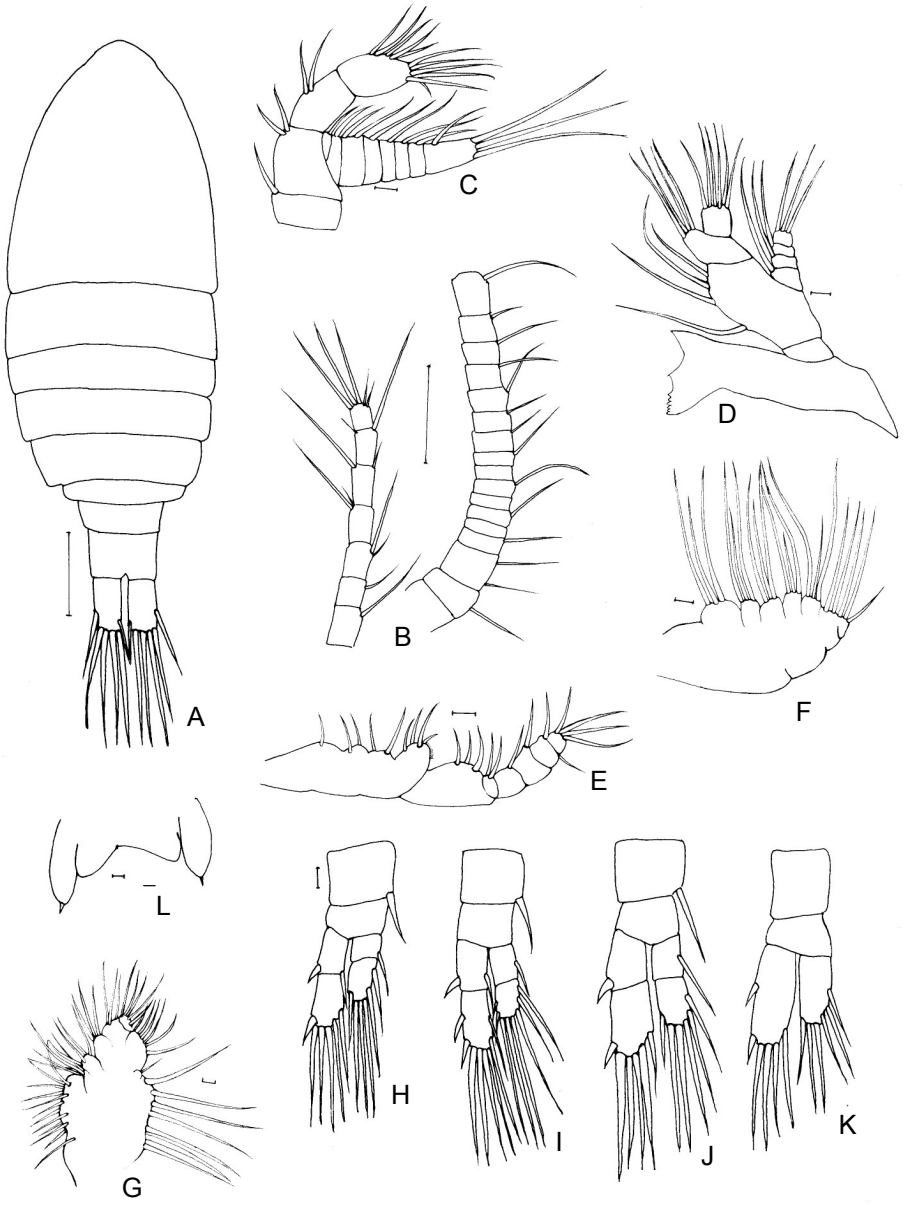

Fig. 9. *Neutrodiaptomus tumidus* Kiefer copepodid III. A. Dorsal view; B. Antennule; C. Antenna; D. Mandible; E. Maxilliped; F. Maxilla; G. Maxillule; H. First swimming leg; I. Second swimming leg; J. Third swimming leg; K. Fourth swimming leg; L. Fifth swimming leg. Scales for specimens and antennule represent 0.1 mm; scales for appendages represent 0.01mm.

swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 spine and 5 setae; endopod 2 segmented, 1st segment with 1 inner seta, 2nd segment with 6 setae. Third swimming leg: exopod 1 segmented with 2 lateral spines and 4 setae; endopod 1 segmented with 6 setae. Fourth swimming leg: rudimentary and bilobed, lateral lobe bearing 3 terminal setae, medial lobe with 1 terminal seta. Caudal rami about as long as 1st urosomal segment, each with 6 setae.

Copepodid III (Fig. 9)

Total length 0.69 ± 0.04 mm (excluding caudal setae); prosome 0.53 ± 0.03 mm. Prosome 6 segmented and urosome 2 segmented. Ratio of prosome to urosome 3.17 ± 0.27.

Antennule 24 segmented, extending to last urosomal segment. Antenna: endopod 2 segmented, 1st segment with 2 setae, 2nd segment with 5 medial and 6 terminal setae; exopod 8 segmented with 1, 1, 2, 1, 1, 1, 1, and 4 setae. Mandible: endopod 2 segmented with 4 and 6 setae; exopod 4 segmented with 1, 1, 1, and 3 setae; masticatory process with 6 small points and 2 broad points. Maxilliped syncoxa with 1, 2, 2, and 4 setae, basispod with 3 setae, endopod 5 segmented with 2, 1, 1, 2, and 4 setae. Maxilla with 5 endites, with 3, 3, 3, 3, and 3 setae plus a ramus with 5 setae. Maxillule: precoxa endite with 12 setae; exite of coxa with 7 setae, endite of coxa with 4 setae; exite of basis with 1 seta; endite 1 of basis with 4 setae, endite 2 with 3 setae; exopod 1 segmented, shorter in length than endopod, with 6 setae along lateral margin; endopod 2 segmented with 3 and 5 setae.

First swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 spine and 5 setae; endopod 2 segmented, 1st segment with 1 inner seta, 2nd with 6 setae. Second swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 2 lateral spines and 6 setae; endopod 2 segmented, 1st segment with 1 inner seta, 2nd segment with 8 setae. Third swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine, 2nd segment with 1 lateral spine and 5 setae; endopod 2 segmented, 1st segment with 1 inner seta, 2nd segment with 6 setae. Fourth swimming leg: exopod 1 segmented with 2 lateral spines and 4 setae; endopod 1 segmented with 6 setae. Fifth swimming leg rudimentary and bilobed, outer lobe bearing 1 terminal seta. Caudal rami about as long as 1st urosomal segment, each with 6 setae.

Copepodid IV (Fig. 10)

Male and female become distinguishable by the 5th legs. Total length of female 0.73 ± 0.01 mm (excluding caudal setae); prosome 0.54 ± 0.01 mm. Prosome 6 segmented and urosome 3 segmented. Ratio of prosome to urosome 2.84 ± 0.13. Total length of male 0.72 ± 0.01 mm (excluding caudal setae); prosome 0.53 ± 0.01 mm. Prosome 6 segmented and urosome 3 segmented. Ratio of prosome to urosome 2.87 ± 0.15.

Antennule 25 segmented, extending to last urosomal segment. Antenna: endopod 3 segmented, 1st segment with 2 setae, 2nd segment with 6 setae, 3rd segment with 3 medial and 4 terminal setae; exopod 8 segmented with 1, 1, 2, 1, 1, 1, 1, and 4 setae. Mandible: endopod 2 segmented with 2 and 6 setae; exopod 4 segmented with 1, 1, 1, and 3 setae; masticatory process with 1 thumb and 7 teeth. Maxilliped syncoxa with 11 setae in 4 groups as 2, 2, 3, and 4 respectively, basispod with 3 setae, endopod 6 segmented with 2, 2, 2, 1, 2, and 4 setae. Maxilla with 5 endites, with 3, 3, 3, 3, and 3 setae plus a ramus with 5 setae. Maxillule: precoxa endite with 14 setae; exite of coxa with 8 setae, endite of coxa with 4 setae; exite of basis with 1 seta and endite 1 of basis with 4 setae; endite 2 of basis with 3 setae; exopod 1 segmented, shorter in length than endopod, with 6 setae along lateral margin; endopod 2 segmented with 3 and 5 setae.

First swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 lateral spine and 5 setae; endopod 2 segmented, 1st segment with 1 inner setae, 2nd with 6 setae. Second swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 2 lateral spines and 7 setae; endopod 2 segmented, 1st segment with 1 inner seta, 2nd segment with 9 setae. Third swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 2 lateral spines and 6 setae, endopod 2 segmented, 1st segment with 1 inner seta, 2nd segment with 8 setae. Fourth swimming leg: coxa with 1 inner seta; exopod 2 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 lateral spine and 6 setae, endopod 2 segmented, 1st segment with 1 inner seta, 2nd segment with 7 setae. Fifth swimming leg: biramous in both male and female; exopod and endopod 1 segmented, both with 2 terminal spines. In male, exopod of right leg with longer terminal spine on the outer side, length

about 4-5 times longer than spine on exopod of left leg. In female, legs slightly asymmetrical, inner spine of exopod longer than outer one. Caudal rami about as long as last urosomal segment, each with 6 setae.

Copepodid V (Fig. 11)

Male and female are easily recognized by antennules and 5th swimming legs. Total length of female 0.84 ± 0.02 mm (excluding caudal setae); prosome 0.62 ± 0.02 mm. Prosome 6 segmented and urosome 4 segmented. Ratio of prosome to urosome 2.76 ± 0.14. Total length of male 0.82 ± 0.02 mm (excluding caudal setae); prosome 0.60 ± 0.01 mm. Prosome 6 segmented and urosome 4 segmented. Ratio of prosome to urosome 2.75 ± 0.12.

Antennule 25 segmented, extending to last urosomal segment. Left antennule of male and female similar, right antennule of male slightly modified: segments 14 and 15 dilated slightly and segments 18 and 19 elongate; from segments 1 to 17 right antennule of male with more setae than female; from segments 18 to 25 of male with 2, 1, 1, 1, 1, 1, 1, and 5 setae and female with 1, 1, 1, 1, 1, 1, 2, and 5 setae. Antenna: endopod 3 segmented, 1st segment with 2 setae, 2nd segment with 7 setae, 3rd segment with 3 medial and 4 terminal setae; exopod 8 segmented with 1, 1, 2, 1, 1, 1, 1, and 4 setae. Mandible: endopod 2 segmented

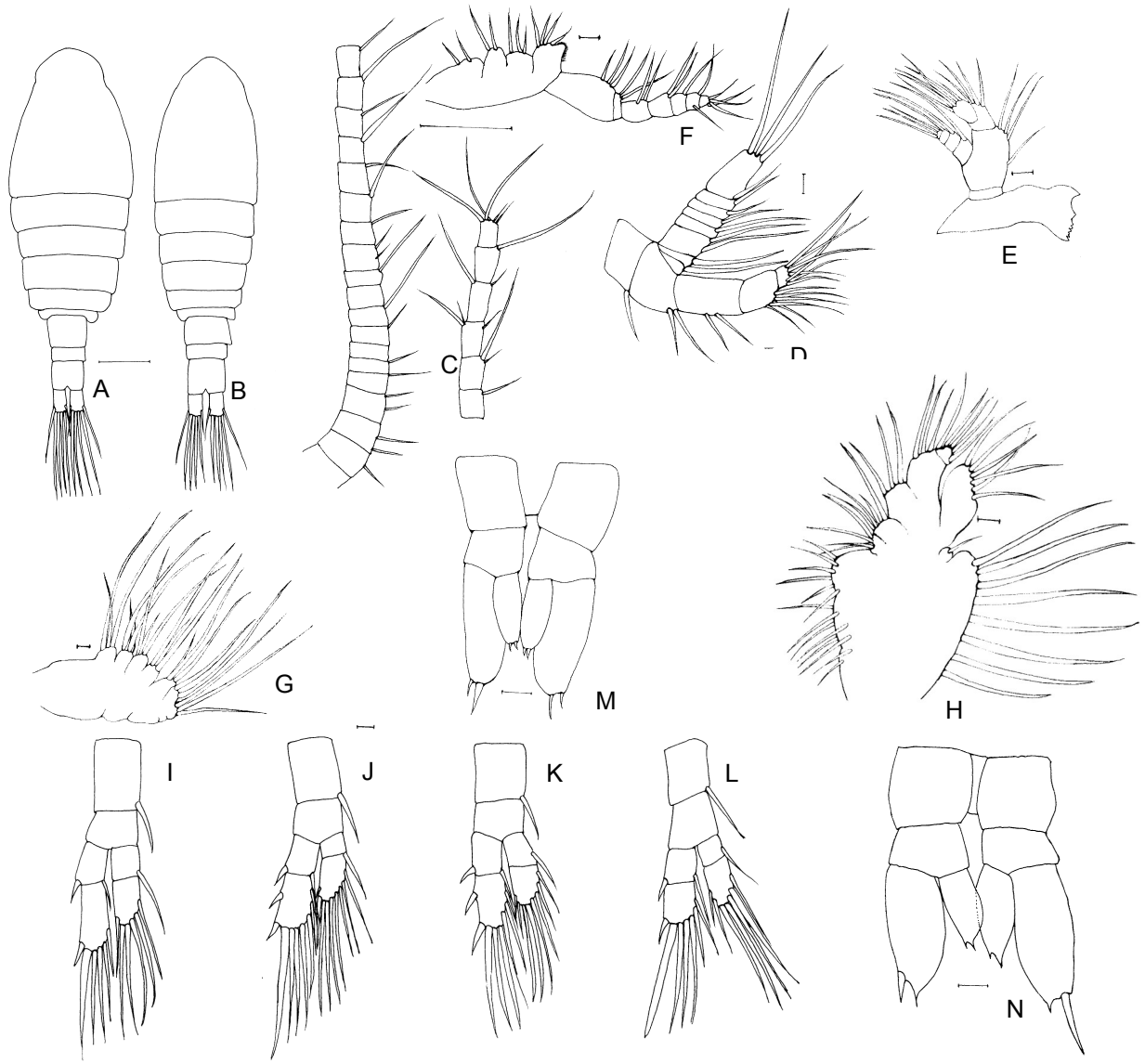

Fig. 10. *Neutrodiaptomus tumidus* Kiefer copepodid IV. A. Female dorsal view; B. Male dorsal view; C. Antennule; D. Antenna; E. Mandible; F. Maxilliped; G. Maxilla; H. Maxillule; I. First swimming leg; J. Second swimming leg; K. Third swimming leg; L. Fourth swimming leg; M. Fifth swimming leg of female; N. Fifth swimming leg of male. Scales for specimens and antennule represent 0.1 mm; scales for appendages represent 0.01 mm.

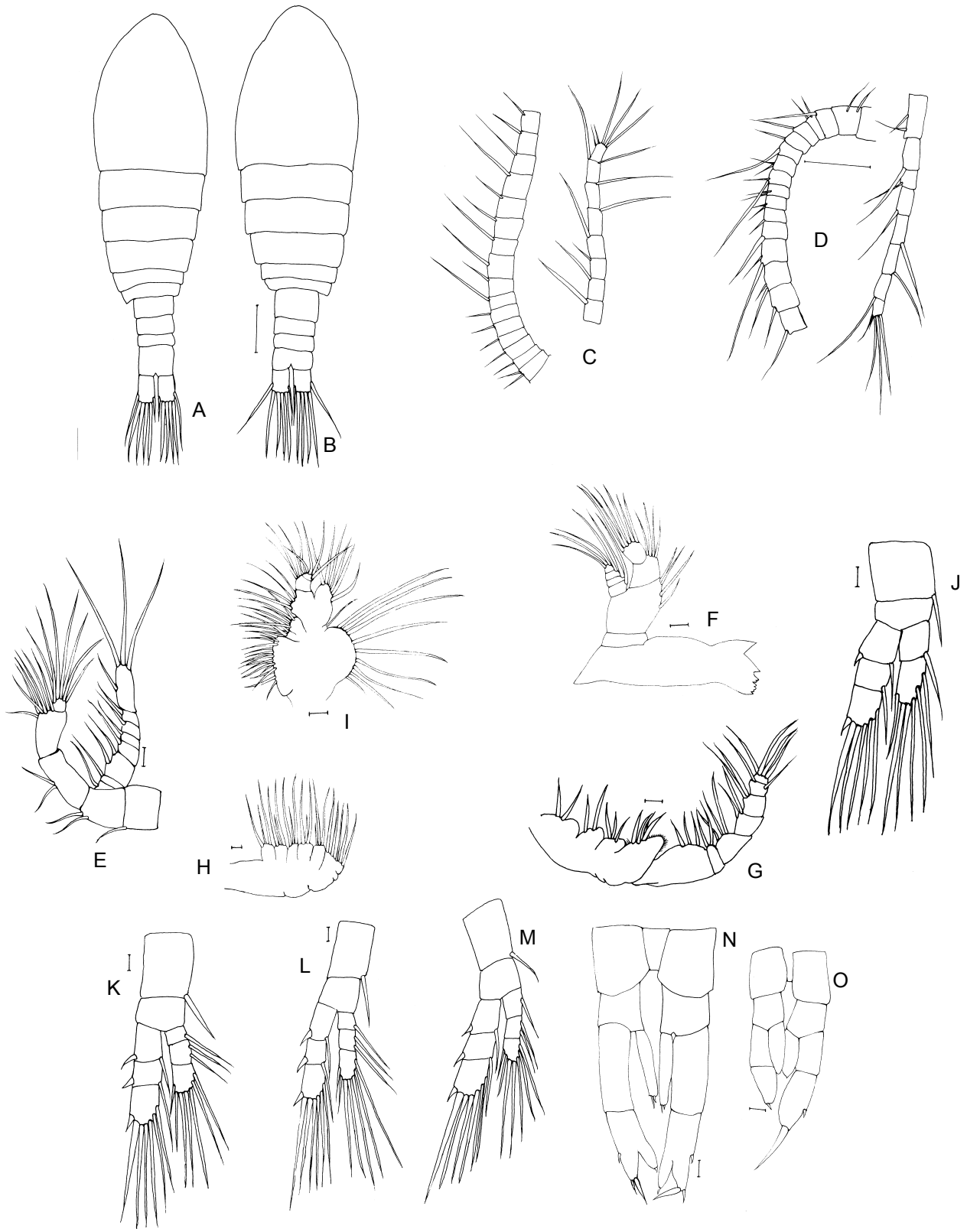

Fig. 11. *Neutrodiaptomus tumidus* Kiefer copepodid V. A. Male dorsal view; B. Female dorsal view; C. Antennule of female; D. Antennule of male; E. Antenna; F. Mandible; G. Maxilliped; H. Maxilla; I. Maxillule; J. First swimming leg; K. Second swimming leg; L. Third swimming leg; M. Fourth swimming leg; N. Fifth swimming leg of female; O. Fifth swimming leg of male. Scales for specimens and antennule represent 0.1 mm; scales for appendages represent 0.01 mm.

with 4 and 6 setae, exopod 4 segmented with 1, 1, 1, and 3 setae; masticatory process with 1 thumb and 7 teeth. Maxilliped syncoxa with setae in 4 groups as 2, 2, 3, and 4, basispod with 3 setae, endopod 6 segmented with 2, 3, 2, 2, 2, and 4 setae. Maxilla with 5 endites, with 3, 3, 3, 3, and 3 setae plus ramus with 5 setae. Maxillule: precoxa endite with 16 setae; exite of coxa with 9 setae; endite of coxa with 4 setae; exite of basis with 1 seta, endite 1 of basis with 5 setae; endite 2 of basis with 4 setae; exopod 1 segmented, shorter in length than endopod, with 6 setae along lateral margin; endopod 2 segmented with 3 and 5 setae.

First to 4th swimming legs similar in male and female, 5th swimming leg very different by gender. First swimming leg, 1 inner seta on coxa, exopod 3 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 inner seta, the 3rd segment with 1 spine and 5 setae; endopod 2 segmented, 1st segment with 1 inner seta, 2nd with 6 setae. Second swimming leg with 1 inner seta on coxa, exopod 3 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 lateral spine and 1 inner seta, 3rd with 1 lateral spine and 6 setae; endopod 3 segmented, 1st segment with 1 inner seta, 2nd segment with 2 inner setae, 3rd with 7 setae. Third swimming leg, 1 inner seta on coxa, exopod 3 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 lateral spine and 1 inner seta, 3rd segment with 1 spine and 6 setae, endopod 3 segmented, 1st segment with 1 inner seta, 2nd segment with 2 inner setae, 3rd with 7 setae. Fourth swimming leg, 1 inner seta on coxa, exopod 3 segmented, 1st segment with 1 lateral spine and 1 inner seta, 2nd segment with 1 lateral spine and 1 inner seta, 3rd segment with 1 spine and 6 setae, endopod 3 segmented, 1st segment with 1 inner seta, 2nd segment with 2 inner setae, 3rd with 7 setae. Fifth swimming leg biramous in both male and female, exopod 2 segmented and endopod 1 segmented. In male, exopod of right leg with 1 terminal spine, length of spine as long as 2nd exopod, left leg shorter than right with 1 small terminal spine, endopod of both legs with inconspicuous spine on tip. In female, both legs almost symmetrical, right leg slightly longer than left, 2nd exopod deeply forked, outer process with 2 spines and inner process with 1 spine, inner spine of outer process of right leg slightly longer than that on left leg, endopod similar in shape with 2 small spines on tip. Caudal rami about as long as last urosomal segment, each with 6 setae.

Copepodid VI (Fig. 12)

Female: Total length 0.97 ± 0.27 mm (excluding caudal setae); prosome 0.70 ± 0.01 mm. Ratio of prosome to urosome 2.63 ± 0.09. The 5th and 6th thoracic somites fused dorsally, lateral wings well developed, slightly asymmetrical, left wing upward and right outward. Both wings with 1 spine at tip. Urosome with 3 somites, 1st an asymmetrical genital complex; length of complex almost equal to maximum width, left side slightly dilated. Right side with complex lobe protruding outward and backward with 1 spine at tip. Inner margins of caudal rami hairy and with 6 caudal setae on each side. Antennules long, extending beyond caudal setae by the last 1-2 segments. Antenna: endopod 4 segmented with 2, 2, 7, and 7 setae; exopod 8 segmented with 1, 1, 2, 1, 1, 1, 1, and 4 setae. Mandible: endopod 2 segmented with 4 and 6 setae; exopod 4 segmented with 1, 1, 1, and 3 setae; masticatory process with 1 thumb and 7 teeth. Maxilliped syncoxa with 4 group of setae of 2, 2, 3, and 4 , basispod with 3 setae, endopod 6 segmented with 2, 4, 1, 2, 2, and 4 setae. Maxillule: precoxa endite with 16 setae; exite of coxa with 9 setae, endite of coxa with 5 setae; exite of basis with 1 seta; endite 1 of basis with 5 setae; endite 2 of basis with 4 setae; exopod 1 segmented, shorter in length than endopod, with 6 setae along lateral margin; endopod 2 segmented with 5 and 4 setae. Maxilla with 5 endites, with 4, 3, 4, 3, and 3 setae plus ramus with 5 setae, totaling 22 setae.

First to fourth swimming leg similar to those of copepodid V. Fifth swimming leg slender, both legs almost symmetrical, distal corner of outer margin of coxa with strong chisel-shaped spine arising directly from segment. Claw of 2nd exopod saw-toothlike along inner side. Third exopod with 2 small spines. Endopod short, about 1/2 length of 1st exopod and with 3 small spines.

Male: Total length 0.94 ± 0.27 mm (excluding caudal setae); prosome 0.69 ± 0.01 mm. Ratio of prosome to urosome 2.65 ± 0.134.

Fifth and 6th thoracic somites complete, lateral wings weakly developed on both sides with 1 spine at tip. Urosome limbless with 5 somites, 1st with genital opening. Inner margins of caudal rami hairy and with 6 caudal setae on each side. Antennules long, last segment not extending beyond caudal setae. Right antennule 22 segmented with strong spines on segments 10, 11, 13, 15, and 16, spine on segment 13 the largest. Antepenultimate segment with very small lobe of hyaline process on outer margin, and distal corner of outer margin without process or process very small.

First to 4th swimming legs similar to those of copepodid V. Right swimming leg 5: inner margin of 2nd

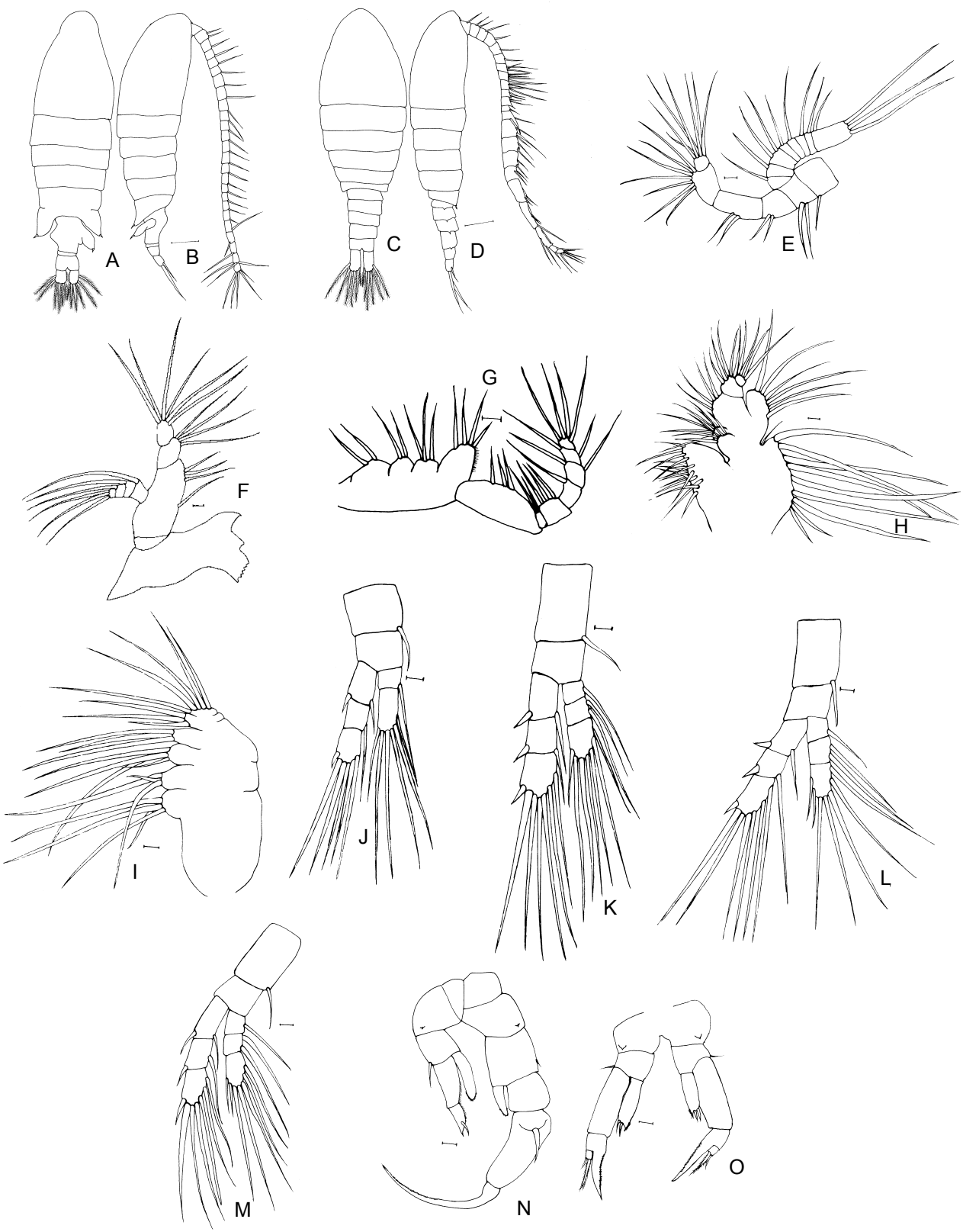

Fig. 12. *Neutrodiaptomus tumidus* Kiefer copepodid VI. A. Female dorsal view; B. Female lateral view; C. Male dorsal view; D. Male lateral view; E. Antenna; F. Mandible; G. Maxilliped; H. Maxillule; I. Maxilla; J. First swimming leg; K. Second swimming leg; L. Third swimming leg; M. Fourth swimming leg; N. Fifth swimming leg of male; O. Fifth swimming leg of female. Scales for specimens and antennule represent 0.1 mm; scales for appendages represent 0.01 mm.

exopod segment concave and short seta inserted laterally at base with disk-like process near joint, tip of seta reaching midpoint of segment. End claw sickle shaped with strong denticles on inner curve. Endopod slightly longer than 1st exopod, tip pointed with small hairs terminally. Left swimming leg 5: basis with 1

Table 1. Summary of morphological characters of nauplii of *Neutrodiaptomus tumidus*

Character/Napulius	I	II	III	IV	V	VI
Mean of body length (n = 10), excluding caudal setae	0.18 ± 0.01	0.22 ± 0.05	0.25 ± 0.06	0.30 ± 0.14	0.34 ± 0.21	0.38 ± 0.12
Setae on 3rd segment of antennule	3	3	6	10	12	14
Segments of exopod of antenna	4	5	6	6	6	6
Setae on exopod of antenna	2,1,1,2	1,1,1,1,3	0,1,1,1,1,3	0,3,1,1,1,3	0,3,1,1,1,3	0,4,1,1,1,3
Setae on endopod of antenna	3	4	5	6	9	10
Segments of exopod of mandible	3	4	4	4	4	4
Setae of exopod of mandible	1,1,2	1,1,1,3	1,1,1,3	1,1,1,3	1,1,1,3	1,1,1,3
Setae on endopod of mandible	4	6	7	8	9	10
Setae of maxillule	-	-	1	Exo. 4 Endo. 3	Exo 5 Endo. 4	Exo. 6 Endo. 7
Setae of maxilla	-	-	-	-	2	11
Presence of maxilliped (bud)	-	-	-	-	-	+
Presence of 1st swimming leg (bud)	-	-	-	-	-	+
Presence of 2nd swimming leg (bud)	-	-	-	-	-	+

Table 2. Summary of morphological characters of copepodids of *Neutrodiaptomus tumidus*

Character/Copepodid	I	II	III	IV	V	Adult
Mean body length (n = 10), excluding caudal setae	0.48 ± 0.01	0.6 ± 0.01	0.70 ± 0.01	♀ 0.73 ± 0.01 ♂ 0.72 ± 0.01	♀ 0.84 ± 0.02 ♂ 0.82 ± 0.02	♀ 0.97 ± 0.01 ♂ 0.94 ± 0.01
Segments of antennule	11	17	24	25	25	♀ 25 ♂ 22
Setae on inner margin of 2nd endopod of antenna	8	9	11	13	14	14
Setae on 2nd endopod of mandible	4	5	6	6	6	6
Setae on precoxal endite of maxillule	9	10	12	14	16	16
Setae on exite of coxa of maxillule	4	5	7	8	9	9
Total setae of maxilla	18	20	20	20	20	22
Total setae on endopod of maxilliped	5	8	10	13	15	15
Segments of endopod of maxilliped	2	4	5	6	6	6
Pedigers (bud)	2(1)	3(1)	4(1)	5	5	5
Number of prosomites	4	5	5	5	5	4
Number of urosomites	1	1	2	3	♀ 3 ♂ 4	♀ 3 ♂ 5
Segments of 1st swimming leg (exopod/endopod)	1/1	2/2	2/2	2/2	3/2	3/2
Segments of 2nd swimming leg (exopod/endopod)	1/1	2/2	2/2	2/2	3/3	3/3
Segments of 3rd swimming leg (exopod/endopod)	-	1/1	2/2	2/2	3/3	3/3
Segments of 4th swimming leg (exopod/endopod)	-	-	1/1	2/2	3/3	3/3
Setae on terminal segment of 1st swimming leg (exopod/endopod)	4/4	5/5	5/6	5/6	5/6	5/6
Setae on terminal segment of 2nd swimming leg (exopod/endopod)	4/5	5/6	6/8	7/9	6/7	6/7
Setae on terminal segment of 3rd swimming leg (exopod/endopod)	-	4/6	5/6	6/8	6/7	6/7
Setae on terminal segment of 4th swimming leg (exopod/endopod)	-	-	4/6	6/7	6/7	6/7

seta on outer margin. First and 2nd exopod inner margins with dense hairs; terminal process of 2nd exopod pointed, length of terminal spine as long as the process. The endopod rod shaped and as long as proximal exopod, terminating in 2 small spines.

DISCUSSION

A summary of postembryonic developmental characters of *N. tumidus* is given in tables 1 and 2. The different stages of nauplii collected from different pools exhibited greater size variation than did copepodids from 2 collecting sites. The size variation may result from growth under different nutritional states. Changes in size and body structure are significant from nauplius VI to copepodid I. Gender becomes distinguishable by the 5th swimming legs in male and female copepodid IV. As in the same taxonomic category, most postembryonic developmental characters of *N. tumidus* are similar to those of other diaptomid species in general (Comita and Mcnett 1976, Shih and Maclellan 1979, Reddy and Devi 1985, Devi and Reddy 1989a, Devi and Reddy 1989b, Reddy and Devi 1989, Reddy and Devi 1990a, Reddy and Devi 1990b). Some minor differences in segmentation and setation are species spe-

Table 3. Developmental setation of 1st to 4th swimming legs of *Neutrodiaptomus tumidus* compared to other diaptomid copepodids in Asia

Species and reference	Setae on terminal segment of 1st swimming leg (exopod/endopod)					Setae on terminal segment of 2nd swimming leg (exopod/endopod)				
Copepodid stage	CI	CII	CIII	CIV	CV	CI	CII	CIII	CIV	CV
Megadiaptomus hebes; Reddy and Rama 1985	4/7	5/7	5/6	5/6	5/6	4/6	5/7	6/8	6/9	6/7
Hellodiaptomus contortus; Reddy and Devi 1989	4/7	5/7	5/6	5/6	5/6	4/6	5/7	6/7	6/8	6/6
Allodiaptomus raoi; Devi and Reddy 1989	4/7	5/7	5/6	5/6	5/6	4/6	5/6	6/7	6/8	6/6
Paradiaptomus greeni; Devi and Reddy 1998	4/7	5/6	5/6	5/6	5/6	4/5	5/7	6/8	6/9	6/7
Hellodiaptomus cinctus; Reddy and Devi 1990	4/7	5/7	5/6	5/6	5/6	4/6	5/7	6/8	6/9	6/7
Phyllodiaptomus blanci; Reddy and Devi 1990	4/7	5/7	5/6	5/6	5/6	4/6	5/7	6/8	6/9	6/7
Tropodiaptomus informis; Devi and Reddy 1990	4/7	5/7	5/6	5/6	5/6	4/6	5/7	6/8	6/9	6/7
Neutrodiaptomus tumidus; This study	4/4	5/5	5/6	5/6	5/6	4/5	5/6	6/8	7/9	6/7

Species and reference	Setae on terminal segment of 3rd swimming leg (exopod/endopod)					Setae on terminal segment of 4th swimming leg (exopod/endopod)				
Copepodid stage	CI	CII	CIII	CIV	CV	CI	CII	CIII	CIV	CV
Megadiaptomus hebes; Reddy and Rama 1985		4/7	5/7	6/8	6/7			4/6	6/7	6/7
Hellodiaptomus contortus; Reddy and Devi 1989		4/6	5/6	6/7	6/6			4/6	6/6	6/6
Allodiaptomus raoi; Devi and Reddy 1989		4/6	5/6	6/7	6/6			4/6	6/6	6/6
Paradiaptomus greeni; Devi and Reddy 1998		4/6	5/7	6/8	6/7			4/6	6/6	6/7
Hellodiaptomus cinctus; Reddy and Devi 1990		4/7	5/7	6/8	6/7			4/6	6/7	6/7
Phyllodiaptomus blanci; Reddy and Devi 1990		4/6	5/7	6/8	6/7			4/6	6/7	6/7
Tropodiaptomus informis; Devi and Reddy 1990		4/6	5/7	6/8	6/7			4/6	6/7	6/7
Neutrodiaptomus tumidus; This study		4/6	5/6	6/8	6/7			4/6	6/7	6/7

cific after close comparison between these species. The developmental pattern of segmentation from the 1st to the 4th swimming legs of *N. tumidus* is similar to that of other diaptomid species (Ferrari 1991). There are differences in the developmental pattern of setation from the 1st to the 4th swimming leg between *N. tumidus* and other diaptomid species which have been studied in Asia (Table 3). *N. tumidus* has 4 setae on the terminal segment of the endopod of the 1st swimming leg at copepodid I and 5 setae at copepodid II, while other species always have 7 and 6-7, respectively. The exopod of the 2nd swimming leg at copepodid IV has 7 setae, which is more than that of other species with 6 setae.

Acknowledgments: We thank Dr. Chang-Tai Shih for his kind help with systematic suggestions and encouragement. We thank Dr. Frank D. Ferrari and Dr. Hans-U. Dahms for their reviewing and commenting on the manuscript. We also wish to thank the National Science Council for the grant (NCS-86-2311-B-134-001) with which made this study possible.

REFERENCES

Bănărescu P. 1990. Zoogeography of fresh waters. Vol. 1. General distribution and dispersal of freshwater animals. Wiesbaden: Aula-Verlag. Chapter 6, Distribution and dispersal of some groups of Entomostraca, inhabiting mainly temporary pools; pp. 406-413.

Comita GW, SJ McNett. 1976. The postembryonic developmental instars of *Diaptomus oregonensis* Lilljeborg, 1889 (Copepoda). Crustaceana **30:** 123-163.

Devi CR, YR Reddy. 1989a. The complete postembryonic, development of *Paradiaptomus greeni* (Gurney, 1906) (Copepoda, Calanoida) reared in the laboratory. Crustaceana **56:** 141-161.

Devi CR, YR Reddy. 1989b. The complete postembryonic development of *Allodiaptomus raoi* Kiefer, 1936 (Copepoda, Calanoida) reared in the laboratory. Crustaceana **56:** 246-266.

Devi CR, YR Reddy. 1990. The complete postembryonic development of *Tropodiaptomus informis* Kiefer, 1936 (Copepoda, Calanoida) reared in the laboratory. J. Plankton Res. **12:** 246-266.

Ferrari FD. 1991. Using patterns of appendage development to group taxa of Labidocera, Diaptomidae and Cyclopidae (Copepoda). Bull. Plankton Soc. Jap. Spec.**1991:**115-127.

Kiefer F. 1937. S sswassercopoden aus Ostasien II neue Diaptomiden und Cyclopiden von der Insel Formosa. Zool. Anz. **119:** 58-64.

Reddy YR, CR Devi. 1985. The complete postembryonic development of *Megadiaptomus hebes* Kiefer, 1936 (Copepoda, Calanoida) reared in the laboratory. Crustaceana **48:** 40-63.

Reddy YR, CR Devi. 1989. The complete postembryonic development of *Heliodiaptomus contortus* (Gurney, 1907) (Copepoda, Calanoida) reared in the laboratory. Crustaceana **57:** 113-133.

Reddy YR, CR Devi. 1990a. The complete postembryonic development of *Heliodiaptomus cinctus* (Gurney, 1907) (Copepoda, Calanoida) reared in the laboratory. Crustaceana **58:** 45-66.

Reddy YR, CR Devi. 1990b. Postembryonic development of *Phyllodiaptomus blanci* (Guerne and Richard 1896) (Copepoda, Calanoida). Hydrobiologia **190:** 155-170.

Shih CT, DC Maclellan. 1977. Descriptions of copepodid stages of *Diaptomus* (*Leptodiaptomus*) *nuds* Marsh, 1904 (Crustacea: Copepoda). Can. J. Zool. **55:** 912-921.

臺灣產肥胖蕩鏢水蚤 *Neutrodiaptomus tumidus* Kiefer, 1937（甲殼類：橈腳類）各發育階段之描述

楊樹森

肥胖蕩鏢水蚤 *Neutrodiaptomus tumidus* Kiefer, 1937 生活在臺灣的高山湖泊，在這些水域並無其他種類的哲水蚤與之共同生存，本研究採集能高山及安東軍山附近高山湖泊的樣品中獲得其各個發育階段之標本，並詳細繪圖描述之。本文為首次描述肥胖蕩鏢水蚤之各個發育階段。

關鍵詞：肥胖蕩鏢水蚤，無節幼生，橈腳幼生，哲水蚤，後胚期發育。

國立新竹師範學院自然科學教育系