

Temora turbinata(橈脚類:カラヌス目)の発育段階

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The Developmental Stages of *Temora turbinata* (Copepoda : Calanoida)^{1), 2)}

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Abstract

Particular attention is focused on the development of *Temora turbinata* (DANA) to distinguish the differentiation of developmental stages between three species of the genus *Temora* in the waters around Japan. The nauplius of *Temora turbinata* is tadpole-shaped, rounded at anterior end, and extended slightly towards posterior portion ending in strong spines. The posterior portion becomes clearly distinguished from the carapace in late naupliar stages. The body is pale green in color. The naupliar appendages of this species resemble those of *Calanus*, but the caudal armature is asymmetrical, resembling that of *Sinocalanus*. The cephalothorax is tapering posteriorly in all copepodid stages. The secondary sexual character appears in the 5th feet, the abdominal segment and the antennule. The postero-lateral angles of the cephalon of earlier copepodid stages in *Temora turbinata* are pointed as in *Temora stylifera*, but are rounded in the 5th copepodid stage and adult. Postero-ventral corner of the last thoracic segment is not pointed as in *Temora stylifera* and *Temora discaudata*.

There are three species of the genus *Temora* in the waters around Japan, namely, *Temora discaudata*, *Temora stylifera* and *Temora turbinata*. *T. discaudata* and *T. turbinata* were recorded by SATO (1913) from the adjacent waters of Hokkaido. *T. discaudata*, *T. stylifera* and *T. turbinata* were reported by MORI (1937) from the adjacent waters of Japan. These species were also found from the Izu region by TANAKA (1936). The adult of *Temora stylifera*, however, has not been recorded from Japanese waters. TANAKA (1957) and FURUHASHI (1975) doubted whether MORI's specimen was *T. stylifera* or not. TANAKA (1957) referred it to be the young form of *T. turbinata*, while FURUHASHI (1975) considered it as the young form of *T. discaudata*.

OBERG (1906) first described the nauplii of *Temora longicornis* from Kiel Bay. LINDQUIST (1959) reported that the nauplii of *Limnocalanus grimaldii* are similar to those of *T. longicornis* based on the specimens from the northern Baltic. However, his illustrations are not detailed. GAUDY (1961) reported the nauplii and copepodids of *Temora stylifera* from the Gulf of Marseilles. BJÖRNBERG (1972) described the 4th and 6th? nauplii of *Temora turbinata* from Piscadera's inner bay (Curaçao), and the 4th nauplius of *Temora stylifera* from the water off Ubatuba (Brazil). KOGA (1984) observed 6 naupliar stages of *Temora turbinata* from Fukuoka Bay. However, the appendages of these nauplii were not described.

Temora turbinata is common in Fukuoka Bay, northern Kyushu, from summer to autumn. The author obtained all the developmental stages of this species from laboratory culture popu-

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²⁾ *Temora turbinata* (橈脚類: カラス目) の發育段階

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lation and field specimens. It has been clarified that the nauplius of *T. turbinata* is similar to that of *T. longicornis* and *Limnocalanus*, and MORI's illustration of *T. stylifera* is obviously different from any stage of *T. turbinata*. Therefore, it is necessary to check all the developmental stages in order to distinguish these three species of *Temora*. In the present paper the entire stages of *Temora turbinata* will be described.

Materials and Methods

The laboratory cultures of *Temora turbinata* were initiated from gravid females collected in Fukuoka Bay during July, 1979. The females were isolated individually into separate dishes containing approximately 100 ml of filtered sea water, and maintained at 28°C in an incubator. Cultured diatoms, *Skeletonema constatum*, *Nitzschia* sp., etc. were put in culture dishes as diet. The females were taken away from culture dishes after egg-laying. Many nauplii easily grew up to early copepodid stages. However, only a few of them reached up to adult. Some young copepodids collected from the field developed to adult in different laboratory cultures.

The descriptions of nauplius and 2 early stages of copepodid were made based on the cultured specimens. Subsequent stages of copepodid and adult were described based on the specimens collected in Fukuoka Bay.

Results

Nauplius Stages

The 1st nauplius is oval in shape. The body of meta-nauplius is tadpole-shaped, pale-green in color, rounded at its anterior end, and slightly extended towards posterior portion, ending in strong spines. The posterior portion becomes clearly distinguishable from the carapace in

TABLE 1. SEGMENTATION AND SETATION OF APPENDAGES OF *Temora turbinata* NAUPLII (I-VI).

Numerals: number of setae; h: hook; s: spine; ss: many spines; mp: masticatory process; tp: toothed process; +: indicates separate groups of setae; basip: basipodite; endop: endopodite; exop: exopodite; vent: ventral; dors: dorsal; lat: lateral; rud: rudimentary; Roman numerals: indicate stage of nauplius

Antennule. 1st segm: 1(I-VI); 2nd segm: 2(I-VI); 3rd segm (vent•dors•term): 0•0•3, 0•0•4, 1•2•4, 2•4•4, (2+2)•(6+4s)•4, (2+3)•(8+4s)•4.

Antenna. coxa: 1 (I), 1+1 (II), 2mp+1 (III-VI); basip: 1 (I), 1mp+1+1 (II), 1mp+2+1 (III-VI); endop (lat•term): 1•2, 2•3, 3•4, 3•4, 4•(3+2), 4•(3+2); exop: 0•2•1•1•2, 0•2•1•1•1•2, 0•3•1•1•1•1•2, 0•3•1•1•1•1•3, 0•3•1•1•1•1•3, 0•(3+1s)•1•1•1•1•1•3.

Mandible. coxa: 1 (I-III), 1tp+1 (IV-VI); basip: 2 (I-II), 3 (III), 5 (IV-VI); endop (lat•term): 2•(1+2) (I), 3•(2+3) (II, III), (3+1)•(2+2+2) (IV-VI); exop: 1•1•1•2 (I), 2•1•1•2 (II-IV), 1•1•1•1•2 (V, VI).

Maxillule (precoxa•coxa•basip•endop•exop): 1 (rud) (III), 0•0•2•3•3 (IV), 1•2•2•(2+2+2+2)•5 (V), 1•(1+2)•3•(2+1+2+4)•(5+2) (VI).

Maxilla (coxa•basip•endop): 2•(2+2)•(2+2+2) (VI).

Maxillipede: 1+1+8s (rud) (VI).

Caudal armature. end spine: 1+1 (I-VI); end setae: 1+1 (III-VI); ventral hook: 2 (III), 2+2 (IV-VI); lateral hook: 2+2 (IV), 2+2+2 (V), 2+2 (VI).

later stages. There is a small rostrum ventrally at the anterior margin. The labrum is of normal size. The nauplius eye is represented by a very small red spot. The caudal armature is asymmetrical. The maxillule appears as a ventral seta at the 3rd stage. The segmentation and setation of all stages of the nauplii are shown in Table 1.

Nauplius I (Figs. 1-1; 2-1, 7, 13): Length 0.09-0.12 mm, average 0.11 mm. Caudal armature consists of 2 subequal hook-like spines. Antennule bears 3 terminal setae. Antenna and mandible are bilobed.

Nauplius II (Figs. 1-2; 2-2, 8, 14): Length 0.13-0.16 mm, average 0.15 mm. Body pear-shaped. Caudal armature consists of 2 asymmetrical spines, the left larger one being $2/3$ body length, and the right smaller one $1/2$ as long as the former. Antennule bears 4 terminal setae. Coxa and basipodite of antenna have 1-2 strong masticatory processes proximally.

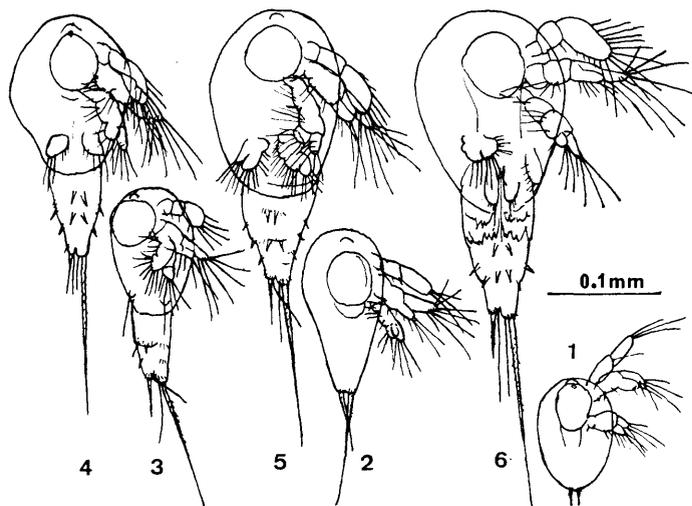


Fig. 1. The 1st-6th nauplii of *Temora turbinata*.

Nauplius III (Figs. 1-3; 2-3, 9, 15): Length 0.15-0.20 mm, average 0.18 mm. Posterior part of body more extended. Body resembles the larva of amphibian tadpole. Carapace is clearly distinguished from the abdomen. Abdomen with a pair of ventral hooks and many small spines. Maxillule is represented by a seta. Caudal armature is separated into 2 parts. Each part consists of a stout spine and a seta. Left long spine is $2/3$ body length, and right short one is less than $1/4$ the length of the former.

Nauplius IV (Figs. 1-4; 2-4, 10, 16): Length 0.18-0.22 mm, average 0.21 mm. Maxillule rudimentary, bilobed, inner lobe bearing 3 setae, outer lobe bearing 2+3 setae. Caudal armature as in Nauplius III. Two pairs of ventral and lateral hooks on the abdomen. The inner part of coxa of mandible extends into a masticatory process.

Nauplius V (Figs. 1-5; 2-5, 11, 17, 20, 24): Length 0.22-0.26 mm, average 0.24 mm. Maxillule more developed than that of stage IV. Abdomen with 3 pairs of lateral hooks.

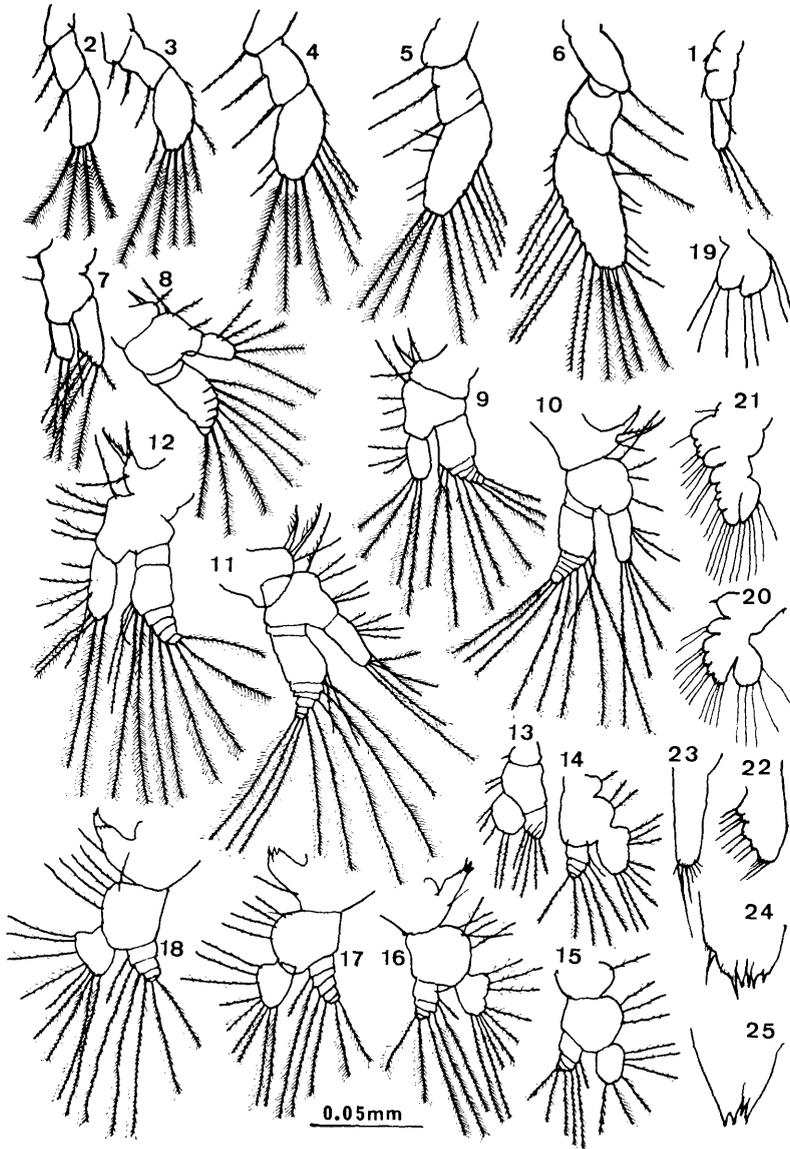


Fig. 2. The appendages and the swimming feet of nauplii of *Temora turbinata*. Roman numerals indicate stage of nauplius.

1-6: Antennule (I-VI); 7-12: Antenna (I-VI); 13-18: Mandible (I-VI);
 19-21: Maxillule (IV-VI); 22: Maxilla (VI); 23: Maxillipede (VI);
 24, 25: Rudimentary swimming feet (V, VI).

Nauplius VI (Figs. 1-6; 2-6, 12, 18, 21, 22, 23, 25): Length 0.24-0.32 mm, average 0.27 mm. Maxillule becomes functional. Maxilla and maxillipede are rudimentary. The primordia of 1st and 2nd feet present. Masticatory process of mandible becomes considerably broader with indications of teeth.

TABLE 2. SEGMENTATION AND SWIMMING FEET OF COPEPODID STAGES OF *Temora turbinata*.
d: dorsal; t: terminal; b: blade; m: male; f: female; others as in Table 1.

Stage	I		II		III		IV		V		Adult	
	Sex		Sex		Sex		f	m	f	m	f	m
Segment												
Cephalothorax	3		4		5		5	5	5	5	5	5
Abdomen	2		2		2		4	4	4	5	4	5
Furca	1+3+1(pair)		2+3+1(pair)		as in II		as in III		as in IV		as in V	
Swimming feet												
F I Coxa	0		0		0		0		as in IV		as in V	
Basipod	1		1		1		1					
Endop 1	3+1+1(d)		3+1+1(d)		1		1					
2					3+2+1(d)		5+1(d)					
Exopod 1	3+3h(d) (1b+1h)(t)		0+1h(d)		1+1h(d)		1+1h(d)					
2			4+2h(d) (1b+1h)(t)		4+2h(d) (1b+1h)(t)		1+(1h+1s)(d)					
3							4+1h(d) (1b+1h)(t)					
F II Coxa	1		1		1		1		as in IV		as in V	
Basipod	0		0		0		0					
Endop 1	6+1(d)		3+1+2+1(d)		1+3+3+1(d)		3					
2							5+1(d)					
Exopod 1	3+2h(d) (1b+1s+1h)(t)		0+(1h+1s)(d)		0+(1h+1s)(d)		ss+1+1h(d)					
2			4+(1h+1s)(d) (1b+1s+1h)(t)		5+2h(d) (1b+2s+1h)(t)		1+1h(d)					
3							5+2h(d) (1b+2h)(t)					
F III Coxa	rud		0		1		1		1		as in V	
Basipod			0		0		0		0			
Endpod 1			3+2+1(d)		4+2+1(d)		4+3+1(d)		3			
2									3+2+1(d)			
Exopod 1			4+2h(d) (1b+2h)(t)		4+(2h+2s)(d) (1b+1h+2s)(t)		1+1h(d)		as+2+2h(d)			
2							5+2h(d) (1b+1h+2s)(t)		5+2h(d) (1b+2h+1s)(t)			
F IV Coxa			rud		0		1		1		1	
Basipod					0		0		0		0	
Endpod 1					2+3+1		3+3+1(d)		3		3	
2									2+2+1(d)		2+2+1(d)	
Exopod 1					3+2h (1b+1h+1s)(t)		5+3h (1b+1h+1s)(t)		2+(2h+2s)(d)		1+(1h+1s)(d)	
2									5+2h(d) (1b+1h+1s)(t)		1+(1h+1s)(d)	
3											5+2h(d) (1b+1h+1s)(t)	
F V Coxa							f	m	f	m	f	m
Basipod							0	0	0	0	0	0
Exopod 1							0	0	0	0	0	0
2							2s	4s	3h	2h, 2s	1s	3h
3											ss+1	2s
											1+2h	2h

Copepodid Stages

Cephalon broadly rounded. Postero-lateral corner of cephalon of the 1st to 4th stages extends backwards into a process. Cephalothorax is tapering towards its posterior end. The sexual characters first appear in the 5th swimming feet and antennules at the 4th stage. The segmentation and swimming feet of copepodids and adult are shown in Table 2.

Copepodid I (Figs. 3-1; 4-1, 7): Length 0.33-0.40 mm, average 0.36 mm. Cephalon large, broadly rounded, its postero-lateral corner extends backwards. Posterior thoracic segments

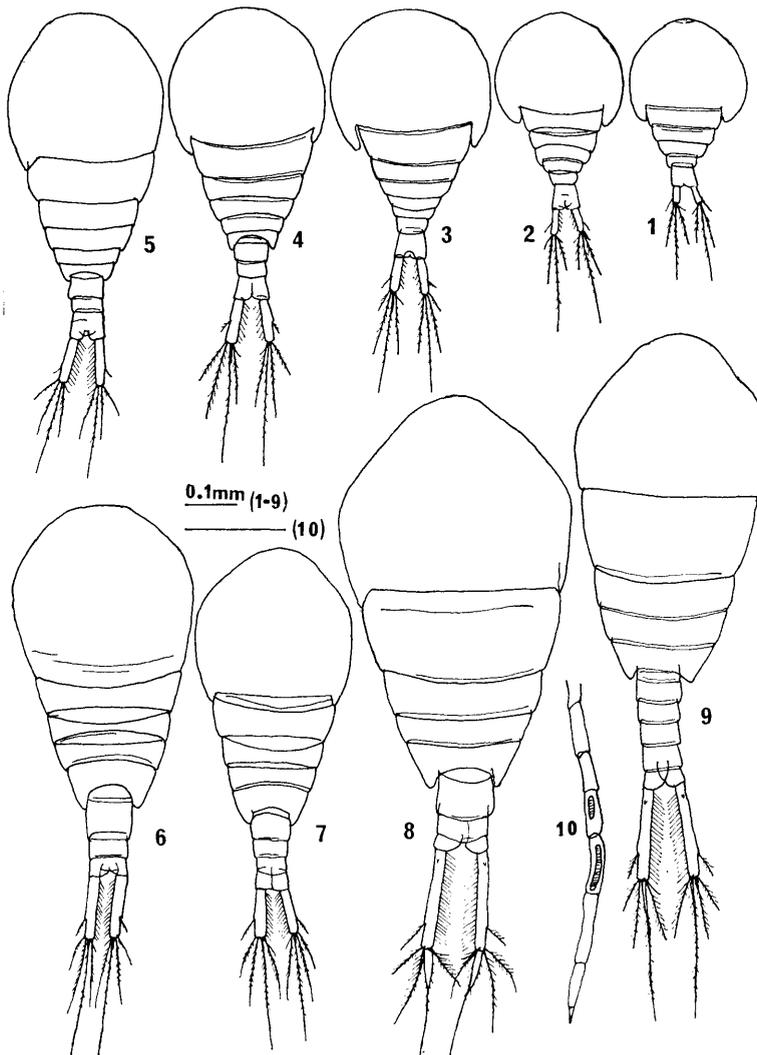


Fig. 3. Copepodids and adults of *Temora turbinata*. 1-3: Copepodid (I-III); 4, 7, 9: Male (CIV, CV, adult); 5, 6, 8: Female (CIV, CV, adult); 10: Distal part of grasping antennule of adult male, segments 18-19 and 20-21 fused having a row of small notches.

become smaller. Abdomen consists of 2 segments. Furca with 5 setae as in the adult. 1st and 2nd swimming feet rudimentary, consisting of coxa, basipodite, and 1-segmented endo- and exopodite.

Copepodid II (Figs. 3-2; 4-2, 8, 13): Length 0.39-0.47 mm, average 0.44 mm. Postero-lateral

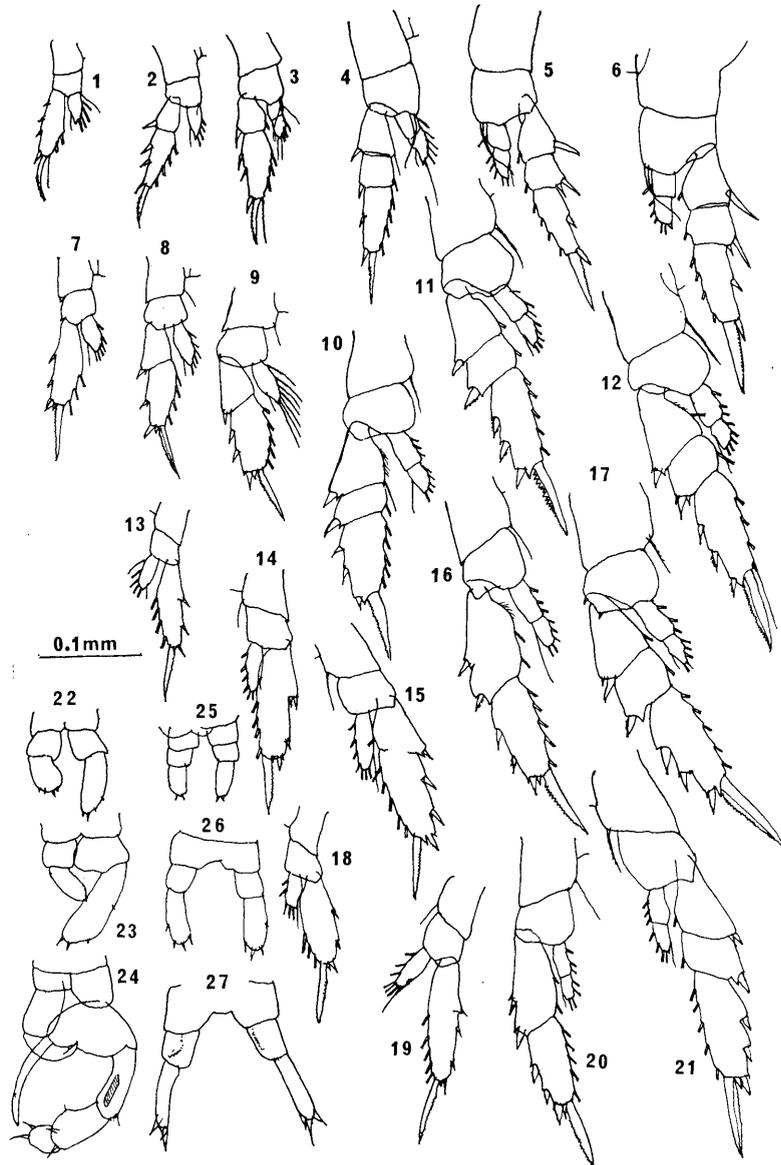


Fig. 4. Swimming feet of copepodids and adults of *Temora turbinata*. 1-6: 1st feet (CI-V, adult); 7-12: 2nd feet (CI-V, adult); 13-17: 3rd feet (CII-V, adult); 18-21: 4th feet (CIII-V, adult); 22-24: 5th feet of male (CIV-V, adult), 3rd segment (1st exopodite) of left foot in adult having a row of small notches; 25-27: 5th feet of female (CIV-V, adult).

corner of cephalon pointed. Thorax composed of 4 segments, and abdomen of 2 segments. There are 3 pairs of swimming feet, and primordia of 4th feet. Exopodites of 1st and 2nd feet 2-segmented.

Copepodid III (Figs. 3-3; 4-3, 6, 14, 18): Length 0.49-0.60 mm, average 0.56 mm. Posterolateral corner of cephalon pointed. Thorax 5-segmented, and abdomen 2-segmented. There are 4 pairs of swimming feet, and the primordia of 5th feet.

Copepodid IV (Figs. 3-4, 5; 4-4, 10, 15, 19, 22, 25): Length 0.65-0.77 mm, average 0.74 mm (female), length 0.60-0.71 mm, average 0.66 mm (male). The processes of 1st thoracic segment small. Thorax composed of 5-segments. Abdomen 4-segmented. 5th swimming foot uniramous and 3-segmented. Male 5th feet asymmetrical, terminal segment bearing 4 small spines, left foot longer than the right (Fig. 4-22). Female 5th feet symmetrical, terminal segment bearing 2 small spines (Fig. 4-25).

Copepodid V (Figs. 3-6, 7; 4-5, 11, 16, 20, 23, 26): Length 0.80-0.94 mm, average 0.86 mm (female), length 0.72-0.85 mm, average 0.78 mm (male). Abdomen consists of 4 segments in female and 5 in male. Male 5th swimming feet asymmetrical. The left foot becomes longer than in 4th stage, bearing a small terminal spine (Fig. 4-23). Female 5th feet symmetrical, bearing 3 terminal hooks (Fig. 4-26).

Adult (Figs. 3-8, 9, 10; 4-6, 12, 17, 21, 24, 27): Length 0.95-1.45 mm, average 1.10 mm (female), length 0.89-1.37 mm, average 1.09 mm (male). Segmentation of body as in Copepodid V. Small protuberances present at both ends of the 5th thorax. A row of small spines on the 2nd segment of 5th feet of female, and 3 hooks on terminal segment (Fig. 4-27). Male 5th feet asymmetrical forming a forceps-like, grasping organ. Left foot consists of 5 segments; 2nd segment (=basipodite) bearing a strong thumb-like process on its inner part, 3rd (=1st segment of exopodite) having a row of small notches, many spines and a small hair-like seta terminally, 4th (=2nd segment of exopodite) bearing a small hair-like seta and 2 hooks, and terminal bearing 2 hooks. Right foot small; 3rd segment (=exopodite) bearing 2 hooks (Fig. 4-24). Antennule is also modified into a grasping organ. Segments 18-19 and 20-21 fused, each of them having a row of small notches (Fig. 3-10).

Discussion

Only two nauplius stages of *Temora turbinata* have been reported by BJÖRNBERG (1972). In the present study, the whole developmental stages of *Temora turbinata* were clarified. Nauplius of *T. turbinata* is not as wide anteriorly as that of *T. stylifera* which was reported by GAUDY (1961) and BJÖRNBERG (1972), with distinctly circular anterior portion. The posterior portion of late naupliar stages of the genus *Temora* is distinguishable from the carapace. The caudal armature on the posterior portion of *Temora* nauplius is composed of end spines (hooks), end setae, ventral and lateral hooks. The stout caudal spines are asymmetrical in *T. turbinata*, but almost symmetrical in *T. stylifera*.

Nauplius of *T. turbinata* is similar to that of *Temora longicornis* which was described by OBERG (1906). The number of lateral hooks on abdomen of both species are 2 pairs in the

4th and 6th stages, but 3 pairs in the 5th stage. Both species have a pair of stout terminal spines at the caudal end. The left end spine of *T. turbinata* is 2-3 times longer than that of the right, while in *T. longicornis* the left spine is 1.5-2.0 times longer than that of the right.

LINDQUIST (1959) compared the nauplius of *Limnocalanus grimaldii* with that of *T. longicornis*, and described the differentiation in the number of the lateral hooks on the abdomen, viz. there are 3 pairs of lateral hooks on the abdomen in the late 3 naupliar stages of *L. grimaldii*. The developmental stages of *Sinocalanus tenellus* described by MATSUDAIRA (1957) are not in detail. Therefore, the author compared the nauplii of *S. tenellus* collected from a pond in Fukuoka with those of *Temora turbinata*. Both species are actually distinguishable by the lateral hooks on abdomen as well as the carapace. The body of late naupliar stages of *S. tenellus* is tadpole-shaped resembling that of *T. turbinata*, and has 3 pairs of lateral hooks on the abdomen as in *Limnocalanus grimaldii*. The carapace of *S. tenellus* is 1.5-2.0 times longer than wide in nauplius of *T. turbinata*. In the early stages, the caudal armature of *T. turbinata* nauplius is similar to that of *Centropages* which was described by OBERG (1906), KOGA (1960, 1970), LAWSON & GRICE (1970) and BJÖRNBERG (1972). However, nauplius of *Centropages* has a simple caudal armature consisting of a pair of end hooks, end setae and ventral hooks even in the last stage. On the other hand, nauplius of *T. turbinata* has an asymmetrical complicated armature in late stages.

MORI (1937) described an immature stage of *Temora stylifera* provided with the processes on the cephalon and the last thoracic segment. TANAKA (1957) reported that MORI's specimens may have been an immature stage of *T. turbinata*. According to the present study, however, the corresponding immature stage of *T. turbinata* lacks the processes on the last thoracic segment. Therefore, it is presumably true that MORI's specimen is not *T. turbinata*. FURUHASHI (1975) considered that specimens examined by MORI (1937) and TANAKA (1963) are the 5th copepodid stages of *Temora discaudata*, and pointed out the necessity of systematic study of the developmental stages of these species. The question proposed by FURUHASHI (1975) needs to be clarified through examination of the developmental stages of *Temora discaudata*.

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Note Added in Proof

LI and FANG (1983) recently published a paper describing the developmental stages of *Temora turbinata* (DANA) (LI and FANG, 1983. *J. Xiamen Univ. (Nat. Sci.)*, **22**: 96-101), but neither the paper nor its abstract has been accessible to the author.