J. mar. biol. Ass. India, 1975, 17 (1) : 87 - 95

POST-NAUPLIAR DEVELOPMENT OF THE CALANOID COPEPOD *TEMORA TURBINATA* (DANA), WITH REMARKS ON THE DISTRIBUTION OF THE SPECIES OF THE GENUS *TEMORA* IN THE INDIAN OCEAN

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ABSTRACT

The post-naupliar developmental stages of *Temora turbinata* (Dana) (Copepodites I to VI) are described and illustrated. The differences in the meristic characters associated with growth have been investigated. The segmentation and setation of the maxillipeds of copepodid stages offer important criteria for separating the different stages. Special attention has been given to study the developmental sequence of the mandibular teeth as the teeth structure helps to understand the feeding habits of these stages.

The status and validity of the species of *Temora* recorded from the Indian Ocean are also discussed. The present study as well as the previous distributional records provide evidence to the inference that *Temora stylifera* (Dana) and *T. discaudata* Giesbrecht are allopatric, with the former restricted in distribution to the Atlantic and its adjacent seas and the latter to the Indo-Pacific.

INTRODUCTION

SPECIES of *Temora* are of economic importance as they form one of the major food items of the commercially important shoaling fishes. Adults and larvae of the species of *Temora* occur in great abundance during certain seasons in the inshore waters of the Indian seas and they form a quantitatively dominant group in the plankton. Three species of *Temora* viz., *T. turbinata* (Dana), *T. discaudata* Giesbrecht and *T. stylifera* (Dana) have been recorded from the Indian seas of which the first two species are most abundant in the neritic waters. Although there are many records of *T. stylifera* from Indian seas, as suggested in the ensuing discussion, it is highly doubtful whether the records refer to this species.

Practically no study has been carried out on the developmental stages of *Temora* from the Indian seas. Krishnaswamy (1950) briefly discussed one copepodid form 'collected in large numbers during November-December period from the Madras Coast' which he designated as '*Temora* sp.' He has given the size of the specimens 0.52 mm, and described the A-1 to contain 8 segments. Although, he had not assigned this copepodid form to any stage, the present studies show that it belongs to the copepodid stage II of *Temora turbinata*. He has also remarked that as adults of both *T. turbinata* and *T. discaudata* were met with in the plankton, these copepodites though undoubtedly belong to the genus, cannot be identified specifically. However, while examining the plankton samples, the copepodid stages of both *T. turbinata* and *T. discaudata* were observed and the latter could be separated from the co-occurring copepodites of the former species by the characteristic posterior margin of the prosome which is drawn out into acuminate points whereas in *T. turbinata* the posterior margin of the prosome is evenly rounded without acuminate tips.

While examining the surface zooplankton samples collected from Cochin Backwater during February, 1970 copepodites of *T. turbinata* in different stages were seen. Since the copepodid stages of this species remains undescribed, the present detailed account will rectify this deficiency. Special emphasis is also given to study morphometric and meristic variations during the developmental stages.

The Author wishes to express his gratitude to Dr. E.G. Silas, Director, C.M.F.R. Institute for his constant guidance, many valuable suggestions and for critically going through the manuscript.

DESCRIPTION

The salient features by which the different stages of copepodites are separated are summarised in Table 1. Gaudy (1962) recorded copepodites I and II of *T. stylifera* as having two urosomal segments. Corkett (1967) recorded only one urosomal segment for the copepodid stages I and II for *T. longicornis*. As has been stated earlier, the small anterior segment present anterior to the urosomal segment is separated from the preceding thoracic segment at the moult from C-I to C-II and therefore belongs to the thorax (Pillai, 1972). In the adult, T-IV and T-V are fused together, although in earlier stages separation is evident. As in *T. longicornis*, the number of endopodal segment and the arrangements of setae on endopods on either side and on the basipodal segment of maxillipeds are useful in distinguishing developmental stages.

TABLE 1. *Identification Table for the copepodid stages of* Temora turbinata (*Dana*)

Character	C-I	C-II	C-III	C-IV	C-V	ADULT
No. of specimens	6	18	19	41	65	110
Range	0.34–	0.56–	0.61–	0.78–	1.05–1.10 (F)	1.35–1.49 (F)
Length (mm)	0.39	0.58	0.69	0.82	0.96–1.02 (M)	1.33–1.41 (M)
Mean	0.37	0.57	0.64	0.80	1.08 (F)	1.42 (F)
					0.99 (M)	1.36 (M)
No. of prosomal segments	4	5	5	5 (F, M)	5 (F,M)	4 (F, M)
No. of urosomal segments	1	1	2	3 (F, M)	3 (F), 4 (M)	3 (F), 4 (M)
No. of swimming feet	2	3	4	5 (F, M)	5 (F, M)	5 (F, M)

Sexes can be separated as early as C-IV as the Re of male P-5 shows asymmetry, although the animal exhibits the same number of urosomal segments. By stage V, the differences get well established.

APPENDAGES OF C-I TO C-V AND ADULT

A-1: (Fig. 1 b, p, q)

Copepodites I to IV have 9, 13 and 20 segments respectively, arrangements of setae, spines and aesthetets as in Table 2; segments 24-25 fused in C-IV, C-V and in adult. Right A-1 of male in C-IV with two spinous processes on segment 19 in series; in adult, segment 17 with a dorsal plate, overlapping part of segment 18; latter with a denticulated plate dorsally; segment 19–21 also bear 2 adjacent dorsal plates, carrying fine denticulations; hinge present in adult male between segments 18 and 19–21, distal to which are present 3 segments, namely 19–21, 22-23 and 24–25.

A 2: (Fig. 1 c)

C-I with same number of segments as in adults; terminal segment of Ri shows increase in number of terminal and lateral setae from C-I (9) to adult (16). Re 2 in C-I with 2 setae, but in subsequent stages one or more setae is added to segment.

Mnd: (Fig. 1, d, r, s, t, u, v)

Number of setae in B 2 and terminal segment of Ri increases from 3 to 4 and 6 to 8 respectively as development proceeds (Table 2); mandibular blade with 7 blunt teeth and one flagellar seta in C-I; in adult, dorsal tooth remains bluntly pointed and 2 ventral teeth bifurcated; altogether 8 teeth and one bifurcated flagellum-like seta were observed in the adult.

Mx-1: (Fig. 1 e)

In C-I, precoxa bears a gnathobase with 8 bristles; coxa with 2 lobes, internal lobe (endite-1) with 3 setae and external lobe (exite-1) with 4 long setae; B1 also with 2 lobes, internal lobe (endite-2) with 3 setae and external lobe (exite-2) with one strong seta; B2 with 3 setae; Ri with two lobes, Ri 1 with 4 setae and Ri 2 with 5 setae; Re with 7 plumose setae; number of setae increases from C-I to adult and gradual increase in number is observed in all segments except exite-2; gnathobase (8–13); endite-1 (3–4); endite-2 (3–4); exite-1 (4–9); B2 (3–4); Ri 1 (4–8); Ri 2 (5–6) and Re (7–10).

Mx-2 (Fig. 1 f)

C-I with 4 endopodal segments; in all subsequent stages there are 5 segments; number of setae in first endite of basipod increases from 3 in C-I and C-II to 4 in C-III, C-IV, C-V and adult; third segment of Ri carrying a simple setae in C-II and having 2 setae in C-III and subsequent stages.

Mxp: (Fig. 1 w-b 1)

Mxp forms a good criterion for distinguishing different stages of copepodites; Ri of C-I with 2 segments; Re 1 with a distal plumose seta and Re 2 with 3 terminal setae; Ri of C-II and C-III with 4 and 5 segments respectively; Ri of C-IV is of 6 segments and this number is retained in subsequent stages and adult; number of setae on basipods increases from 5 in C-I to 9 in adult (Table 2).

P-1: (Fig. 1 g)

Present in all stages; B1 (coxa) without seta; seta on B2 (basipod) present in all stages; Ri one-segmented in stages I and II, 2-segmented in copepodites III, IV, V and adult; Re one-segmented in C-I, 2-segmented in stages II, III and IV, and 3-segmented in C-V and adult; total number of setae increases from 11 in C-I to 14 in adult.

P-2: (Fig. 1 h)

Present in all stages; seta on B1 (coxa) appears first in C-III; seta on B2 observed only in adult; Ri one-segmented in C-I to C-IV and 2-segmented in C-V and adult; Re one-segmented in C-I, 2-segmented in C-II to C-IV and 3-segmented in C-V and adult; total number of setae increases from 9 in C-I to 18 in adult.

TABLE 2. *Segmentation and setation of the mouth parts of C-I to C-VI*
(Setae in Arabic and spines in Roman numerals)

Characters	Stages					
	C-I	C-II	C-III	C-IV	C-V	C-VI
A-1:						
No. of segments	9	13	20	24	24 (F) 24 (M)	24 (F) 20 (M)
No. of setae	16	22	26	35 (F) 28 (M)	38 (F) 31 (M)	38 (F) 31 (M)
No. of aesthetes	2	7	9–10	13 (F) 10 (M)	16 (F) 10 (M)	20 (F) 11 (M)
No. of spines	0	0	0	0	1 (M)	2–3 (M)
A-2:						
Bl	0	1	1	1	1	1
B2	2	2	2	2	2	2
Ril	2	2	2	2	2	2
Ri2						
lateral	4	5	6	7	8	9
terminal	5	6	7	7	7	7
Re1	1	1	1	1	1	1
Re2	2	3	3	3	3	3
Re3	1	1	1	1	1	1
Re4	1	1	1	1	1	1
Re5	1	1	1	1	1	1
Re6	1	1	1	1	1	1
Re7	4	4	4	4	4	4
Total setae:	24	28	30	31	32	33
Mnd:						
Coxa	7t+1	8t+1	8t+t	8t+1	8t+1	8t+1
Bl	0	0	0	0	0	0
B2	3	3	3	3	4	4
Ril	3	4	4	4	4	4
Ri2	6	6	7	7	7	8
Re1	1	1	1	1	1	1
Re2	1	1	1	1	1	1
Re3	1	1	1	1	1	1
Re4	1	1	1	1	1	1
Re5	2	2	2	2	2	2
Total setae:	19	20	21	21	22	23
Mx-1:						
Gnathobase	8br	9br	11br	11br	13br	13br
Endite 1	3	3	4	4	4	4
Coxa Exite 1	4	6	8	8	9	9
Endite 2	3	3	4	4	4	4
Basis Exite 2	1	1	1	1	1	1
B2	3	3	4	4	4	4
Ri 1	4	4	6	6	8	8
Ri 2	5	5	5	6	6	6
Re	7	7	8	9	10	10
Total setae:	30	32	40	42	46	46

TABLE 2 CONTD.

		C-I	C-II	C-III	C-IV	C-V	C-VI
Mx-2:							
	Endite 1	3	3	4	4	4	4
	Endite 2	3	3	3	3	3	3
B1	Endite 3	3	3	3	3	3	3
	Endite 4	3	3	3	3	3	3
Ri1		3	3	3	3	3	3
Ri2		1	1	1	1	1	2
Ri3		0	1	2	2	2	2
Ri4		2	2	2	2	2	2
Ri5		3	3	3	3	3	3
Total setae:		21	22	24	24	24	25
Mxp:							
Lobes		3	3	4	4	4	4
Setae		1:2:2	2:2:2	1:2:3:3	1:2:3:3	1:2:3:3	1:2:3:3
		(5)	(6)	(9)	(9)	(9)	(9)
Basipod		2	3	3	3	3	3
Ri segments		2	4	5	6	6	6
Setae		1:4	2:1:1	2:1:1	2:2:2	2:3:3	2:3:3
			4	2:4	1:2:4	2:3:4	2:3:4

P-3

Present in C-II, C-III, C-IV, C-V and adult; they appear as rudimentary buds in C-I; B1 (coxa) observed to bear a seta from C-III onwards and B2 with a seta in adult; Ri one-segmented in C-II to C-IV and 2-segmented in C-V and adult; Re one-segmented in C-II to C-IV and 2-segmented in C-V and 3-segmented in adult; number of setae increases from 9 in C-II to 18 in adult.

P-4

Present from C-III to adult and in rudimentary state in C-II; a single seta on B1 (coxa) present from C-I to adult; Ri one-segmented in C-III and C-IV, 2-segmented in C-V and adult; Re one-segmented in C-III and C-IV, 2-segmented in C-V and 3-segmented in adult; number of setae increases from 9 in C-III to 16 in adult.

P-5

Present in C-IV, C-V and adult.

(a) *C-IV*: *Female*: (Fig. 1 c1) Small, symmetrical and 3-segmented; Re one-segmented, with 2 distal spines and one outer marginal spine.

Male: (Fig. 1 f 1) Asymmetrical; each ramus 3-segmented; Re on left side distinctly larger than that of right and terminally with two spines and along outer margin with two spines; right ramus shorter, with one terminal spine and three outer marginal spines.

(b) *C-V*: *Female*: (Fig. 1 d1) Each ramus 3-segmented; Re one-segmented with 2 outer marginal spines and one sub-terminal spine.

Male: (Fig. 1 g1) Asymmetry of Re well marked; left Re large, twice longer than right ramus; left ramus with B2 distinctly produced inwards at its distal corner;

Re with 3 outer marginal spines and 2 terminal spines; right ramus with short Re, carrying an outer marginal spine; terminal portion of Re bluntly rounded.

(c) *Adult*: *Female*: (Fig. 1 e1) Both rami 3-segmented; Re one-segmented and carries an acute spine distally; sub-terminally, inner distal margin of Re with a spine; 2 marginal spines placed equidistant along outer margin.

Male: (Fig. 1 h1) Left leg with a chela; B2 produced externally into a curved claw-like process–the thumb of chela; terminal segment with 2 distal spines which are serrated on both margins; inner mid-margin of segment distinctly swollen and carries a short spine and few scattered spinules; sub-terminal segment of Re with an outer distal spine; right leg with one-segmented Re which carries an outer proximal marginal spine: distal part of segment bent inwards and beak-like.

TABLE 3. *Segmentation and setation of the swimming legs 1–4 of C-I to C-VI*
(Setae in Arabic and spines in Roman numerals)

Characters	Stages					
	C-I	C-II	C-III	C-IV	C-V	C-VI
P-1						
B1	0	0	0	0	0	0
B2	1	1	1	1	1	1
Ri1	—	—	1	1	1	1
Ri2	1:3:3	1:3:3	1:2:3	1:2:3	1:2:3	1:2:3
Re1	—	—	—	—	I+1	I+1
Re2	—	I+1	I+1	I+1	I+1	II+1
Re3	IV+I+3	III+I+4	III+I+4	III+I+4	II+I+4	II+I+4
Total setae	11	13	13	13	14	14
P-2:						
B1	0	0	1	1	1	1
B2	—	—	—	—	—	1
Ri1	—	—	—	—	3+0	3+0
Ri2	1:3:2	1:3:3	1:3:3	1:3:5	1:3:2	1:3:2
Re1	—	—	—	—	I+1	I+1
Re2	—	I+1	I+1	I+1	I+1	I+1
Re3	III+3	I+1+4	II+I+5	II+I+5	II+1+5	II+I+5
Total setae:	9	12	14	16	17	18
P-3:						
B1	—	—	1	1	1	1
B2	—	—	—	—	1	1
Ri1	—	—	—	—	3	3
Ri2	—	1:3:2	1:3:3	1:3:4	1:3:2	1:3:2
Re1	—	—	—	—	—	I+1
Re2	—	—	—	—	II+1	I+1
Re3	—	II+I+3	II+I+4	III+I+6	II+I+5	II+I+5
Total setae:	0	9	12	15	17	18
P-4:						
B1	—	—	—	1	1	1
B2	—	—	—	—	—	—
Ri1	—	—	—	—	3	3
Ri2	—	—	1:3:2	1:3:3	1:2:2	1:3:1
Re1	—	—	—	—	—	I+1
Re2	—	—	—	—	II+1	I+1
Re3	—	—	II+I+3	III+I+5	II+I+5	II+I+5
Total setae:	0	0	9	13	15	16

DISCUSSION

The post-naupliar development of *Temora turbinata* follows in essential details that of the pattern of *T. longicornis* (O. F. Müller), as described by Corkett (1967). However, the following differences were observed in the morphological characters of *T. turbinata*:(1) Re of P-4 in the adult male and female is 3-segmented in *T. turbinata* while in *T. longicornis* Re of adult male P-5 is reported to have 3 segments and in female of only 2 segments (Corkett, 1967); (2) The dorsal margin of segments 15 and 16 of the geniculate A-1 of the male is devoid of dorsal plates in *T. turbinata* even in the late copepodid stages and adults. In *T. longicornis* 2 distinct non-serrated plates are present on the dorsal margin of these segments (Corkett, 1967).

TAXONOMY AND DISTRIBUTION OF THE SPECIES OF THE GENUS *TEMORA* FROM THE INDIAN OCEAN

Under the name *Diaptomus* Lubbock (1856) described the species *D. dubius* from the Atlantic Ocean. Brady (1883) recorded examples of what he took to be the same species and placed it under the genus *Temora*. Giesbrecht (1892) considered *T. dubia* as a synonym of *T. stylifera* and *T. discaudata*. However, Brady (1914) did not accept this and maintained that *T. dubia* was a valid species. Further, on the basis of specimens obtained from Durban Bay, which also showed agreement in the characters to the specimens earlier described by him from the CHALLENGER expedition, he discussed the validity of this species. In the same paper he described *T. africana* (Brady, 1914) but it is now evident that his descriptions and figures are referrable to *T. turbinata*.

Thus, up to now, three species of *Temora* are recorded from the Indian Ocean *viz.*,*T. turbinata* (Dana) (=*T. africana* Brady),*T. discaudata* Giesbrecht and *T. stylifera* (Dana) (=*T. dubia* (Lubock). Although there are many records of *T. stylifera* from various parts of the Indian Ocean, it is highly doubtful whether these records refer to the adult material of this species. Distribution records of *T. stylifera* from the Indian seas show that except Pesta (1912) no author has illustrated or described it from this area. Moreover, on many occasions, the late copepodites of *T. discaudata* have been found to occur in the plankton collected from different areas in the Indian seas, and they closely resemble *T. stylifera* and could be very easily mistaken as belonging to that species. The late copepodites of *T. discaudata* are characterised by: (1) the produced posterior corners of cephalosome; (2) symmetrical anal segment, and (3) the distal segment of P-5 in these forms being shorter than that in the adult. According to Gonzales and Bowman (1965) the two species, *T. stylifera* and *T. discaudata* are probably allopatric, with the former restricted in distribution to the Atlantic Ocean and the latter to the Indo-Pacific. Besides, the Pacific records of *T. stylifera* by Wilson (1942, 1950) are considered erroneous by them. They also opined that other Pacific records of *T. stylifera* are either unillustrated records in faunal works or misidentifications (Mori, 1937; Chiba, 1953). Recently, Fleminger and Hulsemann (1973) stated that *T. stylifera* is endemic to the Atlantic Ocean and its adjacent seas, while *T. discaudata* replaces it in the Indian and Pacific Oceans. In the light of these clarifications, it would appear that the reported occurrence of *T. stylifera* in the Indian Ocean is incorrect.

Temora longicornis (O. F. Müller) recorded without description from West Hill Sea (SW coast of India) by Jacob and Menon (1947) and from Bay of Bengal by Thompson (1900) are evidently misidentifications of *T. turbinata* (Dana).

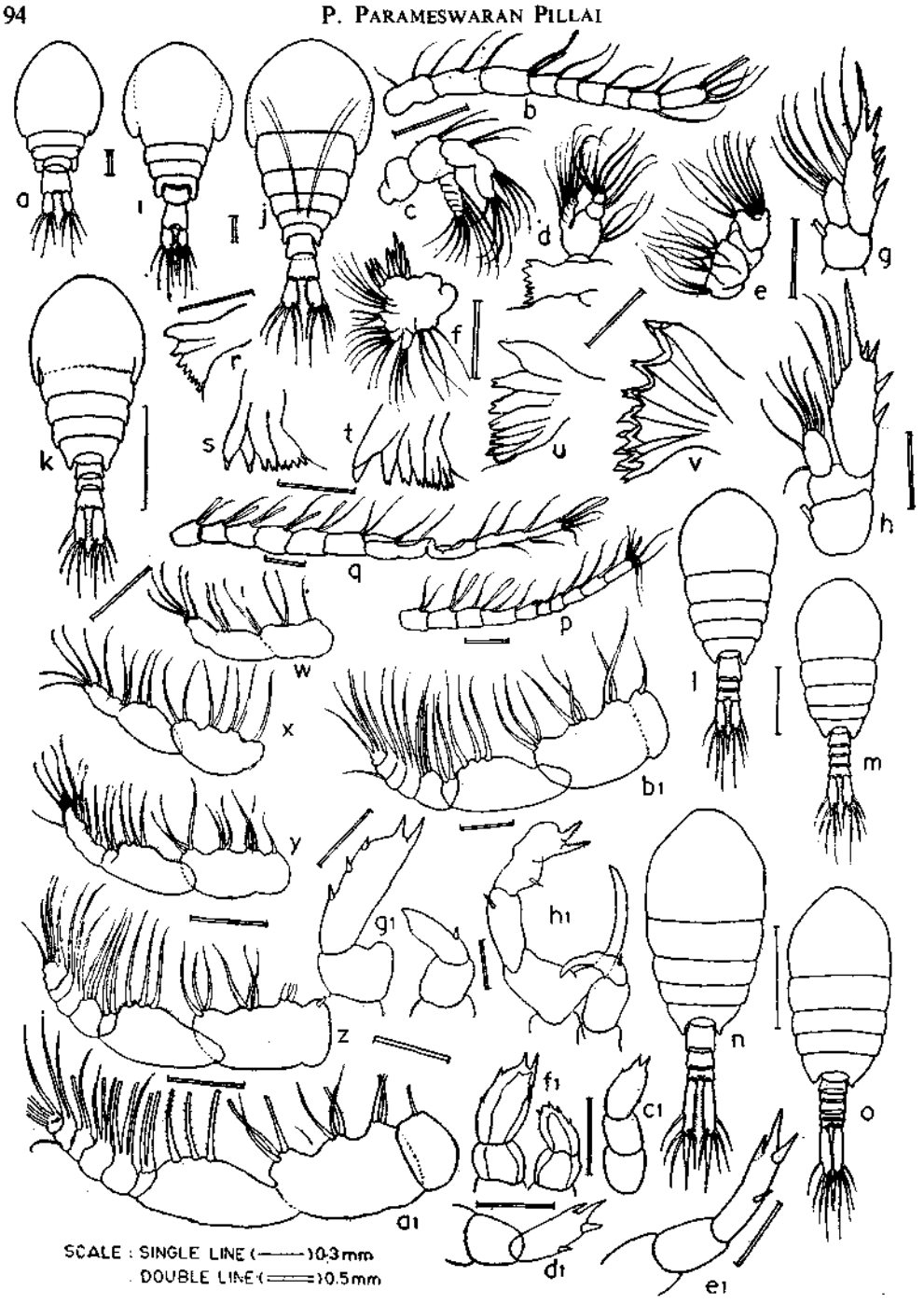

Fig. 1. Post-naupliar developmental stages of *Temora turbinata* (Dana): a. C-I, dorsal view; b. C-I, A-1; c. C-I, A-2; d. C-I, Mnd; e. C-I, Mx-1; f. C-I, Mx-2; g. C-I,P-1: h. C-I, P-2; i. C-II, dorsal view; j. C-III, dorsal view; k. C-IV, dorsal view; l. C-V, female, dorsal view; m. C-V, male, dorsal view; n. C-VI, female, dorsal view; o. C-VI, male, dorsal view; p. C-V, male A-1, part enlarged; q. C-VI, male A-1, part enlarged; r. C-II, Mnd; s. C-III, Mnd; t. C-IV, Mnd; u. C-V, Mnd; v. C-VI, Mnd; w. C-I, Mxp; x. C-II, Mxp; y. C-III, Mxp; z. C-IV, Mxp; a1. C-V, Mxp; b1. C-VI, Mxp; c1. C-IV, female P-5; d1. C-V, female P-5; e1. C-VI, female P-5; f1. C-IV, male P-5; g1. C-V, male P-5; and h1. C-VI, male P-5.

Temora turbinata is a common constituent of the neritic plankton occurring in maximum abundance in the coastal and shelf waters and randomly in the oceanic area whereas *T. discaudata* is uniformly widespread in neritic and oceanic waters, with high concentrations offshore.

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