

PREFERENCE OF *TEMORA STYLIFERA* (CALANOID COPEPOD) FOR PLANKTONIC CILIATES AND EGG PRODUCTION

by

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ABSTRACT

The investigation of feeding and egg production of the calanoid copepod *Temora stylifera* was carried out between September and November 1988. The copepods were fed on natural ciliates and phytoplankton assemblage. Planktonic ciliates composed of 2.20 to 3.83 g C l⁻¹ representing 15.2 to 58.7% of total biomass in standing stock. They were consumed by these copepods at rates ranging from 11.25 to 38.14 g C mg DW⁻¹ d⁻¹ or about 27.6 to 74.8% of total food consumed. The increase of ciliates/phytoplankton biomass ratio in the food consumed by the copepods in the all experiments indicates the preference for ciliates, in which as a good quality of food they can improve the rates of copepods egg production.

INTRODUCTION

Successful reproduction of planktonic crustaceans requires the efficient and coordinated utilizations of metabolic resources. The observation that zooplankton graze microplanktonic ciliates (Turner & Anderson 1983; Stoecker & Sanders 1985; Stoecker & Egloff 1987; Robertson 1983; Wiadnyana & Rassoulzadegan 1989) could be due to motility, greater size or nutritional quality of these preys. It is doubtful that motility and size alone drive feeding selectivity. It now is well known that copepods are capable of eating a wide range of cell sizes and shapes (Poulet 1973; Price *et al.* 1983), but active selection for larger cell size has not been demonstrated (Frost 1980). By contrast, feeding rate as well as fecundity and growth are affected by species of phytoplankton ingested (Mullin & Brooks 1970). Moreover, higher ingestion rate by copepods for phytoplankton cells having low C/N ratios also has been reported (Cowles *et al.* 1988), suggesting that nutritional quality of the food source is important. Therefore, both food quantity and quality have a strong influence on copepod reproduction (Checkley 1980; Cowles *et al.* 1988). The degree to which microplanktonic ciliates provide nutritional requirements of marine copepods has not been fully explored.

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Ciliates are quantitatively an importance and potential source of food for planktonic crustaceans in coastal and oceanic waters because of their abundance and size distribution. They have been estimated to account for 20 to 50 % of the biomass available in the plankton of 20 to 200 size range (Stoecker & Capuzo 1990).

In general, ciliates are larger in size than the algae or bacteria they eat. Much of the bacterial and phytoplankton production occurs in cells < 4-6 μm in size (Sherr *et al.* 1986). Cells smaller than 4-6 μm are not efficiently grazed by most crustacean plankton (Nival & Nival 1976) and thus microzooplanktonic ciliates are thought to be an important link between "microbial" production and crustacean zooplankton (Conover 1982 ;Sherr *et al.* 1986). Almost all the ciliates are large enough to be efficiently grazed by most crustacean zooplankton.

In order to understand the role of planktonic ciliates in marine food webs, we need to consider the preference of zooplankton for ciliates, the contribution of these organisms in the diet of their consumers and the nutritional requirements of zooplankton fed on ciliate preys.

MATERIAL AND METHODS

In the study of the feeding and fecundity in zooplankton. Six time series of experiments were done between September and November 1988 by using the calanoid copepod *Temora stylifera* Dana. Copepods were collected by using plankton net (0.28 mm mesh size) from the surface coastal waters of the Mediterranean N-W, France (43° 4' 10" N, 7° 19' 0" E). Fresh zooplankton was kept in a 10 l polycarbonate bottle, Sea water, containing ciliates (loricate and aloricate ciliates) and phytoplankton assemblages, was sampled by using a Niskin bottle and poured onto 20 l polycarbonate bottle. Zooplankton and sea water samples were immediately transported to the laboratory. Adults of female, *Temora stylifera*, were then gently isolated by pipette and placed in 5-liter glass jar, containing sea water and acclimated for about 6 h to allay the organisms. Seawater utilized in the experiment was filtered through a 100 μm mesh to remove unknown predators by using an inverse screening device (Sheldon & Rassoulzadegan 1987).

Experiments were conducted using 1 liter cylinder flexis-glass placed into inside each glass jar. Group of 5 female (total 0.24 mg dry weight) *Temora stylifera* in ripe reproductive stages were kept in each cylinder containing sea waters that were screened with 200 μm mesh to prevent the predation of copepods on eggs (Yassen 1984).

Four experimental jars and two controls were incubated in a dark chamber at 17°C constant temperature for 24 h period. Samples of 200 ml were taken in the beginning and last of the experiment and preserved with Lugol's iodine solution (**Thronsdon 1978**). The remain of samples was concentrated by a sieve of 30 µm mesh until 50 ml aliquotes for egg counting. Before cell enumeration, samples were kept in a dark preservation chamber at 4°C temperature to avoid the cell damage due to the Lugol discoloration.

Eggs and cell numbers counting from 50 and 100 ml aliquotes were done under an inverted microscope after settled in the Utermohl chamber for >12 hours (**Rassoulzadegan & Gostan 1976**). Beside of cell enumeration, the biovolume of microplankton was measured also to estimate the wet weight biomass. Carbon biomass was found by multiplying wet weight biomass to the coefficient of **Putt & Stoecker (1989)** for ciliates (0.19) and Wiadnyana & Da Silva (Unpubl.) for phytoplankton (0.046 for diatoms and 0.134 for dinoflagellates). Specific ingestion rate was calculated using equation of **Marin et al. (1986)**.

RESULTS

The calanoid copepod, *Temora stylifera* DANA, was exposed to mixtures of natural microplanktonic ciliates and phytoplankton (diatom and dinoflagellates) assemblages. These microplanktonic organisms provided as foods varied in both abundance and composition (Table I). The aloricate ciliates of size 10 µm, 30 µm, 30 x 50 µm, and 40 x 60 µm occurred always in the experiments. Tintinnids (loricate ciliates) occurred only in experiment V and VI, and composed of a low contribution to the standing stock. Total standing stock of aloricate ciliates and tintinnids represented 13.2 to 54.2% and 2.1 to 6.6 % respectively. The phytoplankton taxa as *Leptocylindrus danicus*, *Rhizosolenia* spp (large diatoms) and *Rhizosolenia stolterforthii* fairly occurred and were predominant diatoms, ranging from 0.8. to 12.4%, 1.4. to 4.2% and 1.9. to 11.5% respectively. Various species of peridinales (dinoflagellates) occurred in the experiments. The dinoflagellates: *Ceratium furca* (2.3. to 14.5%), *Gyrodinium spirale* (1.0. to 6.0%), *Helgolandicus subglobosum* (0.9 to 3.0%), *Protocentrum micans* (0.4. to 3.2%) and *Protoperidinium pyriforme* (2.9. to 5.6%) were always found in the experiments. A large dinoflagellate, *Pyrophacus horologicum* was dominant in carbon standing stock at range from 26.0 to 36.6% when it was occurred.

Total numbers of cells ranged from 2.43×10^3 to 1.05×10^4 cells l^{-1} . The available biomass formed about 4.26 to 18.35 g C l^{-1} after converted the total number of cells

(ciliates + phytoplankton) to total carbon. Total ciliates (aloricate ciliates + tintinnids) and phytoplankton (diatoms + dinoflagellates) carbon ranged from 2.20 to 3.83.g C l⁻¹ (15.2 to 58.7% of total carbon) and 2.04 to 25.55 g C l⁻¹ (39.3 to 84%), respectively in standing stock. The consumption rate of *Temora stylifera* was 11.25 to 38.14 g C mg DW⁻¹ d⁻¹ (27.6 to 74.8%) for ciliates and 8.40 to 69.05 g C mg DW⁻¹ d⁻¹ (25.2 to 72.4%) for phytoplankton.

Daily rates of total carbon consumed by the copepods were 19.65 to 95.11 g C mg DW⁻¹ and eggs produced varied from 430.7 to 1058.6 eggs mg DW⁻¹ (19 to 58 eggs female⁻¹ d⁻¹). Results, in detail, were out lined in Table II.

Higher total ingestion of ciliates than phytoplankton was shown by ciliates (CIL) carbon/phytoplankton (PHY) carbon ratio (Fig. 1) The ingestion ratios increased largely in the all six experiments, where initial carbon of CIL : PHY ratios were near to 1, excepted in the experiment III, where phytoplankton dominated the carbon standing stock (84.8%).

The rates of copepod egg production were positively correlated to the proportion of ciliates in the food consumed by the copepods (Fig. 2). The results presume that the egg production of copepods increases 8,1 to 20,2% (average = 14,8%) with increasing about 10 % of ciliates consumed by the copepods.

DISCUSSION

Fecundity studies in copepods fed on natural foods, have been reported previously to determine the relationship between the egg production and total foods ingested (**Ambler 1985**). Such investigation on the food consumption of natural plankton assemblages, however, excluded planktonic ciliates (oligotrichous ciliated and loricate tintinnids) that were, furthermore, important in carbon standing stock (15 to 59 % reported in this study). The difficulty of technique (**Gifford 1985; Choi & Stoecker 1989**) is probably the raison to not observe these planktonic components.

Our specific observations on natural assemblages of planktonic ciliates different to those realized by **Turner & Tester (1989)**, revealed the selective feeding of the copepods on ciliates (**Stoecker & Sanders 1985; Sheldon et al. 1986; Wiadnyana & Rassoulzadegan 1989**). The exiting of a such behavior is supported by the fact that the ciliates/phytoplankton biomass ratios determined in food ingested by the copepods increase and reach the values higher to those of ciliates/phytoplankton biomass ratios observed in the environment (Fig. 1). A such preference of the copepods

for the ciliates seems to be the consequence of the attract direction angle of the latter's toward the ciliates (**Jonsson & Tiselius 1990**). In fact, the ciliates constitute food nutrient rich in protein, amino acids and lipid (**Claustre et al. 1988; Putt & Stoecker 1989; Stoecker & Capuzzo 1990; Verity & Langdon (1984)**). Those elements might influence the feeding intensity of the copepods upon microzooplankton. Elsewhere, the preference of the copepods for the ciliates over the phytoplankton may be related to the nature chemically defavorable of the latter. The avoidance and rejection of certain phytoplankton preys (specially dinoflagellates) by zooplankton can be due to the toxicity of those preys (**Huntley et al 1983; Stoecker et al. 1987; Uye & Takamatsu 1990**). Nevertheless, the phytoplanktonic species observed in the experiments seem to be not toxic (Tabel 1). Although the diatoms and dinoflagellates could constitute a food source for the copepods, they must be ingested at high rates, by the fact that their nutritional value is relatively poor than the plank tonic ciliates {**Claustre et al. 1988; Putt Stoecker 1989; Verity & Langdon 1984**} Besides, the ciliates have carbon/cell volume ratios higher (0.19; **Putt & Stoecker 1989**) than those of the phytoplankton (diatoms = 0.05 and dinoflagellates= 0.13 Strathmann 1967).

Even if disregarding the other factors for copepod reproduction (**Landry 1978; Uye 1981; Ambler 1985; Ianora et al. 1989**), this study shows that the quality of food strongly influences the copepod *egg* production. Evidence that the copepod consumed more carbon of ciliates than phytoplankton. *Temora stylofera* seems increase its consumption on ciliates carbon in its diets compared to phytoplankton carbon (Fig. 1). Similar results are shown by **Gifford & Dagg (1988)** for *Acartia tonsa*. A determination of the ratios of ciliates carbon: phytoplankton carbon consumed by the copepods (Fig. 1) might be used as an indication to prove the important nutritional value of ciliates in the diet of the copepod.

At the concentrations of natural environment, the copepod *T. Stylifera* appears to enhance its egg production with ingesting preferentially on the ciliates. In fact the copepods increase their egg production (15 %) with increasing about 10% of ciliates in their food consumed (Fig. 2). The results are comparable to those reported by (**Stoecker & Egloff 1987**), in *Acartia Tonsa*. The enhancement of the fecundation in copepods proves high nutritional quality of the ciliates as food for the planktonic microcrustacean (**Stoecker & Egloff 1987**). Indeed, Klepper et al. (1991) found that the variability of the number of eggs produced by the copepods seems to be independent of the variation phytoplanktonic biomass, but this variability is affected by the biomass of microzooplankton ciliates in the waters. It might explain the rapid consummation of the microplankton in other groups of zooplanktonic consumers as well as in some zooplankton gelatinous (**Pomeroy et al. 1987**).

In Laboratory, the copepod nauplii can grow on phytoplanktonic foods (**Harris & Peffenhofer 1976**). Since the quality of this food is inferior to those of microzooplanktonic ciliates (**Claustre et al. 1988; Verity & Langdon 1984**), the larvae and young copepods must require a much quantity of phytoplankton to assure their survival and growth. In temperate region, important bloom of the phytoplankton occurs just in the spring, and then the larva survival out of this period would be supported by microplanktonic preys that occur in all the seasons (**Rassoulzadegan 1982**) as suggested by **Sorokin (1978)**, who constated that microzooplankton (including ciliates) may be a major food source and main alternative food for zooplankton. In a number of studies, it has remarked the importance of microzooplanktonic preys to certain life history stages of planktonic invertebrates and fish larvae (**Cetta & Capuzzo 1982; Stoecker et al. 1987**).

In conclusion, we observed that: (i) the ciliates appear to be a source of preferred food for the copepods, and (ii) this preference allow an efficient assimilation of the microzooplankton food, since the productivity is clearly improved.

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Table I. Relative abundace (%) of predominant plankton observed in the grazing and egg production experiments of *Temora stylifera* from Spetember to November 1988:I(14.09); II(27.09); III (28.09) IV (25.10); V (07.11). SAC and CAC = spherical and conical aloricate ciliates,CV = cell biovolume.

Group/taxon	CV (μm^3)	Experiment					
		I	II	III	IV	V	VI
10 μm SAC	600	0.48	0.77	0.26	0.03	0.20	0.22
20 μm SAC	8200					5.69	4.23
25 X 30 μm CAC	11200	6.30	4.60	2.37	7.40		23.68
30 μm SAC	14100	1.32	5.02	0.38	3.11	2.30	1.45
20 x 40 μm CAC	14500	17.67	33.76	6.01	9.18		2.99
30 x 50 μm CAC	21000	2.76	2.88	1.70	4.63	12.00	2.06
40 x 60 μm CAC	32700	9.20	7.17	2.50	8.10	17.35	3.37
50 x 110 μm CAC	79200					6.46	
<i>Dadayiella ganymedes</i> (Entz Sr.)	19850					1.22	0.61
<i>Dictyocista</i> sp. (Ehrbg.)	42500					4.16	1.31
<i>Salpingella</i> sp. (Jorg)	13830					1.18	0.21
<i>Coscinodiscus</i> sp.	30000					0.59	
<i>Chartoceros peruvianus</i> Brigtn	8315				0.11	0.58	0.10
<i>Leptoylindrus danicus</i> Cleve	3660	12.39	2.28	4.86	0.17	0.22	
<i>Leptocylindrus minimus</i> Gran	1280						0.03
<i>Licmophora abbreviata</i> Agardh	1500					0.01	
<i>Navicula</i> sp.	120000					2.37	3.00
<i>Nitzschia closterium</i> (Ehr.)	95						0.01
<i>Nitzschia delicatissima</i> Cleve	338					0.03	0.01
<i>Nitzschia longissima</i> Ralfs	270	0.01					
<i>Nitzschia seriata</i> Cleve	1640				0.50	0.07	0.18
<i>Pleurosigma angulatum</i> (Quekett)	11780					0.35	
<i>Rhizosolenia</i> spp.	58000	4.21	3.46	1.71	1.55	1.43	
<i>Rhizosolenia stolterforthii</i> Perag.	22200	7.15	1.91	6.49	11.54		0.28
<i>Thalassionema nitshiodes</i> Grup. .	470					0.68	0.43

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<i>Ceratium furca</i> (Ehr) Clap. et Lachm.	63450	2.94	9.81	14.51	4.93	7.31	2.31
<i>Ceratium fusus</i> (Ehrbg.)	26225				2.27	1.91	
<i>Ceratium tripos</i> (Mull) Nitsch	147500	3.90	2.85	1.87		6.37	
<i>Dinophysis acuta</i> Ehr.	65000			3.72			
<i>Dinophysis</i> spp.	25300					3.64	
<i>Gyrodium spirale</i> (Bergh) Kof. U. Swizy	24000	0.95	6.03	2.59	1.86	2.42	1.75
<i>Katodinium</i> sp.	8200				0.80	0.94	1.79
<i>Helgolandicum subglobosum</i> Stosch	5000	1.72	2.99	2.13	0.29	1.30	0.91
<i>Minuscula bipes</i> (Pauls) Lebour	2000			0.29		0.17	0.07
<i>Oxytoxum scolapax</i> Stein	19680					0.57	1.43
<i>Peridinium conicum</i> , (Gran)	62200					4.48	
<i>Podolampas bipes</i> Stein	41500					2.39	1.51
<i>Podolampas spinifer</i> (Pav)	11200					0.81	
<i>Prorocentrum micans</i> Ehr.	8750	0.35	3.21	0.78	0.59	1.01	0.64
<i>Protoperidinium pyriforme</i> Pauls	32150	4.89	5.59	5.000	5.31	3.70	2.92
<i>Pyrophacus horologicum</i> Stein	335000			29.79			36.55

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<i>Prorocentrum micans</i> Ehr.	8750	0.35	3.21	0.78	0.59	1.01	0.64
<i>Protoperdinium pyriforme</i> Pauls	32150	4.89	5.59	5.000	5.31	3.70	2.92
<i>Pyrophacus horologicum</i> Stein	335000			29.79			36.55

Table II. Summary of microplankton carbone standing stock and consumed by copepods Percentage in parenthese.

I	3.83 (49.5)	3.90 (50.5)	7.73
II	3.76 (58.7)	2.65 (41.3)	6.40
III	2.79 (15.2)	15.55 (84.8)	18.35
IV	3.05 (51.1)	2.93 (48.9)	5.98
V	2.36 (53.7)	2.04 (46.4)	4.39
VI	2.20 (51.8)	2.05 (48.2)	4.26
Specific Ingestion Rate ($\mu\text{g C/mg DW/d}$)			
I	19.60 \pm 8.01 (66.9)	9.27 \pm 3.36 (34.1)	28.76 \pm 9.78 744.8 \pm 140.2