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Feeding of the copepod Eurytemora hirundoides (Crustacea) on different algal cultures

Göran Gyllenberg

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Adults of *Eurytemora hirundoides* (Nordqv.) were fed on bacteria-free cultures on the algae *Ankistrodesmus* sp., *Chlorella* sp., *Selenastrum* sp., *Scenedesmus spinosus* and *S. quadricauda*, and on these algal cultures infested with monocultured bacteria. Consumption rates levelled out at 1—7 μg dry weight per individual per day for concentrations higher than 100 μg dry weight per ml at +20°C. The high consumption rate and high assimilation efficiency (100 %) in cultures with bacteria prompted the conclusion that these copepods feed more efficiently on decayed than on intact algal cells.

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1. Introduction

Particulate organic detritus is often quoted as a possible food source for plankton (Heinle & Flemer 1975, Heinle et al. 1977, Roman 1977). The use of fluorescing gut material has made it possible to determine the proportion of the gut contents constituted by detritus (e.g. Gerber & Marshall 1974). Paffenhöfer & Strickland (1970) found that *Calanus helgolandicus* consumed dead diatoms and faecal pellets.

Living algal material is insufficient as food for *Eurytemora affinis* (Heinle & Flemer 1975, Heinle & Flemer 1976, Heinle et al. 1977). In this study I offered *Eurytemora hirundoides* (Nordqv.) fresh algal cultures with and without bacteria. The bacteria (white bacterial strain) used were obtained from monocultures. It seems that algae as such do not form a suitable food for copepods, but when the algal cells were decayed by bacteria they were ingested and assimilated at an adequate rate.

2. Material and methods

Individuals of *Eurytemora hirundoides* were caught from the coastal waters off Helsinki. All the experiments were performed at +20°C (room temperature). The copepods were kept at room temperature in sterile sea water for 1 day in order to get rid of any food in the gut. Thereafter the zooplankton was introduced into pure cultures of each algal species with and without bacteria in 100-ml glass bottles. The concentrations of the algae ranged from 400 μg dry weight/ml down to 10 μg dry weight/ml. The concentration was regulated by diluting concentrated solutions with ^{14}C isotope in the form of $NaH^{14}CO_3$. The concentration of bacteria was from 10 μg dry weight/ml to 0.01 μg dry weight/ml.

Food consumption of the radioactive carbon ingested was calculated from the following formula:

$$C = kQ$$

where C is consumption, Q the ^{14}C in the animal's body and k the elimination coefficient, which is $\ln 2/T_b$, where T_b is the biological half-life.

The animals were allowed to feed on radioactive algae for 1 day, and were then transferred to non-radioactive food. Samples of a few (3—4) individuals were then used to determine the radioactivity of their bodies and gut contents with a Geiger-Müller counter (cf. Gyllenberg & Lundqvist 1978). Samples of *Eurytemora* individuals taken from the non-radioactive medium at 24-h intervals were used to determine the biological half-life of the material assimilated (T_b in Figs. 1—4).

In the cultures the food particles were gently rotated with the aid of a stirrer. The radioactivity of the surrounding water was measured and found to be insignificant in relation to the radioactivity of the algae.

The algae were cultured as described by Tarkiainen & Rinne (1973). Bacterial cultures (agar plates) were obtained from fresh sea water.

3. Results and discussion

Figs. 1—4 give the radioactivity measured from the day the copepods were transferred from a radioactive to a non-radioactive food medium. As shown by these figures and by Table 1, food consumption was mostly significantly higher in the algal cultures with bacteria than in those without.

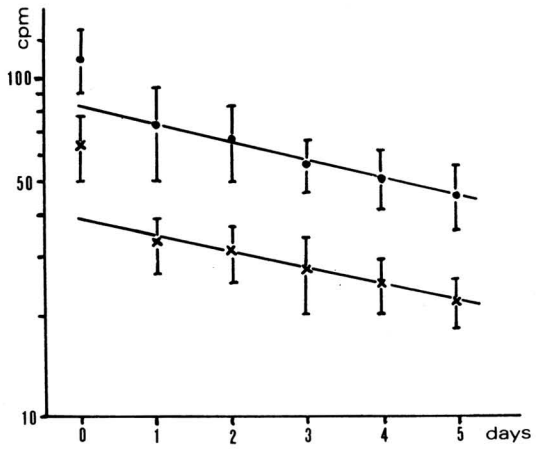

Fig. 1. Radioactivity (cpm) of *Eurytemora hirundoides* fed on cultures of different algae without bacteria: crosses = *Ankistrodesmus* sp. and circles = *Chlorella* sp. The time is given as the number of days after transfer to non-radioactive medium. The values are means of 5 replicates.

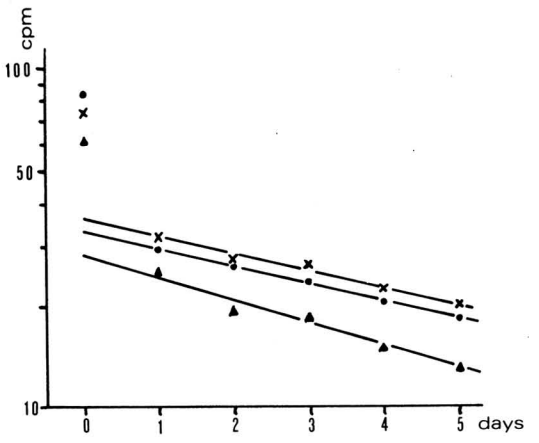

Fig. 2. Radioactivity (cpm) of *Eurytemora hirundoides* fed on cultures of different algae without bacteria: crosses = *Selenastrum* sp., circles = *Scenedesmus spinosus* and triangles = *S. quadricauda*. The values are means of 5 replicates. The standard errors are within ± 25 % of the means.

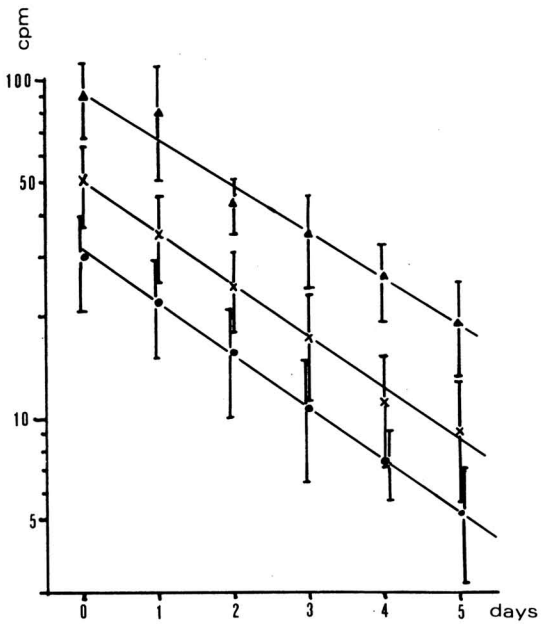

Fig. 3. Radioactivity (cpm) of *Eurytemora hirundoides* fed on cultures of different algae with bacteria: crosses = *Ankistrodesmus* sp., circles = *Chlorella* sp. and triangles = *Selenastrum* sp. The values are means of 5 replicates.

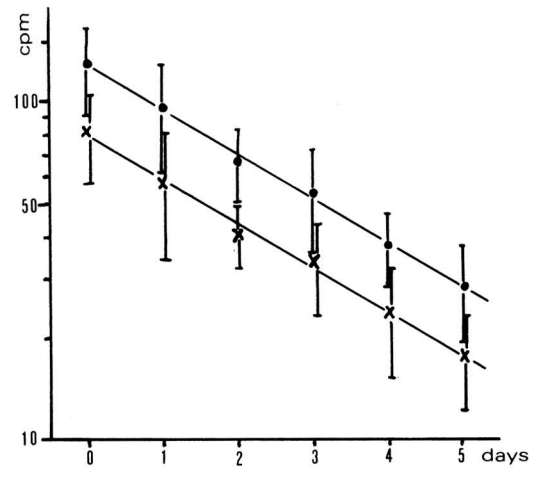

Fig. 4. Radioactivity (cpm) of *Eurytemora hirundoides* fed on cultures of different algae with bacteria: crosses = *Scenedesmus spinosus*, circles = *S. quadricauda*. The values are means of 5 replicates.

The difference may be explained as follows:

1) In the cultures without bacteria the copepods ingest only the algal cells, which are then assimilated. In the cultures with bacteria the copepods consume bacterial cells in addition to algae, thereby attaining a higher ingestion rate.

Table 1. Consumption rates compared at the O_2 consumption plateau for cultures with and without bacteria. Test animal: *Eurytemora hirundoides*.

Food source	Consumption µg/individual + bact.	— bact.	N	t
Ankistrodesmus sp.	1.87±0.32	0.75±0.11	5	3.30*
Chlorella sp.	2.46±0.41	2.69±0.46	5	0.37
Selenastrum sp	3.10±0.55	0.95±0.15	5	3.77*
Scenedesmus spinosus	4.70±0.59	1.80±0.29	5	4.41**
S. quadricauda	6.88±0.93	1.66±0.27	5	5.34**

2) Algal cells as such are not digestible, but when decayed by bacteria they provide an ample food source. This explanation is supported not only by the consumption measurements, but also by the results of measurement of assimilation efficiency (Table 2) and turnover (T_b) of food. Assimilation was measured at the point of intersection of the T_b line with the y axis. The difference between the intersection point and the radioactivity on day 0 is assumed to give the fraction assimilated.

In the cultures with bacteria assimilation efficiency was close to 100, showing the high assimilability of the algal food consumed. Moreover, the algae that gave the poorest assimilation efficiency in pure culture were the two species of *Scenedesmus*, which have thick cellulose walls and are poorly assimilated by zooplankton (Infante 1973). In contrast, *Scenedesmus* decayed by bacteria for 220 days enhances both production and reproduction of zooplankton (Otsuki et al. 1969). In my experiments I used decay periods of 30 days.

The question arises whether the *Eurytemora* individuals in this investigation obtained their food material from the algae directly or from the bacteria feeding on the algae. Fenchel (1970) assumed that the microfauna associated with detritus is important. Heinle et al. (1977) came to a different conclusion and considered that detritus may be assimilated as such, although also via bacteria. It seems unlikely that the bacteria offer assimilable food for the *Eurytemora* individuals, since the assimilation efficiency was

Table 2. Assimilation as a percentage of consumption and biological half-life T_b measured for *Eurytemora hirundoides* individuals.

Food source	% assimilation + bact.	— bact.	T_b + bact.	— bact.
Ankistrodesmus sp.	100	59.4	1.95	6.05
Chlorella sp.	100	73.0	1.8	6.15
Selenastrum sp.	100	48.6	2.2	5.85
Scenedesmus spinosus	100	39.3	2.3	6.15
S. quadricauda	100	45.9	2.3	4.15

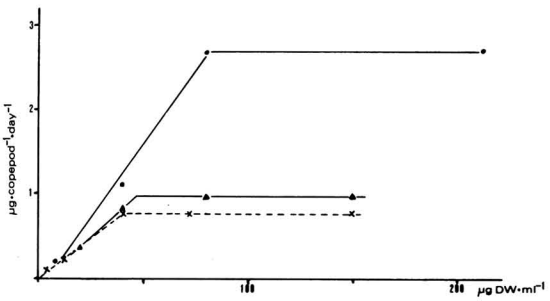

Fig. 5. The relationship between consumption by *Eurytemora* in µg/copepod/day and concentration of food in µg dry weight/ml in three algal cultures without bacteria: *Ankistrodesmus* sp. (crosses), *Chlorella* sp. (circles) and *Selenastrum* sp. (triangles).

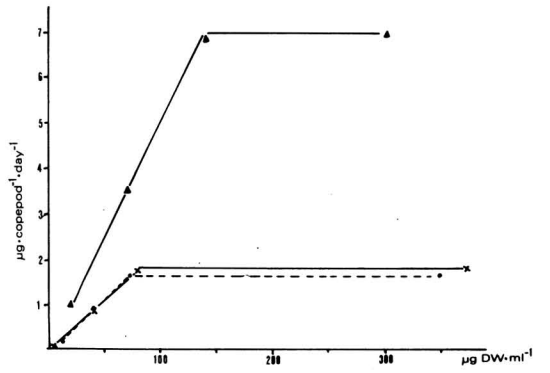

Fig. 6. The relationship between consumption by *Eurytemora* in µg/copepod/day and concentration of food in µg dry weight/ml in two algal cultures without bacteria: *Scenedesmus spinosus* (crosses) and *S. quadricauda* (circles), and in one algal culture with bacteria: *Scenedesmus quadricauda* (triangles).

100 % in the ingestion experiments with mixtures of algae and bacteria. Such a high assimilability would not be expected from intact bacterial cells.

Figs. 5—6 show the consumption at different concentrations of the algal species. The pattern follows a typical flattened curve type, as already exemplified by Rigler (1971). Likewise Roman (1977) found a critical level of food biomass above which the ingestion rate remained constant.

The consumption value at the plateau level was around 1—3 µg dry weight/copepod/day for algal cultures without bacteria, and up to 7 µg dry weight/copepod/day for cultures with bacteria. These values are in agreement with the values of 2.37 to 5.35 µg C/individual/day

reported by Bell & Ward (1970) for *Daphnia pulex*. In *Daphnia* the explanation for a curve of this shape is that the movements of the thoracic legs are slower at high food concentrations, but up to a certain level this is compensated by a more rapid movement of the mandibles, which keeps the consumption rate steady (Burns 1968).

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References

Bell, R. K. & Ward, F. J. 1970: Incorporation of organic carbon by Daphnia pulex. — Limnol. Oceanogr. 15:713—726.

Burns, C. W. 1968: Direct observations of mechanism regulating feeding behaviour of Daphnia in lakewater. — Int. Rev. Ges. Hydrobiol. 53:83—100.

Fenchel, T. 1970: Studies on the decomposition of organic detritus derived from turtle grass Thalassia testudinum. — Limnol. Oceanogr. 15:14—20.

Gerber, R. P. & Marshall, N. 1974: Ingestion of detritus by the lagoon pelagic community at Eniwetok Atoll. — Limnol. Oceanogr. 19:815—824.

Gyllenberg, G. & Lundqvist, G. 1978: Utilization of dissolved glucose by two copepod species. — Ann. Zool. Fennici 15:323—327.

Hargrave, B. T. & Geen, G. H. 1970: Effects of copepod grazing on two natural phytoplankton populations. — J. Fish. Res. Board Canada 27: 1395—1403.

Heinle, D. R. & Flemer, D. A. 1975: Carbon requirements of a population of the estuarine copepod Eurytemora affinis. — Mar. Biol. 31:235—247.

—»— 1976: Flows of materials between poorly flooded tidal marshes and an estuary. — Mar. Biol. 35: 359—373.

Heinle, D. R., Harris, R. P., Ustach, J. F. & Flemer, D. A. 1977: Detritus as food for estuarine copepods. — Mar. Biol. 40:341—353.

Infante, A. 1973: Untersuchungen über die Ausnutzbarkeit verschiedener Algen durch das Zooplankton. — Arch. Hydrobiol. Suppl. 42:340—405.

Otsuki, A., Hanya, T. & Yamagishi, H. 1969: Residue from bacterial decomposition of green algal cells as food for Daphnia. — Nature 122:1182.

Paffenhöfer, G.-A. & Strickland, J. D. H. 1970: A note on the feeding of Calanus helgolandicus on detritus. — Mar. Biol. 5:97—99.

Rigler, F. H. 1971: Zooplankton. — In: Edmondson, W. T. & Winberg, G. G. (eds.), A manual on methods for the assessment of secondary productivity in fresh waters. IBP Handbook No. 17: 228—256. Blackwell Scient. Publ., Oxford and Edinburgh.

Roman, M. R. 1977: Feeding of the copepod Acartia tonsa on the diatom Nitzschia closterium and brown algae (Fucus vesiculosus) detritus. — Mar. Biol. 42:149—155.

Tarkiainen, E. & Rinne, I. 1973: Algal assay procedure used in Water Conservation Laboratory. — Reports of the Water Conservation Laboratory 5:1—24.

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