Offprint from "Marine Biology"
International Journal on Life in Oceans and Coastal Waters, Vol. 12, No. 3, February 1972, Pages 219—221

The reproductive potential of copepods in brackish water

C. Heip

Laboratorium voor Morfologie en Systematiek; Gent, Belgium

Abstract

The reproductive potential of 3 harpacticoid and 1 cyclopoid copepods, measured by the intrinsic rate of natural increase, was calculated from field data. Calculated values are much smaller than those obtained from laboratory experiments. The difference between species is small and cannot account for differences in occurrence.

Introduction

There is a fast extending literature on the culture and reproduction of harpacticoid copepods under laboratory conditions. However, it is obvious that populations in nature do not exist under laboratory conditions (constant temperature, absence of predation, unlimited food supply etc.). The aim of this study was to establish the reproductive potential of several species of copepods in wild populations. The importance of harpacticoid copepods in most aquatic ecosystems is well known; in the meiobenthos of most marine and brackish-water localities they are outnumbered only by nematodes.

As it is impossible to evaluate the influence of all factors acting upon reproduction, and as an exponential growth of the population occurs during bloom, we made use of the simplest available mathematical model representing population growth. When we assume that the number of animals which is born or dies is constant and proportional to the size of the population, we can write:

$$dN/dt = bN - dN = (b - d)N = rN\ ,$$

or

$$N_t = N_0 e^{rt}$$

where N denotes numbers at the time considered; r is the intrinsic rate of natural increase and is equal to:

$$r = \frac{1}{t} \ln \frac{N_t}{N_0}.$$

The value of r is a measure of the reproductive potential of a species and is of great ecological importance, as has been stressed by several authors (Andrewartha and Birch, 1954; Slobodkin, 1962; Macfadyen, 1963; Fenchel, 1968); it allows a comparison between the reproductive rate of different species, even of unrelated groups.

Material and methods

The locality studied is a shallow, brackish-water pond, called Dievengat. It is situated in northern Belgium, about 2 km from the shore of the North Sea.

Salinity fluctuates greatly during the year (8 to 24‰ S), depending upon weather conditions; sampling depth is about 15 cm. The sediment is a fine sand, covered with a layer of detritus. Three samples were taken at fortnightly intervals, with a glass tube covering a surface area of 6.06 cm² and pushed 5 cm into the sediment. The samples were preserved with 70% alcohol. In the laboratory, the samples were placed in a shallow trough as described by Barnett (1968) and washed in tapwater. The material washed away was caught in a sieve of mesh size 50 μm. The method was tested and proved to be about 100% efficient. Because all the detritus was also washed away, a very careful extraction of the copepods from the detritus under the dissecting microscope was necessary. The copepods were determined to species and counted. Distinction was made between females, males and copepodites. As extraction of the smallest nauplii is very difficult, these were omitted from calculations.

The investigations began in August 1968, and are still continuing.

Results and discussion

Eleven species of copepods were determined during the investigation. Only four of these occurred in sufficient numbers to enable the necessary calculations to be made: *Halicyclops magniceps* (Lilljeborg, 1853); *Canuella perplexa* T. & A. Scott, 1893; *Tachidius discipes* Giesbrecht, 1882; and *Paronychocamptus nanus* (Sars, 1908). The value of r was calculated from the data obtained during the spring bloom. The data comprise the number of adult individuals per 100 cm² of the species concerned. For 2 species (*C. perplexa* and *H. magniceps*) this was possible only for a period of one year as numbers during the other years were not sufficient.

From Table 1, the following r values were calculated:

Paronychocamptus nanus	Spring	1969: 0.042
	Spring	1970: 0.056
	Spring	1971: 0.043
	Autumn	1970: 0.048
Canuella perplexa	Spring	1970: 0.042
Halicyclops magniceps	Spring	1970: 0.056
Tachidius discipes	Spring	1969: 0.049
	Spring	1970: 0.045
	Spring	1971: 0.056

These values do not differ much and lie in the range of 0.04 to 0.06 per day; the lowest value, for *C. perplexa*, may be attributed to the fact that this is the largest species.

From these values, the time needed to double the size of the population can be calculated as

$$t = \frac{\ln 2}{r} = \frac{0.69}{r}.$$

Table 1. *Numbers of adult copepods*

Species	Date	Number/100 cm²
Paronychocamptus nanus	7 Apr. 1969	214
	21 Apr. 1969	346
	5 May 1969	562
	19 May 1969	2574
	12 June 1969	3895
	25 Mar. 1970	297
	8 Apr. 1970	660
	22 Apr. 1970	1420
	2 Sept. 1970	214
	16 Sept. 1970	395
	30 Sept. 1970	940
	14 Oct. 1970	1601
	15 Apr. 1971	973
	29 Apr. 1971	1962
	13 May 1971	2739
Tachidius discipes	10 Mar. 1969	17
	24 Mar. 1969	34
	7 Apr. 1969	50
	21 Apr. 1969	133
	5 May 1969	215
	19 May 1969	1220
	25 Mar. 1970	99
	8 Apr. 1970	132
	22 Apr. 1970	594
	5 May 1970	833
	4 Mar. 1971	33
	17 Mar. 1971	82
	31 Mar. 1971	115
	15 Apr. 1971	198
Canuella perplexa	3 June 1970	125
	17 June 1970	264
	1 July 1970	390
	15 July 1970	461
Halicyclops magniceps	5 May 1970	16
	20 May 1970	38
	3 June 1970	75
	17 June 1970	132

The following values have been obtained:

Paronychocamptus nanus	12—17 days
Canuella perplexa	17 days
Halicyclops magniceps	12 days
Tachidius discipes	12—15 days.

These values are of the same magnitude; however, as the moment when the species attain their maximum occurrence varies, it seems that a mechanism other than fast or slow reproductive rates must govern their succession. This factor could be the temperature needed to initiate reproduction. Once this critical temperature level is reached, population growth is about equal for all species examined.

It appears, furthermore, that when reproduction begins earlier and when temperature during bloom is lower, a higher value of r is obtained:

Paronychocamptus nanus	Spring 1970	7.6 °C	0.056
	Spring 1969	15.0 °C	0.042
	Spring 1971	15.4 °C	0.043
Tachidius discipes	Spring 1971	7.8 °C	0.056
	Spring 1969	9.8 °C	0.049
	Spring 1970	10.5 °C	0.045

This is of course in contradiction to all observations from laboratory experiments; but conditions are certainly very different in the field; intensified predation probably causes this phenomenon. The main predator, *Protohydra leuckarti*, is not able to reproduce quickly below temperatures of about 10 °C.

The r values as calculated from field data are much smaller than those obtained from laboratory rearing experiments. Indeed, r can be calculated as:

$$r = \frac{\ln R}{T}$$

where R = net reproductive rate per generation = N_{T+1}/N_T and T = generation time.

From studies of Muus (1967), r has been calculated for harpacticoid copepods by Fenchel (1968). In the case of *Tachidius discipes*, laboratory experiments showed that the female produces at least 5 egg sacs containing an average of 29 eggs each. Every fourth day a new egg sac is produced. The first adults appear after 11 to 12 days, the last, therefore, appears after about 31 days. Taking $T = 21$ days, and $R = 5 \times 29 = 145$, r is calculated as $\frac{\ln 145}{21} = 0.237$. Two important modifications to this calculation, as made by Fenchel (1968) are, however, necessary. Firstly, the percentage of females carrying eggs in the adult population must be taken into account; this was 35% in 1969, 44% in 1970 and 41% in 1971. Taking 40% as a representative value, r reduces to $\frac{\ln 58}{21} = 0.193$. Secondly, mortality has not been included in this calculation. Mortality can be estimated from field observations in periods when no reproduction occurs, as indicated by the absence of females carrying eggs.

Table 2. *Tachidius discipes. Numbers of adult after bloom*

Date	Number/100 cm²
19 May 1969	1238
12 June 1969	643
26 June 1969	99
15 July 1969	0
5 May 1970	833
20 May 1970	544
3 June 1970	247
17 June 1970	82
1 July 1970	16
15 July 1970	0

For *T. discipes*, this is the case in late spring and early summer (Table 2); calculated mortalities are $m = 0.047$ in 1969 and $m = 0.050$ in 1970. Subtracting 0.049 from 0.193, the value $r = 0.144$ is obtained; this is about 3 times the value of r as observed from field data. This shows that only $\frac{1}{3}$ of the possible reproductive rate is realised in nature for this species.

Summary

1. Intrinsic rates of natural increase were calculated from field data for 4 species of copepods (*Halicyclops magniceps, Canuella perplexa, Tachidius discipes, Paronychocamptus nanus*).

2. The calculated values did not differ much for the species examined, and were in the range of $r = 0.04$ to 0.06 per day.

3. Accordingly, the time needed to double the size of the population varies between 12 and 17 days.

4. The value of r appeared to be higher when the temperature during bloom was lower.

5. Compared to laboratory rearing experiments, apparently only $\frac{1}{3}$ of the reproductive potential is actually reached in the field for one of the species, *Tachidius discipes*.

Acknowledgement. This work was supported by a grant to the author as aspirant of the Belgian National Foundation for Scientific Research (N.F.W.O.).

Literature cited

Andrewartha, H. G. and L. C. Birch: The distribution and abundance of animals, 782 pp. Chicago: University Press 1954.

Barnett, P. R. O.: Distribution and ecology of harpacticoid copepods of an intertidal mudflat. Int. Revue ges. Hydrobiol. **53**, 177—209. (1968)

Fenchel, T.: The ecology of marine microbenthos. III. The reproductive potential of Ciliates. Ophelia **5**, 123—136 (1968).

Macfadyen, A.: Animal ecology, aims and methods, 344 pp. London: Sir Isaac Pitman & Sons 1963.

Muus, B.: The fauna of Danish estuaries and lagoons. Meddr. Danm. Fisk.- og Havunders. (N.S.) **5**, 1—316 (1967).

Slobodkin, L. B.: Growth and regulation of animal populations, 184 pp. New York: Holt, Rinehard & Winston 1962.

Author's address: C. Heip
Laboratorium voor Morfologie
en Systematiek
Ledeganckstraat 35
B-9000 Gent
Belgium

Date of final manuscript acceptance: September 22, 1971. Communicated by J. W. de Blok, Texel