Growth and Respiration of *Cyprideis torosa* Jones 1850 (Crustacea Ostracoda)

P.M.J. Herman and C. Heip
Marine Biology Section, Zoology Institute, State University of Ghent, Belgium

Summary. The ostracod *Cyprideis torosa* Jones 1850 is a dominant species in brackish water habitats. To assess its importance, growth and respiration were measured. The shells form an increasing part of total weight as the animals grow but there is no correlation between shell weight and soft parts weight in the adults, indicating that tissue growth is a continuous process in these ostracods.

Respiration was measured at 20° C. The slope of the log-log regression of respiration on dry weight was 0.746, showing that *Cyprideis torosa* follows the general rule for this relationship. The respiration rate per unit biomass was 0.246 nl O_2 μg^{-1} h^{-1}, which is low but well within the range of observed meiobenthic respiration rates.

The Q_{10}, expressing the temperature dependence of respiration, was 2.15. The general validity of Price and Warwick's (1980) hypothesis relating Q_{10} to stability of food supply is questioned.

Introduction

Information on life-cycles and energetics of meiobenthic species, particularly of ostracods, is still scarce. The importance of the latter as microfossils has directed research mainly to morphological and palaeoecological aspects, to the extent that most studies on ostracod growth do not even mention size or weight of the animal itself but focus entirely on its shells.

In certain habitats ostracods are an ecologically important group and may represent a considerable part of benthic biomass. This is certainly the case for *Cyprideis torosa* Jones 1850, a widespread and extremely common species in shallow, quiet brackish water habitats (Vesper 1972; Heip 1976). The mean annual density of this species in the habitat we studied was around 467,000 individuals m^{-2}, and it presumably has an important part in total energy flow.

To assess this importance, we measured respiration of *Cyprideis torosa* as a function of developmental stage and temperature, and its weight. The influence of temperature on respiration was studied because the life-cycle of *Cyprideis torosa* is closely linked to temperature (Heip 1976) and the link may be the general temperature dependence of metabolism. Besides being a measure of metabolic activity, respiration also indicates the magnitude of the energy flow passing through a population (McNeill and Lawton 1970).

Offprint requests to: P.M.J. Herman

Materials and Methods

The animals were taken from a very shallow (about 10 cm) brackish water pond, the "Dievengat", situated in a polder in north-western Belgium. Salinity fluctuated between 6 ⁰/₀₀ and 40 ⁰/₀₀ in the period 1968–1980, with a mean of 19 ⁰/₀₀. The sediment is a well-sorted fine sand (median grain-size 0.223 mm). It is covered with large amounts of detritus, mostly debris of *Phragmites*. This type of sediment is preferred by *C. torosa* (Vesper 1972).

For the weighings a sediment sample was taken on 9 April 1981. In the laboratory the animals were immediately sorted alive and then fixed in a neutralized isotonic 4% formaldehyde solution, where they remained for no longer than 1 week.

Dry weight was determined on a Mettler ME22 microbalance to a precision of ±1 µg. Before weighing the animals were washed four times in bidistilled water, and dried for 2 h at 110° C.

For the determination of shell weight, the animals were placed in a boiling 1N KOH solution. The shells were then checked under the dissecting microscope, and if soft parts remained, they were carefully removed. The shells were washed, dried and weighed again in the same way as the whole animals. For the adults, total weight and shell weight were determined individually for each animal. This could not be done for the juveniles, where several individuals were weighed together.

Length and height of the left shells were measured. These shells were mounted with the concave side down and drawn with a camera lucida. On these drawings length and height were determined following Vesper (1972).

Respiration was measured with a stoppered diver Cartesian Diver respirometer (Klekowski 1971). The divers had a gas volume of 2 µl for measurements with adults, and 1 µl for the juveniles. Each diver contained one animal. The animals were acclimated to the experimental temperature for at least 3 days in Petri dishes containing natural sediment, which were kept in incubators under constant temperature and a natural light-dark cycle. Salinity was controlled daily and kept constant to 20 ⁰/₀₀. The animals were not kept in the laboratory for longer than 2 weeks.

Results

The weights of individual adult animals and their shells are presented in Table 1. The weights of the whole animals

Table 1. *Cyprideis torosa:* Total weight, shell weight and soft parts weight of adults (μg dwt ind^{-1}). Mean and standard deviation of n measurements

	Total weight (μg)			Shell weight (μg)			Animal weight (μg)		
	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
♀	102.95	14.08	65	88.63	15.83	16	19.81	8.23	16
♂	81.32	9.26	47	59.19	9.77	16	19.88	6.99	16

Table 2. *Cyprideis torosa:* Length and height of adult shell valves (mm). Mean and standard deviation of n measurements

	Length (mm)			Height (mm)		
	$\bar{x}$	s	n	$\bar{x}$	s	n
♀	0.9991	0.02658	20	0.57305	0.02050	20
♂	1.0672	0.02322	20	0.55680	0.01444	20

Table 4. *Cyprideis torosa:* Growth factors for length of successive stages (after Heip, 1976)

Stage	Growth factor $=L_{n+1}/L_n$	Stage	Growth factor $=L_{n+1}/L_n$
VIII	1.345	IV	1.228
VII	1.335	III	1.284
VI	1.337	II	1.246
V	1.265	I	1.265

Table 5. *Cyprideis torosa:* Mean respiration (nl O_2 h^{-1} ind^{-1}) of juvenile instars VI–VIII and of adults. Mean and standard deviation of n measurements

Stage	Mean resp. (nl O_2 ind^{-1} hr^{-1})	s	n
AD. Fem.	19.298	4.5836	5
AD. Male	16.0446	4.5730	5
VIII	9.8951	2.5716	13
VII	6.0053	1.2879	5
VI	4.1170	0.7301	7

are normally distributed in both sexes (Kolmogorov-Smirnov test, $P<0.001$), and significantly different for males and females ($P<0.001$). However, the weights of the soft parts (total weight−shell weight) are almost exactly the same in both sexes. The difference in total weight can thus be attributed to the heavier shell of the females.

There is no correlation between total weight and shell weight in males ($r=0.335$; $n=18$; $F=2.02$). Since the form of the shell is different in males and females, and as there is no reason to believe that a difference exists according to sex, only data from males were used. Length and height of these same shells are presented in Table 2. There is a significant correlation between shell length and shell height ($r=0.605$; $n=18$; $P<0.001$). The correlation between shell weight and shell length is almost significant at $P=0.05$, but there is no relationship at all between animal weight and shell length.

Table 3 shows the mean weights of whole animals, shells, and soft parts, respectively, of the last three juvenile instars. Since these weights were not individually determined, no standard deviations can be given. The contribution of the soft parts to total weight declines steadily towards the end of the ontogenetic series, with a sudden drop in adults. Thus growth of the metabolically active tissue is slower than would be inferred from weighings of whole animals. This is reflected in the "growth factors", ratios of values in successive stages, for the measured parameters. (We calculated these growth factors mainly for comparison with other papers on ostracod growth, where they seem to constitute a strong tradition). The growth factors for

soft parts are the lowest, but also the most constant, in this set. Measurements of the length of larval stages and adults from the same habitat have been previously published by Heip (1976). In Table 4 we give the growth factors calculated from these figures.

The results of the respiration measurements at 20° C are presented in Table 5. Figure 1 shows the regression of respiration rate on body weight (i.e. the weight of the soft parts). Individual weighing of the juveniles was technically impossible, and shell measurements were not used because of the absence of any relationship between any shell measurement and tissue weight of the adults. Therefore, we could not determine the body weight of the juveniles used in the experiments, and for this reason we used the mean

Table 3. *Cyprideis torosa:* Total weight, shell weight and soft parts weight of instars VI–VIII (μg dwt ind^{-1}). GF (growth factor) is the proportion of the weight of successive stages. Mean of n determinations

Stage	Total (μg)			Shell (μg)			Soft Parts (μg)		% SP
	$\bar{x}$	GF	n	$\bar{x}$	GF	n	$\bar{x}$	GF	
VIII	35.75	2.574	23	25.42	2.907	38	10.33	1.921	28.89
VII	17.52	2.041	90	12.19	2.085	38	5.33	1.938	30.44
VI	8.65	2.025	69	5.78	2.109	27	2.87	1.857	33.20

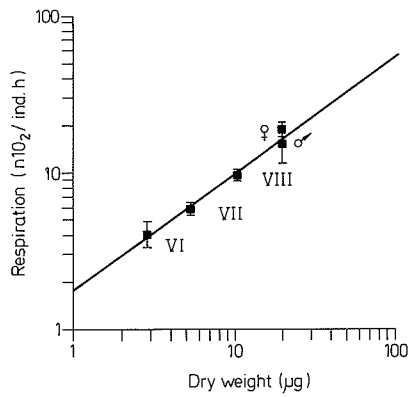**Fig. 1.** *Cyprideis torosa:* mean respiration (nl $O_2 h^{-1} ind^{-1}$) of instars VI–VIII and adult males and females as a function of body weight (μg dwt ind^{-1}). Mean and standard error of 5–13 determinations
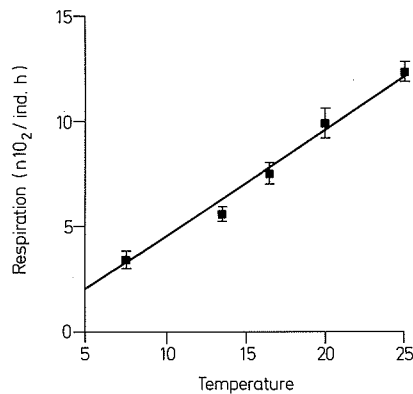

Fig. 2. *Cyprideis torosa:* mean respiration (nl $O_2 h^{-1} ind^{-1}$) of instar VIII individuals as a function of temperature. Mean and standard error of 3–13 determinations

Table 6. *Cyprideis torosa:* Q_{10} values as calculated from the Arrhenius equation for different temperature intervals

Temp. °C	0–5	5–10	10–15	15–20	20–25	25–30
Q_{10}	2.318	2.250	2.188	2.130	2.077	2.027

weight of the stage as the best estimate of their actual weight, both for juveniles and adults.

The dependence of respiration rate on body weight is given by $\log R = 0.246 + 0.746 \log W$ (1) ($n = 35$; $r = 0.91$; $F = 164$), where R is expressed in nl O_2 individual^{-1} h^{-1}, and W in μg dry weight individual^{-1}.

We also calculated the regression of respiration on total weight (including shells). In this case the slope $b = 0.618$ (SE 0.046), which is significantly different from 0.75, the generally accepted theoretical value. When the weight of the shell is included, the estimate of the slope is seriously biased.

For the analysis of the relationship between respiration rate and temperature we used only animals of the last juvenile instar, since these were the most abundant in the field population at the time of the experiments. Experimental temperatures were 7.5° C, 13.5° C, 16° C, 20° C and 25° C. Figure 2 shows the results of these experiments. The curve

fitted through the points is the function $R = 0.351\ T^{1.100}$ ($r = 0.911$; $n = 36$; $F = 167$), which, of all models tried, gave the best fit.

The Q_{10} values, as calculated from the Arrhenius' curve for different temperature intervals following Ivleva (1980), are given in Table 6. The (constant) Q_{10} calculated directly from the Van 't Hoff equation is 2.15.

Discussion

One of the purposes of this study was to investigate whether the growth of Ostracoda is continuous or not. In this regard it is interesting to note that there is no correlation between animal (soft tissue) weight and length or weight of the shell. The dimensions of the shell are probably determined by the condition of the animal when it moults, which may be almost independent of its condition several weeks or even months afterwards. This will be true especially when growth of the soft parts is a continuous process, and the absence of a correlation therefore supports this hypothesis. It is further supported by the considerable range in the soft part weights: in fact, several adult animals weighed less than 10 μg, the mean weight of stage VIII animals. When total weight, including shells, is considered, there is no overlap at all.

The growth factors (ratios of successive stages) for length, total weight and soft tissue weight are not constant throughout larval development. This is in agreement with recent studies on ostracod growth (Heitkamp 1979; Gillandt 1977) in which these variations are related to differentiation of organ systems in the animal. An exponential increase in these growth factors, as implicitly assumed by Anderson (1964), was not found in *C. torosa*.

The dependence of respiration on body weight, as described by the slope of the log-log relationship between respiration rate and body weight, is very near to the mean value 0.75, which has been found to apply to a wide range of organisms (Hemmingsen 1960), more especially to Crustacea (Ivleva 1980), and is also well established for meiobenthos (Warwick and Price 1979). However, considerable scatter around this value is observed, and it is not known how much of this represents biological reality. Part of it is undoubtedly due to experimental errors, but other types of error could be important: when the ratio of organic weight to total weight is not constant throughout development, this will result in a biased estimate of b. The low b value ($b = 0.440$) found for the Ostracod *Conchoecia* sp. (in Ivleva 1980), the only other ostracod species for which a respiration-body weight relationship is known, may result from this error. At present, we may not assume that ostracods are an exception to the 0.75 rule. The value of a in Eq. (1) is a measure of the intensity of respiration, as it represents the corrected respiration per unit biomass. It is difficult to compare a-values since they depend on the units of measurement for both respiration and body weight. Recalculated to the units used in Ivleva (1980) (μl O_2, mg), we get $a = -0.516$ for *C. torosa*, which is considerably less than her mean value of 0.505 ($s = 0.217$) for marine Crustacea at 20° C. For comparison of our a-value with other meiofauna, as summarized by Teare and Price (1979; Fig. 5) we assumed a wet weight: dry weight ratio of 4:1 and a specific gravity of 1.1. The respiration-body weight relationship thus recalculated for *C. torosa* is at the lower end, but well within the range of meiobenthic respiration rates.

Possibly respiration intensity of meiobenthos as a whole is lower than average. Compared to the nematode data of Warwick and Price (1979), *C. torosa* would be what these authors call a "moderately slowly" respiring organism.

The Q_{10} value expressing the temperature dependence of respiration rate is around 2.15, which is very near to the value of 2.17 found by Teare and Price (1979) for the meiobenthic harpacticoid *Tachidius discipes* and the value of 2.20, as calculated from Lasker et al. (1970) for *Asellopsis*, another harpacticoid (see Teare and Price, 1979). Ivleva (1980), expressing temperature dependence by the parameter μ in the Arrhenius equation, finds this parameter to lie within rather narrow limits: $\mu = 55,509$ J mol^{-1} ($s = 541$). This μ value corresponds to a Q_{10} in the 15° C–20° C range of 2.203 ($s = 0.017$). Miller and Mann (1973) find a mean and constant Q_{10} of 2.05 for marine invertebrates from the northern hemisphere. All these data are very consistent.

Price and Warwick (1980), when reviewing Q_{10} values for meiobenthic species, propose that there exist two distinct groups in meiofauna: animals with a "stable food supply" (organic matter, nematodes), with a Q_{10} of 1, and animals with an "unstable food supply" (diatoms, bacteria) with a Q_{10} of 2. However, it is hardly possible to see whether *C. torosa*, which is a selective deposit feeder, actually eats the bacteria or the detritus. In general, the distinction between feeding on bacteria and feeding on other organic material is hard to make. It is tautological to argue that a Q_{10} of 2 evolved because it enables exploitation of temperature-dependent resources. Anyway, there are good reasons to believe that a Q_{10} of 2 is the most primitive state, since it reflects the general temperature dependence of chemical reactions, and one should therefore look for reasons why an animal would evolve towards a lower Q_{10}. A stable food supply in itself does not seem to constitute a good reason, as it is not clear why a stable food supply for one species could not be the same for another species, so that only when other limitations are present would competition be prevented. Anyway, it seems better to wait for more data on temperature dependence of meiofauna respiration rates before drawing far-reaching conclusions.

The population dynamics of *C. torosa* in this habitat are in apparent contrast with the hypothesis of Price and Warwick. Heip (1976) suggested that its density is not regulated by food availability. He showed further the profound influence of the yearly temperature-cycle on the dynamics of the species. Since the species survives freezing only in the egg stage, its life-cycle must be adapted to this. This regulation of the life-cycle in agreement with environmental temperature can only be achieved if temperature has a net effect on metabolism, i.e. if the Q_{10} is high enough. Thus there is no adaptive value for the species in evolving towards a lower Q_{10}.

References

Anderson FW (1964) The law of ostracod growth. Palaeontology 7:85–104

Gillandt L (1977) Größenwachstum bei Ostracoden, untersucht an der Larvalentwicklung von Dypridopsis parvoides Martens 1977 (Crustacea, Ostracoda, Podocopida). Abh. Verh Naturwiss Ver Hamburg 20:99–112

Heip C (1976) The life-cycle of Cyprideis torosa (Curstacea, Ostracoda). Oecologia (Berl) 24:229–245

Heitkamp U (1979) Postembryonales Größenwachstum limnischer Cyprididae (Crustacea, Ostracoda). Zool Anz Jena 202:391–412

Hemmingsen AM (1960) Energy metabolism as related to body size and respiratory surfaces, and its evolution. Rep Steno Hosp (Kbh) 9:1–11

Ivleva IV (1980) The dependence of crustacean respiration rate on body mass and habitat temperature. Int Revue Gesamten Hydrobiol 65:1–47

Klekowski RZ (1971) Cartesian diver microrespirometry of aquatic animals. Pol Arch Hydrobiol 18:93–114

Lasker R, Wells JBJ, McIntyre AD (1970) Growth, reproduction and carbon utilization of the sand-dwelling harpacticoid copepod, Asellopsis intermedia. J Mar Biol Assoc UK 50:147–160

McNeill S, Lawton JH (1970) Annual production and respiration in animal populations. Nature 225:472–474

Miller RJ, Mann KH (1973) Ecological energetics of the seaweed zone in a marine bay on the Atlantic coast of Canada. III. Energy transformations by sea urchins. Mar Biol 18:99–114

Price R, Warwick RM (1980) The effect of temperature on the respiration rate of meiofauna. Oecologia (Berl) 44:145–148

Teare M, Price R (1979) Respiration of the meiobenthic harpacticoid copepod, Tachidius discipes from an estuarine mudflat. J Exp Mar Biol Ecol 41:1–8

Vesper B (1972) Zur Morphologie und Ökologie von *Cyprideis torosa* Jones 1850 (Crustacea, Ostracoda, Cytheridae) unter besondere Berücksichtigung seiner Biometrie. Mitt Ham Zool Mus Inst 68:21–77

Warwick RM, Price R (1979) Ecological and metabolic studies on free-living nematodes from an estuarine mudflat. Estuarine Coastal Mar Sci 9:257–271