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The Effect of Temperature on the Respiration Rate of Meiofauna

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Summary. The effect of temperature on respiration rate has been established, using Cartesian divers, for the meiofaunal sabellid polychaete *Manayunkia aestuarina,* the free-living nematode *Sphaerolaimus hirsutus* and the harpacticoid copepod *Tachidius discipes* from a mudflat in the Lynher estuary, Cornwall, U.K. Over the temperature range normally experienced in the field, i.e. 5–20° C the size-compensated respiration rate (R_c) was related to the temperature (T) in °C by the equation $\mathrm{Log}_{10} R_c = -0.635 + 0.0339T$ for *Manayunkia,* $\mathrm{Log}_{10} R_c = 0.180 + 0.0069T$ for *Sphaerolaimus* and $\mathrm{Log}_{10} R_c = -0.428 + 0.0337T$ for *Tachidius,* being equivalent to Q_{10} values of 2.19, 1.17 and 2.17 respectively. In order to derive the temperature response for *Manayunkia* a relationship was first established between respiration rate and body size: $\mathrm{Log}_{10} R = 0.05 + 0.75\ \mathrm{Log}_{10} V$ where R = respiration in $\mathrm{nl} \cdot \mathrm{O}_2 \cdot \mathrm{ind}^{-1} \cdot \mathrm{h}^{-1}$ and V = body volume in nl.

The Q_{10} values are compared with values for other species derived from the literature. From these limited data a dichotomy emerges: species with a $Q_{10} \simeq 2$ which apparently feed on diatoms and bacteria, the abundance of which are subject to large short term variability, and species with $Q_{10} \simeq 1$ apparently dependent on more stable food sources.

Introduction

The metabolic compensations of meiofauna to changes in environmental factors are reviewed by Lasserre (1976), who describes "respiration adaptive plateaus" for several species. Any assessment of the energetic role played by meiofauna must take such adaptations into account, but such data are lacking for all but a few species.

A mud-flat in the River Lynher estuary, Cornwall, U.K. has been the site for several studies of energy flow through components of the benthos (Warwick and Price, 1975; Joint, 1978; Warwick and Price, 1979; Teare and Price, 1979; Price and Warwick, in press). Warwick et al. (1979) constructed a steady state model of energy flow through the mudflat which indicated the energetic importance of meiofauna in the system. However, in this model the Q_{10} for respiration of all meiofauna groups was taken as 2.05 over the range of temperatures experienced in the field, an average value for temperate marine poikilotherms (Miller and Mann, 1973). The present study facilitates a more accurate assessment of the energy loss from the system via meiofauna respiration by investigating the effect of temperature on the respiration rates of three important species.

Materials and Methods

Sediment samples were collected from the mid-tide level of a mudflat in the Lynher Estuary, Cornwall (described by Warwick and Price, 1975). These samples were covered with 26‰ filtered seawater and maintained at the experimental temperature overnight. Measurements to determine oxygen consumption were made on single animals using a Cartesian diver respirometer (Holter, 1943) with 2 µl stoppered divers (Zeuthen, 1950) as modified by Klekowski (1971). These measurements were completed within six hours of the animals extraction from the sediment.

On completion of the above determinations the animals were retrieved and preserved in a 4% formalin solution in 26‰ sea water. The volume of each experimental animal was then determined using scale drawings and models (see Warwick and Price, 1979; Teare and Price, 1979). The experimental work spanned a period from October 1977 to May 1978.

The effect of temperature on the respiration rate of the meiofaunal sabellid polychaete *Manayunkia aestuarina,* the free-living nematode *Sphaerolaimus hirsutus* and the harpacticoid copepod *Tachidius discipes* was investigated by comparing respiration rate per unit metabolic body size (R_c) over a range of experimental temperatures (T). The weight dependency of respiration for *Sphaerolaimus* is taken from Warwick and Price (1979) and that for *Tachidius* from Teare and Price (1979). No such relationship was available for *Manayunkia*; the relationship between respiration and body volume was therefore established at 20° C and is expressed in the form $\mathrm{Log}_{10} R = \mathrm{Log}_{10} a + b\ \mathrm{Log}_{10} V$, *where* R represents respiration rate ($\mathrm{nl} \cdot \mathrm{O}_2\ \mathrm{ind}^{-1}\ \mathrm{h}^{-1}$), V represents body volume (nl), a and b are constants. The equation was solved by the method of least squares regression. Shortly after extraction from the sediment the majority of *Manayunkia* vacated their tubes and consequently all measurements were made on this species free from its tube.

The $\log_{10}$ of the respiration rate (R_c) has been plotted against experimental temperature. Relationships in the form $\mathrm{Log}_{10}\ R_c = c + d \cdot T$ have been established for the temperature range normally experienced by the animals under natural conditions, namely 5–20° C. Q_{10} values over this range have been calculated from the equation $\mathrm{Log} Q_{10} = 10 \cdot d$. For *Sphaerolaimus* additional measurements were made outside this range (0, 25, 30 and 35° C).

Data for the harpacticoid copepod *Asellopsis intermedia* were read from the graph in Lasker et al. (1970); no account could be taken of the probable non-linear weight dependency of respiration rate for this species, though it is unlikely that this would markedly affect the Q_{10} value obtained.

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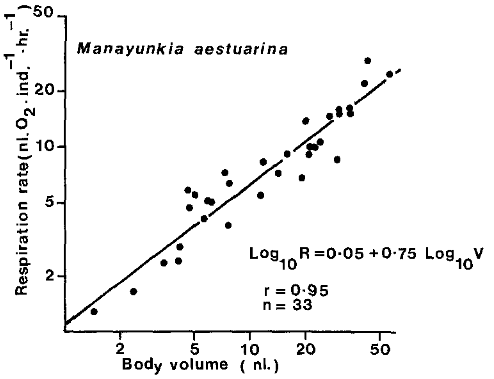

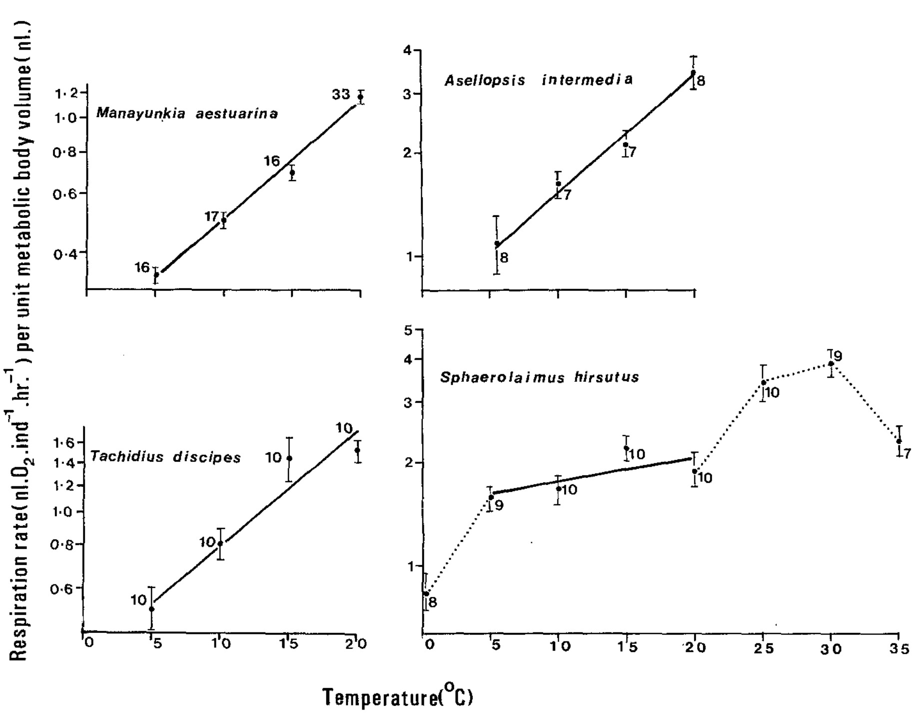

Fig. 1. The relationship between respiration and body size for *Manayunkia aestuarina*

Fig. 2. The effect of temperature on the respiration rate of four meiofauna species showing the number of data points and standard error at each temperature. Solid lines show calculated regression lines over the normal temperature range (see text). Data for *Asellopsis* are taken from Lasker et al. 1970

Results

The respiration rate of *Manayunkia* (R) in nl O_2 ind^{-1} h^{-1} is related to body volume in nl by the equation

$\mathrm{Log}_{10}R = 0.05\ (\pm 0.05) + 0.75\ (\pm 0.05)\ \mathrm{Log}_{10}V$ (see Fig. 1).

Fig. 2 illustrates the metabolic response to temperature for *Manayunkia, Tachidius, Asellopsis* and *Sphaerolaimus.* It can be seen that, compared to the other three species, the respiration rate of *Sphaerolaimus* is little affected by temperature over the range normally experienced in the field. Equations relating size compensated respiration rate (R_c) in nl. $O_2 \cdot h^{-1}\ nl^{-1}$ to temperature (T) in °C over the range 5–20° C are

$\mathrm{Log}_{10}R_c = -0.635\ (\pm 0.03)\ + 0.0339\ (\pm 0.0018)\ T$
for *Manayunkia*

$\mathrm{Log}_{10}R_c = -0.428\ (\pm 0.066)\ + 0.0337\ (\pm 0.0048)\ T$
for *Tachidius*

$\mathrm{Log}_{10}R_c = -0.157\ (\pm 0.070)\ + 0.0343\ (\pm 0.0050)\ T$
for *Asellopsis*

$\mathrm{Log}_{10}R_c = 0.180\ (\pm 0.049)\ + 0.0069\ (\pm 0.0035)\ T$
for *Sphaerolaimus*

These equations are equivalent to Q_{10} values of 2.19, 2.17, 2.20 and 1.17 respectively. The response of *Sphaerolaimus* outside of the range 5–20° C does not conform to any simple mathematical model. Over the ranges 0–5° C and 20–25° C the respiration rate of *Sphaerolaimus* increases rapidly with increased temperature. At higher temperatures the animals became moribund and showed a reduced respiration rate.

Discussion

The relationship between respiration rate and body size established for *Manayunkia* is very similar to that described for nematodes at the same site by Warwick and Price (1979). The mean values of $\log_{10}$ a and b established for the nematodes were 0.01 and 0.76 respectively compared to 0.05 and 0.75 for *Manayunkia.* Teare and Price (1979) showed that the harpacticoid copepod *Tachidius discipes* taken from the same site had a slightly lower metabolic intensity at 20° C than *Manayunkia* indicated by the value of $\log a = -0.10$, but a similar weight dependency with $b = 0.82$. "b" values of 0.75 apply to a wide range of organisms (Hemmingsen, 1960) including the meiofauna (Vernberg and Coull, 1974; Lee and Atkinson, 1976; Lassere, 1976).

Comparison of the effect of temperature on respiration between meiofauna species is not simple. Different acclimatisation procedures have been adopted by different authors, some of whom give no account of pretreatment at all. The shapes of curves describing effects of temperature on the metabolism of ectothermic animals result from a network of physiological processes and control mechanisms (Wieser, 1973). However, over the temperature range normally experienced by the experimental animal we frequently observe a relationship that can be roughly described by a straight line on a log (Respiration): linear (Temperature) plot. The slope of the line (d) can be directly related to the Q_{10} over this temperature range where

$\mathrm{Log}Q_{10} = 10 \cdot d.$

Table 1. Estimated Q_{10} in relation to temporal variability in diet. Sources of data: *1* This paper; *2* Lasker et al. (1970); *3* Lasserre and Renaud-Mornant (1971); *4* Wieser and Schiemer (1977); *5* Lasserre (1971)

Species	Estimated Q_{10}	Source	Diet	
Crustacea				
Copepoda				
Tachidius discipes	2.17	*1*	Diatoms	(Variable)
Asellopsis intermedia	2.20	*2*	Diatoms and bacteria	(Variable)
Mystacocarida				
Derocheilocaris remanei	Non-linear	*3*	Subsurface organic material	(Stable)
Nematoda				
Sphaerolaimus hirsutus	1.17	*1*	Nematodes	(Stable)
Trefusia schiemeri	$\simeq 2.0$	*4*	Bacteria?	(Variable)
Theristus floridanus	Non-linear	*4*	Organic material?	(Stable)
Annelida				
Polychaeta				
Manayunkia aestuarina	2.19	*1*	Diatoms and bacteria	(Variable)
Oligochaeta				
Marionina achaeta	$\simeq 1.0$	*5*	Organic material	(Stable)
Marionina spicula	$\simeq 1.0$	*5*	Organic material	(Stable)

Table 1 compares Q_{10} values estimated from the available data for a range of meiofauna species. Against each species is noted the animals diet and an assessment of the variability of the food level. In assessing the variability of the food level we have allowed two categories, "variable" and "stable". Diatoms and bacteria are both considered "variable" in that both are capable of exhibiting a large local, short term variation in abundance. On the Lynher mud-flat, for example, the production of microbial autotrophs is an order of magnitude higher in the summer than in winter, while the density of heterotrophic bacteria varies by four orders of magnitude (Joint, 1978). Elsewhere individual diatom species have been shown to have periods of rapid growth and decline and may apparently be absent in certain seasons (Hopkins, 1964). Organic material and nematodes are both considered "stable". On the Lynher mud-flat the overall organic content (measured in terms of nitrogen) varied between very narrow limits (3.5–4.5 mg N g^{-1} in the top 0.5 cm of sediment) (Joint, 1978); the abundance of nematodes at this site varies seasonally only by a factor of two (Warwick and Price, 1979).

It appears, from the limited data available, that there are two separate categories within the meiofauna, animals with $Q_{10} \simeq 2$ whose food supply is variable and animals with $Q_{10} \simeq 1$ whose food supply is quite stable.

Since availability of "variable" food supplies tends to increase with temperature the higher Q_{10} value of animals feeding on these diets could be considered functional in enabling them to fully exploit the increased food level, or conversely to reduce their food requirements under colder conditions and lower food levels. Such mechanisms are discussed by Wieser (1973). Lasserre (1971) explained the confinement of *Derocheilocaris remanei* to the lower shore in terms of its poor ability to regulate its metabolism against changes in temperature. However *Tachidius discipes, Asellopsis intermedia* and *Manayunkia aestuarina* all occur at mid-tide level in spite of their Q_{10} values being in excess of 2.0. It may be that the rate of adaptation to temperature change is a more important factor in governing such species distributions.

References

Hemmingsen, A.M.: Energy metabolism as related to body size and respiratory surfaces, and its evolution. Rep. Steno. Hosp. (Kbh.) **9** (2), 1–11 (1960)

Holter, H.: Techniques of the Cartesian Diver. C-r. Trav. Lab. Carlsberg (Chim.) **24**, 399–478 (1943)

Hopkins, J.T.: A study of the diatoms of the Ouse estuary, Sussex. III. The seasonal variation in the littoral epiphyte flora and the shore plankton. J. mar. biol. Ass. U.K. **44**, 613–644 (1964)

Joint, I.R.: Microbial production of an estuarine mud flat. Est. cstl. mar. Sci. **7**, 185–195 (1978)

Klekowski, R.Z.: Cartesian diver microrespirometry of aquatic animals. Polsk. Arch. Hydrobiol. **18**, 93–114 (1971)

Lasker, R., Wells, J.B.J., McIntyre, A.D.: Growth, reproduction, respiration and carbon utilisation of the sand-dwelling harpacticoid copepod, *Asellopsis intermedia*. J. mar. biol. Ass. U.K. **50**, 147–160 (1970)

Lasserre, P.: Données écologiques sur la répartition des oligochètes marins méiobenthiques. Incidence des paramètres salinité – température sur le métabolisme respiratoire de deux espèces euryhalines du genre *Marionina* Michaelsen (1889) *(Enchytraeidae, Oligochaeta)*. Vie et Milieu **22**, 523–540 (1971)

Lasserre, P.: Metabolic activities of benthic microfauna and meiofauna. In: The benthic boundary layer (I.N. McCave, ed.), pp. 95–142. New York – London: Plenum Press 1976

Lasserre, P., Renaud-Mornant, J.: Interprétation écophysiologique des effets de température et de salinité sur l'intensité respiratoire de *Derocheilocaris remanei biscayensis* Delamare, 1953 *(Crustacea, Mystacocarida)*. C.R. Acad. Sci. Paris, Ser. D, **272**, 1159–1162 (1971)

Lee, D.L., Atkinson, H.J.: Physiology of nematodes. (2nd Ed.) 215 pp., London: Macmillan Press 1976

Miller, R.J., Mann, K.H.: 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 (1973)

Teare, M., Price, R.: Respiration of the meiobenthic harpacticoid copepod, *Tachidius discipes* Giesbrecht, from an estuarine mud-flat. J. exp. mar. Biol. Ecol. **41**, 1–8 (1979)

Vernberg, W.B., Coull, B.C.: Respiration of an interstitial ciliate and benthic energy relationships. Oecologia **16**, 259–264 (1974)

Warwick, R.M., Joint, I.R., Radford, P.J.: Secondary production of the benthos in an estuarine environment. Proc. 1st Europ. Ecol. Symp. 429–450 (1979)

Warwick, R.M., Price, R.: Macrofauna production in an estuarine mud flat. J. mar. biol. Ass. U.K. **55**, 1–18 (1975)

Warwick, R.M., Price, R.: Ecological and metabolic studies on free-living nematodes from an estuarine mud flat. Est. coastl. mar. Sci. **9**, 257–271 (1979)

Wieser, W.: Temperature relations of ectotherms. A speculative review. In: Effects of temperature on ectothermic organisms (W. Wieser, ed), pp. 1–23. Berlin-Heidelberg-New York: Springer 1973

Wieser, W., Schiemer, F.: The ecophysiology of some marine nematodes from Bermuda: seasonal aspects. J. exp. mar. Biol. Ecol. **26**, 97–106 (1977)

Zeuthen, E.: Cartesian diver respirometer. Biol. Bull. mar. Lab. Woods Hole **98**, 303–318 (1950)

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