The Effect of Temperature on the Respiration Rate of Meiofauna

R. Price and R.M. Warwick
Institute for Marine Environmental Research, Prospect Place, The Hoe, Plymouth PL1 3DH, U.K.

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 ($R_e$) was related to the temperature ($T$) in °C by the equation $\log_{10} R_e = -0.635 + 0.0339 T$ for *Manayunkia*, $\log_{10} R_e = 0.180 + 0.0069 T$ for *Sphaerolaimus* and $\log_{10} R_e = -0.428 + 0.0337 T$ 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: $\log_{10} R = 0.05 + 0.75 \log_{10} V$ where $R$ = respiration in nl-O$_2$ ind$^{-1}$ 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 $Q_{10} \approx 2$ which apparently feed on diatoms and bacteria, the abundance of which are subject to large short term variability, and species with $Q_{10} \approx 1$ 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 plateau" 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 mud-flat in the Lynher Estuary, Cornwall (described by Warwick and Price, 1975). These samples were covered with 26/0 filtered sea-water 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 26/0 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 ($R_e$) 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 $\log_{10} R = \log_{10} a + b \log_{10} V$, where $R$ represents respiration rate (nl-O$_2$ ind$^{-1}$ 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 ($R_e$) has been plotted against experimental temperature. Relationships in the form $\log_{10} R_e = c + d T$ 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 $\log Q_{10} = 10 d$. For *Sphaerolaimus* additional measurements were made outside this range (0, 25, 30 and 35 °C).

Data for the harpacticoid copepod *Asellus intermedius* 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.
Results

The respiration rate of *Manayunkia* \( (R) \) in nl \( \text{O}_2 \) ind\(^{-1}\) h\(^{-1}\) is related to body volume in nl by the equation

\[
\log_{10} R = 0.05 (\pm 0.05) + 0.75 (\pm 0.05) \log_{10} V \quad \text{(see Fig. 1)}.
\]

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 \( \text{O}_2 \cdot \text{h}^{-1} \cdot \text{nl}^{-1} \) to temperature \( (T) \) in °C over the range 5-20°C are

\[
\log_{10} R_c = -0.635 (\pm 0.03) + 0.0339 (\pm 0.0018) T \quad \text{for *Manayunkia*}
\]

\[
\log_{10} R_c = -0.428 (\pm 0.066) + 0.0337 (\pm 0.0048) T \quad \text{for *Tachidius*}
\]

\[
\log_{10} R_c = -0.157 (\pm 0.070) + 0.0343 (\pm 0.0050) T \quad \text{for *Asellopsis*}
\]

\[
\log_{10} R_c = 0.180 (\pm 0.049) + 0.0069 (\pm 0.0035) T \quad \text{for *Sphaerolaimus*}
\]

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

\[
\log Q_{10} = 10 \cdot d.
\]