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The effects of temperature and salinity on the oxygen consumption of Eurytemora hirundoides (Crustacea, Copepoda)

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O_2 consumption was measured in *Eurytemora hirundoides* Nordqv. individuals acclimated to two salinities, 3 $^0/_{00}$ and 9 $^0/_{00}$. In 9 $^0/_{00}$ the animals were unable to maintain osmotic equilibrium, and were therefore thought to face physiological stress when transferred to either lower or higher salinity.

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1. Introduction

Salinity and its effect on O_2 consumption has been investigated extensively (for references, see Kinne 1971, Schlieper 1971). These investigations led Kinne (1971) to propose the following relations of salinity to O_2 consumption: for euryhaline invertebrates 1) an increase in subnormal salinities and/or a decrease in supranormal salinities and 2) an increase in sub- and supranormal salinities, 3) for stenohaline invertebrates a decrease in sub- and supranormal salinities, and 4) for holeuryhaline invertebrates an O_2 consumption that remains more or less unaffected by salinity. The interaction of temperature and salinity in relation to O_2 consumption has not been extensively investigated, although Dehnel (1960), Dimock & Groves (1975) and others have demonstrated that the response of O_2 consumption to salinity is affected by temperature. Under certain conditions a euryhaline organism may respond like a stenohaline form (see e.g. Dehnel & McCaughran 1964).

In the present paper we have investigated the effect of temperature and salinity on O_2 consumption of the brackish-water copepod *Eurytemora hirundoides* Nordqv. This copepod's range extends to the southern part of the Baltic Sea, and thus part of the population faces salinities of about 9 $^0/_{00}$. We compared a population freshly caught from 3 $^0/_{00}$ salinity with the same population acclimated for a week to 9 $^0/_{00}$ salinity, and transferred some individuals to different temperatures and salinities while measuring their O_2 consumption.

2. Materials and methods

All the *Eurytemora* individuals were caught in water of 3 $^0/_{00}$ salinity outside Helsinki. One week was allowed for acclimation of the animals transferred to 9 $^0/_{00}$ sea water. Such sea water (9 $^0/_{00}$) was obtained by diluting aged 33 $^0/_{00}$ Heligoland water with distilled water.

The animals used were fasted for at least 1 day before the experiments. Short-term food deprivation should stabilize the metabolic rate at standard level (Wallace 1973, Aldrich 1975). The animals were used freshly caught at 6°C in 3 $^0/_{00}$ water, or acclimated in 9 $^0/_{00}$ salinity in the laboratory in 6°C. These animals were then transferred to different experimental salinities and temperatures. Respiration was measured with the polarographic equipment as explained by Gyllenberg & Lundqvist (1976). During the experiment, the first hour was disregarded to allow equilibrium within the chamber. Readings were then taken at intervals of about 2 h.

Osmotic concentrations was determined by the melting-point technique with a microcryoscope, as described by Ramsay (1949). Some modifications were made: the thermometer was replaced by a thermoelement that was connected to a recorder. The thermoelements could be inserted directly into the animal, and the results were therefore easy to interpret.

The glass capillary in which the animal was placed was an unheparinized blood capillary. When the animal was in position the capillary was sealed with Radiometer Sealing Wax D 553.

The freezing chamber was a small paraffined box of polystyrene, provided with a cover of transparent acryl and with a hole on one side through which the capillary could be passed. The temperature was reduced to —20°C by freezing with 96 % alcohol.

Temperature was recorded with a pair of copper-constantan elements connected in series, and attached to the recorder Radiometer REC 51. One of the elements had a sharp point that could be thrust into the animal, whereas the other (reference element) was put into a stabilizing bath in the cryostat. The readings were accurate to within 0.01°C. The unity of the readings was calibrated with a Beckman precision thermometer and the zero point was checked every day with distilled water.

3. Results

The results of the experiments are presented in Figs. 1 and 2. As is shown, the respiratory rate increases with temperature, but not as much as would be expected (cf. Q_{10} values in Table 1). This agrees to some extent with the results obtained earlier by Gyllenberg (1973). In that study a respiratory compensation plateau was found for *Eurytemora hirundoides* between temperatures of 4° — 15°C.

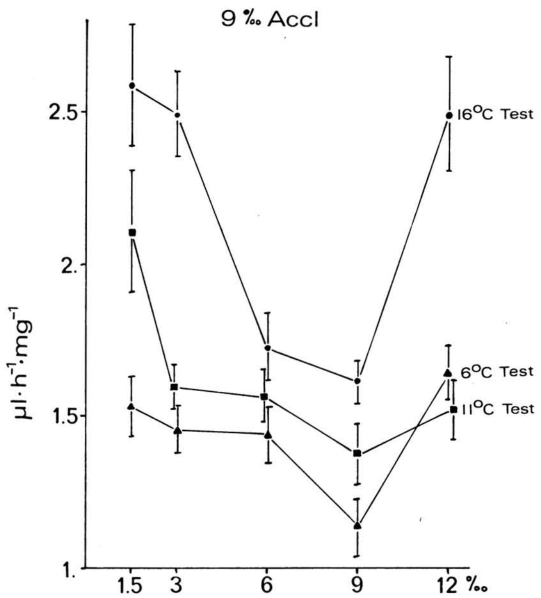

Fig. 2. *Eurytemora hirundoides.* Effects of acclimation to 9 $^{0}/_{00}$ salinity on oxygen consumption at various temperatures and salinities. The values are means ± SE. N = 4.

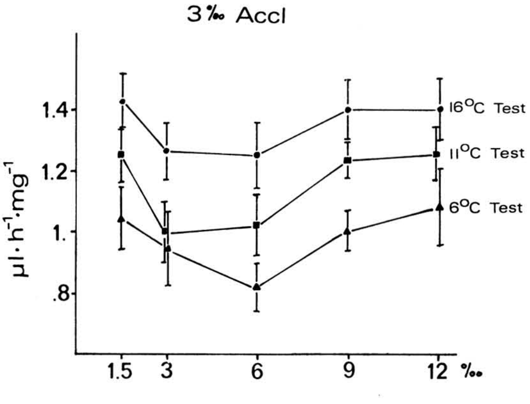

Fig. 1. *Eurytemora hirundoides.* Effects of acclimation to 3 $^{0}/_{00}$ salinity on oxygen consumption at various temperatures and salinities. The values are means ± SE. N = 4.

Salinity effects pose several problems. In the animals acclimated to 3 $^{0}/_{00}$ salinity the O_2 consumption was lowest at 6 $^{0}/_{00}$, and increased on transfer to both lower and higher salinities. This shows that the animals are able to regulate their osmotic concentration (Fig. 3). It thus seems that the isoosmotic point of the animals lies at 6 $^{0}/_{00}$ salinity. For the animals acclimated to 9 $^{0}/_{00}$ the O_2 consumption values reach their lowest point at 9 $^{0}/_{00}$, and increase in solutions of both higher and lower salinity.

Furthermore, it is to be noted that the values at 9 $^{0}/_{00}$ for animals acclimated to 3 and 9 $^{0}/_{00}$ were not significantly different (Table 4), whereas at all the other salinities tested the plateaus for the two acclimation stages differed significantly. For animals acclimated to any

Table 1. *Eurytemora hirundoides.* Q_{10} values for difference in O_2 consumption between experimental temperatures at various salinities.

Acclimation salinity $^{0}/_{00}$	Experimental salinity $^{0}/_{00}$	Q_{10} 6–11°C	Q_{10} 11–16°C
3	1.5	1.4	1.3
3	3	1.1	1.6
3	6	1.6	1.5
3	9	1.5	1.3
3	12	1.3	1.2
9	1.5	1.9	1.5
9	3	1.2	2.5
9	6	1.2	1.2
9	9	1.5	1.4
9	12	0.9	2.7

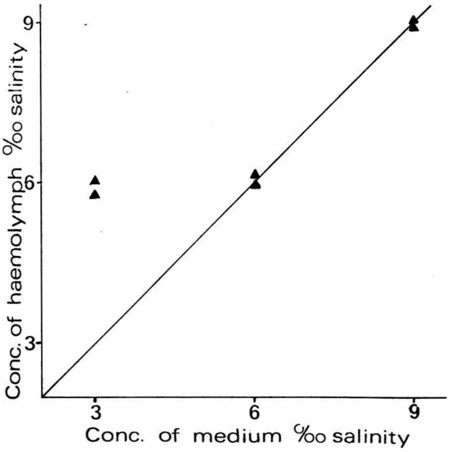

Fig. 3. Freezing-point determinations in *Eurytemora hirundoides* from localities with 3 $^{0}/_{00}$ salinity. The temperatures are related to salinity according to tables given in physiological textbooks.

Table 2. *Eurytemora hirundoides*. Significance of differences in O_2 consumption at various experimental temperatures by correlation analysis. At each salinity and temperature four animals were used.

Acclimation	Experimental	Experimental temperatures 6, 11 and 16°C	
salinity $^{0}/_{00}$	salinity $^{0}/_{00}$	slope b	r
3	1.5	0.039	0.689*
3	3	0.032	0.582*
3	6	0.043	0.714**
3	9	0.03	0.514
3	12	0.032	0.567
9	1.5	0.045	0.756**
9	3	0.104	0.860**
9	6	0.029	0.547
9	9	0.048	0.778**
9	12	0.085	0.707**

Table 3. *Eurytemora hirundoides*. Significance of differences in O_2 consumption at various experimental salinities by ANOVA. At each salinity and temperature four animals were used.

Acclimation salinity $^{0}/_{00}$	Experimental temperature °C	Experimental salinity 1,5 ... 12 $^{0}/_{00}$ F value
3	6	0.96
3	11	1.78
3	16	0.73
9	6	4.10
9	11	5.21*
9	16	10.01**

Table 4. *Eurytemora hirundoides*. Significance of differences in O_2 consumption at different acclimation salinities by ANOVA. At each salinity and temperature four animals were used.

Experimental salinity $^{0}/_{00}$	Experimental temperature °C	Acclimation salinities 3 and 9 $^{0}/_{00}$ F value
1.5	6, 11 and 16	23.16***
3	6, 11 and 16	21.90***
6	6, 11 and 16	32.02***
9	6, 11 and 16	2.77
12	6, 11 and 16	15.45***

given salinity the O_2 consumptions at different temperatures are mostly significantly different (Table 2). O_2 consumption at different salinities, on the other hand, is significantly different for only two temperatures in animals acclimated to 9 $^{0}/_{00}$ (Table 3).

4. Discussion

The oxygen consumption curves (Figs. 1 and 2) for the animals acclimated to 3 $^{0}/_{00}$ and 9 $^{0}/_{00}$ are clearly different. Fig. 1 shows a minimum O_2 consumption in 6 $^{0}/_{00}$ salinity, whereas the animals acclimated to 9 $^{0}/_{00}$ have a minimum at 9 $^{0}/_{00}$ salinity. There are two possible hypotheses to explain this phenomenon:

1) The animals acclimated to 9 $^{0}/_{00}$ are exposed to an additional type of stress, reflected in the readings, when transferred to the higher and lower salinities. It is obvious that the 9 $^{0}/_{00}$ salinity is the only one in which there are no differences between the curves (Table 4). At all other salinities O_2 consumption is significantly higher in the animals acclimated to 9 $^{0}/_{00}$.

2) The animals have their isoosmotic point at 6 $^{0}/_{00}$ salinity (Fig. 3). At higher salinities (9 $^{0}/_{00}$) *Eurytemora hirundoides* loses its ability to osmoregulate, and the internal concentration follows that of the surrounding medium. The curve in Fig. 3 is typical of brackish-water animals, as has been demonstrated earlier by Smith (1955) for *Nereis diversicolor*, by Brand & Bayly (1971) for *Sulcanus conflictus* (Copepoda), and by Beadle (1943) for brackish-water animals in general.

Since *Eurytemora hirundoides* lacks the capacity for hyposmotic regulation, it becomes an osmoconformer above ca 6 $^{0}/_{00}$ salinity. Acclimation to 9 $^{0}/_{00}$ appeared to cause physiological stress, for O_2 consumption was higher than in animals acclimated to 3 ‰. Transfer from 9 ‰ back to lower salinities caused a marked transitional increase in O_2 consumption, which probably reflects active readjustment to hyperosmotic regulation.

Eurytemora hirundoides is a typical euryhaline animal as defined by Kinne (1971): it has an increased O_2 consumption in both hypo- and hypersaline media. This increase remains even after acclimation to higher salinity.

The values for thermoadaptation of *Eurytemora hirundoides* show that within a certain temperature range the copepod is capable of a certain degree of respiratory compensation, the Q_{10} values remaining fairly small. Certain combinations of salinity and temperature in the different acclimation conditions offered were apparently too large for the compensation to cope with, and Q_{10} increased to the normal range between 2 and 3.

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