RESPIRATORY RATE OF MAYFLY NYMPHS IN WATER WITH DIFFERING OXYGEN AND IONIC CONCENTRATIONS

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ABSTRACT

With increasing concentrations of dissolved oxygen the average rate of gill movements of *Heptagenia* (?) sp. mayfly nymphs significantly decreased ($p < 0.05$). The length of periods of gill movement was significantly ($p < 0.05$) higher in the boiled water treatments, and the length of the resting periods was longer in the aerated treatments ($p < 0.05$). The number of gill movement periods showed no clear trend. There were no obvious differences between the responses of the nymphs to rainwater and distilled water.

INTRODUCTION

Gills of mayfly nymphs are thought to be involved in absorption of both oxygen (e.g. Eriksen and Mœur this volume) and dissolved ions (e.g. Filshie and Campbell 1984). Nymphs of many mayflies, including *Heptagenia* (?) sp used in this study, display discontinuous gill movements which would replenish the water adjacent to the gills thus improving the efficiency of absorption of oxygen and ions. In this study the movements of nymphal gills were measured in rainwater and distilled water which had been boiled, equilibrated with air and aerated. This provided two different ionic strengths of water and three different dissolved oxygen levels.

METHODS

Thirty replicates of each of 6 experiments were carried out in petrie dishes lined with filter paper. Distilled and rainwater were used each with two treatments (boiled for 40 minutes and aerated for 30 minutes) as well as in the untreated form. Oxygen concentrations were measured using the Rideal-Steward modification of the Winkler technique, and were significantly different depending on the treatment (Table 1).

Nymphs for use in the experiments were 10-15 mm long with dry weights of 16–24 mg (Table 1). They were kept in aerated stream water at 26°C for approximately 24 hr after collection for acclimation. Each experiment used a single nymph, and after transfer to the experimental petrie dish the rate of gill movement, the length of period of gill movement and resting period, and the number of gill movement periods were recorded from the second to the sixth minute after transfer using a hand counter and a stop watch. After each experiment the nymph used was dried at 60° for 24 hr and weighed.

RESULTS AND DISCUSSION

The results of the experiments using rainwater and distilled water were similar (Table 1, Fig. 1),

I.C. Campbell (ed.) Mayflies and Stoneflies, 105–107.

Table 1. Rates of gill movement, length of gill movement periods and resting periods, and numbers of gill movement periods of mayfly nymphs in water with differing concentrations of ions and dissolved oxygen. Values given are means with standard deviations following in brackets. BDW = boiled distilled water, DW = distilled water, ODW = oxygenated distilled water, BRW = boiled rain water, RW = rain water, ORW = oxygenated rainwater

Water type	Dissolved oxygen mg l^{-1}	Dry Wt of nymph mg	Rate of movement sec^{-1}	Length of movement period sec	Length of resting period sec	No. of movement periods per 5 mins
BDW	4.28	18.63	4.05	36.14	2.60	8.10
	(0.29)	(2.12)	(0.34)	(18.69)	(0.83)	(1.44)
DW	7.21	18.70	3.50	26.91	3.53	10.13
	(0.07)	(1.68)	(0.34)	(21.02)	(2.98)	(2.30)
ODW	23.03	19.66	2.18	28.46	9.14	8.33
	(0.45)	(2.05)	(0.26)	(14.44)	(7.64)	(1.64)
BRW	3.18	18.10	1.83[1]	60.65	13.74	3.33
	(0.17)	(1.50)	(0.29)	(38.65)	(8.29)	(0.54)
RW	6.00	18.76	3.56	32.80	3.99	8.40
	(0.10)	(2.51)	(0.34)	(17.85)	(4.58)	(1.52)
ORW	25.43	18.23	2.10	32.36	10.25	7.46
	(0.28)	(1.65)	(0.17)	(17.77)	(7.80)	(1.10)

[1] This value excludes the first 0.5–1.0 minute after transfer of the nymphs. With this first period included the value is 4.17 (0.64).

indicating that the gill responses of the animals were primarily respiratory rather than osmotic.

The average number of gill movements per second decreased with increasing oxygen concentration in both types of water. The differences between the values obtained for each treatment of the water were significant at the 0.05 level. One result, that for nymphs in boiled rainwater, was anomalous, with very high rates of gill movement in the first minute that the animals were placed in the water, but with the rates then declining and most nymphs dying within the first 3 minutes. This indicates that the oxygen levels were below the animals tolerance threshold. In both the table and the figure the results are given including and excluding the rates during the period 0.5–1.0 minutes after the animal was placed in the water.

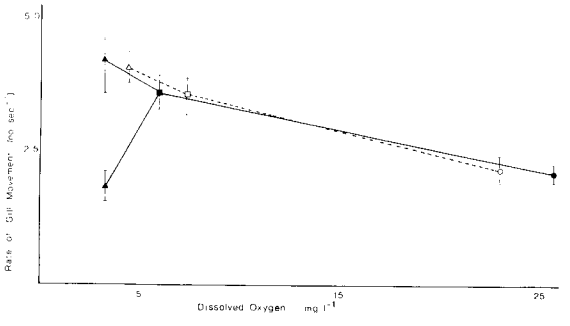

Fig. 1. The relationship between the rate of gill movement and oxygen concentration of the water. Solid symbols indicate rain water, open symbols indicate distilled water. The circles indicate values for aerated water, the squares for non-boiled water and the triangles for boiled water. The higher value for boiled rain water includes the values for the period 0.5–1.0 minute after the transfer. The vertical lines indicate one standard deviation around the mean.

The lengths of the periods of gill movement decreased significantly between the boiled and untreated water types but were not significantly different between the untreated and aerated waters, which possibly indicates a threshold effect. Similarly the length of the resting periods increased markedly from the untreated to the aerated water types but were not very different between the boiled and untreated types.

In treatments with low dissolved oxygen periods of gill movement were always longer than resting periods, but during the course of each experiment the length of movement periods decreased while resting periods increased in length. The

only exception to this was the boiled rainwater experiment in which the gill movement periods continued to increase until the death of the animal after the fourth period.

The number of gill movement periods were significantly different between treatments (Table 1) but there was no obvious pattern. The results for boiled rainwater were particularly low due to the short mean survival time (3.9 minutes) of nymphs in water with this treatment. The mean survival time for nymphs in water with other treatments was 4.6 minutes. In the oxygenated water the nymphs tended to have a higher number of gill movements but a lower rate of gill movement.

CONCLUSIONS

Heptagenia (?) mayfly nymphs show discontinuous patterns of gill movement, which seem to be related to respiratory requirements rather than osmoregulatory requirements. With increasing concentrations of dissolved oxygen the rate of gill movements and the length of periods of gill movements increased while the resting periods decreased in length. The number of gill movement periods showed no clear pattern in relation to dissolved oxygen concentration.

REFERENCES

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