Evidence of a Spring Rise in Metabolic Rate in the Burrowing Mayfly Ephemera simulans Walker

by

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INTRODUCTION

Most invertebrate animals acclimated to low winter temperatures have a higher Q10 than similar animals acclimated to higher summer temperatures. This, of course, means that with warming of the environmental waters in the spring and the rise of total metabolic demands, the Q10 will decrease. However, also in the literature are examples of metabolic rate increases with rising water temperature in the spring, perhaps due to such factors as increased growth rate or gonad development. The studies of MORGAN & WILDER (1936), working with *Hexagenia recurvata* MORGAN, and BERG et al. (1958), using the fresh water limpet *Ancylus fluviatilis* (O. F. MÜLLER), are just two of those attesting to the reality of such a phenomenon.

This paper points to *Ephemera simulans* WALKER as one more example showing a metabolic rate increase in the spring. I also have some evidence that the same phenomenon occurs in the closely related species *Hexagenia limbata* (SERVILLE) and hence further study is warranted. The value of such information is that it affords data within a closely related group (burrowing mayflies), thus increasing our knowledge about the occurrence of this phenomenon.

MATERIALS AND METHODS

Experimental animal and collection conditions

The experimental animal used in the study was the burrowing mayfly nymph *Ephemera simulans* WALKER. All individuals were

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within a 16 to 21 mm size range. *E. simulans* was collected from a sand, gravel and pebble substratum in Fleming Creek, Washtenaw County, Michigan, and from a marl, sand and gravel substratum in Silver Lake, Washtenaw County, Michigan. Collections were made in February, March, and early and late April. Water temperatures varied only between 1° and 5°C from November through the early April collections. However, during the latter part of April, water temperatures sometimes reached 13°C but averaged only about 10°C well into May.

Procedure in studies of oxygen consumption

After acclimation for 24 hours at the experimental temperature, experiments were conducted for five hours in the dark at 13.0 ± 1.4°C and in distilled water which assured a non-toxic, chemically constant medium. Because of the relatively large bottom surface area afforded by the nymphs for burrowing into the added experimental substratum, 250 ml flasks were selected as the experimental containers.

Oxygen concentration was measured by the Micro-Winkler method. Titrations were made with N/1000 sodium thiosulphate on three 15 ml subsamples in order to obtain an average reading for eachc ontainer. Accuracy of the method proved to be ± 0.03 cc/O_2/l.

Oxygen consumption of the nymphs was measured by the "closed-bottle" method which compares the oxygen in a known volume of water at the beginning and end of an experiment. The difference in concentrations is assumed to be the oxygen consumed by the organisms over the span of the experiment.

WAUTIER & PATTÉE (1955) originally indicated that oxygen consumption of burrowing mayflies varies with the particle size of the substratum. Thus, in order to measure oxygen consumption of the nymphs under conditions as close to normal as possible, the "most suitable substratum" for *Ephemera* (determined by ERIKSEN, 1961) was added to the experimental containers. Fourty cc of a washed and sterilized Ø-1 fraction (2—4 mm) were added. Five nymphs were placed in each flask. At the termination of an experiment the oxygen concentration in each flask was determined and compared to the controls. Nymphs were removed to vials and dried for 24 hours at 105°C. Dry weight was obtained using a Mettler, B6, analytical balance with an accuracy of ± 0.02 mg. Results were calculated in terms of cc of oxygen consumed per gram oven dry weight per hour.

RESULTS

The oxygen consumption of *Ephemera* nymphs was determined

in their most suitable substratum (Ø-1) on several different occasions during the winter and spring of 1960. Oxygen concentration in the experimental containers varied between 1.50 and 6.00 cc/l. As *E. simulans* is capable of respiratory regulation in oxygen concentrations exceeding 1.25 cc/l (ERIKSEN, 1961), environmental oxygen concentrations greater than this value affect only slightly, if at all, the oxygen consumption of the nymphs (Table I). Over the time span of February 19—26, 1960, nymphs of *E. simulans* had an average oxygen consumption of 0.21 cc/g/hr. From March 20—30, they averaged 0.23 cc/g/hr and from April 6—9, ten experiments showed 0.24 cc/g/hr consumed. Finally, on April 23, experiments resulted in an average of 0.37 cc/g/hr — a significant rise in oxygen consumption (Table I).

TABLE I.

Ephemera simulans: Oxygen consumption (cc/g dry wt/hr) in an "optimal substratum" (ø-1) during winter and spring

date 1960	o_2 conc. cc/l	o_2 consumed	date 1960	o_2 conc. cc/l	o_2 consumed
2—26	5.71	0.17	4—6	5.53	0.27
2—26	5.65	0.21	4—6	5.48	0.19
2—20	5.48	0.19	4—9	5.24	0.28
2—26	5.46	0.22		5.23	0.22
2—19	5.41	0.15		5.23	0.19
2—19	5.31	0.23		5.18	0.28
2—19	5.20	0.29		5.14	0.20
				5.14	0.23
average	5.46	0.21		5.12	0.22
				5.12	0.29
3—20	2.63	0.22			
	2.62	0.18	average	5.24	0.24
	2.61	0.27			
	2.59	0.20	4—23	1.71	0.34
	2.57	0.23		1.69	0.37
				1.67	0.40
average	2.60	0.22			
			average	1.69	0.37
3—30	3.84	0.17			
	3.83	0.20	4—23	5.47	0.36
	3.80	0.24		5.38	0.41
	3.74	0.26		5.37	0.38
	3.70	0.27			
			average	5.41	0.38
average	3.78	0.23			
3—30	1.42	0.24			
	1.41	0.22			
	1.41	0.23			
	1.40	0.21			
	1.32	0.27			
average	1.39	0.23			

Discussion

Ephemera simulans maintains an oxygen consumption in a suitable substratum (Ø-1) of approximately 0.23 cc/g/hr from at least February, and probably before, through approximately the middle of April at which time it rises to around 0.37 cc/g/hr (Table I). Such data indicate quite clearly that a rise in metabolic rate occurs in the spring in this burrowing mayfly. On the other hand, most studies show that after cold acclimation, Q10 falls with acclimation to the warmer temperatures of spring and summer. The involvement with passing of time of such factors as warmer temperatures, age, increased body size and increased food should serve to reduce the Q10. In spite of all these factors, Q10 rose.

A surge of growth and gonad development in April and May is here suggested as the factor most likely responsible for the metabolic increase. Observation of successive collections of nymphs at this time of year makes obvious the rapid development.

Summary

Ephemera simulans maintains an oxygen consumption in a suitable substratum (Ø-1) of approximately 0.23 cc/g/hr from at least February, and probably before, through approximately the middle of April at which time it rises to around 0.37 cc/g/hr. Such data indicate quite clearly that a rise in metabolic rate occurs in the spring in this burrowing mayfly. A surge of growth and gonad development in April and May is here suggested as the factor most likely responsible for the metabolic increase. Observation of successive collections of nymphs at this time of year makes obvious the rapid development.

Zusammenfassung

Ephemera simulans hält in einem geeigneten Substratum (Ø-1) von ungefähr 0.23 cc/g/hr einen Sauerstoff-Verbrauch aufrecht, der von mindestens Februar an, und wahrscheinlich bevor, bis etwa Mitte April dauert, und zu welcher Zeit die Ablesung auf etwa 0.37 cc/g/hr ansteigt. Diese Daten zeigen ganz offensichtlich, dass ein Ansteigen der metabolischen Geschwindigkeit im Frühling, in dieser sich eingrabenden Eintagsfliege, stattfindet. Ein Anschwellen des Wachstums und der Gonaden-Entwicklung im April und im Mai wird hier als ein Faktor vermutet, der sehr wahrscheinlich verantwortlich für das Ansteigen des Metabolismus ist. Die Beobachtung von aufeinanderfolgenden Sammlungen von Nymphen zu dieser Jahreszeit lässt die rasche Entwicklung offenbar werden.

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