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THE EFFECT OF TEMPERATURE ON THE RESPIRATION OF THE FRESHWATER MUSSEL *LAMPSILIS SILIQUOIDEA* (BIVALVIA: UNIONIDAE)

Melody Myers-Kinzie
Department of Forestry and Natural Resources
Purdue University
West Lafayette, Indiana 47907

ABSTRACT: The respiration of the freshwater mussel *Lampsilis siliquoidea* (fatmucket) was monitored during the experimental manipulation of temperature. The oxygen consumed for one hour was measured at water temperatures ranging from 10° to 25° C. Correlation of water temperature and oxygen consumption shows a direct linear relationship with an overall Q_{10} of 4.1.

KEYWORDS: Bivalve respiration, *Lampsilis siliquoidea*, oxygen consumption, unionid.

INTRODUCTION

Freshwater mussels (Bivalvia: Unionidae) are an integral part of aquatic communities. Surveys of unionid mussels in North America have documented declines in species diversity and distributional ranges (Meyer, 1968; Dineen, 1971; Cummings, *et al.*, 1992). Of the 297 native freshwater mussels in the United States and Canada, 71.7% are considered endangered, threatened, or of special concern (Williams, *et al.*, 1993). Factors contributing to this decline include commercial harvest, pollution, siltation (Parmalee, 1967), and the invasion of the zebra mussel, *Dreissena polymorpha* (Ricciardi, *et al.*, 1998).

Energy processes, such as oxygen consumption, are indicators of an organism's overall physiological health (Mehrle and Mayer, 1985) and may also be important in studies of population health (Huebner, 1982). Hierstand (1938) has shown that oxygen consumption by aquatic mollusks, including unionids, is relatively uniform from normal saturation levels to low oxygen percentages. Because mollusks are poikilothermic organisms, the temperature of the water must be taken into account when evaluating oxygen consumption. Physiological studies with marine bivalves (Marsden and Weatherhead, 1998; Pilditch and Grant, 1999) indicate that metabolic rates are directly affected by water temperature. Temperature-induced changes in any rate function can be described by the Q_{10}, the factor by which the function changes with a 10° C increase in temperature (McMahon, 1991).

Lampsilis siliquoidea (= *radiata*) Barnes (1823) is a common and widespread mussel. This species is distributed throughout the entire Mississippi River drainage basin and beyond (from western New York to North Dakota and from Texas and Louisiana to Canada east of the Rocky Mountains (Parmalee, 1967)).

This mussel is found in rivers, lakes, and small streams and may be locally abundant (Parmalee, 1967; Cummings and Mayer, 1992). The mussel's reproductive biology (Trdan, 1981), seasonal variation in respiration (Huebner, 1982), habitat selection (Bailey, 1989), and bioassays using artificially cultured juveniles (Myers-Kinzie, 1998) have all been studied.

Although measuring the physiological responses of freshwater mussels can yield important information about the condition of the individuals and, by inference, the population, few studies have addressed these issues. Those studies that have focused on respiration rates in response to environmental stress (Kulkarni and Keshavan, 1989; Aldridge, *et al*, 1987; Naimo, *et al.*, 1992) have found that respiration can be an important indicator of individual and/or population health. Because many mussel species are in decline, it is important to select a test species that is common to serve as a surrogate for other, more rare species. In this study, I used a common species to establish a baseline for mussel respiration at varying temperatures.

MATERIALS AND METHODS

Adult *L. siliquoidea* (60 to 74 mm shell length) were collected in July 1994 from Crooked Lake in Noble County, Indiana. Crooked Lake is a mesotrophic lake with a forested nature preserve along part of the shore and moderate residential development on the remaining shoreline. Mussels were collected from shallow water along the shoreline next to the nature preserve, and identification numbers were etched into their shells. The experiment took place over a period of three weeks. The same mussels were used for each temperature trial, and they were returned to the collection area between trials.

At the beginning of each temperature trial, the mussels were transported immediately after collection to an on-site research facility and placed in respiration chambers that were completely filled with lake water. These respiration chambers were constructed of Nalgene plastic and were 14.5 cm in height and 11 cm in diameter; their maximum volume was 1.1 liters. All mussels were observed to be filtering normally before the chambers were sealed and testing began.

Each temperature trial was done separately. Test time was one hour, and temperature and dissolved oxygen (mg/L) were measured with a YSI 54A oxygen meter at the start and completion of the test period. Six temperatures ranging from 10° to 25° C were tested; 15 mussels were tested at each temperature. The tests (conducted at 18°, 21.5°, 23°, and 25° C) were done with ambient temperature lake water. For the lower temperatures (10° and 15.5° C), the respirometers were placed in water baths to which ice was gradually added until the test temperature was attained. Tests were conducted outside away from direct sunlight. A control respirometer containing an empty mussel shell was included at each temperature, and observations from respirometers in which large air bubbles were discovered during the testing period were discarded.

Table 1. The mean (± S.E.) respiration rates (mg O_2 /L/g/hr) of *Lampsilis siliquoidea* tested at various temperatures.

Temperature (°C)	*n*	Mean (± S.E.)
10	11	0.1492 (± 0.02)
15.5	11	0.2735 (± 0.03)
18	10	0.4337 (± 0.05)
21.5	15	0.6193 (± 0.04)
23	15	0.7701 (± 0.06)
25	15	0.9089 (± 0.06)

At the end of the study, the mussels were sacrificed to determine their dry weight. All soft tissues were removed from the shells, dried for two days at 75° C, and weighed on an analytical balance. The changes in dissolved oxygen per liter of water were then calculated on a per gram dry weight basis for each mussel. Regression analysis was performed on these data, and Q_{10} values were calculated.

RESULTS AND DISCUSSION

Respiration increased with temperature (Figure 1) in a direct linear relationship ($r^2 = 0.95$) over the temperature range tested. Average rates ranged from 0.149 mg O_2/L/g/hr at 10° C to 0.909 mg O_2/L/g/hr at 25° C (Table 1). From these data, the regression equation ($y = -0.44757 + 0.051685x$) was calculated, where x represents the water temperature, and y represents oxygen consumption. During each temperature trial, the dissolved oxygen content of the control respirometers did not change more than ± 0.1 mg/L. The overall Q_{10} was 4.1.

The physiological processes of aquatic mollusks speed up with increasing water temperature as expressed by Q_{10} values. In a study by Pohill and Dimock (1996), the heart rates of juvenile and adult *Utterbackia imbecillis* and *Pyganodon cataracta* increased in response to increasing temperature with Q_{10} values approaching 4.5. Huebner (1982) studied seasonal variation in the respiration of *Lampsilis radiata* (= *siliquoidea*) in Manitoba, Canada, and found that the respiration Q_{10} values averaged 3.3 from 6.5° to 17.5° C and 3.4° from 17.5° to 23.5° C. While the Q_{10} for the entire temperature range in the present study was 4.1, its value was 3.4 between 15° and 25° C, the same value obtained by Huebner for temperatures between 17.5° and 23.5° C. Huebner found no relation between Q_{10} and animal size or season; however, the Q_{10} values did indicate an overall high metabolic sensitivity to temperature change. Schneider (1992) developed a bioenergetics model for *D. polymorpha* in which the Q_{10} was estimated at 3.1, indicating that the respiration rates of other freshwater bivalves respond in a similar manner to that of unionids.

Respiration rates may also be expressed as the amount of the oxygen consumed per unit time on a dry weight basis. Naimo, *et al.* (1992) found that *Lampsilis ventricosa* had average respiration rates from 0.496 to 0.558 mg O_2/L/g/hr when tested at 20° C. Using the regression equation obtained in the present study, the calculated oxygen consumption of *L. siliquoidea* at 20° C would be 0.589 mg O_2/L/g/hr, indicating similar respiration rates for the two *Lampsilis* species. Huebner (1982) found that respiration (calculated as the amount of oxygen consumed per hour for 5 grams dry weight) increased linearly with temperature up to 24° C. Respiration rate-temperature curves were similar for both winter and

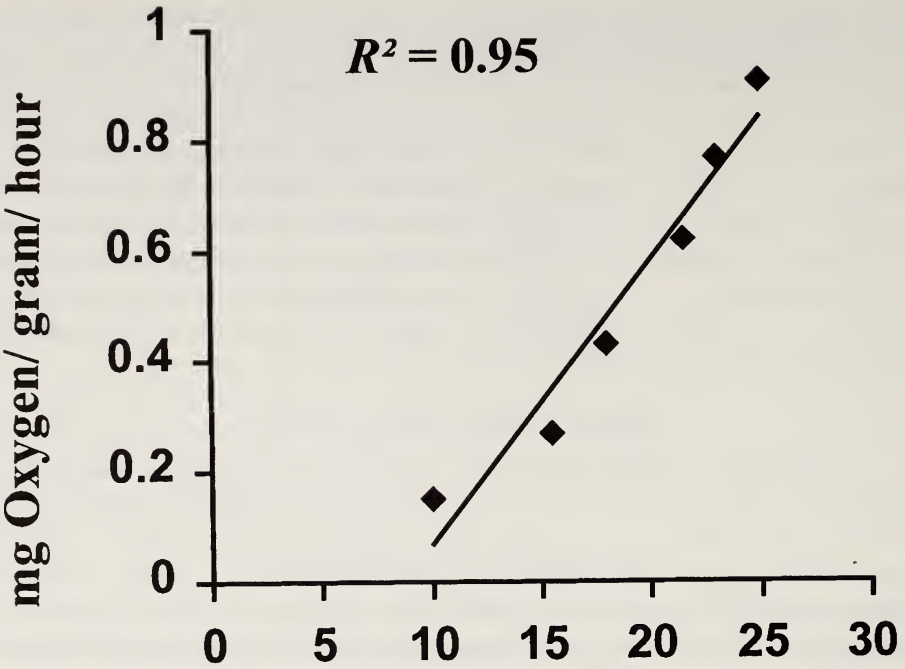

Figure 1. Mean respiration rates of *Lampsilis siliquoidea* as a function of temperature.

summer mussels, and no significant differences in responses were seen in the respiration of males and females (Huebner, 1982). Therefore, *L. siliquoidea* is suitable to use in studies on mussel respiration rates because season and sex would not be confounding factors.

Respiration rates could be used to evaluate mussel stress and overall fitness for survival and reproduction. Since *L. siliquoidea* is a common mussel, this species could be used as an experimental surrogate for other, more rare, species occurring at a potentially stressed site. My results would aid in estimating the effect of water temperature on the mussels' respiration rate when assessing the condition of individuals or populations of these imperiled organisms.

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