Experiments on Standard Metabolish of Bluegill, *Lepomis macrochirus*

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Abstract

Standard metabolism of bluegill ranging in size from about 1 to 23 grams was measured at 13 and 24° Centigrade. Least squares regressions relating oxygen consumption to weight at the two temperatures had slopes of 0.432 (13° Centigrade) and 0.405 (24° Centigrade). Differences in slopes from previously published values were probably due primarily to spontaneous activity of smallest fish and the restricted size range. The Q_{10} standard metabolic rate change due to temperature ranged from 1.8 for smallest fish to 1.5 for largest fish.

Introduction

Standard metabolism in fish is theoretically the lowest constant level of oxygen consumption attained with no activity (3). Extensive literature has accumulated concerning the standard metabolish of fish. The methods used, species of fish studied, and results obtained are summarized by Winberg (8). Environmental and physiological factors affect oxygen consumption of fish. An increase in oxygen consumption with increased size or weight has been shown by numerous authors. An increase in temperature also results in an increase in oxygen consumption, although some fish have the ability to adjust over a temperature range (3, 7). Other factors such as photoperiod, season, acclimation, handling, and state of health may influence the standard metabolic rate.

This investigation was undertaken because relatively little information exists on the standard metabolic rate of bluegill, *Lepomis macrochirus* (5, 6). Extensive analysis of metabolism for a species is necessary to elucidate the influence of specific extrinsic or intrinsic variables on metabolic rate.

Methods and Materials

Respiration Chambers

The respiration chambers used in this experiment were modified from a chamber described by Hanson and Stanley (4). Respiration chambers were situated on the bottom of a 10-gal aquarium which was supplied with aerated, chlorine free water from a reservoir aquarium. Aquarium water was maintained within ± 0.5 ppm of oxygen saturation. A small heater was used to raise the temperature of 24° C from the ambient 13° in the laboratory. Daily temperature fluctuations, measured with a Taylor maximum-minimum thermometer, were less than 1° C. Each flowing-water respiration chamber was a rubber-stoppered colorless plastic cylinder. Plastic capillary tubing (1.2 mm inside diameter) was positioned through the center of each stopper. Water

[1] Deceased August 1, 1972.

flowed through the chamber at a mean rate of 8.4 ml/min into 67.3 ml sample bottles which were allowed to overflow. Chambers were either 48 or 61 mm inside diameter. Chamber length was varied by adjusting the inside stopper until the chamber was slightly longer than the length of fish tested. This provided minimal room for movement of fish. The bottom and sides of the chambers were covered with aluminum foil to limit visual stimuli which might have excited the fish. The top of each chamber was left uncovered to permit observation and entrance of light.

Experimental Procedure

Bluegill were seined from Lake Placid near Hartford City, Indiana, on October 21 and from a hatchery pond owned by George Meyers of Pleasant Lake, Indiana, on October 24. In the laboratory, the fish were placed individually in separate compartments of two large wooden tanks to prevent interaction. The bluegill were acclimated at a rate of about 1°C/day from a temperature of about 17° C at time of capture to 13 and 24°C in respective tanks. The daily light period of 8.5 hours began at 7:00 AM. This regimen was maintained over the 43-day study period. Fish were not fed during the acclimation and holding period.

Prior to weighing at the start of each testing period, the fish were anaesthetized with tricainemethanesulphonate (MS-222, Sandoz Chemical Co.). After a fish was anaesthetized, excess water was blotted from the body with a chamois and the fish was weighed to the nearest 0.01 g. At the end of each test the fish were reweighed allowing calculation of mean weight during the experiment.

After initial measuring, each fish was placed individually in a respiration chamber and maintained for 72 hours. Oxygen consumption was determined daily at approximately 8:00, 12:00, and 15:00 hours. Initial oxygen consumption was measured after a 16-hour recovery period in the chamber. Oxygen concentration in chambers did not go below 50% saturation in any test. Oxygen was measured using a modification of the Winkler method (1) as follows: One half milliliter each of manganous sulfate and alkaline iodide solution were added to each sample bottle. After appropriate mixing and settling, 0.5 ml of concentrated sulfuric acid was added. The samples were then titrated using a standardized 10% phenylarsene oxide solution instead of sodium thiosulfate.

Results

Oxygen consumption was determined for 11 bluegill at 13° C and for 9 at 24° C during November and December 1970. Fish at 13° C ranged in weight from 1.67 to 20.98 g and those at 24° C ranged from 1.09 to 22.93 g.

Mean oxygen consumption from nine determinations over 72 hours was calculated for each fish. Oxygen consumption in mg/hr was examined in relation to mean fish weight (Fig. 1). The least squares method was used to fit a regression line to the data according to the equation $\log Y = a + b \log X$. Total oxygen consumption increased with

increased mean fish weight as expected. A comparison of regression lines for fish at the two temperatures revealed only slight differences between slopes. The slopes of the relationship between mean weight and oxygen consumption in mg/hr were 0.432 at 13° C and 0.405 at 24° C (Fig. 1). Correlation coefficients (r) ranged from 0.92 to 0.97. Oxygen consumption by bluegill in relation to weight change in this study has different slopes than published previously (5 , 6).

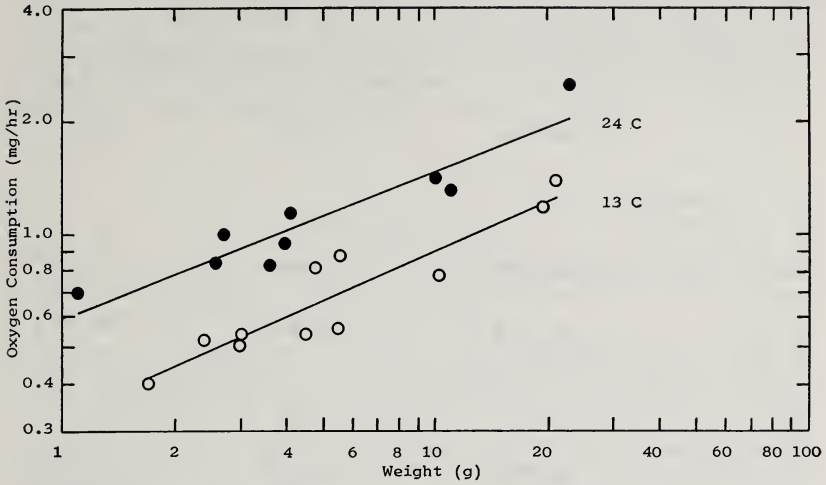

FIGURE 1. *Relationship between mean weight and oxygen consumption in mg/hr for bluegill in experiments. Regressions were log Y = —0.218 + 0.405 log X at 24°C and log Y = —0.475 + 0.432 log X at 13°C.*

Daily fluctuations in oxygen consumption was also investigated. Oxygen consumption in mg/g/hr was plotted against the time spent in the respiration chambers for three fish representative of the size range in each temperature (Fig. 2). There were no regular daily fluctuations in oxygen consumption during the 3-day test period indicating a relatively constant metabolic rate. The smaller fish at both 13 and 24° C showed the greatest fluctuations from a constant level of oxygen consumption over the 3-day period. This was probably due to the spontaneous activity observed in small fish in the respiration chambers.

The oxygen consumption by the bluegill in relation to the temperature change from 13 to 24° C was investigated. The Q_{10} standard metabolic rate was calculated for the temperature increase using the van't Hoff equation for Q_{10}. The increase in metabolic rate varied from 1.8 times for 1.67 g fish to 1.5 times for 20.98 g fish.

Discussion

Effect of Weight on Metabolic Rate

Winber (8) and others have substantiated the fact that with an increase in weight of fish there is an increase in oxygen consumption.

Previous studies on bluegill metabolism (5, 6) show regression lines relating log weight to log oxygen consumption with slopes ranging from 0.6 to 0.7. In this study a slope of 0.4 was found for the regression line relating oxygen consumption to weight. The decreased slope for bluegill in this study is probably due at least in part to spontaneous movement by smaller fish resulting in abnormally high oxygen consumption per gram weight as compared to larger fish (Fig. 2). It may also be due in part to limited observations and limited data for larger fish.

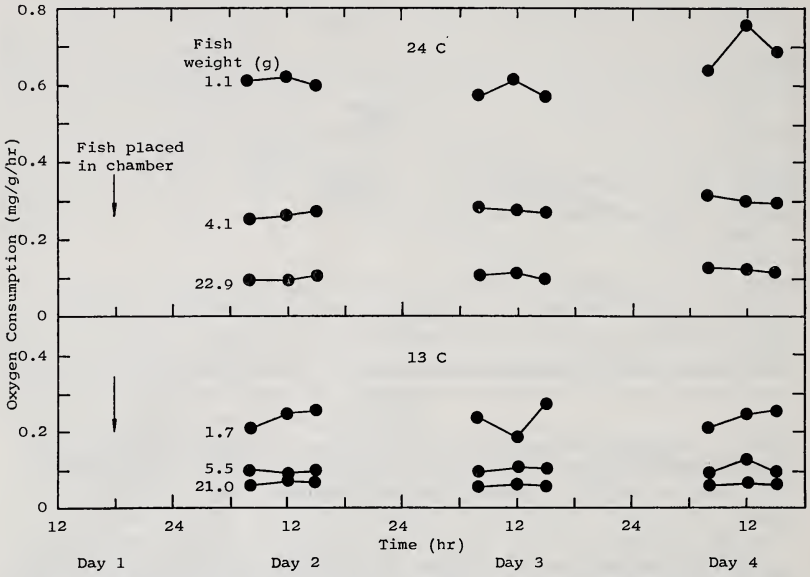

FIGURE 2. *Relationship between oxygen consumption in mg/g/hr and time in the respiration chamber for bluegill representative of the size range at 18 and 24°C.*

Effect of Temperature on Metabolic Rate

According to the van't Hoff Law a 10° C increase in temperature should give a Q_{10} increase in metabolic rate equal to or greater than two. It has been demonstrated that when fish are tested at a temperature to which they have been acclimated the Q_{10} is usually less than two (5). O'Hara (6) gives values ranging from 1.6 to 1.8 for bluegill. Similar Q_{10} values of 1.5 to 1.8 were found in this study.

Effect of Diurnal Rhythms

A diurnal rhythm of standard metabolism due to environmental factors or an endogenous response by the fish may produce a diurnal fluctuation in standard metabolic rate. Not all fish, however, appear to exhibit diurnal rhythms. Diurnal rhythm of standard metabolism has been observed in largemouth bass (2) but no diurnal fluctuation in the metabolic rate of bluegill has been reported (5). Oxygen consump-

tion was measured just during the day in this study and only small inconsistent fluctuations were noted when comparing daytime oxygen consumption by individual fish. The fluctuations in small fish, as noted earlier, appeared to be related to spontaneous activity.

Possible Seasonal Effects

In comparing the bluegill standard metabolic rate found in this study with that measured by Moss and Scott (5) some of the differences in slope with weight change may be related to seasonal effects. Most of Moss and Scott's work was done in the spring and summer, while this investigation occurred during the fall. Seasonal differences in metabolic rate of bluegill have been noted previously (9) but additional work in this area is needed for clarification.

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