PRELIMINARY EXPERIMENTS ON STANDARD METABOLISM OF BLUEGILL, *LEPOMIS MACROCHIRUS*

BY

Sandra J. Eggleston

Submitted to

Dr. Thomas S. McComish

May 28, 1971

For

Senior Honors Thesis ID 499

Ball State University

I recommend this thesis for acceptance by the Honors Program of Ball State University for graduation with honors.

Thomas L. McCormick

Thesis Adviser

Department of Biology

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The effects of temperature and weight on standard metabolism of bluegill, Lepomis macrochirus, were examined. Experiments were conducted at 13 and 24 C with bluegill ranging in weight from 1.09 to 22.93 g. Oxygen consumption per gram weight decreased with increased weight and total oxygen consumption increased with increased weight. The Q_{10} standard metabolic rate increased from 1.8 times for small fish to 1.5 times for large fish with an increase in temperature from 13 to 24 C. The standard metabolic rate found for bluegill, as related to weight and temperature, is in general agreement with previously reported standard metabolism of this species.

INTRODUCTION

Standard metabolism in fish, as defined by Fry (1967), is the lowest level of metabolism, being theoretically based on zero activity. An enormous volume of literature has accumulated concerning the standard metabolism of fish. The methods used, species of fish studied, and results obtained have been summarized by Winberg (1956). Methods used to study standard metabolism basically vary according to the type of apparatus used (a sealed vessel or a flowing water system) and in the length of recovery time after handling (4 to 24 hours) before measurement of oxygen consumption. Regardless of the method employed, measuring rate of oxygen consumption has proven to be an accurate method of determining metabolic rates in fish.

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 (Fry,1967; Roberts,1967). Other factors such as photoperiod, seasonal effects, acclimation, and handling may also influence the standard metabolic rate of fish.

While metabolism has been studied in many species of fish, there is relatively little data available for bluegill, Lepomis macrochirus. The most thorough study

is that of Moss and Scott (1961), in which a flowing water system was used and bluegill over an extended size range were tested at 25, 30, and 35 C. O'Hara (1968) presents results for bluegill metabolism which are in general agreement with those reported by Moss and Scott. The effects of weight and temperature on standard metabolism of bluegill in this investigation were compared with the findings of the authors noted above.

METHODS AND MATERIALS

Respiration Chambers

The respiration chambers used in this experiment were designed after a chamber described by Hanson and Stanley (1969) (Fig. 1). Respiration chambers were situated on the bottom of a ten gallon aquarium which was supplied with airated, chlorine free water from a reservoir aquarium. The aquarium water was at oxygen saturation with the maximum fluctuation of dissolved oxygen being 0.5 ppm. A small heater was used to raise the temperature to 24 C from the ambient 13 C in the laboratory. Daily temperature fluctuations were noted on a Taylor maximum-minimum thermometer. The largest daily fluctuation recorded was 1 C. Each flowing water respiration chamber was a rubber-stoppered plastic cylinder with plastic capillary tubing (I.D. 0.047", O.D. 0.067") entering and leaving the chamber through the center of the stoppers. Water flowed through the chambers at a mean rate of 8.4 ml/min into 67.3 ml sample bottles which were allowed to

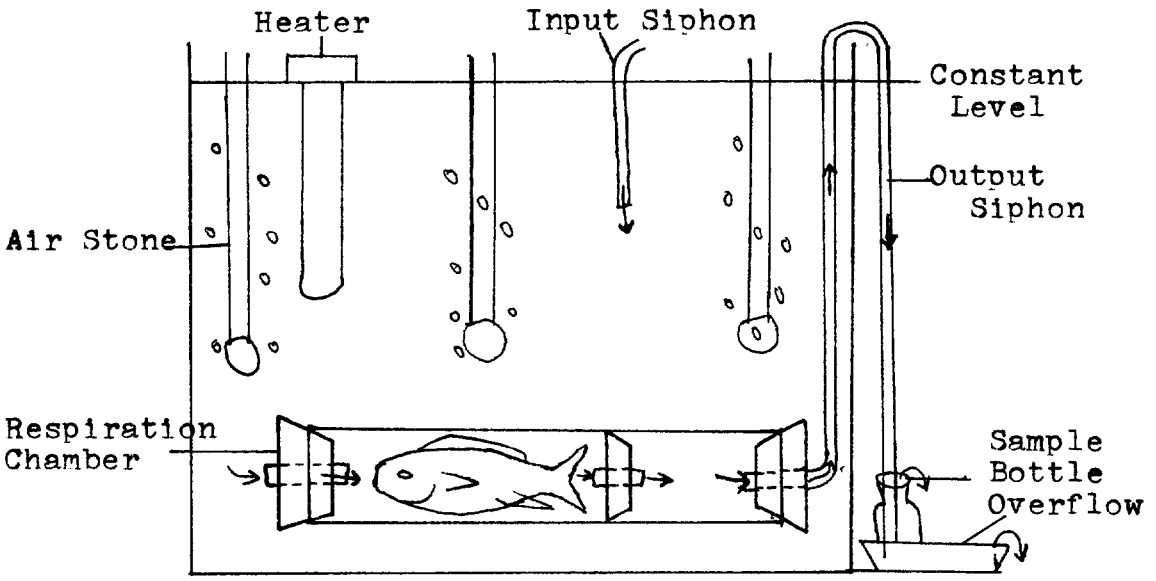


Figure 1.-- Diagram of the flowing water respiration chamber used to determine standard metabolism of bluegill, Lepomis macrochirus.

overflow. Chambers were either 48 or 61 mm in diameter. The length of the chambers were varied according to the size of the 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 continuation of the established photoperiod.

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 in order to prevent interaction. The bluegill were acclimated at a rate of 1 C/day from a temperature of about 17 C at

time of capture to 13 and 24 C in respective tanks. A photoperiod length of 8.5 hr. daily was maintained over the 43 day study period. Fish were not fed during the acclimation and holding period.

Prior to weighing and measuring at the start of each testing period, the fish were anaesthetized with tricaine methanesulphonate (MS-222, Sandoz Chemical Co.). After a fish was anaesthetic, excess water was blotted from the body with a chamois and the fish was weighed on a Mettler balance to the nearest 0.01 g. Fish length to the nearest millimeter was measured with dividers from the tip of the mandible to the ventral lobe of the caudal fin. 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 hr. recovery period in the chamber. Oxygen was measured using a modification of the Winkler method described in Standard Methods (Amer. Pub. Health Assoc. et al.,1965). One-half milliliter each of manganous sulfate and alkaline iodide solution were added to each sample bottle. After appropriate mixing and settling, one-half milliliter of concentrated sulfuric acid was added. The samples were then titrated using a 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 from 1.67 to 20.98 g. and those at 24 C ranged from 1.09 to 22.93 g. (Table 1).

Oxygen consumption in mg/hr was calculated by taking the flow rate (l/hr) times the difference in oxygen (mg/l) between the aquarium and the water sample collected from the chamber. By dividing the oxygen consumption in mg/hr by the mean weight of the fish in grams, oxygen consumption in mg/g/hr was obtained.

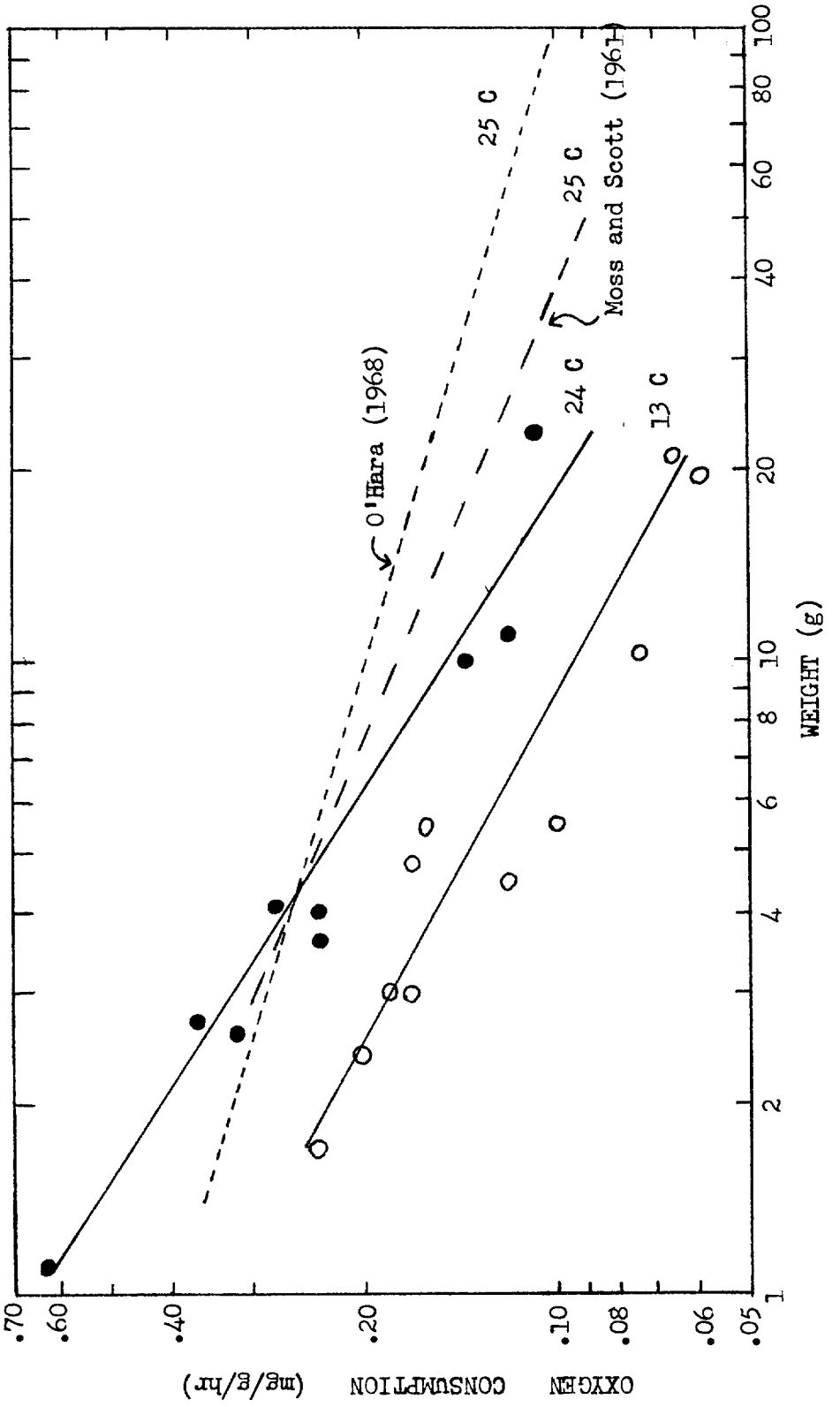
Table 1.--Mean oxygen consumption of individual bluegill over 72 hours at 13 and 24 C.

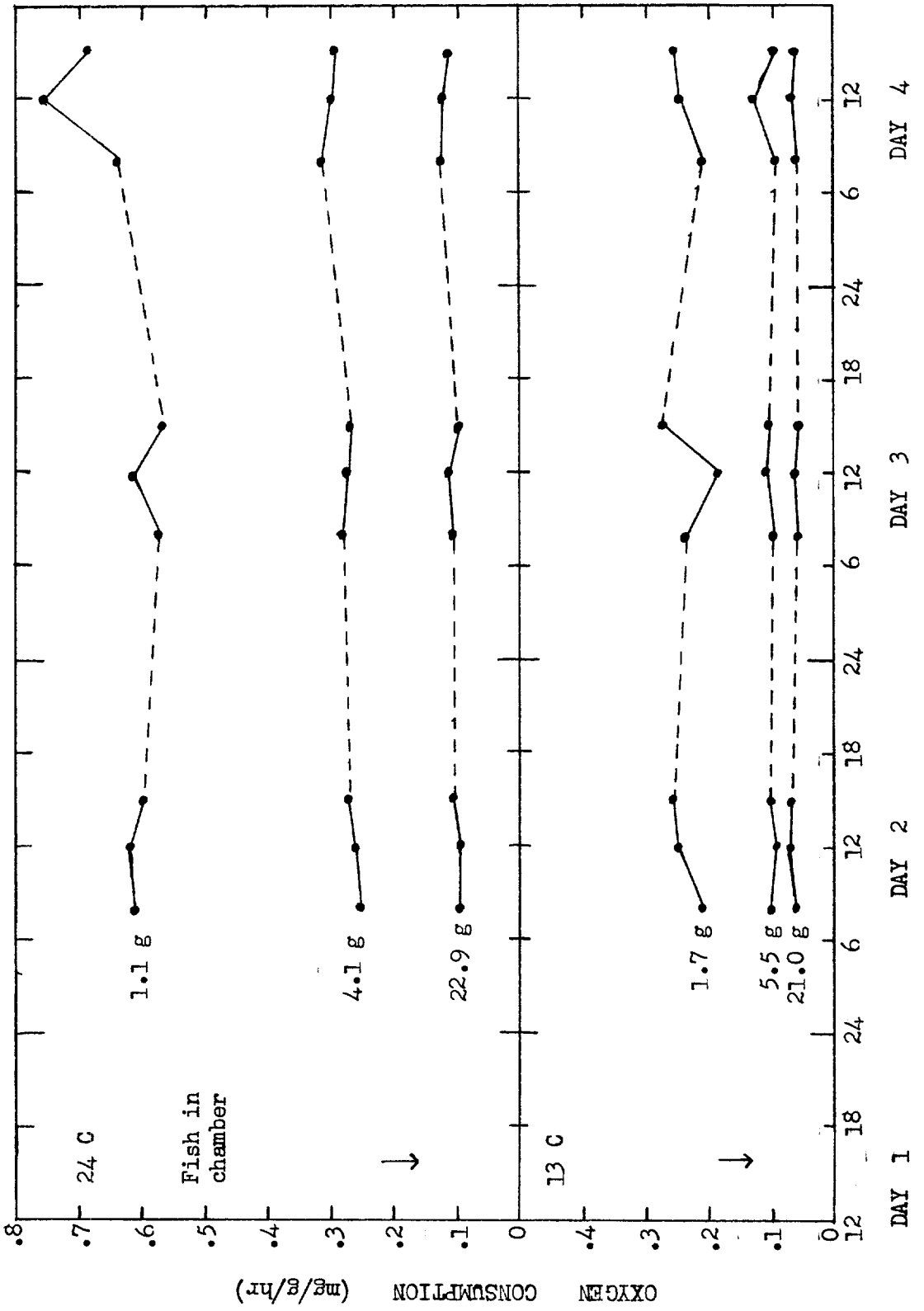
Temp. (C)	Fish No.	Mean Wt. (g)	Oxygen Consumption* (mg/hr)	Oxygen Consumption* (mg/g/hr)
13	1	4.79	0.806	0.168
	2	5.53	0.890	0.161
	3	10.23	0.772	0.076
	4	1.67	0.405	0.242
	5	2.98	0.555	0.186
	6	3.03	0.510	0.168
	7	19.66	1.183	0.060
	8	4.50	0.548	0.122
	9	5.49	0.574	0.105
	10	20.98	1.388	0.066
	11	2.42	0.526	0.217
24	12	2.71	0.995	0.367
	13	4.09	1.142	0.280
	14	1.09	0.691	0.634
	15	3.97	0.961	0.242
	16	10.02	1.388	0.139
	17	2.63	0.850	0.324
	18	3.56	0.837	0.235
	19	11.06	1.306	0.118
	20	22.93	2.514	0.110

*Mean of nine observations on each individual fish.

Mean oxygen consumption from nine determinations over 72 hours was calculated for each fish (Table 1). Oxygen consumption in mg/hr and mg/g/hr was examined in relation to mean fish weight (Fig. 2 and 3). 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 and oxygen consumption per gram weight decreased with increased mean fish weight. A comparison of computed regression lines 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.2). The regression lines relating mean weight to oxygen consumption in mg/g/hr had slopes of -0.567 at 13 C and -0.631 at 24 C (Fig.3). Correlation coefficients (r) ranged from 0.92 to 0.97. Oxygen consumption by bluegill in relation to weight change in this study is in general agreement with data presented by Moss and Scott (1961) and O'Hara (1968) (Fig. 2 and 3). The slopes of the regression lines show a direct relationship between oxygen consumption in mg/hr and mean fish weight and an inverse relationship between oxygen consumption in mg/g/hr and mean fish weight.

Daily fluctuation in oxygen consumption was investigated. Oxygen consumption in mg/g/hr was plotted against the time spent in the respiration chambers for several fish representative of the size range (Fig. 4). For the three day test period there were no regular daily


OXYGEN CONSUMPTION (mg/g/hr)
.70
.60
.40
.20
.10
.08
.06
.05
1
2
4
6
8
10
20
40
60
80
100
WEIGHT (g)
O'Hara (1968)
25 C
Moss and Scott (1967)
25 C
24 C
13 C


OXYGEN CONSUMPTION (mg/g/hr)
24 C
Fish in chamber
1.1 g
4.1 g
22.9 g
13 C
1.7 g
5.5 g
21.0 g
DAY 1
DAY 2
DAY 3
DAY 4

fluctuations in oxygen consumption, 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 three day period. This was probably due to spontaneous activity observed in small fish in the respiration chambers.

Oxygen consumption increased with an increase in temperature from 13 to 24 C. 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

Winberg (1956) and others have substantiated the fact that with an increase in weight of fish there is an increase in oxygen consumption. Studies on bluegill by Moss and Scott (1961) and O'Hara (1968) show regression lines relating log weight to log oxygen consumption with slopes ranging from 0.6 to 0.717. In the present study a slope of 0.43 was found for the regression line relating oxygen consumption in mg/hr to weight. The decreased slope for bluegill in this study may be due to spontaneous

*$\log Q_{10} = \frac{10}{t_2 - t_1} \log \frac{k_2}{k_1}$ where t_1 and t_2 are the two temperatures and k_1 and k_2 are the rates of reaction at these temperatures.

movement by smaller fish resulting in abnormally high oxygen consumption per gram weight as compared to larger fish (Fig. 3). It may also be due in part to limited observations and the lack of data for larger fish.

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. Moss and Scott (1961) and others have shown, however, that when fish are tested at a temperature to which they have been acclimated, the Q_{10} is less than two. O'Hara (1968) gives values ranging from 1.6 to 1.8 for bluegill. This is in agreement with the Q_{10} values of 1.5 to 1.8 found in this study.

Some fish have the ability to adjust and maintain their metabolism over a temperature range (Winberg,1956). Roberts (1967) reports a Q_{10} of about one for pumkinseed, Lepomis gibbosus, in the 10-17.5 C range. For temperatures above and below this range, the Q_{10} values increase. Hanson and Stanley (1969) worked with the mudminnow, Umbra limi, and found it had homostatic control over a wide range of temperatures (5-20 C). While bluegill apparently do not show homostatic control, the species has a lower metabolic rate than pumkinseed for the temperature range from 25-30 C (O'Hara, 1968).

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. Clausen (1936) observed diurnal rhythms of standard metabolism in largemouth bass, but Moss and Scott (1961) reported an absence of any diurnal fluctuation in the metabolic rate of bluegill. In the experiment reported here, the oxygen consumption was only measured during the day. Only small inconsistent fluctuations were noted when comparing daily oxygen consumption by individual fish. These were greatest in small fish as noted earlier and appeared to be related to spontaneous activity. Therefore, these data appear to support the findings of Moss and Scott.

Possible Seasonal Effects

In comparing the bluegill metabolism found in this study with that found by Moss and Scott (1961), there are some differences which may be related to seasonal effects. Most of Moss and Scott's study was done in the spring and summer, while this investigation occurred during the fall. Wohlschlag and Juliano, (1959) also reported seasonal differences in metabolic rate of bluegill.

SUMMARY AND CONCLUSIONS

Bluegill, ranging in size from 1.09 to 22.93 g. were tested at 13 and 24 C. The effects of weight and temperature on standard metabolism were studied and other factors affecting metabolism were considered.

1. Oxygen consumption in mg/hr increased with increased mean weight. Oxygen consumption in mg/g/hr

decreased with increased mean weight.

2. Standard metabolism increased from 1.5 times for 1.67 g. fish to 1.8 times for 20.98 g. fish with an increase in temperature from 13 to 24 C.

3. Oxygen consumption of small bluegill showed fluctuations probably due to spontaneous movement.

4. In general the standard metabolism outlined for bluegill in this study is similar to that found by Moss and Scott (1961) and O'Hara (1968), but the slopes of regressions relating mean weight to oxygen consumption were less than expected. Differences may be related to spontaneous activity by small fish, possible seasonal effects, the small number of observations, and the restricted size range of fish in the experiment.

ACKNOWLEDGMENTS

I wish to express my thanks to Dr. Thomas S. McComish who willingly served as my adviser and who provided equipment and encouragement throughout the experiment. Without his advice and suggestions this paper would never have been written.

LITERATURE CITED

American Public Health Association, American Water Works Association, Water Pollution Control Federation. 1965. Standard methods for the examination of water and wastewater. Amer. Public Health Assoc., New York, 769 p.

Clausen, R. G. 1936. Oxygen consumption in fresh water fishes. Ecol. 17: 216-225.

Fry, F. E. J. 1967. Responses of vertebrate poikilotherms to temperature. In: A. H. Rose (ed.), Thermobiology. Academic Press, New York, pp. 375-410.

Hanson, R. C., and J. G. Stanley. 1969. Studies of oxygen metabolism in the central mudminnow, Umbra limi (Kirtland). Proc. 12th Conf. Great Lakes Res.: 39-44.

Moss, D. D., and D. C. Scott. 1961. Dissolved-oxygen requirements of three species of fish. Trans. Amer. Fish. Soc. 90: 377-393.

O'Hara, J. 1968. The influence of weight and temperature on the metabolic rate of sunfish. Ecol. 49: 159-161.

Roberts, J. L. 1967. Metabolic compensations for temperature in sunfish. In: C. L. Prosser (ed.), Molecular mechanisms of temperature adaptation. Amer. Assoc. Adv. Sci., Washington, D.C. pp. 245-262.

Winberg, G. G. 1956. Rate of metabolism and food requirements of fishes. Translation Series No. 194 (1960). Jour. Fish. Res. Bd. Can. 253 p.

Wohlschlag, D. E., and R. O. Juliano. 1959. Seasonal changes in bluegill metabolism. Limnol. and Oceanogr. 4(2): 195-209.