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RATES OF RESPIRATION OF ESTUARINE FISH [1]

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ABSTRACT

A flowing-water respirometer was used to measure oxygen consumption of five species of estuarine fish: pinfish, *Lagodon rhomboides*; black sea bass, *Centropristes striatus*; Atlantic croaker, *Micropogon undulatus*; oyster toadfish, *Opsanus tau*; and mummichog, *Fundulus heteroclitus*. The relation between the amount of oxygen consumed and body size, in general, may be expressed by the formula Q = a Weight^k, where a and k are constants derived from experimental data for a species. Some investigators have stated that k values do not vary significantly among species of fish. In my investigations the value of k did vary significantly between certain species. The values obtained for k are given and the methods used to measure respiration rates are discussed.

INTRODUCTION

The rates of respiration of fish and the relation between these rates and the weight of the fish have been used to calculate energy requirements of populations of fish. Respiration is generally related to body weight by the equation $Q = aW^k$ where Q is the respiration rate or routine metabolism (Beamish and Mookherjii, 1964), a and k are constants for the species, and W is the weight of the fish. Some question concerning this relation exists, however. Winberg (1956) implied that respiration rate and weight are linearly related throughout life but Hickman (1959) believed that the relation changes with the development of the fish.

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Extensive data on rates of respiration of many species of fish, predominantly fresh water, have been compiled by Winberg (1956). From these data (which were collected by many investigators using different methods), he calculated a basic equation ($Q = 0.3W^{0.8}$) to use as a first approximation of the relation between weight and metabolism in fish. The assumption is made that the relation between weight and metabolism is linear (double logarithmic plot) and does not change during ontogeny of the species. A modification of Winberg's equation was used to measure the energy requirements of a population of fish in a river (Mann, 1965). According to Mann, evidence is abundant that Winberg's value of 0.8 for k is correct, but that the value of a may vary over a considerable range for different species. Calculated regression lines for several species of fish, therefore, would have the same slope (k) but not necessarily the same intercept (a). Thus, Mann has recommended using a fixed slope of 0.8 and calculating the value of a from the empirical data.

The purpose of my experiments was to determine whether Winberg's basic equation or Mann's modification describes the relation between oxygen consumption and weight in selected species of estuarine fish of the Beaufort, N. C. area.

METHODS AND MATERIALS

Fish used in these experiments were collected near Beaufort, N. C., and maintained in tanks in the laboratory before their rates of respiration were measured. The species were: pinfish, *Lagodon rhomboides*; black sea bass, *Centropristes striatus*; Atlantic croaker, *Micropogon undulatus*; oyster toadfish, *Opsanus tau*; and mummichog, *Fundulus heteroclitus*.

Oxygen consumption was measured in a recirculating water system which was a modification of that used by Keys (1936) and by other investigators (Figure 1). Although this system was designed to recirculate the water it could easily be converted to a single pass system, depending on the needs of the investigator. The system consisted of a reservoir, respirometer tank, constant-level tank, and respiration chambers constructed of plastic. Water from the reservoir was pumped into the elevated constant level tank and then flowed by gravity to each respiration chamber; the excess water from the chamber returned through the overflow to the reservoir. Water flowing from the respiration chamber also returned to the reservoir. The rate of flow of water through each respiration chamber was regulated by adjusting the height of the plastic tube leaving the chamber (Figure 1) and was measured by diverting the flow from the chamber into a graduated cylinder for specific intervals of time. Rate of flow was measured just before water samples were analyzed for oxygen content with an oxygen meter. The water was maintained at 20° ± 1° C. and saturated with oxygen. Sea water of 33 ± 1 °/00 salinity was used in all experiments. The test fish were not fed for two days before an experiment and were acclimated to the respiration chamber for 24 hours before the first oxygen sample was taken.

COMPARISON OF RESPIRATION RATES

Knowledge of the metabolism of organisms may be used to estimate their food or energy requirements in ecological field studies. An estimation of metabolism may be obtained by measuring the oxygen consumption of fish. Regression coefficients for the relation between metabolism and weight can be calculated on the basis of oxygen consumption and weight of the fish. There are two possible interpretations of this relation between metabolism and weight (Winberg, 1956). One is that the values for a and k obtained from the experiments are typical for all fish, and indicates a general relation between metabolism and weights; the other is that metabolism varies with size in different species. Winberg concluded that, in general, the first interpretation is correct and that usually the relation between total metabolism and weight may be approximated by the equation $Q = 0.3W^{0.8}$. Mann (1965) agreed that

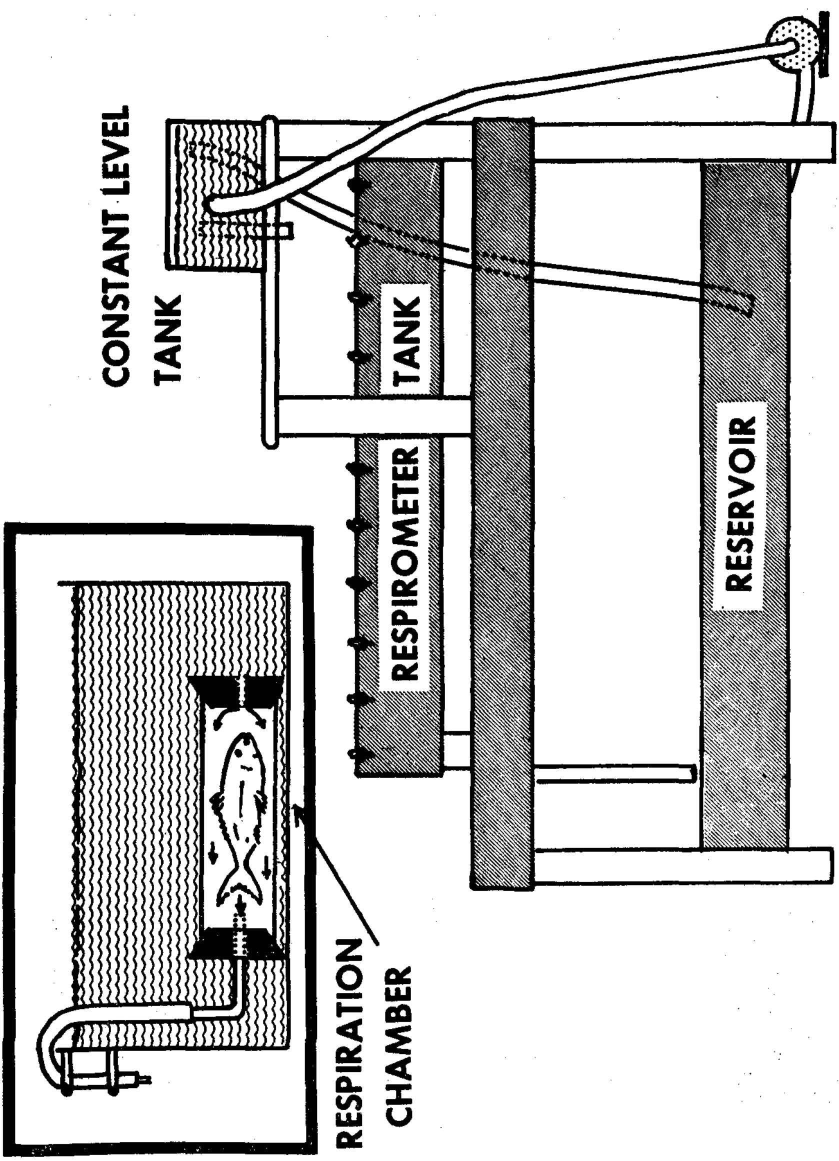

Figure 1. Recirculating water system used to measure respiration in fish. The insert is a transverse section through one of the 10 respiration chambers.

the slope of the regression line (k) would be near 0.8 but stated that the intercept (a) varies among species and should be calculated from the empirical data and a fixed k value of 0.8.

In these experiments, both Winberg's and Mann's methods were used to calculate regression lines for the experimental data. These lines were then compared with the regression line calculated by the least-squares method from the data obtained in this study. For each species of fish, the mean rate of oxygen consumption was plotted against total body weight on a double logarithmic scale (Figures 2 and 3).

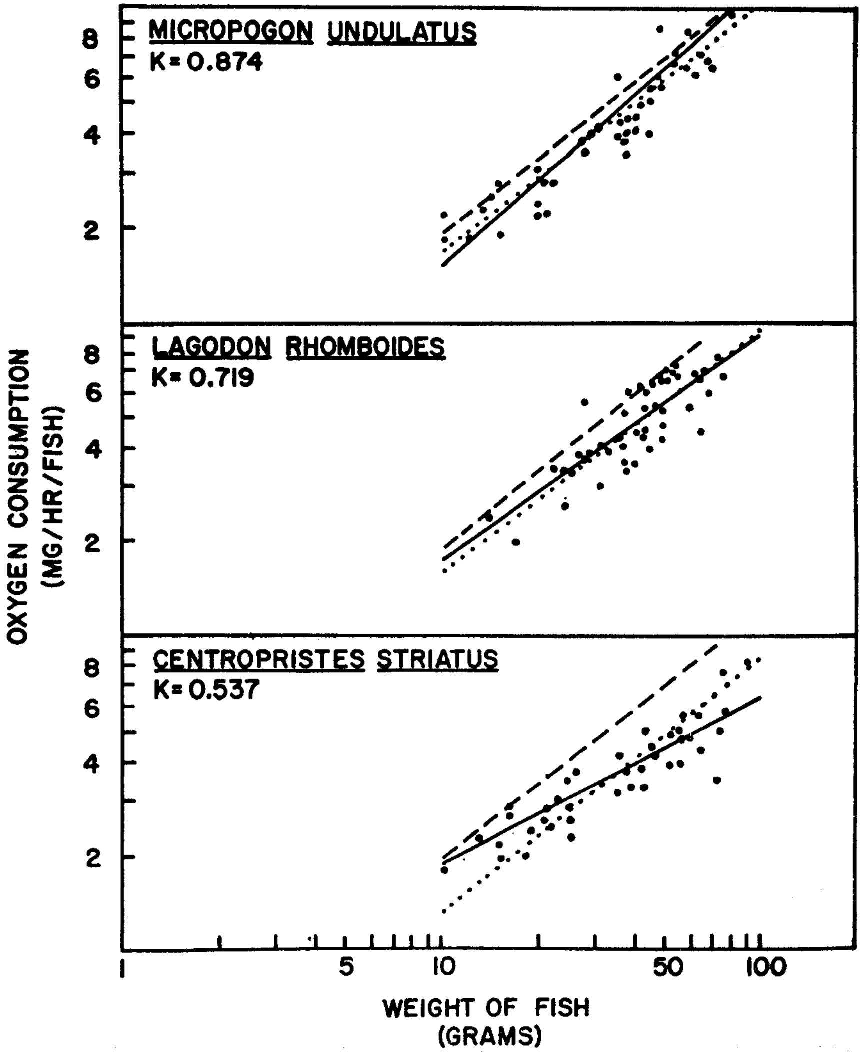

Figure 2. The effect of weight on rate of respiration of Atlantic croaker, pinfish, and black sea bass. The solid line is the calculated regression line, the broken line is from Winberg's basic equation, and the dotted line is from Mann's modification. Each point represents the mean of five measurements on a single fish.

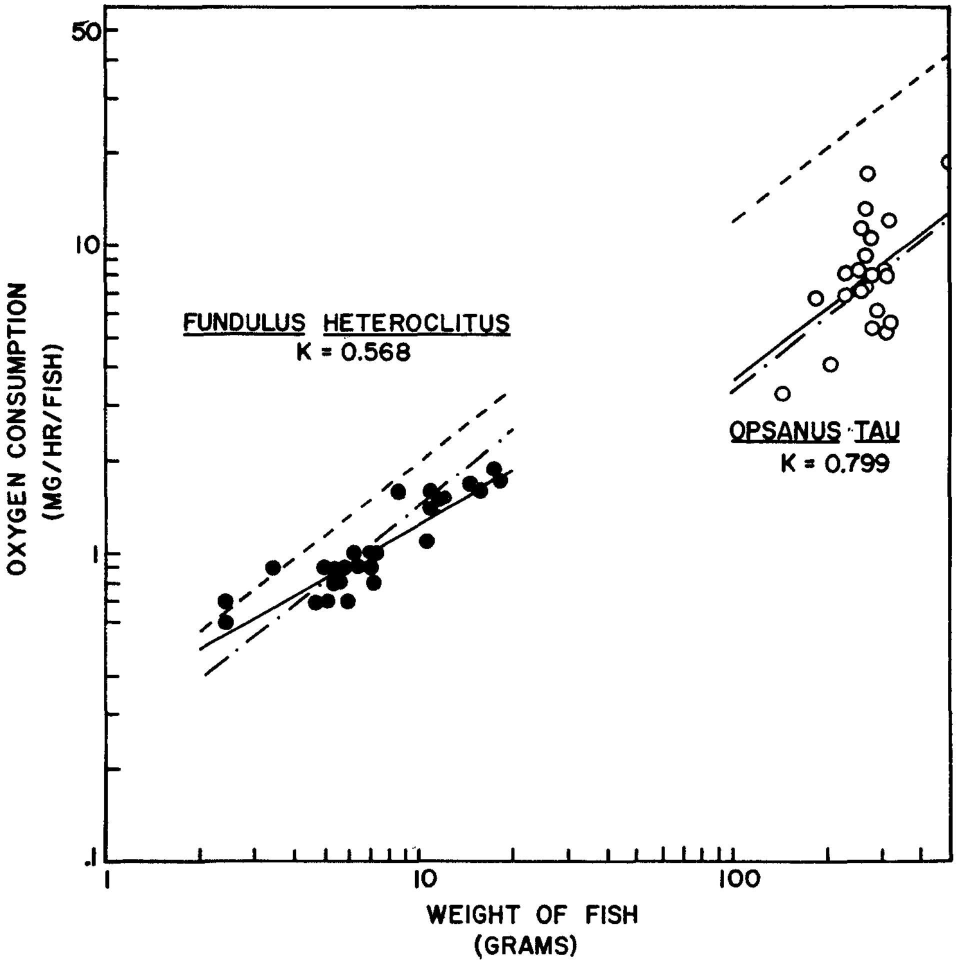

Figure 3. The effect of weight on rate of respiration of mummichog and toadfish. The solid line is the calculated regression line, the broken line is from Winberg's basic equation, and the dotted line is from Mann's modification. Each point represents the mean of five measurements on a single fish.

The slope (k) of the regression line for each species of fish was less than unity; oxygen consumption per unit weight thus is greater for smaller than for the larger fish (Table 1). This finding is in general

TABLE 1 — SUMMARY OF OXYGEN CONSUMPTION EXPERIMENTS ON FIVE FISHES OF THE BEAUFORT, N. C. AREA

Species	Number of fish	Weight range (grams)	a	k	Standard error of k
Micropogon undulatus	42	10-80	0.198	0.874	0.066
Lagodon rhomboides	46	13-74	0.335	0.719	0.072
Centropristes striatus	41	10-72	0.536	0.537	0.045
Fundulus heteroclitus	27	2-18	0.339	0.568	0.054
Opsanus tau	21	150-500	0.092	0.799	0.320

agreement with reports (Beamish 1963, Hickman 1959, Winberg 1956) on other species of fish which showed, with few exceptions, that oxygen consumption per gram decreased with increased weight. The k values ranged from 0.874 (croaker) to 0.537 (black sea bass). The calculated k values for croaker, pinfish, and toadfish are only slightly different from the value calculated by Winberg. The slopes of the lines for black sea bass and mummichog, however, differed considerably from Winberg's basic equation. The difference in number of fish of each species examined, size distribution, and relatively high individual variation of oxygen consumption made statistical comparison of respiration differences difficult. Also, as pointed out by Hickman (1959), fish in different stages of development cannot be compared. For example, a 10 g. mummichog would be considered a mature fish and not comparable to a 10 g. juvenile toadfish. Statistical comparisons, therefore, were made only among black sea bass, pinfish, and croaker, since a substantial number of fish (Table 1) over a comparable size range (10 to 100 g.) were available for these three species.

The calculated regression line for each species extrapolated to 1 g. is shown in Figure 4. The data were tested by analysis of covariance to determine whether a true difference existed between the slope of the three regression lines. The hypothesis that the three lines are parallel was rejected at the 0.01 probability level, indicating that the relation between metabolism and weight is not the same for all three species of fish.

The most accurate estimate of a and k for each species was obtained from regression lines calculated from the experimental data. Neither Winberg's basic equation nor Mann's modification gave satisfactory regression lines for all five fish, but Mann's method gave results that were consistently closer to the calculated regression line than Winberg's (Figures 2 and 3). In the experiments where it was possible to compare respiration in three species of fish at about the same stage of development (Figure 4), a statistical difference among the slopes of the three regression lines was demonstrated. This difference indicates that metabolism does vary with size among the species examined, and therefore one equation will not describe the relation between metabolism and weight for all species of fish.

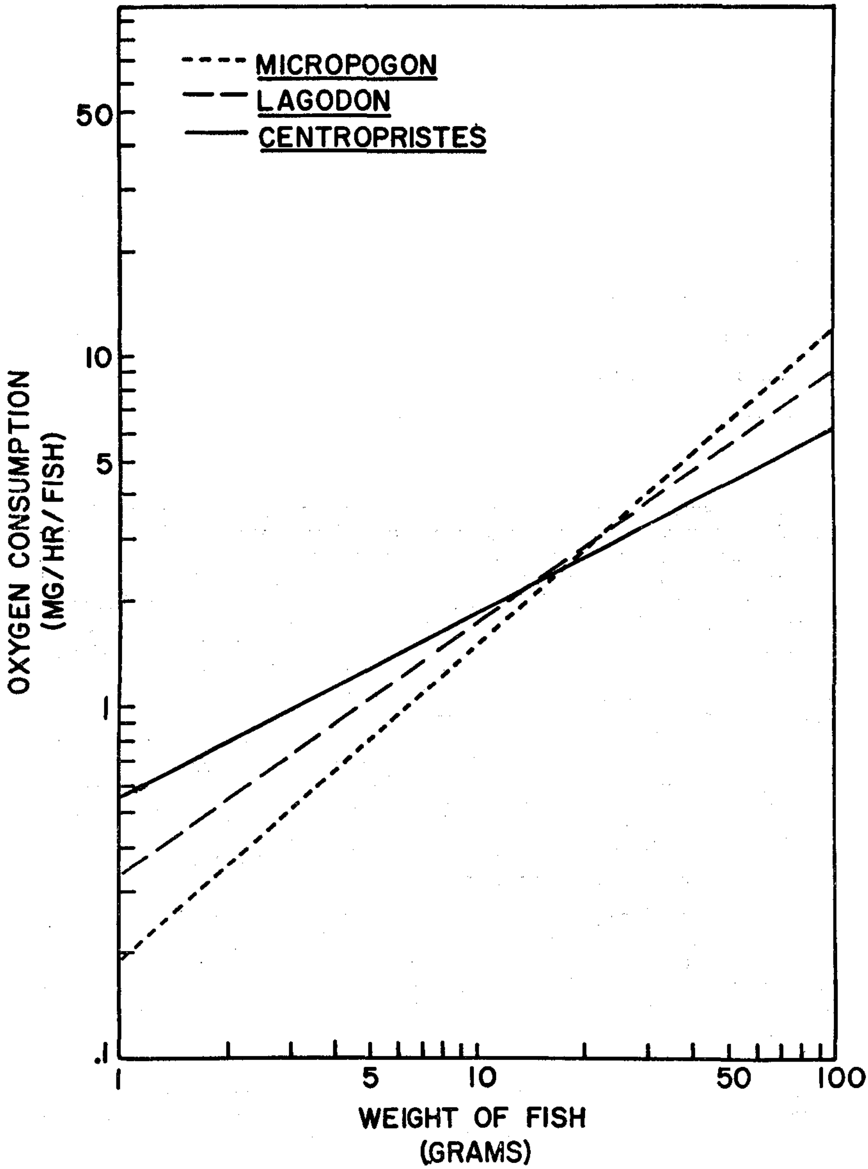

Figure 4. A comparison of the regression of oxygen consumption on weight for Atlantic croaker, pinfish, and black sea bass.

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SOME EFFECTS OF SALINITY ON TWO POPULATIONS OF RED SWAMP CRAWFISH, *Procambarus clarki (Girard)*[1]

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ABSTRACT

Salinity tolerance was compared between an inland population of red swamp crawfish, *Procambarus clarki*, from Baton Rouge, Louisiana, and a coastal marsh population from Grand Chenier, Louisiana.

Newly hatched crawfish from each population were killed in less than one week in salinities of 15, 20 and 30 ppt. Crawfish, 30 mm in total length, withstood salinities up to 20 ppt, but died in 30 ppt in two to three days. Crawfish, 40 to 120 mm in total length, showed no significant mortality after one week in salinities up to 30 ppt.

Thirty-millimeter crawfish exposed to salinities of 0, 10, 20 and 30 ppt for four weeks grew very little when fed fresh fish flesh, tropical fish food pellets, and *Oedogonium* sp. All 30-mm crawfish in 30 ppt died. Growth varied inversely with salinity.

Forty- to fifty-mm crawfish held in 0, 10, and 20 ppt salinity for four weeks had average increases in weight of 4.4, 13.5 and 4.9%, respectively. They were fed mixed green algae, which they ate continually. Growth in 10 ppt was significantly greater ($<.05$) than that in 0 or 20 ppt.

INTRODUCTION

The red swamp crawfish, *Procambarus clarki* (Girard), is becoming an important food in Louisiana and in other parts of the country. Because of improved processing techniques, crawfish can be obtained

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