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Oxygen Consumption and Respiratory Behaviour of Three Nile Fishes

by

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Abstract

1. The respiratory behaviour and patterns of oxygen consumption of three Nile species have been investigated.

2. *Tilapia nilotica* showed a typical pattern of oxygen consumption with an ambient region, adaptive plateau and lethal region (Fig. 2).

3. Specimens of *Polypterus senegalus* and *Clarias lazera* (body weights 20—30 and 30—45 g respectively) showed patterns of consumption comparable to that of *Tilapia* (Fig. 3a and 4a). In larger specimens of the two species the adaptive plateau was either insignificant or completely absent.

4. Specimens of *Polypterus* and *Clarias* (20—30 g and 30—45 g respectively) could survive in waters saturated with oxygen (7.4 mg/l) but their tolerance to lower oxygen concentrations was limited. Larger specimens of *Polypterus* and *Clarias* failed to survive in oxygen saturated waters.

5. The tolerance of *Tilapia nilotica* to extremely low oxygen concentration is an adaptation of a tropical and completely aquatic species. *Polypterus* and *Clarias* resort to their compensatory mechanisms only when the aquatic respiratory surface fails to satisfy their oxygen requirements.

Introduction

The oxygen consumption and respiratory adaptations of fishes have been investigated by many workers. Ivlev (1938) found that fish showed high rates of oxygen consumption during the first hours of experiment, after which these rates gradually subsided. Von Ledebur (1939) concluded that a reduced oxygen consumption could not be interpreted as a restriction of the fish activity. Graham (1949) observed that the activity of *Salvinus fontinalis* was markedly diminished when the oxygen content of the water was reduced to a level well below the limit of tolerance. Black, Fry & Scott (1939), Fry (1957) and Hart (1957) pointed out that the reduced oxygen consumption in low oxygen concentrations was not imposed by a restriction of the vital activity of the fish. Nasr El Din &

ABDEL MAGID (1968) showed that the oxygen consumption by *Tilapia nilotica* remained low when the oxygen content of the water was below critical levels irrespective of the activity of the fish. A direct relationship between oxygen consumption and oxygen content of water was found. Nevertheless, most experiments so far performed on the oxygen consumption of fishes, have been unsatisfactory in that it is not always certain that precautions were made to ensure that the fish were in a state of quiet respiration before the experiment began. Investigation of the oxygen consumption in flowing water systems would provide a better chance of acclimation and observation of the behaviour of fish under almost natural conditions. It would also eliminate the effect of handling of the fish on oxygen consumption in the first hours of the experiment. In the present work a comparative survey of oxygen consumption and respiratory behaviour of three Nile species with different adaptations was carried out. Experiments were also made to clarify the effect of body weight on the respiratory adaptations of fish with accessory breathing organs. The results quoted in this paper represent typical experiments.

MATERIAL AND METHODS

Experiments were carried out on 56 specimens: of those 21 were *Polypterus senegalus* of body weight 20—390 g, 27 were *Clarias lazera* weighing 30—450 g and 8 were *Tilapia nilotica* (50—194 g). Some of the material was collected from the White Nile near Jebel Awlia, about 30 miles south of Khartoum, but most of the material came from the Green Belt in the vicinity of Khartoum, where this work was carried out. Experiments were carried out in sealed respiration chambers (NASR EL DIN & ABDEL MAGID, 1968) and in a flowing water system (ABDEL MAGID, 1971). In the latter the oxygen concentration was controlled by bubbling compressed nitrogen and air through the water. Samples from the circulating water were taken immediately before entering and after leaving the respiration chamber. The oxygen content of water was estimated by the modified Winkler's technique (MACKERETH, 1963) The opercular frequencies were recorded by using a stop watch.

RESULTS

Patterns of oxygen consumption

In the first hours of each experiment, at high ambient oxygen concentrations (7.4—3.1 mg/l), *Tilapia nilotica* showed rates of

oxygen consumption higher than those of the succeeding hours at lower oxygen concentrations (Fig. 1 and 2). The consumption had a linear relationship with time (ambient region) till a critical oxygen concentration was reached (Fig. 2). In concentrations lower than critical the consumption was uniform for some time as is indicated

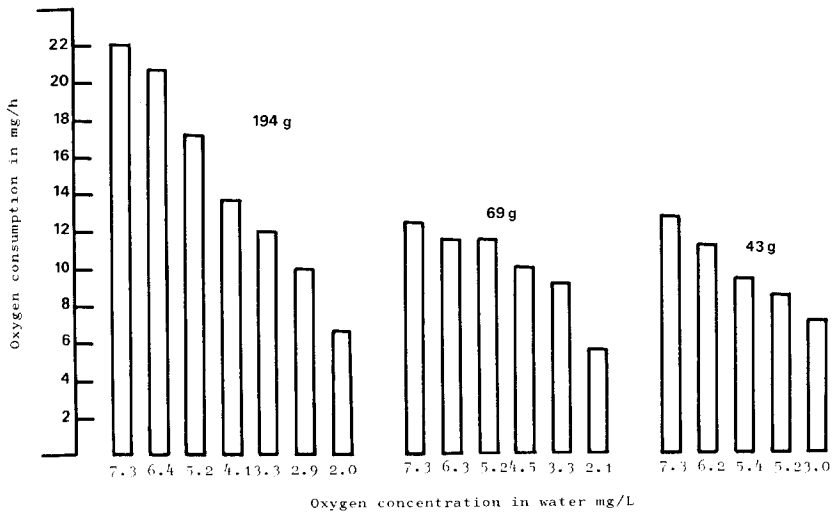

Fig. 1. Variation of oxygen consumption at different oxygen concentrations (in flowing water system) by fishes of different weights in relation to time. *Tilapia nilotica.*

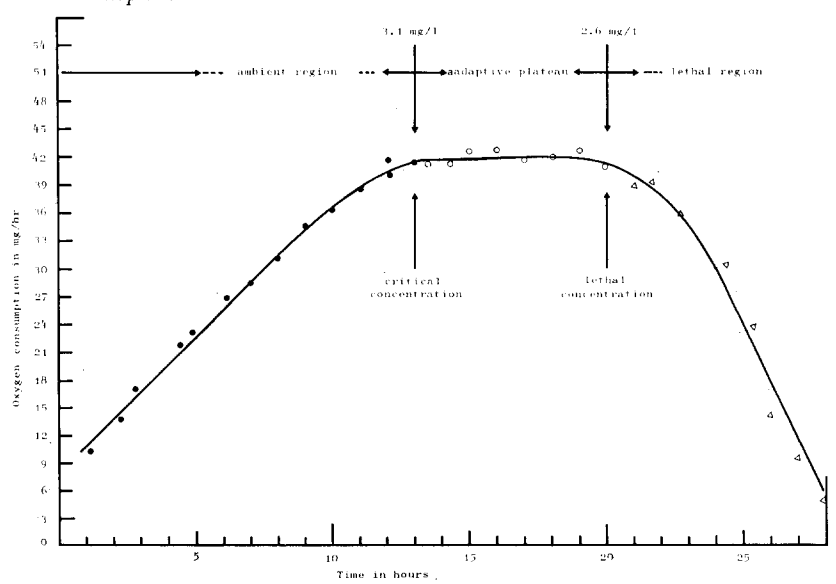

Fig. 2. Pattern of oxygen consumption (in sealed respirometer) in relation to time. *Tilapia nilotica.*

by the horizontal part of the curve (adaptive plateau) in Figure 2. Oxygen concentrations lower than those of the adaptive region were lethal. These are represented by a steep decline in the consumption curve (lethal region).

Similar patterns of consumption were also shown by specimens of *Polypterus* and *Clarias* of body weights of 30 g and 45 g respectively (Fig. 3a and 4a). In specimens of 225 and 270 g body weight the

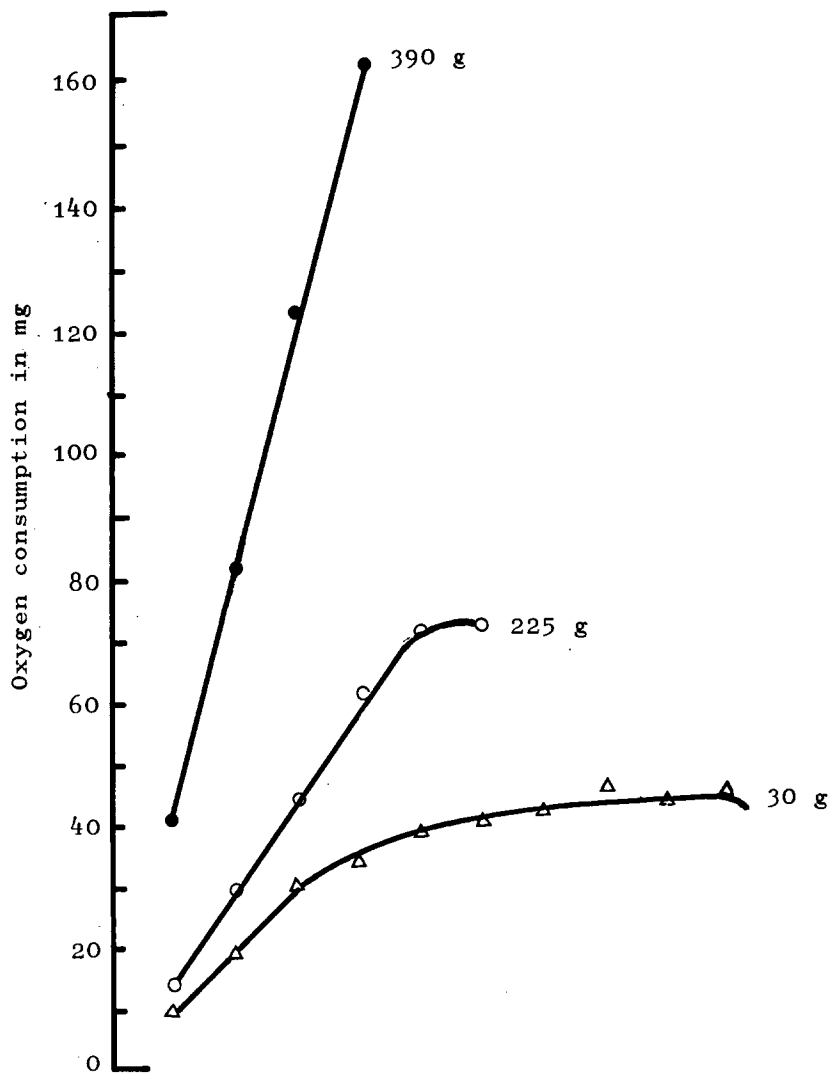

Fig. 3a. Patterns of oxygen consumption (in sealed respirometer) by fishes of different weights in relation to time. *Polypterus senegalus*.

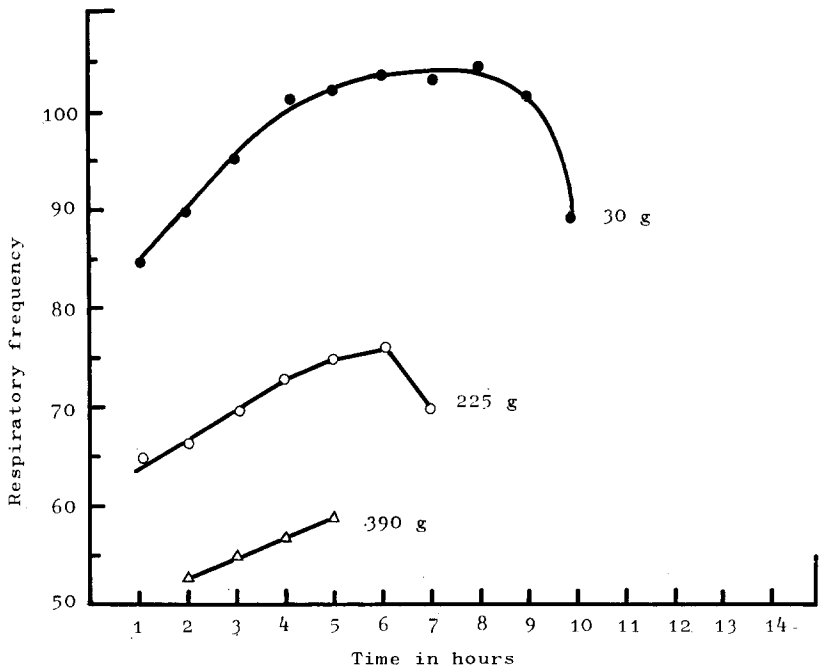

Fig. 3b. Respiratory frequency of fishes of different weights. *Polypterus senegalus*.

adaptive plateau was not significant. For specimens of 390 and 450 g body weight this part of the curve (adaptive plateau) completely disappeared (Fig. 3a and 4a) and a linear pattern of consumption was shown until vital activities ceased. A direct correlation can also be seen between the patterns of consumption and the respiratory frequencies (Fig. 3a, b and 4a, b).

Consumption and tolerance ranges

As in *Tilapia*, *Polypterus* and *Clarias* showed high rates of oxygen consumption under high oxygen concentrations, but in the first hours of each experiment all specimens investigated showed lower rates than in the subsequent hours (Fig. 5 and 6). At critical oxygen concentrations, however, the large specimens of *Polypterus* and *Clarias* showed a marked and sudden drop in their consumption rates before the fish finally succumbed.

The ability of the three species investigated to survive in depleted oxygen concentrations varies with the species and size of the fish. *Tilapia* could endure and survive in oxygen concentrations of about 0.1 mg/l for a few hours and all sizes could survive in all concentrations of the adaptive plateau, but only under respiratory stress, as

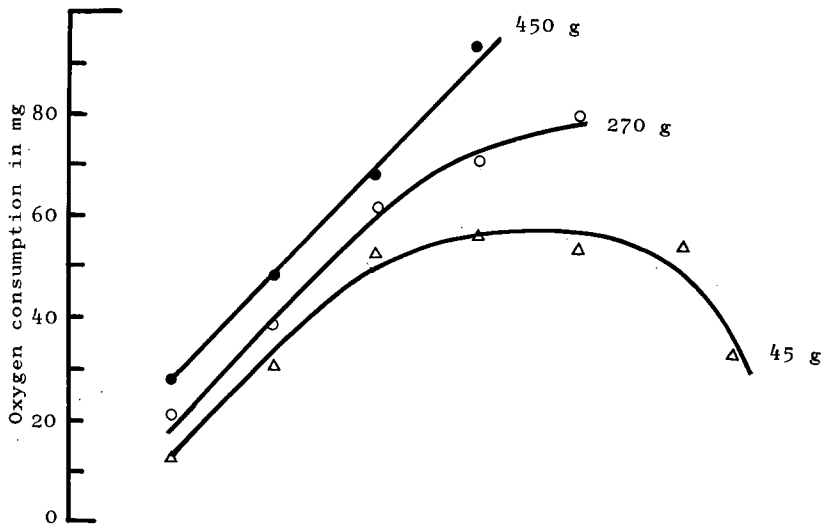

Fig. 4a. Patterns of oxygen consumption (in sealed respirometer) by fishes of different weights in relation to time. *Clarias lazera.*

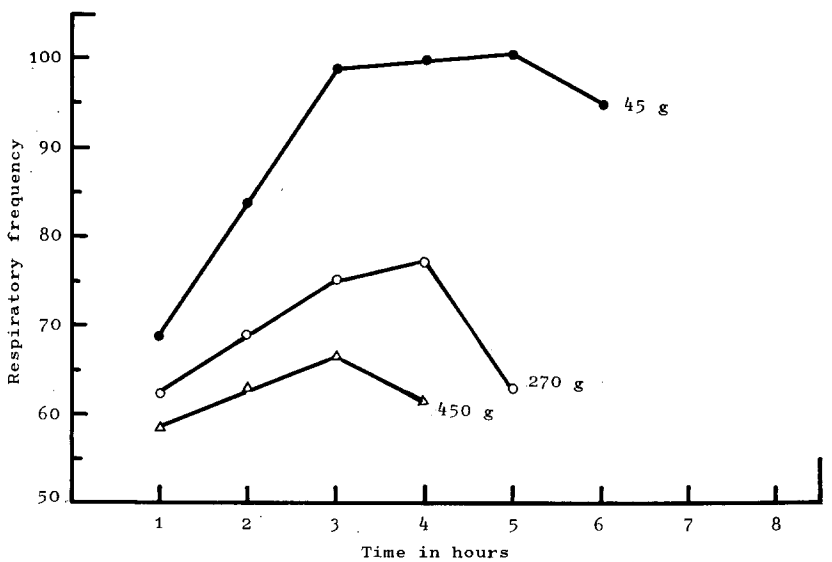

Fig. 4b. Respiratory frequency of fishes of different weights. *Clarias lazera.*

indicated by high rates of opercular frequencies. Specimens of *Polypterus* (100—390 g) started to decline in oxygen concentrations below 3—5 mg/l after two hours. Even when kept in oxygen saturated water (7.4 mg/l) they only survived for 12—8 hours. Specimens of 20—30 g body weight survived in waters saturated with oxygen

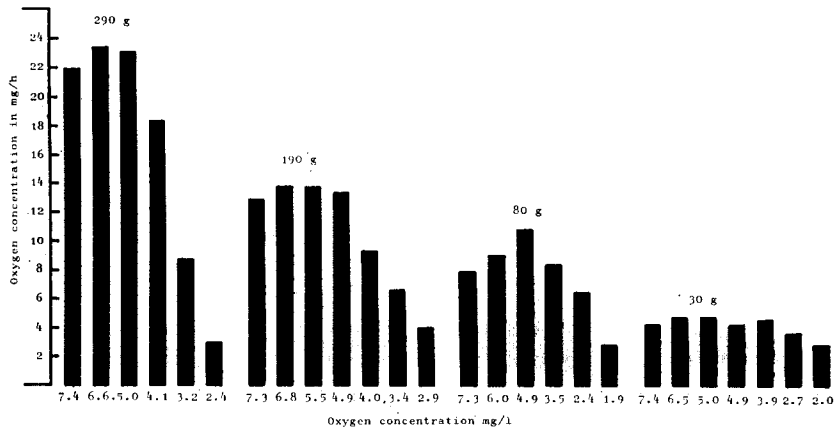

Fig. 5. Oxygen consumption (in flowing water system) of fishes of different weights in different oxygen concentrations. *Polypterus senegalus*.

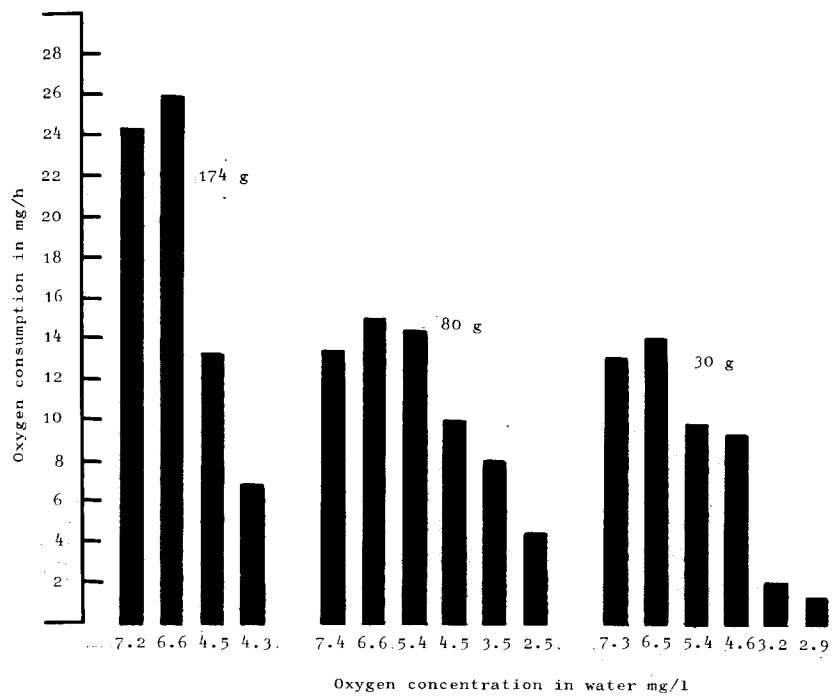

Fig. 6. Oxygen consumption (in flowing water system) of fishes of different weights in different oxygen concentrations. *Clarias lazera*.

(7.4 mg/l) and endured oxygen concentrations of 2.4 mg/l for about 4 hours before they started declining. *Clarias lazera* (30—45 g) also survived in oxygen saturated water (7.4 mg/l) and endured depleted oxygen concentrations (0.8 mg/l) for about 8 hours.

Specimens (100—450 g) declined after about 8 hours when kept in oxygen concentrations of 1.5—4.5 mg/l.

Discussion

Tilapia nilotica and specimens of *Polypterus* and *Clarias* (20—30 g and 30—45 g respectively) show comparable patterns of oxygen consumption (Fig. 2, 3a and 4a). The ability of specimens of *Polypterus* and *Clarias* (20—30 g and 30—45 g respectively) to survive when immersed in waters with high oxygen content (7.4 mg/l) suggests that their aquatic respiratory surface is sufficiently adequate to satisfy their respiratory needs, although their ability to tolerate lower oxygen concentrations is limited. Failure of specimens of *Polypterus* and *Clarias* (100—390 and 100—450 g respectively) to survive in dissolved oxygen concentrations of 7.4 mg/l indicates that their aquatic respiratory mechanisms are inadequate and the use of accessory respiratory organs as compensatory mechanisms becomes of vital importance. The fact that the swimbladders are used as accessory respiratory organs in *Polypterus* has been established by Abdel Magid, Vokač & Nasr El Din (1970). That *Clarias* uses its accessory respiratory organs in depleted oxygen concentrations in the water has also been pointed out by Abdel Magid (1971). Accordingly the lower rates of oxygen consumption in high oxygen concentrations, shown by these two species at the beginning of the experiments (Fig. 5 and 6), must be due to the inhalation of air while the fish were being transferred from the stock to the experimental aquaria. The three species investigated are tropical species that live in waters often subjected to low oxygen concentrations. The tolerance of *Tilapia* to extremely low oxygen concentrations is an adaptation of a tropical and completely aquatic species. This species, being completely dependant on aquatic respiration, shows a typical pattern of consumption (Fig. 2), with an ambient region at optimum oxygen concentrations and an adaptive plateau with a wider range of oxygen concentrations when compared to *Polypterus* and *Clarias*. The latter, however, resort to their compensatory mechanisms only when the aquatic respiratory surface fails to satisfy their oxygen requirements.

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