Diurnal Variation in the Bimodal Oxygen Uptake in an Air-Breathing Catfish, *Clarias batrachus*

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Abstract A definite rhythm was observed in the bimodal oxygen uptake of the air-breathing siluroid fish, *Clarias batrachus*. The total oxygen uptake was at its peak (222.3±20.25 m$l$$O_2$·$kg^{-1}$·$h^{-1}$) during dawn (04–06 h), whereas the minimum oxygen uptake (63.68±5.14 m$l$$O_2$·$kg^{-1}$·$h^{-1}$) was recorded in the midday hours (12–14 h). It seems that the rhythmic fluctuations in the metabolism of *C. batrachus* are related to the diurnal fluctuations of dissolved oxygen and free carbon dioxide in the swamps where this fish normally inhabits.

Rhythmic variations in the metabolism of fish are due to the activity patterns and behavioural changes. The phenomenon has been observed in a number of air-breathing fishes, viz., *Amphipnous cuchia* (Patra et al., 1978), *Channa* species (Munshi et al., 1979) and *Anabas testudineus* (Ghosh and Biswas, 1980). The observations are based on measurements of bimodal oxygen uptake. This paper reports the diurnal rhythm in the bimodal oxygen uptake in a commercially important freshwater catfish, *Clarias batrachus* (Linnaeus). It is provided with four pairs of gills for aquatic respiration (Munshi, 1976) and dendritic organs lodged in the suprabranchial chamber for aerial breathing (Munshi, 1961). Data are available on the aquatic and bimodal oxygen uptake in *C. batrachus* from the works of Munshi et al. (1976) and Patra et al. (1983), respectively.

Variation in the total oxygen uptake mainly depends on the rate of aerial oxygen uptake by the fish. Knowledge of such variations in the metabolism of fishes is essential for correct interpretation of measurements at different hours of the day. These studies may also help in the planning of feeding schedules (Rao et al., 1982), fish catch, and so forth.

Materials and methods

Live and healthy *Clarias batrachus* maintained in laboratory aquaria were used for experiments. The experimental fishes were first acclimatized to the laboratory conditions for about a month and then further acclimatized for 24 hours in the respirometer before experimentation.

A closed glass respirometer similar to that used by Ghosh et al. (1986) and Ghosh and Munshi (1987) was used for determining oxygen uptake from water and air simultaneously. The respirometer was filled with 4 l of tap water and a thermocol (Stylofoam) float having a semicircular hole was put over the water surface. The air-phase of the respirometer was attached to a fluid manometer. Aerial oxygen uptake by the fish resulted in an imbalance in the manometric fluid. The amount of pure oxygen injected through a graduated syringe to restore the imbalance showed the oxygen uptake by the fish. The liberated carbon dioxide was absorbed by KOH pellets kept in a Petri dish over the float.

Aquatic oxygen uptake was calculated from the difference of oxygen levels of the ambient water in the respirometer before (initial) and after (final) the experiment and the amount of water (i.e., 4 l). Dissolved oxygen content was measured applying Winkler's volumetric method (Welch, 1948). The fish was allowed to rest after two hours of experimentation and fresh tap water was re-introduced. All the experiments were performed at 32.0±1°C (SD) in a thermally insulated room under diffused light.

Mean values for oxygen uptake of fish of 57.0±4.0 g (in body weight) are illustrated in Fig. 1.

Results

It was observed that in the laboratory condition the fish preferred to remain quiet at the

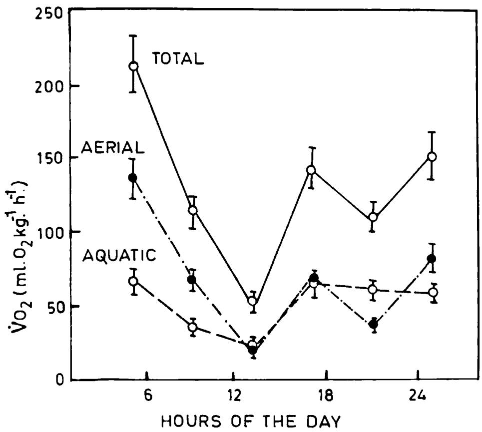

Fig. 1. Mean values of the aerial, aquatic and total oxygen uptake ($ml O_2 \cdot kg^{-1} \cdot h^{-1}$) by *Clarias batrachus* (n=13) at different hours of the day. The mean values and their standard deviations are indicated with circles and vertical lines, respectively.

bottom of the aquarium during the mid-day hours, whereas they frequently came to the water surface during late night and early morning hours for gulping air.

The oxygen uptake in fish of 57.0±4.0 g (SD) on the average through its air-breathing organs was at its peak ($147.2 \pm 13.18\ ml O_2 \cdot kg^{-1} \cdot h^{-1}$) during early morning hours (04–06 h) followed by the second peak ($92.11 \pm 9.76\ ml O_2 \cdot kg^{-1} \cdot h^{-1}$) during midnight hours (24–02 h). The lowest aerial uptake ($29.47 \pm 1.97\ ml O_2 \cdot kg^{-1} \cdot h^{-1}$) was recorded in the midday (12–14 h). The maximum aquatic oxygen uptake ($75.09 \pm 6.17\ ml O_2 \cdot kg^{-1} \cdot h^{-1}$) was observed in the early morning (04–06 h) and early evening (16–18 h) and minimum ($34.21 \pm 2.98\ ml O_2 \cdot kg^{-1} \cdot h^{-1}$) in the midday hours (12–14 h). Similar to the aerial and aquatic oxygen uptake, the total oxygen uptake (aerial+aquatic) was highest ($222.3 \pm 20.25\ ml O_2 \cdot kg^{-1} \cdot h^{-1}$) and lowest ($63.68 \pm 5.14\ ml O_2 \cdot kg^{-1} \cdot h^{-1}$) in the early morning (04–06 h) and midday (12–14 h) respectively (Fig. 1).

Discussion

Definite rhythms in the bimodal oxygen uptake with peaks at different hours of the day have been reported by earlier workers. *Amphipnous cuchia* and *Channa punctatus* show a peak of bimodal oxygen uptake during dusk (Patra et al., 1978; Munshi et al., 1979), *C. striata* and *C. gachua* during early hours of night (20–22 h) and *C. marulius* during mid-night (Munshi et al., 1979). Both *Anabas scandens* and *A. testudineus* show peaks during early morning and night hours (Reddy and Natarajan, 1970; Ghosh and Biswas, 1980). Most remarkably all these fishes show greatly reduced oxygen uptake in the midday hours. Rao et al. (1982) observed diurnal variations in the oxygen uptake of the juveniles of Indian major carps. Such fluctuations in oxygen uptake have been attributed to various factors: viz., higher metabolism at a particular hour of the day, variation in the physico-chemical

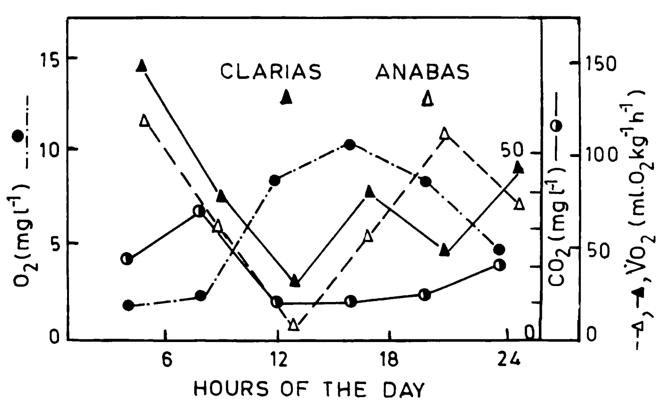

Fig. 2. Graphic illustration of the dissolved oxygen ($mg \cdot l^{-1}$) and free carbon dioxide ($mg \cdot l^{-1}$) of Barela Chaur (Rai and Munshi, 1979) showing relationship with the aerial oxygen uptake ($ml O_2 \cdot kg^{-1} \cdot h^{-1}$) of *Anabas testudineus* (Ghosh and Biswas, 1980) and *Clarias batrachus* (the present study) at different hours of the day.

conditions, feeding and other behavioural manifestations. The peaks indicate active periods of the fishes while minimal values account for their low activity periods (Rao et al., 1982).

Clarias batrachus resembles *Anabas* more in its respiratory rhythms. When a graph was plotted of the diurnal variations of O_2 and CO_2 in a swamp, the Barela Chaur (Rai and Munshi, 1979) and it was superimposed on the graphy variations in aerial oxygen uptake of *A. testudineus* (Ghosh and Biswas, 1980) and *C. batrachus*, it was found that in both the fishes the aerial oxygen uptake is mostly related to the decrease and increase in the O_2 and CO_2 levels of the swamps (Fig. 2). The marked increase in the aerial O_2 uptake during early morning hours is perhaps due to the depletion of O_2 ($1.26\ ml O_2 \cdot l^{-1}$) in the swamp-water (Rai and Munshi, 1979), where these fishes normally inhabit.

If the hypothesis regarding the regulatory mechanisms of the respiratory rhythm given by Woldring and Dirken (1951) and Serbenyuk et al. (1959) is applied to the present context, the concentration of O_2 and CO_2 seems to act as signals which originate in the autonomic respiratory center and are modified by reflex processes in the form of increased or decreased aerial breathing. The respiratory rhythms here are thus determined by the physico-chemical features of the habitat of the fishes. It appears that the respiratory rhythms shown in the natural environment continues to persist even in the laboratory conditions.

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空気呼吸魚 *Clarias batrachus* の両式酸素摂取量の日周変化

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空気呼吸をするヒレナマズ科の *Clarias batrachus* の両式（水呼吸及び空気呼吸）酸素摂取量に，明らかな日周変化が認められた．総酸素摂取量は明け方（04–06 時）に最大（$222 \pm 20\ \mathrm{m}l\mathrm{O_2 \cdot kg^{-1} \cdot h^{-1}}$）となり，日中（12–14 時）に最小（$64 \pm 5\ \mathrm{m}l\mathrm{O_2 \cdot kg^{-1} \cdot h^{-1}}$）となった．本種の代謝量の日周的な変動は，その生息する池沼水中の溶存酸素及び遊離二酸化炭素の日周変動と関係しているように思われる．