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Original Research Paper

Effects of Circadian Rhythm on Aquatic and Aerial Oxygen Consumption in Freshwater Teleost, *Channa gachua* Ham.

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ABSTRACT

Usually behaviour and physiology of organisms are rhythmic in nature. The biological rhythm in oxygen consumption in air breathing fishes is interesting. The circadian rhythm has now become an inherent property of the system which they transmit even under artificial conditions of the laboratory. An attempt has been made to study the effect of circadian rhythm on aquatic and aerial oxygen consumption in freshwater teleost, *Channa gachua*. The maximum oxygen uptake from aquatic route was recorded in the early morning with moderately higher at noon and evening i.e., 54.74, 52.8, and 50.76 mL/kg/hr respectively. The highest rate of oxygen consumption from aerial route was observed in the morning, and noted as 85.61, 60.27 and 51.78 mL/kg/hr at noon and during evening period. Minimum oxygen uptake was recorded at mid night as 40.20 mL/kg/hr. The total oxygen consumption i.e., 140.35, 112.06 and 101.68 mL/kg/hr were recorded in the morning, afternoon and evening respectively. However, the minimum value of 85.54 mL/kg/hr was noted at mid night. It was found that percentage of aerial oxygen uptake in the morning, midday, evening and midnight was 60.985%, 53.41%, 52.92% and 46.9%. Circadian rhythm of the oxygen consumption has been correlated with diurnal fluctuation of metabolism of the ecosystem. The details have been discussed in this paper.

INTRODUCTION

Organismic physiology and behaviour are often rhythmic and these rhythms will persist in the laboratory in the absence of photoperiod and various physicochemical factors of the environment in which organisms live under natural conditions. Because they do preserve, it is concluded that they are under the control of the so-called biological clock. Often in the artificial constancy of the laboratory, the periods of these rhythms deviate slightly from the ones displayed in nature and are referred to as circadian (Palmer 1976).

In India there are many swampy areas infested with floating water hyacinth, *Eichhornia crassipes*, and/or rooted *Cyperus* communities. In summer the water logged in these areas become hypoxic and hypercarbic. The physicochemical factors of this adverse ecological environment show rhythmic fluctuations at different hours of the day. These rhythms seem to govern the physiology and behaviour of an interesting group of air-breathing fishes, which thrive well in such swampy areas. These fishes exhibit various degrees of bimodal gas exchange mechanism. The relative dependence of the fish on gill and air-breathing has been studied in a few dual-breather species (Hughes & Singh 1970, 1971, Singh & Hughes 1971, 1973, Singh 1976, Lomholt & Johansen 1976, Ojha et al. 1978). However, little is known about the interspecific variations in the circadian rhythm of bimodal oxygen uptake in fishes (Patra et al. 1978).

This paper reports observations and detailed measurement of the interspecific variations in the circadian rhythm of bimodal oxygen uptake in *Channa gachua* and correlates them with the fluctuations in some of the physicochemical factors of their natural habitat, the swamps. Murrels are widely distributed in the freshwater swamps and ponds of temperate and tropical Asia and tropical Africa. Of about 21 species reported, four, i.e. *Channa marulius, C. striatus, C. gachua* and *C. punctatus* are commonly found in the swampy areas of northern India. All are air-breathing with a pair of suprabranchial chambers which assist the gills in gaseous exchange (Munshi 1962).

MATERIALS AND METHODS

Live specimen of *Channa gachua* were procured from local fish market at Hazaribag (latitude 25º59' N and longitude 85°22' E) and maintained in large glass aquaria (90 × 60 × 60 cm) with continuous flow of water. The fish were fed on chopped goat liver daily during a minimum acclimation period of 15 days in laboratory. Routine oxygen consumption from air and still water was measured in a closed glass respirometer containing three litres of water (initial O_2 content = 6.5 mg/L; pH = 7.2) and 0.51 mL of air. The concentration of dissolved O_2 in water was estimated by Winkler's method (Welch 1948) as shown in Fig. 1. Oxygen uptake from air was measured and calculated from the reading of volume change in the manometer and by the use of combined gas law equation of vapour pressure (Dejours 1975, Quasur & Sadhu 2009). The experimental fish were divided into different groups based on weights and sizes.

Mean values of oxygen uptake of adult fish were observed at standard temperature pressure dry (STPD) and standard deviation was calculated. The pH of ambient water was measured by a pH meter. Student's *t*-test was employed to test the level of significance of the differences between the sample means of the dual mode of oxygen consumption during various hours of the day.

RESULTS AND DISCUSSION

The data showing the circadian rhythm of aquatic, aerial and total oxygen consumption are given in Table 1. The maximum rate of oxygen consumption was 54.74 mL/kg/hr from water at early morning (05:00 - 06:00 hr) with a moderately higher of 52.8 mL/kg/hr at noon (11:00 - 12:00 hr) and 50.76 mL/kg/hr at early evening (17:00 - 18:00 hr). The minimum rate of oxygen uptake form water was recorded in the midnight (23:00 - 24:00 hr) at 45.35 mL/kg/hr. The highest rate of oxygen consumption from air, recorded in the morning (5:00-6:00 hr), was 85.61 mL/kg/hr followed by 60.27 and 51.78 mL/kg/hr at noon (11:00-12:00 hr) and in evening (17:00-18:00 hr) respectively. The minimum rate of oxygen uptake of 40.20 mL/kg/hr from air was recorded in midnight (23:00-24:00 hr). The highest value of total oxygen consumption was observed in the morning (05:00-06:00 hr) at 140.35 mL/kg/hr followed by 112.85 and 101.68 mL/kg/hr at noon (11:00-12:00 hr) and in evening (17:00-18:00 hr), whereas the minimum value of 85.54 mL/kg/hr oxygen consumption was recorded at mid night (23:00-24:00 hr).

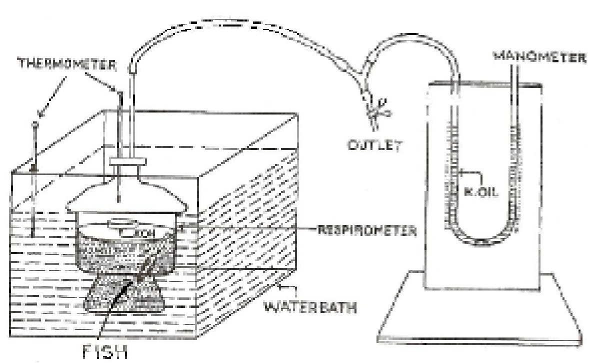

Fig. 1: Experimental set up for the measurements of dual mode of O_2 uptakes in *Channa gachua*.

The percentage of aquatic oxygen consumption was lowest (39.01) in

Table 1: Circadian rhythm in aquatic, aerial and total O_2 and percentage of aquatic and aerial O_2 in *Channa gachua* (body wt. 41.0 ± 1.5g).

S.No.	Hours of Day	Bimodal Oxygen Uptake (mL/kg/hr)			Bimodal Oxygen Uptake (Percentage)	
		Aquatic	Aerial	Total	Aquatic	Aerial
1	05.00-06.00	54.74	85.61	140.35	39.01	60.99
2	11.00-12.00	52.80	60.27	112.85	46.59	53.41
3	17.00-18.00	50.80	51.78	101.68	49.08	50.92
4	23.00-24.00	45.35	40.20	85.54	53.01	46.99

morning which gradually increased up to 46.59 in day, 49.08 in the afternoon and 53.01 in midnight. The percentage of aerial oxygen consumption was highest 60.99 mL/kg/hr in morning (05:00-06:00 hr) and gradually decreased in day to 53.41, 50.92 mL/kg/hr in afternoon. The lowest percentage of aerial oxygen consumption of 46.99 mL/kg/hr was recorded in midnight (23:00-24:00 hr).

The discovery of biological rhythm in oxygen consumption in air-breathing fishes is interesting. This is a physiological adaptation of air-breathing fishes in relation to the fluctuations of oxygen and carbon dioxide contents of their natural habitat. The ability of a murrel to obtain oxygen from the water will vary with the oxygen tension of the water in swamps, and capacity of the gills to extract it from water. In general, gills are not so well developed in murrels (Hakim et al. 1978). All the four species of *Channa* show distinct circadian rhythm in their metabolism. This rhythm seems to be associated precisely with the dual fluctuation of oxygen and carbon dioxide tensions of the water in swamps.

This study on murrels clearly indicates that there are large inter-specific variations in the circadian rhythm of their total metabolic rate. Differences in the percentage of aerial oxygen uptake in the four species of murrels may be due to inter-specific variations in the oxygen uptake efficiency of the bimodal gas exchange machinery (Hakim et al. 1978, Ojha et al. 1978). While two species (*C. striatus* and *C. marulius*) are obligate air-breathers, the other two are facultative ones. However, certain common features in their behaviour in the respirometer have been noted, viz.,

i. All are more active at night as they become very restive and frequently take air-breathe.
ii. During the day the fish breathe quietly exchanging gases mostly with gills, and behave like oxygen conformers.
iii. Interestingly enough, all the species show very low metabolic rates at mid-day.

Behavioural studies of the four species indicate that they would avoid bright light and hide themselves under the coverage of macro vegetation. They come out in the open waters after dusk in search of prey and are more active at night. Two distinct micro-environments in terms of dissolved oxygen and free CO_2 were found in the open and vegetation covered water areas. Generally, dissolved oxygen was lower, free CO_2 higher, pH lower and temperature lower under the water hyacinths than in the open water (Ultsch 1973, Rai & Datta-Munshi 1979). A sort of dual fluctuation of O_2 and free CO_2 in the two microhabitats has also been recorded (Rai & Munshi 1979).

The availability of these data should enable some interesting ecological conclusions to be drawn about animals inhabiting swamps. The dissolved oxygen under macro vegetation depletes rapidly to almost zero by 04:00 hr especially in the summer, when the O_2 demand of most aquatic organisms is greatest. As such, most of the vertebrates found in swamps are either entirely dependent upon aerial breathing (snakes, tortoises) or supplemental air-breathers like murrels. Further, the dependence upon aerial breathing of an organism utilizing bimodal (air and water) gas exchange can be evaluated as a function of time of the day. Thus, the two metabolic systems, one of habitat (swamp) and the other of fishes, are closely interlocked with each other, one influencing the other. The general metabolism of the swamp may be contemplated as a big metabolic wheel driving all the small metabolic wheels of different biotic communities. There are some sorts of feedback mechanisms in which the metabolic activities of different biotic communities influence the whole metabolism of the ecosystem. Assemblage of air-breathing fishes form an integral part of swamp ecosystems since their origin several millions years ago. The circadian rhythm has now become an inherent property of their system which they transmit even under the artificial conditions of the laboratory.

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