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Thermal stress and compensatory metabolic regulation in Puntius sophore

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Fishes are generally water breathers, where gills are responsible for the metabolic gases exchange. In many teleost fishes, gills are supplemented by skin and buccopharyngeal breathing which is also known as bimodal gas exchange. Majority of fishes show a remarkable ability to acclimate according to different temperature in the environment. They show a compensatory regulation in their metabolism to seasonal thermal variations. Poikilotherms regulate their metabolism and activity in the compensatory direction against thermal stress on the natural as well as laboratory conditions (RAO, 1971). In the present investigation in Puntius sophore a tropical freshwater teleost, compensation in the O_2 consumption related to the seasonal thermal variations has been studied. In P. sophore at acute temperature the winter fish consumed more O_2 than the summer one and at the respective habitat temperatures the winter and summer fish consumed O_2 almost at the same level despite the difference in the habitat temperatures. Thus there is a compensatory regulation in the O_2 consumption to the seasonal thermal variation in P. sophore.

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I. Introduction

Puntius sophore(Ham. Syn. Barbus stigma of Day) is common all over India. It is found in the tidal reaches of cooum river and in shallow ponds and streams extending inland upto 600m. Body silvery with yellowish tinge; Size up to to13 cm. long.Though the fish is reported to have bitter test, it is consumed in large quantities by the poor. It considered medicinal in Madras.

In majority of fishes there is general increase in metabolic rate with increasing water temperature. Influence of metabolic rate, as expressed in terms of O_2 consumption, has been studied in a number of fish species (pandey, 1978; Khan, 1993; Kumar,1993; Kumari Rashmi, 2002; Dixit & Kaur, 2003 and Shukla, 2003). Metabolic compensation to thermal stress was demonstrated in several poikilotherms under natural as well as laboratory conditions. These studies were directed at the different organisational levels of the animals, such as organismal, the Cellular and sub-cellular levels. This type of approach, besides establishing the fact of metabolic compensation to thermal stress, elucidates its modus operandi (Bullock, 1955; Prosser, 1958; Kanungo and Prosser,1959; Das and Prosser, 1967 a, b Parvatheswararao 1967, 1968 a, b, c). In all these studies only compensatory changes on a long-term basis were reported i.e. changes after exposing the animal to thermal stress over a period of days or even weeks. Not much is known of the changes occurring on a short-term basis. Nevertheless the short- term metabolic changes in the compensatory direction are as important as and actually precede the ones reported on a long-term basis, manifesting as metabolic homeostasis in the new thermal regime. In this study the initial or short term metabolic responses to thermal stress at the organismal level of the species P. sophore has been attempted.

II. Material and methods

Live specimens of different sizes of P sophore (Ham) were procured through local fish dealers and were transfer to laboratory in glass aquarium with continuous flow of water. The fishes were acclimatized to the laboratory conditions for a fortnight. The fishes were fed daily on pieces of earthworm.

1.Respiratory surface determinations-

Gill area: Measurements of the gill dimensions of 9 weight groups of fishes were made according to the weight method described by Muir and Hughes (1969):

Total gill area A = (2.L)/d'bl.....(i)

Where L = total length of gill filaments. 2/d'= secondary lamellae per mm on both sides of the gill lamellae (weighted).

The weighted value for secondary lamellae per 2/d' was determined by dividing the total number of secondary lamellae by the total length of filament. bl = average bilateral surfaces area of the secondary lamellae (weighted).

Skin area: Skin area determination of different weight groups of fishes were made by removing the entire skin of fishes fixed in 5% neutral formalin and tracing their outlines on graph paper ruled in mm^2.

2. O_2 consumption rates: The rate of O_2 consumption through gills and skin was measured in P. sophore of different body weights during winter (21+1°C) and summer (31+1°C) seasons.

3. Thermal stress and compensatory metabolic regulation: The winter fish samples were collected in November and stocked in laboratory aquaria till their O_2 consumption was measured towards the middle of January. The summer samples were collected in April and stocked in laboratory aquaria till their O_2 consumption was measured towards the middle June. The winter measurement to mid-January and the summer measurement to mid-June, the fish could be exposed to the respective seasonal thermal regimes for long enough to enable them to acclimate the thermal regimes characteristic of the season. The O_2 consumption of the fish of different body sizes was measured at 25°C (winter)and 35°C (summer) as described by Parvatheswararao (1959) using the unmodified Winkler's iodometric method as described by Welch and Smith (1960).

O_2 consumption (O_2 ml/hr) of individual fish was measured at 24 hrs interval at room temperature thrice successively. After the third measurement the fish were abruptly transferred on the same day, as suggested by Grainger (1958), to the acclimation temperature, 35°C or 20°C. After allowing an equilibrium time of about 30 minutes, the O_2 consumption of individual fish was measured at this temperature. Thereafter, the fish were maintained at the acclimation temperature and their O_2 consumption measured at 24 hours interval till the attainment of a new stable layer.

Calculation of Q_{10} Values: Q_{10} (change per 10°C rise in temperature) values were calculated by the following formula:

$\text{Log}Q_{10} = (\log M2_2 - \log M_1)/(T_2 - T_1) \times 10$

Where M_1 and M_2 are mean value of parameters at ambient water temperature T_1 and T_2.

III. Results and Discussion

The data on the O_2 consumption (O_2 ml/hr) of the winter and summer samples, measured at 25°C and 35°C are plotted as size-metabolism curves (fig. 4A and 4B). The winter fish, despite their being acclimated to a lower temperature consumed oxygen at a higher rate than the summer ones. Thus it is clear that the winter fish could step up their O_2 consumption to compensate for the depressing effects of the lower winter temperature. Conversely, the summer fish could step down their O_2 consumption to compensate for the stimulating influence of the high summer temperature.

From the size metabolism curves in Fig. 4A and 4B the weight specific O_2 consumption (O_2 ml/hr) of fish of 1 and 8 g body weight was calculated for the winter and summer samples separately and this values are plotted as rate temperature (R-T) curves Fig.5. Examination of these temperature R-T curves clearly reveals that while the weight specific O_2 consumption increases with increasing temperature in all cases, such an increase is size dependent in the summer fish, but not so in the winter ones. Thus it is seen that amongst the summer fish the weight specific O_2 consumption of the 1 g individual increases with temperature to a greater degree than that of the 8 g individual. This trend is clearly reflected in the Q 10 values. Accordingly, the 1 g summer fish has a much higher Q_{10} value (2.05)than the 8 g summer fish(1.7), while in the winter fresh both 1 g and 8 g individuals have almost identical Q_{10} values (1.60 and 1.58 respectively).On the whole the Q_{10} values are higher in the summer fish than in the winter ones.

The data on the O_2 consumption (O_2 ml/hr) of the winter and summer fish, measured at their respective habitat temperatures (25°C for the winter fish and 31°C for the summer fish) are plotted as size- metabolic curves (fig. 4C). It is interesting that the two curves of the winter and summer fish almost coincide despite the fact that the former were acclimated to a lower temperature and the latter to a higher temperature. It is thus evident that notwithstanding the seasonal thermal changes, the fish are able to regulate their O_2 consumption at a more or less constant level all the year round- winter or summer. Hence this is to be considered an instance of metabolic homeostasis operating against the ambient seasonal temperature changes.

At the acute temperatures the winter fish consume more O_2 than the summer ones and at the respective habitat temperatures the winter and summer fish consumed O_2 almost at the same level, despite the difference in the habitat temperatures. Thus there is a compensatory regulation in the O_2 consumption of P. sophore to the seasonal thermal variation. The different Q10 Values in winter and summer samples of the fish indicate operation of different enzymatic pathways in the winter (cold acclimated) and summer (warm acclimated) fish.

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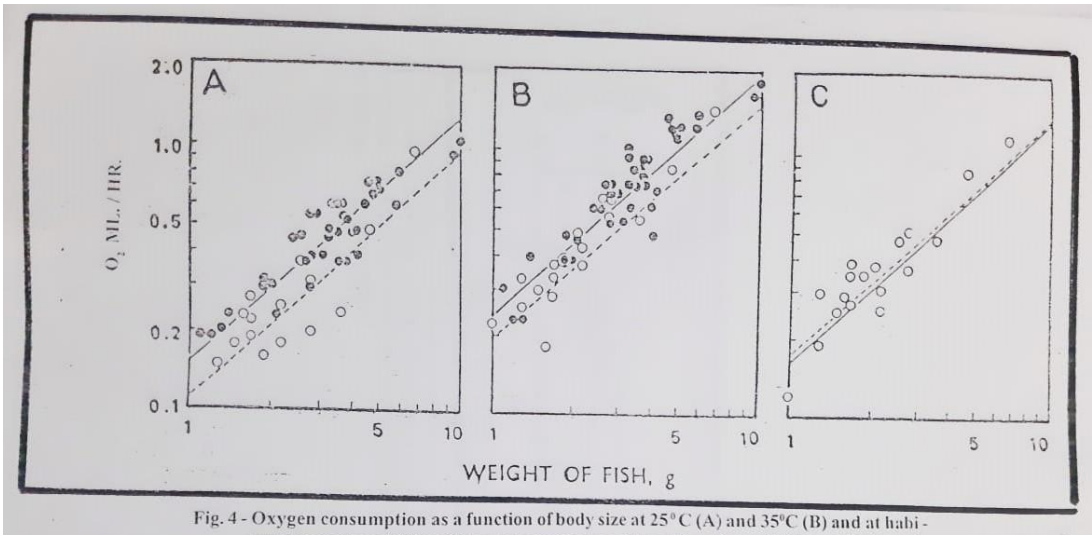

Fig. 4 - Oxygen consumption as a function of body size at 25°C (A) and 35°C (B) and at habitat temperature (C) in winter and summer samples of P.sophore [Winter (● - ●) and summer (O --- O) samples ; double logarithmic grid. Each point represents a single measurement . At each temperature winter and summer curves are compared . Oxygen consumption was measured at the winter habitat temperature (25 °C) for winter sample and summer habitat temperature (31°C) for summer samples .The winter measurements in (C) are same as in (A) and hence not shown.]

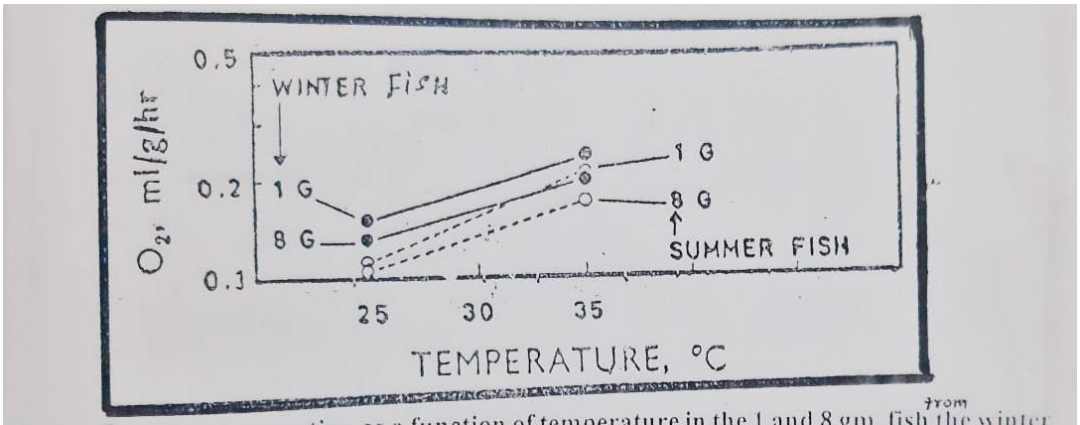

Fig. 5 - Oxygen consumption as a function of temperature in the 1 and 8 gm. fish from the winter and summer samples of P. sophore [Values calculated from the corresponding size - metabolism curves of Fig. 4 and plotted on a semilogarithmic grid . Winter (● - ●) and summer (O ---- O) samples]

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