Oxygen uptake in relation to body weight in a Hill-stream fish *Glyptothorax telchitta* (Ham.)

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Abstract

Oxygen uptake (VO_2) through the gills of a hill-stream fish *Glyptothorax telchitta* from the Saptakoshi river (Nepal) has been studied in relation to different body weights. The oxygen uptake was determined at 24.0±1°C using a cylindrical glass respirometer with continuous water flow system. The aquatic oxygen uptake through the gills increased from 1.048 to 8.115 $mlO_2\ kg^{-1}.h^{-1}$ within the body weight range of 3.215 to 31.355 g. A fish of 17.052 g average body weight consumes 4.461 mlO_2 while the weight specific oxygen uptake was found to be 267.915 $mlO_2\ kg^{-1}.h^{-1}$. The relation between oxygen uptake (VO_2) and body weight was determined by performing regression analysis using logarithmic transformation. It has been found that with a unit increase in body weight, the oxygen uptake per unit time (mlO_2h^{-1}) increases by a power of 0.930 showing significant positive correlation whereas, the weight specific oxygen uptake decreases by a power of 0.070 showing significant but negative correlation.

***Key words*:** Hill-stream, *Glyptothorax telchitt*a, body weight, oxygen uptake.

Introduction

Oxygen uptake is considered as a measure of energy requirements for metabolism. Generally, with an increase in metabolic activity, the rate of oxygen uptake also increases. Oxygen uptake in a fish depends on various extrinsic and intrinsic factors viz. temperature, level of dissolved oxygen and carbon dioxide in ambient water, pH, salinity, season, nutrition, sex of fish, level of hormones, body weight (Fry, 1947; Dejours, 1975). Several workers have studied the relationship between oxygen uptake and body weight in fishes (Pravateshwararao, 1960; Mookerji, 1964; Kamler, 1972; Munshi, 1984; Rooj, 1984; Singh *et al.*, 1991; Farrell *et al.*, 2001; 2003; Bhattacharya & Subba, 2006).

In the present study an attempt has been made to study the routine oxygen uptake in a hill-stream fish, *Glyptothorax telchitta* of different body weight to establish the relationship between the weight and oxygen uptake.

Materials and Methods

Live specimens of *G. telchitta* of different weight groups were collected from the Saptakoshi river (at Tribeni of Dhankuta district) and Barahkshetra and maintained in a plastic drum of 250 liter capacity. The plastic drum was connected with a pipe for

continuous supply of cold water supplied from the stream. At the bottom of the drum, pebbles collected from the river bed were kept to provide a natural condition to the fish. Just above two inches from the bottom of the drum, an outlet with a tap to control the water level was fitted with. The fishes were fed with earthworm and pupae of white ant twice a day. Water of the drum was changed completely once in every 24 hrs. Feeding was stopped at least 24 hrs before experimentation.

The oxygen uptake rate from water was measured in a closed glass respirometer as designed by Munshi and Dube (1973). The flow of water from the reservoir (a plastic drum of 30 l capacity) to the respirometer was maintained according to the size of the fish to avoid suffocation and stress. The respirometer was covered with a piece of black cloth leaving a small space with a view to keep the fish stress free and count the opercular frequency. Two sets of water samples were taken i.e., inspired (collected before the respirometer) and the expired i.e., the water coming out of the respiometer (Fig. 1). Oxygen concentration of inspired and expired water was measured by means of Winkler's volumetric method (Welch, 1948). The difference between the oxygen contents of the inspired and expired water together with the rate of water flow (ml/h) through the respirometer, were used to calculate the oxygen uptake rate.

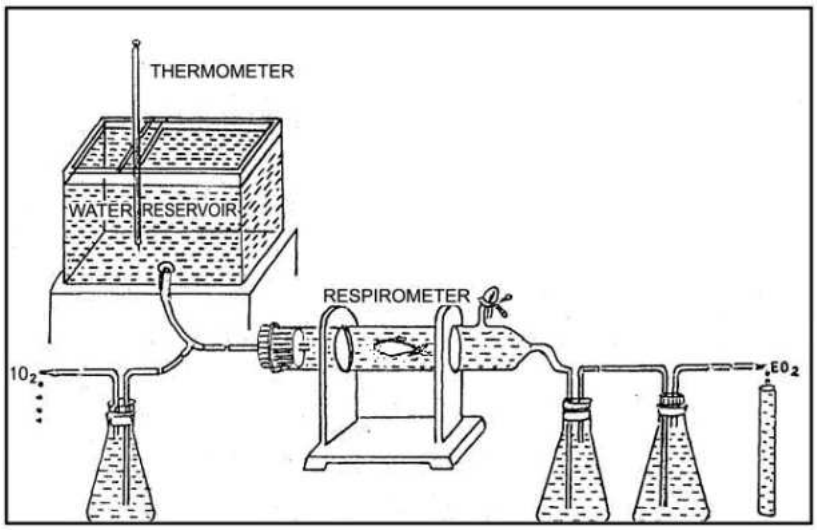

Figure 1. Experiment setup for measurement of aquatic oxygen uptake in *Glyptothorax telchitta*.

Three to four readings were taken at every half an hour interval for each fish. The experiments were performed at 24.0±1°C. Regression analysis using logarithmic transformation was done to show the relation between oxygen uptake and body weight.

Observation and Results

Glytothorax telchitta a benthic hill-stream fish is a purely water breathing Sisorid. Its gills are respiratory organs for the extraction of oxygen from water. Measurements of the rate of routine oxygen uptake from the flow-through water in eight (8) weight groups of *Glyptothorax telchitta* were made and the data is summarized in Table 1. The data were analyzed using logarithmic transformations for the allometric relationship which are in the (Table 2). Computerised data on oxygen uptake for 1, 10, 50 and 100 g fish are presented in the Table 3.

Table 1. Means value of the rate of oxygen uptake (VO_2) per unit time ($mlO_2.h^{-1}$) in relation to body weight (W) in *Glyptothorax telchitta* at 24.0±1.0°C temperature.

Body weight (g)	Opercular frequency	Oxygen uptake VO_2 ($mlO_2.h^{-1}$)		
		Observed value	Estimated value	95% Confidence limit
3.215±0.723	98±1	1.048±0.353	0.950	1.160
				0.780
5.650±0.000	88±0	1.48±0.000	1.600	1.920
				1.340
10.093±3.192	90±1	2.608±0.113	2.750	3.260
				2.320
15.190±1.441	89±0	3.838±2.336	4.020	4.770
				3.400
19.405±1.188	87±2	4.948±0.184	5.050	6.000
				4.260
24.310±0.000	87±3	6.517±0.000	6.230	7.420
				5.230
27.200±1.626	87±2	7.136±1.116	6.920	8.260
				5.800
31.355±0.000	85±0	8.11±0.000	7.900	9.460
				6.590

Intercept 'a' = 0.3202, Regression coefficient 'b'=0.9303, Correlation coefficient 'r' = 0.9968

Table 2. intercept 'a' regression coefficient 'b' and correlation coefficient 'r' to show the relationship between oxygen uptake VO_2 ($mlO_2.h^{-1}$) and body weight.

Fish	Oxygen uptake	Intercept (a)	Slope (b)	Correlation coefficient (r)
G. telchitta	$VO_2(mlO_2.h^{-1})$	0.320	0.069	0.997
	$VO_2(mlO_2.g^{-1}.h^{-1})$	0.320	-0.069	0.683

Table 3. Summary of equations showing the relationship between body weight and oxygen uptake at 24.0±1.0°C temperature.

Parameter	VO_2 per unit time $mlO_2.h^{-1}$	VO_2/gram body weight $mlO_2.g^{-1}.h^{-1}$
Body weight vs. oxygen uptake.	Log VO_2=0.3202+0.9303 log W or, $VO_2=0.3202W^{0.9303}$	Log VO_2=0.3202-0.0697 log W or, $VO_2= 0.3202\ W^{-0.0697}$

VO_2= Oxygen uptake, W= Weight of the fish (g)

As soon as the fish was introduced into the cylindrical glass respirometer containing little water, the fish showed erratic movements for a while. When the respirometer was completely filled up with the reservoir water, the fish moved to and fro in search of hiding place. The fish seemed to be under stress. The opercular movement was so high that it could not be counted accurately through eyes; however, the fish gradually became quiet after about 30 to 40 minutes. Then the flow rate of inspired water was so adjusted that the fish did not feel any stress and could move freely within the cylindrical chamber.

The atmospheric temperature recorded during the experimental time ranged from 25°C to 26°C whereas, the temperature of water ranged from 23°C to 25°C, the pH of water ranged from 6.8 to 7, similarly the oxygen content of ambient water ranged from 14.18 to 15.62 mg^{-1}.

Relationship between body weight and oxygen uptake per unit time ($m1O_2.h^{-1}$) at 24.0±1°C.

In *Glytothorax telchitta,* the oxygen uptake gradually increased from 1.048 to 8.115 $mlO_2.h^{-1}$ with increase in body weight from 3.315g to 31.355g. A fish of 19.026g average body weight consumed 4.344 $mlO_2.h^{-1}$. A straight line was obtained when these data were plotted on a graph

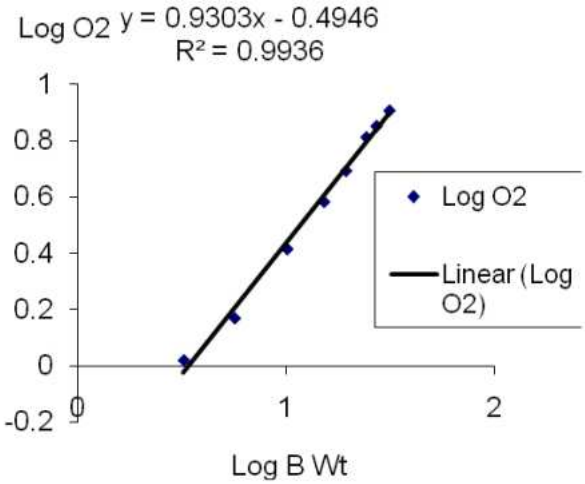

Figure 2. Log/log plots showing the relationship between body weight and oxygen uptake ($m1O_2.h^{-1}$) at 24.0±1°C in *G. telchitta*.

The expression of the relationship between the two variables has been made by the following allometric equation.

$VO_2 = {}_aW^b$ (Where, VO_2= Oxygen uptake per unit time, a= intercept or value for 1 g fish, b= slope of regression line and W= body weight)

The log of the oxygen uptake ($mlO_2.h^{-1}$) in relation to body weight gave a straight line, when different scores were fitted by the least squares regression method (Fig. 2). The slope (b) of the regression line was 0.9303. The estimated value of oxygen uptake for 1 g fish and the correlation co-efficient 'r' between oxygen uptake and body weight were 0.3202 and 0.9968 ($p<0.001$) respectively. The latter value indicates a high degree of correlation. The relationship between oxygen uptake per unit time ($mlO_2.h^{-1}$) and body weight (Table 2) may be represented by the following equation.

$VO_2 = 0.3202\ w^{0.9303}$
Or, log VO_2 = oxygen uptake per unit time ($mlO_2.h^{-1}$)
Slope 'b' = 0.9302
Intercept 'a'= 0.3202
W= body weight of the fish and
Correlation coefficient 'r' = 0.9968; $P<0.001$.

Summary of the equations are in the Table 3.

The computed values for the rate of oxygen uptake for a fish weight 1, 10, 50 and 100 g body weight were 0.3202, 2.7275, 12.180 and 23.2319 ($mlO_2.h^{-1}$) respectively (Table 4).

Table 4. Statistically estimated data for oxygen uptake (VO_2) at temperature 240.±1.0°C for 1, 10, 50 and 100 g fishes based upon regression analysis using least square method. Their 95% confidence limits are also given.

Body weight (g)	Oxygen uptake $mlO_2.h^{-1}$	95% confidence Limit	Oxygen uptake $mlO_2g^{-1}.h^{-1}$	95% confidence limit
1.00	0.0320	0.392	0.0320	0.0392
		0.262		0.262
10.00	2.728	3.963	0.0273	0.0296
		1.877		0.188
50.00	12.189	8.963	0.420	0.399
		7.440		0.149
1000.00	23.232	40.078	0.232	0.401
		13.467		0.135

Relationship between body weight and oxygen uptake per unit body weight ($mlO_{2g}^{-1}.h^{-1}$) at 24.0±1°C.

The weight specific oxygen uptake ($mlO_2g^{-1}.h^{-1}$) decreased with increasing body weight (Table 1). The weight specific oxygen uptake in *G. telchitta* decreased from 0.326 to 0.258 $mlO_2g^{-1}.h^{-1}$ with increase in body weight from 3.22 g to 31.36 g. The weight specific oxygen uptake of a fish of 19.039 average body weight was found to be 0.26 $mlO_2g^{-1}.h^{-1}$

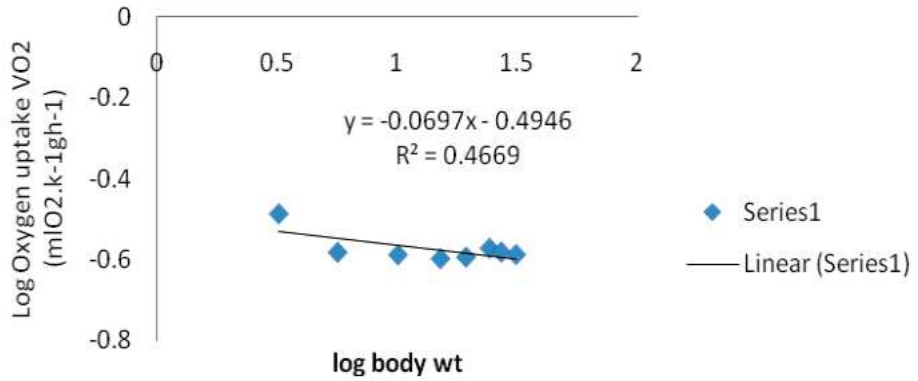

Figure 3. Log/log plots showing the relationship between body weight and weight specific oxygen uptake ($mlO_2g^{-1}.h^{-1}$) at 24.0±1°C in *G. telchitta.*

A straight line with slope of 0.0698 was obtained when the data for weight specific oxygen uptake rate were plotted against body weight on log-log coordinates (Fig. 3). The estimated value for a 1 g fish was 0.3202. The relationship between the body weight specific oxygen uptake rate has been shown by the following expressions.

$VO_2 = 0.3202\ W^{-0.0697}$

Or, Log VO_2 = 0.3203-0.0697 Log W.

From the above expression; it is evident that the weight specific oxygen uptake rate decreased with unit increase in body weight by a power of -0.0697. The correlation coefficient 'r' was found to be 0.6826 ($P<0.2$) which indicates that the relationship is significant. The estimated value of oxygen uptake rate ($mlO_2g^{-1}.h^{-1}$) for 1, 10, 50 and 100 g fish were 0.3202, 0.273, and 0.232 respectively.

Discussion

The rate of oxygen uptake in fish depends upon various abiotic and biotic factors (Imabayashi and Takahashi, 1987). Of the different biotic factors, body weight plays a very important role and it is well known that a normal increase in oxygen uptake is associated with an increase in body weight. Since the value of exponent 'b' relating to oxygen uptake per minute time in most of the fish is less than 1, the weight specific to oxygen uptake ($mlO_2 g^{-1}.h^{-1}$) decreases with increase in body weight.

Several workers have suggested different exponent values to state the relationship between oxygen uptake and body weight. Proser and Brown (1961) broadly generalized this value and suggested that it could range from 0.67 to 1.0. However, exception to this range is not uncommon. Exponent value as low as 0.5 was reported by Ruhland (1965) and 0.531 by Munshi and Dube (1973). Similarly, exponent values of more than 1.0 have also been reported (Wares and Igram, 1979; Munshi *et al.*, 1978). An exponent 'b' value greater than 1.0 means that it predicts the weight specific oxygen uptake increase with increasing body weight.

In the present study, the oxygen uptake per unit time in hill-stream Sisorid catfish, *Glytothorax telchitta* was estimated to be 0.930. This value is higher than the exponent values reported for a number of purely aquatic breathing fishes (Jager and Dekkers, 1975; Ojha and Singh, 1981; Sinha 1983; Roy and Munshi, 1984; Singh *et al.*, 1991). The slope value of *G. telchitta* was much higher than the 'b' values of many air breathing fish (Munshi and Dube, 1973; Ojha *et al.*, 1978). But the exponent value 0.841, in the facultative air-breathing Siluroid, *Clarias batrachus* (Munshi *et al.*, 1976) was comparatively very closer to the exponent value of *G. telchitta* (i.e., 0.9303.).

The exponent value 0.9303 'b' of *G. telchitta* was very close to 0.960 and 0.976 in *Puntius sophore* and *Crenimugil labrosus* repectively (Flowerdew and Grove, 1980). But it was lower than 1.053 in *Pimephles promelas* (Wares and lgram, 1979).

When the exponent value of *G. telchitta* was compared with other hill stream fishes, it was found to be a little more than 0.873 that of *Garra lamta* but less than 1.20 that of *Noemacheilus rupicola* (Rooj, 1984). The higher exponent value of *G. telchitta* suggests that the gills of this fish are better developed than most of the fish mentioned above. This slope values may be attributed to their active life in the oxygen rich water.

The slope values for weight specific oxygen uptake (i.e., VO_2 $mlO_2 g^{-1}.h^{-1}$) was found to be -0.0697 in *G. telchitta*. The computed slope values -0.1259 and 0.1346 in *G. lamta* and *N. rupicola* respectively indicate that the oxygen uptake per unit body weight decreased more rapidly in *G. lamta* (1.259) than in *G. telchitta* (0.0697) as the body weight of the fish increased. However, in *N. rupicola* the weight specific oxygen uptake will continue to increase with increase in body weight by a power function of 0.1346 on the basis of Lipskaya's (1974) definition it may be said that the intensity of metabolism was more in *N. rupicola* followed by *G. lamta* and *G. telchitta*.

The intercept value 'a' in case of *G. telchitta* was found to be 0.320 which is higher than the values for many purely aquatic breathing fishes (Ojha and Munshi, 1974; Jager and Dekkers, 1975; Roy and Munshi, 1984; Singh, and Munshi, 1991) but lower than the intercept values for some aquatic breathing fishes.

For 1 g fish, the computed value of intercept 'a' in case of *G. telchitta* found to be 0.320 which is higher than the values reported for many purely aquatic breathing fishes (Table 5). This is an indication to a higher rate of metabolic decrease with unit increase in body weight in *G. telchitta* but this intercept value is lower than the values reported for some other purely aquatic breathing fishes (Table 5).

Table 5. Computed data on aquatic oxygen uptake rate ($mlO_2.h^{-1}$) for different fish species of 1 g body weight for comparison with *G. telchitta*.

Fish species	$VO_2mlO_2h^{-1}$	References
Ictalurus nebulosus	0.084	Jager & Dekkers (1975)
Clarias batrachus	0.134	Munshi *et al.* (1974)
Macrognathus aculeatum	0.140	Ojha & Munshi (1974)
Cyprius casrpio	0.186	Jager & Dekkers (1975)
Macrognathus auleatum	0.213	Ojha & Munshi (1974)
Heteropneustes fossilis	0.215	Munshi *et al.*(1978)
Catostomus commersonii	0.216	Jager & Dekkers (1975)
Catla catla	0.263	Kunwar *et al.* (1989)
Cirrhinus mrigala	0.251	Roy & Munshi (1984)
Anguilla annquilla	0.277	Iager & Dekkers (1991)
Rita rita	0.287	Singh *et al.* (1991)
Glyptothorax relchitta	0.320	Subba (1999)
Glossogobius giuris	0.321	Singh & Munshi (1985)
Channa gachua	0.394	Ojha *et al.* (1978)
Salmo trutta	0.368	Jager & Dekkers (1975)
Samlo gairdneri	0.369	Jager & Dekkers (1975)
Mystus cavasius	0.532	Ojha & Singh (1981)
Anabas testudineus	0.545	Munshil & Dube (1973)
Nemacheilus rupicola	0.575	Rooj (1984)
Acipencer stellatus	0.577	Jager & Dekkers (1975)
Garra lamta	0.816	Rooj (1984)

The intercept values 'a' reported for certain air breathing fishes *Clarias batrachus* (0.134), *Heteropnuesters fossilis* (0.215) and *Anguilla anguilla* (0.277) were less than the intercept value of *G. telchitta* but it was found to be higher in *Chana gachua* (0.394) and *Anabus testudineus* (0.545) in the same condition.

The oxygen uptake for 1 g in hill-stream fishes, *N. rupicola* (0.628) and *G. lamta* (0.813) are two to three times more than the intercept 'a' value for *G. telchitta*. This suggests that the metabolic rate of 1 g *N. rupicola* and *G. lamta* are almost two to three times more than that of a *G. telchitta* of similar body weight.

From the studies of oxygen uptake rate of *G. telchitta* it can be concluded that the rate of oxygen uptake is neither high nor low.

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