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# Oxygen-uptake from Water through the Respiratory Organs in *Channa punctata* (Bloch) in Relation to Body Weight

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(1) In *Channa punctata*, the oxygen-uptake ($\dot{V}o_2$) through gills and suprabranchial chambers has been studied in relation to body weight ($W$) and respiratory surface area ($A$) at two seasonal temperatures (winter 20±1°C, and summer 31±1°C) and under experimental conditions, when air-breathing is either allowed or prevented. (2) The relationship under the two conditions may be expressed as (i) $\dot{V}o_2 = 0.0838$. $W^{0.7872}$ at 20±1°C and $\dot{V}o_2 = 0.2457$. $W^{0.6013}$ at 31±1°C, when air-breathing was allowed; and (ii) $\dot{V}o_2 = 0.256$. $W^{0.6249}$ at 20±1°C and $\dot{V}o_2 = 0.4235$. $W^{0.6292}$ at 31±1°C when air-breathing was prevented. (3) The relationship between the total respiratory surface area and oxygen-uptake rate may be expressed by the equation: $\dot{V}o_2 = 0.00045\ A^{0.9897}$ at 20±1°C and $\dot{V}o_2 = 0.00067\ A^{1.0031}$ at 31±1°C. (4) At the higher temperature of 31±1°C the slope '$b$' is reduced from 0.7872 to 0.6013, as the fish depends more on air-breathing. (5) The oxygen-uptake in fish not allowed to surface for air, is directly proportional to the combined surface area of the gills and the suprabranchial chambers.

**Key Words: Oxygen-uptake, Respiratory organs, *Channa punctata*, Body weight**

## Introduction

The oxygen-uptake rate ($\dot{V}o_2$) in fish depends on several anatomical, physiological, environmental and organismic factors.

That oxygen-consumption within a single species depends on body size, was first demonstrated by Rubner (1883). He observed that the metabolic rate in different breeds of dogs was proportional to the 2/3rd power of the body weight. Zeuthen (1953) concluded that the slope ($b$) of the regression line of a log/log plot of metabolic rate vs body weight had three ranges: about 0.7 (unicellular forms), 0.95

(in the weight range 1-40 mg) and 0.75 (wt above 40 mg). In different animal groups (inter-and intra-specific), '*b*' ranges from 0.45 to 1.0, but in most cases it is a little more than 0.7 (Winberg 1956, Hemingsen 1960, Parvateswararao 1960, Paloheimo & Dickie 1965, Kamler 1972).

The present study deals with the body weight/$O_2$-uptake relationship of *Channa punctata* (Bloch), a common air-breathing fish from India. An associated study of the morphometry of the respiratory organs has already been published (Hakim et al. 1978).

## Materials and Methods

Live specimens of *Channa* (=*Ophicephalus*) *punctata* (Bloch) of different weight groups, collected from Bhagalpur and nearby ponds were maintained in the aquaria for acclimatization. They were fed with goat liver, spleen and earthworms on alternate days. Feeding was discontinued about 24 hr before experimentation. The oxygen-consumption rate from water was measured for different body-weights under two experimental conditions, viz., (*i*) when the fish were free to breathe air, and (*ii*) when they were prevented from surfacing. The experimental set up was as described by Hughes and Singh (1970a) and Munshi and Dube (1973).

The oxygen-content of the water samples collected was measured by Winkler's volumetric method (Welch 1948). The difference between the oxygen-content of the inlet and outlet water together with the water flow rate (ml/min) through the respirometer were used to calculate the oxygen-consumption rate (ml/hr). Five to seven readings were taken at hourly intervals for each fish.

The frequency and the amplitude of the opercular movements were observed at the same time. The observations were recorded at seasonal temperatures of $20 \pm 1°C$ in winter and $31 \pm 1°C$ in summer. Regression analysis using logarithmic transformations was done to show the relation between the oxygen-consumption rate from water and the body weight and respiratory surface area.

## Results

Under natural conditions, during winter the interval between air-breaths ranged from 10 min to 1 hr and, occasionally, the fish did not surface for several hours, while in summer the fish were very frequently seen to surface for an air gulp–the time interval varying from 1 to 25 min.

The frequency and the amplitude of opercular movements varied in relation to temperature and the experimental conditions. At $20 \pm 1°C$, when surfacing was allowed, the opercular frequency ranged from 23–45/min and rose to 45, 60/min at $31 \pm 1°C$. At low winter temperatures the opercular-amplitude was very mild.

When air-breathing was prevented, the opercular-frequency ranged from 35–55/min (winter) and 45, 75/min (summer). Interestingly, when access to air was prevented in the respirometer the fish became restless in the beginning and tried to release the 'foul' air lodged in the suprabranchial chambers and to gulp in fresh air. This restlessness continued for 3–10 min in summer and 10–20 min in winter. After releasing the foul air, the fish settled down at the bottom of the respirometer.

### *Oxygen-uptake from Water in Relation to Body Weight*

The oxygen-uptake from water increased with the increase in weight of the fish. $\dot{V}o_2$ during summer was almost double that of in winter (tables 1 & 2). When

**Table 1** *Oxygen consumption in* Channa punctata *during winter season (20±1°C) in two different conditions*

| Sl No. | No. of specimens | Mean body wt (g) | Oxygen consumed | | | |
|---|---|---|---|---|---|---|
| | | | Surfacing allowed | | Surfacing prevented | |
| | | | ml/hr | ml/kg/hr | ml/hr | ml/kg/hr |
| 1. | 3 | 8.33 | 0.497 | 58.050 | 1.086 | 130.526 |
| 2. | 3 | 12.33 | 0.584 | 48.023 | 1.232 | 101.954 |
| 3. | 3 | 26.66 | 1.078 | 40.455 | 1.710 | 64.238 |
| 4. | 3 | 33.33 | 1.217 | 36.558 | 1.954 | 58.854 |
| 5. | 3 | 45.66 | 1.596 | 34.926 | 2.617 | 57.368 |
| 6. | 4 | 55.00 | 1.866 | 33.932 | 2.984 | 54.370 |
| 7. | 4 | 62.00 | 2.091 | 33.731 | 3.270 | 52.782 |
| 8. | 3 | 75.66 | 2.536 | 33.524 | 3.938 | 52.078 |
| 9. | 3 | 85.66 | 2.837 | 33.120 | 4.373 | 51.070 |
| 10. | 3 | 93.66 | 3.098 | 33.082 | 4.723 | 50.449 |
| 11. | 3 | 102.33 | 3.409 | 33.322 | 5.137 | 50.218 |
| Average | | 54.60 | 1.908 | 38.066 | 3.008 | 65.810 |

surfacing was prevented there was an incresae in $\dot{V}o_2$.

Mean values for $\dot{V}o_2$ and $\dot{V}o_2/W$ were plotted against body weight on log/log coordinates and straight lines fitted by the least square regression method. The relationship between the body weight and the rate of oxygen-consumption obeyed the following equations:

$$\dot{V}o_2 = aW^b \quad \ldots (1)$$

or $log\ \dot{V}o_2 = log\ a + b\ log.W$

where, $\dot{V}o_2$ = rate of oxygen consumption (ml/hr or ml/kg/hr), $a$ = intercept, indicating estimated oxygen-consumption for 1g fish, $b$ = regression coefficient (slope of the regression line), and $W$ = wet body weight (g) of the fish.

1. $\dot{V}o_2$ *from water during air breathing*

Tables 1 and 2 give the details of oxygen consumption ($\dot{V}o_2$) during winter and summer respectively.

The log/log plot of $\dot{V}o_2$ against body weight gave a straight line (table 3, figure 1) as follows:

$$log\ \dot{V}o_2 = log\ 0.0838 + 0.7872.log.W$$

or $$\dot{V}o_2 = 0.0838.W^{0.7872} \quad \ldots (2)$$

Equation (2) suggests that $\dot{V}o_2$ will increase by a fractional power of 0.7872 for unit increase in fish body weight. Thus the weight-specific oxygen-consumption rate (ml/kg/hr) is higher in the smaller fish (58.05 ml/kg/hr in a 8.3g fish) (table 1).

The log/log plot of $\dot{V}o_2$ vs body weight gave a straight line (table 3, figure 2):

$$log\ \dot{V}o_2 = log\ 0.2457 + 0.6013\ log.\ W$$

or $$\dot{V}o_2 = 0.3457.W^{0.6013} \quad \ldots (3)$$

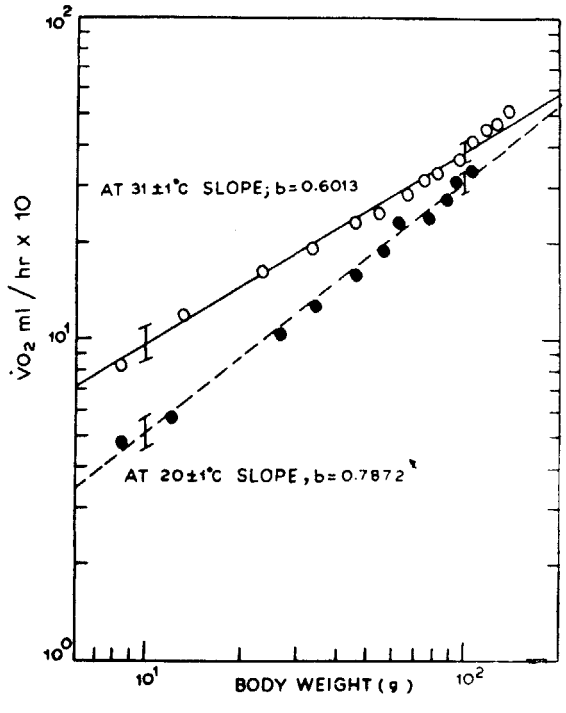
The low slope value ($b$) again shows that the smaller fish (8.3g) consume more oxygen (106.49 ml/kg/hr) than the larger

**Table 2** *Oxygen consumption in* Channa punctata *during summer season (31±1°C) under two different conditions*

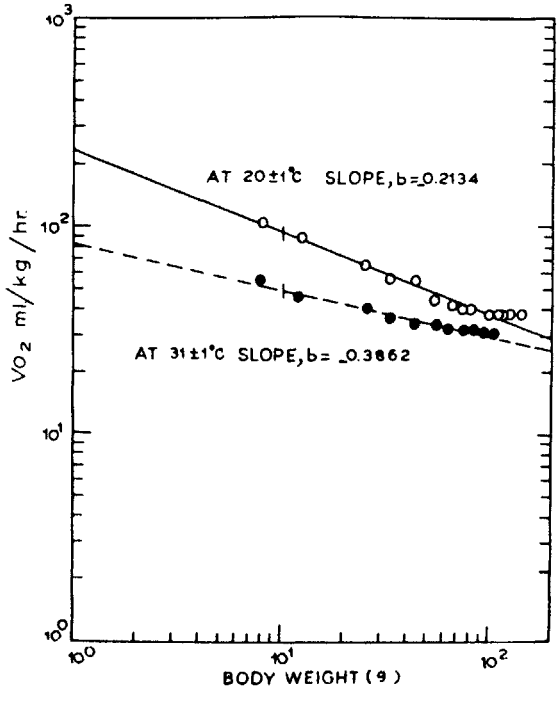
| Sl No. | No. of specimens | Mean body wt (g) | Oxygen consumed | | | |
|---|---|---|---|---|---|---|
| | | | Surfacing allowed | | Surfacing prevented | |
| | | | ml/hr | ml/kg/hr | ml/hr | ml/kg/hr |
| 1. | 3 | 8.33 | 0.884 | 106.493 | 1.731 | 208.603 |
| 2. | 3 | 12.66 | 1.118 | 88.688 | 2.338 | 187.310 |
| 3. | 3 | 23.66 | 1.620 | 68.436 | 3.117 | 132.391 |
| 4. | 3 | 33.66 | 2.085 | 61.951 | 3.132 | 95.776 |
| 5. | 3 | 43.00 | 2.320 | 54.114 | 3.950 | 94.167 |
| 6. | 3 | 53.66 | 2.376 | 44.333 | 4.831 | 89.990 |
| 7. | 3 | 67.00 | 2.779 | 41.487 | 5.807 | 86.655 |
| 8. | 3 | 75.33 | 3.054 | 40.554 | 6.477 | 85.969 |
| 9. | 3 | 81.00 | 3.273 | 40.409 | 6.784 | 83.768 |
| 10. | 3 | 97.00 | 3.825 | 39.607 | 7.965 | 81.944 |
| 11. | 3 | 105.00 | 4.122 | 39.291 | 8.443 | 80.558 |
| 12. | 3 | 115.00 | 4.518 | 39.254 | 8.744 | 75.806 |
| 13. | 3 | 125.66 | 4.976 | 39.283 | 9.309 | 73.885 |
| 14. | 3 | 134.00 | 5.214 | 38.909 | 9.472 | 70.783 |
| Average | | 69.64 | 3.018 | 52.958 | 5.864 | 103.398 |

**Table 3** *Regression coefficient (slope 'b'), the intercept 'a' (values for 1g fish) and the correlation coefficient (r)*

| Experiment and the experimental conditions | Regn coeff. | | Intercept 'a' | | Correln coeff (r) | |
|---|---|---|---|---|---|---|
| | ml/hr | ml/kg/hr | ml/hr | ml/kg/hr | ml/hr | ml/kg/hr |
| A. OXYGEN-CONSUMPTION RATE IN RELATION TO BODY WEIGHT | | | | | | |
| I. *In flowing ambient water—surfacing allowed* | | | | | | |
| (a) at 20±1°C | 0.7872 | —0.2134 | 0.0838 | 83.61 | 0.9891 | —0.9556 |
| (b) at 31±1°C | 0.6013 | —0.3862 | 0.2457 | 245.90 | 0.9789 | —0.9794 |
| II. *In flowing ambient water—surfacing prevented* | | | | | | |
| (a) at 20±1°C | 0.6249 | —0.3651 | 0.2560 | 255.90 | 0.9610 | —0.9544 |
| (b) at 31±1°C | 0.6292 | —0.3765 | 0.4235 | 235.48 | 0.9752 | —0.9426 |
| B. OXYGEN-CONSUMPTION RATE IN RELATION TO RESPIRATORY SURFACE | | | | | | |
| *In flowing ambient water—surfacing prevented* | | | | | | |
| (a) at 20±1°C | 0.9897 | —0.5824 | 0.0045 | 10398.00 | 0.9966 | —0.9965 |
| (b) at 31±1°C | 1.0031 | —0.6000 | 0.0067 | 20588.00 | 0.9966 | —0.9965 |




(1)




(2)

ones (134.0g, $\dot{V}o_2$ = 38.91 ml/kg/hr). Theoretically, the rate of decrease can be calculated by subtracting 1 from 0.6013 which gives a value of —0.3987 but the actually obtained slope value was slightly less ($b$ = — 0.3862) than the theoretical value (figure 2). The correlation coefficient ($r$) for the weight-related increase and decrease in uptake-rate, was respectively 0.9789 and —0.9794 ($p<0.001$).

2. *Aquatic Breathing*

Under this condition the fish could obtain oxygen only from water, since air-breathing was completely prevented. The ventilatory movements, as indicated by the greater amplitude and frequency of the opercular movements, increased sharply resulting in the initial increase of $\dot{V}o_2$. (tables 1 & 2).

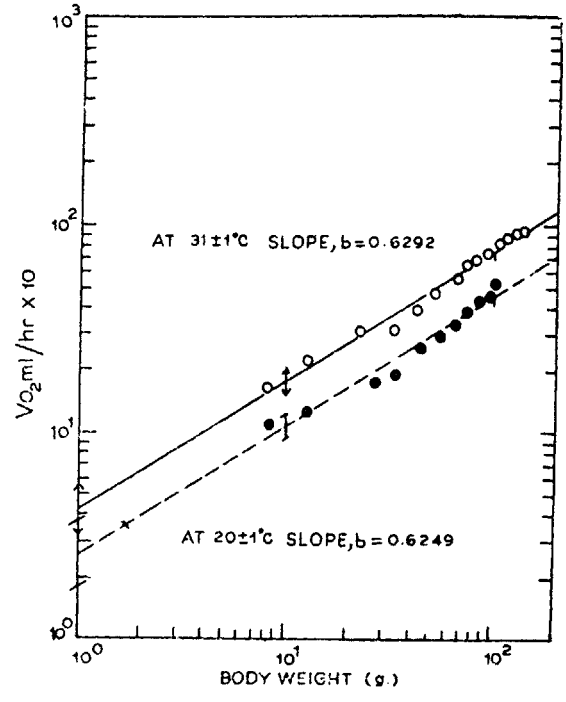
The log $\dot{V}o_2$ against log body weight plot gave a straight line with a slope of 0.6249 and intercept of 0.256 ml/hr (table 3 & figure 3) i.e.:

$$log\ \dot{V}o_2 = log\ 0.256 + 0.6249\ log\ W$$
$$\dot{V}o_2 = 0.256.W^{0.6249} \quad \ldots (4)$$

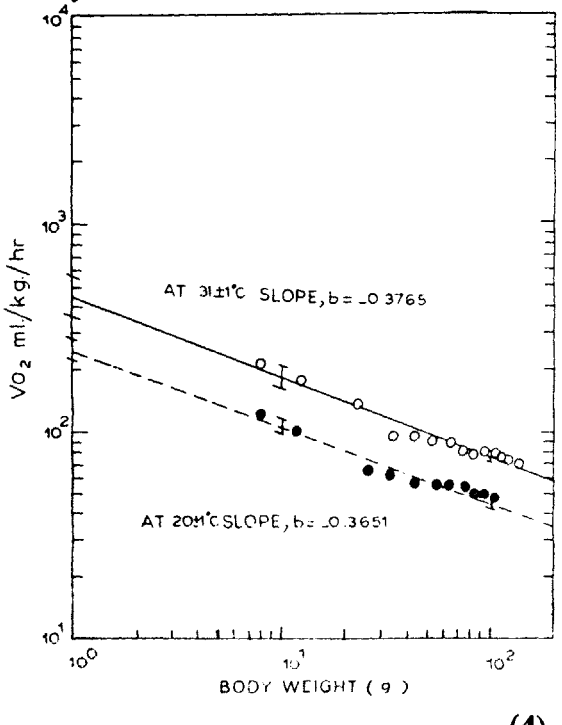
The weight-specific $\dot{V}o_2$ was much higher under this condition than when both water and air-breathing were allowed. In addition, the weight-specific rate was higher in smaller fish than the larger ones (tables 1 & 2). The log/log plot of the weight-specific $\dot{V}o_2$ (ml/kg/hr) against body weight in the different weight groups gave a straight line with a slope value ($b$) — 0.3651 and the estimated value of $\dot{V}o_2$ for a 1g fish was 255.9 ml/kg/hr (table 3 & figure 4).

Thus, there was a fall in weight-specific $\dot{V}o_2$ by a fractional power of — 0.3651 for unit increase in body weight.

**Figures 1 & 2** Bilogarithmic plots (fig. 1) and Log/log graphs (fig. 2) showing the relationship between body weight and $\dot{V}o_2$ under surfacing allowed condition in winter (20±1°C) and summer (31±1°C) seasons




(3)




(4)

There was a high degree of positive correlation in $\dot{V}o_2$ (ml/hr) ($r = 0.9610$) and negative correlation ($r = -0.9544$) in the rate of weight-specific oxygen-consumption (ml/kg/hr) with body weight ($P<0.001$) (table 3).

At $31 \pm 1°C$, the opercular frequency and amplitude were much higher than at $20 \pm 1°C$ and $\dot{V}o_2$ ranged from 1.731 to 9.473 ml/hr. The average $\dot{V}o_2$ and body weight were 5.865 (ml/hr) and 69.64g (n=42) respectively.

The slope ($b$) of the regression line for $\dot{V}o_2$ against body weight was 0.6292 and the estimated $\dot{V}o_2$ for a 1g fish was 0.4235 ml/hr (figure 2), i.e.:

$$log\ \dot{V}o_2 = log\ 0.4235 + 0.6292\ log.W$$
$$or\ \dot{V}o_2 = 0.4235.W^{0.6292} \quad \ldots (5)$$

There is a good positive correlation between body weight and the rate of oxygen consumption (ml/hr), $r = 0.9752$ ($P<0.001$). The slope (0.6292) is close to the value (0.6249) obtained at $20 \pm 1°C$ when surfacing was prevented.

The weight-specific rate of oxygen consumption (ml/kg/hr) ranged from 208.6 to 70.75 for a body weight range 8.3 to 134.0g (table 2).

For weight-specific $\dot{V}o_2$ the relationships were:

$$log\ \dot{V}o_2 = log\ 435.4783 + (-0.3765) log.\ W$$
$$or\ \dot{V}o_2 = 435.4783.\ W^{-0.3765} \quad \ldots (6)$$

Equation (6) suggested that there was a fall in the weight-specific $\dot{V}o_2$ from the smaller to larger fish (table 2 & 3, figure 4).

The correlation coefficient ($r = -0.9426$) shows a good correlation between the weight specific $\dot{V}o_2$ and body weight.

**Figure 3 & 4** Bilogarithmic plots (fig. 3) and Log/log graphs (fig. 4) showing the relationship between body weight and $\dot{V}o_2$ under surfacing-prevented condition in winter ($20 \pm 1°C$) and summer ($31 \pm 1°C$) seasons

*Oxygen-uptake from Water in Relation to Total Respiratory Surface-area when Surfacing is Prevented*

In the present investigation, total respiratory surface area (gill area+area of the suprabranchial chamber) is considered, because drowning experiments (Hakim et al. 1978) on *C. punctata* and cannulation of the suprabranchial chambers suggested that these chambers contain water, when surfacing is prevented and hence their surfaces are probably involved in aquatic gas exchange under these conditions.

When air-breathing was prevented at 20 ±1°C, the rate of oxygen consumption ranged from 0.764 to 4.691 ml/hr for fish having respiratory surface areas ranging from 1915.4 to 12248.0 mm² (table 4).

Log respiratory surface area was plotted against log $\dot{V}o_2$, and regression lines fitted by the least square method showed the following relationships (figure 5 & table 3).

$$log\ \dot{V}o_2 = log\ 0.00045 + 0.9897.\ log\ A$$
$$\text{or } \dot{V}o_2 = 0.00045\ A^{0.9897} \quad \ldots (7)$$

Where $A$ = total respiratory surface area. Equation (7) suggests that the rate of oxygen consumption through the respiratory surface increased by a power of 0.9897 for unit increase in the respiratory surface area, i.e. the respiratory surface area is related to $\dot{V}o_2$ by an exponent value 0.9897.

The correlation coefficient ($r$) 0.9966 suggested a very good correlation between total respiratory surface area and $\dot{V}o_2$ ($P<0.001$) (table 3).

At 31 ±1°C for the same range of respiratory surface area (1915.4 to 12248.0 mm²), $\dot{V}o_2$ ranged from 1.2618 to 7.9483 ml/hr (table 4). When regression line was fitted it had a slope of 1.0031 and an intercept value of 0.00067 ml/hr.

$$log\ \dot{V}o_2 = log\ 0.00067 + 1.0031\ log\ A$$
$$\text{or } \dot{V}o_2 = 0.00067\ A^{1.0031} \quad \ldots (8)$$

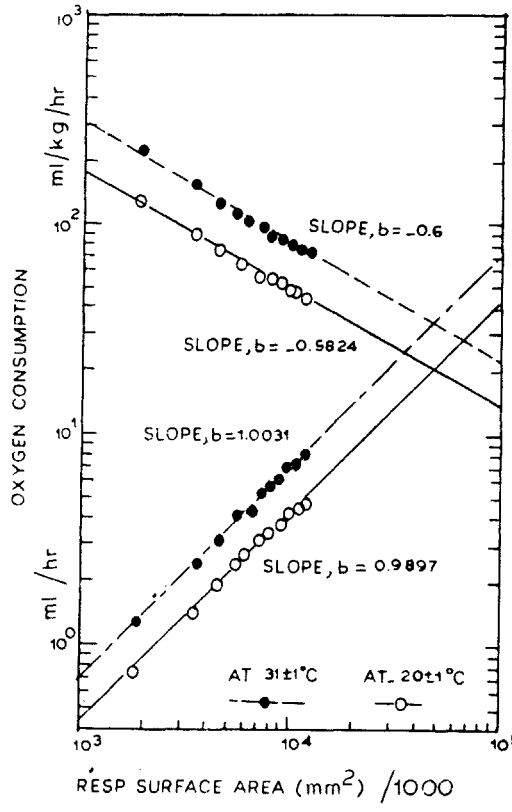



**Figure 5** Bilogarithmic plots showing the relationship between respiratory surface area (gills+suprabranchial chambers) and $\dot{V}o_2$ (ml/hr) at winter (20±1°C) and summer (31±1°C) temperatures under surfacing-prevented condition

Equations (7) and (8) suggest that $\dot{V}o_2$, when air-breathing is prevented, is directly proportional to the total respiratory surface-area and their ratio thus remains constant. The correlation coefficient ($r$) 0.9966 again suggests a very high degree of correlation.

The weight-specific fall in $\dot{V}o_2$ (ml/kg/hr) is comparatively high (table 3). For unit increase in the respiratory area at 20 ±1°C and 31 ±1°C, the fall would be by a power of —0.5824 and —0.6 respectively.

The weight-specific fall in $\dot{V}o_2$ appears to be highly correlated with the body weight ($r$ = 0.9965, $P<0.001$).

**Table 4** *Total respiratory surface area (mm²) and calculated oxygen-consumption at two seasonal temperatures under surfacing-prevented condition in* Channa punctata

| Sl No. | Respiratory surface area (mm²) | At 20±1°C (winter) | | At 31±1°C (summer) | |
|---|---|---|---|---|---|
| | | ml/hr | ml/kg/hr | ml/hr | ml/kg/hr |
| 1. | 1915 | 0.76396 | 130.520 | 1.2618 | 226.547 |
| 2. | 3573 | 1.39700 | 91.500 | 2.3347 | 157.080 |
| 3. | 4526 | 1.99310 | 75.204 | 3.2631 | 128.320 |
| 4. | 5669 | 2.42130 | 58.130 | 4.0650 | 112.510 |
| 5. | 6250 | 2 69770 | 62.121 | 4.5361 | 105.370 |
| 6. | 754 | 3.20950 | 56.086 | 5.4198 | 94.831 |
| 7. | 7946 | 3.43620 | 53.877 | 5.7976 | 90.981 |
| 8. | 9228 | 3.76000 | 51.095 | 6.3522 | 86.143 |
| 9. | 10236 | 4.06770 | 48.784 | 6.8796 | 82.130 |
| 10. | 11130 | 4.35250 | 46 882 | 7.3677 | 78.830 |
| 11. | 12248 | 4.69010 | 44.860 | 7.9483 | 75.334 |
| Average | 7297 | 2.98082 | 66.1023 | 5.0205 | 112.5524 |

## Discussion

The rate of oxygen consumption in any animal is related to the magnitude of the energy-requirements of the animal, which much depends on the body weight of the animal besides other organismic (Von Bertalanffy 1957) and environmental factors (Dejours 1976, Vivekanandan 1977).

Interestingly enough, the *b* value of the regression line varied under two different experimental conditions used in this study. A reduction in slope of the regression line was invariably found when air-breathing was prevented (table 5). This fall in the '*b*' value may be due to the stress created by the abnormal conditions when the fish are not allowed surfacing. Ultsch (1976) has also reported depression in slope when sirenids are submerged.

The behaviour of *Channa punctata* in winter at 20 ± 1°C suggests that it is mainly a water-breathing fish at low temperature. There was an appreciable decrease in frequency of surfacing and the fish often lie at the bottom for hours without coming to the surface. The '*b*' value of 0.7872 is close to that obtained for most water-breathing fishes (Brett 1965, Ralph & Everson 1968, Winberg 1956, Paloheimo & Dickie 1965).

In summer, at the higher temperatures of 31 ± 1°C the slope is 0.6013 when surfacing is allowed and it becomes 0.6292 when surfacing is prevented. The low value for the slope (0.6013) when surfacing was allowed at 31 ± 1°C suggests that at this temperature the fish depends much more on air breathing.

However, at 31 ± 1°C, when the fish is prevented from surfacing the slope value increases (0.6292). The rate of increase in $\dot{V}o_2$ from water for unit increase in the body weight appears to be insufficient to meet the oxygen demand of the body and this rate was supplemented by air-breathing. When air-breathing is pervented, the oxygen demand of the body is met by increasing the rate of oxygen consumption, and this increase is brought about by utilising the surface area of the

**Table 5** *A summary table of the slope (b) values under two experimental conditions*

| Name of species | Experimental conditions | | Authors |
|---|---|---|---|
| | Natural condition (air breathing & water breathing) | Water breathing | |
| *Channa punctata* | | | |
| (a) at 20±1°C | 0 7872 | 0.6249 | Hakim et al. |
| (b) at 31±1°C | 0.6013 | 0.6292 | |
| *Channa gachua* | | | |
| (a) 27.5±1°C | 0.681 | 0.641 | Ojha et al. 1976 |
| *Anabas testudineous* | | | |
| at 27.5±1°C | 0.6661 | 0 5259 | Munshi and Dube 1973 |
| *Clarias batrachus* | | | |
| at 26.5±1°C | 0.869 | 0.841 | Munshi et al. 1976 |
| *Saccobranchus fossilis* at 26±1°C | | | |
| (a) 1—25g | 1.0839 | 0.478 | Munshi et al. 1978 |
| (b) 26—75g | 0.986 | 0.799 | |

suprabranchial chamber for oxygen uptake from water. The use of the suprabranchial chamber increases the total respiratory surface area for gas-exchange.

When air-breathing was prevented at 20±1°C the slope was slightly lower than that at 31±1°C. These differences are not significant but may indicate that the slope of the regression line is temperature-dependent, possibly, due to an increase in the biochemical processes because of the temperature-rise.

In surfacing-allowed condition at 27.5±1.5°C *Channa gachua*, comparatively more active than *C. punctata*, had '*b*' value (0.641) (Ohja et al.1976) slightly more than that of *C. punctata* at 20±1°C (0.6249). It suggests that '*b*' value depends on activity also.

It is interesting to note that the '*b*' values of 0.6249 at 20°C and 0.6292 at 31°C are very similar to those obtained for respiratory surface area and body weight ($b = 0.6225$) in this fish. This corroborates the finding of Muir and Hughes (1969) for tunny that "relationship of area to weight is similar to that between oxygen-consumption rate and body weight". However, in subsequent studies on other fishes it has been found that the slope of the regression lines for total gill area is not always the same as that of the slope of the $\dot{V}o_2$/body weight relationship. In fact, three possibilities have been pointed out (Hughes 1972) with particular reference to the condition in salmonid fish. The slope of the gill area line may be taken as indicative more of the relationship for active $\dot{V}o_2$ than resting or standard $\dot{V}o_2$ and this suggests that with increasing body weight there is greater scope for activity in such species (Hughes 1976).

During prevented air-breathing condition, *C. punctata* perhaps utilises its respiratory surface area to its full capacity for gaseous exchange from water, which is a facultative air-breather. The increase in the amplitude and frequency of opercular breathing when surfacing

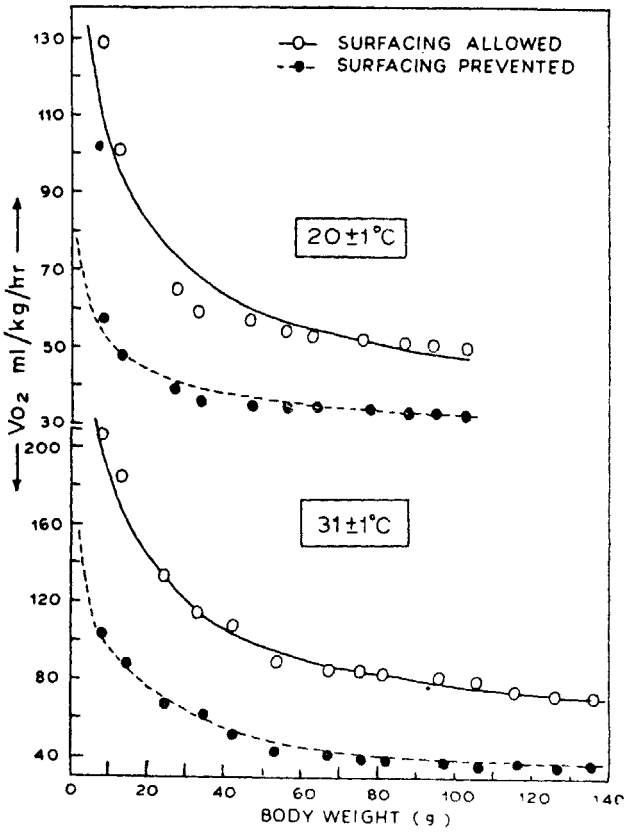



**Figure 6** Graphs showing the relationship between body-weight and $\dot{V}o_2$ under different experimental conditions

is prevented appear to be compensatory response adopted by the fish to maintain their metabolic rate (Hughes 1964, Munshi & Dube 1973).

The findings of the drowning experiment on *C. punctata* at high ambient temperature like 31±1°C are interesting. The death of the fish as reported by Boake (1865-66), Day (1868), Dobson (1874) and Ghosh (1934) in the drowning experiments was due to the hypoxia created by the depletion of the oxygen in the ambient reservoir water and not because the fish could not breathe air. Hora (1935) also reported *C. punctata* to survive for several days when access to air was prevented. All these findings support the view that *Channa punctata* is a facultative air-breathing fish and the provision for air-breathing in this species is a special adaptation for survival in the hypoxic conditions of the ambient environment.

It is amply clear from the works of Willmer (1934) on *Erythrinus*, Dehadrai (1962) on *Notopterus*, Johansen (1966) on *Symbranchus*, Hughes and Singh (1970a,b) on *Anabas*, Singh and Hughes (1973) on *Anabas* that these fish resort to air-breathing under abnormal conditions when the water becomes unsuitable for breathing. The fish living in such waters simply use water to avoid dessication (Singh 1976) and for elimination of carbon dioxide.

Dehadrai and Tripathy (1976) have enumerated the physicochemical characters of the waters where *C. punctata* thrive. Such waters are those of the senescent or semi-senescent swamps or ponds infested with weeds. They live at the root complex systems of floating and marginal vegetations and as such seasonal decrease or increase in the levels of waters has not much effect on the biology of these fishes (Kramer & Meclure 1981).

The higher weight-specific metabolic rate (ml/kg/hr) in small weight group of fishes (8.3g) in comparison to larger ones (102.3g or 134.0g) is in agreement with the findings of previous workers. From extrapolation of values for oxygen consumption rate (ml/kg/hr) after temperature corrections, it appears that *C. punctata* is not a very active fish.

The weight-specific rate of fall in the total respiratory surface area ($b = -0.3775$) is almost equal to the weight-specific decrease in $\dot{V}o_2$ when air-breathing is prevented ($b = -0.3765$ at 31±1°C and

—0.3651 at $20 \pm 1°C$). This means that in *C. punctata*, the routine $\dot{V}o_2$ is proportional to the total respiratory area.

The oxygen-consumption rate of an animal depends on the extent of the surface area for gaseous exchange and the permeability of the blood-water barrier to oxygen of the respiratory surface. In fish in which there is no apparent change in the thickness of blood-water barrier with growth, the value '*b*' is generally directly proportional to the surface area as is seen in *Macrognathus aculeatum* (Ojha & Munshi 1975). In *C. punctata*, the slope value '*b*' of log respiratory surface area to log $O_2$ consumption 0.9897 (at $20 \pm 1°C$) and 1.0031 (at $31 \pm 1°C$) suggest that the oxygen-uptake rate in *C. punctata* is almost directly proportional to the total respiratory surface area.

The present findings are in agreement with the suggestions of Muir and Hughes (1969). Hemingsen (1960) also argued the importance of respiratory surface area while considering oxygen-consumption rate. He asserted that the higher metabolic rates are directly related to the increase in the respiratory surface area per unit body weight as one follows the sequence from unicellular organisms to homeotherms. Whitford and Hutchison (1967), Anderson (1970) and Brett (1972) have also suggested by their respective studies on salamanders, spiders, reptiles and mammals respectively, that a higher metabolic rate is a concomitant phenomenon of respiratory surface area increase.

The weight-specific fall in the metabolic rate ($b = -0.5824$ at $20 \pm 1°C$ and $-0.6$ at $31 \pm 1°C$) in relation to respiratory surface area, at two temperatures is interesting. This fall in the weight-specific metabolic rate in relation to gas exchange surface is indicative of the capacity of the fish to extract more oxygen when needed.

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