Morphometrics of the Respiratory Organs of a Freshwater Major Carp, *Cirrhinus mrigala* in Relation to Body Weight

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Abstract The surface area of the gills of a freshwater major carp, *Cirrhinus mrigala* was measured in specimens of body weight range from 5.0 to 1821.0 g and the data were analysed with respect to body weight using logarithmic transformations ($\log Y = \log a + b \cdot \log W$). The slope of the regression line for total gill area was 0.8158 and for the 1st, 2nd, 3rd and 4th gill arches were 0.8013, 0.8068, 0.8157 and 0.8457 respectively. The slope value for secondary lamellae is 0.3151, whereas the intercept value for the same parameter comes to 178,887.98. The slope for average bilateral surface area of a secondary lamella is 0.5007. These results indicated differences in growth patterns for the dimensions of different gills. The growth related decrease in number of secondary lamellae per mm filament length ($b = -0.1287$) and gill area/g body weight ($b = -0.1842$) together with evidence from oxygen uptake suggests that larger fishes consume less energy per unit body weight than the smaller ones. The percentage shrinkage due to fixation in Bouin's fluid in filament length and average bilateral surface area were $3.05 \pm 0.47\%$ and $15.19 \pm 3.48\%$ respectively.

In general the gills are able to utilize 80% of oxygen dissolved in water (van Dam, 1938; Saunders, 1962) and also they are the sites of ion-exchange and osmoregulation. In this context the measurement of gill area and other allied parameters becomes a fascinating field of research, which throws light not only on the inter- and intraspecific variations in the architectural plan of gill sieve of different fishes, but also on the degree and mode of their respiratory adaptation (Hughes, 1984). Exact quantitative measurements applying statistical methods have been made by Hughes (1966, 1970a, b, 1972), Muir (1969), Muir and Hughes (1969), Hughes and Gray (1972), Landolt and Hill (1975), Hakim *et al.* (1978), Sharma *et al.* (1982) and Oikawa and Itazawa (1985).

The present work is an attempt to evaluate and correlate gill surface area and its allied parameters in relation to body weight of a freshwater major carp, *Cirrhinus mrigala* (Hamilton).

Materials and methods

A large number of live specimens of *Cirrhinus mrigala* of different weight groups were collected from different local ponds at Bhagalpur, India, maintained in glass aquaria and acclimatized to laboratory condition. The fishes of known body weight were fixed directly in Bouin's solution for 24 hours and the four gills of one side were dissected out completely. Every 10th filament of each hemibranch was taken as sample for the measurement and the morphometric measurements were carried out by weighted method as described by Muir and Hughes (1969). The area of a secondary lamella was measured by drawing it on tracing graph paper with the help of Ermascope (a camera lucida type).

Hand cut section of gill filaments were also made from fresh materials and length of filaments and area of lamella were measured. Then the same materials were fixed in Bouin's fixative for 1 to 3 hours and again the filament length and secondary lamellar areas were measured. From the differences in both the measurements the percentage shrinkage in filament length and secondary lamellar surface area was calculated.

The data were analysed and characteristics of the regression lines relating the logarithm of each parameter to log body weight were calculated by linear least square-method using an electronic

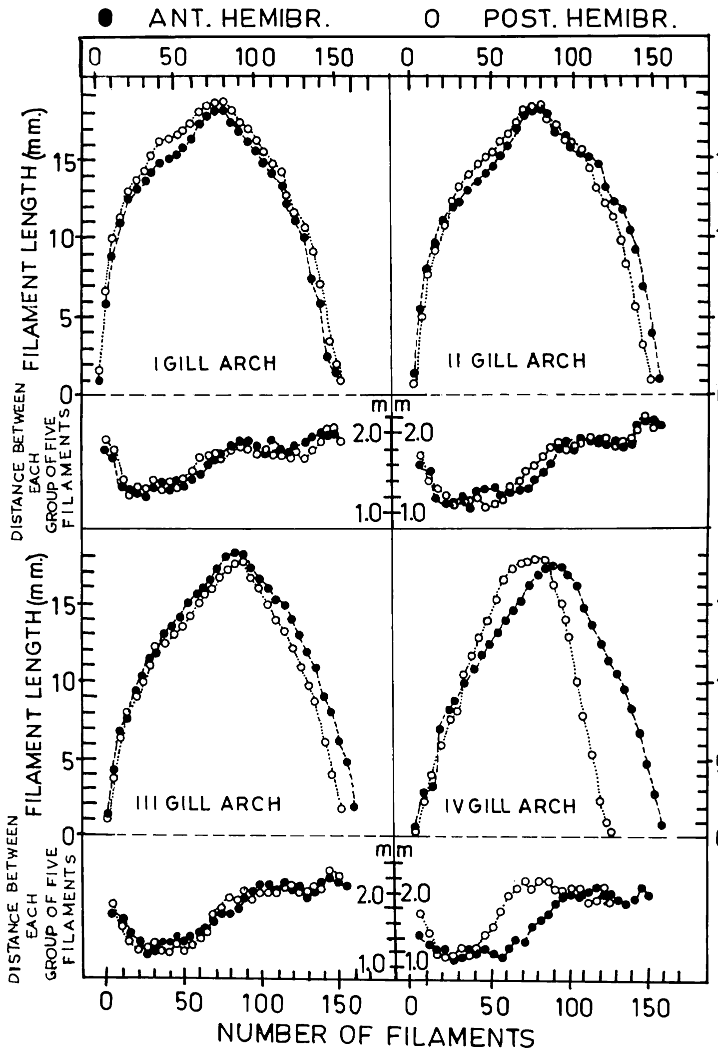

Fig. 1. Plots showing length and distance between each fifth gill filaments from both anterior and posterior hemibranch of all the four gill arches.

calculator (Casio fx-39).

Results

There are four pairs of well developed but heterogenous gills in this species. The filament length and distance between each five filaments of oral and aboral hemibranchs vary along the length of each gill arch (Fig. 1).

The profile of the secondary lamellae varies from tip to the base of each filament. The lengths and heights of the lamellae at the tip of filament are almost in the same dimension, but the length becomes multiple of height at the base (Fig. 2).

As one might expect the values of total number of filaments, filament length, mean number and area of secondary lamella and total lamellar area increase with increase in body weight. The computed data on the measurements of gill area and different component parameters of gill dimensions in relation to body weight in *C. mrigala* have been summarized in Table 1.

Relationship between body weight and total number and average length of filaments. In all the gill arches total filament number and average

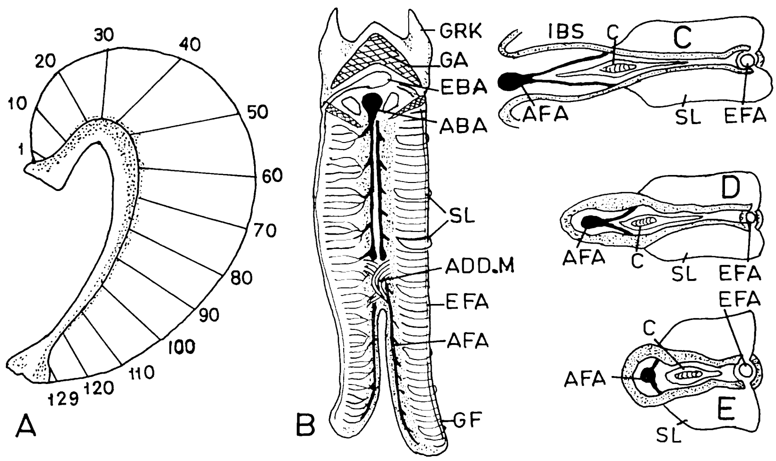

Fig. 2. Diagrammatic view of the gill of *Cirrhinus mrigala*. A, a hemibranch showing the position of filaments selected for measurement. B, longitudinal section (optically reconstructed) of a gill. C, cross-section of a gill filament through base. D, cross-section of a gill filament through middle region. E, cross-section of a gill filament through tip region. ABA, afferent branchial artery; ADDM, adductor muscle; AFA, afferent filamental artery; C, cartilage; EBA, effecent branchial artery; EFA, efferent filamental artery; GA, gill arch; GF, gill filament; GRK, gill raker; IBS, interbranchial septum; SL, secondary lamellae.

filament length increased with increasing body weight (Table 1).

The total filament length is a multiple product of average filament length and number. It increased with increase in body weight and the log-log plots of body weight and total filament length for each gill arch and total gill arches considered together always gave straight lines with slope value ranging from 0.4288 to 0.4746 (Table 1). The weight specific total filament length of fishes of 1, 10, 100 and 1000 g were 1414.236, 3929.20, 109.166 and 30.330 mm respectively.

These three parameters have shown a high and positive correlation with body weights (Table 1).

Relationship between body weight, secondary lamellae/mm filament length (on both sides) and total number of secondary lamellae. In all the four gill arches the number of secondary lamellae per mm filament length decreased with increasing body weight, the slopes varying from −0.1265 to −0.1309 (Table 1). The number of secondary lamellae per mm length of filament for fish of 1, 10, 100, 1000 g were 126.489, 94.057, 69.941, 52.008 respectively. The correlation coefficient for each of the four gill arches exceed 0.96 but negative in value (Table 1).

Product of secondary lamellae per unit length and total filament length gives the value for total secondary lamellae and when the number of total secondary lamellae were plotted against body weight on log-log graph, in all the gill arches taken separately or together straight lines with slope value varying from 0.3023 to 0.3437 were obtained. The two variables showed a good and positive correlation. The "r" value were all greater than 0.97 (Table 1).

The weight specific numbers of secondary lamellae in this species were quite high; 178,887.98 for 1 g, 369,556.7 for 10 g, 763,450.99 for 100 g and 1,577,179.63 for 1000 g fish.

Relationship between body weight and average bilateral surface area of a secondary lamella. The average bilateral surface area of a secondary lamella increased with increasing body weight and the log-log plots of both the variable always gave straight lines in all the 4 gill arches and total arches taken together. The respective slopes for 1st, 2nd, 3rd, 4th and total gill arches are 0.4989, 0.5034, 0.4986, 0.5018 and 0.5007 (Table 1). The correlation coefficient always exceeded 0.98 (Table 1). The average bilateral surface areas for fish of 1 g, 10 g, 100 g, and 1000 g were 0.00615, 0.020952, 0.066358 and 0.210172 mm^2 respectively.

Table 1. Results of regression analysis for the total gills and different gills of *Cirrhinus mrigala* in relation

Body weight vs gill dimensional parameters	First gill arch			Second gill arch		
	a	b	r	a	b	r
Gill filaments						
a) No. of gill filaments	296.689	0.1075	0.9376	305.204	0.1087	0.9429
b) Average filament length (mm)	1.396	0.3213	0.9985	1.328	0.3231	0.9977
c) Total filament length (mm)	414.218	0.4288	0.9933	405.336	0.4318	0.9931
Secondary lamella						
a) Secondary lamella/mm	119.900	−0.1265	−0.9646	124.127	−0.1283	−0.9659
b) Total secondary lamella	49,664.275	0.3023	0.9783	50,312.975	0.3034	0.9720
c) Average bilateral surface area (mm^2)	0.00705	0.4989	0.9935	0.00676	0.5034	0.9875
Gill area						
a) Total area (mm^2)	349.985	0.8013	0.9955	340.212	0.8068	0.9945
b) Gill area/g body weight (mm^2/g)	349.983	−0.1987	−0.9355	340.283	−0.1943	−0.9154

Table 2. Value of different gill parameters of *Cirrhinus mrigala* of 100 g body weight. Absolute values after shrinkage correction are also given.

Different gill parameters	Value from fixed gill	Absolute value after shrinkage correction
Number of gill filaments	1911.044	1911.044
Average filament length (mm)	5.712	5.892
Total filament length (mm)	10,916.582	11,260.080
Secondary lamella/mm	69.941	67.807
Total secondary lamella	763,516.100	763,516.100
Average bilateral surface area (mm^2)	0.06636	0.07824
Total gill area (mm^2)	50,666.324	59,740.980
Gill area/g body weight (mm^2/g)	506.661	597.408

Relationship between body weight and gill surface area. Measurements of average bilateral surface area and total number of secondary lamellae when multiplied together gave values for total gill area and it increased with increasing body weight in all the gill arches. The correlation coefficient of two variables were positive and very high (Table 1). The slope for all the gill arches taken together was 0.8158 and for individual arches it ranged from 0.8013 to 0.8456.

Relationship between body weight and weight specific gill area. The gill area/g body weight when plotted against respective body weights on a bilogarithmic grid always gave straight lines with negative slope values (Table 1). The weight specific gill area for fish of 1 g, 10 g, 100 g and 1000 g were 1183.389, 774.326, 306.663 and 331.524 mm^2 respectively.

Allowance for shrinkage. The shrinkage in filament length was found to vary from 2.34 to 3.69%, while the shrinkage in average bilateral surface area was found to vary from 8.72 to 20.52%. The average values came to be 3.05± 0.47% and 15.19±3.48% for filament length and bilateral surface areas respectively. The shrinkage corrections were made in the gill parameters of a 100 g fish (Table 2).

Discussion

The relative curved orientation of the four gills and variation in their filament lengths of the two to body weight as based on $Y=aW^b$. Correlation coefficients (r) have also been given.

Third gill arch			Fourth gill arch			Total gill arches		
a	b	r	a	b	r	a	b	r
289.501	0.1169	0.9388	227.415	0.1356	0.9438	1117.984	0.1164	0.4299
1.235	0.3280	0.9966	1.099	0.3390	0.9958	1.265	0.3274	0.9980
357.493	0.4449	0.9937	250.124	0.4746	0.9901	1414.236	0.4438	0.9931
129.034	−0.1278	−0.9717	132.890	−0.1309	−0.9655	126.489	−0.1287	−0.9693
46130.145	0.3171	0.9816	33,225.915	0.3437	0.9709	178,887.980	0.3151	0.9785
0.00645	0.4986	0.9920	0.00619	0.5018	0.9939	0.00662	0.5007	0.9927
297.559	0.8157	0.9973	205.603	0.8457	0.9967	1183.386	0.8158	0.9968
297.559	−0.1843	−0.9509	205.869	−0.1548	−0.9215	1183.389	−0.1842	−0.9420

hemibranchs along the entire gill arch may be related with the limited accommodation available in the branchial space and formation of a complete gill sieve. The distance between filaments of the hemibranch remains almost the same, but in the upper middle portion of the gill arch near the angles, the distance is reduced so as to accommodate more filaments (Fig. 1). Less number of filaments in the 4th arch especially on the aboral hemibranch is a noteworthy feature of the system and it is so because only a limited quantity of water flows through the aboral side of the 4th gill arch. The change in the profile of the secondary lamella from tip to base (Fig. 2) is according to change in the functional demand and growth of the gill filaments.

The existing data on the relationship of gill area to body weight of different fishes have been summarized in Table 3, to indicate that generally the slope (b) of the regression line ranges from 0.5 to 1.0 in different species, although Oikawa and Itazawa (1985) observed a slope value of more than 1 for body mass relationship in *Cyprinus carpio* (Table 3). However, this value is only observed in prelarval and post-larval developmental stages. The power value of 0.8158 for *C. mrigala* seems to be almost equal to the value reported for Gray's intermediates (0.82, Ursin, 1967; 0.811, Jager and Dekkers, 1975). This value seems to be less than those of active fishes like *Thunnus albacares* and *T. thynnus* but higher than many air-breathers like *Channa* spp., *Anabas testudineus*, *Heteropneustes fossilis* (Table 3). The statistically estimated data for a 1 g fish of *C. mrigala* was found to be 1183.3 mm^2 which is lower than that of very active fishes like *Katsuwonus pelamis*, *Coryphaena hippurus* (Table 3). The total gill area (intercept value) of *C. mrigala* is much higher than that of the air-breathing fishes (Table 3), however, this value comes nearer to the value reported for Gray's intermediates (Table 3). Hughes (1966) has suggested that gill area is proportional to the activity of the fish. It has also been proposed that its smallness indicates the sluggish behaviour or habitat in high dissolved oxygen. It is presumed that in amphibious and air-breathing fishes the smaller gill area is related to its smaller role in respiration by the gill in water. Tamura and Moriyama (1976) suggested a comparative gill ratio as follows:

Amphibious and air-breather$<$
sluggish$<$water breather

The gill area of *C. mrigala* suggests its intermediate level of activity.

As has been found for other species of fish (Muir and Hughes, 1969; Hughes *et al.*, 1973, 1974) the sum of the slope values for total filament length, number of secondary lamellae/mm and average bilateral surface area of a secondary lamella gave a value equal to the slope of the gill area computed separately (Table 4). Similarly the sum of slope values of total secondary lamellae and average bilateral surface area is equal to the slope of the gill area (Table 5). This suggests the validity of the least square method.

Hughes and Gray (1972) and Hughes and Morgan (1973) found that the sluggish fishes have a lower number of larger secondary lamellae, while active fishes have a higher number of smaller secondary lamellae. In *C. mrigala*, the number of secondary lamella/mm for 1 g fish (126.49/mm) is much higher than the air-breathing fishes like *Anabas* (73/mm) (Hughes *et al*., 1973), *Heteropneustes* (63/mm) (Hughes *et al*., 1974), *Clarias* (51/mm) (Munshi *et al*., 1980), *Macrognathus* (84/mm) (Ojha and Munshi, 1974). Higher number of secondary lamellae increases the efficiency of gas exchange machinery.

The average bilateral surface area of a secondary lamella (0.0066 mm^2) in *C. mrigala* was found to be smaller than *Anabas testudineus* (0.0149 mm^2, Hughes *et al*., 1973), *Heteropneustes fossilis* (0.0096, Hughes *et al*., 1974), *Boleophthalmus boddaerti* (0.0111 mm^2, Biswas *et al*., 1981), *Botia lohachata* (0.0176 mm^2, Sharma *et al*., 1982) but higher than *Macrognathus aculeatum* (0.0054, Ojha and Munshi, 1974). This however is compensated by the presence of a large number of secondary lamellae (a=178,887.98). The slope value for the area of an average bilateral surface

Table 3. Summary table of the regression coefficient (b) and intercept (a) values for the relationship between body weight and gill area of different fishes.

Species	Intercept a	Slope b	References
Micropterus dolomieu	865.0	0.780	Price, 1931
Gray's intermediate*	1392.0	0.820	Ursin, 1967
Katsuwonus pelamis } *Thunnus albacares*	5218.0	0.850	Muir and Hughes, 1969
Thunnus thynnus	3151.0	0.875	
Scyliorhinus canicula	262.3	0.961	
Scomber scombrus	424.1	0.997	
Coryphaena hippurus	5208.0	0.713	Hughes, 1970b
Tinca tinca	2846.0	0.522	
Tinca tinca	867.2	0.698	
Blennius pholis	1156.1	0.850	Milton, 9171
Opsanus tau	560.7	0.790	Hughes and Gray, 1972
Anabas testudineus	556.0	0.615	Hughes *et al*., 1973
Heteropneustes fossilis	186.1	0.746	Hughes *et al*., 1974
Macrognathus aculeatum	217.3	0.733	Ojha and Munshi, 1974
Channa punctatus	470.4	0.592	Hakim *et al*., 1978
Stizostedian vitreum	224.6	1.070	Nimi and Morgan, 1980
Salmo gairdneri	156.2	1.050	
Clarias batrachus	227.6	0.781	Munshi *et al*., 1980
Boleophthalmus boddaerti	281.3	0.709	Biswas *et al*., 1981
Botia lohachata	913.3	0.699	Sharma *et al*., 1982
Cyprinus carpio			
Prelarval	6.74×10^{17}	7.066	
Postlarval	1334.0	1.222	Oikawa and Itazawa, 1985
Juvenile+Adult	846.0	0.794	
Cirrhinus mrigala	1183.4	0.8158	Present authors

* Gray's intermediates consist of 19 species i.e. *Sarda sarda*, *Mugil cephalus*, *Caranx crysos*, *Roccus lineatus*, *Archosargus probatocephalus*, *Chilomyceterus schoepfi*, *Stenotomus chrysops*, *Tautogo onitus*, *Prionotus strigatus*, *Poronotus triacanthus*, *Cynoscion regalis*, *Palinurichthyes perciformes*, *Echenies naucrates*, *Spheroides maculatus*, *Centropristis striatus*, *Peprilus alepidatus*, *Prionotus carolinus*, *Trichiurus lepturus*, *Peralichthys dentatus* and are selected from a total of 31 species whose gills were investigated (Gray, 1954) excluding most active oceanic species, e.g. *Katsuwonus pelamis*, *Coryphaena hippurus*, *Gymnosarda alleterata* and the sluggish species, e.g. *Opsanus tau*, *Lophius piscatorius* and *Lophopsetta maculata*.

Table 4. Comparison of the sum of slope values of total filament length, secondary lamellae/mm and bilateral surface area of an average secondary lamella with that obtained for total gill area in different fish species.

Species	Regression coefficient b					References
	Total filament (1)	Second. lamella/mm (2)	Bilateral surface area of a secondary lamella (3)	Sum of columns 1, 2 and 3	Total gill area	
Thunnus albacares, *T. thynnus*, *Katsuwonus pelamis*	0.382	−0.089	0.583	0.876	0.875	Muir and Hughes, 1969
Coryphaena hippurus	0.431	−0.036	0.327	0.722	0.713	Hughes, 1970a
Scyliorhinus canicula	0.351	−0.071	0.684	0.964	0.961	Hughes, 1970b
Blennius pholis	0.510	−0.160	0.480	0.830	0.850	Milton, 1971
Opsanus tau	0.485	−0.075	0.372	0.782	0.790	Hughes and Gray, 1972
Anabas testudineus	0.335	−0.152	0.426	0.609	0.615	Hughes *et al.*, 1973
Heteropneustes fossilis	0.435	−0.095	0.408	0.748	0.746	Hughes *et al.*, 1974
Macrognathus aculeatum	0.467	−0.069	0.347	0.745	0.733	Ojha and Munshi, 1974
Channa punctata	0.4253	−0.1376	0.3043	0.5920	0.5919	Hakim *et al.*, 1978
Clarias bxtrachus	0.4150	−0.0830	0.4500	0.8820	0.7810	Munshi *et al.*, 1980
Boleophthalmus boddaerti	0.3620	−0.0830	0.4300	0.7090	0.7090	Biswas *et al.*, 1981
Botia lohachata	0.2913	−0.0056	0.4142	0.6999	0.6999	Sharma *et al.*, 1982
Cirrhinus mrigala	0.4438	−0.1287	0.5007	0.8158	0.8158	Present authors

area (b=0.5007) in *C. mrigala* is higher than many other fishes (Tables 4, 5), which means that the lamellae grow at a faster rate than in other fishes.

The slope for secondary lamellae/mm in *C. mrigala* (−0.1287) is much higher than *Botia lohachata* (−0.0056), tunny (−0.0893) but lower than *Anabas testudineus* (−0.1520), *Blennius pholis* (−0.1600) (Table 4), suggesting a decrease in secondary lamella/mm with increase in body weight, thus increasing the physiological dead space.

In *C. mrigala* the slope for gill area and body weight relationship was 0.8158, while for oxygen uptake and body weight relationship it was 0.8113 and 0.7961 at summer and winter temperatures respectively (Roy and Munshi, 1984). Further gill area per unit body weight (mm^2/g) decreases with the increase in body weight by a power of −0.1842, which approximates the weight specific oxygen uptake value (ml O_2/kg/h) of −0.1887 at 31.5±1°C and −0.2038 at 21.5±1°C (Roy and Munshi, 1984). It suggests that the relationship of area to weight is similar to that between metabolism and body weight. Oikawa and Itazawa (1985) also observed 0.832 slope value for metabolism and weight relationship in *Cyprinus carpio* and it is somewhat equal to the slope value (0.794) for gill area weight relationship in juvenile and adult stages. Comparison between different gill arches in *C. mrigala* suggests differential growth pattern and also some changes in surface area distribution. Table 6 reveals that the fourth pair of gill arch is relatively less developed than the first one, but the rate of development of the 4th gill arch is relatively high (Table 1).

$Å_{200}$ (gill surface area, mm^2/g of a standard fish of 200 g) values of *C. mrigala* when calculated by using the formula of log $Å_{200}$=log−b. log 200, were 455.841 mm^2, which is higher than those reported for air-breathing fishes like *Anabs testudineus* (72.29); *Clarias batrachus* (71.29); amphibious fish like *Boleophthalmus boddaerti* (60.24), *Macrognathus aculeatum* (65.08). However, it is lower than that of very active fishes like *Coryphaena hippurus* (1382), *Katsuwonus pelamis* (2444), *Scomber scombrus* (1100), *Thunnus albacares* (2040) (Fig. 3) while it is in range of Gray's intermediates.

The average shrinkage caused in filament length is 3.05±0.47% due to fixation in Bouin's solution while the average shrinkage in respiratory surface area is calculated to 15.19±3.48% (range 8.72 to 20.52%). This is higher than the value reported (5%) by Sharma *et al.* (1982) in *Botia lohachata*. Oikawa and Itazawa (1985) observed 2.9% shrinkage in filament length and 5.7% of gill area of *Cyprinus carpio* after fixation in formalin cortland saline. Hughes (1984) observed various shrinkage ranges in gills of different species when left in Bouin's solution. He suggested that the average shrinkage in filament length will be

Table 5. Comparison of the sum of the slope values of total secondary lamellae and average bilateral surface area of a secondary lamella with that obtained of total gill area in different fishes.

Species	Regression coefficient b: Total secondary lamella (1)	Bilateral surface area of a secondary lamella (2)	Sum of the columns (1) and (2)	Total gill area	References
Coryphaena hippurus	0.3900	0.3270	0.7170	0.7100	Hughes, 1970a
Opsanus tau	0.4200	0.3600	0.7800	0.7700	Hughes and Gray, 1972
Anabas testudineus	0.1770	0.4260	0.6030	0.6150	Hughes *et al.*, 1973
Heteropneustes fossilis	0.3360	0.4070	0.7430	0.7450	Hughes *et al*,, 1974
Macrognathus aculeatum	0.4042	0.3469	0.7511	0.7330	Ojha and Munshi, 1974
Channa punctata	0.2889	0.3043	0.5932	0.5919	Hakim *et al.*, 1978
Clarias batrachus	0.3210	0.4500	0.8610	0.7810	Munshi *et al.*, 1980
Boleophthalmus boddaerti	0.2850	0.4300	0.7150	0.7090	Biswas *et al.*, 1981
Botia lohachata	0.2856	0.4142	0.6998	0.6999	Sharma *et al.*, 1982
Cirrhinus mrigala	0.3151	0.5007	0.8158	0.8158	Present authors

Table 6. Comparative table showing percentage of several characters for the 4th gill arch to first gill arch in different fish species.

Species	Respiration	Body weight (g)	Percentage value (4th/1st)							
			No. of filaments	Length of filament	No. of secondary lamella/mm	Total no. of secondary lamellae	Length of a secondary lamella	Area of a secondary lamella	Total gill area	Total length of filament
Periophthalmus centonensis[1]	Amphibious	5.3	76.0	62.0	104.0	—	76.0	—	—	—
BoleophthalMus chinensis[1]		35.2	126.0	62.0	129.0	—	75.0	—	—	—
B. boddaerti[4]		10.0	115.0	61.1	121.7	85.4	—	45.0	39.5	70.3
Anabas testudineus[1]	Air-breathing	27.0	20.0	16.0	119.0	—	41.0	—	—	—
Clarias batrachus[3]		100.0	85.3	104.0	97.1	86.3	—	142.5	114.6	89.0
Channa argus[1]		671.0	40.0	42.0	101.0	—	39.0	—	—	—
Channa punctatus[2]		100.0	65.3	79.0	100.3	51.7	—	80.0	41.4	51.6
Anguilla japonica[1]	Water-breathing	10.5	97.0	79.0	101.0	—	95.0	—	—	—
Carasius carasius[1]		30.5	92.0	89.0	104.0	—	95.0	—	—	—
Cyprinus carpio[1]		17.2	90.0	108.0	97.0	—	89.0	—	—	—
Cirrhinus mrigala[5]		100.0	87.2	85.5	108.6	81.0	—	83.0	72.0	74.6

1, Tamura and Moriyama (1976); 2, Hakim *et al.* (1978); 3, Munshi *et al.* (1980); 4, Biswas *et al.* (1981); 5, Present authors.

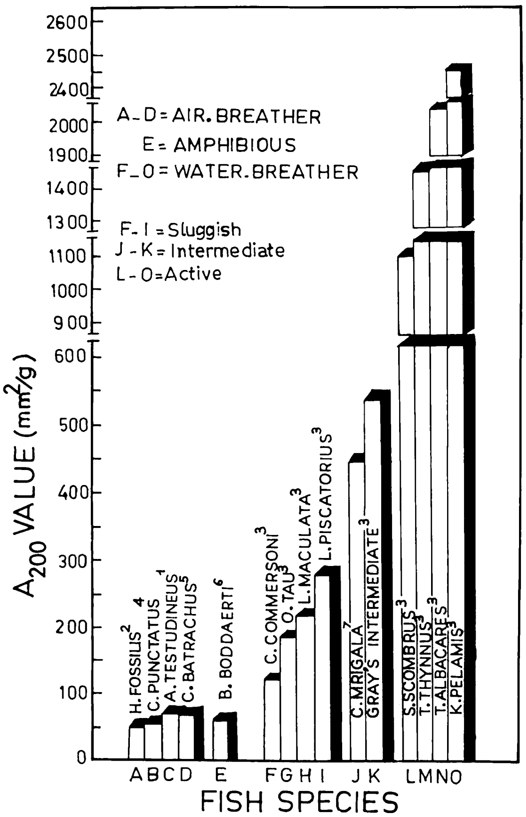

Fig. 3. A_{200} (gill area of a fish of standard body weight 200 g) value of different fish species. References: 1, Hughes *et al.*, 1973; 2, Hughes *et al.*, 1974; 3, Jager and Dekkers, 1975; 4, Hakim *et al.*, 1978; 5, Munshi *et al.*, 1980; 6, Biswas *et al.*, 1981; 7, Present authors.

2–3% during first two or three days, but in longer periods it may exceed even 10%. He further suggested that secondary lamellar shrinkage is generally 5 to 10% but may exceed this in long periods of fixation. Bouin's fluid may cause shrinkage in biological material by bringing the shrinkage in cell volume due to protein precipitation and altering both protein and lipid contents.

Thus, by shrinkage correction the absolute values for different parameters like filament length, average bilateral surface area (mm^2), gill area (mm^2) becomes higher than the values obtained for the fixed materials. The number of secondary lamellae per mm filament length also becomes less (Table 2).

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Literature cited

Biswas, N., J. Ojha and J. S. Datta Munshi. 1981. Morphometrics of the respiratory organs of an estuarine goby, *Boleophthalmus boddaerti*. Japan. J. Ichthyol., 27: 316–326.

Dam, L. van. 1938. On the utilization of oxygen and regulation of breathing in some aquatic animals. Doctoral Dissertation, Groningen.

Hakim, A., J. S. Datta Munshi and G. M. Hughes. 1978. Morphometrics of the respiratory organs of the Indian green snakeheaded fish, *Channa punctata*. J. Zool., Lond., 184: 519–543.

Hughes, G. M. 1966. The dimensions of fish gills in relation to their function. J. Exp. Biol., 45: 177–195.

Hughes, G. M. 1970a. Morphological measurements on the gills of fishes in relation to their respiratory function. Folia Morph., Praha, 18: 78–95.

Hughes, G. M. 1970b. Gill dimensions in relation to other respiratory parameters. Proc. IXth Int. Congr. Anat. Leningrad.

Hughes, G. M. 1972. Morphometrics of fish gills. Resp. Physiol., 14: 1–26.

Hughes, G. M. 1984. Measurement of gill area in fishes: Practice and problems. J. Mar. Biol. Ass. U.K., 64: 637–655.

Hughes, G. M., S. C. Dube and J. S. D. Munshi. 1973. Surface areas of the respiratory organs of the climbing perch, *Anabas testudineus*. J. Zool., Lond., 170: 227–243.

Hughes, G. M. and I. E. Gray. 1972. Dimensions and ultrastructure of toad fish gills. Biol. Bull. Mar. Biol. Lab., Woods Hole, 143: 150–161.

Hughes, G. M. and M. Morgan. 1973. The structure of fish gills in relation to their respiratory function. Biol. Rev., 45: 419–475.

Hughes, G. M., B. R. Singh, G. Guha, S. C. Dube and J. S. D. Munshi. 1974. Respiratory surface areas of an air-breathing siluroid fish. *Saccobranchus* (=*Heteropneustes*) *fossilis* in relation to body size. J. Zool., Lond., 172: 215–232.

Jager, S. de and W. J. Dekkers. 1975. Relations between gill structure and activity in fish. Netherland. J. Zool., 25: 276–308.

Landolt, J. and L. C. Hill. 1975. Observations on the gross structure and dimensions of the gills of three species of gars (Lepisosteidae). Copeia, 1975(3): 470–475.

Milton, P. 1971. Oxygen consumption and the osmoregulation in the shanny, *Blennius pholis*. J. Mar. Biol. Ass. U.K.,'51: 247–265.

Muir, B. S. 1969. Gill dimensions as a function of fish size. J. Fish. Res. Bd. Can., 26: 165–170.

Muir, B. S. and G. M. Hughes. 1969. Gill dimensions for three species of tunny. J. Exp. Biol., 51: 271–285.

Munshi, J. S. D., J. Ojha and A. L. Sinha. 1980. Morphometrics of the respiratory organs of an air-breathing catfish, *Clarias batrachus* (Linn.) in relation to body weight. Proc. Indian Natn. Sci. Acad., B46: 621–635.

Nimi, A. Z. and S. L. Morgan. 1980. Morphometric examination of the gills of walleye, *Stizostedian vitreum vitreum* (Mitchell) and rainbow trout, *Salmo gairdneri* (Richardson). J. Fish. Biol., 16: 685–692.

Oikawa, S. and Y. Itazawa. 1985. Gill and body surface areas of the carp in relation to body mass, with special reference to the metabolism size relationship. J. Exp. Biol., 117: 1–14.

Ojha, J. and J. S. D. Munshi. 1974. Morphometric studies on the gill and skin dimensions in relation to body weight in a fresh-water mud eel, *Macrognathus aculeatum* (Bloch). Zool. Anz. Jena, 193: 364–381.

Price, J. W. 1931. Growth and gill development in the small mouthed black bass, *Micropterus dolomieu* Lacepede. Ohio St. Univ. Stud., 41: 1–46.

Roy, P. K. and J. S. D. Munshi. 1984. Oxygen uptake in relation to body weight and respiratory surface area in *Cirrhinus mrigala* (Ham.) at two different seasonal temperatures. Proc. Indian Natn. Sci. Acad., B50: 387–394.

Saunders, R. L. 1962. The irrigation of gill as in fishes. II. Efficiency of oxygen uptake in relation to respiratory flow, activity and concentrations of oxygen and carbondioxide. Can. J. Zool., 40: 817–862.

Sharma, S. N., G. Guba and B. R. Singh. 1982. Gill dimensions of a hill-stream fish, *Botia lohachata* (Pisces: Cobitidae). Proc. Indian Natn. Sci. Acad., B48: 81–91.

Tamura, O. and T. Moriyama. 1976. On the morphological feature of the gill of amphibious and air-breathing fishes. Bull. Fac. Fish. Nagasaki Univ., 41: 1–8.

Ursin, E. 1967. A mathematical model of some aspects of fish growth respiration and mortality. J. Fish. Res. Bd. Can., 24: 2355–2453.

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淡水メジャーカープ *Cirrhinus mrigala* の呼吸器官の形態計測値と体重の関係

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体重 5.0–1820.0 g の淡水メジャーカープ *Cirrhinus mrigala* の鰓表面積を計測し，その結果を log Y = log a + b log W (Y: 計測値，W: 体重) の式によって分析した．回帰直線の傾斜は，全鰓面積については 0.8158, 第一ないし第四鰓弓の鰓面積についてはそれぞれ 0.8013, 0.8068, 0.8157 および 0.8457 であった．二次鰓弁は，総数 178,887.98 その傾斜 0.3151，両面面積平均値についての傾斜 0.5007 であった．

これらの結果は，鰓弓間で鰓要素の発達様式に相違があることを示している．二次鰓弁密度についての傾斜は −0.1287，体重 1g 当り鰓面積についての傾斜は −0.1842 であり，これらの結果は酸素摂取量について知られている事実と共に，大型魚は単位体重当り酸素消費量が小型魚より少ないことを示唆するものである．ブアン液固定による収縮率は，鰓弁長について 3.05±0.47%，二次鰓弁の両面面積平均値について 15.19±3.48% であった．