Japanese Journal of Ichthyology
Vol. 38, No. 3 1991

魚類学雑誌
38巻3号 1991年

Gross Structure and Dimensions of the Gills in a Hill-Stream Sisorid Catfish, *Glyptothorax pectinopterus*

Arun Kumar Sinha, Indrajit Singh
and B. R. Singh

Department of Zoology, Bihar University, Muzaffarpur, Bihar, India

Abstract Gross structure and dimensions of the gills have been examined in a hill-stream sisorid catfish, *Glyptothorax pectinopterus*, which remains adhered to rocks by means of an adhesive organ developed on the ventral side of the thorax. The fish shows a greater weight-specific gill area and greater length of the gill filaments by comparison with other hill-stream fishes. Adaptation for life in a hill-stream habitat is shown by the presence of additional filaments on the gills and patches of specialised cells on the filament epithelium.

Glyptothorax pectinopterus (Siluriformes: Sisoridae) is a water-breathing hill-stream fish found in Uttar Pradesh, Bihar, Bengal and Nepal. Individuals descending into the lakes and calmer waters of the plains look somewhat different from those inhabiting rapid streams. The fish attaches itself to the rocky bottom by means of an adhesive organ developed on the ventral side of the thorax. The adhesive organ consists of alternating longitudinal ridges and grooves, and provides a firm grip for the fish whilst adhering to rocks in torrential streams (Sinha et al., 1990).

Investigations on the structure and dimensions of the gills of hill-stream fishes are few. Some of the studies made during recent years include those on the gill dimensions of three species of loaches, i.e., *Noemacheilus barbatulus*, *Cobitis taenia* (Robotham, 1978) and *Botia lohachata* (Sharma et al., 1982), an intestinal air-breathing loach, *Lepidocephalichthys guntea* (Singh et al., 1981) and the cyprinid *Garra lamta* (Ojha et al., 1982). The results indicate that marked inter- and intra-specific variations occur in the respiratory surface area of the gills of fishes inhabiting different ecological niches. This investigation aims at describing the functional relationships existing between various parameters of the gills of *G. pectinopterus*, which usually remains attached to rocks in torrential streams, showing little mobility.

Materials and methods

Gills were fixed in aqueous Bouin's solution and their dimensions were measured by dividing each gill arch into different sections at intervals of 5 or 10 filaments. An average filament length was determined for each section. The total number of gill filaments and the number of secondary lamellae/mm occurring along the length of each filament were counted under an Ermascope. The average bilateral surface area of secondary lamella was determined with the help of camera lucida diagrams made on hand cut sections from the tip, middle and base of a filament.

The gill area was calculated using the equation of Hughes (1966):

$$\text{Gill area} = (2L/d')bl$$

where L = total length of filaments;
l/d' = spacing (no./mm) of secondary lamellae on one side of a gill filament;
and bl = average bilateral surface area of the secondary lamellae.

Measurements of the gill dimensions were made on 25 specimens of *G. pectinopterus* varying in weight from 2.05 to 7.97 g and body length 6.30 to 9.70 cm and classified into 5 weight groups. Various gill parameters (Y) such as total filament length, number of secondary lamellae/mm, average area of the secondary lamellae and total gill area were plotted on a double logarithmic grid against body weight (W) and analysed using the equation,

$$\text{Log}\,Y = \text{Log}\,a + b \cdot \text{Log}\,W$$

Fixation of the gills in aqueous Bouin's solution caused nearly 5% shrinkage and the data presented here for gill dimensions have not been corrected for

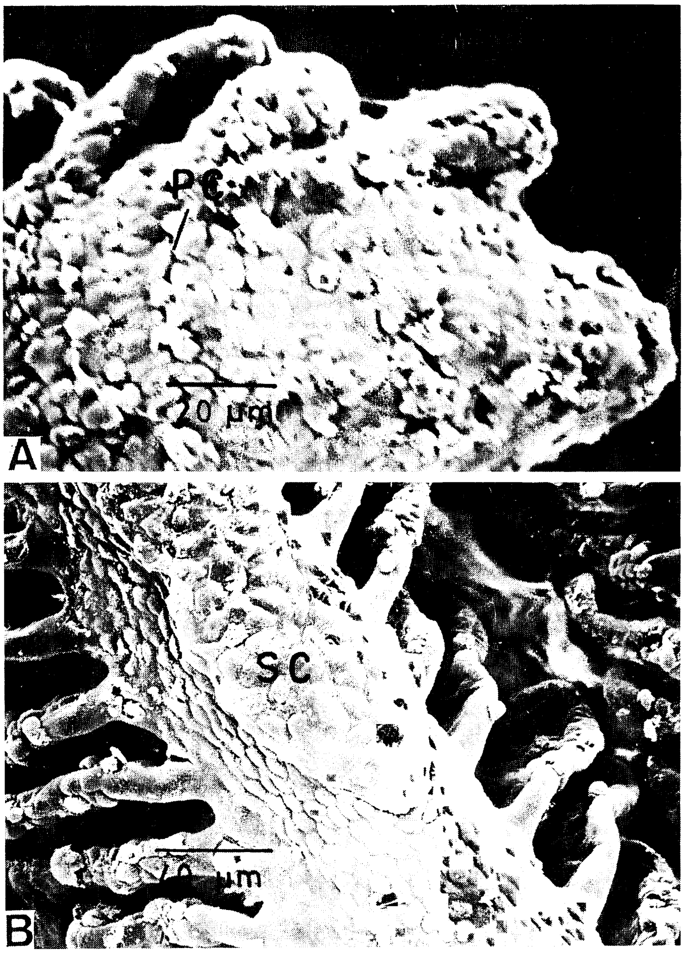

Fig. 1. A: SEM of a gill filament showing pavement cells (PC) ×720. B: SEM of the proximal end of a gill filament showing specialized cells (SC) ×360.

this shrinkage. However, such a shrinkage did not affect the estimate for the number of secondary lamellae since its effects were automatically compensated for by a corresponding increase in the frequency of secondary lamellae.

For Scanning Electron Microscope (SEM) studies, gill tissues were fixed in 2.5% glutaraldehyde in 0.1 M phosphate buffer (pH 7.4) at 4℃ for 24 hours. The fixed tissues were then washed in 2–3 changes of 30 min each in phosphate buffer and dehydrated in a graded alcohol series. The tissues were immersed in amylacetate before exposure to critical point drying using CO_2 as the transitional medium. Dried tissues were mounted on brass stubs with the aid of double sided tape, and then sputter-coated with gold in a gold coating unit. Examination was by a P SEM 500. Photographs were taken at 25 KV with a spot size of 320 A at the Bose Research Institute, Calcutta.

Results

The gill structure of *G. pectinopterus* is almost identical to that of a generalized teleost as described by Hughes (1984). However, it shows some anatomical adaptations which are particularly suited to the rapidly flowing water of the hill-streams in which it lives. The gills are characterized by additional filaments or secondary filaments, which are mostly found in the 3rd and 4th gill arches.

The gill arches are provided with well developed gill rakers, taste buds and mucous cells. The gill filaments are covered by stratified epithelium containing pavement cells, which imparts a beaded appearance under SEM (Fig. 1A). At the proximal end, a few specialized cells grouped together are clearly distinguished from the other epithelial cells on the afferent side of the filament edge (Fig. 1B). The gill lamellae are wing-shaped structures. The sieve diameters between the lamellae are small.

The data obtained on gill dimensions for 5 different weight groups of *G. pectinopterus* have been summarised in Table 1. In Table 2, the gill area and other parameters of *G. pectinopterus* are compared with those of other hill-stream fishes.

The total gill area for a fish weighing 4.36 g was 4849.31 mm^2. The slope of the gill area vs body weight was 0.51. Among the individual gill arches, the slope for the 3rd gill arch was the highest (b= 0.50). The average weight-specific gill area (gill area/g body weight) for the fish was 1257.68 mm^2.

Regression analysis showed that the weight-specific gill area decreased with an increase in body weight by a power function of −0.49. Similar relationships were also shown by the weight-specific gill area of the individual arches.

The slope for filament length was higher (b=0.45) by comparison with those of the filament number (0.15), total number of secondary lamellae (0.32) and average bilateral area of secondary lamellae (0.17). The number of secondary lamellae/mm was inversely correlated (b=−0.11) with the body

Table 1. Gill parameters of *G. pectinopterus*.

Sl. No.	Body weight (g)	Body length (cm)	Total No. of filament	Average filament length (mm)	Total filament length (mm)	Secondary lamellae/mm on both sides of a filament	Total No. of secondary lamellae	Average bilateral surface area of secondary lamellae (mm^2)	Total gill area (mm^2)	Gill area/g body weight (mm^2)
1.	2.05	6.30	512	1.6	805.4	69.4	55770.9	0.058	3219.8	1570.6
2.	2.57	7.00	584	1.7	1024.2	69.0	70457.2	0.061	4306.9	1675.8
3.	3.38	7.60	604	1.7	1057.7	61.4	65016.2	0.062	4039.4	1196.0
4.	5.86	8.70	652	2.1	1397.3	60.2	84109.3	0.066	5640.1	962.4
5.	7.97	9.70	652	2.3	1557.9	60.4	94268.8	0.074	7040.1	883.3
Av.	4.366	7.86	600.8	1.9	1168.5	64.1	73924.5	0.064	4849.3	1257.6
S.E.	1.113	0.6054	25.9052	0.1	134.2	2.0	6850.5	0.002	1227.6	158.7

Table 2. Comparison of the gill parameters in some hill stream fishes. Respective slope values are given in the brackets. Body weight * 1.0 g, ** 1.25 g, *** 4.1 g.

Fish species	Total No. of filaments	Aserage length of filaments (mm)	Total filament length (mm)	Secondary lamellae/mm on both sides of a filament	Total No. of secondary lamellae	Average surface area of a secondary lamellae (mm^2)	Total gill area (mm^2)	Gill area/g body weight m^2/g	References
*Lepidocephalichthys guntea**	372.2 (0.16)	0.70 (0.47)	264.6 (0.63)	90.01 (−0.22)	23800 (0.41)	0.020 (0.32)	493.6 (0.74)	492.1 (−0.25)	Singh et al. (1981)
*Botia lohachata**	517.4 (0.06)	1.27 (0.29)	661.5 (0.29)	77.96 (−0.005)	51570.0 (0.28)	0.017 (0.41)	913.3 (0.69)	907.1 (−0.29)	Sharma et al. (1982)
*Nemacheilus barbatulus***			207.2	72.8		0.051	770.8	616.6	Robotham (1978)
*Cobitis taenia**			218.4	91.0		0.020	413.4	413.4	Robotham (1978)
*Garra lamta****	796	1.52	1210.9	66.06	79999.61	0.016	1317.59	321.36	Ojha et al. (1982)
*Glyptothorax pectinopterus**	483.7 (0.15)	1.276 (0.28)	617.4 (0.45)	74.45 (−0.11)	46834.4 (0.32)	0.051 (0.17)	2333.3 (0.51)	2372.9 (−0.49)	Present authors

weight.

Discussion

Morphometric analysis of the different parameters of the gills in *Glyptothorax pectinopterus* revealed some interesting features correlated with the life style of a hill-stream inhabiting fish. The different parameters of the gills in which such adaptations are well documented are the number of gill filaments and their length, the number of secondary lamellae/mm and their surface area and, consequently, the total gill area of the fish.

The gill area in *G. pectinopterus* is higher than that of the bimodal breather, *Lepidocephalichthys guntea* (Singh et al., 1981) because of a greater number of gill filaments as well as greater length in the former. Its gill area is also higher in comparison to some totally aquatic breathers like *Botia lohachata* (Sharma et al., 1982) and *G. lamta* (Ojha et al., 1982), although the latter have a greater number of gill filaments and greater filament length. As for individual gill arches, the number of gill filaments is almost equal on the first two gill arches, but more on the third arch. The number is much reduced on the fourth gill arch. The slope for the number of gill filaments in relation to body weight ($b=0.15$) is almost similar to that of the freshwater cobitid *L. guntea* (Singh et al., 1981). The filament length is almost equal to that of *B. lohachata* (Sharma et al., 1982) but smaller than *G. lamta* (Ojha et al., 1982). The slope of the filament length is smaller (Table 2) compared with that of *L. guntea* (Singh et al., 1981).

The average number of secondary lamellae/mm on a gill filament (64.11) or its value obtained through regression analysis for a 1 g fish (74.45), is lower compared with the cobitids but higher than the cyprinid fishes studied (Table 2). The number of secondary lamellae/mm on a gill filament was reported by Gray (1954) and Hughes (1966) to be 62 in active and pelagic mackerel, 22–24 in sluggish and benthic species and 44 in intermediate species (sensu Grey, 1954). Using such criteria, *Glyptothorax* can be considered to lead an active mode of life. However, the fact remains that the fish is adhered to rocks for most of the time and shows but little mobility during the night when capturing food organisms.

The gill area of the fish ($2333.3\,mm^2$) is comparatively higher due to a larger bilateral surface area of the secondary lamellae ($0.05\,mm^2$). The acquisition of a greater gill area by *Glyptothorax* is advantageous for the fish in extracting O_2 from rapidly-flowing, O_2-rich water of hill streams, and meets its O_2 demand, even though the fish usually remains motionless.

The slope of the gill area (0.51) in relation to body weight differs considerably from other teleosts. The exponents reported for the gill area in fishes are known to range from 0.5 to 1.0 (Hughes, 1972). A lower exponent in *Glyptothorax* (0.51) is strongly consistent with a slower rate of increase in the gill surface area.

It can be concluded that adaptation of the gills of *G. pectinopterus* for life in a hill-stream habitat, where the fish normally remains adhered to rocks, is strongly expressed by the presence of a large number of elongated gill filaments and consequently a greater respiratory surface area of the gills. The presence of additional gill filaments is an adaptation for life in rapidly-flowing water.

Literature cited

Gray, I. E. 1954. Comparative study of the gill area of marine fishes. Biol. Bull., 107: 219–225.

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

Hughes, G. M. 1972. Morphometrics of fish gill. Respir. Physiol., 14: 1–25.

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

Ojha, J., N. C. Rooj and J. S. D. Munshi. 1982. Dimensions of the gills of an Indian hill-stream cyprinid fish *Garra lamta.* Japan. J. Ichthyol., 29(3): 272–278.

Robotham, P. W. J. 1978. The dimensions of the gills of two species of loach, *Noemacheilus barbatulus* and *Cobitis taenia.* J. Exp. Biol., 76: 181–184.

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

Singh, B. R., A. N. Yadav, J. Ojha and J. S. D. Munshi. 1981. Gross structure and dimensions of the gills of an intestinal air-breathing fish (*Lepidocephalichthys* guntea). Copeia, 1981(1): 224–229.

Sinha, A. K., I. Singh and B. R. Singh. 1990. The morphology of the adhesive organ of the sisorid fish *Glyptothorax pectinopterus.* Japan. J. Ichthyol., 36(4): 427–431.

(Received October 23, 1990; accepted May 17, 1991)

渓流性ナマズ目魚類 *Glyptothorax pectinopterus* の鰓の構造と計測的諸形質

Arun K. Sinha·Indrajit Singh·B. R. Singh

体前部腹側の付着器官により岩に付着して生活する *Glyptothorax pectinopterus* の鰓の構造と計測的諸形質を調べた．本種は他の渓流性魚類に比べ単位体重当りの鰓面積が広く，鰓弁長が長く，渓流生活への適応を示唆している．