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ADAPTIVE ROLE OF PECTORAL FIN IN FISHES OF HILL-STREAMS

G. M. Yazdani

Zoological Survey of India, Gangetic Plains, Regional Station, Patna

ABSTRACT

Observations have been made on the shape, size and position of pectoral fins in different groups of hill-stream fishes. Different functions of pectoral fin among bony fishes have been reviewed and their adaptive role pointed out. Correlation has been established between pectoral fin pattern and mode of living in hill-stream fishes. It has been concluded that in all the bottom-living hill-stream fish the pectoral fin has acquired a particular type of inclination which is quite suitable to utilise the force of water current for pressing the body further against the substratum.

Introduction

The torrential streams of hills and mountain ranges offer an unusual environment to which many fishes have successfully adapted by evolving mechanical devices to resist the force of current. The structural modifications resulting from such conditions have involved, among others, certain modifications of pectoral fins for taking up entirely new functions such as lateral support at the bottom and development of adhesive structures on their ventral side. In addition, the pectoral fin by virtue of its position and inclination on the body appears to play a definite role, the adaptive significance of which is not properly understood. This paper is mainly concerned with this aspect of pectoral fin function in hill-stream fishes.

Material and Method

Specimens of the following hill-stream fishes have been examined.

Cyprinidae

Barilius bola Hamilton
Schizothorax richardsonii (Gray)
Garra gotyla (Ham.)
Crossocheilus diplochilus (Heckel)

Cobitidae

Noemacheilus multifasciatus Day

Homalopteridae

Bhavania australis (Jerdon)

Sisoridae

Glyptothorax brevipinnis Hora
Pseudecheneis sulcatus (McClelland)

In most species, mode of living and pectoral fin movements have been observed in the field. In some species, these observations have also been confirmed by keeping specimens in an aquarium. Information on the mode of life of *Bhavania australis* has been obtained from published work (Hora, 1933).

The illustrations have been drawn free hand and are semidiagrammatic. The paired fins are shown partially spread out in the position of rest.

THEORY

Among free-swimming teleosts, pectoral fin is useful in such manoeuvres as climbing, diving, banking and braking. In primitive bony fish such as *Salmo* they are placed low on the body, ventral to the centre of gravity. When the pectoral fins are in this position a fish which brakes by spreading its pectoral fin outwards must either make a pitching movement or else rise bodily in water as it stops. If the pectoral fins are spread vertically so that the force on them consists entirely of horizontal drag it will pitch, with its head sinking and its tail rising. If, however, they are held at such an angle that they produce lift as well as drag, and the resultant force on them acts through the centre of gravity of the fish there will be no tendency to pitch, but the fish will rise in water as it stops. While braking a fish cannot stop without pitching or rising unless other fins are used with the pectorals or the pectorals lie on the same plane as the centre of gravity (Alexander, 1967).

If the pectorals are spread out in such a way that their spine-supported leading edges are higher than the trailing edges, the fish would experience lift during swimming. Similarly, if the pectorals are spread out in such a way that their trailing edges are higher than the leading edges the fish would experience downward pull. Accordingly, the fishes living at the bottom of fast stream are also likely to experience lift or downward pull depending on the inclination of their pectorals on the body, because the principle of hydrodynamics is same whether a body moves under water or water moves over a stationary body.

Figure 1 gives a diagrammatic representation of pectoral fin inclination in fishes. The pectorals are shown in resting position and are assumed to lie in the same level as the centre of gravity of the fish. Now suppose the fish in Fig. 1(a) to 1(c) start swimming. If the fish in Fig. 1(a) spreads its pectorals, it would stop without pitching or rising. If the fish in Fig. 1(b) spreads its pectorals, it would either stop with rising or experience lift during swimming. If, however, the fish in Fig. 1(c) spreads its pectorals, it would either stop with sinking or experience downward pressure during swimming. In case the fish in Fig. 1(c) stays at the bottom of a fast stream it would also experience a downward pull so long as its pectorals are spread out.

MODE OF LIVING

Three main factors *viz.*, strength of current, abundance of oxygen and nature of food have been mainly responsible for adaptation and adaptive radiation in fishes of hill-streams (Hora, 1930). Based on the mode of life, these fishes can be conveniently divided under the following two categories :

I. *Free-swimming fishes* : These fish occur in pools, pot-holes in the bed of stream and along the edges of stream. They are affected by the swiftness of current and on the rush of water seek shelter under rocks and stones at the bottom or hide under crevices along the edges of streams. They are capable of progressing against the current. Examples are species of *Tor*, *Acrossocheilus*, *Barilius* and *Schizothorax.*

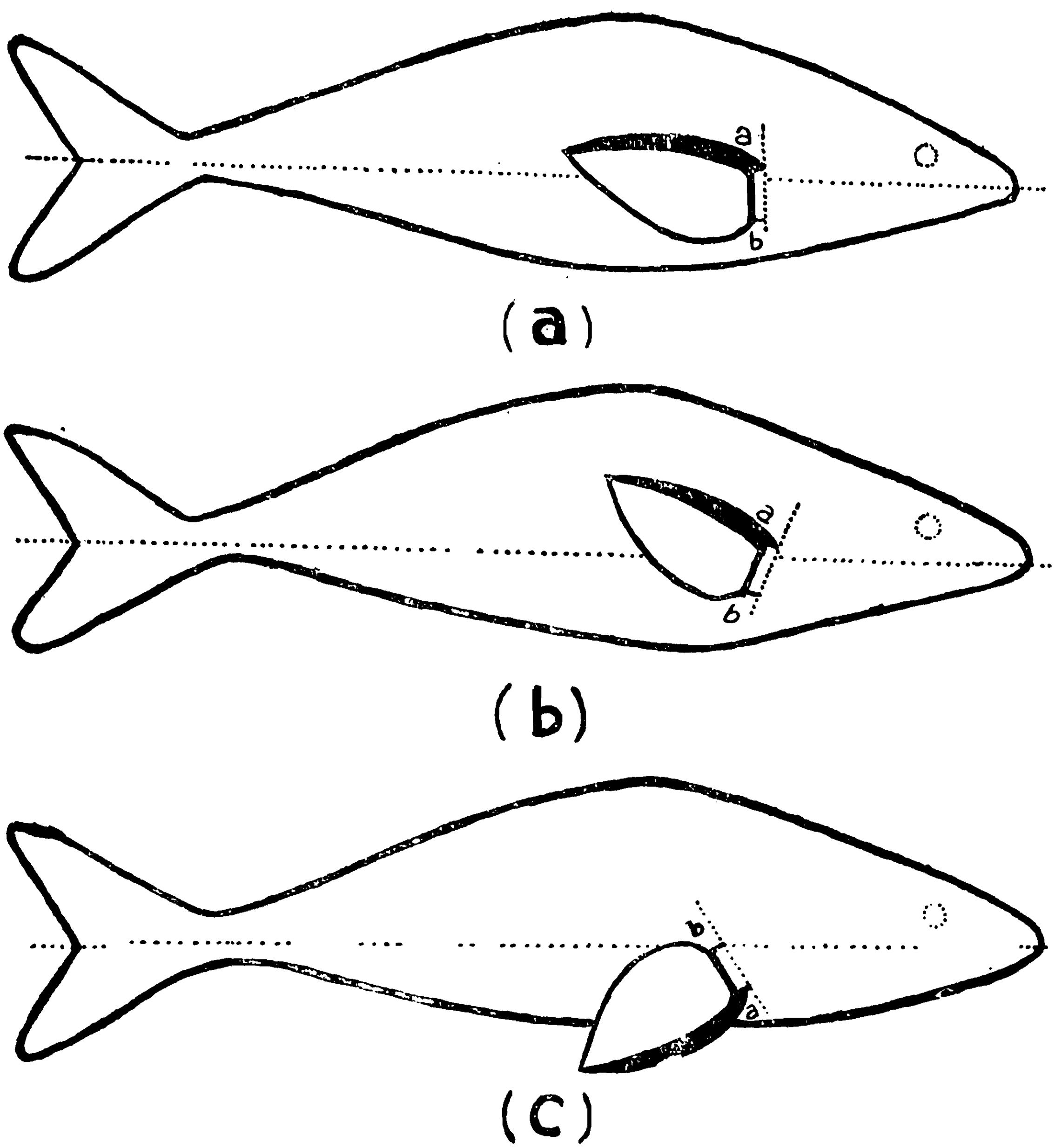

Fig. 1. Diagrammatic lateral view of fishes showing different types of pectoral fin inclination and angle of insertion on the body (a-b, axis of fin insertion). (a), a-b almost at right angles to the body axis ; stiff part of the fin uppermost. (b), a-b at an oblique angle to the body axis, stiff part of the fin uppermost. (c), a-b at an oblique angle to the body axis ; stiff portion of the fin lowermost.

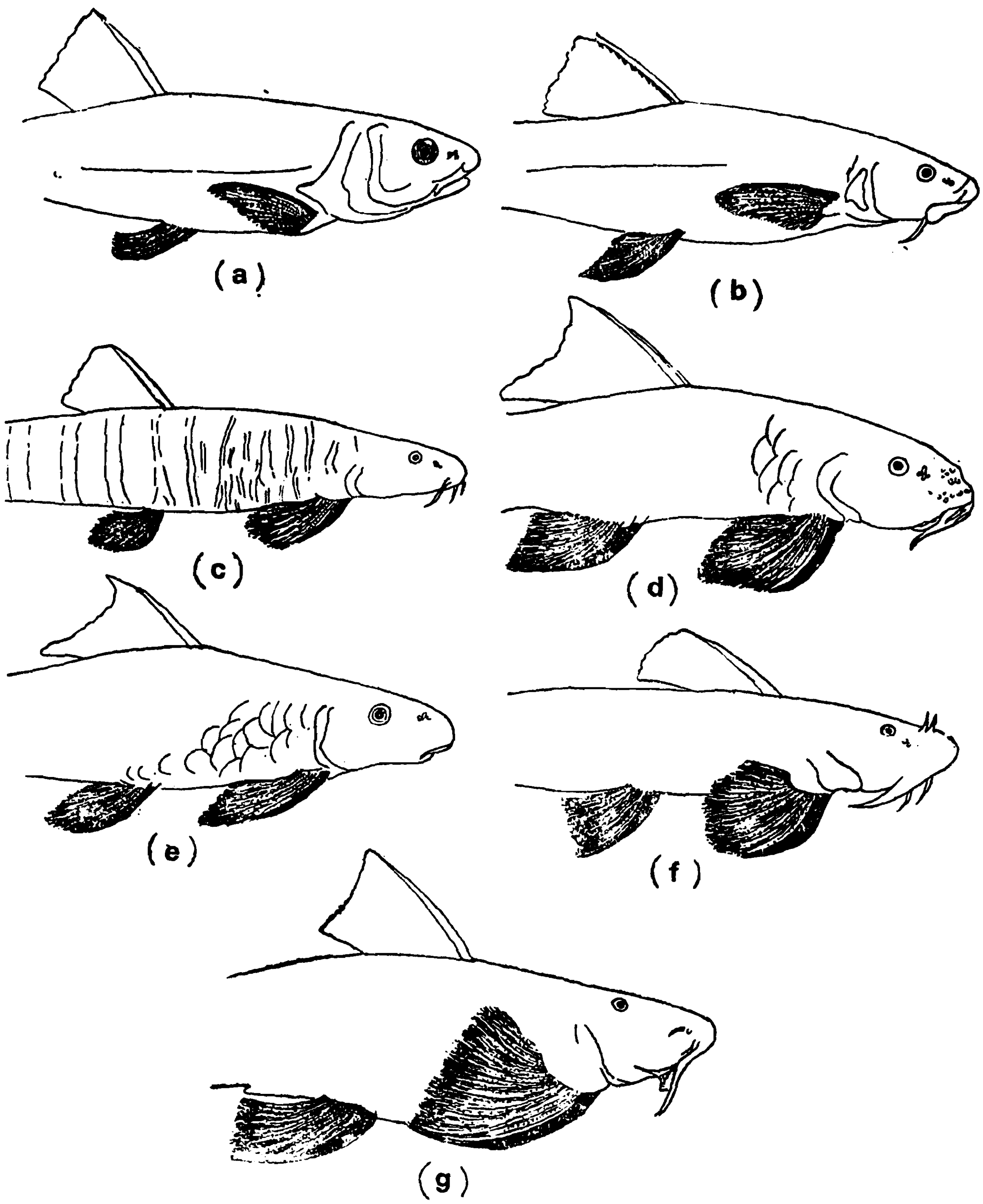

Fig. 2. Lateral view of some hill-stream fishes showing their paired fins. (a) *Barilius bola*, (b) *Schizothorax richardsonii*, (c) *Noemacheilus multifasciatus*, (d) *Garra gotyla*, (e) *Crossocheilus diplochilus*, (f) *Glyptothorax brevipinnis*, (g) *Pseudecheneis sulcatus*.

II. *Bottom-living fishes* : The fishes of this category spend most of their time at the bottom and adhere to the substratum by means of some adhesive device. Examples are species of *Botia*, *Noemacheilus*, *Bhavania*, *Garra*, *Crossocheilus*, *Glyptothorax* and *Pseudecheneis*.

PECTORAL FINS

The pectoral fins of each species will now be described (Fig. 2).

1. *Barilius bola* (Fig. 2a) : The pectoral fin of this fish is situated just near the lower edge of the body. It is moderate in size and contains 13 rays. Its axis of insertion is almost oblique to the body axis. The stiff leading edge of the fin is directed upwards.
2. *Schizothorax richardsonii* (Fig. 2b) : The pectoral fin of this species is rather similar to that of *Barilius bola.*
3. *Garra gotyla* (Fig. 2d) : The pectoral fin of this fish is situated almost on the ventral side. It is fairly well-developed and contains 15 rays. Its axis of insertion is almost parallel to the body axis. The stiff leading edge of the fin is directed forwards.
4. *Crossocheilus diplochilus* (Fig. 2e) : The pectoral fin of this species resembles that of *Garra gotyla*.
5. *Noemacheilus multifasciatus* (Fig. 2c) : The pectoral fin of this loach is situated quite low on the body. It is of moderate size and contains 11 rays. Its axis of insertion is almost parallel to the body axis. The stiff leading edge of the fin is directed almost forward.
6. *Bhavania australis* : The pectoral fin of this south Indian homalopterid fish is situated almost on the ventral side of the body. It is well-developed and contains around 20 rays. Its axis of insertion is oblique to the body axis in such a way that the stiff leading edge is somewhat directed downwards. When spread out, it appears more or less horizontally placed but its trailing soft edge is higher than the stiff leading edge.
7. *Glyptothorax brevipinnis* (Fig. 2f) : The pectoral fin of this species is fairly well-developed and contains strong, broad spine which is sharply denticulated ventrally, and 7 soft rays. It is placed low on the body, almost on the ventral edge. Its axis of insertion is almost horizontal to the long body axis. However, when the fin is spread out, the stiff spine-supported leading edge is somewhat directed downwards.
8. *Pseudecheneis sulcatus* (Fig. 2g) : The pectoral fin of this fish is very well-developed and contains a flattened, pectinated spine and 13 soft rays. Its axis of insertion is oblique to the long axis of the flattened body in such a way that the stiff spine-supported edge is directed downwards. When spread out, the trailing soft edge of the fin is much higher than the leading edge.

DISCUSSION

The pectoral fin of each species of hill-stream fish will now be discussed in relation to its mode of life.

Barilius bola and *Schizothorax richardsonii* have moderate sized pectoral fins. In both species the axis of fin insertion is oblique to the body axis and the stiff anterior edge is directed upwards. This type of pectoral fin inclination seems well-suited for free-swimming fishes.

In *Noemacheilus multifasciatus*, *Garra gotyla* and *Crossocheilus diplochilus* the axis of pectoral fin insertion is almost parallel to the body axis and the stiff anterior end of the fin is directed forwards. When the fin is spread out, its soft trailing edge is higher than its stiff leading edge, and as a result the fish experiences a downward pull which is advantageous for staying at the bottom of a fast stream. Since the pectoral fin is placed quite low on the body, these fish also appear to obtain lateral support by these fins and thus ensure a more stable equilibrium at the bottom.

In most other bottom-living forms such as *Bhavania australis*, *Glyptothorax brevipinnis* and *Pseudecheneis sulcatus* the pectoral fin inclination is such that the stiff leading edge always rests at the bottom and the soft trailing edge is kept well raised. As a result, these fish get the advantage of downward pull over their bodies in a fast stream. Since the pectoral fins are placed quite low on the body, they also provide lateral support and hence a more stable equilibrium. In some of these fish, certain adhesive structures are also present on their ventral side whichprovide them a firm grip over the substratum.

Conclusion

While evolution of depressed body with a broad and somewhat flat underside in fishes of hill-streams ensures a stable equilibrium at the bottom, the modification of pectoral fins with inclination shown in Fig. 1(c) further provides lateral support to the body and permits the fast current to hit the expanded pectoral fin in such a way that the fish would experience a downward push. Consequently, other adhesive and frictional structures present ventrally are likely to come into play and strengthen the grip over the bottom. The modification of pectoral fins to utilise the strength of current i.e. for adhering firmly at the bottom, seems to be one of the most remarkable features in the evolutionary history of hill-stream fishes.

Among the strictly bottom-living hill-stream fishes, the pectoral fins have to perform the following functions owing to their modification. 1. lateral support to the body for achieving stability at the bottom. 2. generation of downward pressure by a particular type of inclination of pectoral fin. 3. provision of sufficient space for the development of various frictional and adhesive structures (see Hora, 1930). 4. pumping out water from under side of the fish (see Hora, 1930).

It may now be concluded that among hill-stream fishes, the free-swimming forms possess moderate sized pectoral fins with axis of insertion placed at right angles or at an oblique angle to the long body axis and the stiff spine-supported leading edge directed upwards, whereas the strictly bottom-dwellers have developed rather large sized pectoral fins, with axis of insertion at an angle oblique to the body axis and the stiff spine-supported leading edge directed downwards.

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