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Morphological Study of Swim Bladder in Some Fishes Belonging to Family Cyprinidae and Cobitidae

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Abstract: Morphology and structure of swimbladder in three species of family cyprinidae and two species of family cobitidae has been studied. It was observed that a comparative study of swim bladder is very useful to establish the taxonomic position of fish. Remarkable differences were observed between the species of the two families.The swim bladder of Labeo calbasu was similar in shape with that of Puntius chonchonius but still the covering of the wall in the swim bladder of Puntius was single as compared to that of Calbasu. The gas secreting complex in Puntius was arranged as two red coloured patches whereas L.calbasu and Thynmichthys sandkhol such shows no distinct area. The Swim bladder of T.sandkhol was different from the other two as the posterior chamber bears a horn like extension on its left anterior corner.
The organ concerned was structurally different in Lepidocephalichthys sandkhol and Noemacheilus botia of the family cobitidae the swim bladder in L.sandkhol is double chambered and in N.botia it is single chambered. Though both of them were transversly placed and encapsulated.
Keywords: Swim bladder, Gas Secreting complex, Structure, Encapsulated,Chamber.

I. INTRODUCTION

The swim bladder or air bladder or gas bladder, one of the most characteristic organs of fishes is a hollow, oval shaped sac, situated in the abdominal cavity, below the vertebral column between the alimentary tract and kidneys.

The swim bladder acquires a glistening silvery shine and lies either free in the abdominal cavity or sometimes remain attached most intimately by firm and short tissues to the vertebral column, the walls of the abdomen and the intestine. It may be single chambered with a common lumen inside or it may be double chambered with a simple constriction. In many species of fish, the swim bladder remains connected to the gut and the fish can use this connection to control the amount of gas in the swim bladder, this is known as physostomous or open type swim bladder. These fish mostly live in shallow waters and swallow air at the surface of water. This air is then passed into the gut and then into the swim bladder.

In other species the connection with the gut is closed and no gas can be passed from the gut to the swim bladder, this is called the closed type or physoclistous swim bladder. These fish are able to control the amount of gas in their swim bladder by means of one or more areas where the membrane is very thin and richly supplied with capillaries. These area facilitate the gas exchange through the capillaries and the membrane by the formation of a gas secreting complex which comprises of a glandular secretory epithelium – the gas gland and rete mirabile i.e a bundle of close lying arterial and venous capillaries that diffuse gases between one another. The swim bladder helps the fish to attain neutral buoyancy, i.e. the ability to use little or no energy to stay at particular levels of water through the expansion (inflation) and contraction (deflation) of the swim bladder due to varying gas pressures (Schmidt and Nielson, 1997). The volume of the swim bladder is controlled by the expansion and contraction of muscles (Eissele, 1922).

The occurrence of swim bladder in Teleosteans is very irregular and shows some extra-ordinary modifications in its shape, size and location in the fish. The organ is unique and versatile owing to its variable structure and functionality and hence is a reason of attention from the past and even the present research is an approach to reveal the mysteries of its morphological diversity.

Woodland (1911, 1913) investigated the structure of the gas gland and retia mirabilia (rete mirabile) associated with the swim bladder in some teleostean fishes. He also presented notes on the structure and mode of action of the 'oval' in the Pollack (*Gadus pollachius*) and mullet (*Mugil chelo*) respectively. Scholander (1956) made observations on the gas gland in living fish. Dehadrai (1957) studied the swim bladder of mugilidae. Fahlen (1959) gave an account of the rete mirabile in the swim bladder of *Coregonus lavaretus*. Wittenberg *et al* (1964) have studied the unique structure of the gas secreting complex in the swim bladder of the bluefish, *Pomatomus saltatrix*. Jasinski (1965) reported the vascularization of the swim bladder in fishes, such as *Acipenser stellatus, Thymallus thymallus*, *Esox lucius* and *Umbra krameri*.

The relationship of shape and size of the swim bladder with the taxonomy or systematic position of the fish has been observed by Marshall (1960) in deep sea fishes, Greenwood (1963) in African Notopteridae, Ahmad (1971) in certain Sciaenoid fishes, Evans (1975) in four species of Western Atlantic *Peristedion,* Sujatha and Dutt (1985) in Sillaginidae, Hemalatha and Rajkumar (1996) in Cypriniformes.

The subject of swim bladder morphology and its correlation with the weberian ossicles and inner ear or auditory organ has been taken up by Starks (1908), Evans (1925,1930), Nelson (1949), Srivastava (1956), Karandikar and Masurekar (1954), O'connell (1955), Nayak and Bal (1955), Dehadrai (1957, 1959), Sinha (1962), Jasinski (1964), Mahajan (1967), Dixit and Sharma (1970), Allen *et. al*. (1976), Laming and Morrow (1981), Barimo and Fine (1998). The morphological aspect of the swim bladder has been a subject of attention from the very beginning. Some of the major contributions in this field are by :

Kahata (1981) observed differences in the swim bladder of three fishes of genus *Tribolodon.* Cruz-Hofling *et al.* (1981) gave an account of the morphological and histochemical observations on the swim bladder of obligate water breathing and a facultative air breathing fish. The swim bladder morphologies of nineteen species of midwater fishes have been studied by Neighbors and Nafpaktitis (1982). Ono and Poss (1982) traced out the structure and innervations of the swim bladder in *Cynoscion regalis*. Shao *et al*. (1986) compared the swim bladder morphology of various species from the family Sillaginidae.

Some recent investigations and elaboration on the subject is presented by Dallas and Page (2003) in *Percina;* Yamada *et al.* (2004) in *Anguilla japonica*; Carpenter *et al*. (2004) in *Kurtus gulliveri*; Finney *et al*. (2006) in *Danio rerio*; Clemens and Stevens (2007) in *Coregonus hoyi* and *Coregonus artedi*; Tibbetts *et al*. (2007) in *Oxyporamphus convexus* and Lechner and Ladich (2008) in some European catfishes.

II. MATERIALS AND METHODS

About 5 specimens of fish belonging to different orders and families were chosen for the present study. Live or freshly trapped fishes were collected from the fish markets of Khagaria, Katihar, Kahalgaon and Bhagalpur during different seasons of the year. They were immediately dissected in order to observe the organ concerned and its vascular supply in its natural condition.For the study of gross anatomy, mid ventral and lateral dissections of the fishes were made. The live specimens were first anaesthetized in MS_{222} and then dissected to study the structure and position, attachment and vascular network of the swim bladder. The swim bladder was exposed by removing the alimentary canal and fat surrounding them.

For further morphological studies, digital images of the fish, its swim bladder in situ and after removing it from the body cavity. Images of gas gland and the rete mirabile (i.e. the gas secreting complex) and the oval or the gas reabsorbing apparatus were taken with a Canon Power Shot A2000 digital camera. Further detailed studies of these vascularized smaller areas were made through a Binocular Microscope and images were also taken.

The swim bladder length along with the length and weight of the fish was carefully measured using a top pan balance and measuring scale. The morphometric details of the five fish studied during the present work are given in

Table-1.1. Given below is the list of different fishes that were examined during the present work for the study of their swim bladder according to the classification of Berg (1940) with some modifications as suggested by Jayaram (1981):

1) *Order* – Cypriniformes
2) *Family* – Cyprinidae
   a) Labeo calbasu
   b) Puntius conchonius
   c) Thynnichthys sandkhol
3) *Family* – Cobitidae
   a) Lepidocephalichthys guntea
   b) Noemacheilus botia

III. OBSERVATIONS

A. *Labeo Calbasu (Ham.)*

Labeo calbasu is a fresh water teleost belonging to family Cyprinidae of the order Cypriniformes (Plate - I, fig. 1). In *Labeo calbasu*, the swim bladder is a milky white double chambered structure situated longitudinally between the alimentary canal and above the vertebral column. It is the largest organ in its viscera occupying almost full length and half the breadth of the body cavity. The anterior chamber of the swim-bladder is short and is almost half the length of the posterior chamber in size. It is more or less oval in shape. Its wall comprises of two layers, the outer layer is relatively thick and leathery and the inner layer is thinner and transparent in nature.

The outer layer is termed as tunica externa and the inner layer is known as the tunica interna. The anterior chamber bears two openings: one at the anterior end (AO) and other at the posterior end (PO), also known as ductus communicans (DC) (Plate - I, fig. 2 & 3), that serves as a link between the anterior and posterior chambers.

The posterior chamber is an elongated sac like structure, bigger than the anterior chamber. It is cylindrical in shape but the anterior end is broader than the posterior end (Plate - I, fig. 2 & 3). The chamber slowly tapers downwards to form a very narrow tip. It is made up of a single layered wall, the tunica interna and the external covering or the tunica externa is absent in this chamber. The posterior chamber is connected to the alimentary canal by a pneumatic duct, which is situated on the left side of the anterior end, very close to the ductus communicans (shown in figure 3). Thus, the swim bladder is physostomous in nature.

There is no distinct gas secreting complex in its swim bladder. However, the vascular supply is very distinct on the entire length of the lower chamber. Two branches of blood vessels diverge downwards after starting from the junction of the upper and lower chamber and ramify into many small blood capillaries. The blood capillaries are thick at the proximal end and gets thinner on reaching the distal or lower end of the lower chamber. When the lower chamber is cut and spread open, the two lateral branches of blood vessels form a ‘V’ shaped structure because the tip of both the lateral branches unite almost at the distal end (Plate - I, fig. 5).

The anterior chamber is also vascularized from the internal side. The blood capillaries are situated on the outer side of the tunica interna, which remains covered by the tough layer of tunica externa. The two layers are in close association and hence, the blood capillaries are not visible from either side (Plate - I, fig. 4).

B. Puntius Conchonius (Val.)

Puntius conchonius is a fresh water teleost belonging to family Cyprinidae of the order Cypriniformes (Plate - II, fig. 1). In *puntius conchonius* the swim bladder is a milky white double chambered structure situated longitudinally between the alimentary canal and above the vertebral column. It is the largest organ in its viscera occupying almost full length and half the breadth of the body cavity. The anterior chamber of the swim bladder is short and is almost half the length of the posterior chamber in size. It is more or less oval in shape. Its wall comprises of two layers, the outer layer (tunica externa) is relatively thick and leathery and the inner layer (tunica interna) is thinner and transparent in nature. The tunica externa bears two openings: One at the anterior end (AO) and the other at the posterior end (PO). From the posterior end passes the ductus communicans (DC) (Plate - II, fig. 2 & 3), that serves as a link between the anterior and posterior chambers.

The posterior chamber is an elongated sac like structure, bigger than the anterior chamber. It is cylindrical in shape but the anterior end is broader than the posterior end (Plate - II, fig. 2 & 3). The chamber slowly tapers downwards to form a very narrow tip. It is made up of a single layered wall, the tunica interna and the external covering or the tunica externa is absent in this chamber. The posterior chamber is connected to the alimentary canal by a pneumatic duct, which is situated on the left side of the anterior end, very close to the ductus communicans. Thus, the swim bladder is physostomous in nature.

The gas secreting complex is situated on the posterior chamber of *Puntius chonchonius* in the form of two red coloured patches closely placed together. This arrangement is characteristic of the genus *Puntius* and is different from the members of the family where it forms a branching pattern. It signifies the position of the gas gland or the ‘red gland’ and the aggregation of arteries and veins at a single point.

C. Thynnichthys Sandkhol (Skyes)

Thynnichthys sandkhol is a fresh water teleost belonging to family Cyprinidae of the order Cypriniformes (Plate - III, fig. 1). In *Thynnichthys sandkhol* the swim-bladder is a milky white double chambered structure situated longitudinally between the alimentary canal and the vertebral column. It is the largest organ in its viscera occupying almost three-fourth length and half the breadth of the body cavity. The anterior chamber of the swim bladder is short and is almost three-fourth the length of the posterior chamber in size. It is more or less oval in shape. Its wall comprises of two layers, the outer layer is relatively thick and leathery and is known as tunica externa while the inner layer, the tunica interna is thinner and transparent in nature. The outer layer is termed as tunica externa and the inner layer is known as the tunica interna. The tunica externa bears two openings: One at the anterior end (AO) and the other at the posterior end (PO). From the posterior end passes the ductus communicans (DC) (Plate-III, fig. 2 & 3), which is an opening that serves as a link between the anterior and posterior chambers.

The posterior chamber is an elongated sac like structure, bigger than the anterior chamber. It is cylindrical in shape but the anterior end is broader than the posterior end (Plate - III, fig. 2 & 3). The chamber slowly tapers downwards as a narrow tip. It is made up of only, the tunica interna while the external covering or the tunica externa is absent in this chamber.

The posterior chamber is connected to the alimentary canal by a pneumatic duct, which is situated on the left side of the anterior end, very close to the ductus communicans. Thus, the swim bladder is physostomous in nature. The shape of its posterior chamber bears a horn like extension on its left anterior corner. The right side does not bear any such extension. It is a characteristic feature of this particular fish.

D. Lepidocephalichthys Guntea (Ham.)

Lepidocephalichthys guntea is a fresh water teleost belonging to family Cobitidae of the order Cypriniformes (Plate - IV, fig.1). The swim bladder of *Lepidocephalichthys guntea* is small sized, rudimentary structure, deeply seated in the body cavity. It is transversely located in the upper part of the body cavity (Plate - IV, fig. 3). It remains enclosed in a hard bony covering hidden under a thick band of muscles and can be visible only after the removal of these muscles. This bony covering which remains attached with the 3rd vertebrae bears a white coloured, transparent, round shaped swim bladder within it. Thus, it is surrounded by the vertebral column on its dorsal side and the alimentary canal on its ventral aspect. It is pear shaped from external appearance and is little bulged outwards towards the alimentary canal (Plate - IV, fig. 2). It is single chambered in design externally and is visible only after the rupture of the bony covering. No connection with the alimentary canal could be observed. The rete mirabile and gas gland areas are not discernible.

E. Noemacheilus Botia (Ham.)

Noemacheilus botia is a fresh water teleost belonging to family Cobitidae of the order Cypriniformes (Plate - V, fig.1). In *Noemacheilus botia* the swim bladder is situated transversely on the anterior half of its body near the pectoral fin base (Plate - V, fig.2). It is a greatly reduced, brownish coloured structure, encapsulated and deeply seated in the body cavity. The swim bladder remains hidden under the muscles and is comprised of two chambers, laterally placed to each other. The two chambers of the swim bladder are enclosed within a hard bony covering and remain connected to each other by a common transverse channel (Plate - V, fig. 3). The anterior regions of the chamber are round and bulging while the pointed tips are pointed and tapering in nature. Thus, the swim bladder acquires an inverted droplet like shape (Plate - V, fig. 3). The organ seems to have lost its hydrostatic function owing to its reduced structure.

Table -1.1 table showing the relationship between body weight, body length and swim bladder length of different fish species.

Order	Family	Name of fish	Body weight (g)	Total length (cm)	Standard length (cm)	Swim bladder length (cm)	Swim bladder / Standard Length(%)
Cypriniformes	Cyprinidae	*Labeo calbasu*	41.0	15.8	12.2	5.2	42.62
		Puntius conchonius	4.5	6.8	5.3	2.0	37.73
		Thynnichthys sandkhol	75.0	21.1	16.7	5.2	31.13
	Cobitidae	*Lepidocephalichthys guntea*	2.1	7.7	6.4	0.3	4.68
		Noemacheilus botia	3.5	7.5	6.3	0.6	9.52

IV. DISCUSSION

Seventeen specimen belonging to the order Cypriniformes and family Cyprinidae were observed during the present study. The swim bladder of carps or the members of family Cyprinidae have almost similar structural design. The structure is double chambered with both their chambers placed longitudinally one below the other and intercommunicated by a single opening. The common features of swim bladder found in all these species are : It is placed longitudinally above the alimentary canal and below the vertebral column, extending from the posterior region of the oesophagus to the anal region, occupying almost the full length and half the breadth of the body cavity.

The anterior chamber of the swim bladder measures nearly more than half the length of posterior chamber and is almost oval in shape. Its wall comprises of the thicker tunica externa and thinner tunica interna. The posterior chamber is longer than the anterior chamber. It is almost triangular in shape with few thick muscle bands. A pneumatic duct which connects it to the oesophagus is present on the anterior left side of the lower chamber.

Two main blood vessels were seen running on two sides of the posterior chamber from which finer blood capillaries radiate on the inner surface of the swim bladder. Bridge (1968) had also described the arrangement of blood capillaries in the form of fan like radiating tufts over almost the whole inner surface of the swim bladder. The swim bladders of *Labeo calbasu* (Plate - I, fig.5) shows a similar orientation of the blood vessels. The upper or the anterior chamber is vascularized by the ramifications of blood vessels running beneath the tunica externa. The posterior chamber shows an external arrangement of blood vessels in the form of two branches running on two sides of the swim bladder. These vessels converge downwards to form a V- shaped structure. The swim bladder of genus *Puntius* shows a bit different arrangement of blood vessels. The posterior chamber shows a red patch like arrangement of rete mirabile instead of a branching pattern (Plate - II, fig.3). It signifies the shape of a 'red gland' or an aggregation of arteries and veins at a single point. The structure of swim bladder in other speciese *Puntius filamentosus* had been described by Hemalatha and Rajkumar (1996), but they have not provided the details of vascularization. However, the other structural details corroborate the present findings.

The swim bladder of *Thynnichthys sandkhol* has a similar two chambered design but the posterior chamber bears a horn like extension on its left anterior corner (Plate - III, fig.3). This extension is however not present on the other side of the posterior chamber and is unique in its appearance.The swim bladder of cyprinids in general has been described by several authors such as Gunther (1880), Goodrich (1930), Shafi (2000) etc. as a double-chambered organ intercommunicated with each other. It is physostomous in nature i.e. having a pneumatic duct connecting the swim bladder with the alimentary canal.

The swim bladder of *Lepidocephalichthys guntea* of the family Cobitidae is a reduced, rudimentary structure, very deeply seated in the body cavity. The swim bladder remains enclosed in a hard bony covering, hidden under a thick band of muscles (Plate - IV, fig.3). It remains attached to the 3rd vertebrae. The bony covering encloses a white coloured, transparent, round shaped swim bladder beneath it. The bony covering is pear shaped with a convex surface whereas in *Noemachileus botia* it is double chambered structure enclosed within two bulging, inverted water droplet like bony covering connected by a common transverse canal (Plate - V, fig. 2). There is no trace of the rete mirabile and gas gland. It is presumed that the organ has lost its hydrostatic function may be due to its hillstream habitat and hence became encapsulated and reduced in both the species. However the shape of the swim bladder *N. botia* is similar to that of *N. triangularis* (Hemalatha and Rajkumar, 1996).

In the past several authors have correlated swim bladder with the taxonomic position of the fish: Marshall (1960), Greenwood (1963), Popova (1970), Ahmad (1971), Evans (1975), Dzhumaliyev (1978), Sujatha and Dutt (1985), Hemalatha and Rajkumar (1996). Gopalakrishan *et al.* (1970) have quoted that the fundamental similarities among animals are deep seated and the various internal structures show remarkable resemblances, though the animals may superficially look entirely unlike each other. Cain (1971) has ascertained that reliance on a single character will not only group together unrelated forms but may even get us into a position where we can produce no diagnosis at all. Though most of them are of the view that the method of classification of fishes based entirely on the external characters, especially the fin ray count, may not be accurate and so the study of internal structures as tools for establishing taxonomy should be given due consideration.

However, dependence on certain internal factors, apart from external features might create confusion regarding the pre-established tools of classification. If both external and internal features like fin-ray count, presence or absence of scales and swim bladder etc. might be used as tool it would be inappropriate. For e.g. the swim bladder of two cobitids (*N. botia and L. guntea)* are similarly encapsulated but externally the cobitids possesses scales. Both the features oppose each other hence these fishes could not be grouped together. It remains a question which of the tools is to be selected. If the morphological features of the swim bladder is considered in this context why not other organs be also compared. Thus, the introduction of swim bladder as a tool for the determination of taxonomic position does not seem appropriate.

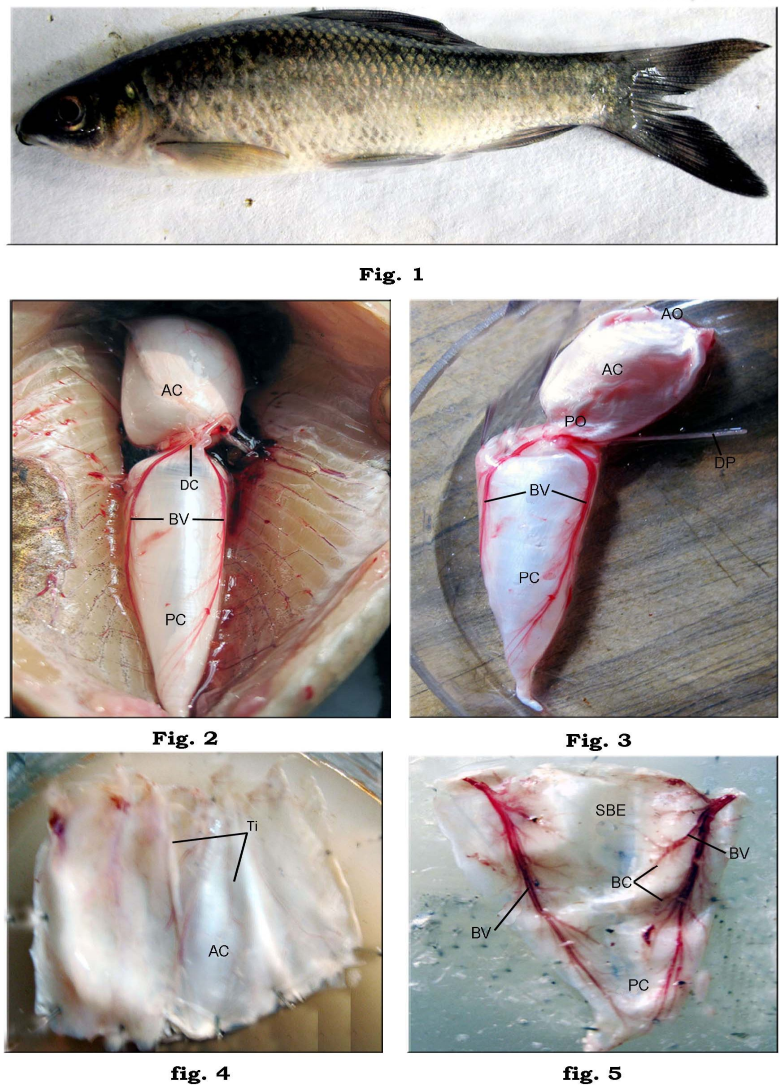
The relative swim bladder length with respect to standard length was measured in about fifty fish species which generally ranged between 30 - 65%. However, fishes belonging to family Cobitidae and of the order Siluriformes showed a reduced swim bladder and therefore the swim bladder percentage calculated was also lesser. The lowest value measured was for *L. guntea* (4.68%).

A. Abbreviations Used In Figure

1) *AC :* Anterior chamber
2) *AO :* Anterior opening
3) *BV :* Blood vessels
4) *DC :* Ductus communicans
5) *DP :* Ductus pneumaticus or pneumatic duct
6) *PC :* Posterior chamber

7) *PO :* Postrior openings
8) *SB :* Swim bladder
9) *SBE :* Swim bladder epithelium
10) *Ti :* Tunica interna
11) *GSC :* Gas secreting complex

PLATE - I



Swim bladder of *Labeo calbasu*

B. *Explanation of Figures*
1) *Fig.1:* Labeo calbasu
2) *Fig.2:* Ventral view of the swim bladder in situ.
3) *Fig.3:* View of the swim bladder afterremoval from body cavity.
4) *Fig.4:* Internal view the internal chamber.

Fig.5:External view of the posterior chamber showing arrangement of blood vessels.

PLATE - II

Fig.1

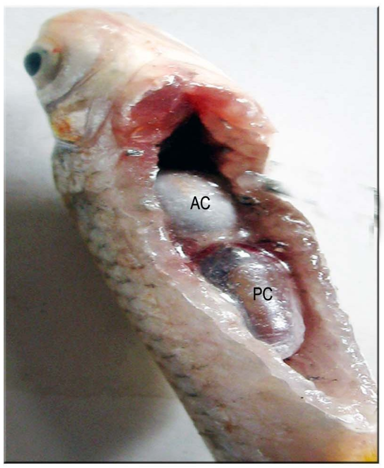


Fig.2

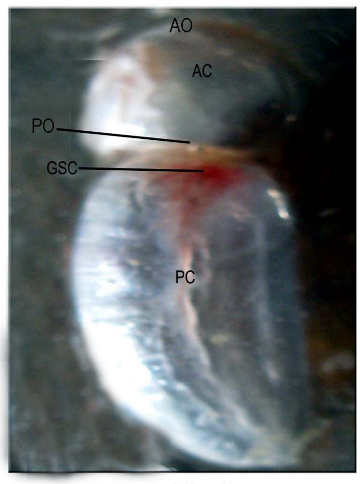


Fig.3

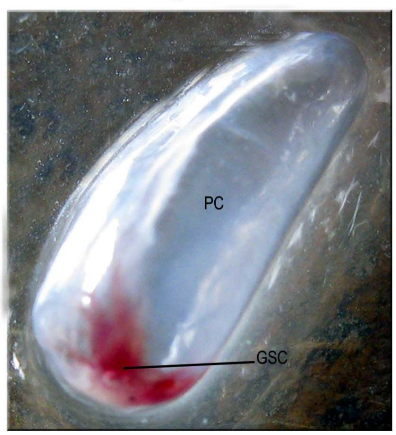


Fig.4

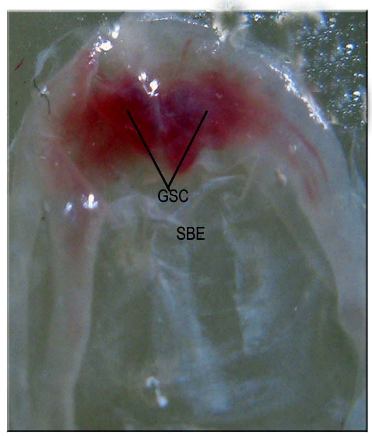


Fig.5

Swim bladder of *Puntius conchonius*

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C. Explanation of Figures

1) *Fig.1: Puntius conchonius*
2) *Fig.2:* Ventral view of the swim bladder in situ.
3) *Fig.3:* View of the swim bladder after removal from body cavity.
4) *Fig.4:* External view of the posterior chamber
5) *Fig.5:* Internal view of the posterior chamber.

PLATE - III

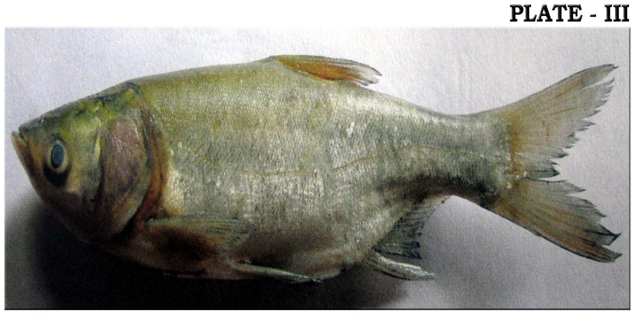

Fig. 1

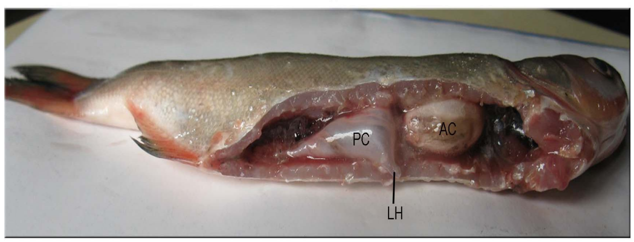

fig. 2

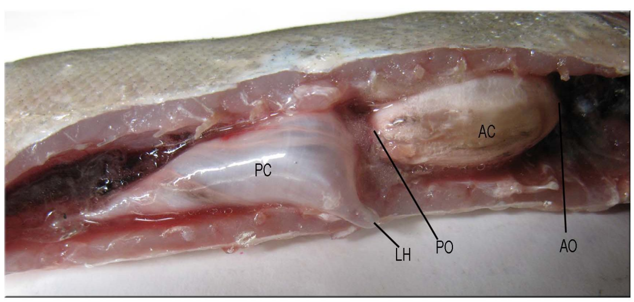

Fig. 3

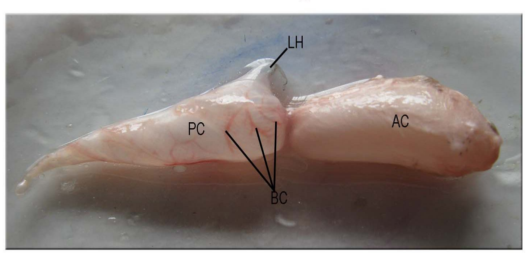

Fig. 4

Swim bladder of *Thynnichthys sandkhol*

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D. Explanation of Figures

1) *Fig.1: Thynnichthys sandkhol*
2) *Fig.2:* Lateral view of the two chambers of swim bladder in situ.
3) *Fig.3:* Close-up View of the two chambers in situ.
4) *Fig.4:* Swim bladder after its removal from body cavity.

PLATE - IV

Fig.1

Fig.2

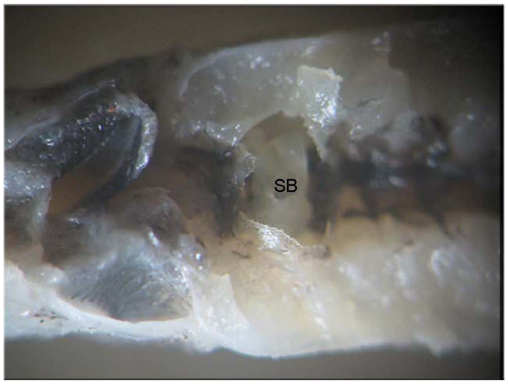
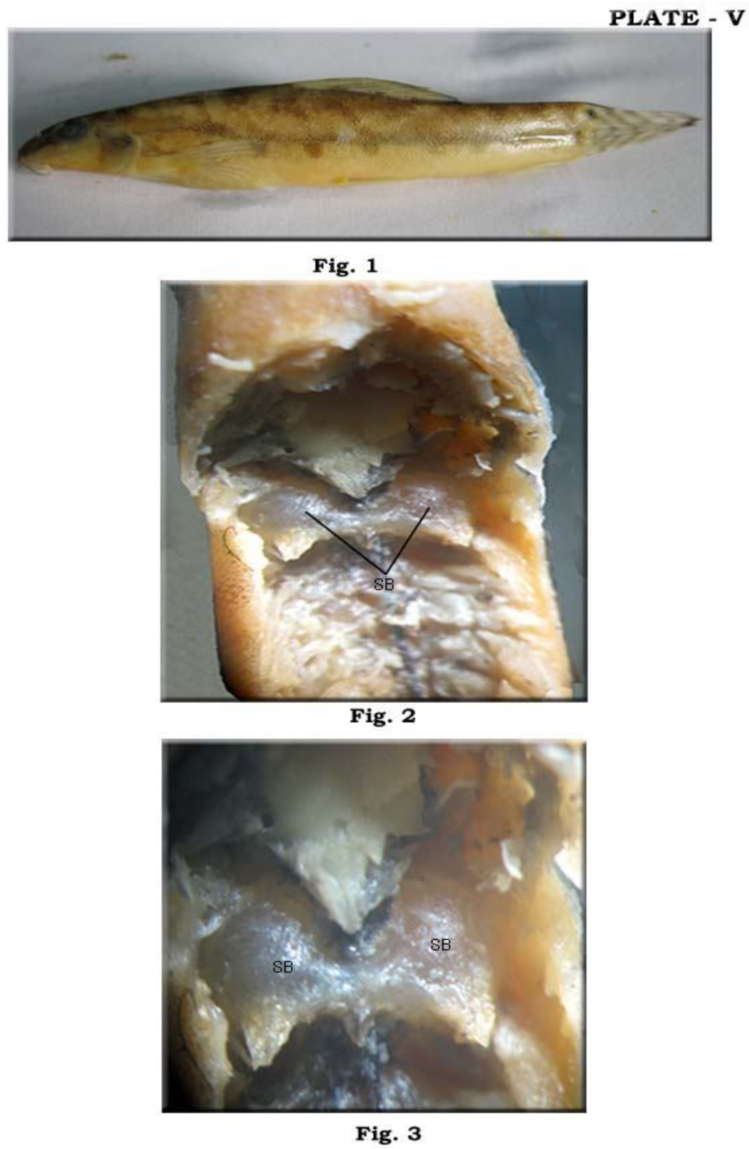


Fig.3

Swim bladder of *Lepidocephalichthys guntea*

E. Explanation of Figures

1) *Fig.1: Lepidocephalichthys guntea*
2) *Fig.2:* Ventral view of swim bladder with the external body covering.
3) *Fig.3:* Close-up View of the two chambers in situ.
4) *Fig.4:* Swim bladder after its removal of external bony covering



Swim bladder of *Noemacheilus botia*

F. Explanation of Figures

1) *Fig.1: Noemacheilus botia*
2) *Fig.2:* Ventral view of the encapsulated swim bladder after dissection..
3) *Fig.3:* Enlarge View of the two lobes of encapsulated swim bladder.

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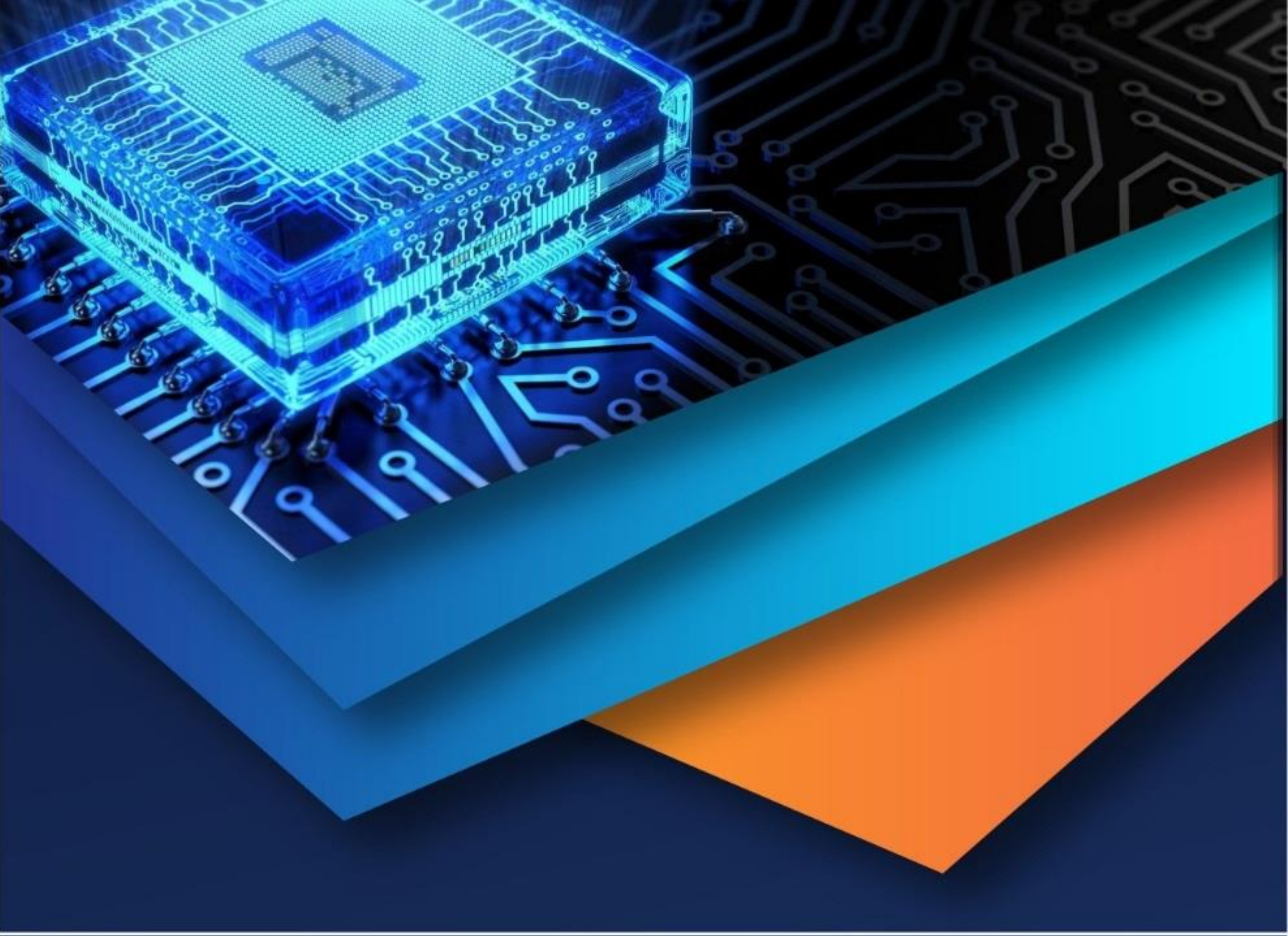

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