

## The olfactory organ of *Macrogathus aculeatus*: morphology, functional significance and growth-related variation

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### ABSTRACT

The present study investigates the morphology, histological organization, and functional significance of the olfactory organ in *Macrogathus aculeatus*, a benthic freshwater teleost inhabiting turbid aquatic ecosystems of the Ganga basin region. Specimens of different size groups collected from freshwater habitats of Gaya and the Phalgu River basin were examined through gross morphology, whole-mount preparations, histological analysis, and morphometric observations. The olfactory organ was found to be highly specialized, consisting of an elongated olfactory rosette with numerous claw-shaped lamellae arranged perpendicularly on either side of a median raphe. Histological studies revealed a well-developed olfactory epithelium containing receptor and supporting cells, while observations on water flow demonstrated an efficient circulation mechanism through the tubular anterior and oval posterior nostrils. Morphometric analysis indicated a progressive increase in lamellar number with increasing body size. Statistical evaluation showed a strong positive correlation between standard length and total number of olfactory lamellae,  $r = 0.888$ . The results suggest that olfactory sensitivity increases during ontogenetic development and that the species relies predominantly on chemoreception for feeding, orientation, and environmental perception. The study establishes *M. aculeatus* as an olfaction-oriented fish possessing marked structural adaptations to benthic and low-visibility freshwater habitats. These findings contribute significantly to the understanding of sensory biology and ecological adaptation in freshwater teleosts.

**Key Words** - Olfactory organ, *Macrogathus aculeatus*, lamellae, rosette, teleost fish

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### INTRODUCTION

Olfactory organ is one of the most important sensory modalities in fishes and plays a crucial role in feeding behaviour, predator avoidance, reproduction, migration, and habitat selection (Hara, 2015; Kasumyan, 2019). In teleosts, the olfactory apparatus exhibits remarkable structural diversity that is often associated with ecological adaptations and behavioural specialization (Bettini *et al.*, 2017; Kermen *et al.*, 2016). Species inhabiting benthic, nocturnal, or turbid freshwater

environments generally possess highly developed olfactory organs because visual perception becomes less effective under low-light and muddy conditions (Teichmann, 1954; Kasumyan, 2019). Therefore, enhancement of the olfactory surface through increased lamellar organization represents an important adaptive feature in such fishes (Yamamoto, 1982).

*Macrogathus aculeatus*, commonly known as the lesser spiny eel or peacock eel, is a benthic

freshwater fish inhabiting rivers, canals, floodplain wetlands, and muddy bottom habitats of the Ganga river basin and adjoining freshwater systems of northern India, including eastern Uttar Pradesh and Bihar region (Talwar & Jhingran, 1991; Jayaram, 2010). Previous ichthyological and fisheries studies have documented the occurrence of this species from the middle Ganga plain, indicating its adaptation to slow-moving and turbid aquatic ecosystems where chemoreception plays a dominant role in survival and behaviour (Sarkar *et al.*, 2012; Singh & Sharma, 2014). The species is predominantly nocturnal and depends greatly on chemical cues for food detection and environmental orientation (Kasumyan, 2019; Hara, 2015).

Although several studies have focused on the reproductive biology, feeding ecology, and larval development of *M. aculeatus* (Parween *et al.*, 2019; Das *et al.*, 2020), detailed investigations concerning the morphology and quantitative organization of its olfactory system remain limited (Bettini *et al.*, 2017). Understanding the structural organization of the olfactory organ is important for interpreting sensory adaptation and ecological specialization in benthic fishes (Yamamoto, 1982; Kapoor & Ojha, 1972). Therefore, the present study was undertaken to describe the morphology of the olfactory organ and to evaluate the relationship between body length and lamellar number in *M. aculeatus*.

## MATERIALS & METHODS

Specimens of *M. aculeatus* of different size groups were collected from freshwater habitats associated with the Gaya region, including ponds and adjoining riverine systems of the Falgu River. The collected fishes were preserved in 10% formalin, while some specimens were examined in fresh condition for detailed morphological observations.

Dissections were carried out carefully in both fresh and preserved specimens in order to study the relationship of the olfactory organs with the skull bones and the brain. The olfactory rosettes were dissected out from the ethmoid region and examined under a stereoscopic binocular microscope. Special attention was given to the

structure of the olfactory chamber, arrangement of the lamellae, and the organization of the olfactory rosette. Whole mount preparations of individual lamellae were also prepared to observe their external morphology and surface projections. In addition to gross morphological observations, detailed sketches and diagrammatic representations of the olfactory apparatus were prepared from dissected specimens. Particular attention was given to the external morphology of the nostrils, arrangement of the olfactory chamber, structure of the olfactory rosette, and morphology of individual lamellae. The observations were compared with stereoscopic microscopic examinations to ensure accuracy of the structural organization.

Fishes of varying body lengths were selected to determine the relationship between body size and the number of olfactory lamellae. Total length (TL) and standard length (SL) of each specimen were measured with the help of a measuring scale. The number of lamellae present in the left and right olfactory rosettes was counted separately and recorded for morphometric analysis.

The olfactory and retinal surface areas were estimated following the method of Teichmann (1954). The direction and flow of water currents within the olfactory chamber were studied with the help of fine carmine particles, sand grains, and coloured chalk particles introduced near the nostrils.

For histological studies, transverse and horizontal sections of the olfactory rosette were cut at 7  $\mu$ m thickness using a rotary microtome. The sections were stained with Ehrlich's haematoxylin and eosin for detailed examination of the internal structure of the rosette, epithelial organization, and arrangement of the olfactory lamellae under the microscope.

## RESULTS

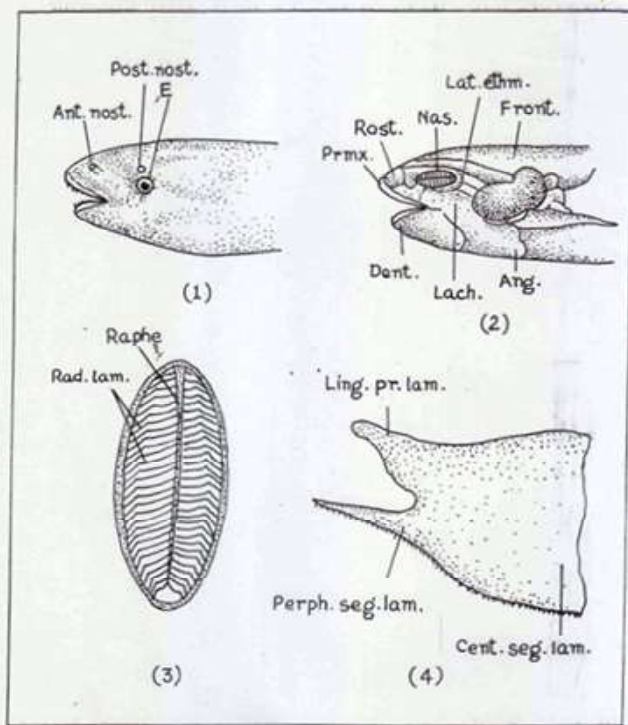
The olfactory organs of *Macrogathus aculeatus* are situated in the ethmoid region of the head and remain enclosed within a well-developed olfactory chamber. Each olfactory organ communicates externally through two nostrils. The anterior nostril

is tubular, elongated, and situated near the tip of the snout, while the posterior nostril is oval in shape and positioned slightly behind the anterior opening. The tubular nature of the anterior nostril facilitates the continuous entry of water carrying dissolved chemical substances into the olfactory chamber. The external morphology of the olfactory organ revealed clearly distinguishable anterior and posterior nostrils situated on the lateral surface of the head. The anterior nostril appeared elongated and tubular, whereas the posterior nostril was oval and comparatively broader. The organization of these structures is illustrated in Fig. 1.

The olfactory chamber is differentiated into a principal chamber and an accessory nasal sac. Dissection of the cranial region further demonstrated the close association of the olfactory organ with the ethmoid region of the skull and anterior part of the brain. The olfactory chamber remained securely lodged within the cranial cavity and communicated externally through the paired nostrils (Fig. 2). The olfactory rosette lies within the chamber and is elongated in appearance. It consists of a distinct median raphe from which numerous olfactory lamellae arise on either side in a perpendicular manner. The lamellae are closely arranged and exhibit claw-shaped outlines with linguiform projections. The elongated rosette with perpendicularly arranged lamellae provides an extensive sensory surface within a relatively restricted chamber. Whole mount preparations showed that the linguiform projections increase the effective epithelial area available for chemo reception (Fig. 3 and Fig. 4). Such projections considerably increase the sensory epithelial surface area available for olfactory reception.

Microscopic examination of whole mount preparations revealed that the lamellae are thin, delicate, and richly folded. Histological sections stained with Ehrlich's haematoxylin and eosin showed that each lamella is lined externally by olfactory epithelium containing receptor as well as supporting cells. The sensory epithelium was found to be more developed along the lateral surfaces of the lamellae. The arrangement of lamellae on both

sides of the raphe forms a compact rosette capable of accommodating a large olfactory surface within a limited space.



**Fig. 1.** Lateral view of the head of *M. aculeatus* showing tubular anterior nostril and oval posterior nostril.

**Fig. 2.** Lateral view of the skull showing the position of the olfactory organ in relation to the ethmoid region and brain.

**Fig. 3.** Structure of the elongated olfactory rosette showing median raphe and perpendicular arrangement of lamellae.

**Fig. 4.** Structure of an individual olfactory lamella showing claw-shaped outline and linguiform projections.

Observations on water flow using fine carmine particles, coloured chalk particles, and sand grains demonstrated a definite unidirectional current passing through the olfactory chamber. Water entered through the anterior tubular nostril, circulated over the lamellar surfaces, and exited through the posterior nostril. This arrangement ensures continuous exposure and stimulation of the sensory epithelium by dissolved chemical substances. Morphometric observations revealed a progressive increase in the number of olfactory

lamellae with increasing body length. Smaller specimens possessed fewer lamellae, whereas larger specimens exhibited more numerous and comparatively larger lamellae. The observations are summarized below:

**Table 1- Relationship Between Body Length and Number of Olfactory Lamellae in the Fish**

S.N.	TL (cm)	SL (cm)	Left Lamellae	Right Lamellae	Total
1	9	7.5	28	24	52
2	11.3	9.5	30	26	56
3	13	11	32	30	62
4	15	13.2	34	32	66
5	16	16	36	34	70

Statistical analysis demonstrated a strong positive correlation between body length and total number of olfactory lamellae. The Pearson's correlation coefficient was calculated as:

$$r = 0.888$$

The obtained value indicates that the number of olfactory lamellae increases proportionately with the growth of the fish, thereby suggesting progressive enhancement of olfactory sensitivity during ontogeny.

## DISCUSSION

The present study demonstrates that *M. aculeatus* possesses a highly specialized olfactory apparatus suited to its benthic and turbid freshwater habitat (Kapoor & Ojha, 1972; Kasumyan, 2019). The elongated olfactory rosette, numerous lamellae, and well-developed accessory nasal sac indicate a strong dependence on chemical perception (Yamamoto, 1982; Bettini *et al.*, 2017). Similar modifications have been reported in bottom-dwelling and nocturnal teleosts where vision is comparatively less effective because of muddy substrata and low light penetration (Hara, 2015; Sarkar *et al.*, 2012). The present observations are further supported by comparative analysis of olfactory and retinal surface areas. In *M. aculeatus*, the total olfactory surface area was found to be greater than the retinal surface area, indicating that olfactory structures are more prominently developed than visual organs. Such disproportionate development strongly supports the classification of the species as an olfaction-

dominant teleost adapted to turbid benthic habitats.

The tubular anterior nostril appears to facilitate efficient intake of water into the olfactory chamber, while the posterior nostril allows continuous outflow (Teichmann, 1954). Such an arrangement ensures uninterrupted circulation of water over the sensory epithelium and increases the efficiency of chemical detection (Kasumyan, 2019). The presence of claw-shaped lamellae with linguiform projections further enlarges the sensory surface area and enhances the capacity for olfactory reception (Bettini *et al.*, 2017; Yamamoto, 1982).

Histological observations revealed a well-developed olfactory epithelium containing receptor and supporting cells, indicating a high degree of sensory specialization (Kermen *et al.*, 2016). The compact arrangement of numerous lamellae on either side of the raphe permits accommodation of an extensive sensory surface within a restricted olfactory chamber (Kapoor & Ojha, 1972). The claw-shaped lamellae and linguiform projections observed in the present study appear to represent adaptive modifications for increasing epithelial surface area without substantial enlargement of the olfactory chamber. Similar structural adaptations are commonly associated with fishes inhabiting muddy freshwater ecosystems. This organization is considered advantageous for fishes inhabiting environments where olfaction serves as the principal sensory modality (Hara, 2015).

The progressive increase in lamellar number with increasing body size suggests continuous development of the olfactory organ during growth (Singh & Sharma, 2014). Larger fishes possess a greater olfactory surface area and are therefore likely to exhibit improved sensitivity towards food, mates, predators, and environmental stimuli (Kasumyan, 2019). The strong positive correlation between standard length and lamellar number further supports the view that sensory efficiency increases with age and body growth (Teichmann, 1954). The near-linear relationship observed in the graphical analysis suggests that development of the olfactory apparatus proceeds proportionately

with somatic growth. Enlargement of the sensory surface during ontogeny may improve efficiency in food localization, environmental orientation, and reproductive behaviour in adult individuals.

The predominance of olfactory structures over visual specialization in *M. aculeatus* reflects ecological adaptation to benthic life in turbid freshwater ecosystems (Jayaram, 2010; Sarkar *et al.*, 2012). Dependence upon olfaction for feeding, orientation, and behavioural responses appears to be a characteristic feature of this species (Parween *et al.*, 2019). The present observations therefore establish *M. aculeatus* as an olfaction-dominant fish possessing significant morphological adaptations for chemoreception.

### CONCLUSION

The present investigation provides a comprehensive account of the olfactory organization in *M. aculeatus* and demonstrates that the species possesses a highly specialized olfactory apparatus adapted for life in turbid benthic freshwater habitats. The elongated olfactory rosette, numerous claw-shaped lamellae, extensive sensory epithelium and well-developed accessory nasal sac collectively indicate a strong dependence on chemical perception. The comparative predominance of olfactory surface area over retinal surface area further confirms the sensory importance of olfaction in this species and reflects adaptation to low-visibility benthic environments where chemical cues are more reliable than visual stimuli.

Histological and functional observations revealed that the arrangement of the nostrils and lamellae ensures continuous circulation of water over the sensory epithelium, thereby increasing the efficiency of odor detection. The increase in the number of lamellae with advancing body size further indicates progressive enhancement of olfactory capability during growth and development. The strong positive correlation between fish length and lamellar number supports the concept that sensory specialization becomes more pronounced with ontogeny.

The predominance of olfactory adaptations over visual specialization confirms the ecological significance of chemoreception in *M. aculeatus*. The species appears to rely extensively on olfactory cues for feeding behaviour, environmental orientation, predator avoidance, and other behavioural activities associated with benthic life. The present study therefore contributes important baseline information on the sensory morphology and functional ecology of this freshwater teleost and may serve as a foundation for future comparative, ecological, and evolutionary studies on fish olfaction.

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