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Morphological and quantitative analysis of the olfactory organs in *Garra gotyla* (Ham.), sampled from Gaya, Bihar

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Abstract- The present study examines the morphological structure and surface area dynamics of the olfactory organs in *Garra gotyla,* a freshwater fish species. Located dorsally in olfactory pits, the paired olfactory organs exhibit structural adaptations corresponding to the fish's growth. A positive correlation ($r = 0.973$, $p < 0.001$) was observed between the standard length of the fish and the number of lamellae in the olfactory rosette, indicating ontogenetic enhancement of olfactory capacity. The olfactory surface area was consistently found to be 450% greater than the retinal surface area, underscoring the significance of olfaction in the ecological behavior of *Garra gotyla.*

Keywords: *Garra gotyla.*, ontogenetic enhancement, olfactory rosette

INTRODUCTION

Garra gotyla thrives in a variety of freshwater environments such as ponds, tanks, shallow lakes (chaurs), wetlands (beels), ditches, and even slow-moving rivers and canals. It is commonly found in areas abundant with aquatic weeds and submerged vegetation. Often observed clinging to the substrate, this species is known for its agile movements and tendency to form small groups. Morphologically, the fish has a rounded, cylindrical body covered in scales. Its dorsal side is dark brown, contrasting with a light pink belly. Dusky spots are visible just behind the upper part of the gill opening. The dorsal fin displays 8–10 rows of dots, forming a dark brownish streak, while a distinct dark stripe runs along the base of the dorsal peduncle. The fins exhibit a yellowish-grey coloration.[1] A distinguishing trait of this species is the presence of a well-developed median proboscis on the snout, with no lateral lobes. Males are further characterized by prominent snouts and well-defined tubercles. *Garra gotyla* is an omnivore, feeding on a variety of food sources including daphnia, worms, mosquito larvae, aquatic insects, algae, and plant debris. Breeding occurs between May and June, typically in flowing waters with sandy bottoms, and at temperatures between 24°C and 26°C. Although a slow swimmer, the fish occupies both the mid-water and bottom zones of its habitat, showing a clear preference for vegetated areas. It can grow to a size of 12–14 cm.

The olfactory system in teleost fishes serves as a highly specialized sensory mechanism that enables the detection of a wide range of chemical cues from the aquatic environment.[2,3] This chemosensory function is vital for mediating essential behaviors such as locating food (foraging), avoiding predators, recognizing conspecifics, navigating habitats, and initiating reproductive activities.

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In bottom-dwelling species, particularly those inhabiting turbid or structurally complex environments, the reliance on olfaction may be heightened due to limited visibility.

The present study undertakes a comprehensive examination of the olfactory organ in *Garra gotyla* (Hamilton, 1822), a benthic cyprinid species widely distributed across freshwater bodies in India. Special emphasis is placed on the anatomical configuration, structural adaptations, and morphometric parameters of the olfactory rosettes and associated nasal structures. Understanding these features not only provides insights into the ecological adaptations of *Garra gotyla* but also contributes to broader knowledge on sensory specialization among freshwater teleosts. Through detailed morphological assessment, this investigation aims to elucidate the correlation between olfactory architecture and the species' bottom-dwelling lifestyle.

MATERIALS & METHODS

A total of five *Garra gotyla* specimens, measuring between 95 mm and 210 mm in total length, were selected for detailed morphological analysis. The study focused on the olfactory system, with dissections and stereo microscopic examinations carried out to document the structural organization of the olfactory apparatus. Morphometric parameters were recorded for each specimen, and statistical analysis using Pearson's correlation coefficient was performed to explore the relationship between standard length and the number of olfactory lamellae.

Live specimens were collected from diverse freshwater habitats across the Gaya district in Bihar, India. Specific collection sites included the Phalgu River (coordinates: 24.7964° N, 85.0008° E), a prominent seasonal river flowing through Gaya, and associated waterbodies such as ponds and tanks. Additional samples were procured from the Kakolat region near Nawada (coordinates: 24.9667° N, 85.5167° E), known for its spring-fed streams and hill-associated aquatic systems. These locations represent ecologically varied habitats conducive to the growth and survival of benthic cyprinid species like *Garra gotyla.*

Both freshly euthanized and preserved specimens were dissected to assess the spatial relationship between the olfactory organs, brain, and adjacent cranial bones. The olfactory rosettes were carefully extracted and examined under a stereoscopic binocular microscope to study the arrangement and number of lamellae. For detailed morphological inspection, individual lamellae were further prepared as whole mounts and observed under magnification to analyze surface features and structural variation.

RESULT & DISCUSSION

In *Garra gotyla*, the olfactory system comprises a pair of dorsally positioned olfactory organs, each situated within a shallow depression on the snout. Each organ is associated with two external openings, the anterior nostril, which is typically oval in shape and functions as the inlet, and the posterior nostril, circular in form, acting as the outlet. These paired nostrils facilitate continuous water flow over the olfactory epithelium, enabling efficient detection of dissolved chemical cues.

Anatomically, the olfactory organs are embedded within a fossa located in the ethmoidal region of the cranium. This region is structurally supported by several cranial bones, notably the nasal, frontal, and lachrymal bones, which form a protective framework for the delicate olfactory structures.

At the core of each olfactory organ lies the olfactory rosette, an oval-shaped sensory structure responsible for detecting chemical stimuli. The rosette features a prominent median raphe, an axial structure to which the lamellae are attached, angled approximately 135° relative to the longitudinal axis of the body. This angular orientation may enhance the exposure of the sensory epithelium to incoming water currents.[4]

The olfactory lamellae are arranged in a bilateral, radial fashion around the raphe, resembling the spokes of a wheel. Each lamella is claw-shaped, with the outer concave margins bearing distinctive linguiform (tongue-like) processes, which likely increase the surface area for olfactory receptor cells. These lamellae are structurally anchored at both ends: laterally to the inner wall of the olfactory chamber, and medially to the raphe, ensuring stability and optimal spatial distribution for sensory function.

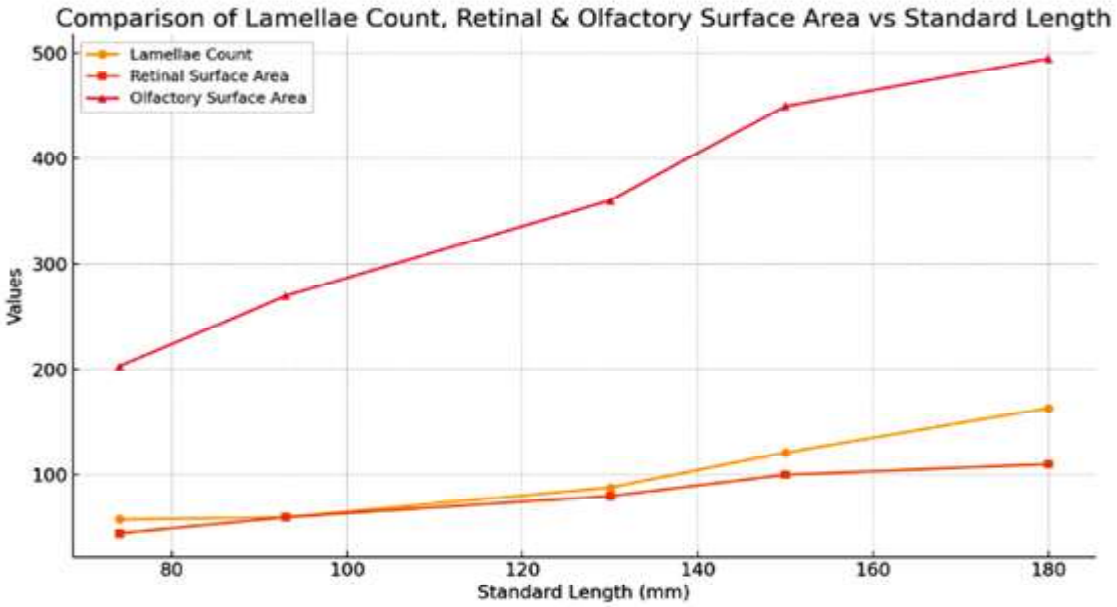
This complex lamellar arrangement, along with the unique orientation of the rosette and supporting skeletal elements, reflects the species' adaptation to benthic habitats where reliance on olfactory cues is critical for survival and ecological interaction.

Quantitative Observations

Table 1- Comparison of Body Length, Olfactory Lamellae Count, and Surface Areas in *Garra gotyla* Specimens

Sl. No.	Total Length (mm)	Standard Length (mm)	Lamellae in left rosette	Lamellae in Right rosette	Total No. of lamellae	Retinal Surface area	Olfactory surface area	% of surface area
1	50	74	28	30	58	45	203	450%
2	110	93	33	33	60	60	270	450%
3	150	130	44	44	88	80	360	450%
4	180	150	60	61	121	100	450	450%
5	210	180	81	82	163	110	495	450%

Graph 1- Comparison of the Total Number of Lamellae, Retinal Surface Area, and Olfactory Surface Area with respect to Standard Length (mm).



Correlation Analysis

- Standard Length (X) vs Total Number of Lamellae (Y)
- Pearson's correlation coefficient:

$$r = \frac{716.6}{\sqrt{73 \times 7420.38}} \approx 0.973$$

Tabulated r (df = 4, p = 0.001) = 0.974

The calculated r value (0.973) is statistically significant, suggesting a strong positive correlation between body size and lamellae count.

The morphology of the olfactory apparatus in *Garra gotyla* reflects specialized adaptations for benthic life.[5] The claw-shaped lamellae with linguiform projections may enhance the surface area for chemoreception. The positive correlation between body size and lamellae count indicates developmental scaling of olfactory capability. Remarkably, the olfactory surface area was consistently 4.5 times larger than the retinal surface, suggesting that olfaction might be the dominant sensory modality in *G. gotyla*.The receptor cells exhibit a long neck and a small basal region, with granular cytoplasm. An oval-shaped nucleus is located at the base of each cell. Similar findings were reported by Evans and Hara (1977)[6] in species such as *Salmo gairdneri, Coregonus clupeaformis, Salvelinus alpinus, S. fontinalis, S. namaycush,* and *Ictalurus melas.* Additionally, proteins are abundantly present in the receptor cells of *G. gotyla*. Acid phosphatase activity is predominantly observed in the nuclei of these receptor cells. This has been similarly documented in mammalian receptor cells by Baradi and Bourne (1953)[7], Amicis and Zorzoli (1957)[8], Barbera (1959)[9], and Bronshtein (1980)[10]. Additionally, they are alcian blue positive, suggesting the presence of acidic mucopoly saccharides, which may have protective,

antitoxic functions for the olfactory epithelium. Mucous gland cells are negative for metachromasia, lipids, phospholipids, and proteins. However, their peripheral walls show positive alkaline phosphatase activity, as also reported by Singh (1967)[11] and Shantha and Nakajima (1970)[12]. These cells do not show acid phosphatase activity, consistent with Singh's (1967)[11] findings.

CONCLUSION

This study highlights the significance of the olfactory system in *Garra gotyla*, demonstrated by its intricate morphology and functional adaptations. The positive correlation between body size and lamellae count indicates a developmental enhancement of olfactory capability, crucial for the species' benthic lifestyle. Furthermore, the remarkably larger olfactory surface area compared to the retinal surface area underscores the dominance of olfaction in *Garra gotyla* ecological and behavioral activities. These findings collectively emphasize the vital role of chemoreception in this species.

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